

EXHIBIT A

JOSEPH JOHN TALGHADER

Professor

Electrical and Computer Engineering

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Joseph Talghader obtained his B.S. in electrical engineering from Rice University. He was awarded an NSF Graduate Fellowship and attended the University of California at Berkeley where he received his M.S. in 1993 and Ph.D. in 1995. He worked at Texas Instruments as a Process Development Engineer, where he investigated EEPROM memory design and reliability issues. After graduating from Berkeley in 1995, he joined Waferscale Integration where he developed microfabrication processes for high-density nonvolatile memory devices. In 1997 Dr. Talghader joined the faculty at the University of Minnesota as an Assistant Professor and was later promoted to Associate and then Full Professor. He has been extensively involved in optical materials, optical coatings, and directed energy component technologies. Among his most impactful work has been on the study of particles on laser-induced material breakdown. His research group also develops thermal infrared and radiation heat transfer devices and micro- and nano-opto-mechanical systems and has demonstrated the highest sensitivity uncooled thermal detectors and the first tunable multispectral thermal detectors. He has several patents and patent applications in these areas. His group works in a number of different fields including recent research on the measurement of the optical and materials properties of glacial ice. Dr. Talghader has received the Antarctic Service Medal of the United States in 2014 from the National Science Foundation, an Outstanding Editor Award from Light: Science and Applications, 3M Faculty Awards on three occasions, and the University of Minnesota Innovations Awards on four occasions. His technology has been a Finalist for the Minnesota Cup for entrepreneurs. He has served on various program committees and reviews, including service on the triennial strategic planning panel for the Army Research Office Electronics Division, as General and multiple Program chairs of the International Conference on Optical MEMS and Nanophotonics, and twice as Guest Editor of the Journal of Selected Topics in Quantum Electronics.

EDUCATION:

Ph.D., 1995, University of California at Berkeley, Electrical Engineering

Advisor: J. Stephen Smith

Thesis Title: Optimization of Vertical-Cavity Surface-Emitting Lasers and Processing for Fluidic Self-Assembly

M.S., 1993, University of California at Berkeley, Electrical Engineering

B.S., 1988, Rice University, Electrical Engineering

PRESENT POSITION:

Professor of Electrical and Computer Engineering

University of Minnesota, 2008-present

Associate Professor of Electrical and Computer Engineering
University of Minnesota, 2003-2008

Assistant Professor of Electrical and Computer Engineering
University of Minnesota, 1997-2003

PREVIOUS POSITIONS:

Senior Device Physicist,
Waferscale Integration (now part of ST Microelectronics), 1995-1996
Development of high density, low power Flash and EPROM memory.

Graduate Student Researcher,
UC-Berkeley, 1991-1992, 1993-1995
GaAs and Si micromachining for optoelectronic self-assembly.
Epitaxial growth, materials research, device design, and fabrication of vertical-cavity surface-emitting lasers.

Process Development Engineer,
Texas Instruments, 1992-1993
Device and materials characterization for EEPROM and CMOS processes.

PROFESSIONAL ACTIVITIES/AWARDS

Outstanding Editor Award 2016, *Light: Science and Applications*, Nature Publishing Group
Antarctic Service Medal of the United States, 2014
Finalist, Minnesota Cup (Entrepreneurship Award), Ascir Inc.
Editor, *Light: Science and Applications*, Nature Publishing Group
Member of Borehole Logging Working Group (sub group of US Polar research Scientific Advisory Board)
Army Research Office, Electronics, Three Year Planning Review Committee
University of Minnesota Innovations Award 2006, 2008, 2014
University of Minnesota Innovations Award 2010, for U.S. Patent 7,800,066, "Detection beyond the standard radiation noise limit using reduced emissivity and optical cavity coupling."
Steering Committee – IEEE Optical MEMS and Nanophotonics Conference, 2015-present, and 2002-2009
Guest Editor, *IEEE Photonics Technology Letters*, Special Issue on Optical MEMS, 2016.
Lead Guest Editor, *IEEE Journal of Special Topics on Quantum Electronics*, Special Issue on Optical Micro- and Nano- Systems
Conference Chair, 2006 IEEE/LEOS Optical MEMS and Nanophotonics Conference, Yellowstone/Big Sky
Guest Editor, *IEEE Journal of Special Topics on Quantum Electronics*, Special Issue on Optical Microsystems
Program Chair, 2015 IEEE Photonics Society Optical MEMS and Nanophotonics Conference, Jerusalem, Israel

Program Chair, 2003 IEEE/LEOS Optical MEMS Conference, Hawaii, Hawaii
 Program Committee, Conference on Lasers and Electro-optics, Pacific Rim. August 2018
 Program Committee, IEEE Optical MEMS and Nanophotonics Conference, 2007-2013, 2017, 2018, 2019, 2021
 Program Committee, 2019, 2017, 2009 Transducers
 Program Committee, 2003-2007 SPIE Micromachining and Microfabrication Conference, San Jose, CA
 Program Committee, Optical MEMS and Nanophotonics Conference, 2000-2002, 2003-2005
 Steering Committee, IEEE Optical MEMS and Nanophotonics, 2015-present
 3M Faculty Award, 2003
 3M Faculty Award, 2002
 3M Faculty Award, 2001
 President of Minnesota Section of the Optical Society of America, 2002-3
 Vice President of Minnesota Section of the Optical Society of America, 2001-2
 Secretary/Treasurer of Minnesota Section of the Optical Society of America, 2000-1
 Participant in NSF ScienceWorks! Program for Minneapolis Public Schools
 HKN/ECS Department Finalist 1999 Teacher of the Year
 National Science Foundation Graduate Fellow
 IEEE, Eta Kappa Nu
 Optical Society of America
 Sigma Pi Sigma

INVITED CONFERENCE TALKS, PRESENTATIONS, AND EDITORIALS:

Keynote J. J. Talghader, “The impact of surface particulates and laser-accelerated particles on continuous-wave laser damage,” *SPIE Laser Damage Conference*, Rochester, NY, 13 October 2021.

Invited Webinar J. J. Talghader, “Fundamental properties and real-world breakdown of low absorption thin films from the visible to infrared,” *OSA Thin Film Technical Group*, 12 October, 2021.
https://www.optica.org/en-us/meetings/webinar/2021/10_october/fundamental_properties_and_real-world_breakdown_of/

J. J. Talghader, High Power Optical Breakdown and Design to Combat Dirt and Airborne Particles, *Proceedings of CLEO, Conference on Lasers and ElectroOptics*, Virtual, May 13, 2020, 2 pages.

J. J. Talghader, A. Brown, and T. Mitra, “The failure of high power optics due to dirt and airborne particles,” *OSA Laser Congress, Advanced Solid State Lasers*, Vienna, Austria, October 2, 2019, AW3A.1.

J. Talghader, “Mitigating Thermal Effects in the Mirrors and Cavities of High Power Laser Systems,” *SPIE Defense + Security, High Power Lasers*, Strasbourg, France, September 12, 2019.

- J. J. Talghader, "Particle acceleration and particle-induced breakdown in high power laser optics," *High Power Lasers Conference in SPIE Defense and Security*, Berlin, Germany, September 12, 2018.
- J. J. Talghader, T. Mitra, A. K. Brown, D. M. Bernot, S. Defrances, "Laser Acceleration of Absorbing Particles and Their Role in Inducing Early Materials Failure," *Optical Trapping and Optical Micromanipulation in SPIE Optics and Photonics*, San Diego, August 22, 2018.
- J. J. Talghader, "Revisiting Planck's Law: Thermal Emission and Radiation Noise in Subwavelength Optical Cavities," *Light Conference 2018*, Changchun, China, July 16-18, 2018.
- J. J. Talghader, "Future Directions for Microbolometers and Thermopile Infrared Detectors," *Image Sensing Technologies: Materials, Devices, Systems, and Applications V in SPIE Defense and Commercial Sensing*, Orlando, FL, April 2018.
- J. J. Talghader, "Future Directions for Uncooled Infrared Detectors," *DoD Basic Research Forum*, Arlington, VA, October 19, 2017.
- J. J. Talghader, "Revisiting Planck's Law: Thermal Emission and Radiation Noise in Subwavelength Infrared Cavities," *Conference on Lasers and Electrooptics Pacific Rim*, Oral 3-2F-1, Singapore, August 3, 2017.
- J. J. Talghader, "Optical breakdown of contaminated materials: Physics wins even with dirt," *Emerging Technologies CMOS Workshop*, Warsaw, Poland, May 29, 2017.
- J. J. Talghader, "Optical breakdown of contaminated materials: Physics wins even with dirt," Seminar, University of Ljubljana, Ljubljana, Slovenia, May 26, 2017.
- J. J. Talghader, "Microsensors and Particles: Infrared detectors, solar driven devices, and sensing inside explosions," *Stanford Photonics Research Conference*, Stanford, CA, September 19-20, 2016.
- J. J. Talghader, "Optical Breakdown of Contaminated Materials: Physics Wins even with Dirt," *Light Conference 2016*, Changchun, China, July 4-8, 2016.
- J. J. Talghader, "Controlling the Infrared: Macro-to-Micro-to-Nano and from Photons to Electron Waves," *EECS Seminar*, Penn State University, State College, PA, October 13, 2016.
- J. J. Talghader, "Controlling Thermal and Photon Emission: Pushing Against the Background Noise Limit and Tuning Bandgaps," *University of Southern California Nanoscience and Technology Seminar*, Los Angeles, CA, October 20, 2016.
- J. J. Talghader, "Microsensors and Particles: Infrared detectors, solar driven devices, and sensing inside explosions," Halliburton, Houston, TX, October 26, 2016.

- J. J. Talghader, "Optical Borehole Logging of Volcanic Layers in Antarctica and Nanomechanical Tuning of the Semiconductor Bandgap," *ECE Seminar*, Rice University, Houston, TX, October 27, 2016.
- J. J. Talghader, "Optical Engineering in Antarctica: Borehole Logging of Volcanic Eruptions and Ice Crystal Structure," *ECE Colloquium*, University of Texas, Austin, TX, November 16, 2016.
- J. J. Talghader, "Controlling the Infrared: Macro-to-Micro-to-Nano and from Photons to Electron Waves," *ECE Seminar*, J. J. Pickle Research Campus, University of Texas, Austin, TX November 17, 2016.
- J. J. Talghader, "Physical Limits of Thermal Infrared Detection", *IEEE Sensors Conference*, Busan, South Korea, November 1-4, 2015.
- J. J. Talghader, "Thermal Performance Limits of Optical Micro- and Nanomechanical Devices," *International Conference on Micro/Nano Optical Engineering*, July 3-5, 2014, Changchun, China.
- J. J. Talghader, "Laser-induced thermal breakdown of optical coatings," *High Power Lasers Conference, Security and Defense Symposium*, Dresden, Germany, September 23, 2013.
- J. J. Talghader, "Thermal performance limits of micro- and nanomechanical devices," *International Symposium on Applications and Potentials of MEMS/NEMS*, Tsinghua University, Beijing, China, April 18-19, 2013.
- J. J. Talghader, "Thermal history sensing using thermoluminescence: measurement concepts and testing," *DTRA Workshop on Time-Dependent Temperature Measurements in Energy Release Processes*, Chicago, IL, October, 10, 2012.
- J. J. Talghader, "High-Sensitivity Infrared Detection and Spectroscopy," 2012 *CMOS Emerging Technologies Workshop*, Vancouver, BC, July 18-21, 2012.
- J. J. Talghader, "Thermal conduction in optical coatings and interfaces: a key to high-power meta-optics," 2011 *Laser Damage Conference*, Talk 8190-40, Boulder, CO, September 18-21, 2011.
- J. J. Talghader, "Nanomechanical Control of Electron States," *International Conference on Micro/Nano Optical Engineering*, June 12-16, 2011, Changchun, China, p. 15.
- J. J. Talghader, "Luminescent microparticles as thermal history sensors," *CMOS Emerging Technologies Workshop*, Vancouver, BC, May 19-21, 2010.

- J. J. Talghader, "Micro- and Nano-particles for the Distributed Sensing of Thermal History," *Seventh International Conference on Networked Sensing Systems*, Kassel, Germany, June 15-18, 2010.
- J. J. Talghader, "Material Signatures and Tunable High Sensitivity Detection in the Infrared," *5th Asia-Pacific Conference on Transducers and Micro-Nano Technology*, Perth, Western Australia, July 6-9, 2010.
- W. B. Song and J. J. Talghader, "IR Detectors with Adaptive Responsivity and Wavelength," SPIE MOEMS-MEMS Micro & Nanofabrication 2007, January 20-25, 2007, *Proceedings of the SPIE*, vol. 6464, *MEMS/MOEMS Components and Their Applications IV*, 2007, article 6460L.
- J. J. Talghader, O. Solgaard, and L. Y. Lin, "Editorial: Introduction to the Issue on Optical Micro- and Nano- Systems," *IEEE Journal on Selected Topics in Quantum Electronics*, vol. 13, no. 2, Mar/Apr 2007, p. 145.
- J. J. Talghader, "From micro- to nano-: thermal effects in micromachined devices," *2006 Conference on Optoelectronic and Microelectronic Materials and Devices*, Perth, Western Australia, December 6-8, 2006.
- J. J. Talghader, "Adaptive imaging with uncooled LWIR detectors," *SPIE Defense and Security Symposium, Intelligent Integrated Microsystems*, Orlando, FL, April 20, 2006.
- J. J. Talghader, "Heat and Temperature in Micromechanical Systems," *2005 International Semiconductor Device Research Symposium*, WP6-03, Bethesda, MD, December 7-9, 2005.
- J. J. Talghader, "Mechanics of Optical Coatings in Extreme Thermal Environments," *2005 International Conference on Metallurgical Coatings and Thin Films*, San Diego, CA, May 2005.
- J. J. Talghader, Topical Review: "Thermal and Mechanical Phenomena in Micromechanical Optics," *Journal of Physics D:Applied Physics*, vol. 37, pp. R109-R122, 2004.
- O. Solgaard, J. Talghader, H. Toshiyoshi, and H. Kopola, "Editorial: Introduction to the Issue on Optical Microsystems," *IEEE Journal on Selected Topics in Quantum Electronics*, vol. 10, no. 3, May/June 2004, p. 433.
- J. J. Talghader, "Ultimate Performance in Optical MEMS," *SPIE International Symposium on Microelectronics, MEMS, and Nanotechnology*, December 10-12, 2003, Perth, Australia.
- J. J. Talghader, "Microsensor communication using self-assembly," *NSF International Workshop on Advances in Micro and Nano Technology for Sensing Applications*, Melbourne, Australia, Dec. 12-14, 2002. Co-Sponsored by the Australian Research Council and the Japan Society for the Promotion of Science.

- J. R. Leger and J. J. Talghader, "Design of microspectrometers," *2002 LEOS Annual Meeting*, Glasgow, Scotland, November 10-14, 2002.
- J. J. Talghader, "Shape control and heat transfer in Optical MEMS," *LEOS Newsletter* (On the Academic Side Feature), vol. 16, no. 3, pp. 3-8, August 2002.
- J. J. Talghader, "MEMS confocal microresonator arrays using mirrors with strain-induced curvature," *SPIE – Photonics West – Laser Resonators and Beam Control V*, San Jose, CA, January 22, 2002.
- J. J. Talghader, "Wavelength tunable thermal cavity technology," *DSRC Workshop on Reconfigurable Focal Plane Detection Systems*, October 22, 2001, Hosted by Richard Osgood, (DSRC and Columbia University) and John Carrano (DARPA).
- J. J. Talghader, "Thermal management in optical MEMS," *Proceedings of the SPIE*, (MOEMS and Miniaturized Systems II Conference), vol. 4561, pp. 20-27, 2001.
- J. J. Talghader, "Optical coatings and flatness in micromirrors," NSF Workshop on Adaptive Optics, Berkeley, CA, Nov. 13, 2000.
- J. J. Talghader, "Integration of VCSELs using fluidic self-assembly," *Proceedings of the SPIE - Vertical Cavity Surface Emitting Lasers II*, vol. 3286, pp. 86-95, 1998.

Many Invited Talks at Universities, Industrial Labs, and National Labs.

RESEARCH FUNDING:

- [1] Title: MRI: Optical and Thermomechanical Design of High Reflectivity Deformable Membranes
 Funding Agency: Joint Technology Office via Office of Naval Research
 PI: Joseph Talghader, co-Is: Tom Bifano (Boston University), Albert Ogloza (Navy Port Hueneme Division), Jeff Thomas (Penn State Electro-optics Center), David Samuels (ATFilms)
 Amount for Base + Option Period: \$3,143,813, (Talghader portion: Approximately \$1,262,808)
 Duration: September 1, 2017 to August 31, 2022 NCE request to August 31, 2023

- [2] Title: Towards uncooled thermal imaging focal plane devices with NETD near 1mK
 Funding Agency: Army Research Office
 PI: Joseph Talghader
 Amount: \$565,358 = \$450,252 original + \$115,106 incoming supplement
 Duration: June 18, 2018 to June 17, 2023

- [3] Title: Collaborative Research: Laser Cutting Technology for Borehole Sampling

- Funding Agency: National Science Foundation
 PI: Joseph Talghader, (A. Kurbatov of U Maine is our collaborator with linked proposal with separate budget)
 Amount: \$318,164
 Duration: September 1, 2020 to August 31, 2022 likely NCE to extend to 2023.
- [4] Title: Miniaturizing the Microbial Fuel Cell Design for Hydrogen Production
 Funding Agency: MNDrive Environment Seed Grant
 Investigators: Daniel Bond (PI, Microbiology), Joseph Talghader
 Duration: August 2020 to December 2021
- [5] Title: Borehole Logging to Classify Volcanic Signatures in Antarctic Ice
 Funding Agency: National Science Foundation
 PI: Joseph Talghader (Ryan Bay of UCB has a separate collaborative proposal)
 Amount: \$100,000
 Duration: May 1, 2017 to September 30, 2019
- [6] Title: Photon Statistics and Spectral Selectivity Limits of Thermal Detectors
 Funding Agency: Army Research Office
 PI: Joseph Talghader
 Amount: \$389,626
 Duration: June 1, 2015 to March 31, 2019
- [7] Title: Fundamental Analyses and Techniques of Plenoptic Imaging
 Funding Agency: DARPA
 Investigators: Jim Leger (PI), Joseph Talghader, Jarvis Haupt, Gary Meyer, Jim Fienup
 Amount: over \$2,999,603
 Duration: January 18, 2016 to December 31, 2020
- [8] Title: MRI: Particulate and Contamination-Induced Breakdown in Large Area Optics
 Funding Agency: Joint Technology Office via Office of Naval Research
 PI: Joseph Talghader, co-I: Albert Ogloza (Naval Postgraduate School), Greg Hartland (Notre Dame), Kevin Kjoller (Anasys), Ramin Lalezari (ATF), Jeff Thomas (Penn State Electro-optics Center)
 Amount: \$3,343,484, (Talghader portion: ~ \$1,248,000)
 Duration: August 15, 2012 – February 28, 2019
- [9] Title: Engineering Van der Waal's Gases in Solids
 Funding Agency: GIA (New Research Area Seed Funding) University of Minnesota
 PI: Joseph Talghader
 Amount: \$47,648
 Duration: January 1, 2016 to June 30, 2017
- [10] Title: MRI: 3D Meta-Optics for High Energy Lasers
 Funding Agency: Joint Technology Office
 Investigators: Eric Johnson (PI), Joseph Talghader, Robert Magnusson, Martin Richardson

Amount: approx. \$2.5million (Talghader portion: \$569,299)
Duration: September 30, 2010 – June 30, 2016

- [11] Title: Optical Fabric and Fiber Logging of Glacial Ice
Funding Agency: National Science Foundation
PI: Joseph Talghader (Ryan Bay of UCB has a collaborative proposal also funded)
Amount: \$398,785
Duration: June 1, 2012 to May 31, 2016

- [12] Title: Luminescence Materials as Nanoparticle Thermal Sensors
Funding Agency: Defense Threat Reduction Agency
Amount: Approximately \$1,750,000 (Talghader Portion: approx. \$759,434)
PI: Eduardo Yukihara, Joseph Talghader, Luiz Jacobsohn
Duration: February 22, 2010 to December 15, 2015

- [13] Title: Continuation: Tunable Narrowband Thermal Infrared Detectors with Ultra-High Sensitivity
Funding Agency: DARPA/Army Research Labs
PI: Joseph Talghader
Amount: \$100,000
Duration: February 3, 2014 – September 30, 2015

- [14] Title: Tunable Narrowband Thermal Infrared Detectors with Ultra-High Sensitivity
Funding Agency: DARPA
PIs: Joseph Talghader
Amount: \$250,000
Duration: October 20, 2011 – May 31, 2013

- [15] Title: High Power Optical Coatings by Atomic Layer Deposition and Signatures of Laser-Induced Damage
Funding Agency: Office of Naval Research
PI: Joseph Talghader
Amount: \$107,000
Duration: August 1, 2009 – July 31, 2012

- [16] Title: Chemical Identification and Thermal Conductivity Characterization of Local Absorbers in HEL Coatings
Funding Agency: Joint Technology Office
Investigators: Kevin Kjoller – Anasys, Inc., Joseph Talghader
Amount: (Talghader portion: \$214,978)
Duration: May 5, 2010 – May 4, 2012

- [17] Title: Hyperspectral and Mid-wave Uncooled Detection with Cryogenic Performance
Funding Agency: Penn State Electro-optics Center
Amount: \$235,000
PI: Joseph Talghader

Duration: November 1, 2008 to April 30, 2011

- [18] Title: Laterally Integrated Photovoltaic Devices
Funding Agency: IREE
Amount: \$800,000
Investigators: Phil Cohen, Joseph Talghader, Jim Leger, Paul Ruden, E. Enemuoh
Duration: May 17, 2009 to May 16, 2012

- [18] Title: Tunable Quantum Coupling in Nanomechanical Heterostructures
Funding Agency: National Science Foundation
PI: Joseph Talghader (co-Is: Len Chen of Raytheon and Chris Palmstrom of UCSB)
Amount: \$330,000
Duration: June 1, 2007 to May 31, 2011

- [19] Title: Infrared Microspectrometer for Unmanned Space Probes
Funding Agency: NASA - Goddard
PI: Joseph Talghader
Amount: \$35,000
Duration: July 20, 2010 to July 19, 2011

- [20] Title: MRI: Optomechanical Coatings for high power mirrors and adaptive optics
Funding Agency: Air Force Office of Scientific Research (from Joint Technology Office)
Amount: \$900,000
PI: Joseph Talghader
Duration: July 1, 2005 to June 30, 2008

- [21] Title: Bioagent Thermal History using Microparticle Trap Luminescence
Funding Agency: Defense Threat Reduction Agency
Amount: \$462,628
PI: Joseph Talghader (co-I: Eduardo Yukihara at Oklahoma State University)
Duration: December 1, 2006 to November 30, 2009

- [22] Title: Uncooled Tunable LWIR Microbolometer
Funding Agency: Army Research Office
Amount: \$497,904
PI: Joseph Talghader
Duration: September 2003 to December 2007 or 2009 depending on options exercised

- [23] Title: MEMS and NEMS Technologies for Temperature Sensitive Semiconductors and Smart Materials
Funding Agency: Australian Research Council (ARC)
Number of Co-PIs: 7 (Prime PI: John Dell at University of Western Australia)
Amount: Total: \$867,000 Australian Dollars
Duration: 2005 to 2008
Comment: This grant does not provide direct funding to my group but rather seeds collaborations such as personnel exchange

- [24] Title: Actuators for Angstrom-scale Movement of Micromachined Devices
 Funding Agency: NSF
 Amount: Total: \$77,955
 PI: Joseph Talghader
 Duration: June 2006 to November 2007

- [25] Title: Innovation Grant: Testing Feasibility of Thermal Detectors
 Funding Agency: Venture Center, University of Minnesota
 PI: Joseph Talghader
 Amount: \$74,660
 Duration: December 14, 2007 to December 14, 2008

- [26] Title: Optical Probing of Deep Glacial Ice
 Funding Agency: Grant-in-Aid, University of Minnesota
 PI: Joseph Talghader
 Amount: \$29,966
 Duration: January 2008 to June 2009

- [27] Title: 3M Faculty Award
 Funded by: 3M
 Amount: \$35,000
 PI: Joseph Talghader
 Duration: N/A

- [28] Title: MRI: Fabrication, testing, coating, and alignment of fast segmental optics
 Funding Agency: Air Force Office of Scientific Research
 PIs: Buddy Martin of the University of Arizona, Jim Burge, Joseph Talghader
 Amount: Total: Approx. \$2.4 million Talghader portion: \$511,000
 Duration: July 2002 to July 2005

- [29] Title: ACTIVE EYES (Acronym)
 Funded by: DARPA
 PIs: Ravi Athale, Joseph Talghader, Jim Leger
 Number of Co-PIs: 4
 Amount: Total: \$2.2 million, Talghader portion: approximately \$509,000
 Duration: June 2000 to July 2005

- [30] Title: Distributed microsensor packaging based on self-assembly after sensing
 Funding Agency: NSF
 Amount: Total: \$210,000
 PI: Joseph Talghader
 Duration: September 2001 to August 2004

- [31] Title: Nanomechanical Control of Electron States
 Funded by: Grant-in-Aid

Amount: \$25,736
Duration: January 2005 to June 2006

- [32] Title: Distributed microfluidic sensors using self-assembled read-out
Funding Agency: University of Minnesota Grant-in-Aid
Amount: \$21,252
Duration: January 1, 2001 to June 30, 2002
- [33] Title: Micromirrors in MO Recording
Funding Agency: Seagate Technologies
Amount: \$50,000
Duration: January 1, 1999 to December 31, 2000
- [34] Title: Sensors for Magnetic Resonance Imaging
Funding Agency: Biomedical Engineering Institute
Amount: \$35,000
Duration: Summer 1998 to Summer/Fall 1999
- [35] Title: Adaptive structures for optical recording
Funding Agency: Seagate Technologies
Amount: \$25,000
Duration: January 1, 1998 to December 31, 1998
- [36] Title: Manufacturing and assembly for micro-optic systems
Funding Agency: Grant-in-Aid of Research, Artistry, and Scholarship
Amount: \$22,020
Duration: July 1, 1997 to December 15, 1998

JOURNAL PUBLICATIONS:

(All publications led by J. Talghader unless marked by *)

- [1] T. Luo, D. Lin, C. Hashemi, J. R. Leger, and J. J. Talghader, "Photography-Based Real-Time LWIR Scattering Estimation Technique," *Journal of the Optical Society of America A*, vol. 38, no. 7, pp. 1041-1050, July 2021. doi.org/10.1364/JOSAA.422069
- [2] P. Lin, M. Mah, J. Randi, S. DeFrances, D. Bernot, and J. J. Talghader, "High Power and Contamination Properties of All-Silica High Reflectivity Multilayers," *IEEE Photonics Journal*, vol. 13, no. 4, 2200407, August 2021. doi: 10.1109/JPHOT.2021.3100803
- [3] M. Mah and J. J. Talghader, "Effects of Kolmogorov turbulence on optical cavity spectral response," *Applied Optics*, vol. 60, no. 19, pp. 5488-5495, 1 July 2021. doi.org/10.1364/AO.424293

- Most Downloaded Papers* [4] A. Das and J. J. Talghader, “Enhanced absorption per unit mass for infrared arrays using subwavelength metal–dielectric structures,” *Journal of the Optical Society of America B*, vol. 38, no. 1, pp. 183-193, January 2021.
- Editor’s Choice* [5] Y. Lee, A. Das, and J. Talghader, "High-Q diamond microresonators in the long-wave infrared," *Optics Express*, vol. 28, pp. 5448-5458, 2020.
- [6] Y.-J. Lee, A. Das, M. L. Mah, J. J. Talghader, “Long-wave infrared absorption measurement of undoped germanium using photothermal common-path interferometry” *Applied Optics*, vol. 59, no. 11, pp. 3494-3497, 2020.
- [7] M. L. Mah and J. J. Talghader, “The decomposition of aberrated or turbulent wavefronts into a spatial mode spectrum using optical cavities,” *Applied Optics*, vol. 58, no. 16, pp. 4288-4299, 1 June 2019. <https://doi.org/10.1364/AO.58.004288>
- [8] A. Das, A. K. Brown, M. L. Mah, J. J. Talghader, “Photon diffusion in microscale solids,” *Journal of Physics: Condensed Matter*, vol. 31, 335703, 2019. <https://doi.org/10.1088/1361-648X/ab1f3d>
- [9] A. Brown, D. Bernot, A. Ogloza, Kyle Olson, Jeff Thomas, Joseph Talghader, “Physical origin of early failure for contaminated optics,” *Scientific Reports*, vol. 9, Article number 635, 24 January 2019.
- [10] T. Mitra, A. K. Brown, D. M. Bernot, S. DeFrances, J. J. Talghader, "Laser acceleration of absorbing particles," *Optics Express*, vol. 26, no. 6, pp. 6639-6652, 19 March 2018.
- [11] Y. J. Lee and J. J. Talghader, “Observational limitations of Bose-Einstein photon statistics and radiation noise in thermal emission,” *Physical Review A*, vol. 97, 013844 (11 pages), 26 January 2018. DOI: 10.1103/PhysRevA.97.013844
- [12] P. Armstrong, M. Mah, H. Ross, and J. Talghader, “Individual Microparticle Measurements for Increased Resolution of Thermoluminescent Temperature Sensing,” *IEEE Sensors*, vol. 18, no. 11, pp. 4422-4428, 1 Jun 2018.
- [13] A. Brown, K. Olson, A. Ogloza, and J. Talghader, “Continuous-Wave Laser Particle Conditioning: Thresholds and Time Scales,” *Optics and Laser Technology*, vol. 89, pp 27-30, March 2017.
- [14] W. S. Chan, M. L. Mah, R. C. Bay, and J. J. Talghader. “Long- wavelength optical fiber logging for high resolution detection of ash layers in glacier ice,” *Journal of Glaciology*, vol.63, no. 237, pp. 17-21, February 2017.
- [15] K. Olson, and J. Talghader “Spectrally dependent fluctuations of thermal photon sources, *Physical Review A*, vol. 94, 013822, 5 pages, 2016.

- [16] J. J. Talghader, M. Mah, E. G. Yukihiro, and A. Coleman “Thermoluminescent Microparticle Thermal History Sensors,” *Invited Microsystems and Nanoengineering*, vol. 2, 16037, Nature Publishing Group, 2016.
- [17] L. Taylor and J. Talghader, “Subsampling Phase Retrieval for Rapid Thermal Measurements of Heated Microstructures,” *Optics Letters*, vol. 41, no. 14, pp. 3189-3192, 2016.
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- [130] W. Liu and J. J. Talghader, "Spatial Mode Control in Microoptical Cavities using Shape-Tunable Mirrors," *Technical Digest of the 2004 IEEE/LEOS Optical MEMS Conference*, pp. 14-15, Takamatsu, Japan, August 2004.
- [131] M. S. Sutton and J. J. Talghader, "Deposition dependence of zirconium tungstate based negative thermal expansion thin films in optical coatings," *2004 Optical Interference Coatings Conference*, Tuscon, AZ, June 27-July 2, 2004.
- [132] W. B. Song and J. J. Talghader, "Microbolometers with adaptive detectivity using electrostatic actuation," *Technical Digest of the 2004 Solid State Sensor and Actuator and Microsystems Workshop*, Hilton Head, SC, June 6-10, 2004, pp. 336-339.
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- [144] R. Supino and J. J. Talghader, "Absorption monitoring and optical damage protection for micromechanical optics," *Proceedings of the 2001 Conference of Lasers and Electro-optics*, Baltimore, MD, p. 155, 2001.
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- [146] R. Supino and J. J. Talghader, "Thermal time response of microfilaments," *Proceedings of the 2000 Optical MEMS Conference*, Kauai, Hawaii, August 21-24, 2000, pp. 123-124.
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CONFERENCE PRESENTATIONS WITHOUT SUMMARIES/PROCEEDINGS

- [151] *Keynote* J. J. Talghader, "The impact of surface particulates and laser-accelerated particles on continuous-wave laser damage," *SPIE Laser Damage Conference*, Rochester, NY, 13 October 2021.
- [152] *Invited Webinar* J. J. Talghader, "Fundamental properties and real-world breakdown of low absorption thin films from the visible to infrared," *OSA Thin Film Technical Group*, 12 October, 2021.
https://www.optica.org/en-us/meetings/webinar/2021/10_october/fundamental_properties_and_real-world_breakdown_of/
- [153] M. Mah, A. Kurbatov, and J. J. Talghader, "Laser Cutting to Collect Ice Samples in Boreholes," *West Antarctic Ice Sheet (WAIS) Workshop*, Sterling, VA, September 20-23, 2021.
- [154] M. L. Mah, M. X. Wulff, A. V. Kurbatov, and J. J. Talghader, "RELIC: Robotics-enhanced laser ice collection," C45D-1024, *AGU (American Geophysical Union) Fall Meeting*, New Orleans, LA, 16 December 2021.
- [155] M. L. Mah and J. J. Talghader, "Effects of Kolmogorov Turbulence on Optical Cavity-Based Measurement," *2021 Advanced High-Power Laser and Beam Control Conference*, Directed Energy Professional Society, Online, August 2021.
- [156] Z. Tebow, J. Hunt, A. Ogloza, and J. Talghader, "Phase Mismatch in Optical Coatings for Multi-Wavelength Adaptive Optics," *2021 Advanced High-Power Laser and Beam Control Conference*, Directed Energy Professional Society, Online, August 2021.
- [157] J. H. Hunt, M. L. Mah, J. J. Talghader, "Laser Annealing of Optical Coatings for Post-Assembly Deformable Mirror Processing," *2021 Advanced High-Power Laser and Beam Control Conference*, Directed Energy Professional Society, Online, August 2021.
- [158] *Invited* J. J. Talghader, A. Brown, and T. Mitra, "The failure of high power optics due to dirt and airborne particles," *OSA Laser Congress, Advanced Solid State Lasers*, Vienna, Austria, October 2, 2019, AW3A.1.
- [159] *Invited* J. Talghader, "Mitigating Thermal Effects in the Mirrors and Cavities of High Power Laser Systems," *SPIE Defense + Security, High Power Lasers*, Strasbourg, France, September 12, 2019.

- [160] J. Talghader and A. Das, "Photon Diffusion Heat Transfer in HEL-Illuminated Surfaces," in *Laser Technology for Defense and Security XV* at the *SPIE Defense and Commercial Sensing Symposium*, Orlando, FL, April 17-18, 2019.
- [161] J. Talghader and M. Mah, "Optical Cavity Spatial Mode Spectra for Sensing Wavefront Aberrations and Turbulence," *2019 Annual DEPS Science and Technology Symposium*, Destin, FL, April 8-12, 2019.
- [162] J. H. Hunt, M. L. Mah, J. J. Talghader, "Observed Aberration-Induced Spectral Changes in Optical Cavities: Applications to Turbulence Sensing," *2020 Annual DEPS Science and Technology Symposium*, West Point, NY, March 9-13, 2020.
- [163] M. L. Mah, A. Ogloza, J. Randi, D. Samuels, and J. J. Talghader, "Impact of Contamination Density on Optical Damage of Directed Energy Optics," *2020 Annual DEPS Science and Technology Symposium*, West Point, NY, March 9-13, 2020.
- *[164] J. Stone, P. E. Spector, T. Hillebrand, J. H. Gombiner, J. K. Feathers, J. Talghader, J. P. Severinghaus, D. Pollard, G. Balco and L. K. Fifield, "West Antarctic Ice Sheet History from a Subglacial Bedrock Core," C21E-1507, *American Geophysical Union Fall Meeting*, San Francisco, CA, December 9-13, 2019.
- *[165] J. Stone, P. Spector, T. Hillebrand, J. Gombiner, J. Feathers, D. Pollard, J. Severinghaus, J. Talghader, G. Balco, N. Brown, and K. Fifield, "Searching for subglacial evidence of past West Antarctic Ice Sheet collapse – 1: Exposure history of a subglacial bedrock core," *26th Annual WAIS (West Antarctic Ice Sheet) Workshop*, Julian, CA, USA, Oct 16-18, 2019.
- [166] J. J. Talghader, *Invited Talk* "Particle acceleration and particle-induced breakdown in high power laser optics," *High Power Lasers Conference in SPIE Defense and Security*, Berlin, Germany, September 12, 2018.
- [167] J. J. Talghader, "Particulate and contamination-induced failure of high power optics," in *Laser Systems, Laser Materials, and Applications I* conference at the *SPIE Defense and Commercial Sensing Symposium*, Orlando, FL, April 15-19, 2018.
- [168] J. J. Talghader, T. Mitra, A. K. Brown, D. M. Bernot, S. Defrances, *Invited Talk*, "Laser Acceleration of Absorbing Particles and Their Role in Inducing Early Materials Failure," *Optical Trapping and Optical Micromanipulation in SPIE Optics and Photonics*, San Diego, August 22, 2018.
- [169] J. J. Talghader, *Invited Talk* "Future Directions for Microbolometers and Thermopile Infrared Detectors," *Image Sensing Technologies: Materials, Devices, Systems, and Applications V* in *SPIE Defense and Commercial Sensing*, Orlando, FL, April 2018.
- [170] J. J. Talghader, *Invited Talk* "Revisiting Planck's Law: Thermal Emission and Radiation Noise in Subwavelength Optical Cavities," *Light Conference 2018*, Changchun, China, July 16-18, 2018.

- [171] T. Mitra, A. Brown, D. M. Bernot, S. DeFrances, and J. J. Talghader, "Acceleration and Forces Induced by High Power Laser Illumination of Absorbing Particles," High Power Laser Ablation Conference, Santa Fe, NM, March 26-29, 2018.
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- [174] T. Mitra, A. Brown, D. M. Bernot, S. DeFrances, and J. J. Talghader, "Acceleration and Forces Induced by High Power Laser Illumination of Absorbing Particles," Accepted for oral presentation at the *High Power Laser Ablation Conference*, Santa Fe, NM, March 2018.
- [175] *Invited Talk* J. J. Talghader, "Future Directions for Uncooled Infrared Detectors," *DoD Basic Research Forum*, Arlington, VA, October 19, 2017.
- [176] *Invited Talk* J. J. Talghader, "Revisiting Planck's Law: Thermal Emission and Radiation Noise in Subwavelength Infrared Cavities," *Conference on Lasers and Electrooptics Pacific Rim*, Oral 3-2F-1, Singapore, August 3, 2017.
- [177] *Invited Talk* J. J. Talghader, "Optical breakdown of contaminated materials: Physics wins even with dirt," *Emerging Technologies CMOS Workshop*, Warsaw, Poland, May 29, 2017.
- [178] A. Brown, A. Ogloza, K. Olson, J. Thomas, and J. Talghader, "Bandgap dependence of particle induced CW laser damage," *DEPS Annual Meeting*, Huntsville, AL, February 13-17, 2017.
- [179] M. L. Mah, W. S. Chan, R. C. Bay, and J. Talghader, "Strong correlation of borehole optical backscattering and volcanic sulfate signatures at Siple Dome," C53A-0699, *American Geophysical Union Fall Meeting*, San Francisco, CA, December 12-16, 2016.
- [180] *Invited Talk* J. J. Talghader, "Microsensors and Particles: Infrared detectors, solar driven devices, and sensing inside explosions," *Stanford Photonics Research Conference*, Stanford, CA, September 19-20, 2016.
- [181] A. K. Brown, A. Ogloza, K. Olson, and J. Talghader, "Continuous-Wave Laser Particle Conditioning: Thresholds and Time Scales," *Directed Energy Professional Society Annual Symposium*, Albuquerque, NM, March 7 – 11, 2016.
- [182] *Invited Talk* J. J. Talghader, "Optical Breakdown of Contaminated Materials: Physics Wins even with Dirt," *2016 Light Conference*, Changchun, China, July 4-8, 2016.

- [183] *Invited Talk* J. J. Talghader, "Physical Limits of Thermal Infrared Detection", *IEEE Sensors Conference*, Busan, South Korea, November 1-4, 2015.
- [184] A. Brown, A. Ogloza, L. Taylor, J. Thomas, and J. Talghader, "Continuous-wave laser damage and conditioning of particle contaminated optics," *Directed Energy (DEPS) Symposium*, Anaheim, CA, March 2015.
- *[185] A. Ogloza, A. Brown, A. Lozano, J. Thomas, and J. Talghader, "CW Laser Damage and Light Refraction due to Sea Water Contamination of Optics," *Directed Energy Society (DEPS) Symposium*, Anaheim, CA, March 2015.
- [186] K. Olson, A. Ogloza, J. Thomas, and J. Talghader, "CW Laser Heating of ultra-low absorption materials," *Directed Energy Society (DEPS) Symposium*, Anaheim, CA, March 2015.
- [187] J. J. Talghader and E. G. Yukihara, "Thermometry using Microparticle Thermoluminescence: Overview and Outlook," *15th International Detonation Symposium*, July 13-18, San Francisco, CA, 2014.
- *[188] E. G. Yukihara, J. J. Talghader, A. Coleman, B. Doull, T. Gustafson, S. Bastani, M. L. Mah, P. R. Armstrong, "Particle Thermometry using Microparticle Thermoluminescence: Overview and Outlook," *15th International Detonation Symposium*, July 13-18, San Francisco, CA, (2014.).
- [189] *Invited Talk* J. J. Talghader, "Thermal Performance Limits of Optical Micro- and Nanomechanical Devices," *International Conference on Micro/Nano Optical Engineering*, July 3-5, 2014, Changchun, China.
- [190] J. J. Talghader, *Invited Talk* "Laser-induced thermal breakdown of optical coatings," *High Power Lasers Conference, Security and Defense Symposium*, Dresden, Germany, September 23, 2013.
- *[191] E. G. Yukihara, D. Wang, B. A. Doull, L. C. Oliveira, B. Obryk, L. L. Campos, J. Lee, and J. J. Talghader. "Temperature sensing using thermoluminescence: Principles and State of the Art". *17th International Conference on Solid State Dosimetry*, Sep 22 - 27, Recife, Brazil (2013).
- [192] J. J. Talghader, *Invited Talk* "Thermal performance limits of micro- and nanomechanical devices," *International Symposium on Applications and Potentials of MEMS/NEMS*, Tsinghua University, Beijing, China, April 18-19, 2013.
- [193] P. R. Armstrong, M. L. Mah, and J. J. Talghader, "The Accidental Sensor: 'Off-label' Uses for Thermoluminescent Radiation Dosimeters," *Design of Medical Devices Conference*, Minneapolis, MN, April 9, 2013.

- [194] L. N. Taylor, A. K. Brown, and J. J. Talghader, "Pulsed vs. CW Thermal Breakdown in Nanolaminate Optical Coatings on Patterned Optics," *15th Annual Directed Energy Symposium*, Albuquerque, New Mexico, November 2012.
- [195] J. J. Talghader, *Invited Talk* "Thermal history sensing using thermoluminescence: measurement concepts and testing," *DTRA Workshop on Time-Dependent Temperature Measurements in Energy Release Processes*, Chicago, IL, October, 10, 2012.
- [196] J. J. Talghader, *Invited Talk* "High-Sensitivity Infrared Detection and Spectroscopy," 2012 *CMOS Emerging Technologies Workshop*, Vancouver, BC, July 18-21, 2012.
- [197] R. Shea, A. Gawarikar, and J. Talghader, "Impact of thermal radiation on the performance of ultrasmall microcoolers" *International Conference of Thermoelectrics*, Aalborg, Denmark, July 9, 2012. (Note that a subset of the presentations from this conference became papers in the Journal of Electronic Materials listed above.)
- *[198] E. G. Yukihiro, B. Doull, L. C. Oliveira, E. D. Milliken, L. G. Jacobsohn, C. L. McPherson, M. Mah, P. Armstrong, and J. J. Talghader. "A survey of thermoluminescent materials for temperature measurements". 2012 International Conference on Defects in Insulating Materials, June 24-29, Santa Fe, NM (2012).
- [199] J. J. Talghader, *Invited Talk* "Thermal conduction in optical coatings and interfaces: a key to high-power meta-optics," *2011 Laser Damage Conference*, Talk 8190-40, Boulder, CO, September 18-21, 2011.
- [200] J. J. Talghader, *Invited Talk* "Nanomechanical Control of Electron States," *International Conference on Micro/Nano Optical Engineering*, June 12-16, 2011, Changchun, China, p. 15.
- [201] M. Mah, P. Armstrong, J. Lightstone, J. Talghader, "Thermal history sensing of post-detonation environments with thermoluminescent microparticles," *APS Shock Compression of Condensed Matter 2011*, Chicago, IL, June 27-July 1, 2011.
- [202] *Invited Talk* J. J. Talghader, "Luminescent microparticles as thermal history sensors," *CMOS Emerging Technologies Workshop*, Vancouver, BC, May 19-21, 2010.
- [203] *Invited Talk* J. J. Talghader, "Material Signatures and Tunable High Sensitivity Detection in the Infrared," *5th Asia-Pacific Conference on Transducers and Micro-Nano Technology*, Perth, Western Australia, July 6-9, 2010.
- [204] W. S. Chan, M. Mah, M. Gugliemi, J. J. Talghader, "Raman probing of gaseous constituents and water isotopes in deep glacial ice," *Eos Trans. AGU*, 88(53), Fall Meet. Suppl., Abstract C41C-0537, 2008.
- [205] J. J. Talghader, "Optical Probing of Deep Glacial Ice using Short Laser Pulses," *14th Annual West Antarctic Ice Sheet Workshop*, September 5-8, 2007, Sterling, VA.

- [206] J. J. Talghader, "From micro- to nano-: thermal effects in micromachined devices," *2006 Conference on Optoelectronic and Microelectronic Materials and Devices*, Perth, Western Australia, December 6-8, 2006.
- [207] J. J. Talghader, *Invited Talk* "Adaptive imaging with uncooled LWIR detectors," *SPIE Defense and Security Symposium, Intelligent Integrated Microsystems*, Orlando, FL, April 20, 2006.
- [208] J. J. Talghader, *Invited Talk* "Mechanics of Optical Coatings in Extreme Thermal Environments," *2005 International Conference on Metallurgical Coatings and Thin Films*, San Diego, CA, May 2005.
- [209] J. J. Talghader, "Optical time domain reflectometry for probing deep glacial ice," *Midwest Glaciology Meeting*, Minneapolis, MN, March 25-26, 2004.
- [210] J. J. Talghader, *Invited Talk* "Ultimate Performance in Optical MEMS," *SPIE International Symposium on Microelectronics, MEMS, and Nanotechnology*, December 10-12, 2003, Perth, Australia.
- [211] J. J. Talghader, *Invited Talk*, "MEMS confocal microresonator arrays using mirrors with strain-induced curvature," *SPIE – Photonics West – Laser Resonators and Beam Control V*, San Jose, CA, January 22, 2002.
- [212] Y. Wang and J. J. Talghader, "Fluorescence-based tracking of micro- and nanosensors in microfluidic systems," *2001 OSA Annual Meeting*, Talk WII3, October 17, 2001, Long Beach, CA.
- [213] R. Supino and J. J. Talghader, "Substrate quenching of microfilaments and thermal microdetectors," *2000 OSA Annual Meeting*, October 22-26, Providence, RI, 2000.
- [214] W. Liu, and J. J. Talghader, "Modeling and fabrication of MEMS reflective modulators using deformable optical coatings," *SPIE Photonics West, Integrated Optics IV*, San Jose, January 2000.
- [215] W. Liu and J. J. Talghader, "Chemical and mechanical properties of hard oxide coatings for MEMS," 1999 Spring Meeting of the Materials Research Society, San Francisco, Presentation BB7.18.
- [216] *Invited Talk* J. J. Talghader, "Integration of VCSELs using fluidic self-assembly," *Proceedings of the SPIE - Vertical Cavity Surface Emitting Lasers II*, vol. 3286, pp. 86-95, 1998.

ISSUED U.S. PATENTS:

- J. Talghader and M. Mah, “Optical Aberration Detection Systems,” U.S. Patent No. 10,962,474 Issued on March 30, 2021.
- J. J. Talghader, “Detection beyond the standard radiation noise limit using reduced emissivity and optical cavity coupling,” U. S. Patent 8,704,179, Issued April 22, 2014.
- J. J. Talghader, A. Gawarikar, and R. Shea, “Detection Beyond the Standard Radiation Noise Limit using Spectrally Selective Absorption,” US Patent 8,629,398, Issued January 14, 2014, Plus related foreign applications.
- J. J. Talghader, Y. Wang, and M. Sutton, “Tunable Finesse Infrared Cavity Thermal Detectors,” U.S. Patent 7,968,846, Issued June 28, 2011, Plus several related foreign applications.
- J. J. Talghader, “Detection beyond the standard radiation noise limit using reduced emissivity and optical cavity coupling,” U.S. Patent 7,800,066. Issued September 21, 2010. Plus several related foreign applications.
- M. Blumenfeld, M.A. Sanders, J. J. Talghader, et. al., “Imaging of biological samples using electronic light detector,” U.S. Patent 7,145,645, Issued December 5, 2006.
- M. Blumenfeld, J. J. Talghader, M. A. Sanders, S. A. Nelson, K. Anderson, S. A. Lewis, “Scanning of Biological Samples,” U.S. Patent 6,867,851, Issued March 15, 2005.
- M. Blumenfeld, J. J. Talghader, and M. A. Sanders, “Direct mapping of DNA chips to detector arrays,” U.S. Patent 6,784,982, Issued August 31, 2004.

BOOK CHAPTERS

- W. S. Chan, P. Armstrong, L. N. Taylor, M. L. Mah and J. J. Talghader. *Fabrication and manufacturing technology for optical MEMS*. Book chapter in Hongrui Jiang (Ed.), *Optical MEMS for Chemical Analysis and Biomedicine*. IET, 2016.
- J. J. Talghader and M. L. Mah, “Sensing Temperature inside Explosions,” in *Smart Sensors for Industrial Applications*, no. 16, K. Iniewski, Ed. CRC Press, 2013, pp. 259–272.
- J. J. Talghader and M. L. Mah, “Luminescent thermometry for sensing rapid thermal profiles in fires and explosions,” Chapter 4 in *Optical, Acoustic, Magnetic, and Mechanical Sensor Technologies*, Ed. K. Iniewski, CRC Press, pp. 79-105, 2012.

STUDENT ADVISING:

PHD STUDENTS

Woo-Bin Song PhD Awarded 2004 University of Minnesota
Thesis: Thermal Control in Micromachined Devices and Its Application

Wei Liu PhD Awarded Spring 2005 University of Minnesota
Thesis: Electrically Tunable Micromirrors and Microcavities

Ryan Supino PhD Awarded Fall 2005 University of Minnesota
Thesis: Autonomous Microfluidic Sensor Particles

Yuyan Wang PhD Awarded Summer 2007 University of Minnesota
Thesis: Tunable Filters for Infrared Detection

Jan Makowski PhD Awarded 2008 University of Minnesota
Thesis: Band-Gap Tuning through Mechanical Semiconductor Heterostructures

Nick Gabriel PhD Awarded Spring 2011 University of Minnesota
Thesis: High-Power and High-Aspect-Ratio Optical Coatings by Atomic Layer Deposition

Sangho Kim PhD Awarded Spring 2013 University of Minnesota
Thesis: Fabrication and Characterization of Micromachined Dielectric Thin Films and Temperature Sensors using Thermoluminescence

Anand Gawarikar PhD Awarded Spring 2013 University of Minnesota
Thesis: Spectrally Selective High Detectivity Uncooled Detectors for the Long Wave Infrared

Ryan Shea PhD Awarded Spring 2013 University of Minnesota
Thesis: Design and fabrication of state of the art uncooled thermopile infrared detectors with cavity coupled absorption

Kyle Olson PhD Awarded Fall 2015 University of Minnesota
Thesis: High Power Continuous Wave Laser Heating and Damage with Contamination, and Non-Uniform Spectrally Dependent Thermal Photon Statistics

Wing Shan Chan PhD Awarded January 2016 University of Minnesota
Thesis: MEMS Actuators for Tuning Nanometer-scale Airgaps in Heterostructures and Optical Instrumentation for Glacier Ice Studies

Luke Taylor PhD Awarded May 2016 University of Minnesota
Thesis: Going Deeper into Laser Damage: Experiments and Methods for Characterizing Materials in High Power Laser Systems

Merlin Mah PhD Awarded July 2017 University of Minnesota

Thesis: Fire and Ice: Thermoluminescent Temperature Sensing in High-Explosive Detonations and Optical Characterization Methods for Glacier Ice Boreholes

Phil Armstrong PhD Awarded July 2017 University of Minnesota
Thesis: Thermoluminescent Microparticles used as Harsh Environment Temperature Sensors
Characterized using MEMS Devices

Andrew Brown PhD Awarded June 2018 University of Minnesota
Thesis: Contamination Induced Continuous Wave (CW) Laser Damage of Optical Elements

Yu-Jen Lee PhD Awarded March 2020 University of Minnesota
Thesis: Spectrally Dependent Radiation Noise in Thermal Emission and Long-Wave Infrared High-Q Diamond Microdisks

MASTERS STUDENTS GRADUATED (As of 2014)

Andrew Bettino
Wing Shan Chan
Ke Cao
Nick Gabriel
Anand Gawarikar
Mousumi Gupta
Wing Shan Chan
Daniel Kelly
Christopher Larson
Wei Liu
Merlin Mah
Jan Makowski
Michael Manfred
Tirtha Mitra
Benjamin Potter
Suffian Zamali
Hongjian Fan
Kyle Olson
Ryan Shea
Charles Sperling
Ryan Supino
Mike Sutton
Luke Taylor
Eric Vogt

TEACHING AND COURSE DEVELOPMENT:

- 1) Bush Mid-Career Teaching Program
- 2) Infrared Technology and Environmental Sensing – EE 5649
This is a new course covering infrared physics and technology and its applications to chemical detection, thermal imaging, spectroscopy, and other fields.
- 3) Introduction to Microsystems Technology - EE 5141
This course was altered from a processing course to a physics-based phenomenological course covering microscale mechanics, actuation, heat transfer, optics, and fluids. The students work on a class fabrication lab as well.
- 4) Optical Fiber Communication – EE5627
- 5) Advanced MOS Devices – EE5953
This course was a new development from my industry experience covering metal-oxide semiconductor device physics.
- 6) Semiconductor Properties and Devices I – EE5163
- 7) Semiconductor Properties and Devices II – EE5164
- 8) Photonic Communication Devices – EE5632
This course was a new development that covered device-physics material related to optical fiber communications. Some of the material of this one-time transition course was merged into 5627.
- 9) Quantum Electronics – EE 8163
This course has been taught in two formats. One covered semiconductor quantum electronics material where the students were introduced to quantum mechanics and field quantization applied to p-n junction lasers and detectors. The second was a quantum optics course covering photon statistics, vacuum fields, microcavity effects, and laser cooling.
- 10) Semiconductor Devices – EE3063
- 11) Semiconductor Devices – EE3161
- 12) Transmission Lines (Electromagnetism) – EE 3601
- 12) Contemporary Optics – EE5630/PHYS5805
- 13) Linear Systems and Circuits – EE2011
- 14) Optical Electronics – EE5624
- 15) Senior Honors Project – Supervised many students 1999-2011
- 16) Senior Design Project – EE 4951 – Selected Project Titles:
 - Surface Roughness Sensor
 - Electronic Article Surveillance
 - RF “Professor” Tracker
 - Sun Tracker (Electronic Visor)
 - Tamper Proof RF Tags
 - Home Lighting Automation

UNIVERSITY AND DEPARTMENTAL COMMITTEES:

Faculty Recruiting Committee Chair, 2008-2009, 2019-2020
 College of Science and Engineering Faculty Consultative Committee, 2011-2015
 Chair, 2014-2015
 Post-Tenure Review Committee, 2007-2009, 2021-2023
 Faculty Recruiting Committee, 2006-2008, 2014-2015, 2018-2019, 2020-2021
 Promotion, Tenure, and Awards Committee, 2009-2011, 2015-17, Chair 2016-2017
 Departmental Faculty Consultative Committee, 1998-2001, 2002-2003

President's Postdoctoral Fellowship Program (Fellowship program to recruit minority faculty)
Review Committee, 2021
Minnesota Futures Review Panel 2022, 2019
Graduate Committee, 2000-2001, 2003-2005, Chair 2005-2006, 2012-2013
External Relations Committee, 2021-2022
Colloquium Coordinator, 2001-2003
HKN Faculty Advisor, 2005-2011

CONSULTING WORK:

Eyesafe, Inc. – Electronic Displays and Blue Light Toxicity
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Hutchinson Technology – Noninvasive Fiber Optic Sensors and Microsystems
Syndia Corp. – Microoptics and Telecommunications Patent Analysis
Guidant – Microelectronics Packaging
Photon Imaging – Advanced Microelectronic Assembly

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OSA Optics Express

OSA Optics Letters
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EXHIBIT B

EXHIBIT B
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- J. J. Talghader, “Detection beyond the standard radiation noise limit using reduced emissivity and optical cavity coupling,” U. S. Patent 8,704,179, Issued April 22, 2014.
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EXHIBIT C

EXHIBIT C

DOCUMENTS CONSIDERED

Court Documents in this Matter:

- Complaint (ECF No. 1).
- Complaint Exhibit A-U.S. Patent 8,901,516 (ECF No. 1-2).
- Complaint Exhibit B-Vilber Newton Marketing Brochure (ECF No. 1-2).
- Answer (ECF No. 16).
- Plaintiff's Disclosure of Asserted Claims and Preliminary Infringement Contentions and Document Production dated July 11, 2022.
- Defendant's Preliminary Invalidity Contentions of Plaintiff's U.S. Patent No. 8,901,516.
- Plaintiff's Patent Local Rule 4-1 Disclosure of Proposed Terms and Claim Elements for Construction dated September 26, 2022.
- Plaintiff's Updated Patent Local Rule 4-1 Disclosure of Proposed Terms and Claim Elements for Construction dated October 14, 2022.
- Plaintiff's Second Updated Patent Local Rule 4-1 Disclosure of Proposed Terms and Claim Elements for Construction dated October 17, 2022.

Patent Documents Reviewed:

1. U.S. Patent 8,901,516 ("516 Patent or **Exhibit D**).
2. U.S. File History for '516 Patent (Spectral_0000022-0000991)
3. Provisional Patent Application No. 61/379,282 ("Provisional Application" or **Exhibit E**, claimed for benefit by the '516 Patent).
4. U.S. Patent Application Publication No. US 2009/0268426 A1 ("Pohlert" or **Exhibit F**)
5. U.S. Patent 6,454,437 ("Kelly" or **Exhibit G**)
6. English Translation of Japanese Patent No. JP 10-040330 A ("Nomura" or **Exhibit H**) in the File History of the '516 patent at Spectral_0000752-0000759.
7. U.S. Patent Application Publication No. 2004/0245170 A1 ("Furze" or **Exhibit I**)
8. U.S. Patent Application Publication No. 2004/0121175 A1 ("Flexman" or **Exhibit J**)
9. U.S. Patent 5,984,494 ("Chapman" or **Exhibit K**)
10. U.S. Patent 6,894,289 ("Nilson")
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Other Resources:

1. <https://www.merriam-webster.com/dictionary/surrounding> last visited October 17, 2022, (**Exhibit L**)
2. IEEE Standard C37.20.10-2016 IEEE Standard Definitions for AC (52 kV and below) and DC (3.2 kV and below) Switchgear Assemblies at p. 24. Definition of "surface-mounted-device." (**Exhibit M**)

EXHIBIT D



US008901516B2

(12) **United States Patent**
Nelson et al.

(10) **Patent No.:** **US 8,901,516 B2**
(45) **Date of Patent:** **Dec. 2, 2014**

(54) **EXCITATION LIGHT SOURCE ASSEMBLY**

(75) Inventors: **Michael B. Nelson**, Tucson, AZ (US);
Michael D. Cable, Tucson, AZ (US)

(73) Assignee: **Spectral Instruments Imaging, LLC**,
Tucson, AZ (US)

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 84 days.

(21) Appl. No.: **13/222,688**

(22) Filed: **Aug. 31, 2011**

(65) **Prior Publication Data**

US 2012/0049089 A1 Mar. 1, 2012

Related U.S. Application Data

(60) Provisional application No. 61/379,282, filed on Sep.
1, 2010.

(51) **Int. Cl.**

G01N 21/64 (2006.01)

G03B 15/05 (2006.01)

(52) **U.S. Cl.**

CPC **G01N 21/645** (2013.01); **G01N 21/6456**
(2013.01); **G03B 15/05** (2013.01); **G01N**
2021/6419 (2013.01); **G01N 2021/6421**
(2013.01); **G01N 2021/6423** (2013.01); **G01N**
2021/6471 (2013.01)

USPC **250/461.1**

(58) **Field of Classification Search**

CPC **G01N 21/645**; **G01N 21/6428**; **G01N**
2021/7786; **G01N 21/6458**; **G01N 2021/6463**

USPC **250/461.1**

See application file for complete search history.

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Primary Examiner — Marcus Taningco

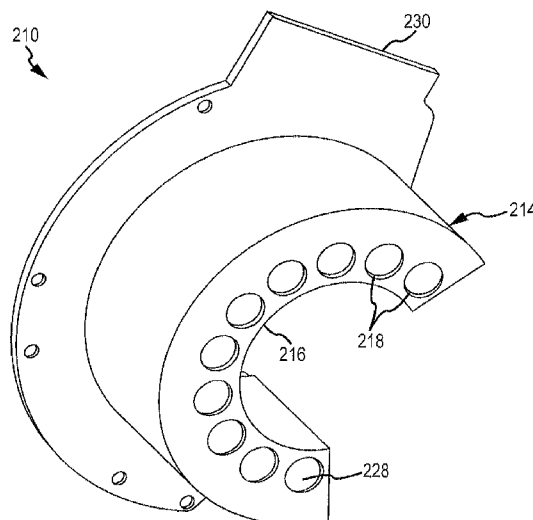
(74) *Attorney, Agent, or Firm* — Fennemore Craig, P.C.

(57)

ABSTRACT

An excitation light source assembly includes a housing defining a central opening therein and a plurality of lamp receptacles surrounding the central opening. The housing is mountable to a support structure having a camera mounted thereto so that a field of view of the camera is substantially unobstructed by the housing. A light source is positioned within each of the plurality of lamp receptacles. A diffuser is positioned adjacent the light source in each of the plurality of lamp receptacles so that each of the diffusers diffuses light produced by each of the light sources. A control system operatively connected to each of the light sources operates selected ones of the light sources to provide a desired excitation illumination to an object within the field of view of the camera.

27 Claims, 12 Drawing Sheets



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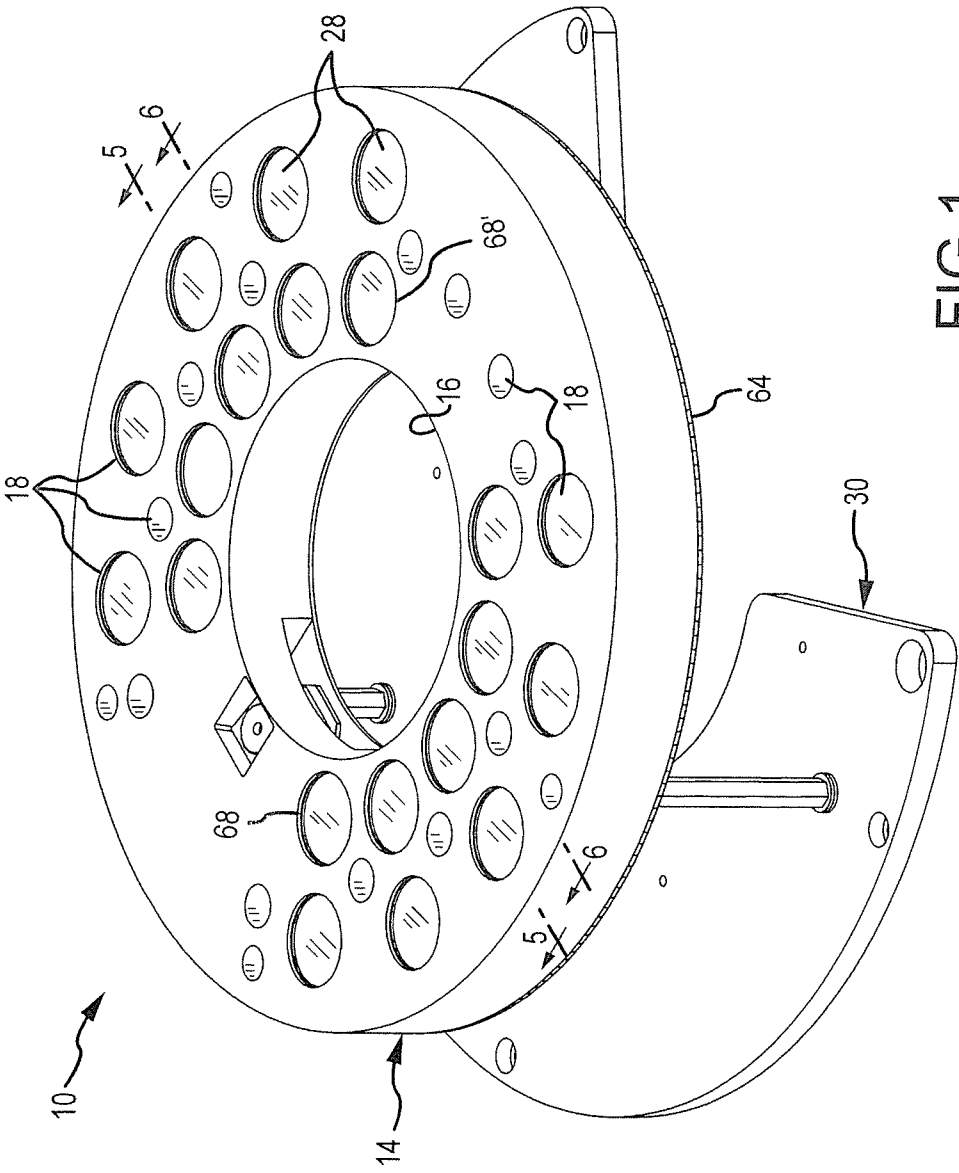


FIG. 1

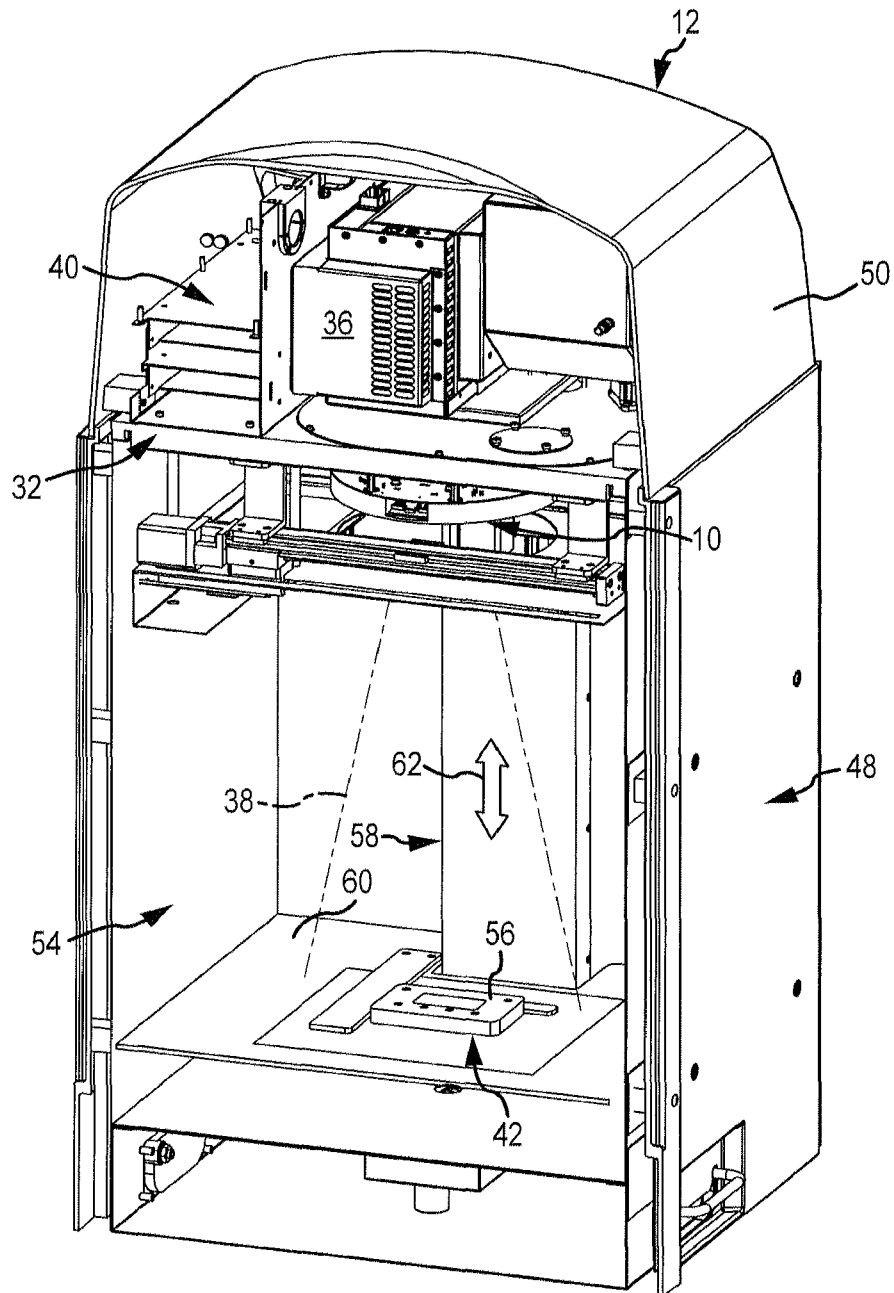


FIG.2

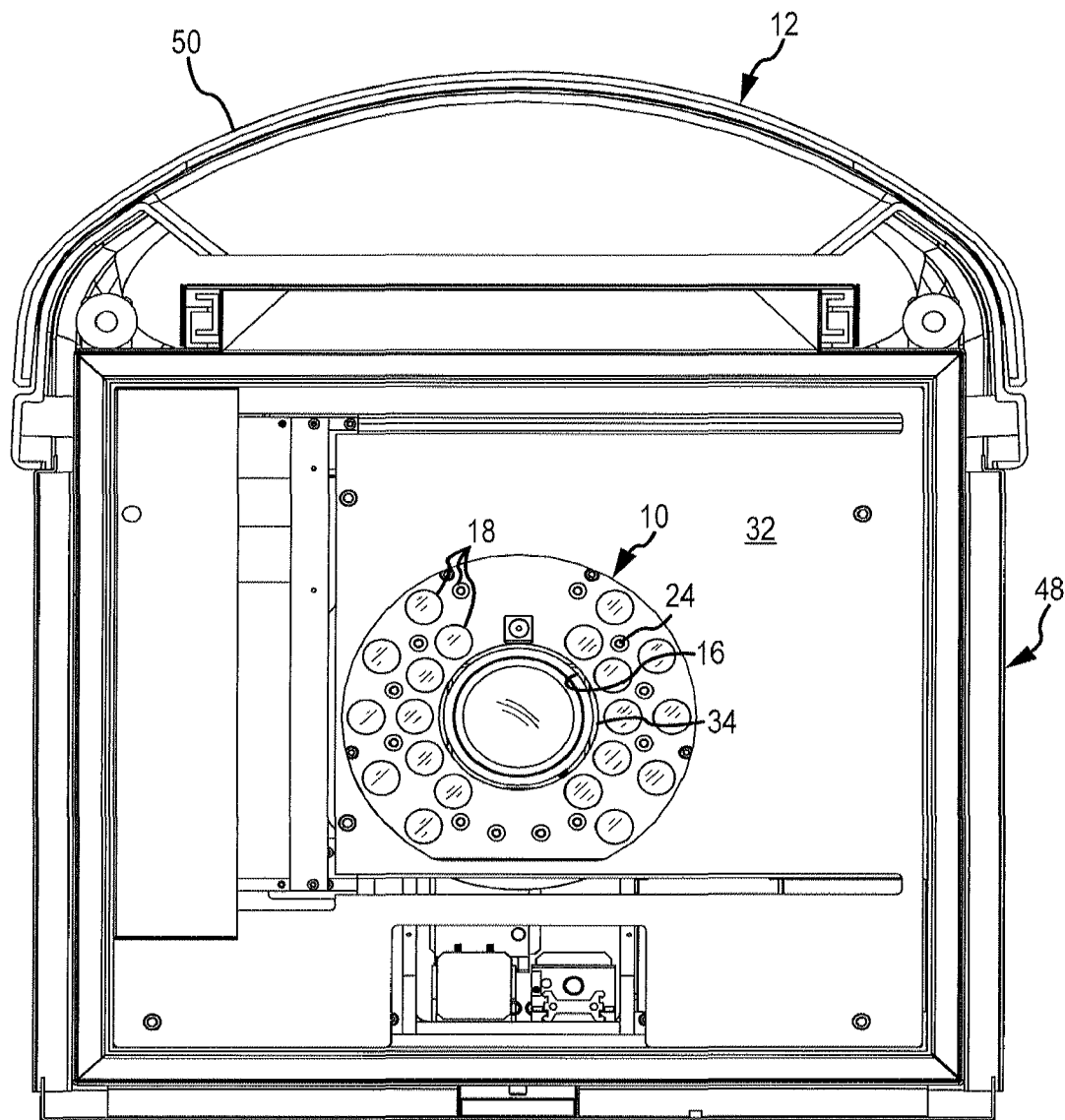


FIG.3

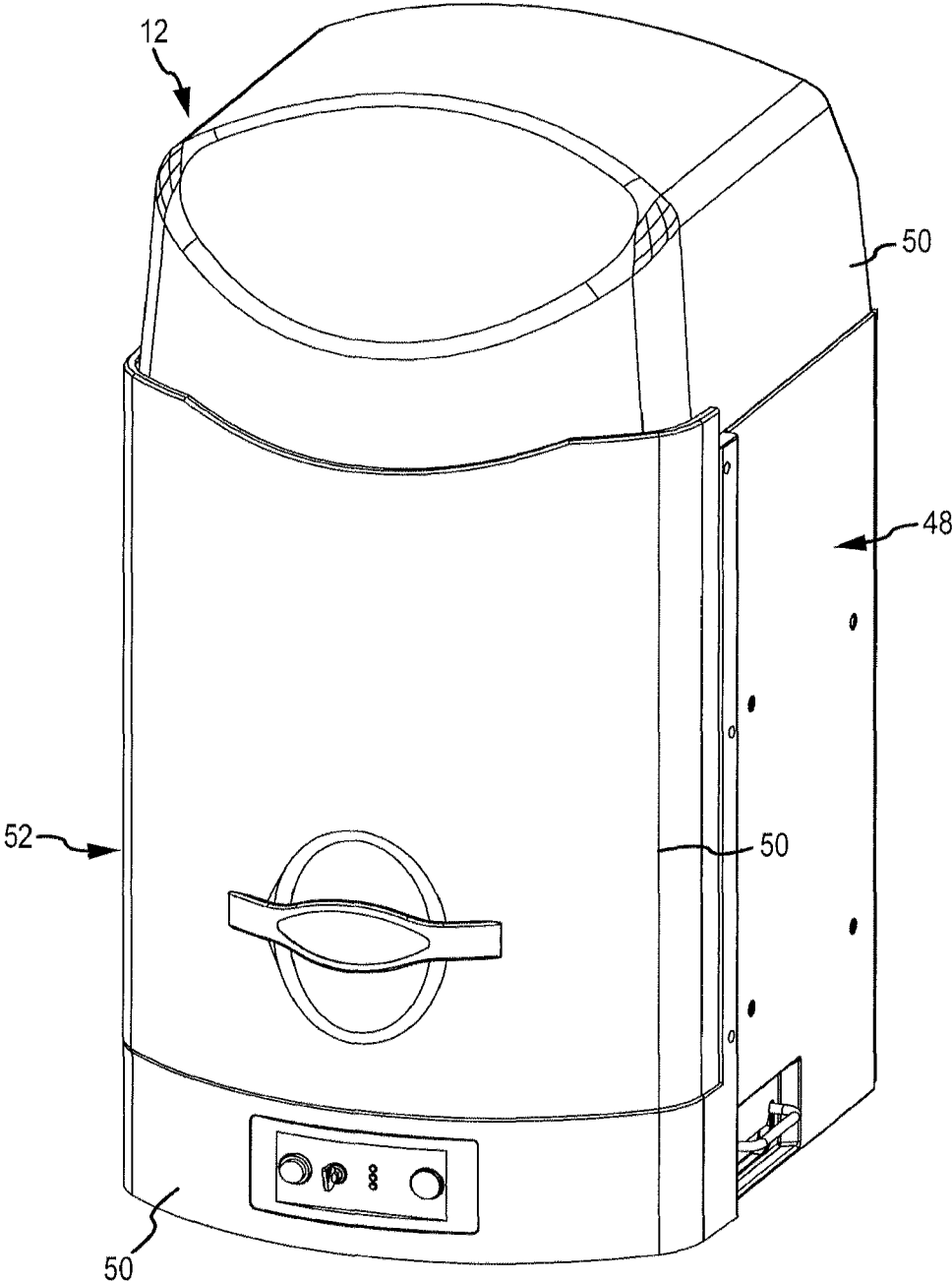


FIG.4

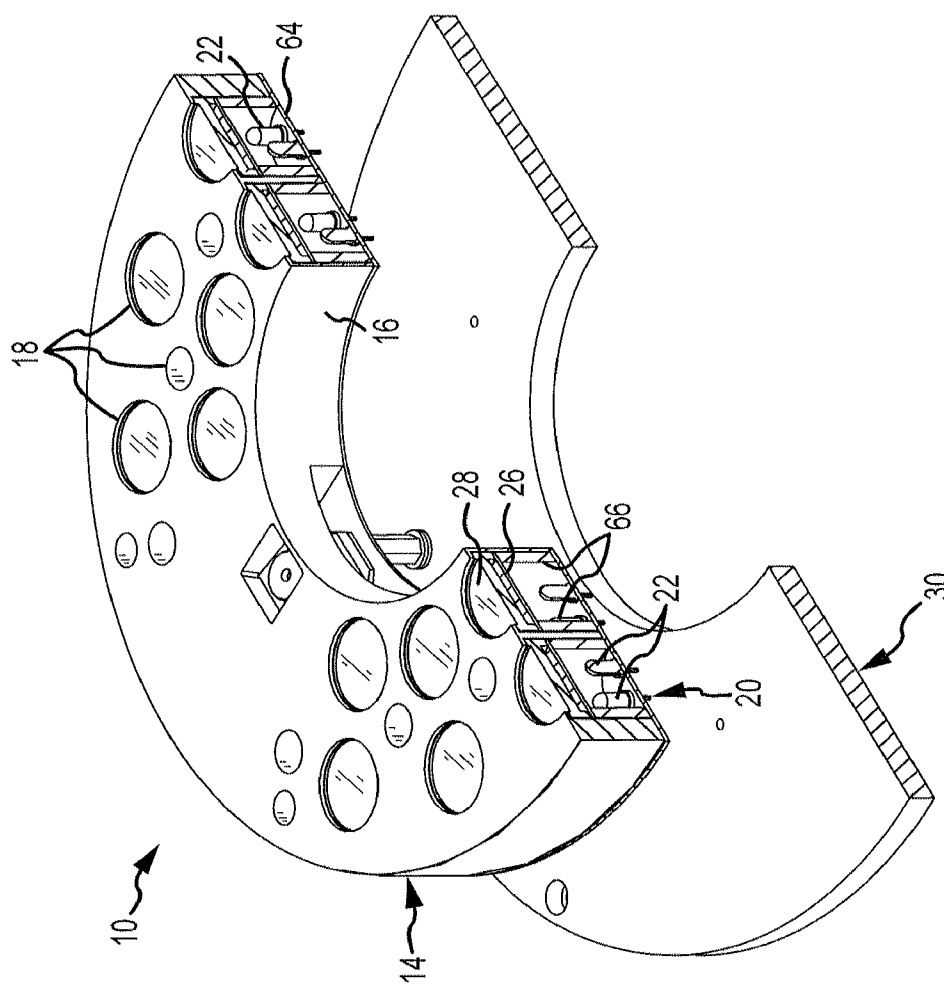


FIG. 5

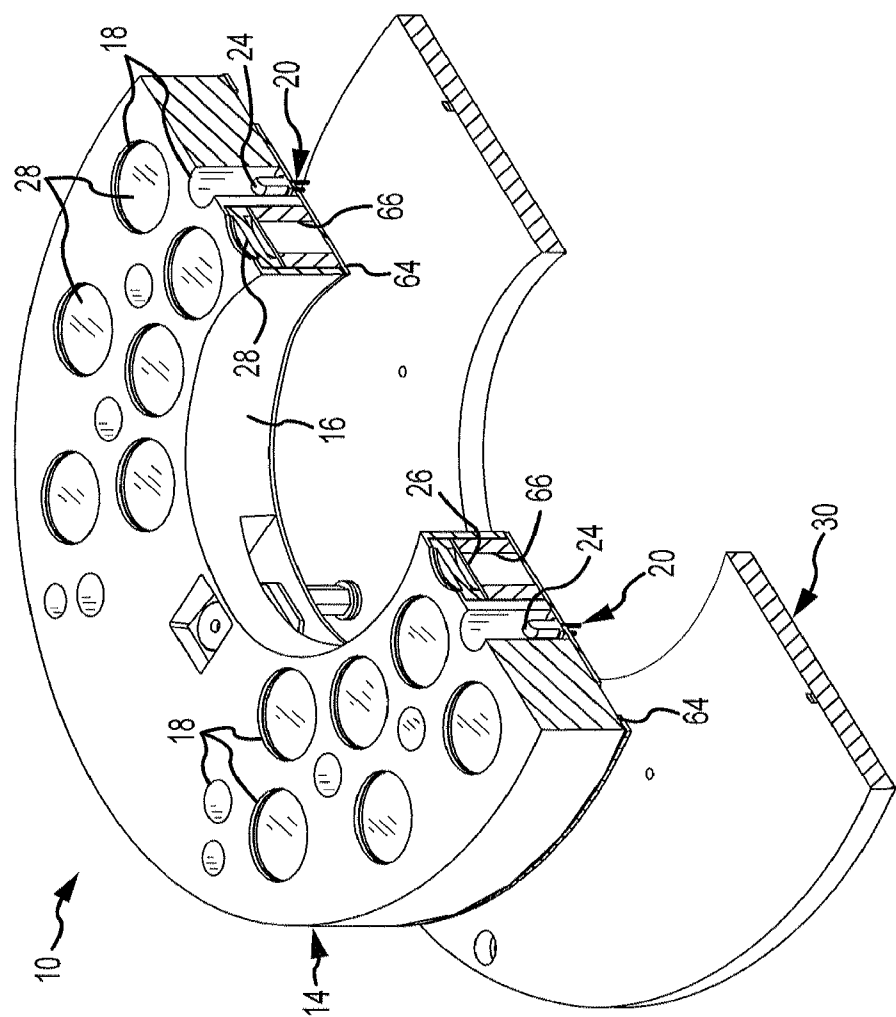


FIG. 6

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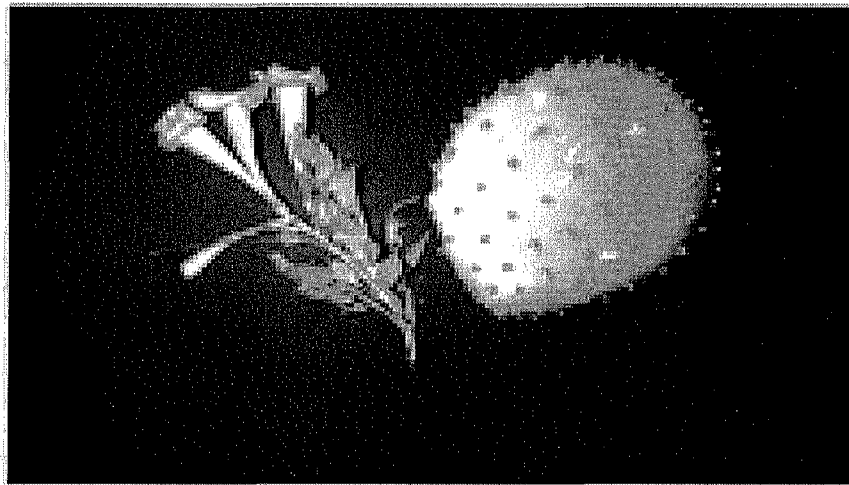


FIG. 7



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FIG. 8

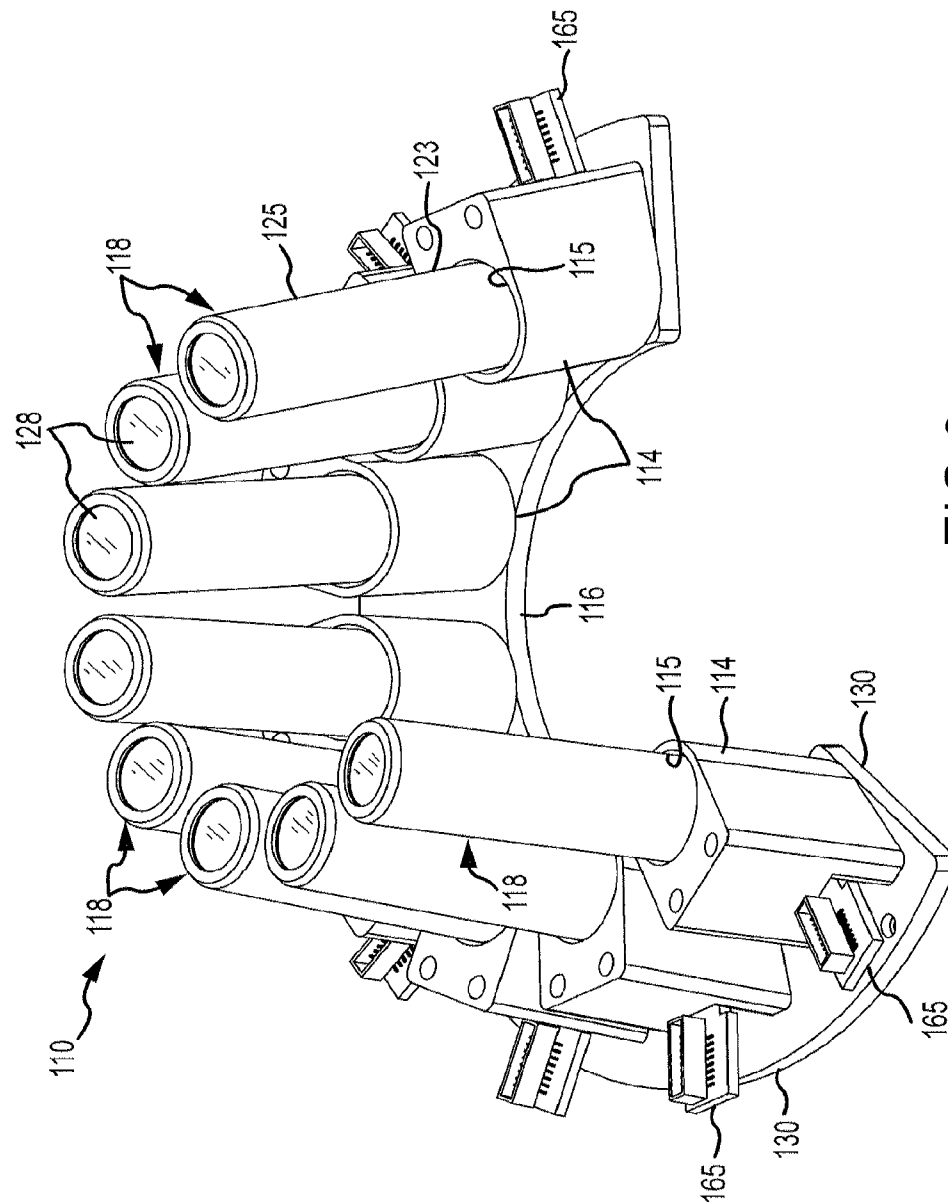


FIG. 9

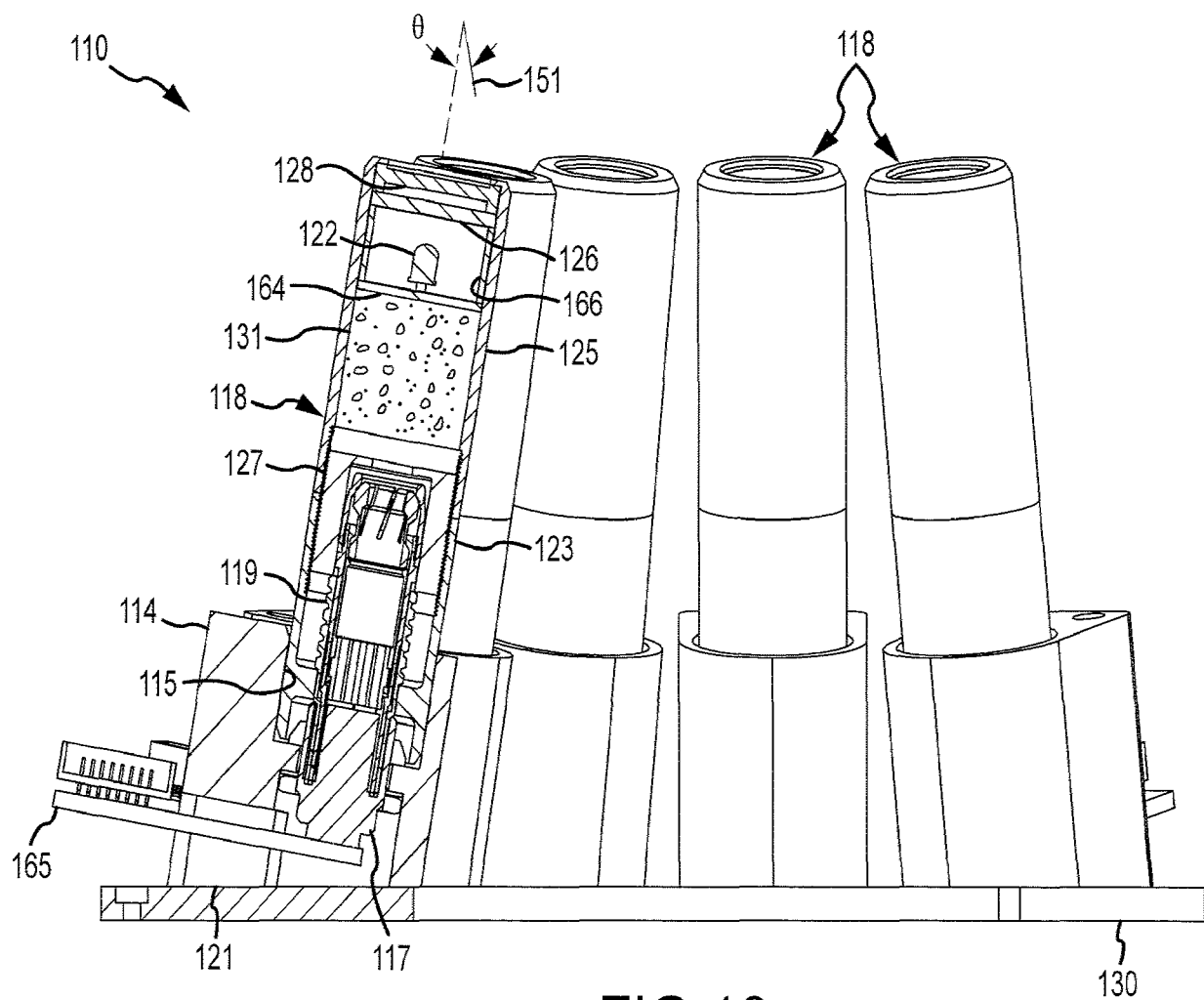


FIG.10

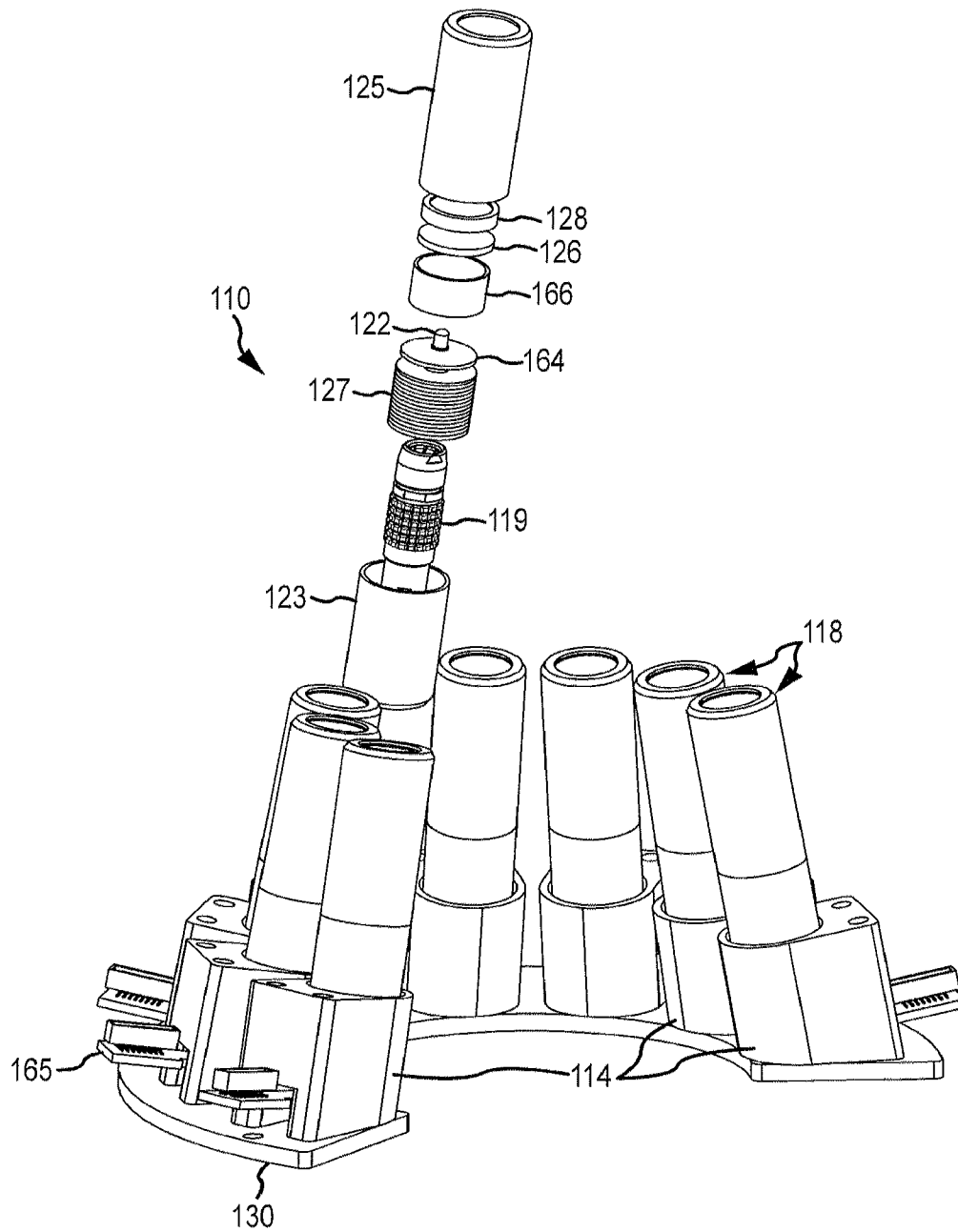


FIG. 11

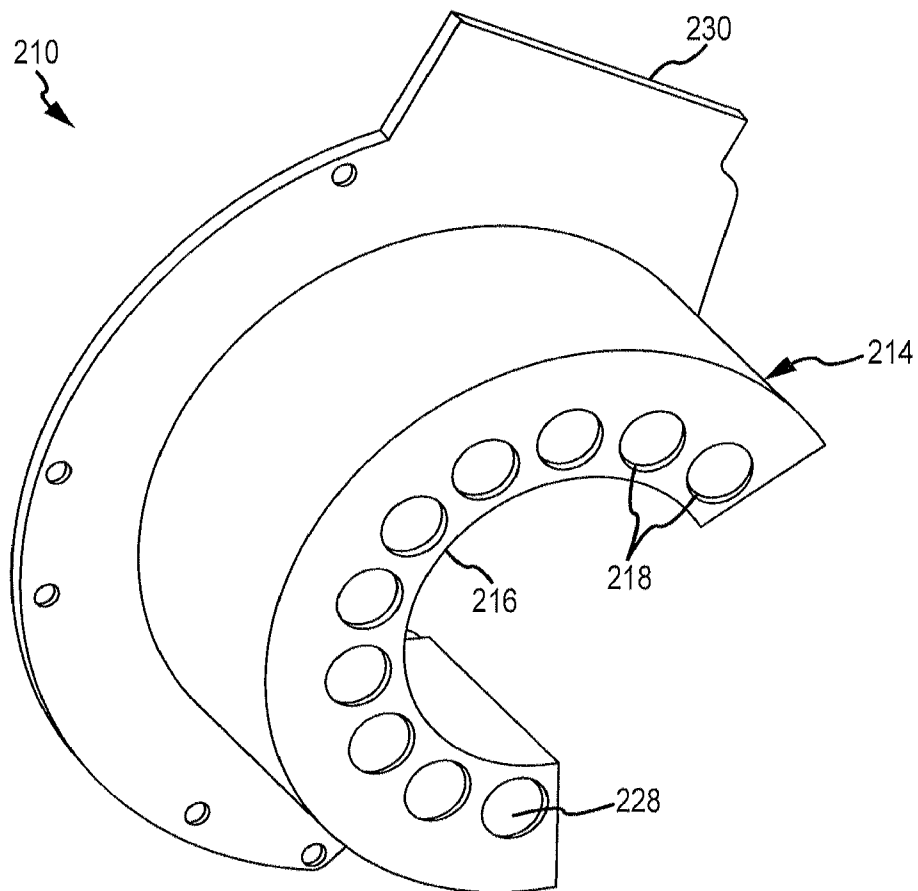


FIG. 12

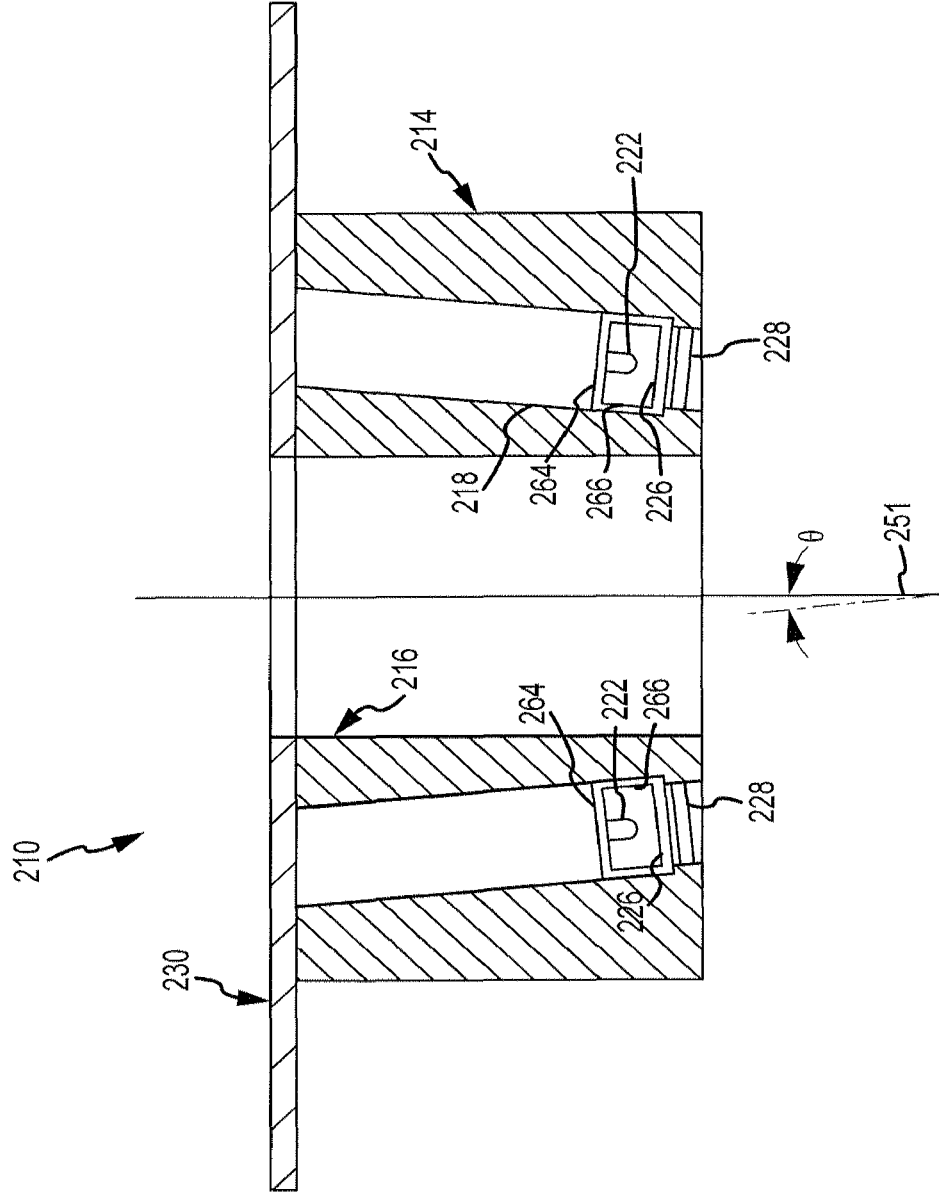


FIG. 13

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EXCITATION LIGHT SOURCE ASSEMBLY**CROSS-REFERENCE TO RELATED APPLICATION**

This application claims the benefit of U.S. Provisional Patent Application No. 61/379,282, filed on Sep. 1, 2010, which is hereby incorporated herein by reference for all that it discloses.

TECHNICAL FIELD

This invention relates in general to systems for exciting fluorescent materials and more particularly to systems for exciting fluorescent materials in molecular imaging applications.

BACKGROUND

Molecular imaging systems are known in the art and are commonly used to capture various types or modes of images from an object or specimen being analyzed. The objects or specimens that are imaged may comprise any of a wide range of compositions and objects, as is well-known. Primarily, such imaging systems are configured to detect extremely low levels of light emitted by the specimen or object under study. The light emitted by the object or specimen may be generated by a bio-luminescence process, a fluorescence process, or by a combination thereof. Such imaging systems may also be capable of capturing reflected light images, in which light reflected by the object is captured by the imaging system camera. Such a reflected light image is often combined with one or more emitted light images to form a single, composite image. Such a composite image allows a user to more easily correlate features and attributes of the emitted light image(s) with physical locations on the specimen or other characteristics that are contained in the reflected light image.

As is known, light emission by fluorescence results from the prior or simultaneous exposure of the fluorescent material to excitation light of suitable wavelength. However, not all fluorescent materials fluoresce or emit light in response to excitation light of the same wavelength. Consequently, the wavelength of the particular excitation light must be selected so that it will excite the particular fluorescent material involved.

Because most molecular imaging systems seek to detect fluorescence from a wide range of fluorescent materials, most such imaging systems are provided with excitation light sources that can be operated to illuminate the fluorescent material with excitation light of the appropriate wavelength. Unfortunately, however, most excitation light sources tend to be expensive and/or difficult to implement in use, and systems are constantly being sought that improve on existing systems.

SUMMARY OF THE INVENTION

An excitation light source assembly according to one embodiment of the invention may include a housing defining a central opening therein and a plurality of lamp receptacles surrounding the central opening. The housing is mountable to a support structure having a camera mounted thereto so that a field of view of the camera is substantially unobstructed by the housing. A light source is positioned within each of the plurality of lamp receptacles. A diffuser is positioned adjacent the light source in each of the plurality of lamp receptacles so that each of the diffusers diffuses light produced by each of the light sources. A control system operatively con-

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nected to each of the light sources operates selected ones of the light sources to provide a desired excitation illumination to an object within the field of view of the camera.

Also disclosed is an excitation light source assembly that includes a housing and a first connector portion mounted to the housing. A lamp receptacle produces light in a first defined wavelength band. A second connector portion is mounted to the lamp receptacle so that the lamp receptacle can be removably engaged with the first connector portion mounted to the housing. The housing is mountable to a support structure so that a field of view of a camera also mounted to support structure is substantially unobstructed by the housing and by the lamp receptacle.

Another excitation light source assembly includes a base member that defines a central opening therein. A plurality of first connector portions are mounted to the base member at positions located around the central opening. The light source assembly also includes a plurality of lamp receptacles, at least some of which produce light in different wavelength bands. A second connector portion mounted to each of the plurality of lamp receptacles is releasably engagable with a corresponding one of the plurality of first connector portions mounted to the base member. The base member is mountable to a support structure so that the central opening is aligned with a camera mounted to the support structure and so that a field of view of the camera is substantially unobstructed by the base member and the lamp receptacles.

Also disclosed is an assembly that includes a support structure and a camera mounted to the support structure. An excitation light source assembly mounted to the support structure includes a housing that defines a central opening therein and a plurality of lamp receptacles that surround the central opening. The housing is mounted to the support structure so that the central opening is aligned with the camera and so that a field of view of the camera is substantially unobstructed by the housing. At least one narrow-band light source is positioned within at least one of the plurality of lamp receptacles. A diffuser is positioned adjacent the narrow-band light source. A control system operatively connected to each of the narrow-band light sources operates selected ones of the narrow-band light sources to provide a desired excitation illumination to a fluorescent material within the field of view of said camera.

BRIEF DESCRIPTION OF THE DRAWINGS

Illustrative and presently preferred exemplary embodiments of the invention are shown in the drawings in which:

FIG. 1 is a perspective view of an excitation light source assembly according to one embodiment of the present invention;

FIG. 2 is a sectional view in perspective of a molecular imaging system having the excitation light source assembly of FIG. 1 provided therein;

FIG. 3 is a plan view of the support structure of the molecular imaging system of FIG. 2 showing the relative positions of the excitation light source assembly and the lens assembly of the camera;

FIG. 4 is an external view in perspective of the molecular imaging system of FIG. 2;

FIG. 5 is a sectional view in perspective of the excitation light source assembly taken along the plane 5-5 of FIG. 1;

FIG. 6 is a sectional view in perspective of the excitation light source taken along the plane 6-6 of FIG. 1;

FIG. 7 is fluorescent image of desert flora obtained with excitation light having a wavelength of about 465 nm and observed at a wavelength of about 550 nm;

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FIG. 8 is a fluorescent of the desert flora of FIG. 7 but observed at a wavelength of about 735 nm;

FIG. 9 is a perspective view of a second embodiment of an excitation light source assembly having a plurality of removable lamp modules;

FIG. 10 is a sectional view in elevation of one of the plurality of removable lamp modules of the second embodiment of the excitation light source assembly of FIG. 9;

FIG. 11 is an exploded perspective view of one of the removable lamp modules of the second embodiment of the excitation light source assembly of FIG. 9;

FIG. 12 is a perspective view of a third embodiment of an excitation light source assembly; and

FIG. 13 is a sectional view in elevation of the excitation light source assembly of FIG. 12.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

One embodiment of an excitation light source assembly 10 is shown in FIGS. 1-3 as it could be used in, or comprise a portion of, a molecular imaging system 12 (also shown in FIG. 4) of the type commonly used in molecular imaging applications. Briefly, the excitation light source assembly 10 may comprise a housing or main body member 14 that defines a central opening 16 therein. The housing or main body member 14 may also define a plurality of lamp receptacles 18 that are arranged around the central opening 16, as best seen in FIGS. 1 and 3. The various lamp receptacles 18 are configured to receive various light sources or lamps 20. More specifically, and as will be described in greater detail below, the light sources or lamps 20 may comprise one or more narrow band light sources 22 and/or one or more broad-band light sources 24, as best seen in FIGS. 5 and 6. Generally speaking, the narrow band light sources 22 are used in fluorescent imaging applications, whereas the broad-band light sources 24 are used in reflected light applications (e.g., to capture a visible light image), although this need not necessarily be the case.

Some of the lamp receptacles 18 may be provided with one or more diffusers 26 and/or one or more filters 28, as best seen in FIG. 5. The diffusers 26 are used to diffuse or spread light produced by the lamps 20, whereas the filters 28 are used to filter or remove light of unwanted or undesirable wavelengths. In a typical application, those lamp receptacles 18 that are provided with narrow band light sources 22 may also be provided with diffusers 26 and filters 28, whereas those receptacles 18 that are provided with broad-band light sources 24 will not be provided with diffusers 26 and filters 28. Alternatively, other arrangements are possible, as will be described herein.

In an embodiment where in the excitation light source assembly 10 is to be used in conjunction with a molecular imaging system 12, it will be generally desirable to provide the excitation light source assembly 10 with the capability to generate or produce excitation light or illumination in a variety of individual bands or colors that extend over a comparatively large wavelength range (e.g., from about 430 nanometers (nm) to about 745 nm). However, other embodiments may extend this range to 800 nm or even 900 nm. In the particular embodiment shown and described herein, the excitation light source assembly 10 is capable of producing or generating ten (10) individual illumination bands or colors having comparatively narrow bandwidths (e.g., in the range of about 30-35 nm), although bandwidths having other ranges may also be used. The ten (10) individual illumination bands or colors (i.e., having relatively narrow bandwidths of about

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30-35 nm) thus may cover the large wavelength range of from about 430 nm to about 745 nm. In another embodiment, the wavelength range may be extended to about 900 nm by providing one or more additional illumination bands or colors having wavelengths that extend to 900 nm.

In addition to the ability to provide illumination via one or more narrow illumination bands, the excitation light source assembly 10 may also be used to provide broad-band (e.g., white light) illumination, which may be desirable in certain imaging applications.

In the particular embodiment shown and described herein, each individual illumination band or color is generated or produced by light sources 22 provided in lamp receptacles 18 that are located on opposite sides of the central opening 16. As will be described in greater detail below, this arrangement provides for more even illumination than would otherwise be the case if the individual illumination band or color were provided by only a single lamp receptacle 18.

In an application wherein the excitation light source assembly 10 is used in conjunction with a molecular imaging system 12, the housing or main body member 14 of the excitation light source assembly 10 may be mounted to a base member 30 that, in turn, may be mounted to a suitable support structure 32 associated with the imaging system 12. See FIGS. 2 and 3. More particularly, the excitation light source assembly 10 is mounted to the support structure 32 so that the central opening of main body 14 is substantially aligned with (i.e., concentric to) a lens assembly 34 of a camera 36 associated with the imaging system 12. The arrangement is such that a field of view (represented schematically by lines 38) of camera 36 is substantially unobstructed by the housing 14 and/or central opening 16 of housing 14 of excitation light source assembly 10.

The excitation light source assembly 10 may be operatively connected to a control system 40 (FIG. 2). Control system 40 may be used to operate selected ones of the various light sources 20 (e.g., narrow-band light sources 22 and broad-band light sources 24) provided in the excitation light source assembly 10 to provide a desired illumination to an object or specimen 42 located within the field of view 38 of camera 36. Camera 36 may then capture an image of fluorescing material in the object or specimen 42. It should be noted that different fluorescent materials in the specimen 42 may be excited or activated by illuminating the specimen 42 with light of various colors or wavelength bands. In addition, different fluorescent materials in the specimen 42 may fluoresce or emit light of different wavelengths even when illuminated with light of the same color or wavelength band. Images of the specimen 42 produced by light emitted in such different wavelengths may be captured by using an appropriate filter in conjunction with the camera 36.

For example, and with reference now to FIGS. 7 and 8, a first fluorescent image 44 of a specimen 42, in this case a cactus pad and flowers, may be obtained by using the control system 40 to activate those light sources 20 that emit light in an individual wavelength band or color that will excite the particular fluorescent material of interest in the specimen 42. In this particular example, the individual wavelength band or color comprised a middle or "center" wavelength of about 465 nm, with a bandwidth of about 30-35 nm. A 550 nm filter was used to capture the image 44 shown in FIG. 7, which was then combined with a visible light image of the specimen 42. The emission at 550 nm reveals the fluorescence of the individual spines of the cactus. However, no fluorescence of the flower appears at this wavelength. In contrast, a second fluorescent image 46 of the specimen 42, depicted in FIG. 8, but

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captured with a 735 nm filter, reveals emission from the leaves of the flowers as well as from the entire surface of the cactus pad.

A significant advantage of the excitation light source assembly of the present invention is that it may be used to illuminate an object or specimen with light in multiple narrow bands or colors, thereby allowing a single excitation light source assembly to be used in imaging applications involving a wide range of fluorescent materials that are excited over a wide range of wavelengths. Moreover, the excitation light of each individual wavelength band or color may be readily increased and decreased in brightness by controlling the number of light sources in each lamp receptacle that are illuminated or activated at any one time. Still further, the ability of the excitation light source assembly to also provide broad-band illumination allows for the ready capture of conventional reflected light images of the object or specimen, which are typically desired in most imaging applications.

Still other advantages are associated with the paring of the lamp receptacles on opposite sides of the central opening, in that such a paring allows for the more even illumination of the object or specimen than would otherwise be the case if the illumination were provided by only a single lamp receptacle.

Still yet other advantages are associated with embodiments having removable lamp receptacles. In such embodiments, the lamp receptacles can be readily removed and replaced in the field, thereby allowing users to conveniently and rapidly tailor the wavelength bands or colors that may be provided by the excitation light source assembly. The present invention also dispenses with the need to provide the illumination via fiber optic bundles, which is expensive and cumbersome. Moreover, such fiber optic bundles must also be carefully selected so that they do not contain materials or elements that themselves would fluoresce in use.

Having briefly described one embodiment of the excitation light source assembly of the present invention, as well as some of its more significant features and advantages, various exemplary embodiments of the excitation light source assembly will now be described in detail. However, before proceeding with the description, it should be noted that while the particular embodiments are shown and described herein as they could be used to provide illumination over certain wavelength ranges and in certain narrow illumination bands or colors having certain bandwidths, the particular wavelength ranges, numbers of illumination bands, as well as the bandwidths of the illumination bands may be varied depending on the any of a wide range of factors, including the requirements of the particular application. Consequently, the present invention should not be regarded as limited to the particular examples, ranges, wavelength bands, and applications shown and described herein.

Referring back now to FIGS. 1-4, an excitation light source assembly 10 according to one embodiment of the present invention is shown and described herein as it may be used in conjunction with a molecular imaging system 12 of the type commonly used in the molecular imaging field. In the particular embodiment shown and described herein, the imaging system 12 may comprise a generally rectangularly-shaped chassis or main enclosure 48 configured to house and support the various components and subsystems required to perform various types of molecular imaging processes. In addition, the main enclosure 48 also may be provided with various external finish panels 50 that cover or overlay the underlying chassis or main enclosure structure 48. In the particular embodiment shown and described herein, the imaging system 12 is designed or configured to be connected to separate computer system (not shown) to allow a user to operate the imaging

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system 12 and view images produced by the imaging system 12 on a suitable display system (also not shown).

The main enclosure 48 of imaging system 12 may be provided with an access door 52 that can be moved vertically between a closed position (shown in FIG. 4) and an opened position (not specifically illustrated in the drawing figures) to allow the user to access an imaging compartment or chamber 54 defined by the main enclosure 48, as best seen in FIG. 2. The imaging compartment 54 is sized to receive one or more objects or specimens 42 to be imaged. Objects or specimens 42 suitable for use with the imaging system 12 include samples that may be provided in a well plate 56, as well as living organisms (not shown). Other types of objects or specimens 42 may be imaged for other purposes as well, as would become apparent to persons having ordinary skill in the art after having become familiar with the teachings provided herein.

Referring now primarily to FIG. 2, the imaging system 12 also may include an imaging system sub-assembly 58 having an object platform or stage 60, as well as a mounting or support structure 32. The object platform 60 is moveably mounted to the sub-assembly 58 so that the object platform 60 can be moved vertically toward and away from the support structure 32, i.e., generally in the direction indicated by arrows 62. The support structure 32 is configured to receive camera 36, control system 40, as well as various other components and systems required for operation of the imaging system 12. However, because such various other components and systems that may be required or desired for the operation of the imaging system 12 are not required to understand or practice the present invention, such additional components and systems will not be described in further detail herein.

The excitation light source assembly 10 may comprise a housing or main body 14 that defines a central opening 16 therein, as best seen in FIG. 1. The housing or main body member 14 may be mounted to a base member 30 to allow the excitation light source assembly 10 to be readily mounted to the support structure 32 of the imaging system 12, as best seen in FIGS. 2 and 3. As mentioned above, the excitation light source assembly 10 is mounted to the support structure 32 so that the central opening 16 of main body 14 is substantially aligned with the lens assembly 34 of camera 36. The arrangement is such that the field of view 38 of camera 36 is substantially unobstructed by the housing 14 and/or central opening 16 of housing 14.

Referring now primarily to FIGS. 3, 5, and 6, the main body member 14 of excitation light source assembly 10 also defines a plurality of lamp receptacles 18 therein that are arranged around the central opening 16. Each of the lamp receptacles 18 is sized or configured to receive one or more light sources or lamps 20 (FIGS. 5 and 6). In particular, the large diameter lamp receptacles 18 may be sized to receive one or more narrow-band light sources 22, as best seen in FIG. 5, whereas the small diameter lamp receptacles 18 may be sized to receive a single broad-band light source 24, as best seen in FIG. 6.

The various lamp receptacles 18 may be provided at locations on the main body member 14 so as to provide substantially uniform illumination to the object or specimen 42 provided on the imaging platform or stage 60. In the particular embodiment shown and described herein, the main body member 14 is provided with twenty (20) large diameter lamp receptacles 18, each of which is provided with a plurality of narrow-band light sources 22 and, optionally, diffusers 26, and filters 28. Moreover, and as will be described in further detail below, a given large diameter lamp receptacle 18 (such as receptacle 68), may be matched with a counterpart large

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diameter receptacle **18** (such as receptacle **68'**) on the opposite side of central opening **16**. See FIG. 1. Both the receptacle **68** and its counterpart receptacle **68'** may be configured to emit light of the same color or wavelength range. Thus, when energized, each such receptacle **68** and counterpart receptacle **68'** will emit light of the same color or wavelength range. Because each such receptacle **68** and counterpart receptacle **68'** are located on opposite sides of the central opening **16**, the specimen **42** will be more evenly illuminated with this arrangement than would otherwise be the case if the light were emitted only by a single receptacle **18**.

As briefly described above, each of the small diameter receptacles **18** may be provided with a single broad-band light source **24**. The various small diameter receptacles **18** also may be provided in spaced-apart relation around the central opening **16** of body member **14** in order to provide substantially uniform illumination of the object **42** provided on the stage **60** when the broad-band light sources **24** are energized.

The housing or main body member **14** may be fabricated from any of a wide range of materials, such as metals or plastics, that would be suitable for the intended application. Generally speaking, it will be desirable to use a material that will not fluoresce in response to the illumination provided by the various light sources **20** provided therein, as such fluorescence of the material comprising the main body member **14** will degrade the performance of the imaging system **12**. By way of example, in one embodiment, the housing or main body member **14** is fabricated from a polyoxymethylene thermoplastic material, such as Delrin®. Alternatively, other materials may also be used, as would become apparent to persons having ordinary skill in the art after having become familiar with the teachings provided herein. Consequently, the present invention should not be regarded as limited to a main body member **14** that is fabricated from any particular material.

With reference now primarily to FIG. 5, each of the large diameter lamp receptacles **18** defined by the housing **14** of the excitation light source assembly **10** is sized or configured to receive at least one, and preferably three (3) narrow-band light sources **22** (only two of which are shown in FIG. 5). As will be described in greater detail below, the individual narrow-band light sources **22** may be individually activated by control system **40** to provide illumination of three (3) different intensity levels by activating various ones of the three narrow-band sources **22** provided to each lamp receptacle. In contrast, each of the small diameter lamp receptacles **18** may be sized to receive a single broad-band light source **24**. However, other arrangements are possible, as would become apparent to persons having ordinary skill in the art after having become familiar with the teachings provided herein. Consequently, the present invention should not be regarded as limited to any particular configuration with respect to the number of light sources **20** that may be provided to each lamp receptacle **18**.

The various light sources **20**, e.g., comprising narrow-band light sources **22** and broad-band light sources **24**, may be mounted to a circuit board **64** which, in turn, may be mounted or affixed to the main body **14**, as best seen in FIGS. 1, 5, and 6. Circuit board **64** provides a means for physically supporting the various light sources **20** within the lamp receptacles **18** and for electrically connecting the light sources **20** to the control system **40**. Circuit board **64** may also be provided with any of a wide range of ancillary systems and devices, such as light source drive circuits and connectors, to allow the light sources **20** to be activated by control system **40**. However, because such devices and systems are well-known in the art and could be readily provided by persons having ordinary

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skill in the art after having become familiar with the teachings provided herein, the circuit board **64** that may be utilized in one embodiment of the present invention will not be described in further detail herein.

Each narrow-band light source **22** is suitable for producing excitation light having a wavelength band or color that comprises at least the wavelength or wavelengths required to excite or activate fluorescence in the particular material or specimen **42** to be imaged or studied. In addition, because it will be desirable to use the imaging system **12** to image a wide range of fluorescent materials, various ones of which may require excitation light having different colors or wavelength bands, in one embodiment, each of the larger diameter lamp receptacles **18** defined by the housing **14** will hold at least one, and preferably three (in one embodiment), narrow-band light source **22** that emits light having wavelengths (i.e., a wavelength band) that is slightly different from the wavelengths produced by the other narrow-band light sources **22** provided in others of the larger diameter lamp receptacles **18**. Stated another way, the various lamp receptacles **18** may emit light of different colors. In this manner, then, the single housing **14** of excitation light source assembly **10** can be used to produce excitation light having wavelengths across any desired wavelength range.

In addition, and as was also mentioned above, each of the larger diameter lamp receptacles **18** (e.g., lamp receptacle **68**, FIG. 1) may be paired with a counterpart receptacle (e.g., lamp receptacle **68'**) on the opposite side of the central opening **16** in order to provide more even illumination of the specimen **42** provided on the imaging platform or stage **60**. For example, if a particular lamp receptacle **68** is provided with a narrow-band light source **22** that is capable of emitting light having middle or center wavelength of about 465 nm, then its counterpart receptacle **68'** should also be provided with a narrow-band light source **22** having a middle or center wavelength of about 465 nm.

In the particular embodiment shown and described herein, the excitation light source assembly **10** is capable of emitting excitation light in a plurality of individual bands or colors over a wavelength range from about 430 nm to about 745 nm. Therefore, it will be generally desirable to use for each light source **20** a comparatively narrow-band light source **22** that emits light having wavelengths over a fairly narrow-band. By way of example, narrow-band light sources **22** having bandwidths in the range of about 30-35 nm can be used to advantage in the present invention. If such narrow-band light sources **22** are used, ten (10) such narrow-band light sources **22**, properly selected, will be sufficient to cover the exemplary wavelength range. In accordance with this objective, then, the main body member **14** is provided with twenty (20) large diameter receptacles **18** that are arranged in ten pairs of two on opposite sides of the central opening **16**. The corresponding receptacle pairs (e.g., **68** and **68'**, FIG. 1) are then provided with narrow-band light sources **22** of the same wavelengths so that the excitation light source assembly **10** is capable of providing illumination in ten different narrow-band wavelength ranges or colors.

Alternatively, another embodiment of the invention may produce light having a wavelength of 800 nm by providing one or more light sources **22** capable of producing light having wavelengths of around 800 nm. In still another embodiment, the range could be extended to wavelengths of 900 nm or even longer by providing the excitation light source assembly **10** with light sources **22** capable of producing light having wavelengths of around 900 nm.

Each narrow-band light source **22** may comprise a light emitting diode (LED) that emits light in the desired wave-

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length band, and ideally, with the desired bandwidth (e.g., of about 30-35 nm). Light emitting diodes having such narrow bandwidths (e.g., about 30-35 nm) along the desired wavelength range (e.g., 430 nm to about 745 nm) are readily commercially available and can be used as the narrow-band sources 22. However, it should be noted that suitable LEDs that emit or produce light in each of the desired wavelength bands may not be available. If so, it may be necessary to use broader-band LEDs, i.e., that emit light having wavelengths outside the desired wavelength range. If so, such LEDs or broad-band light sources may be used in combination with a filter element 28 to filter or remove the undesired wavelengths, as will be described in greater detail below.

Regardless of the particular light source 22 that may be used, it is also generally preferred, but not required, to provide a diffuser 26 within each lamp receptacle 18. The diffuser 26 may be provided at any convenient position within lamp receptacle 18. In one embodiment, diffuser 26 is located at a position immediately adjacent the light source 20, as best seen in FIG. 5. A sleeve 66 provided in the lamp receptacle 18 may be used to support diffuser 26, although other arrangements are possible. As its name implies, the diffuser 26 diffuses or spreads light produced by the light source 20, thereby generally providing for more even illumination than would be provided by the light source 22 alone.

The diffuser 26 may comprise any of a wide range of optical diffusers that are now known in the art or that may be developed in the future that are or would be suitable for the particular application. However, because optical diffusers are well-known in the art and could be readily provided by persons having ordinary skill in the art after having become familiar with the teachings provided herein, the particular diffusers that may be used in one embodiment of the invention will not be described in further detail herein.

As mentioned above, the light output characteristics of the various light sources 20 (e.g., LEDs) that may be utilized in the excitation light source assembly 10 may be such that it may be required, or at least desirable, to further limit the wavelength range of excitation light produced by each light source 20. This may be the case regardless of whether the particular light source 20 involved is a narrow-band light source 22. Accordingly, in one embodiment, each of the large diameter lamp receptacles 18 (e.g., containing or housing the narrow-band light sources 22) may also be provided with a filter element 28. Filter element 28 may remove or filter undesired wavelengths produced by the light source 20, regardless of whether the light source 20 comprises a narrow-band light source 22. In the particular embodiment shown and described herein, each such filter may be positioned adjacent the diffuser 26, as best seen in FIG. 5, although other arrangements are possible.

In the particular embodiment shown and described herein, each filter element 28 may comprise a "notch" type filter having a relatively narrow wavelength bandpass range of about 30 nm around the desired center wavelength or color. Such notch type filters are available over a wide range of wavelengths or colors. In one embodiment of the invention, a separate notch filter 28 is provided for each light source 22, and the notch filter wavelength is selected as appropriate for the particular light source 22 with which it is paired. Thus, when individually activated, each light source/filter combination will emit excitation light having a bandwidth of about 30 nm at a desired color or wavelength band within the desired overall wavelength range (e.g., from about 430 nm to about 745 nm).

Referring now primarily to FIG. 6, the excitation light source assembly 10 may also be provided with a plurality of

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small diameter lamp receptacles 18 therein that are sized to receive a broad-band light source 24. In the particular embodiment shown and described herein, each small diameter lamp receptacle 18 receives a single broad-band light source 24, although other embodiments may be provided with a plurality of broad-band light sources 24 for each receptacle 18. Broad-band light source 24 may comprise any of a wide range of broad-band light sources now known in the art or that may be developed in the future that are, or would be, suitable for the intended application. By way of example, in one embodiment, each broad-band light source 24 may comprise a "white" LED of the type that are readily commercially available. In another embodiment, one or more of the broad-band light sources 24 may be mounted at other locations within the imaging system 12.

Each of the various light sources 20, i.e., comprising narrow-band sources 22 and broad-band sources 24, provided in the various lamp receptacles 18 defined by the housing 14 may be operatively connected to a control system 40 (FIG. 2) via the circuit board 64. Control system 40 may be used to operate or energize the various light sources 20 to turn them on and off. In one embodiment, each of the various light sources 20 (i.e., comprising narrow-band sources 22 and broad-band sources 24) may be individually controlled so that a single light source 20, emitting excitation light in a desired wavelength band or color, may be used to excite the desired fluorescent material contained in the object or specimen 42 being studied. Alternatively, other arrangements are possible. For example, in another embodiment, the control system 40 may operate two or more light sources 20 simultaneously.

The excitation light source 10 may be operated as follows to capture a fluorescent image of a specimen 42, for example a cactus pad and flowers. Once the specimen 42 has been properly positioned on the platform or stage 60 and the imaging system 12 otherwise prepared for operation, the control system 40 may operate selected ones of the various light sources 20 (e.g., narrow-band light sources 22 and broad-band light sources 24) to illuminate the specimen 42 with a desired wavelength band or color. Camera 36 may then capture an image of fluorescing material in the object or specimen 42. As described earlier, different fluorescent materials in the specimen 42 may be excited or activated by illuminating the specimen 42 with light of various colors or wavelength bands. In addition, different fluorescent materials in the specimen 42 may fluoresce or emit light of different wavelengths even when illuminated with light of the same color or wavelength band. Images of the specimen 42 produced by light emitted in such different wavelengths may be captured by using an appropriate filter in conjunction with the camera 36.

For example, and with reference now to FIGS. 7 and 8, a first fluorescent image 44 of specimen 42 may be obtained by using the control system 40 to activate those light sources 20 that emit light having a middle or center wavelength of about 465 nm (and with a bandwidth of about 30-35 nm). Certain materials contained within the specimen 42 will fluoresce in response to this excitation illumination. However, the materials may not all fluoresce or emit light of the same wavelength. Different materials will fluoresce or emit light of different wavelengths, as is known. The particular fluorescent image 44 depicted in FIG. 7 was captured with a 550 nm filter adjacent the camera 36 and is shown combined with a visible light image of the specimen 42. The emission at 550 nm reveals the fluorescence of the individual spines of the cactus. However, no fluorescence of the flower appears at this wavelength. In contrast, the second fluorescent image 46 depicted

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in FIG. 8, but captured with a 735 nm filter, reveals emission from the leaves of the flowers as well as from the entire surface of the cactus pad.

Other variations and configurations are possible for the excitation light source according to the present invention. For example, a second embodiment 110 of an excitation light source assembly according to the teachings of the present invention is illustrated in FIGS. 9-11. The second embodiment 110 differs from the first embodiment 10 in that the second embodiment 110 comprises a plurality of lamp receptacles 118 that are removable from corresponding main bodies 114. The removable lamp receptacles 118 allow the excitation light source 110 to be readily configured (and reconfigured) to produce light of any desired wavelength band or color by simply removing one or more of the lamp receptacles 118 and replacing it or them with another lamp receptacle 118 that configured to produce light in the desired wavelength band or color.

The second embodiment 110 may comprise a base member 130 to which are mounted a plurality of main bodies 114. In the particular embodiment illustrated in FIGS. 9-11, the base member 130 comprises a C-shaped member having a central opening 116. Alternatively, the base member 130 could comprise other shapes and configurations, such as the circular shape of the first embodiment 110. The overall configuration of the C-shaped base member 130 is such that the central opening 116 thereof will be substantially aligned with the lens assembly 34 of camera 36 when mounted to the support structure 32 of imaging system 12. See FIGS. 2 and 3. As was the case for the first embodiment 10, the arrangement of the second embodiment 110 is such that the field of view 38 of camera 36 is substantially unobstructed by the central opening 116 of base member 130, as well as the various light receptacles 118 associated with excitation light source assembly 110.

With reference now primarily to FIG. 10, each main body 114 may be substantially identical to the others and may comprise an opening 115 therein sized to receive the corresponding removable lamp receptacle 118. Main body 114 may also be configured to receive a connector assembly 117 that is sized to removably receive a mating portion 119 provided in the removable lamp receptacle 118. The connector assembly 117 and mating portion 119 provide physical and electrical engagement with the removable lamp receptacle 118. Connector assembly 117 may be electrically connected to an electrical connector assembly 165 provided in the main body 114. See also FIG. 9.

In the particular embodiment shown and described herein, each main body 114 has an angled base portion 121 so that the each lamp receptacle 118 is angled inward, toward the central axis 151 of the housing 114, by an angle θ , as best seen in FIG. 10 (central axis 151 is shown in a displaced position in FIG. 10 for clarity). Such an arrangement allows the excitation light produced by the various lamp receptacles 118 to roughly converge at a point on the image platform or stage 60 where the specimen 42 is to be located during the imaging operation. Alternatively, other arrangements for aiming or directing the lamp receptacles 118, thus excitation light emitted thereby, could also be used, as would become apparent to persons having ordinary skill in the art after having become familiar with the teachings provided herein.

The base member 130 and each of the main bodies 114 may be fabricated from any of a wide range of materials (e.g., metals and plastics) that would be suitable for the intended application. By way of example, in one embodiment the base member 130 may comprise aluminum. Each of the main

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bodies 114 may be fabricated from a polyoxymethylene thermoplastic material, such as Delrin®. Alternatively, other materials may also be used.

Connector assembly 117 and its mating portion 119 may comprise any of a wide range of connector assemblies that are now known in the art or that may be developed in the future that are, or would be, suitable for the particular application. However, by way of example, in one embodiment, connector assembly 117 and its mating portion 119 may comprise a type "FGG" connector assembly available from LEMO USA, Inc. of Rohnert Park, Calif. Alternatively, other types of connectors may be used.

Referring now to FIGS. 10 and 11 simultaneously, each lamp receptacle 118 may be substantially identical to the others and may comprise first and second barrel sections 123 and 125 that may be connected or joined together by a threaded nipple or sleeve section 127. Sleeve section 127 is also configured to receive mating connector portion 119, as best seen in FIG. 10. The upper barrel section 125 may be configured to receive one or more narrow-band light sources 122 (only a single narrow-band light source 122 is illustrated in FIGS. 10 and 11), which may be mounted to a circuit board 164 that is electrically connected to mating connector portion 119 via wires (not shown) or other suitable means. Barrel section 125 may also be configured to receive a diffuser 126 and/or a filter 128, as best seen in FIG. 11. A sleeve 166 may be used to position the diffuser 126 and/or filter 128 with respect to the light source 122. A foam spacer 131 or other elastomeric material may be provided between circuit board 164 and sleeve 127, as best seen in FIG. 10.

The upper and lower barrel sections 123 and 125 may be fabricated from any of a wide range of materials, such as metals or plastics, that would be suitable for the intended application. Consequently, the present invention should not be regarded as limited to any particular material. However, by way of example, in one embodiment, the upper and lower barrel sections 123 and 125 are fabricated from aluminum. The aluminum may be provided with a suitable non-reflective coating.

Still other variations are possible. For example, and with reference now to FIGS. 12 and 13, a third embodiment 210 of the excitation light source assembly may comprise a "C"-shaped housing or main body 214 that defines a central opening 216. The housing 214 also defines a plurality of lamp receptacles 218 that are arranged around the central opening, as best seen in FIG. 12. The housing 214 of the excitation light source assembly 210 is also configured to be mounted to the support structure 32 of imaging system 12, so that the lens assembly 34 of camera 36 is generally concentric with the central opening 216 defined by the housing 214. See FIGS. 2 and 3. As was the case for the other embodiments, the arrangement is such that the field of view 38 of the camera 36 is substantially unobstructed by the housing 214 and/or central opening 216 of housing 214 of the excitation light source assembly 210.

Referring now to FIG. 13, each of the lamp receptacles 218 may be provided narrow-band light source 222 that, in one embodiment, may be mounted to a circuit board 266. A diffuser 226 may also be positioned within each of the lamp receptacles 218, generally at a position adjacent the light source 222. Each diffuser 226 diffuses light produced by the corresponding light source 222 and may be held in position by a sleeve 266. As was the case for the other embodiments, each lamp receptacle 218 may also be provided with a filter 228, if desired or required, to remove or filter any undesired light wavelengths that may be produced by the light source 222.

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The C-shaped housing **214** of the excitation light source assembly **210** allows each of the lamp receptacles **218** provided therein to be conveniently angled (i.e., by an angle θ with respect to the central axis **251** of housing **214**), so that light from the light sources **222** may be directed to a desired area within the field of view **38** of camera **36**.

The housing **214** for the excitation light source assembly **210** may be fabricated from any of a wide range of materials, such as metals or plastics, that would be suitable for the intended application. Consequently, the present invention should not be regarded as limited to housings made from any particular materials. However, by way of example, in one embodiment, the housing is fabricated as a single piece from any of a polyoxymethylene thermoplastic material, e.g., Delrin®.

Having herein set forth preferred embodiments of the present invention, it is anticipated that suitable modifications can be made thereto which will nonetheless remain within the scope of the invention. The invention shall therefore only be construed in accordance with the following claims:

The invention claimed is:

1. An excitation light source assembly, comprising:
a housing defining a central opening therein and a plurality of lamp receptacles surrounding the central opening, said housing being mountable to a support structure so that the central opening is aligned with a camera also mounted to the support structure so that a field of view of the camera is unobstructed by said housing;
a light source positioned within each of the plurality of lamp receptacles, wherein at least one of said light sources comprises a narrow-band light source; and
a diffuser positioned within at least some of the plurality of lamp receptacles, each of said diffusers diffusing light produced by each of said light sources; and
a control system operatively connected to each of said light sources said control system operating selected ones of said light sources to provide a desired excitation illumination to an object within the field of view of said camera, the object fluorescing in response to the excitation illumination provided by said light sources.

2. The excitation light source assembly of claim **1** wherein said narrow-band light source emits light having a bandwidth of about 35 nm.

3. The excitation light source assembly of claim **2** wherein said at least one narrow-band light source comprises a light emitting diode.

4. The excitation light source assembly of claim **1**, further comprising at least one filter positioned adjacent at least one diffuser in at least one of the lamp receptacles defined by said housing.

5. The excitation light source assembly of claim **4**, wherein said at least one filter comprises a notch filter having a wavelength bandpass range of about 30 nm.

6. The excitation light source assembly of claim **1**, wherein at least one of the light sources comprises a broad-band light source.

7. The excitation light source assembly of claim **1**, wherein at least some of said plurality of lamp receptacles comprise opposed pairs of lamp receptacles on opposite sides of said central opening, each opposed pair of lamp receptacles producing light of the same color.

8. The excitation light source assembly of claim **7**, further comprising ten opposed pairs of lamp receptacles on opposite sides of said central opening.

9. The excitation light source assembly of claim **1**, wherein the light source positioned within each of the plurality of lamp receptacles does not extend beyond the lamp receptacle.

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10. The excitation light source assembly of claim **1**, further comprising a plurality of light sources positioned within at least some of the lamp receptacles so that the plurality of light sources do not extend beyond the lamp receptacles.

11. The excitation light source assembly of claim **10**, wherein said plurality of light sources is three light sources.

12. The excitation light source assembly of claim **1**, wherein the plurality of light receptacles defined by said housing comprise a plurality of large diameter receptacles and a plurality of small diameter receptacles.

13. The excitation light source assembly of claim **1**, wherein the plurality of light receptacles defined by said housing comprise generally cylindrically shaped openings having first and second open ends, said excitation light source assembly further comprising a circuit board mounted to a first side of said housing, said light sources being mounted to said circuit board so that said light sources extend through the first open ends of the generally cylindrically-shaped light receptacles.

14. An assembly, comprising:

a support structure;

a camera mounted to said support structure;

an excitation light source assembly mounted to said support structure, said excitation light source assembly comprising:

a housing defining a central opening therein and a plurality of lamp receptacles surrounding the central opening, said housing being mounted to said support structure so that the central opening is aligned with said camera and so that a field of view of said camera is substantially unobstructed by said housing;

at least one narrow-band light source positioned within at least one of the plurality of lamp receptacles; and
a diffuser positioned within at least some of the plurality of lamp receptacles, each of said diffusers diffusing light produced by each of said narrow-band light sources; and

a control system operatively connected to each of said narrow-band light sources, said control system operating selected ones of said narrow-band light sources to provide a desired excitation illumination to a fluorescent material within the field of view of said camera, the fluorescent material fluorescing in response to the excitation illumination.

15. The assembly of claim **14**, further comprising a light filter positioned adjacent each of the diffusers.

16. The assembly of claim **14**, wherein each of the lamp receptacles defined by said housing are angled with respect to a central axis of said housing so that light emitted from each of said narrow-band light sources is directed to a desired area within the field of view of said camera.

17. The assembly of claim **14**, wherein each of said narrow-band light sources is selected to provide desired number of illumination bands over a desired spectral range.

18. The assembly of claim **17**, wherein the desired spectral range is from about 430 nm to about 745 nm.

19. The assembly of claim **17**, wherein the desired number of illumination bands is 10.

20. The assembly of claim **17**, wherein each desired illumination band has a bandwidth ranging from about 30 nm to about 35 nm.

21. The assembly of claim **17**, wherein the desired spectral range is from about 430 nm to about 900 nm.

22. The assembly of claim **17**, wherein the desired spectral range is from about 430 nm to about 800 nm.

23. The assembly of claim **14**, wherein each of said narrow-band light sources comprises a light emitting diode.

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24. The assembly of claim 14, wherein said housing comprises a polyoxymethylene thermoplastic material.

25. An excitation light source assembly, comprising:

a housing defining a central opening therein and a plurality of lamp receptacles therein surrounding the central opening, said housing being mountable to a support structure so that the central opening is aligned with a camera also mounted to the support structure so that a field of view of the camera is unobstructed by said housing;

a light source positioned within each of the plurality of lamp receptacles so that said light sources do not extend beyond the lamp receptacles, wherein at least one of said light sources comprises a narrow-band light source; and a control system operatively connected to each of said light sources, said control system operating selected ones of said light sources to provide a desired excitation illumination to an object within the field of view of the camera, the excitation illumination causing fluorescent materials

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in the object to fluoresce, the camera capturing an image of the fluorescing material in the object.

26. The excitation light source assembly of claim 25, wherein said plurality of lamp receptacles defined by said housing comprise a plurality of large diameter lamp receptacles and a plurality of small diameter lamp receptacles, said large diameter lamp receptacles receiving a plurality of said light sources, said small diameter receptacles receiving a single light source.

27. The excitation light source assembly of claim 25, wherein the plurality of light receptacles defined by said housing comprise generally cylindrically shaped openings having first and second open ends, said excitation light source assembly further comprising a circuit board mounted to a first side of said housing, said light sources being mounted to said circuit board so that said light sources extend through the first open ends of the generally cylindrically shaped light receptacles.

* * * * *

EXHIBIT E

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Provisional Application for Patent Cover Sheet

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)

Inventor(s)

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Title of Invention

EXCITATION LIGHT SOURCE ASSEMBLY

Attorney Docket Number (if applicable)

SPEC US-4 PRV (27560-006)

Correspondence Address

Direct all correspondence to (select one):

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Customer Number

27104

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

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Applicant claims small entity status under 37 CFR 1.27

- ☐ Yes, applicant qualifies for small entity status under 37 CFR 1.27
- ☒ No

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Signature

Please see 37 CFR 1.4(d) for the form of the signature.

Signature	/Bruce E. Dahl/			Date (YYYY-MM-DD)	2010-09-01
First Name	Bruce	Last Name	Dahl	Registration Number (If appropriate)	33670

This collection of information is required by 37 CFR 1.51. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. This form can only be used when in conjunction with EFS-Web. If this form is mailed to the USPTO, it may cause delays in handling the provisional application.

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	SPEC US-4PRV (27560-006)
		Application Number	
Title of Invention	EXCITATION LIGHT SOURCE ASSEMBLY		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

Secrecy Order 37 CFR 5.2

☐	Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)
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Applicant Information:

Applicant 1									
Applicant Authority ☒ Inventor			☐ Legal Representative under 35 U.S.C. 117			☐ Party of Interest under 35 U.S.C. 118			
Prefix	Given Name		Middle Name		Family Name			Suffix	
	Michael		B.		Nelson				
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service									
City	Tucson		State/Province	AZ	Country of Residence	US			
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City	Tucson		State/Province	AZ					
Postal Code		85745		Country	US				
Applicant 2									
Applicant Authority ☒ Inventor			☐ Legal Representative under 35 U.S.C. 117			☐ Party of Interest under 35 U.S.C. 118			
Prefix	Given Name		Middle Name		Family Name			Suffix	
	Michael		D.		Cable				
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service									
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	SPEC US-4PRV (27560-006)	
		Application Number		
Title of Invention	EXCITATION LIGHT SOURCE ASSEMBLY			
Customer Number	27104			
Email Address	ip@fclaw.com	Add Email		Remove Email

Application Information:

Title of the Invention	EXCITATION LIGHT SOURCE ASSEMBLY		
Attorney Docket Number	SPEC US-4PRV (27560-006)	Small Entity Status Claimed ☐	
Application Type	Provisional		
Subject Matter	Utility		
Suggested Class (if any)		Sub Class (if any)	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)	7	Suggested Figure for Publication (if any)	

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)	
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Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Enter either Customer Number or complete the Representative Name section below. If both sections are completed the Customer Number will be used for the Representative Information during processing.			
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This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78(a)(2) or CFR 1.78(a)(4), and need not otherwise be made part of the specification.			
Prior Application Status		Remove	
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	SPEC US-4PRV (27560-006)
		Application Number	
Title of Invention	EXCITATION LIGHT SOURCE ASSEMBLY		

This section allows for the applicant to claim benefit of foreign priority and to identify any prior foreign application for which priority is not claimed. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(a).

			Remove
Application Number	Country ¹	Parent Filing Date (YYYY-MM-DD)	Priority Claimed
			☐ Yes ☒ No
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Assignee Information:

Providing this information in the application data sheet does not substitute for compliance with any requirement of part 3 of Title 37 of the CFR to have an assignment recorded in the Office.

Assignee 1

If the Assignee is an Organization check here. ☒

Organization Name SPECTRAL INSTRUMENTS IMAGING, LLC

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Address 2

City Tucson

State/Province

AZ

Country US

Postal Code

85745

Phone Number

Fax Number

Email Address

Additional Assignee Data may be generated within this form by selecting the **Add** button.

Signature:

A signature of the applicant or representative is required in accordance with 37 CFR 1.33 and 10.18. Please see 37 CFR 1.4(d) for the form of the signature.

Signature	/Bruce E. Dahl/		Date (YYYY-MM-DD)	2010-09-01
First Name	Bruce	Last Name	Dahl	Registration Number
				33670

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

EXCITATION LIGHT SOURCE ASSEMBLY

Technical Field

[0001] The present invention relates in general to systems for exciting fluorescent materials and more particularly to systems for exciting fluorescent materials in biomedical imaging applications.

Summary of the Invention

[0002] In one embodiment, a system for producing excitation light for exciting a fluorescent material may include a support structure having a camera mounted thereto for capturing an image of the fluorescent material. An excitation light assembly is also mounted to the support structure at a position adjacent the camera. The excitation light assembly includes a housing defining a central opening therein as well as a plurality of elongated holes surrounding the central opening. The housing is mounted to the support structure so that a field of view of said camera is unobstructed by the central opening in the housing. A narrow-band light source is positioned within each of the elongated holes provided within the housing. A diffuser positioned adjacent each of the narrow-band light sources diffuses light produced by the corresponding narrow-band light source. A control system operatively connected to each of the narrow-band light sources operates selected ones of the narrow-band light sources to provide a desired excitation illumination to the fluorescent material.

[0003] Also disclosed is an excitation light source assembly having a housing defining a central opening therein and a plurality of elongated holes surrounding the central opening. The housing is mountable to a support structure having a camera mounted thereto so that a field of view of the camera is unobstructed by the central opening in the housing. A light source is positioned within each of the plurality of elongated holes defined by the housing. A

diffuser positioned adjacent the light source within each of the plurality of elongated holes diffuses light produced by each of the light sources. A control system operatively connected to each of the light sources operates selected ones of the light sources to provide a desired excitation illumination to a fluorescent material within the field of view of the camera.

Brief Description of the Drawings

[0004] Illustrative and presently preferred exemplary embodiments of the invention are shown in the drawings in which:

[0005] Figure 1 is a perspective view of one embodiment of an imaging system that may be provided with an excitation light source assembly according to the teachings of the present invention;

[0006] Figure 2 is a front view in elevation of the imaging system of Figure 1 with the certain of the exterior and interior panels removed to show an interior imaging region and the excitation light source assembly of the present invention;

[0007] Figure 3 is a perspective view of the excitation light source assembly showing the alignment of the central opening of the housing with a camera of the imaging system;

[0008] Figure 4 is a front view of the excitation light source assembly showing the central opening and plurality of elongated holes for housing the various light sources;

[0009] Figure 5 is a perspective view of a portion of the support structure with the excitation light source assembly mounted thereto;

[0010] Figure 6 is a cross-sectional view in elevation of the housing of the excitation light source assembly showing the angled relationship of the various elongated holes with respect to the central axis of the housing; and

[0011] Figure 7 is an enlarged side view in elevation of one of the elongated holes in the housing showing the arrangement of the

light source, diffuser, and filter that may be utilized in one embodiment of the invention.

Detailed Description of the Preferred Embodiments

[0012] An excitation light source assembly according to one embodiment of the present invention is shown and described herein as it could be used in, or comprise a portion of, an imaging system of the type commonly used in biomedical imaging applications. Briefly, such biomedical imaging systems may be used to capture various types or modes of images from a biomedical object or specimen being analyzed. Common image types or modes that may be captured by such devices include visible light images, wherein visible light reflected by the object or specimen is captured by a camera associated with the imaging system. In another imaging mode, the visible light comprises light that is emitted by the object itself. In such cases, the emitted light may be generated by a bio-luminescence process, a fluorescence process, or by a combination thereof. As is known, light emission by fluorescence results from the prior or simultaneous exposure of the fluorescent material to excitation light of suitable wavelength. Not all fluorescent materials will fluoresce or emit light in response to excitation light of the same wavelength. Consequently, the wavelength of the particular excitation light must be selected so that it will excite the particular fluorescent material involved.

[0013] Because most biomedical imaging systems seek to detect fluorescence from a wide range of fluorescent materials, most such imaging systems are provided with excitation light sources that can be operated to illuminate the fluorescent material with excitation light of the appropriate wavelength. Unfortunately, however, most excitation light sources tend to be expensive and/or difficult to implement in use, and systems are constantly being sought that improve on existing systems.

[0014] Referring now primarily to Figures 1-5, an excitation light source assembly according to one embodiment of the present invention is shown and described herein as it may be used in conjunction with an imaging system of the type commonly used in the biomedical imaging field. In the particular embodiment shown and described herein, the imaging system may comprise a generally rectangularly-shaped housing that defines an imaging chamber therein that is configured to hold the object or specimen to be studied and imaged. In many instances, the object or specimen will contain one or more different kinds of fluorescent materials.

[0015] The housing may be provided with a door therein that may be moved between an opened and closed position. When in the opened position, the door will allow a user (not shown) to readily add or remove the object or specimen to or from an imaging platform or stage provided within the chamber. When the door is closed, it provides a light-tight seal that substantially prevents ambient or external light from entering the chamber. In the particular embodiment shown and described herein, the imaging system is provided with a camera that is mounted to a top plate or support structure associated with the imaging system. The camera defines a field of view (not illustrated in the drawing figures) that may be substantially coextensive with the imaging platform or stage, thereby allowing the camera to capture an image of the object or specimen and/or the fluorescent material associated with the object or specimen.

[0016] In the embodiment shown and described herein, the excitation light source assembly may also be mounted to the top plate or support structure of the imaging system. In one embodiment, the excitation light source assembly comprises a "C"-shaped housing that defines a central opening. The housing also defines a plurality of elongated holes that are arranged around the central opening, as best seen in Figures 3-6. The housing of the

excitation light source assembly is mounted to the support structure so that the camera is located within the central opening defined by the housing. The arrangement is such that the field of view of the camera is substantially unobstructed by the housing and/or central opening of the housing of the excitation light source assembly. As will be described in greater detail below, a light source (typically a narrow-band light source) may be positioned or mounted in each of the elongated holes provided in the housing. A diffuser may also be positioned within each of the elongated holes, generally at a position adjacent the light source. Each diffuser diffuses light produced by the corresponding light source. In addition, and as will be described in greater detail below, each elongated hole may also be provided with a filter, if desired or required, to remove or filter any undesired light wavelengths that may be produced by the light source or narrow-band light source.

[0017] Referring now primarily to Figure 6, the C-shaped housing of the excitation light source assembly allows each of the elongated holes provided therein to be conveniently angled (i.e., with respect to the central axis of the housing), so that light from the light sources may be directed to a desired area within the field of view of the camera--that is, directed to a desired area of the imaging platform or stage so that a desired portion of the object or specimen provided thereon (i.e., the fluorescent material) will be properly illuminated by the excitation light produced by the excitation light source assembly.

[0018] In the particular embodiment shown and described herein, each of the elongated holes defined by the housing are each angled inward, toward the central axis of the housing, by an angle θ , as best seen in Figure 6. Such an arrangement allows the excitation light produced by the various light sources provided within the various holes to roughly converge at a point on the central axis

some distance "L" from the excitation light source assembly. The distance L will generally correspond to the position of the object being imaged. Alternatively, other arrangements for aiming or directing elongated openings, thus excitation light emitted thereby, could also be used, as would become apparent to persons having ordinary skill in the art after having become familiar with the teachings provided herein.

[0019] The housing for the excitation light source assembly may be fabricated from any of a wide range of materials, such as metals or plastics, that would be suitable for the intended application. Consequently, the present invention should not be regarded as limited to housings made from any particular materials. However, by way of example, in one embodiment, the housing is fabricated as a single piece from any of a polyoxymethylene thermoplastic material, e.g., Delrin®.

[0020] As mentioned above, each of the elongated holes defined by the housing of the excitation light source assembly is configured to receive a light source suitable for producing excitation light having a wavelength band that comprises at least the wavelength or wavelengths required to excited fluorescence in the particular fluorescent material to be imaged or studied. In addition, because it will be desirable to use the imaging system with a wide range of fluorescent materials, various ones of which will require excitation light having different wavelengths or wavelength bands, in one embodiment, each of the elongated holes defined by the housing will hold a narrow-band light source that emits light having wavelengths (i.e., a wavelength band) that is slightly different from the wavelengths produced by the other light sources. That is, the single housing of the excitation light source assembly can be used to produce excitation light having wavelengths across any desired band.

[0021] By way of example, in one embodiment, the excitation light source assembly is capable of emitting excitation light over a wavelength range from about 430 nanometers (nm) to about 745 nm. Therefore, it will be generally desirable to use for each light source a comparatively "narrow-band" light source that emits wavelengths over a fairly narrow band. Generally speaking, narrow-band light sources having wavelength bands in the range of about 30 nm to about 35 nm could be used to advantage in the present invention. If such narrow-band light sources are used, ten (10) such narrow-band light sources, properly selected, and positioned in the ten (10) elongated holes defined by the C-shaped housing will be sufficient to cover this excitation light range.

[0022] Still referring to Figure 6, each narrow-band light source provided in each elongated hole should be selected to cover a specific wavelength range or band within the desired overall wavelength range or band (e.g., 430-745 nm) desired to be covered by the excitation light source assembly. Generally speaking, light emitting diodes (LEDs) that emit light in various narrow wavelength bands (e.g., bands having widths of about 30-35 nm) are available. Accordingly, various narrow-band LED light sources may be selected to cover the desired wavelength range. However, in this regard it should be noted that suitable LEDs that emit or produce light in each of the desired wavelength bands may not be available. If so, it may be necessary to use broader-band LEDs, i.e., that emit light having wavelengths outside the desired wavelength range. If so, such LEDs or broad-band light sources may be used in combination with a filter element to filter or remove the undesired wavelengths, as will be described in greater detail below.

[0023] The various LEDs that may be used with the present invention may comprise any of a wide range of LEDs that are now known in the art or that may be developed in the future that produce light in the desired wavelength ranges. However, because

such LEDs are well-known in the art and could be readily provided by persons having ordinary skill in the art after having become familiar with the teachings provided herein, the particular LEDs that may be utilized in one embodiment of the invention will not be described in further detail herein.

[0024] It is also generally preferred, but not required, to provide a diffuser within each elongated opening, generally at a position immediately adjacent the light source. As its name implies, the diffuser diffuses light produced by the light source, thereby generally providing more even illumination of the object (i.e., fluorescent material) than that provided by the light source alone. The diffuser may comprise any of a wide range of optical diffusers that are now known in the art or that may be developed in the future that are or would be suitable for the particular application. However, because optical diffusers are well-known in the art and could be readily provided by persons having ordinary skill in the art after having become familiar with the teachings provided herein, the particular diffusers that may be used in one embodiment of the invention will not be described in further detail herein.

[0025] As briefly mentioned above, the light output characteristics of the various light sources (e.g., LEDs) that may be utilized in the excitation light source assembly may be such that it is required, or at least desirable, to further limit the wavelength range of excitation light produced by each light source. This may be the case regardless of whether the particular light source involved is a "narrow-band" light source. Accordingly, in one embodiment, each elongated hole defined by the housing may also be provided with a filter element therein that is configured to remove or filter undesired wavelengths produced by the corresponding light source. In the particular embodiment shown and described herein, each such filter may be positioned adjacent the

diffuser, as best seen in Figures 6 and 7. Alternatively, other arrangements are possible.

[0026] In the particular embodiment shown and described herein, each filter element comprises a "notch" type filter having a relatively narrow wavelength bandpass range of about 30 nm. Such notch type filters are available over a wide range of wavelengths. In one embodiment of the invention, a separate notch filter is provided for each light source, narrow-band or otherwise and the notch filter wavelength is selected as appropriate for the particular light source with which it is paired. Thus, when individually activated, each light source/filter combination will emit excitation light having a bandwidth of about 30 nm somewhere within the desired overall wavelength range (e.g., from about 430 nm to about 745 nm) desired to be covered by the excitation light source assembly.

[0027] Each of the various light sources provided in the elongated holes defined by the housing may be operatively connected to a control system (not shown) suitable for operating the various light sources, i.e., turning them "on" and "off." In one embodiment, the light sources may be individually controlled, so that a single light source, emitting excitation light in a single wavelength range or band, may be used to excite the desired fluorescent material contained in the object or specimen being studied. Alternatively, other arrangements are possible. For example, in another embodiment, the control system may operate two or more light sources simultaneously. Such an operational mode may be used to simultaneously excite two or more different kinds of fluorescent materials, which will then fluoresce. Still other arrangements and variations are possible, as would become apparent to persons having ordinary skill in the art after having become familiar with the teachings provided herein. Consequently, the present invention should not be regarded as limited to the

particular elements, applications, and methods shown and described herein.

[0028] Having herein set forth preferred embodiments of the present invention, it is anticipated that suitable modifications can be made thereto which will nonetheless remain within the scope of the invention. The invention shall therefore only be construed in accordance with the following claims:

CLAIMS:

1. An assembly, comprising:
 - a support structure;
 - a camera mounted to said support structure;
 - an excitation light source assembly mounted to said support structure, said excitation light source assembly comprising:
 - a housing defining a central opening therein and a plurality of elongated holes surrounding the central opening, said housing being mounted to said support structure so that the central opening is aligned with said camera, so that a field of view of said camera is unobstructed by said housing;
 - a narrow-band light source positioned within each of the plurality of elongated holes; and
 - a diffuser positioned adjacent said narrow-band light source positioned within each of the plurality of elongated holes, each of said diffusers diffusing light produced by each of said narrow-band light sources; and
 - a control system operatively connected to each of said narrow-band light sources positioned within said plurality of elongated holes, said control system operating selected ones of said narrow-band light sources to provide a desired excitation illumination to a fluorescent material within the field of view of said camera.
2. The assembly of claim 1, further comprising a light filter positioned adjacent each of the diffusers.
3. The assembly of claim 1, wherein each of the elongated holes defined by said housing are angled with respect to a central axis of said housing so that light emitted from each of said

narrow-band light sources is directed to a desired area within the field of view of said camera.

4. The assembly of claim 1, wherein each of said narrow-band light sources is selected to provide desired number of illumination bands over a desired spectral range.

5. The assembly of claim 4, wherein the desired spectral range is from about 430 nm to about 745 nm.

6. The assembly of claim 4, wherein the desired number of illumination bands is 10.

7. The assembly of claim 4, wherein each desired illumination band has a spectral width ranging from about 30 nm to about 35 nm.

8. The assembly of claim 1, wherein each of said narrow band light sources comprises a light emitting diode.

9. The assembly of claim 1, wherein said housing comprises a polyoxymethylene thermoplastic material.

10. The assembly of claim 9, wherein said polyoxymethylene thermoplastic material comprises Delrin.

11. An excitation light source assembly, comprising:

a housing defining a central opening therein and a plurality of elongated holes surrounding the central opening, said housing being mountable to a support structure so that the central opening is aligned with a camera also mounted to

the support structure, so that a field of view of the camera is unobstructed by said housing;

a light source positioned within each of the plurality of elongated holes; and

a diffuser positioned adjacent said light source positioned within each of the plurality of elongated holes, each of said diffusers diffusing light produced by each of said light sources; and

a control system operatively connected to each of said light sources positioned within said plurality of elongated holes, said control system operating selected ones of said light sources to provide a desired excitation illumination to an object within the field of view of said camera.

12. The excitation light source assembly of claim 11 wherein at least one of said light sources comprises a narrow-band light source that emits light in a wavelength range of about 35 nm.

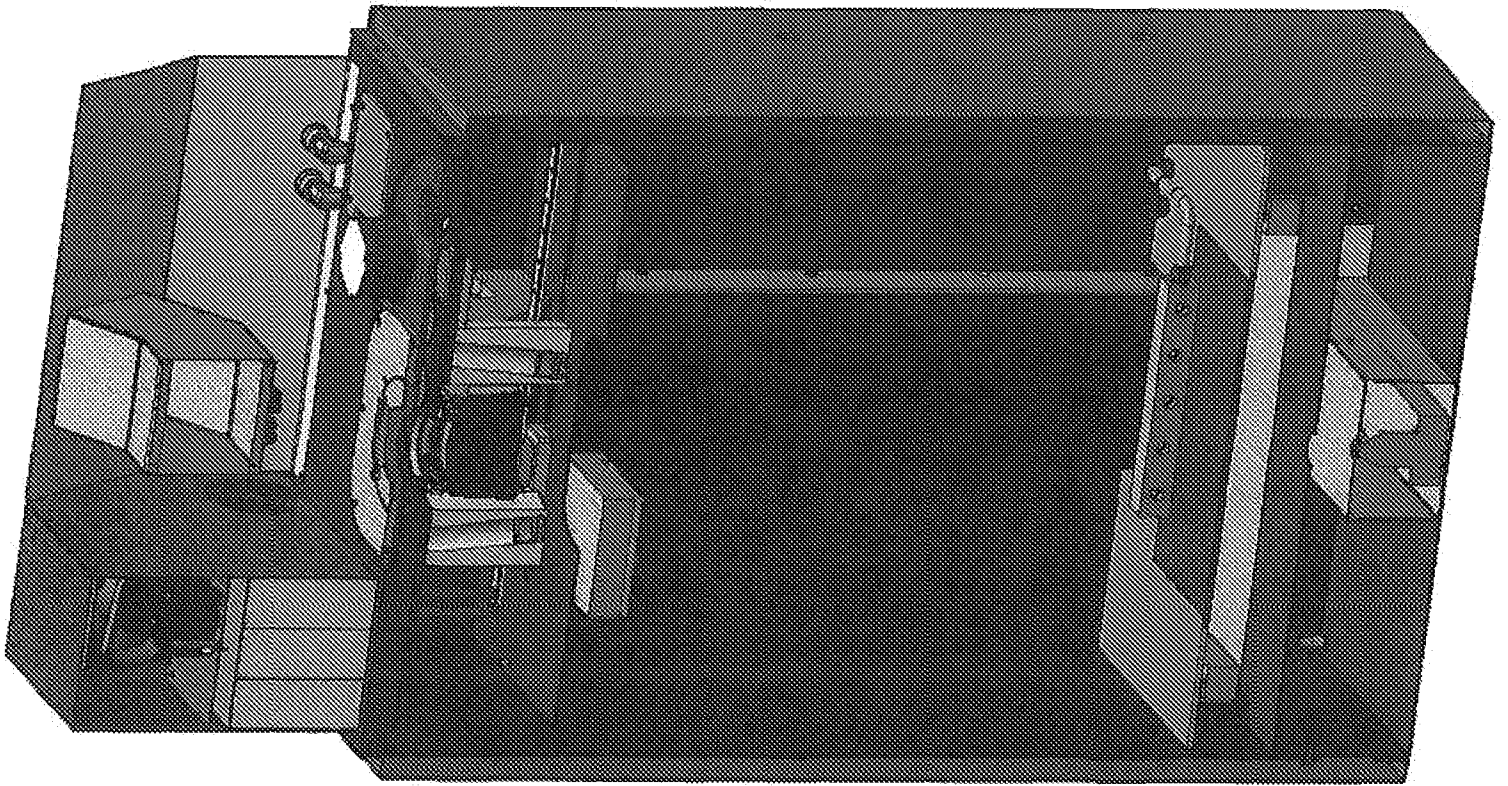
13. The excitation light source assembly of claim 12 wherein said at least one narrow-band light source comprises a light emitting diode.

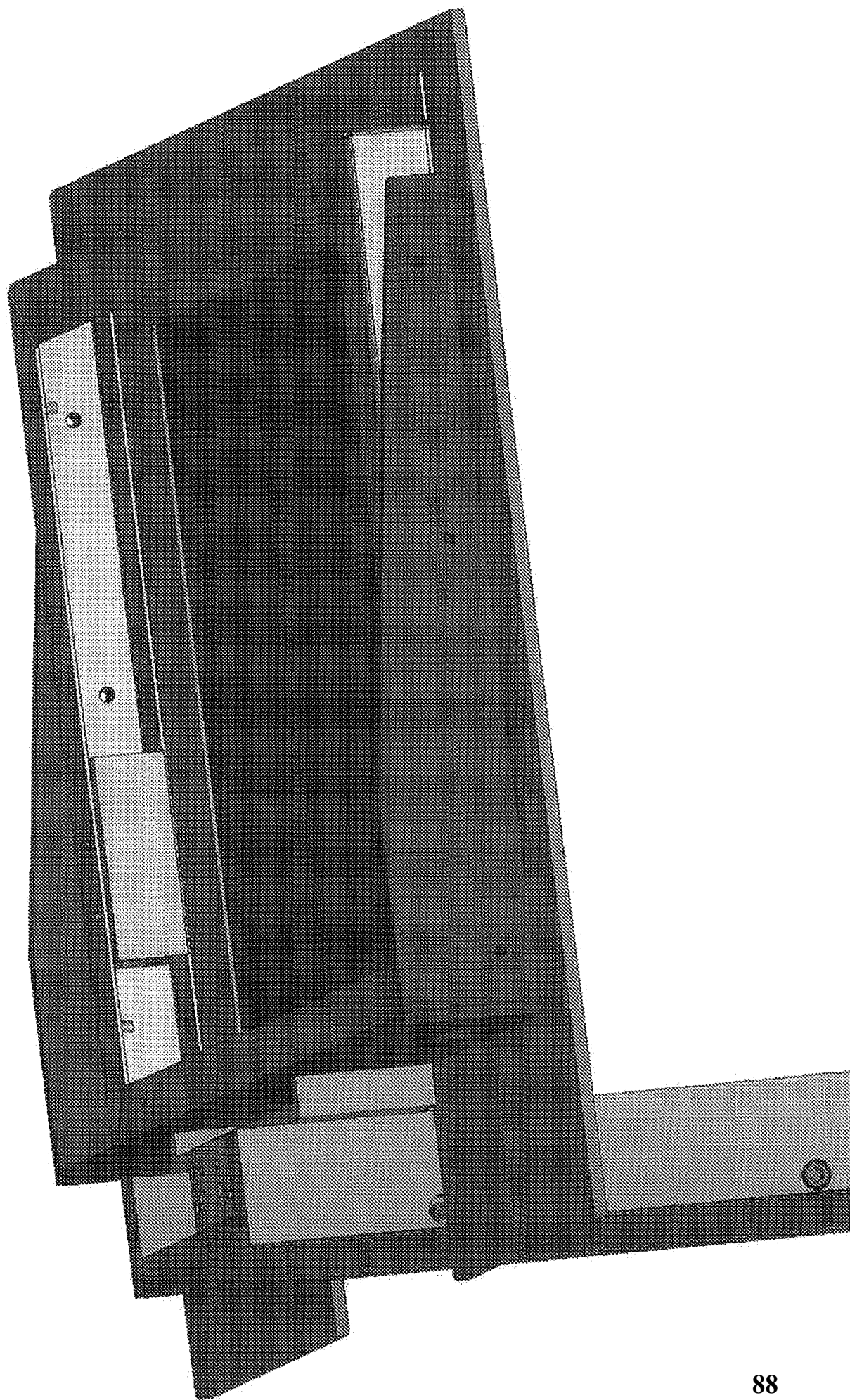
14. The excitation light source assembly of claim 11, further comprising at least one light filter positioned adjacent at least one diffuser in at least one of the elongated holes defined by said housing.

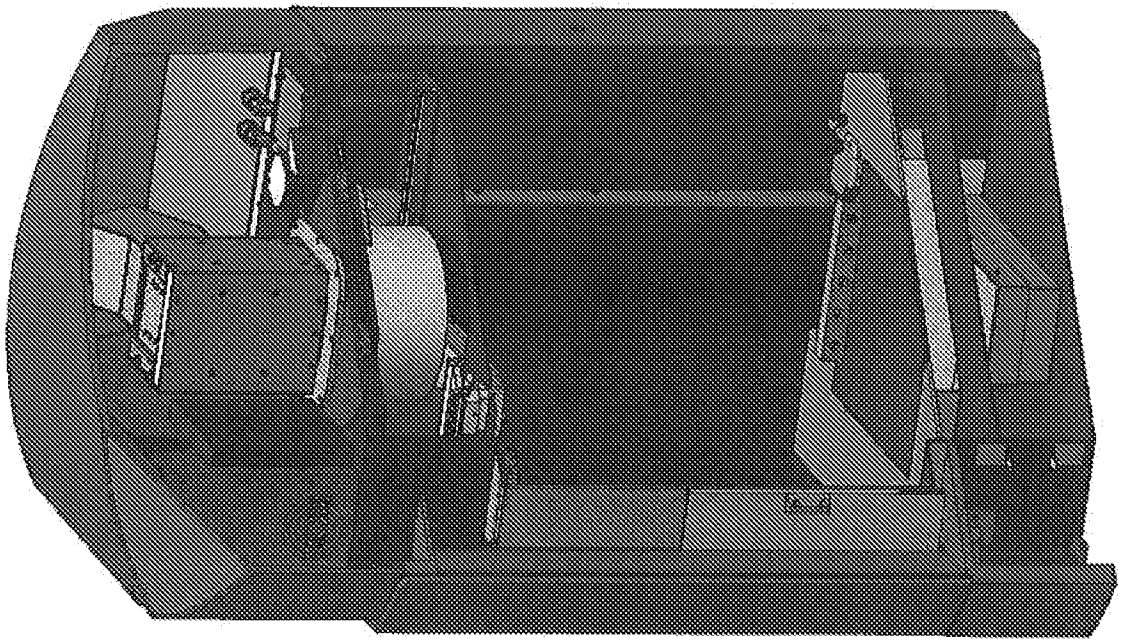
15. The excitation light source assembly of claim 14, wherein said at least one light filter comprises a notch filter having a wavelength bandpass range of about 30 nm.

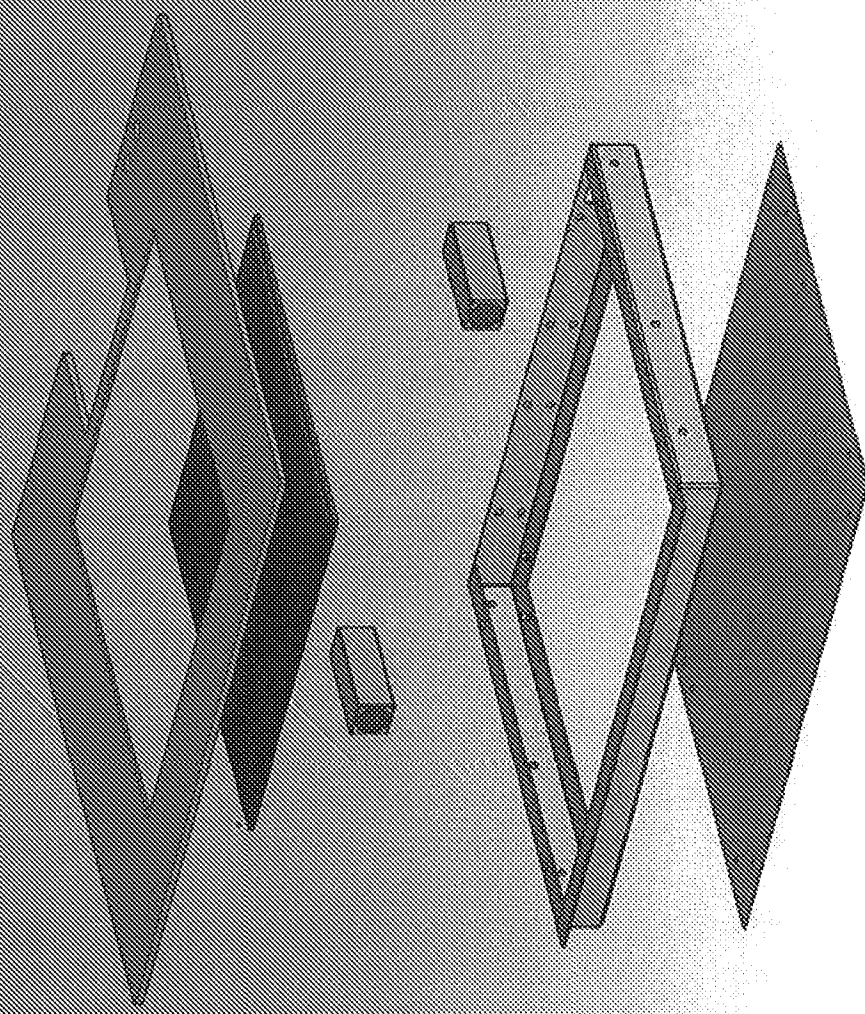
ABSTRACT OF THE DISCLOSURE

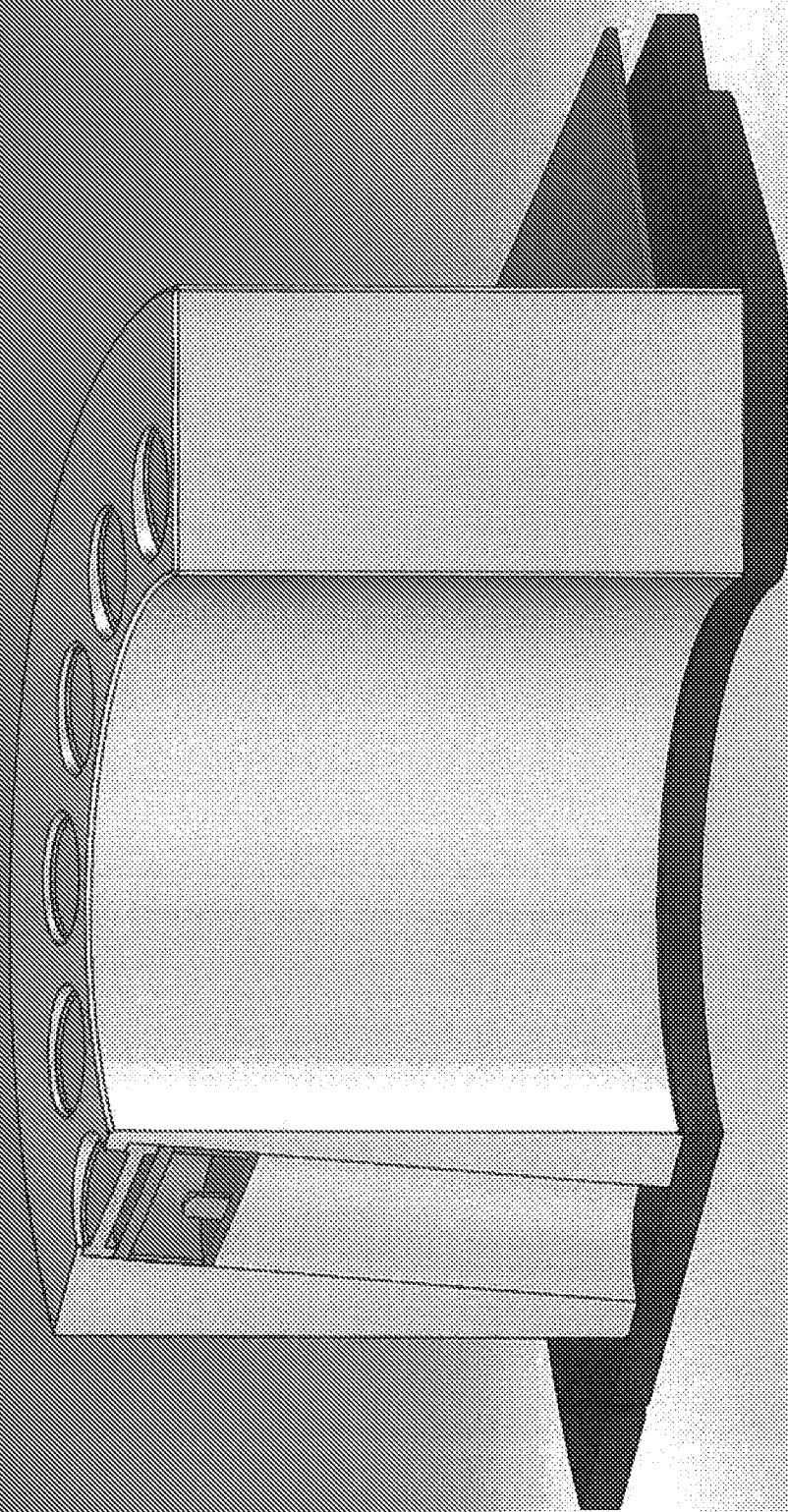
An excitation light source assembly having a housing defining a central opening therein and a plurality of elongated holes surrounding the central opening. The housing is mountable to a support structure having a camera mounted thereto so that a field of view of the camera is unobstructed by the central opening in the housing. A light source is positioned within each of the plurality of elongated holes defined by the housing. A diffuser positioned adjacent the light source within each of the plurality of elongated holes diffuses light produced by each of the light sources. A control system operatively connected to each of the light sources operates selected ones of the light sources to provide a desired excitation illumination to a fluorescent material within the field of view of the camera.

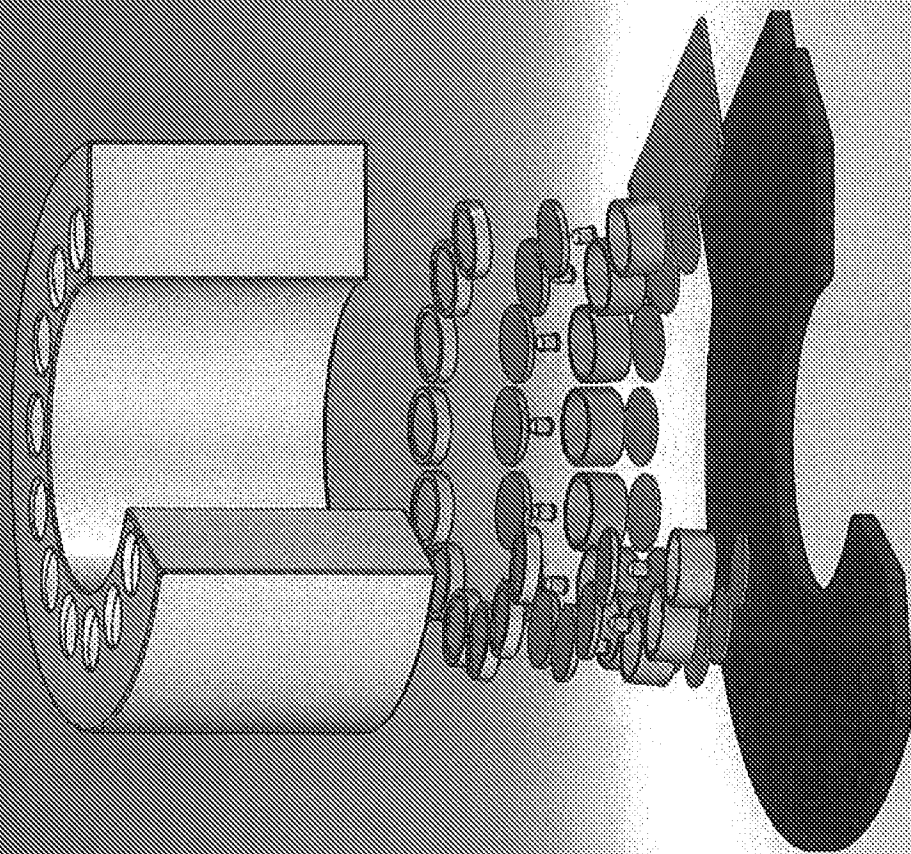


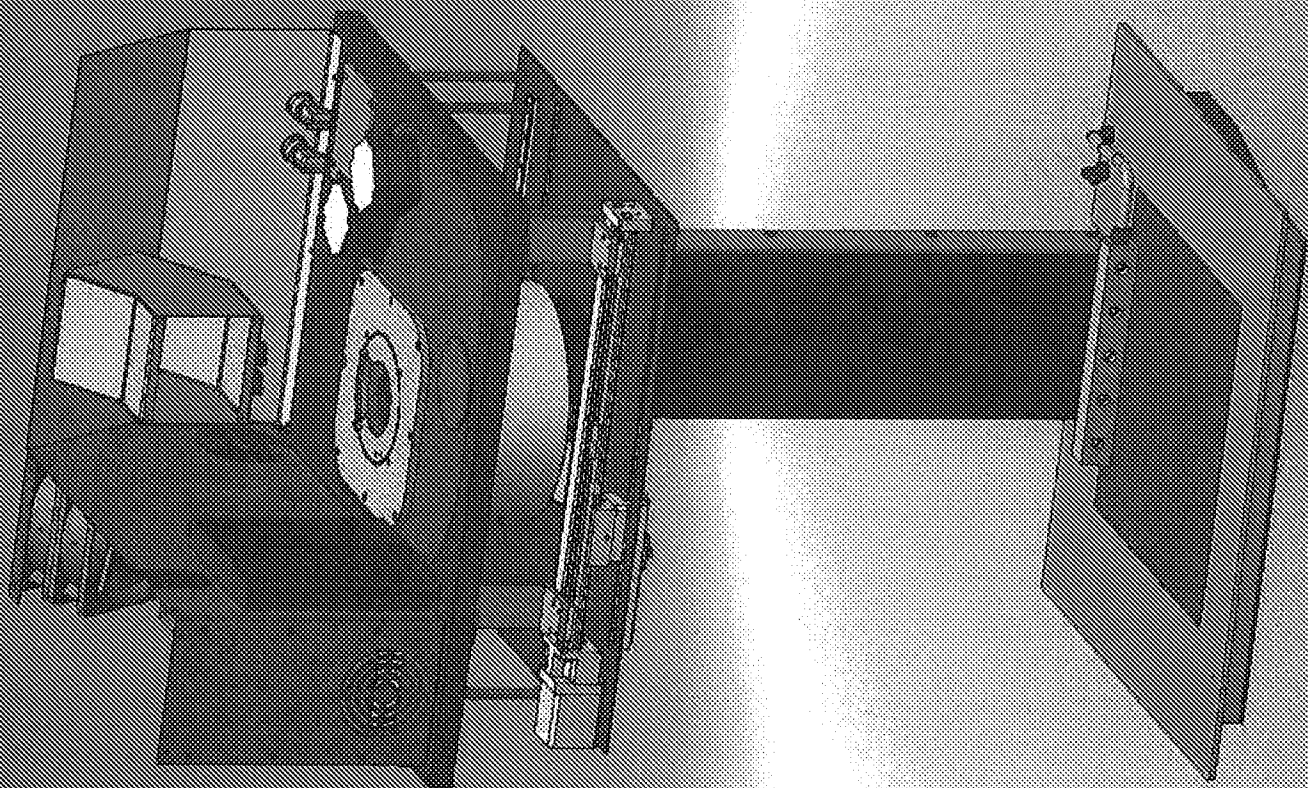


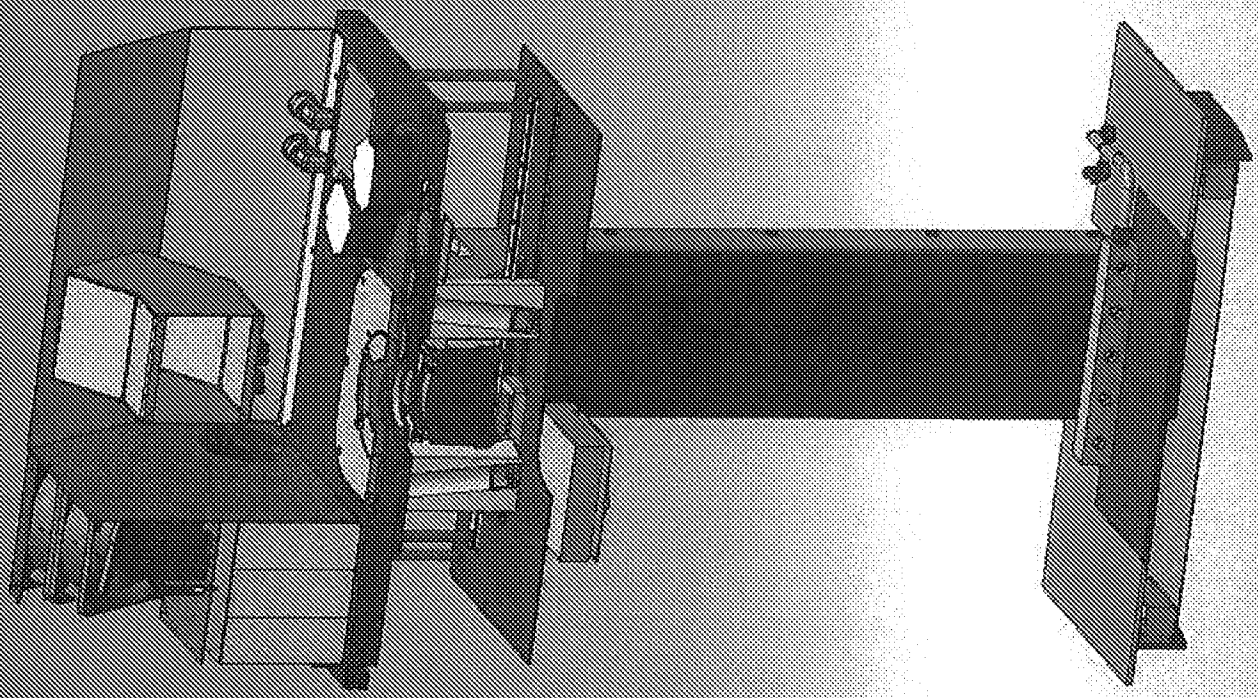


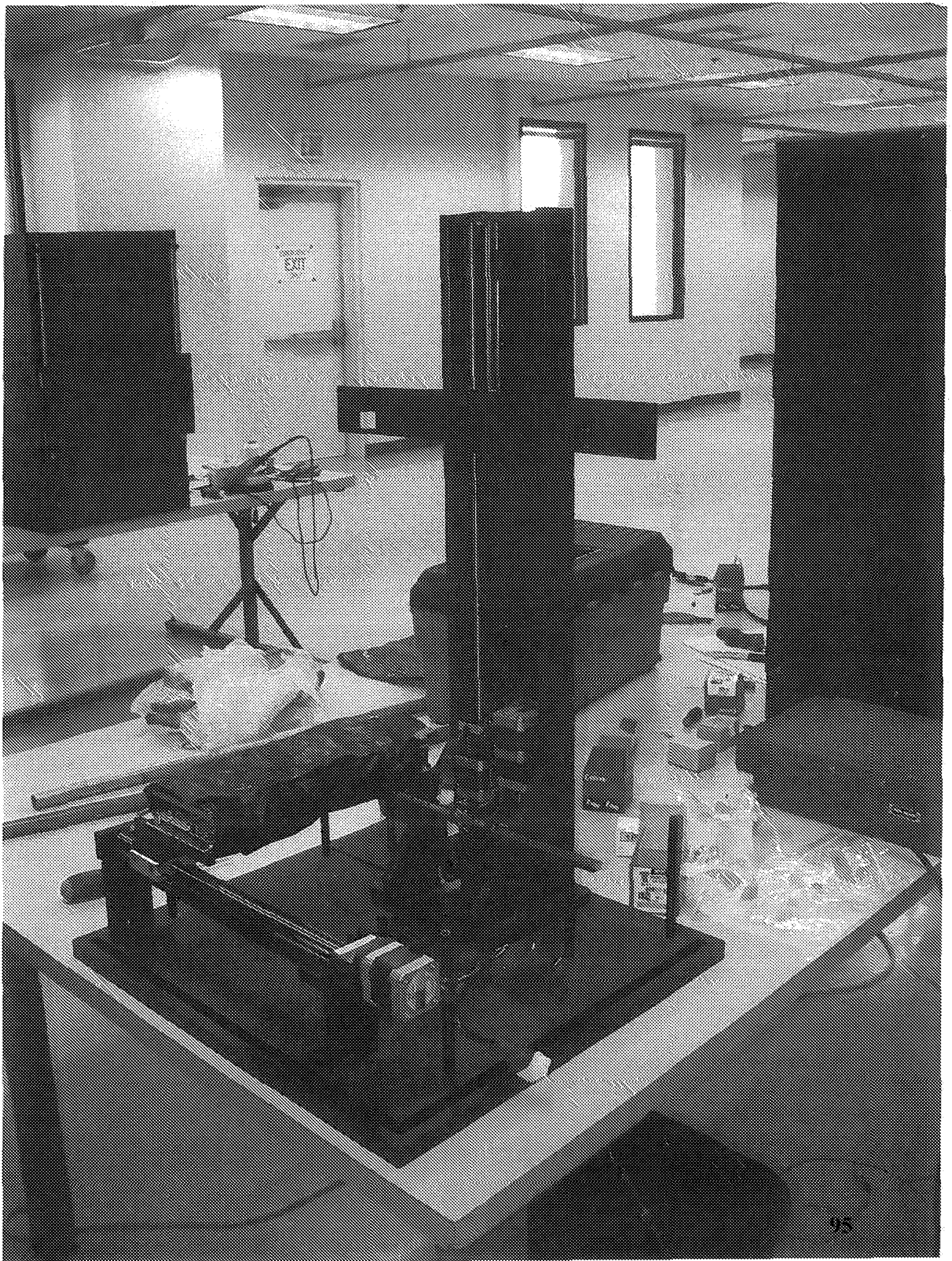


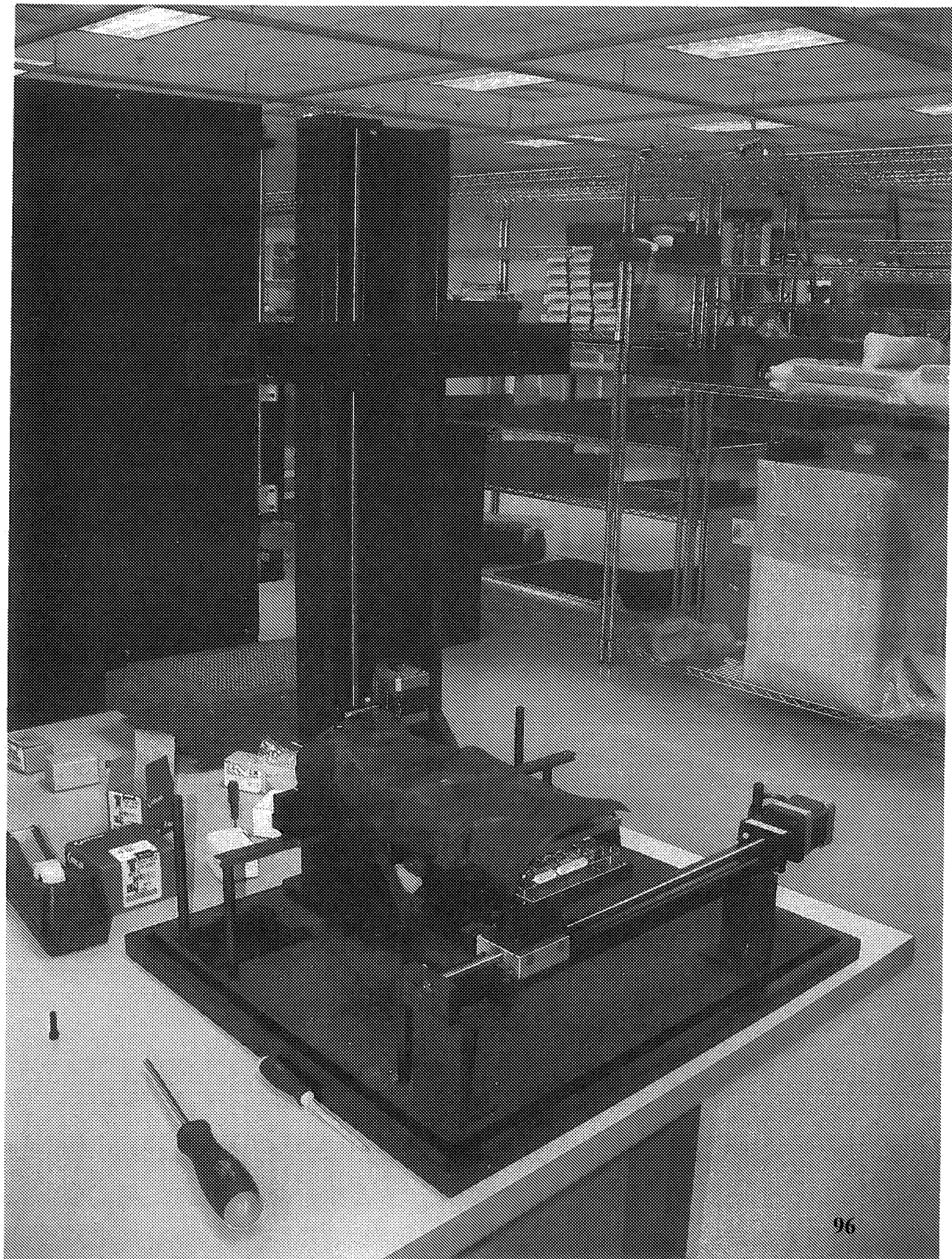


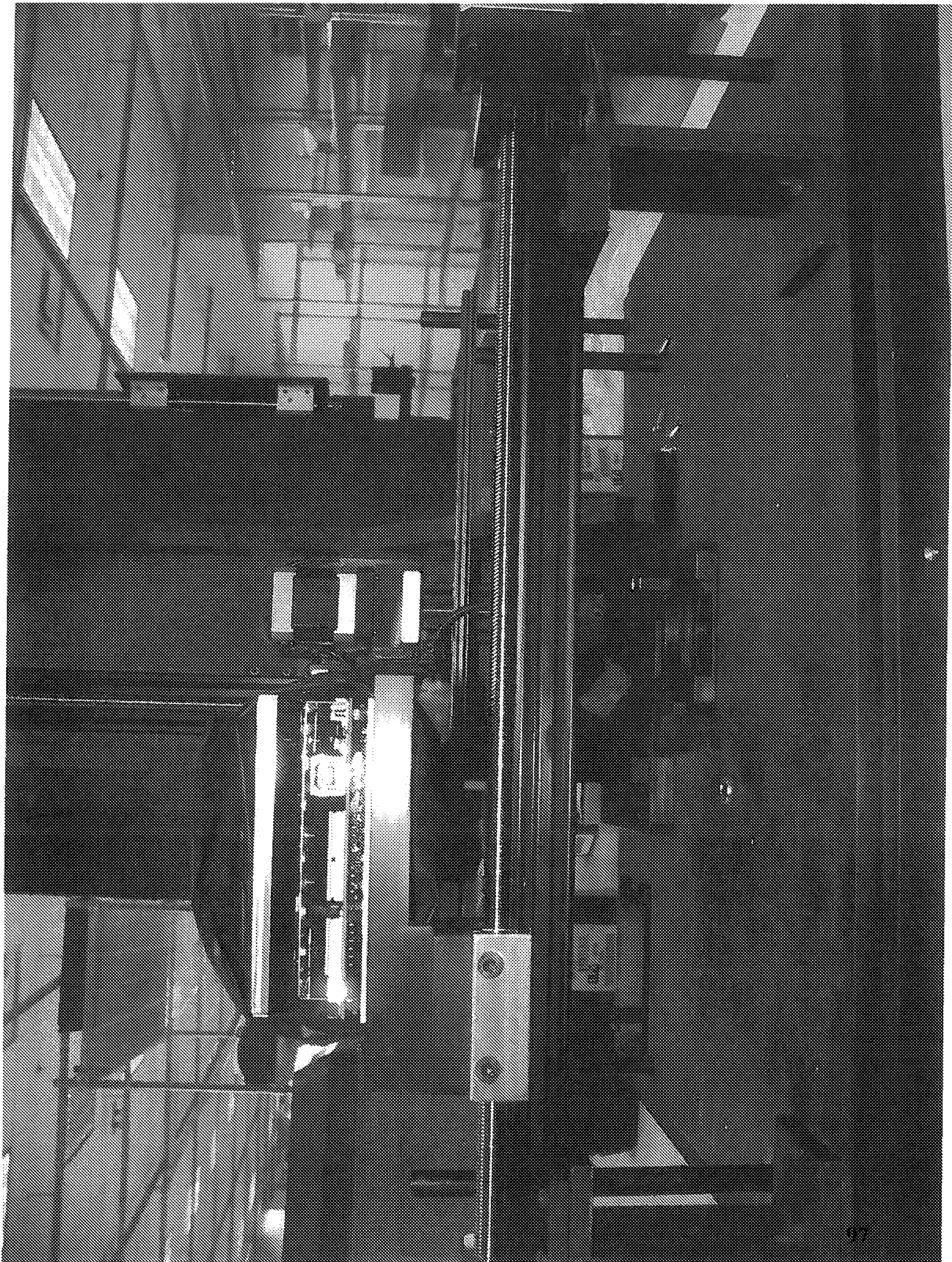




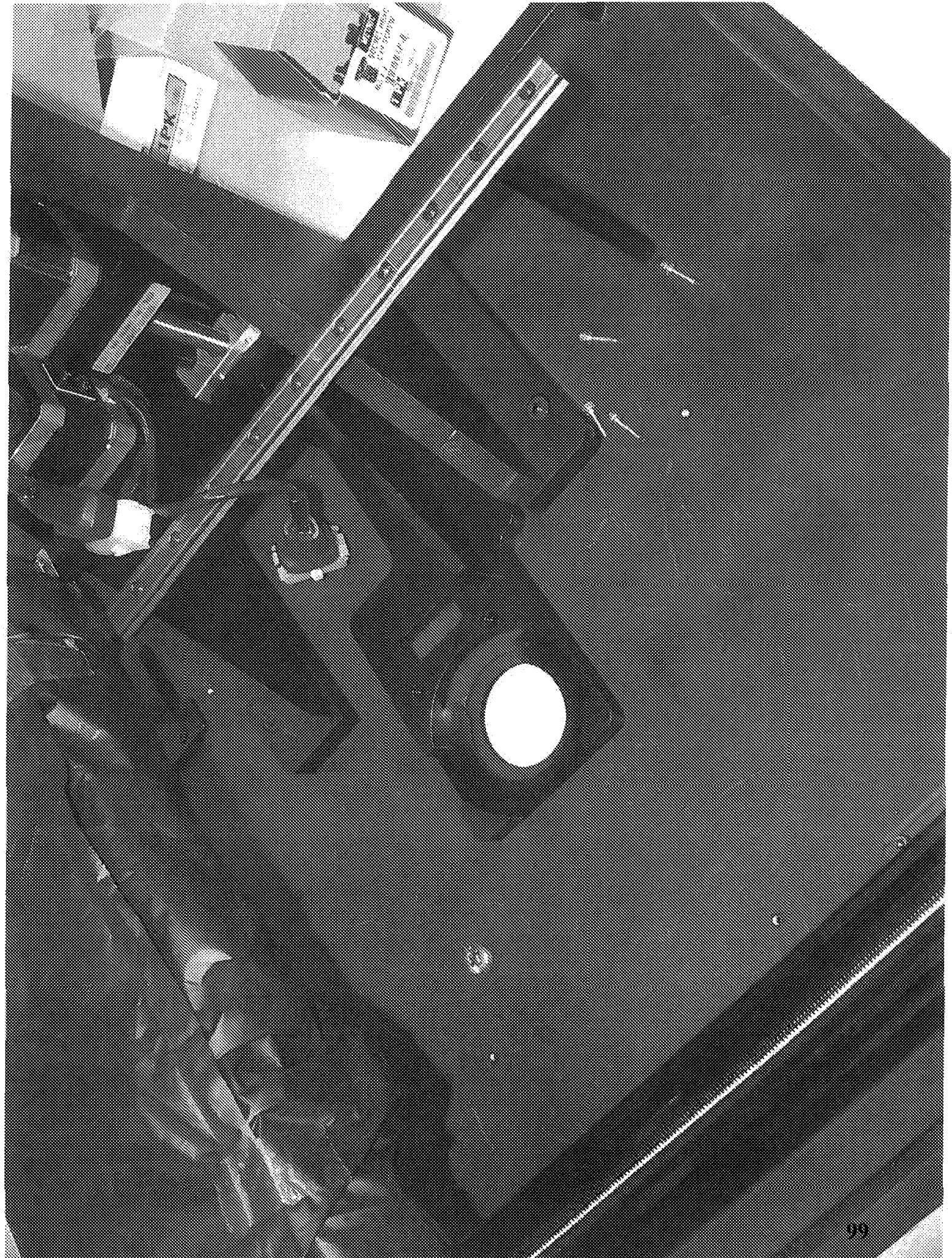


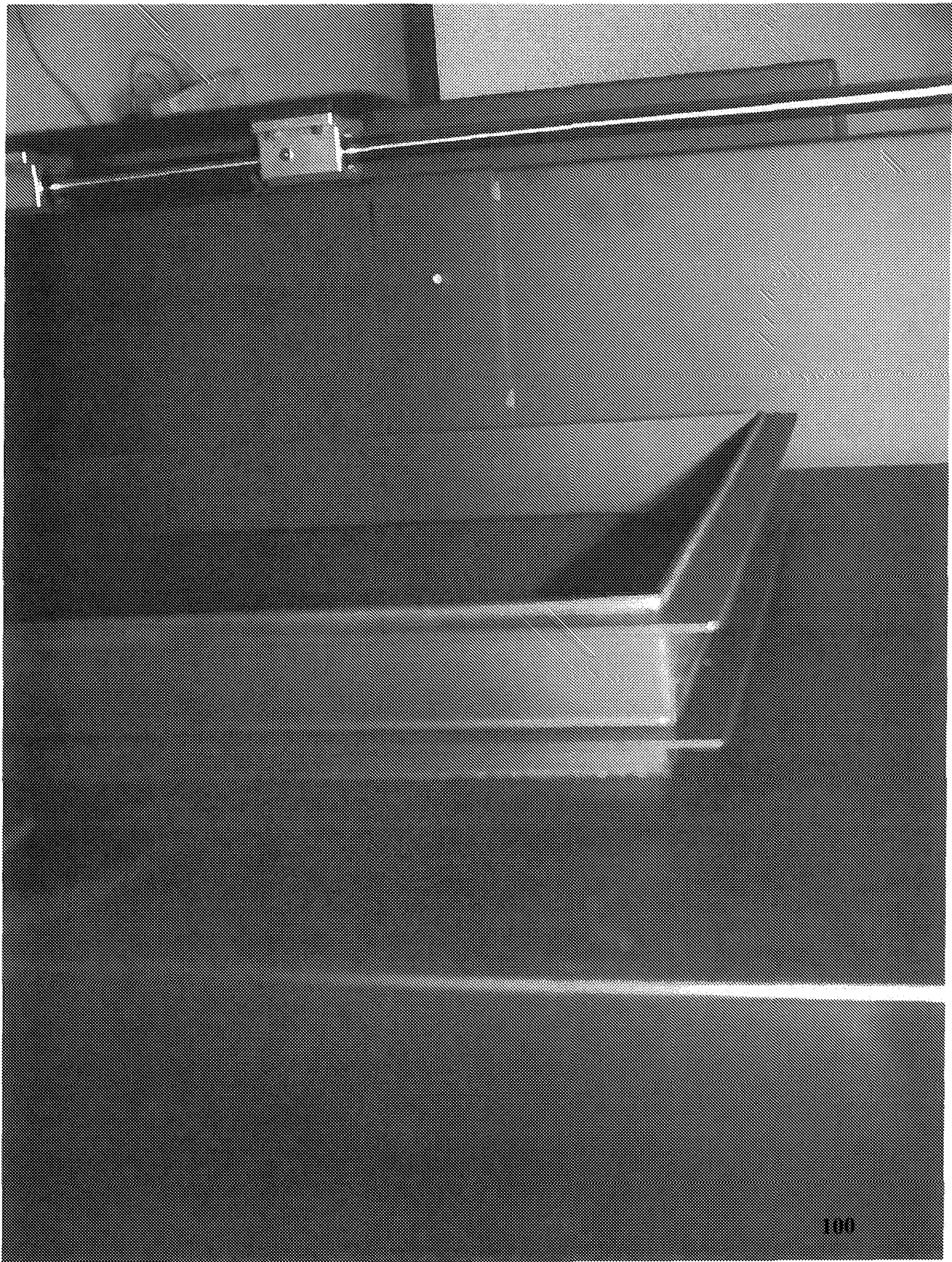


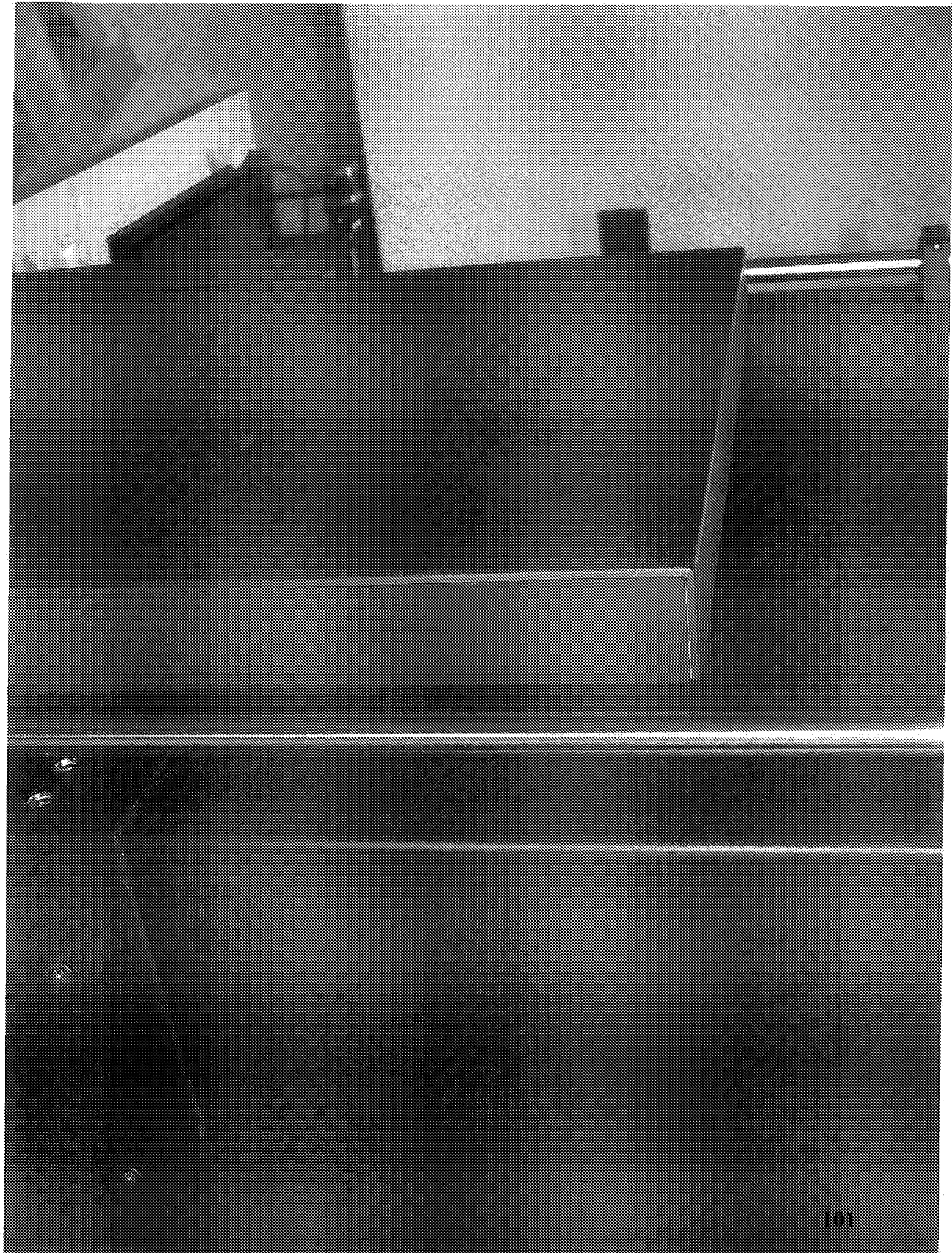


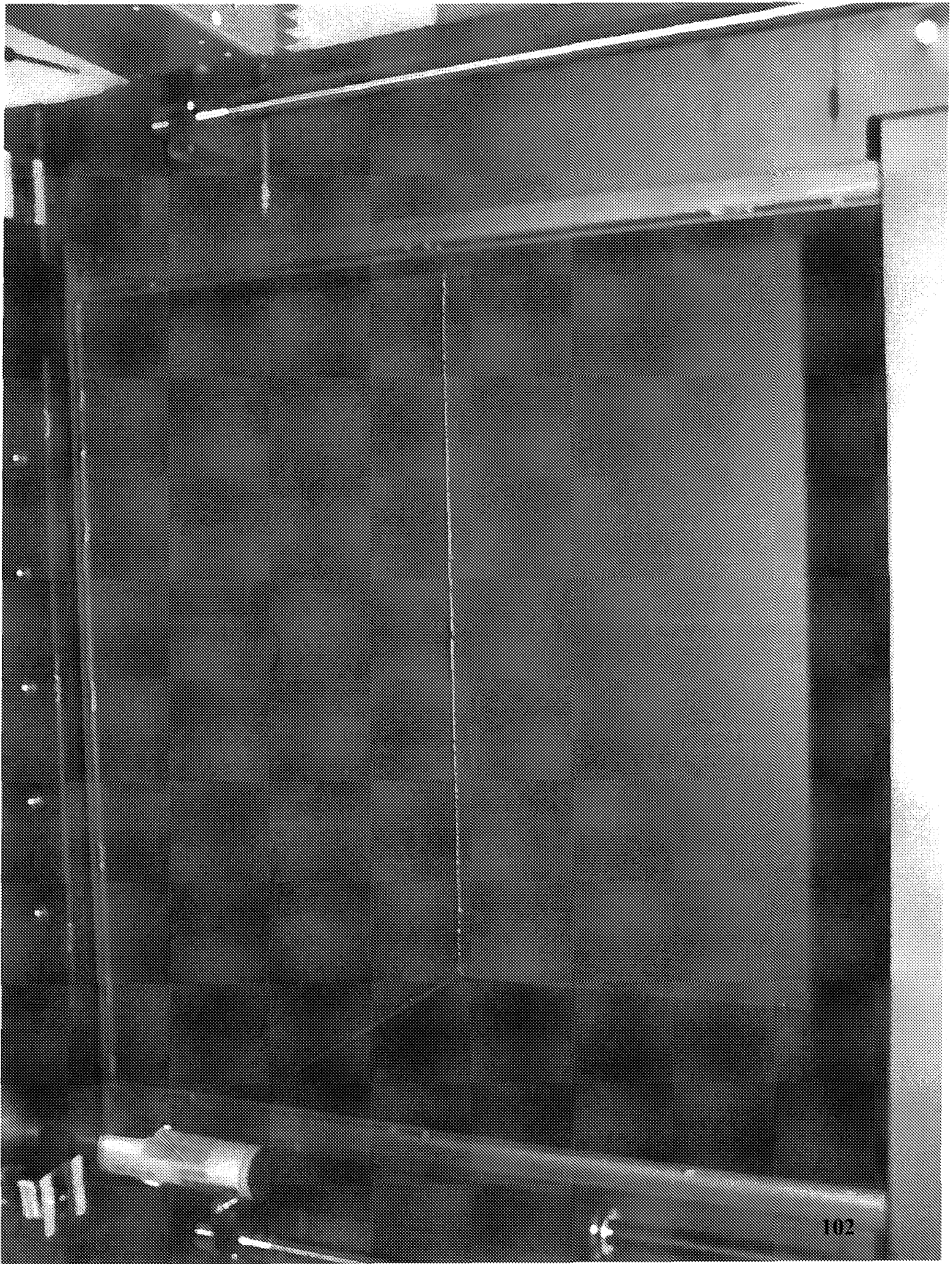


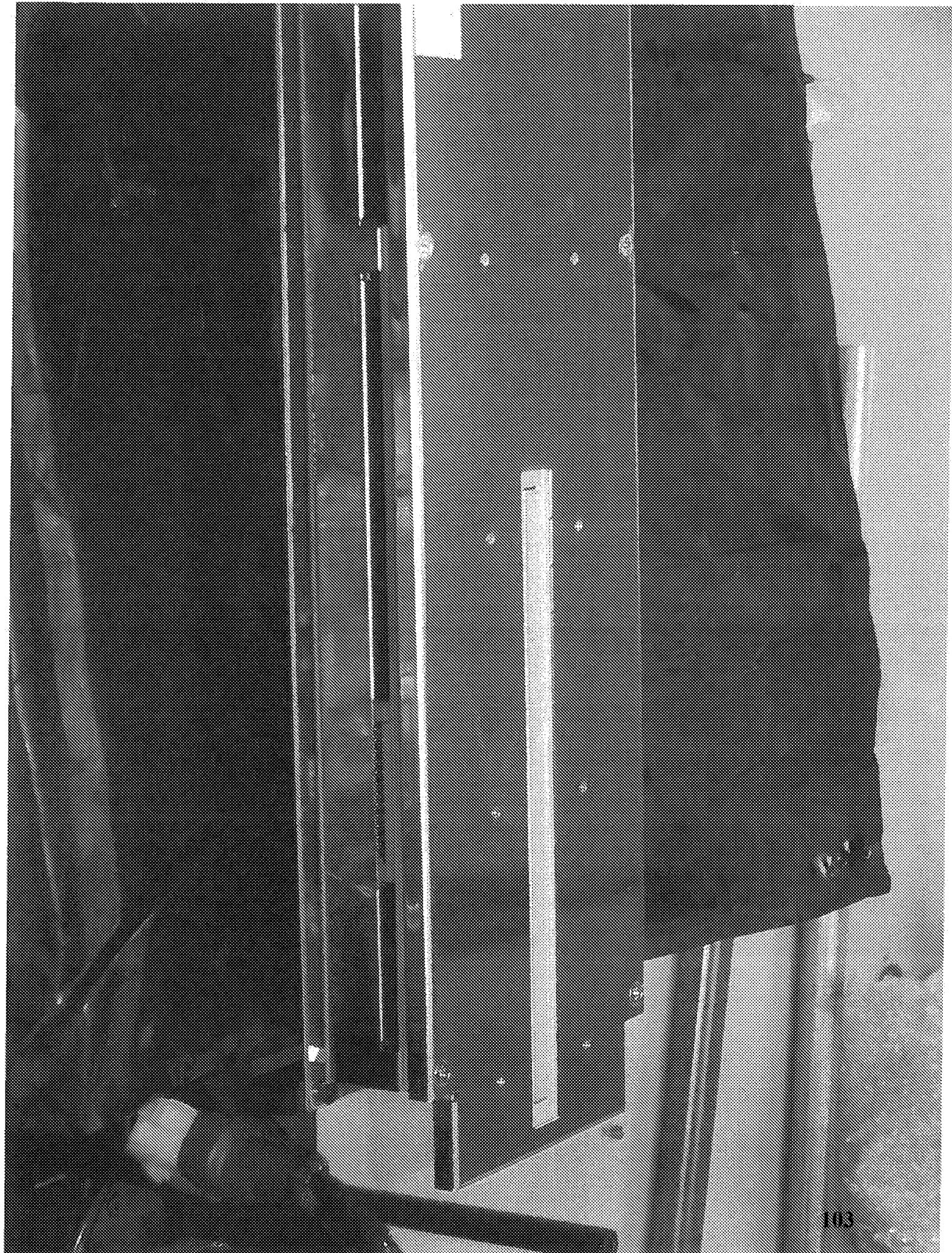












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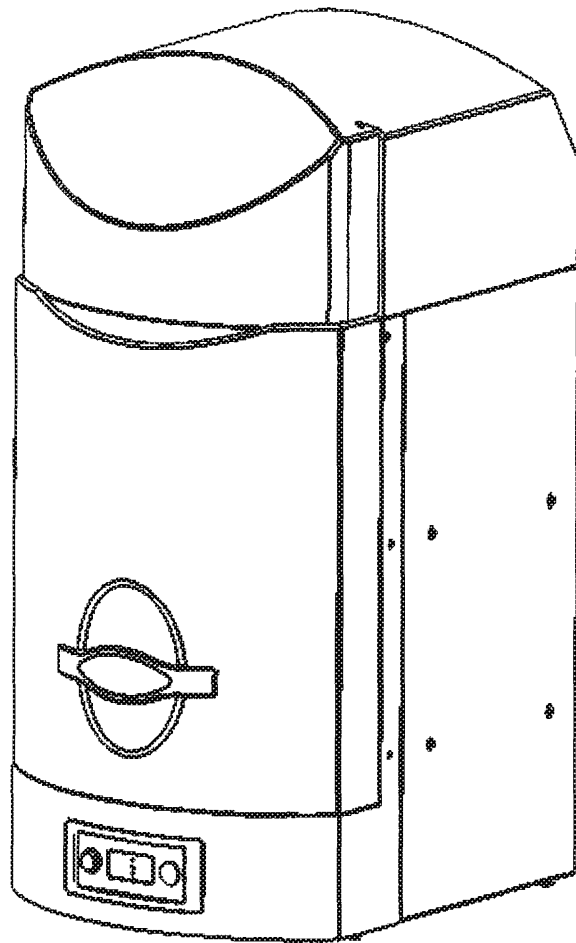


FIG. 1

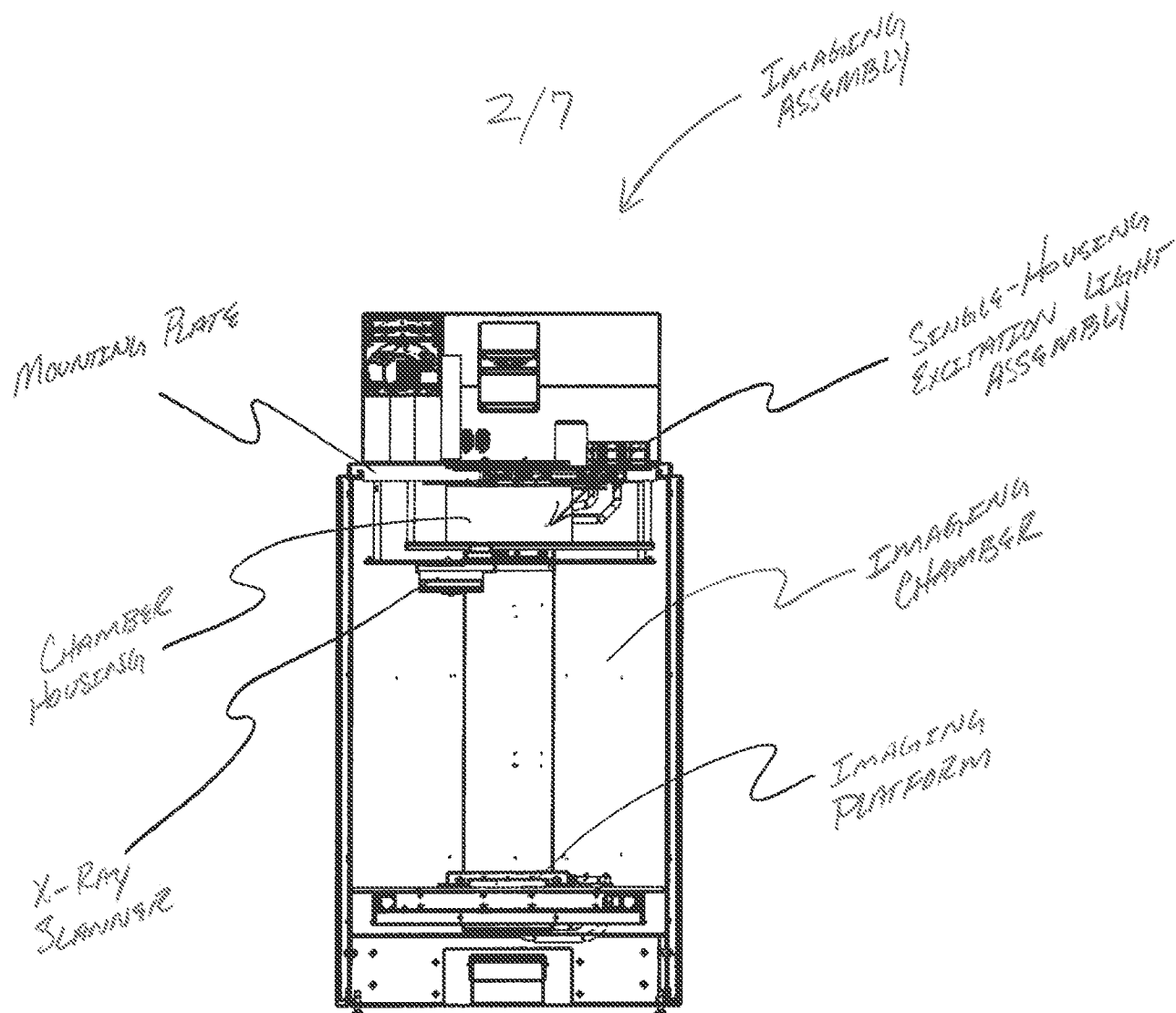


FIG. 2

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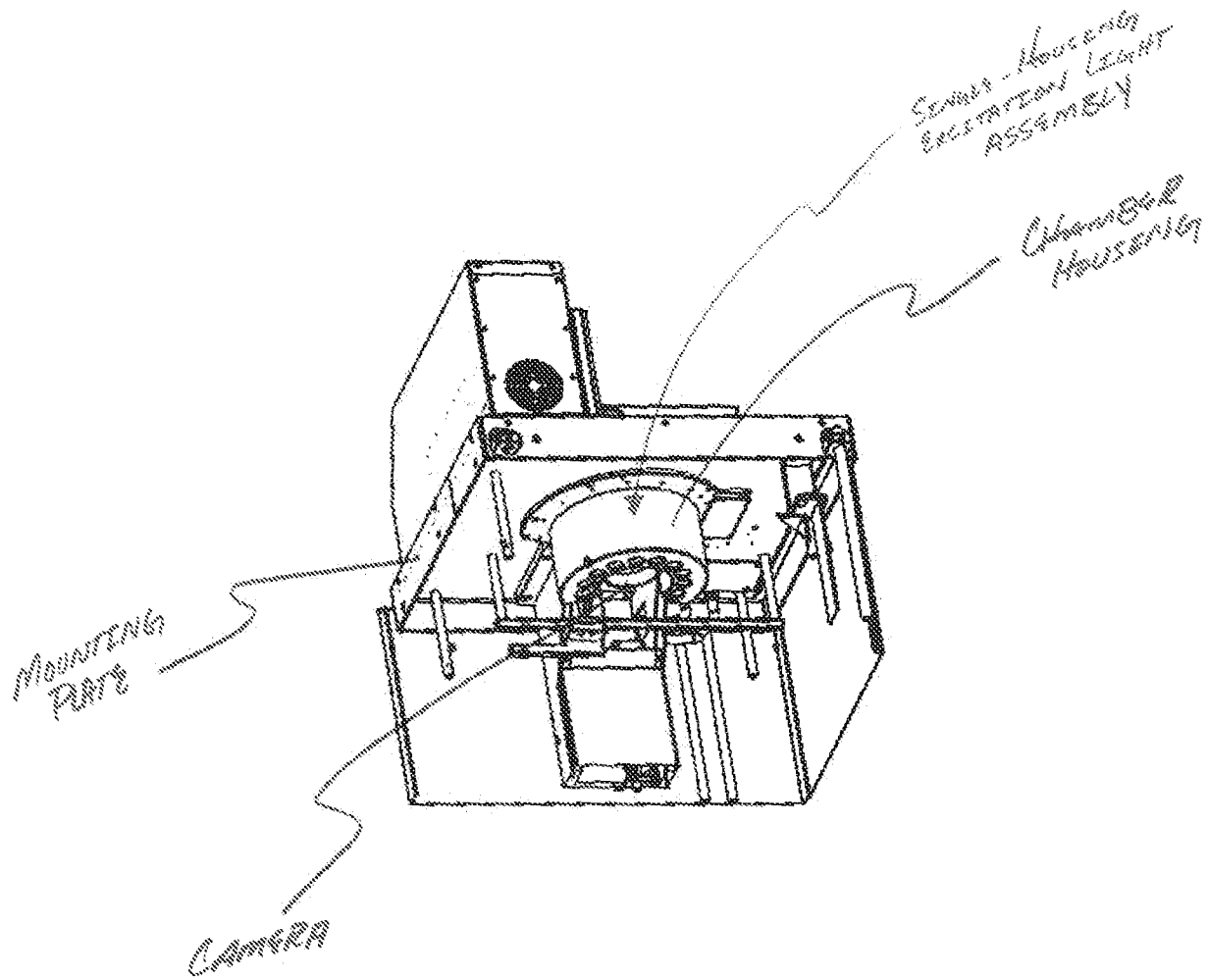


FIG. 3

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LED CHAMBER

SENSOR-HOUSING
EXCITATION ASSEMBLY
BASE PLATE

MOUNTING
PLATE

CHAMBER
HOUSING

SENSOR-HOUSING
EXCITATION LIGHT
ASSEMBLY

CAMERA

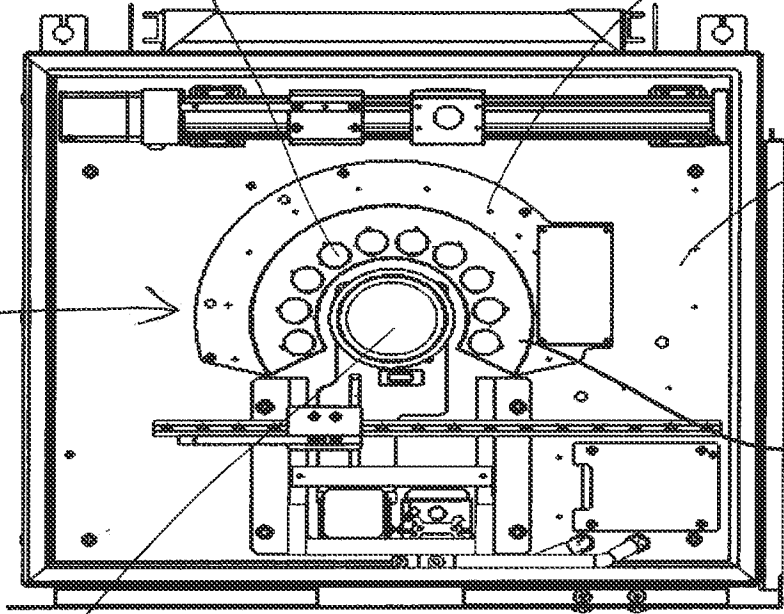


FIG. 4

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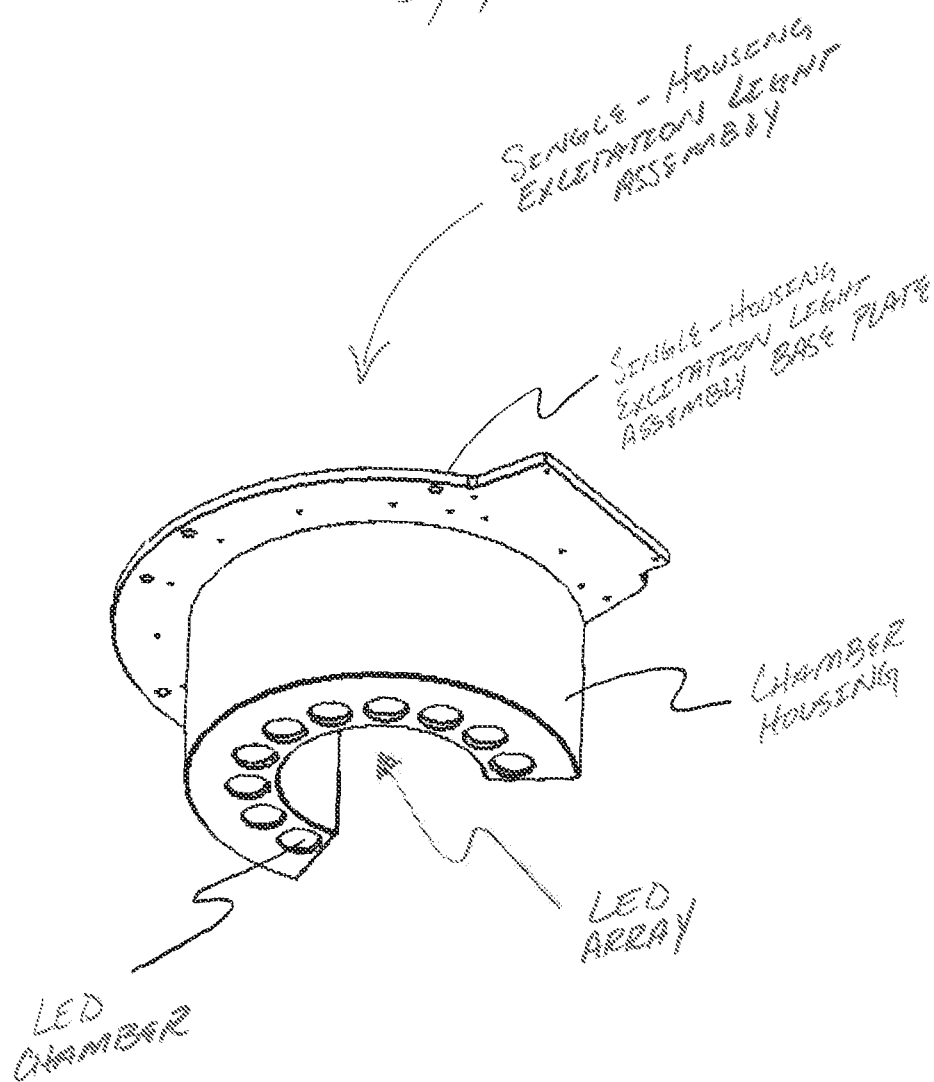


Fig. 5

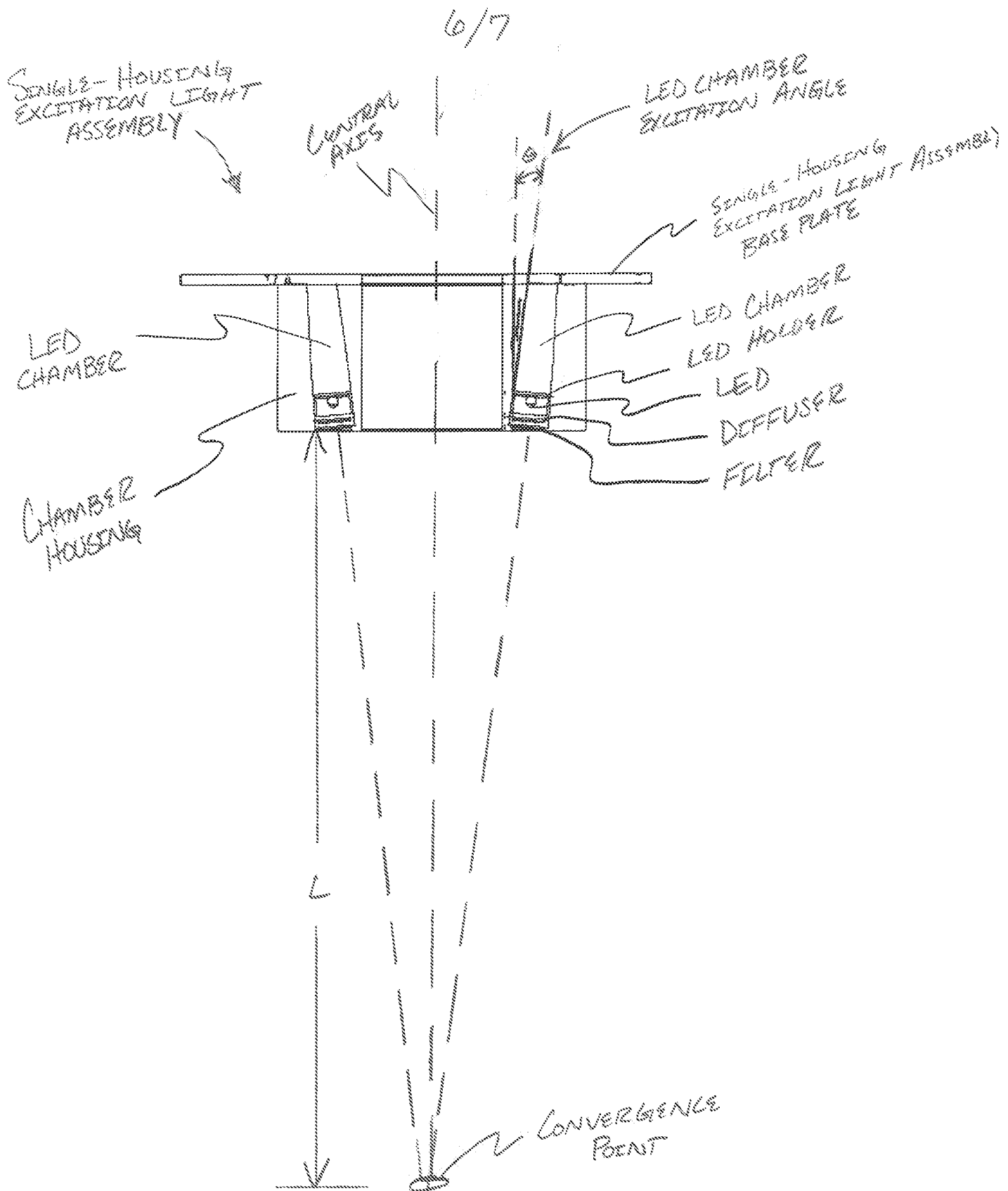


FIG. 6

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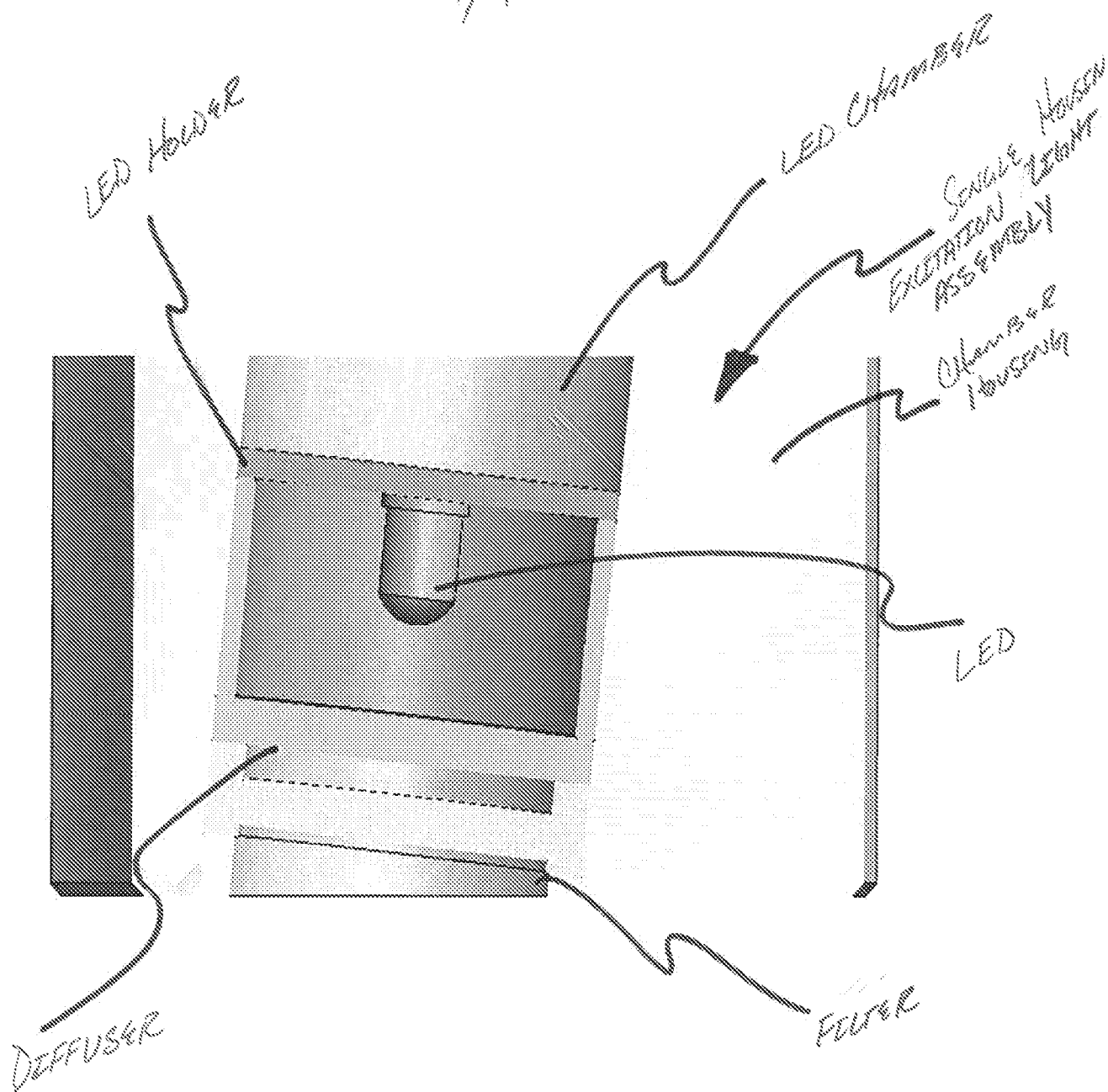


FIG. 7

Electronic Patent Application Fee Transmittal

Application Number:

Filing Date:

Title of Invention:

EXCITATION LIGHT SOURCE ASSEMBLY

First Named Inventor/Applicant Name:

Michael B. Nelson

Filer:

Bruce E. Dahl/Cynthia Sullivan

Attorney Docket Number:

SPEC US-4 PRV (27560-006)

Filed as Large Entity

Provisional Filing Fees

Description

Fee Code

Quantity

Amount

**Sub-Total in
USD(\$)**

Basic Filing:

Provisional application filing

1005

1

220

220

Pages:

Claims:

Miscellaneous-Filing:

Petition:

Patent-Appeals-and-Interference:

Post-Allowance-and-Post-Issuance:

Extension-of-Time:

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Total in USD (\$)				220

Electronic Acknowledgement Receipt

EFS ID:	8340660
Application Number:	61379282
International Application Number:	
Confirmation Number:	6512
Title of Invention:	EXCITATION LIGHT SOURCE ASSEMBLY
First Named Inventor/Applicant Name:	Michael B. Nelson
Customer Number:	27104
Filer:	Bruce E. Dahl/Cynthia Sullivan
Filer Authorized By:	Bruce E. Dahl
Attorney Docket Number:	SPEC US-4 PRV (27560-006)
Receipt Date:	01-SEP-2010
Filing Date:	
Time Stamp:	18:52:14
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$ 220
RAM confirmation Number	17755
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1		PRV-4.PDF	2979083	yes	43
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	Document Description		Start		End
	Provisional Cover Sheet (SB16)		1		2
	Application Data Sheet		3		5
	Specification		6		19
	Appendix to the Specification		20		36
	Drawings-only black and white line drawings		37		43
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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
61/379,282	09/01/2010		220	SPEC US-4PRV (27560-006)		

CONFIRMATION NO. 6512

27104
FENNEMORE CRAIG, P.C.
1700 Lincoln Street
SUITE 2900
DENVER, CO 80203

FILING RECEIPT



OC000000043466434

Date Mailed: 09/14/2010

Receipt is acknowledged of this provisional patent application. It will not be examined for patentability and will become abandoned not later than twelve months after its filing date. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Michael B. Nelson, Tucson, AZ;
Michael D. Cable, Tucson, AZ;

Power of Attorney:

Bruce Dahl--33670

If Required, Foreign Filing License Granted: 09/13/2010

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 61/379,282**

Projected Publication Date: None, application is not eligible for pre-grant publication

Non-Publication Request: No

Early Publication Request: No

Title

EXCITATION LIGHT SOURCE ASSEMBLY

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EXHIBIT F



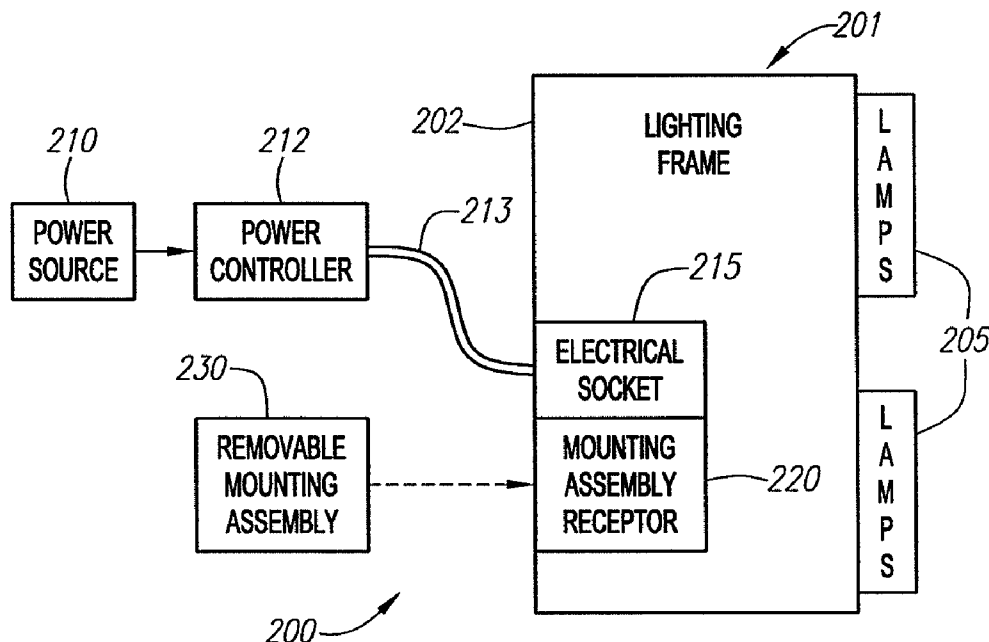
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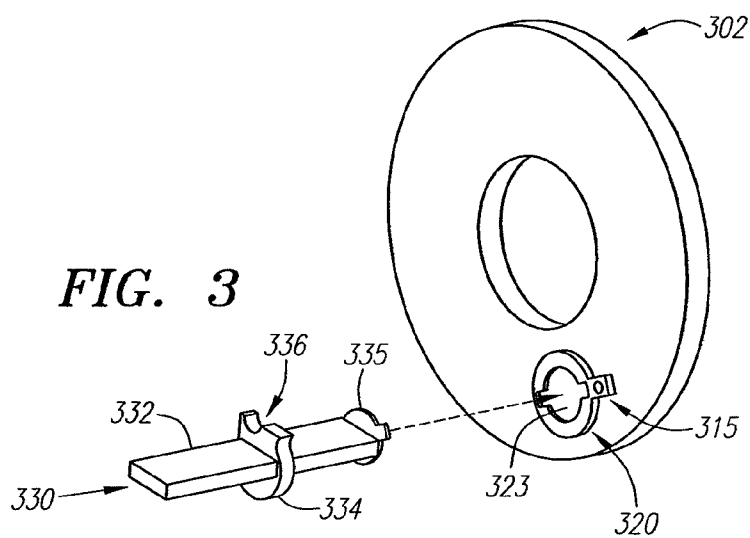
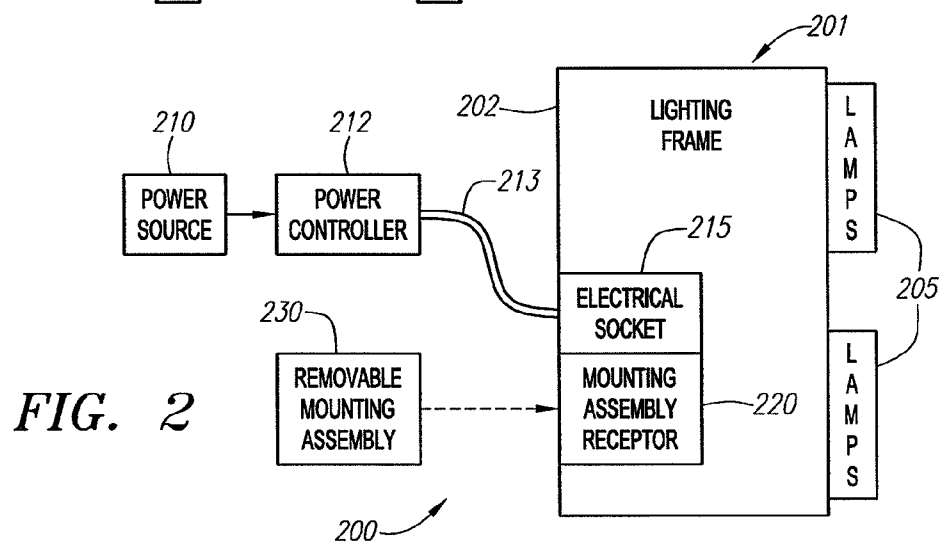
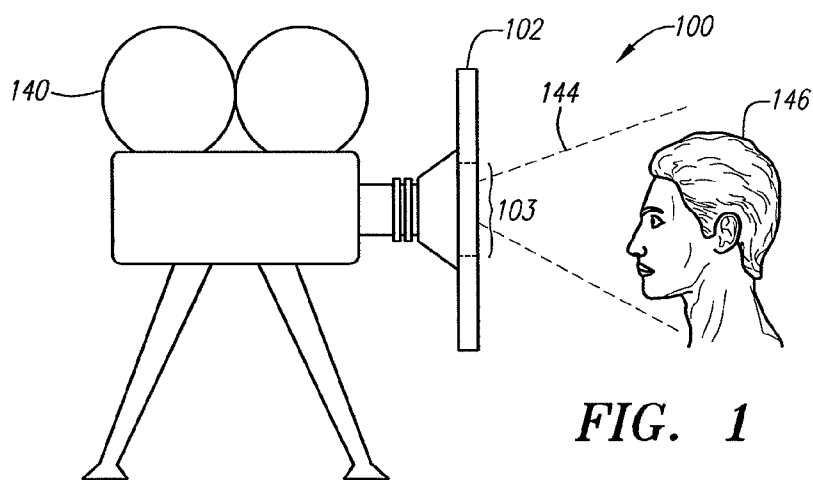
(19) **United States**(12) **Patent Application Publication**
Pohlert et al.(10) **Pub. No.: US 2009/0268426 A1**(43) **Pub. Date: Oct. 29, 2009**(54) **STAND-MOUNTED LIGHT PANEL FOR
NATURAL ILLUMINATION IN FILM,
TELEVISION OR VIDEO**(75) Inventors: **Rudy G. Pohlert**, Calabasas, CA
(US); **Pat Grosswendt**, Agoura, CA
(US); **Kevin C. Baxter**, North
Hollywood, CA (US); **Ken S.
Fisher**, North Hollywood, CA (US)

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1800 AVENUE OF THE STARS, SUITE 900
LOS ANGELES, CA 90067 (US)(73) Assignee: **LITEPANELS LLC**, Van Nuys,
CA (US)(21) Appl. No.: **12/414,643**(22) Filed: **Mar. 30, 2009****Related U.S. Application Data**(63) Continuation of application No. 11/308,004, filed on
Mar. 2, 2006, now Pat. No. 7,510,290, which is a
continuation of application No. 11/005,564, filed onDec. 4, 2004, which is a continuation-in-part of appli-
cation No. 10/238,973, filed on Sep. 9, 2002, now Pat.
No. 6,948,823, which is a continuation-in-part of
application No. 09/949,206, filed on Sep. 7, 2001, now
Pat. No. 6,749,310.**Publication Classification**(51) **Int. Cl.**
G03B 15/02 (2006.01)(52) **U.S. Cl.** **362/11**(57) **ABSTRACT**

A lighting apparatus comprises a light panel having a panel frame, and a plurality of LEDs or other light elements secured to the panel frame. A self-contained battery unit securably attaches to the outside of the panel frame. The light panel may have a dimmer switch, and may also be capable of receiving power from a source other than the self-contained battery unit. The lighting apparatus can be mounted to a camera or a stand through adapters. Diffusion lenses or color gels can be integrated with or detachable from the light panel. The lighting apparatus may conveniently be provided in the form of a kit, with one or more of a light panel, self-contained battery unit, compact stand, connecting cable(s), adapter(s), lenses or color gels, and so on, provided in a single package.





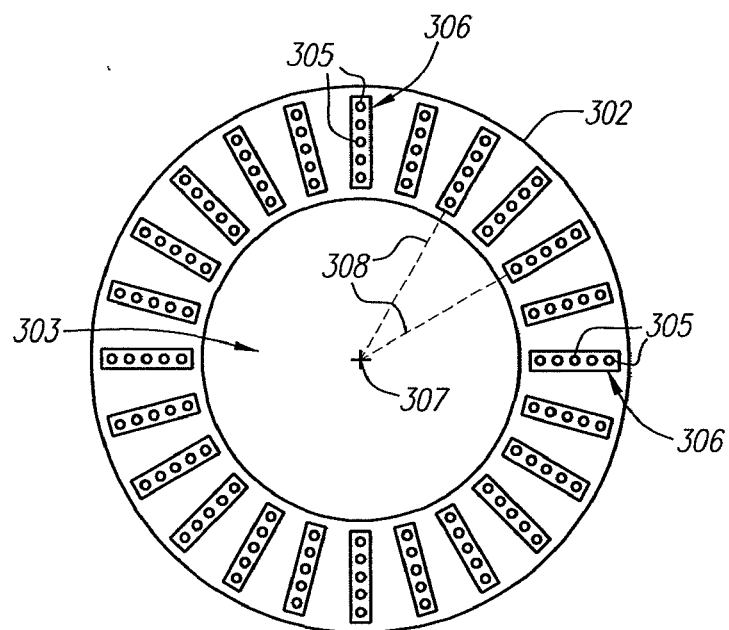


FIG. 4

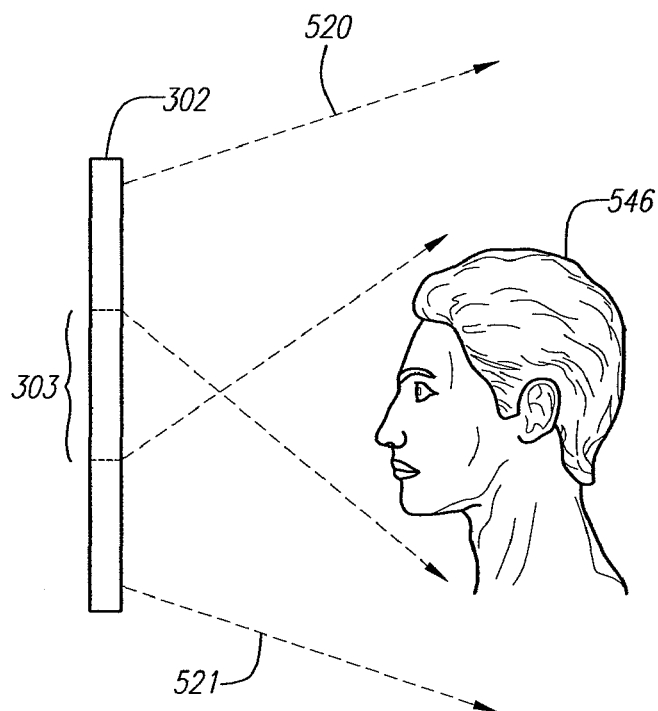


FIG. 5

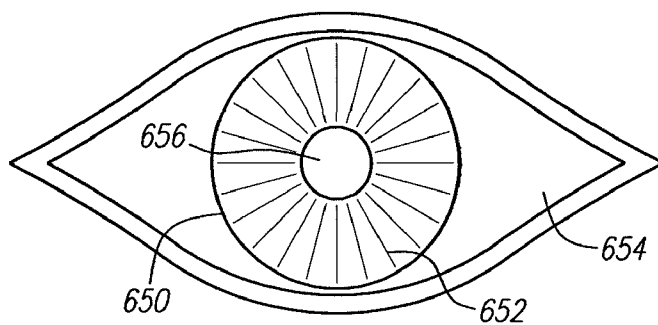


FIG. 6

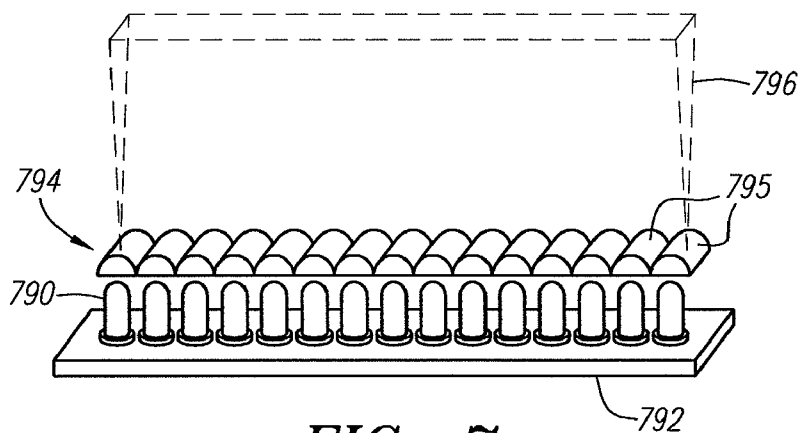


FIG. 7

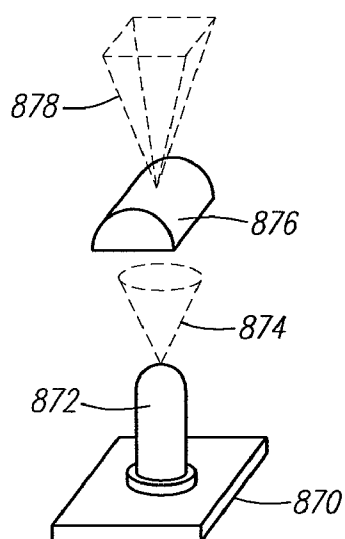


FIG. 8

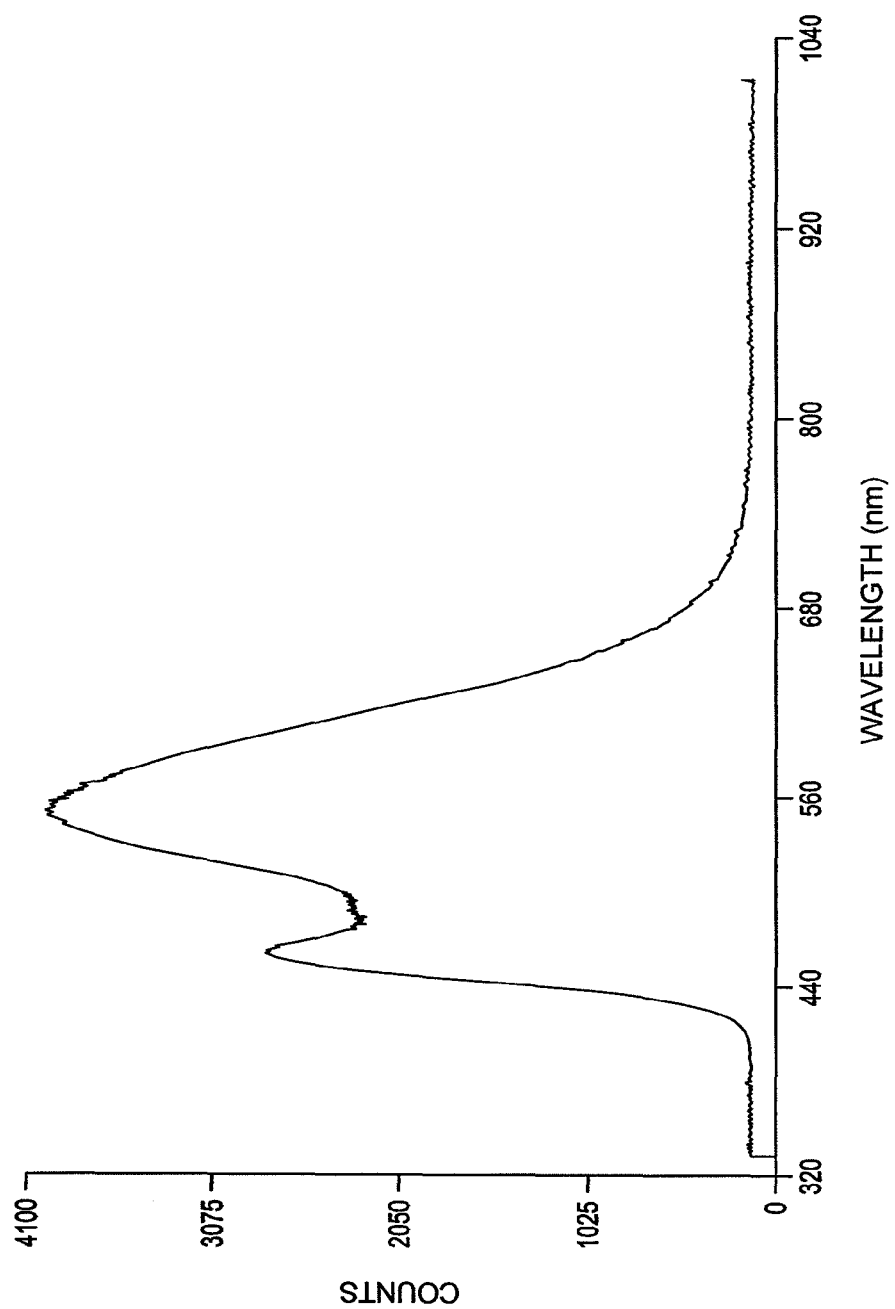


FIG. 9

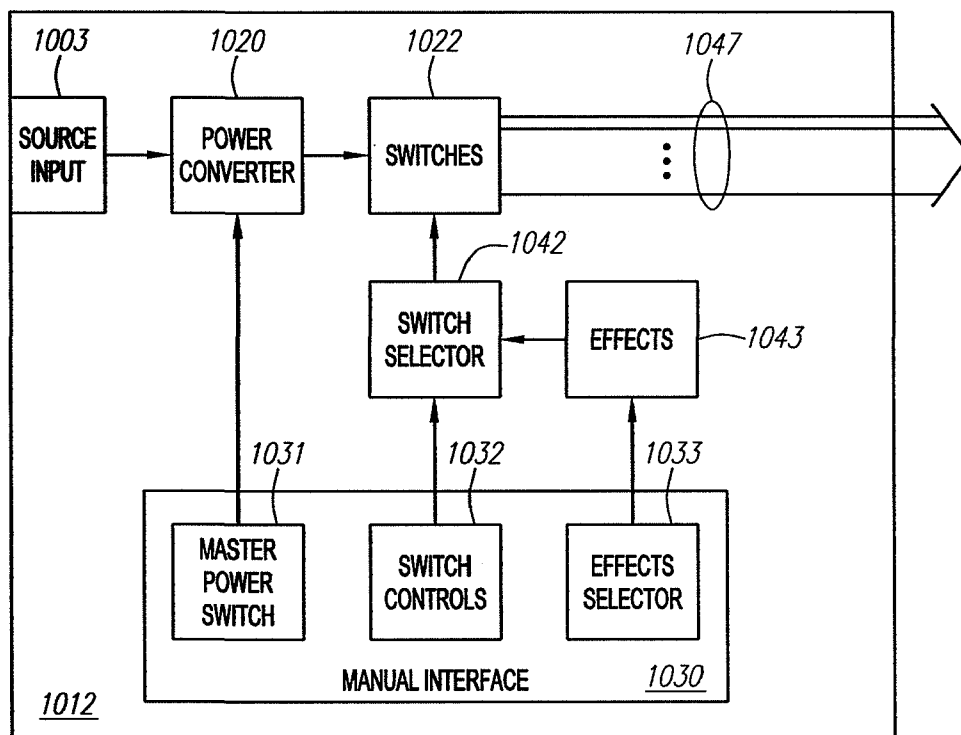


FIG. 10A

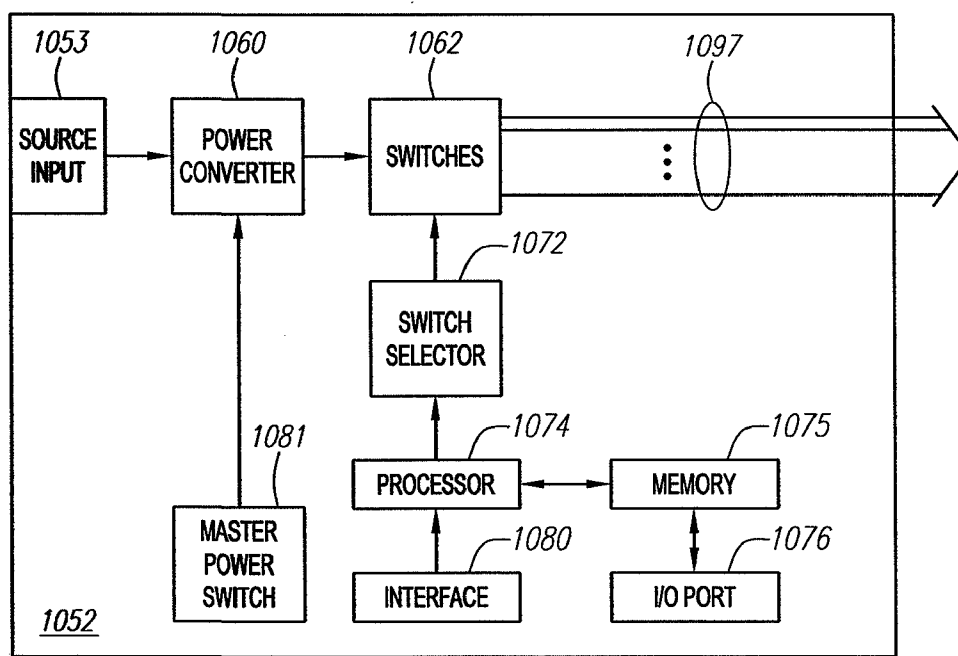


FIG. 10B

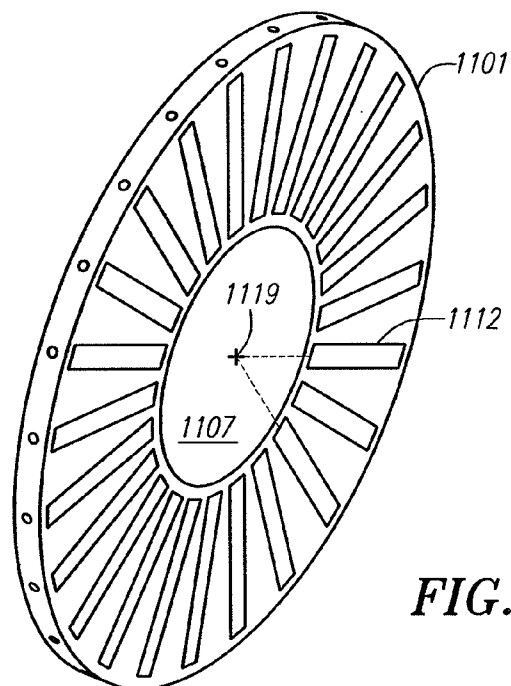


FIG. 11

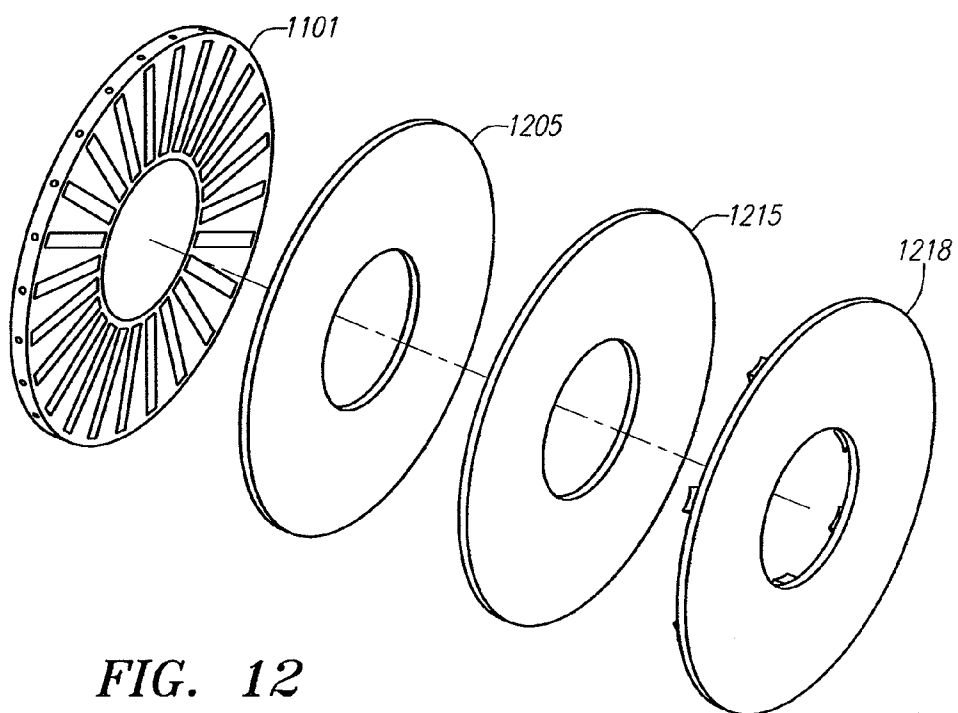


FIG. 12

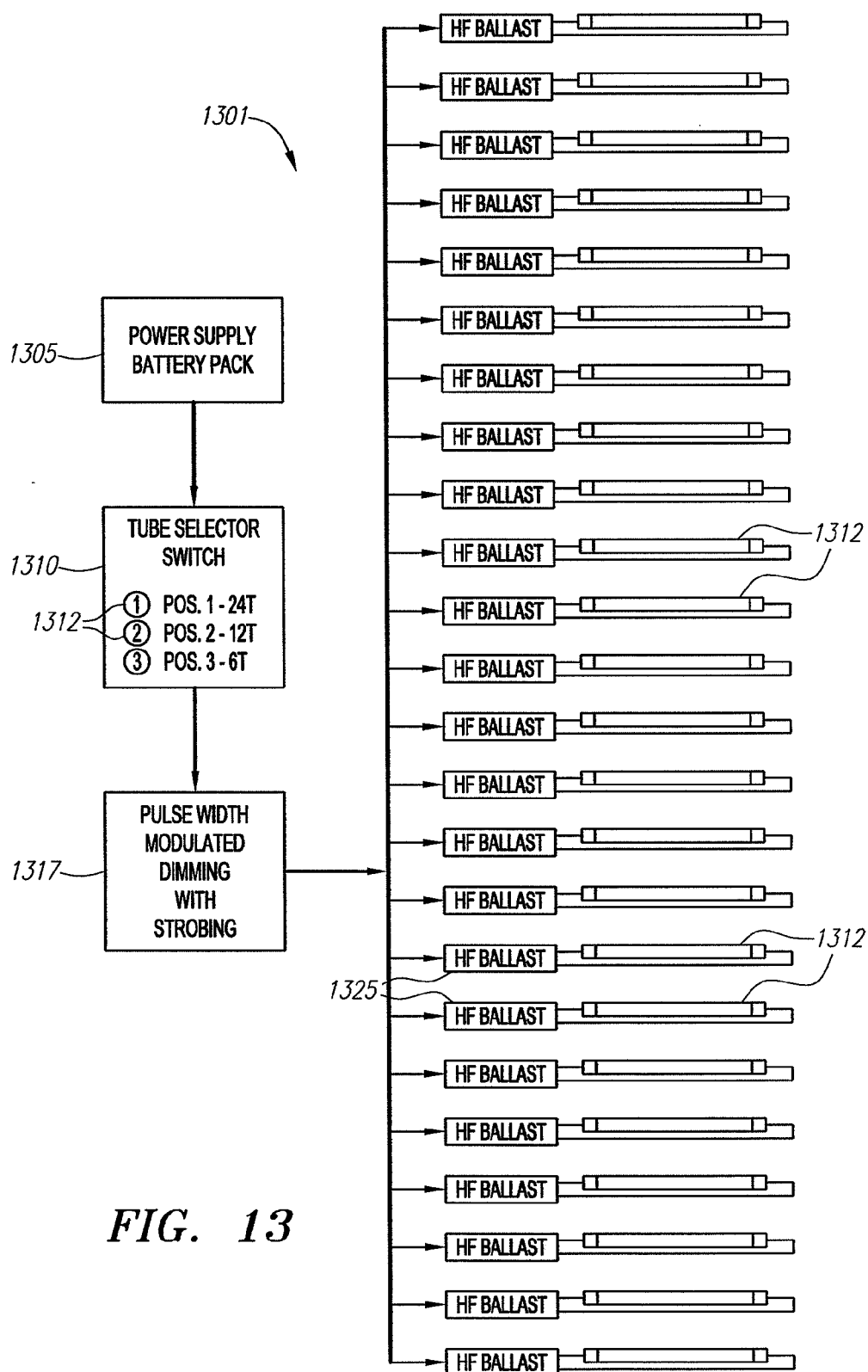


FIG. 13

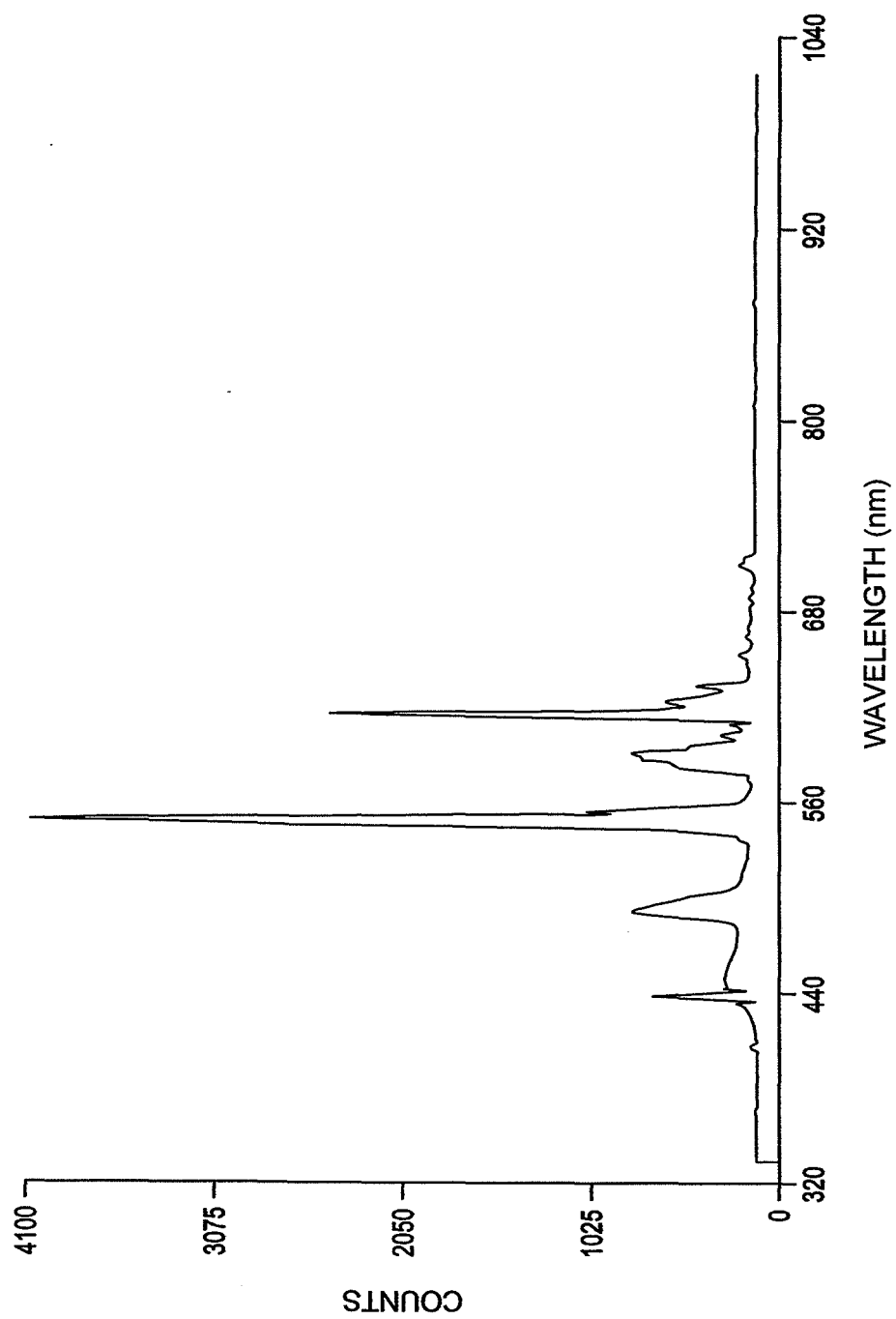


FIG. 14

FIG. 15A

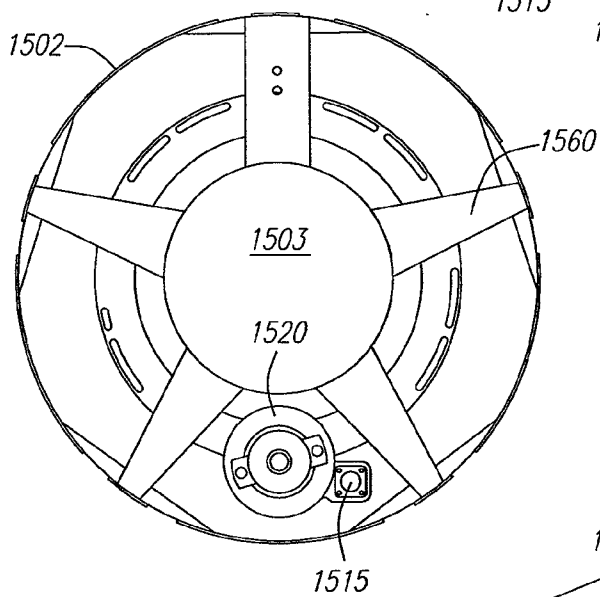
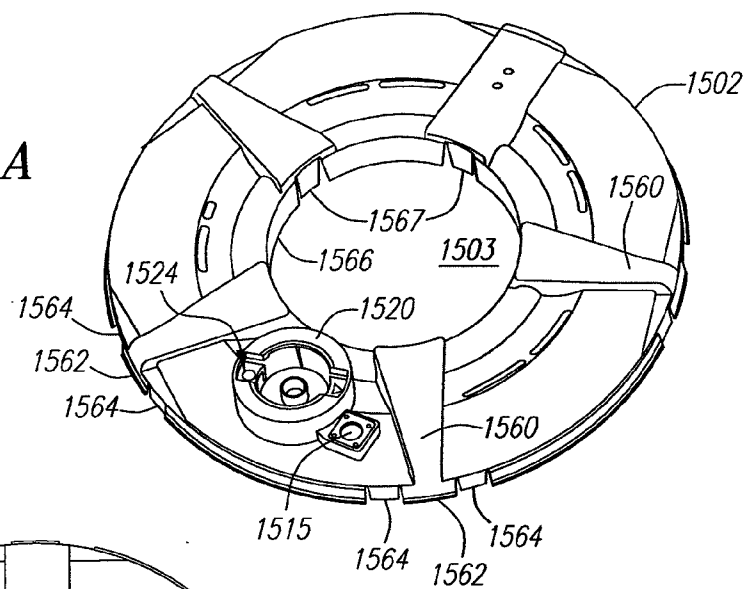
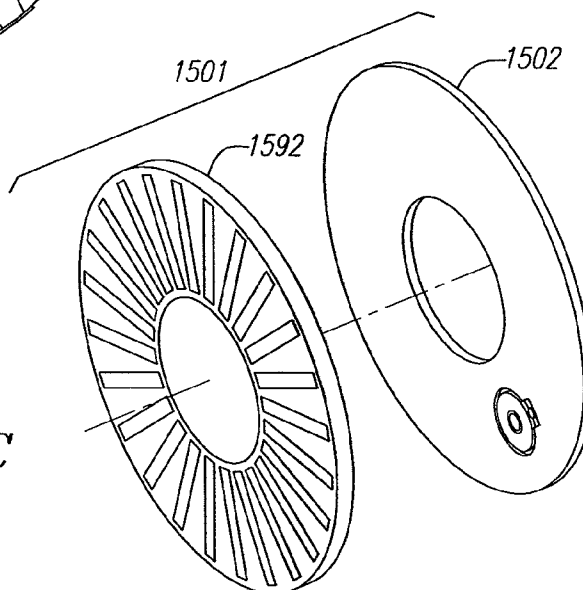


FIG. 15B

FIG. 15C



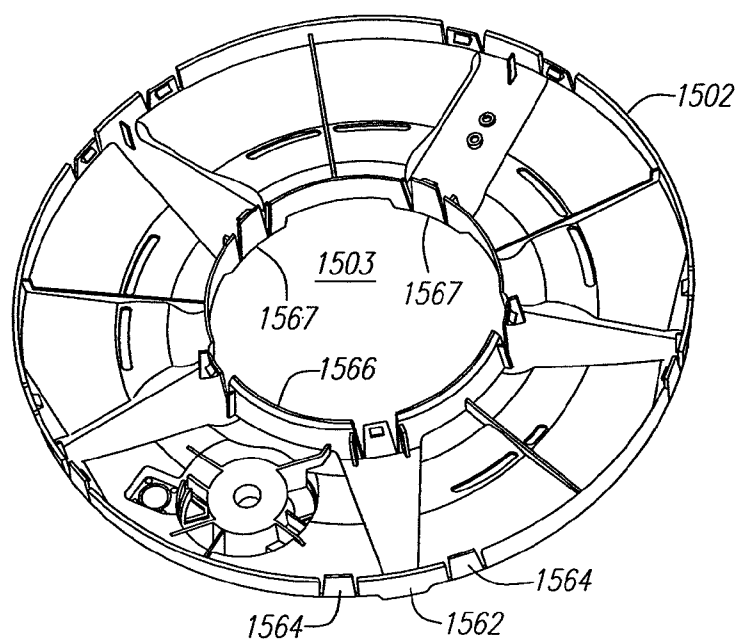


FIG. 16A

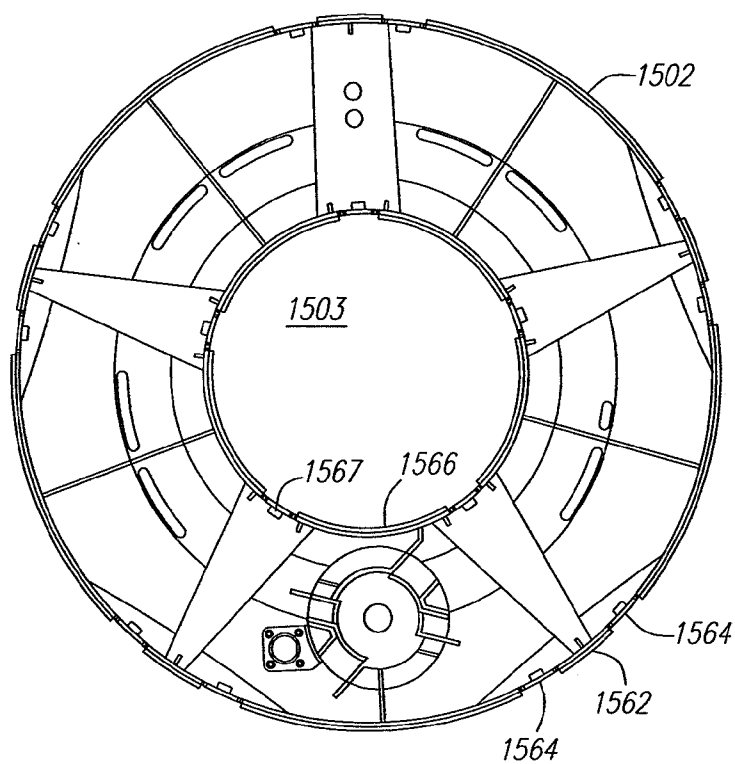


FIG. 16B

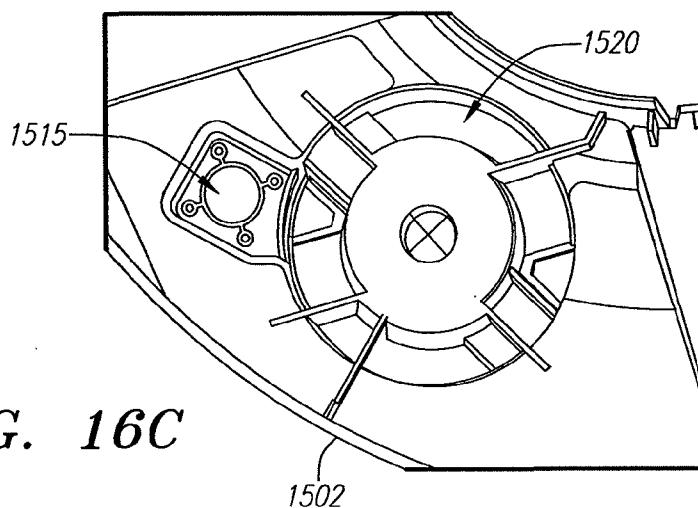


FIG. 16C

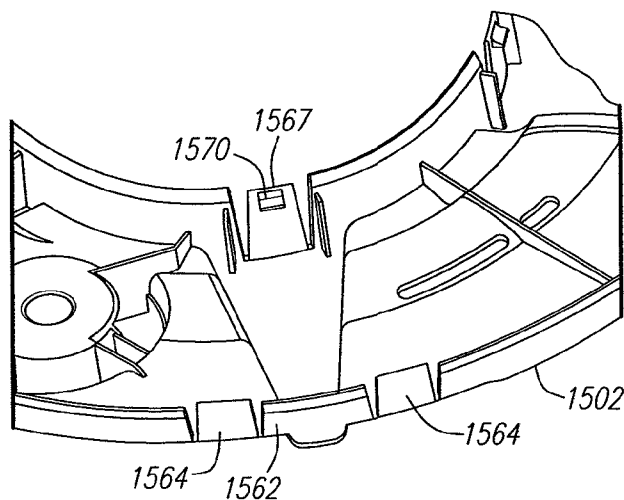


FIG. 16D

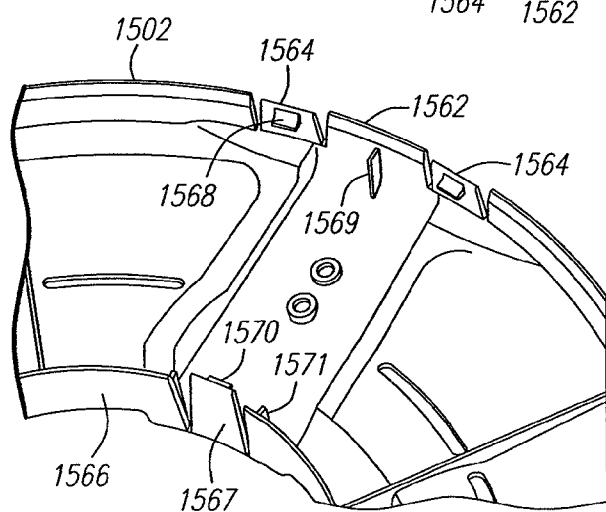


FIG. 16E

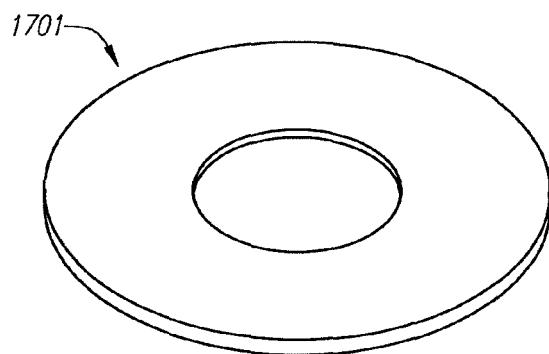


FIG. 17

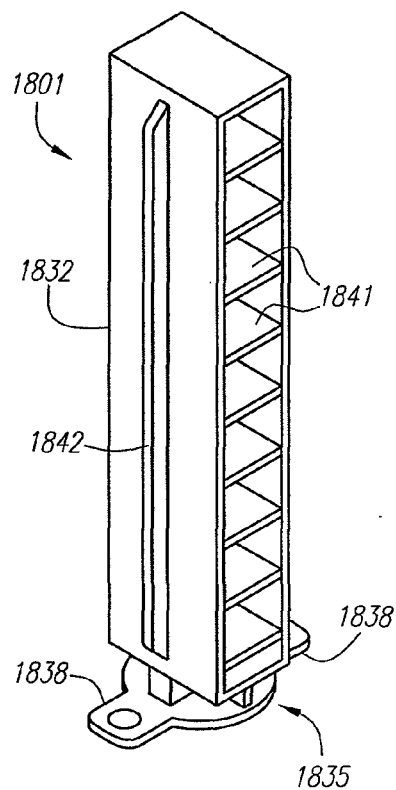


FIG. 18

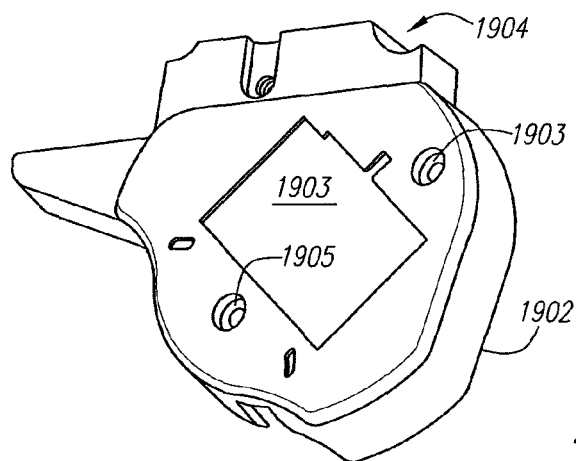


FIG. 19A

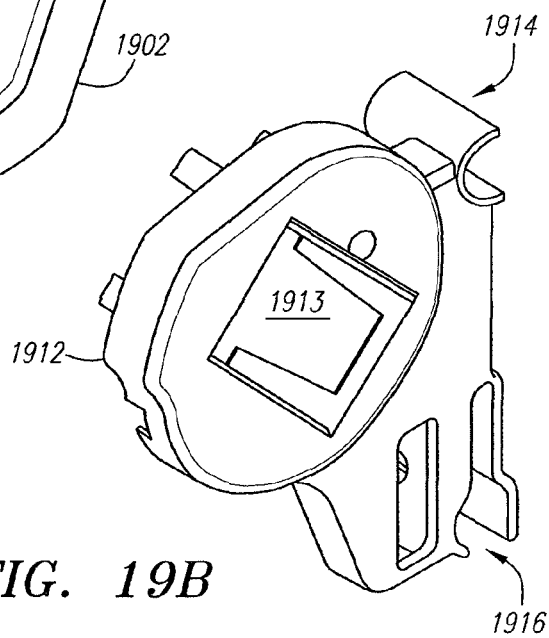


FIG. 19B

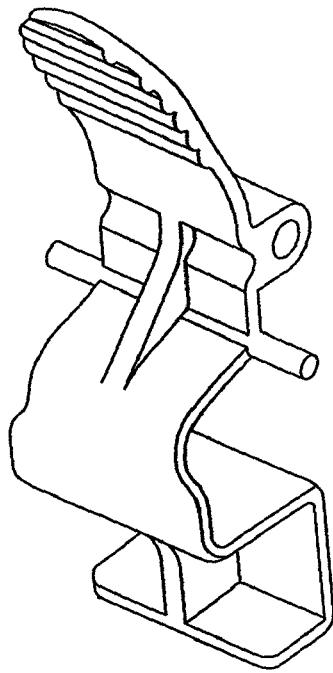


FIG. 20

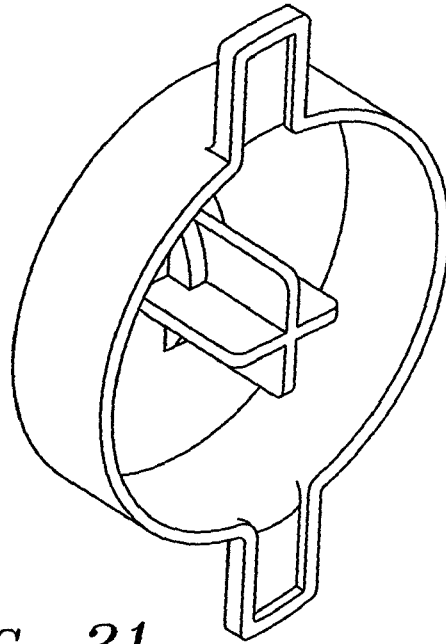


FIG. 21

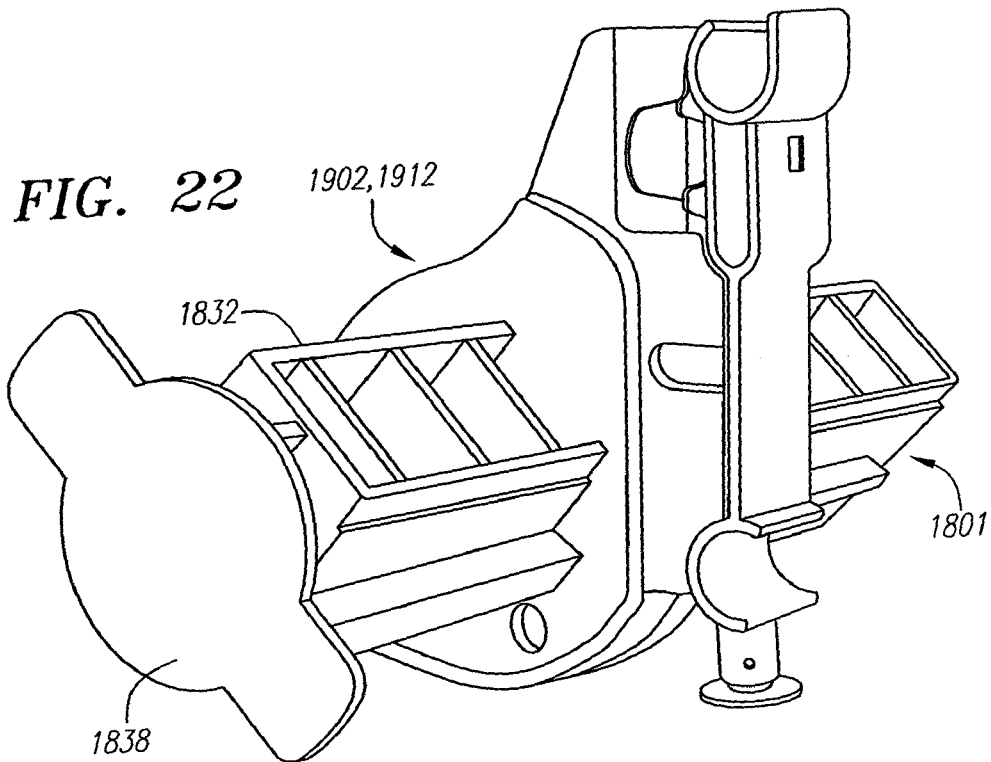
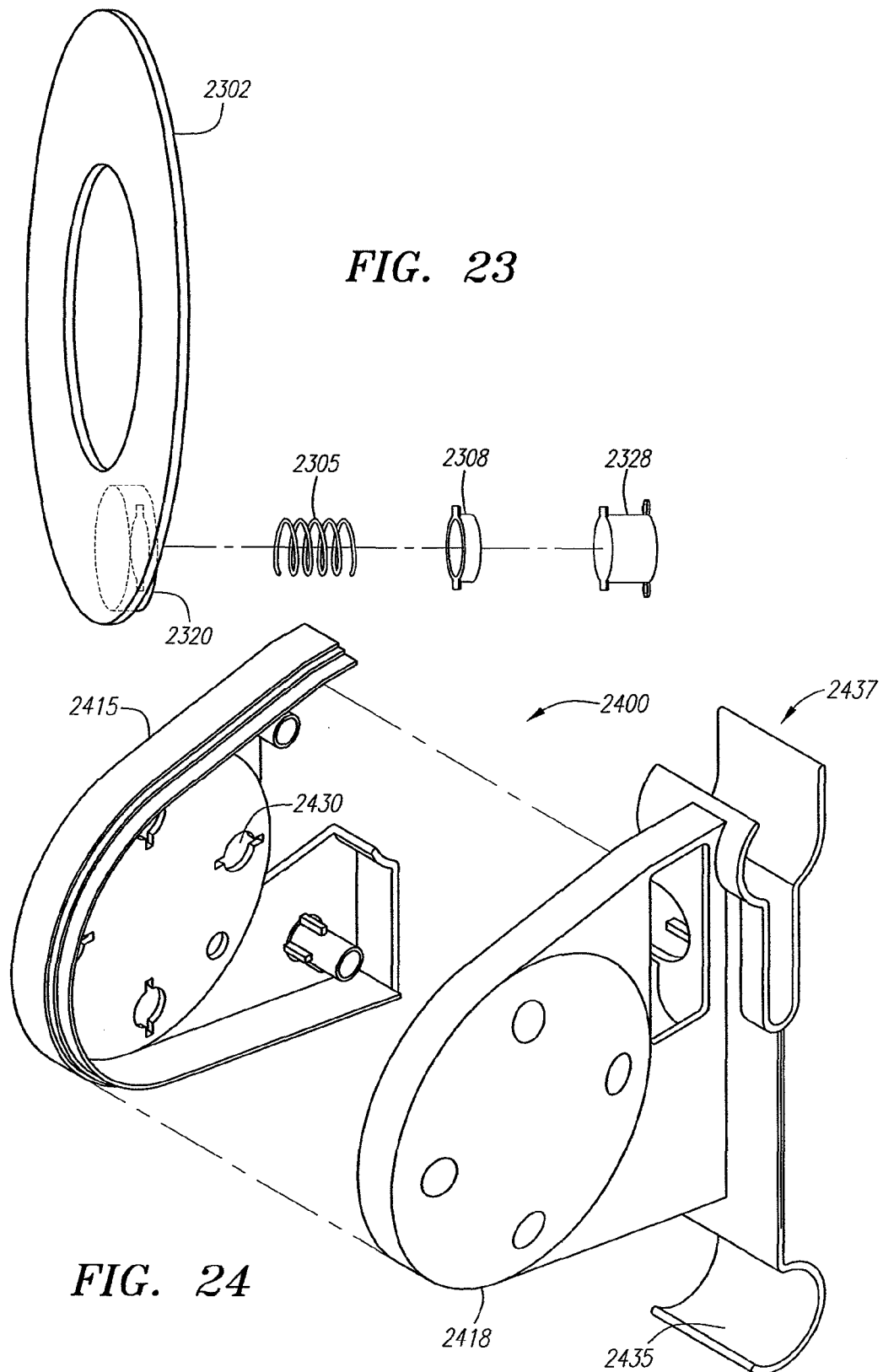


FIG. 22



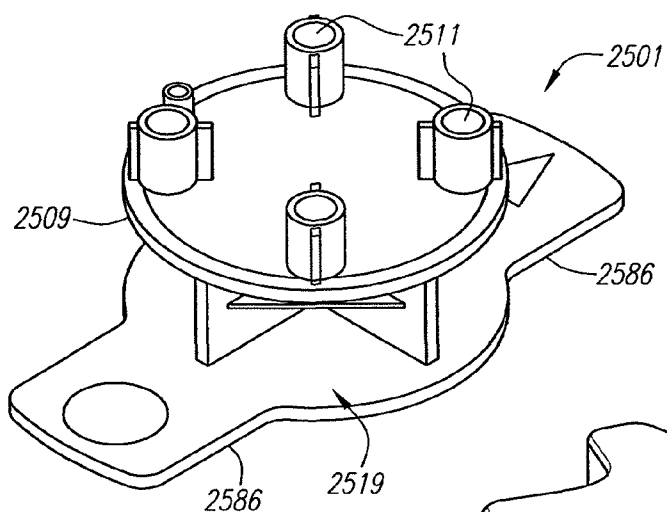


FIG. 25

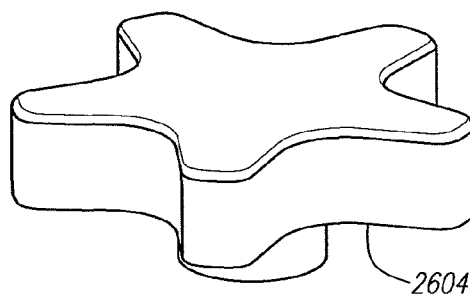


FIG. 26

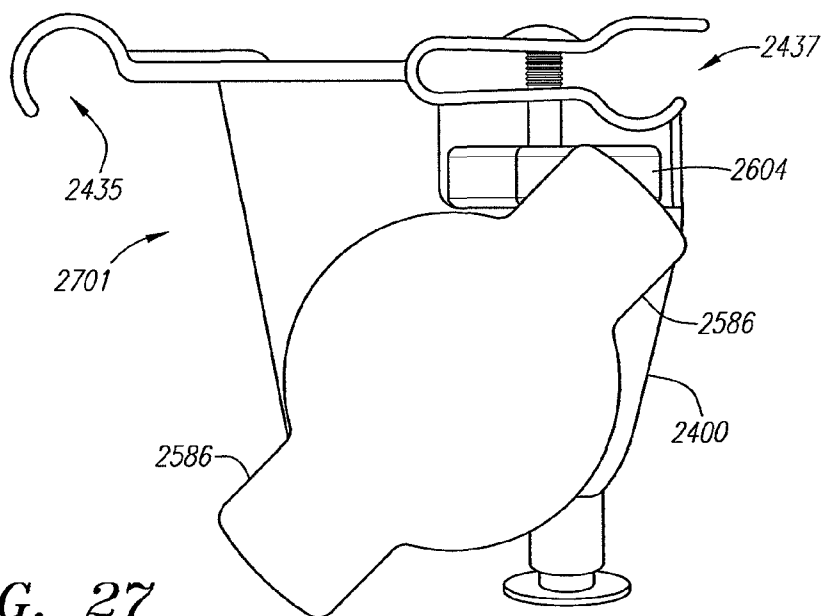


FIG. 27

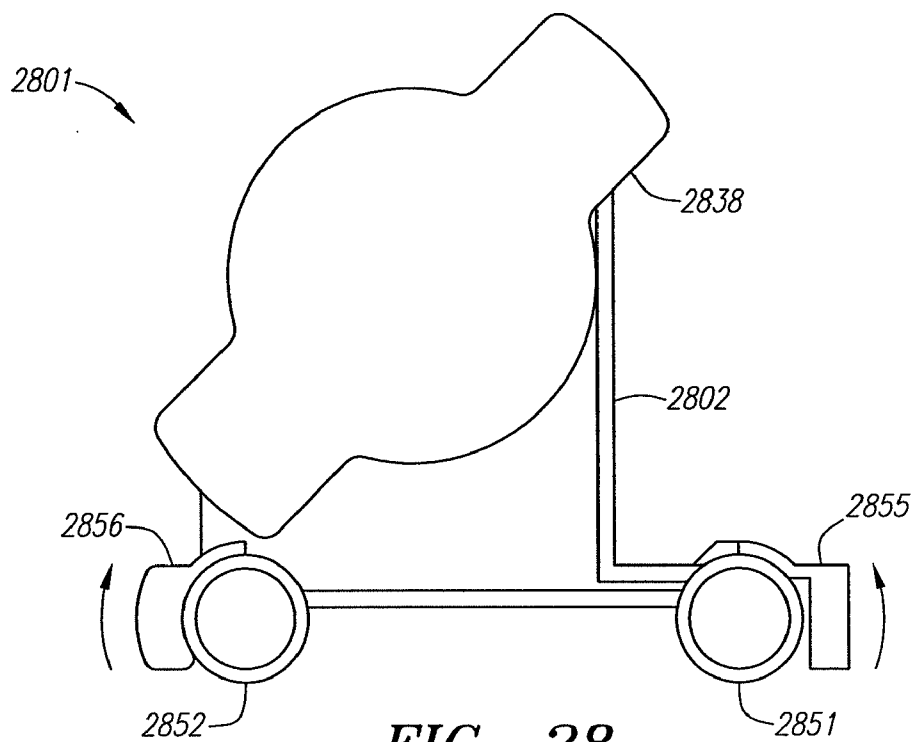


FIG. 28

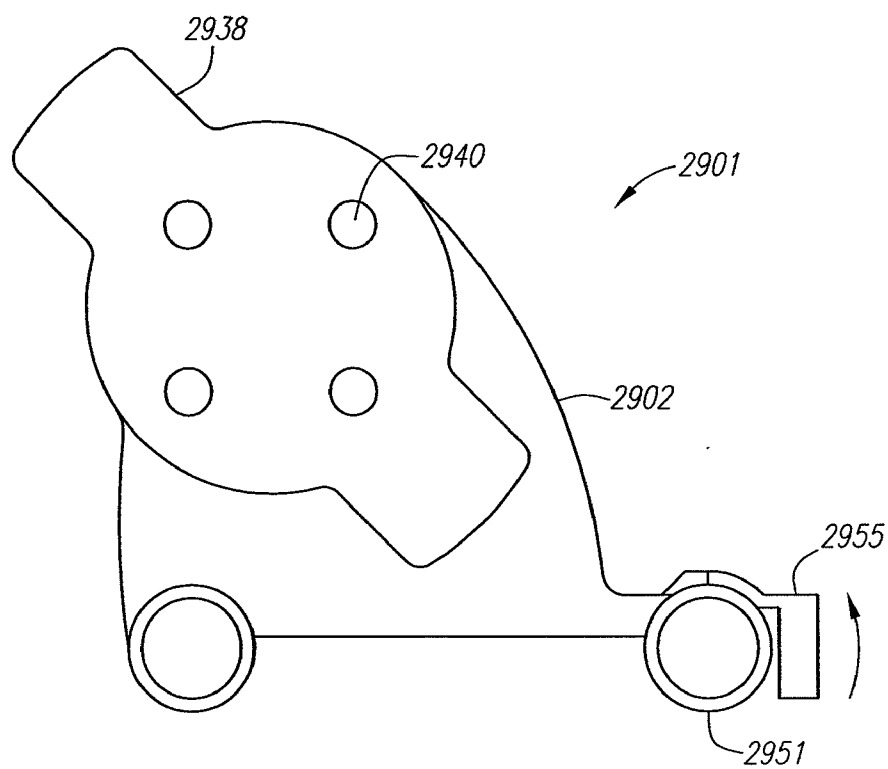


FIG. 29

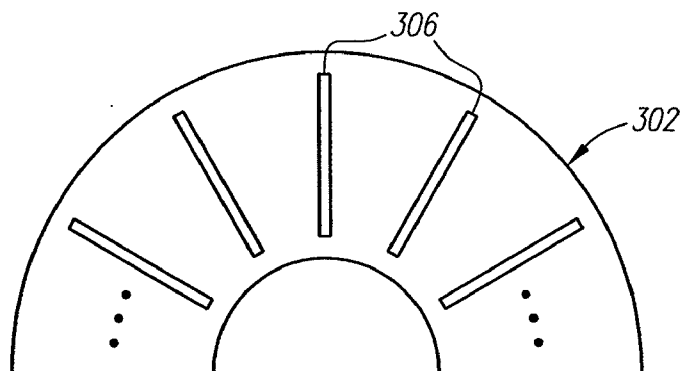


FIG. 30A

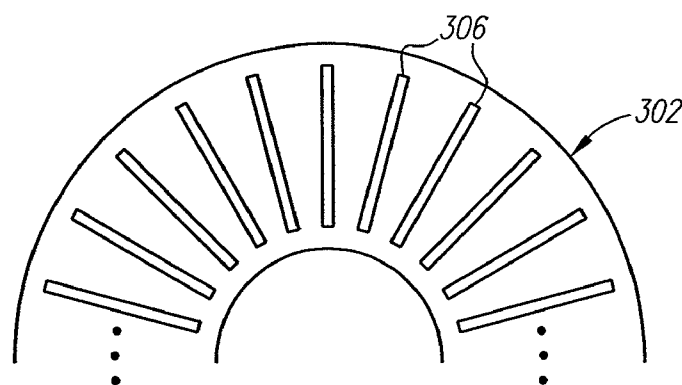


FIG. 30B

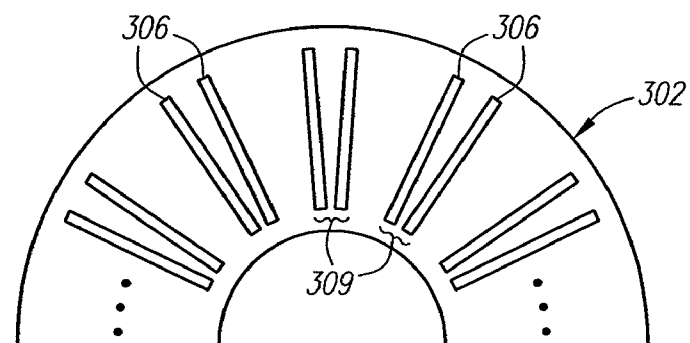


FIG. 30C

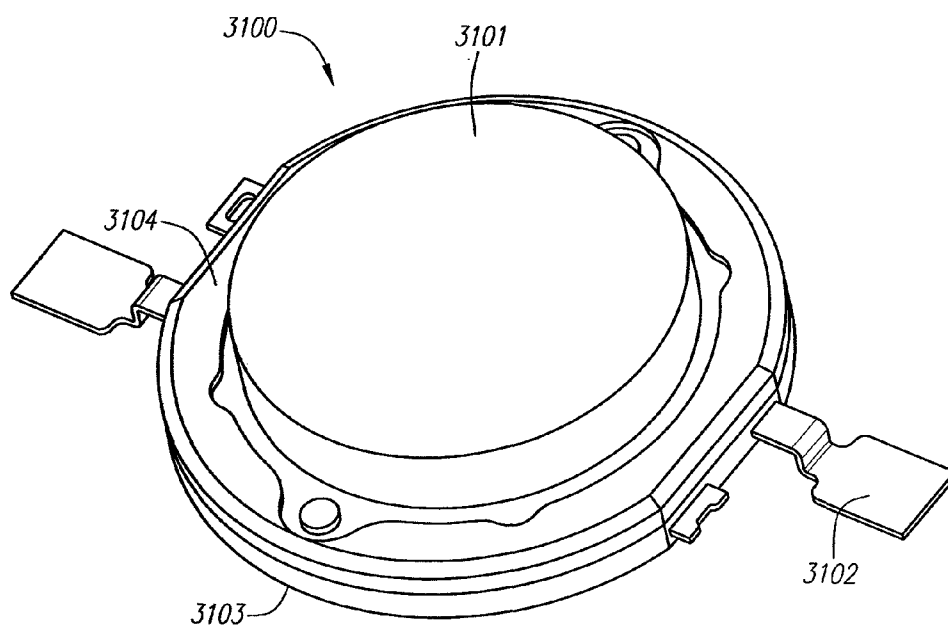


FIG. 31

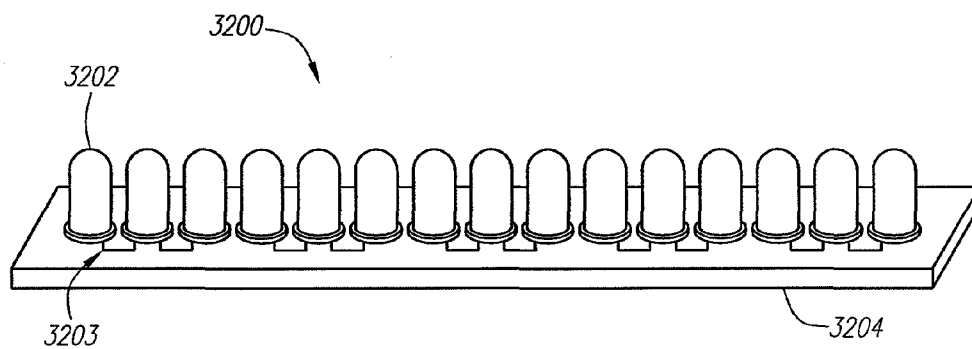


FIG. 32

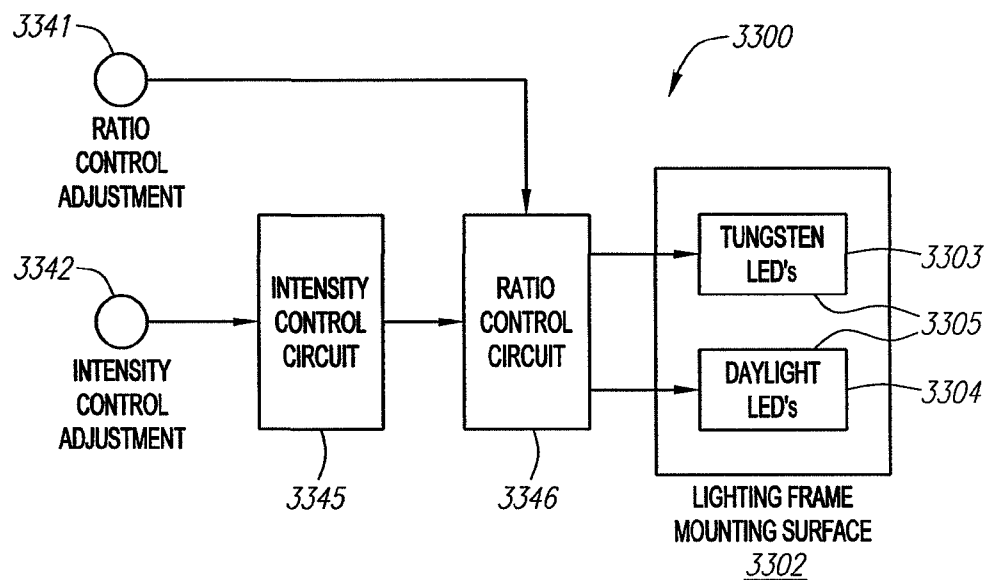


FIG. 33

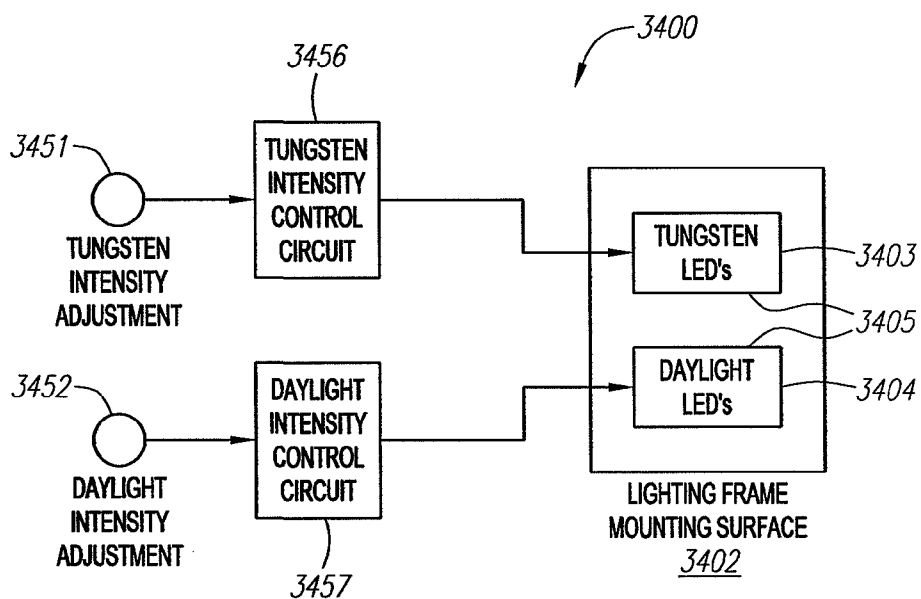


FIG. 34

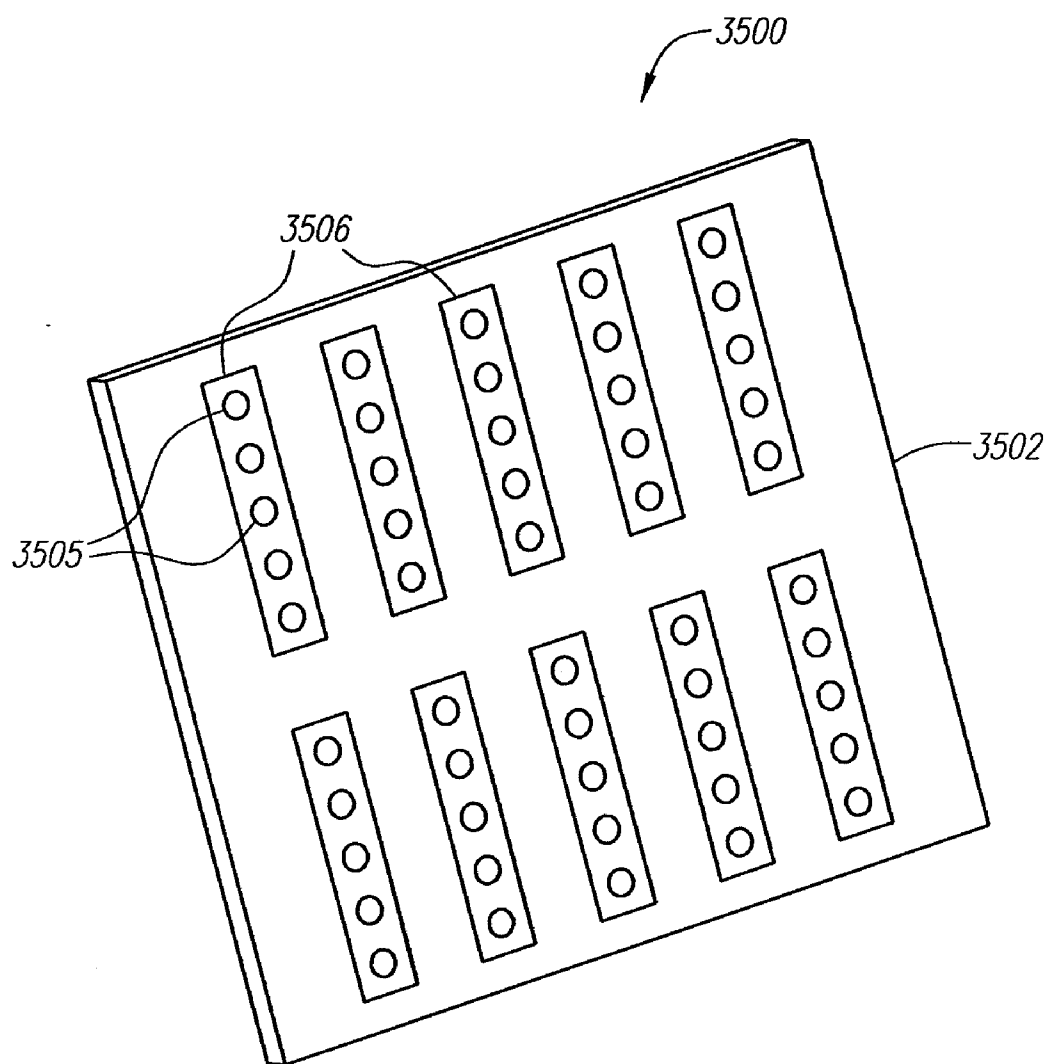


FIG. 35

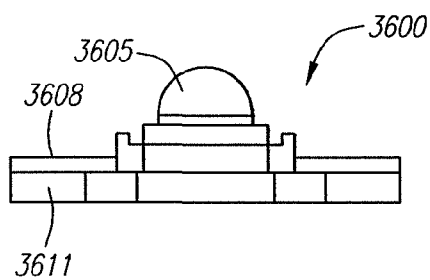


FIG. 36A

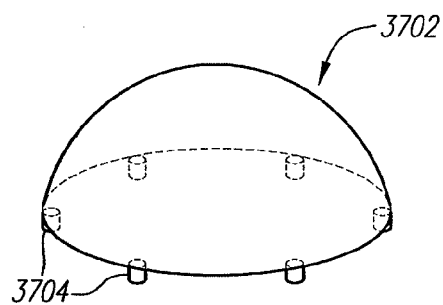


FIG. 37A

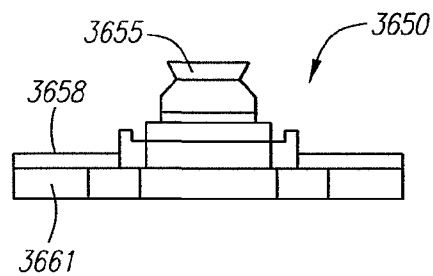


FIG. 36B

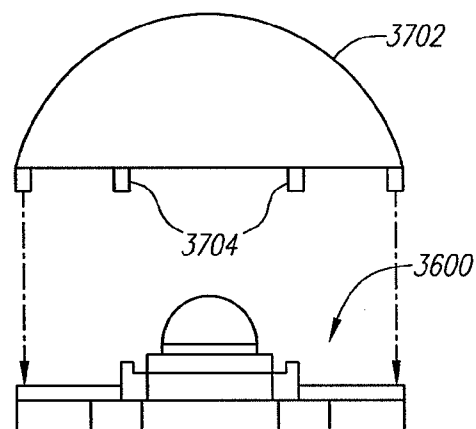


FIG. 37B

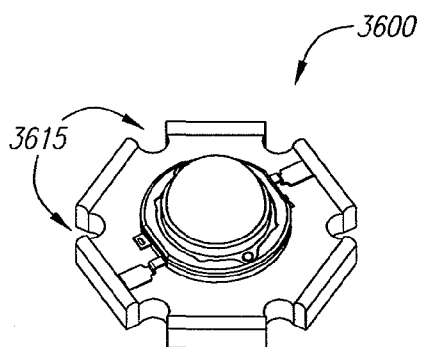


FIG. 36C

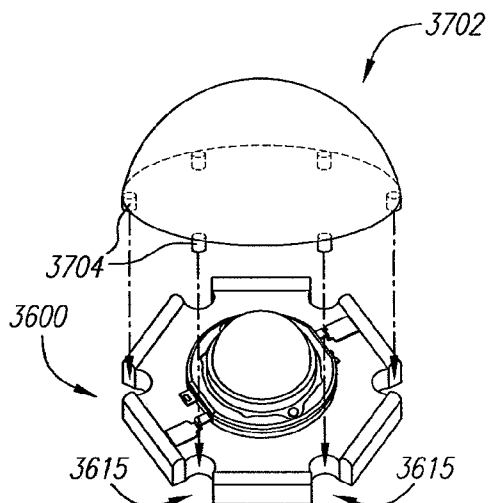


FIG. 37C

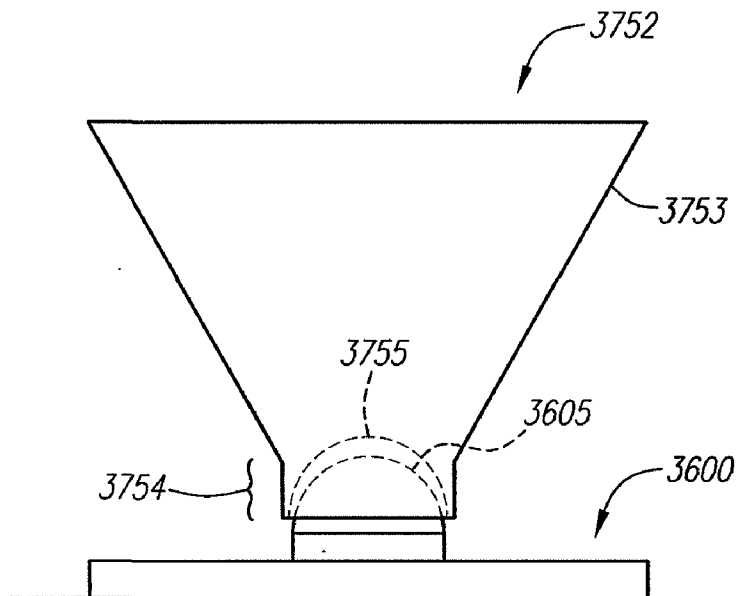


FIG. 37D

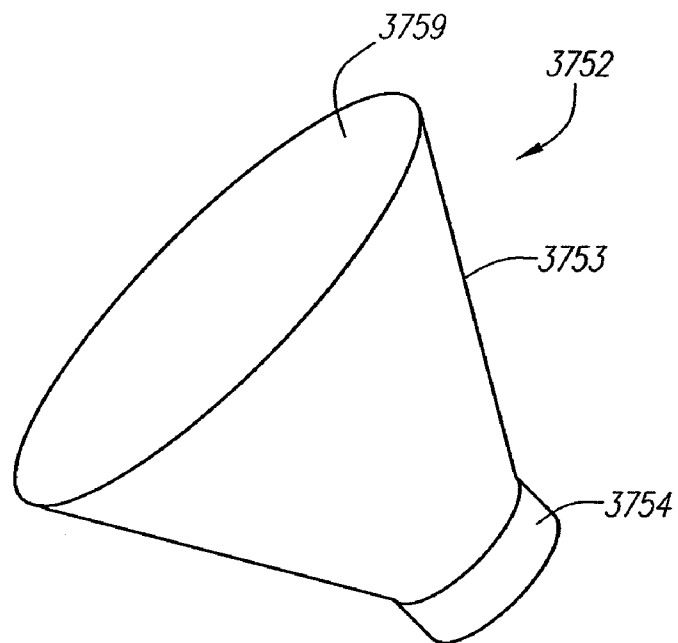


FIG. 37E

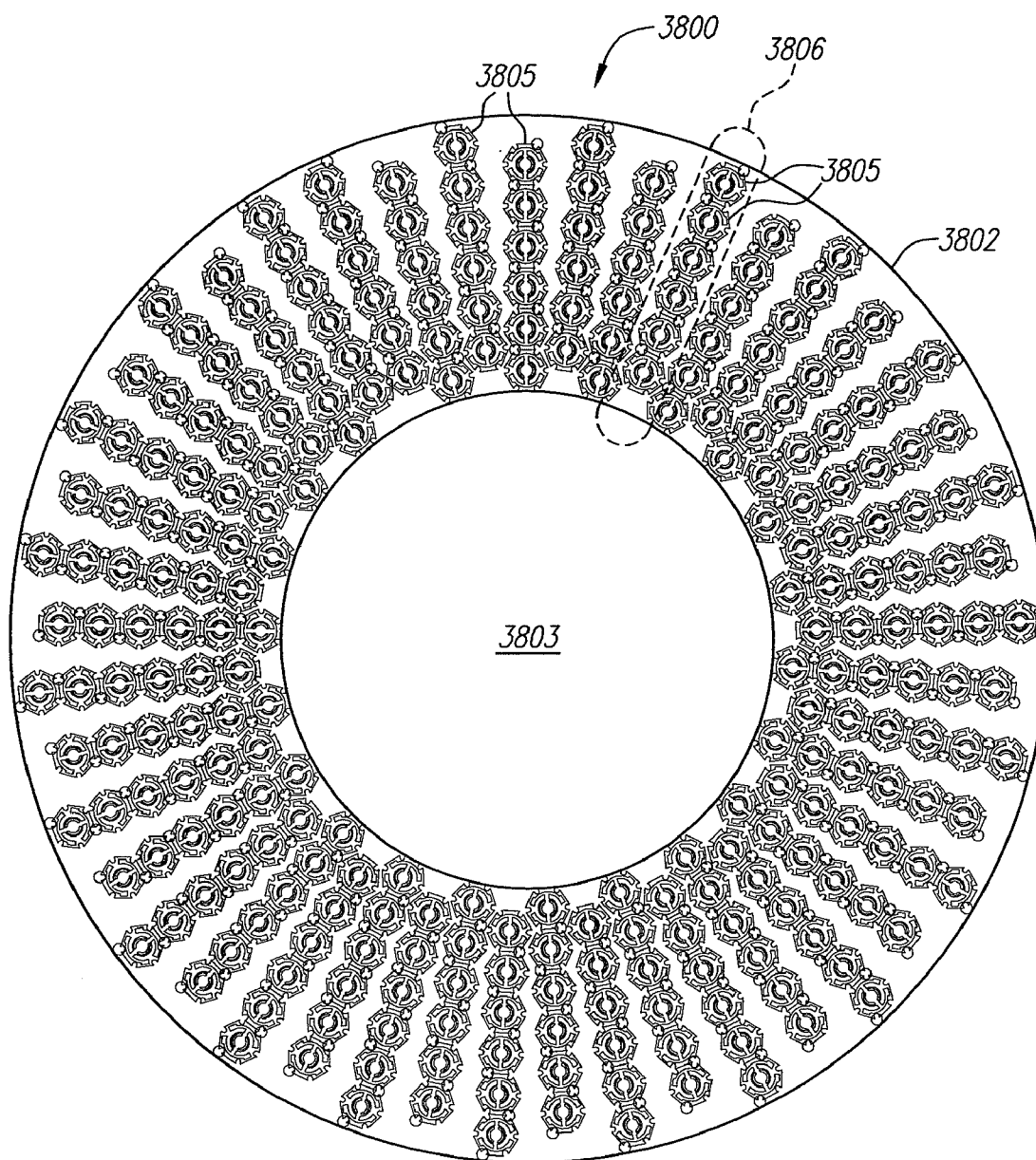
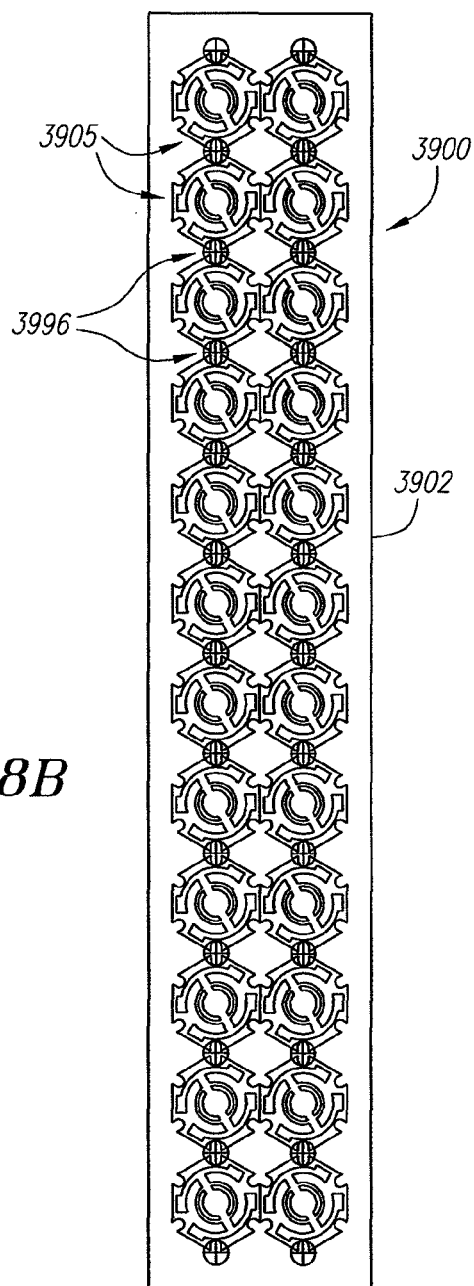
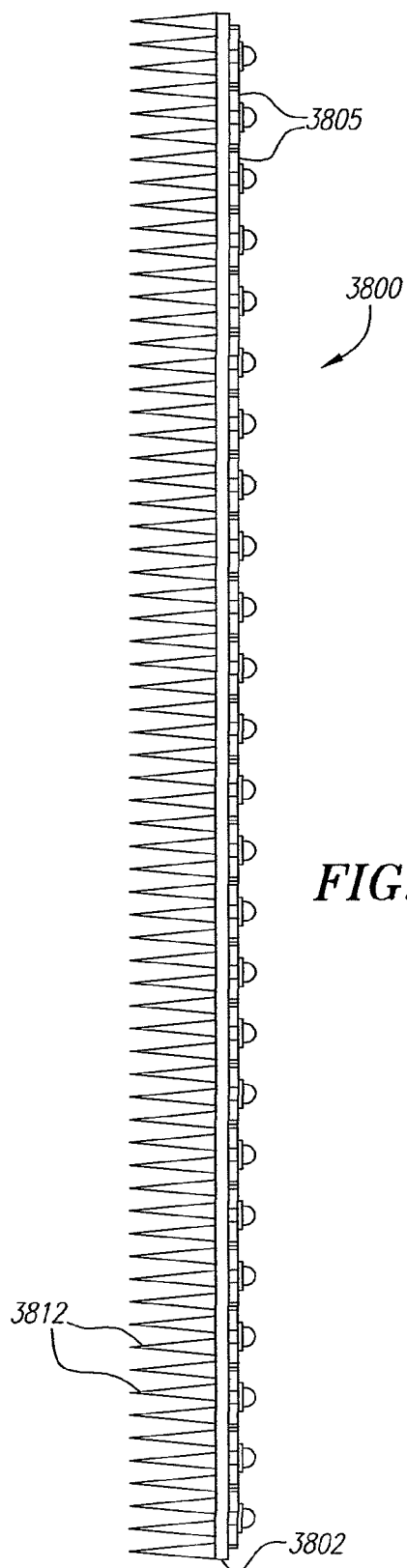


FIG. 38A



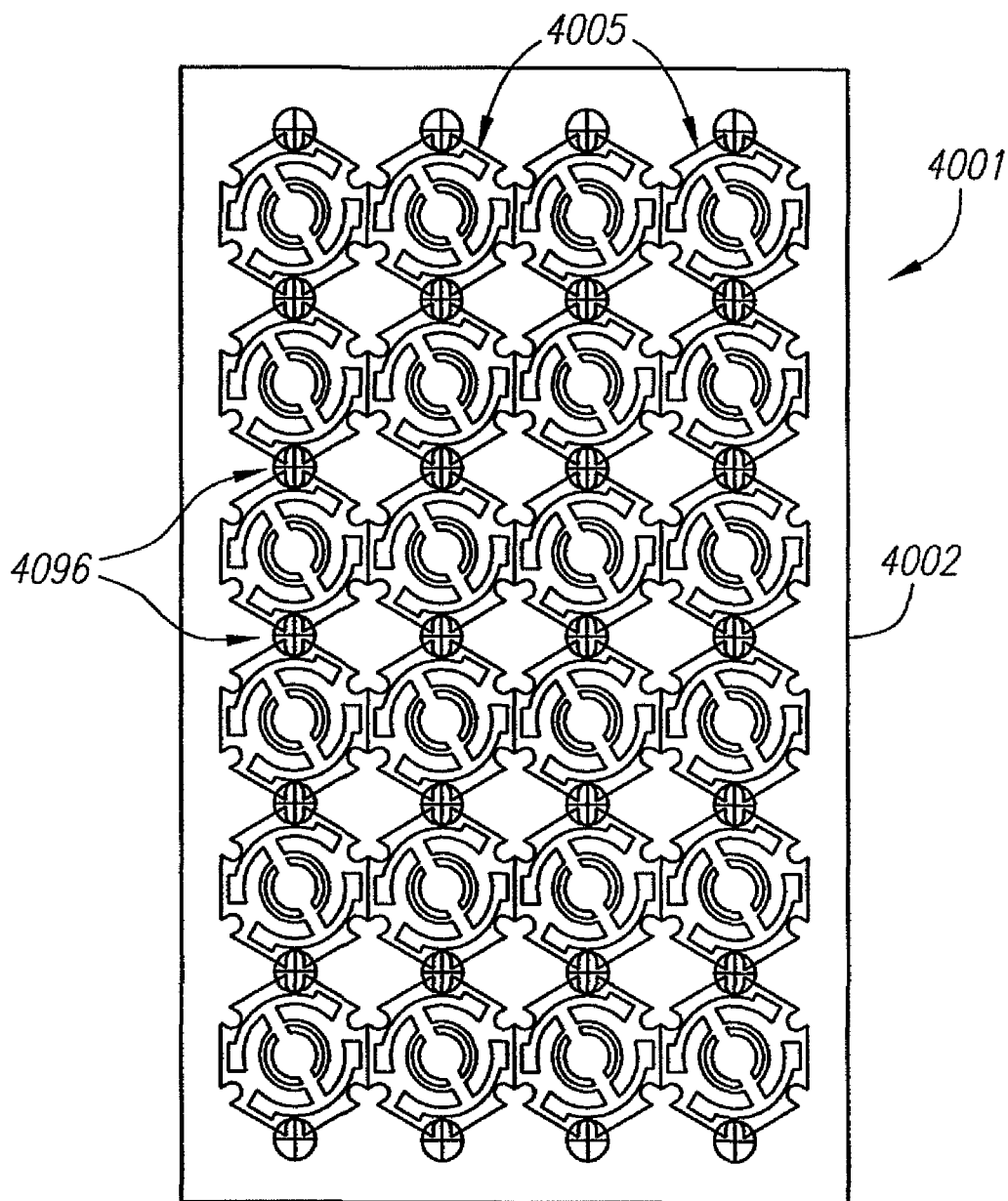
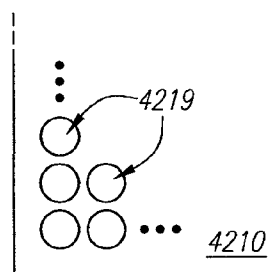
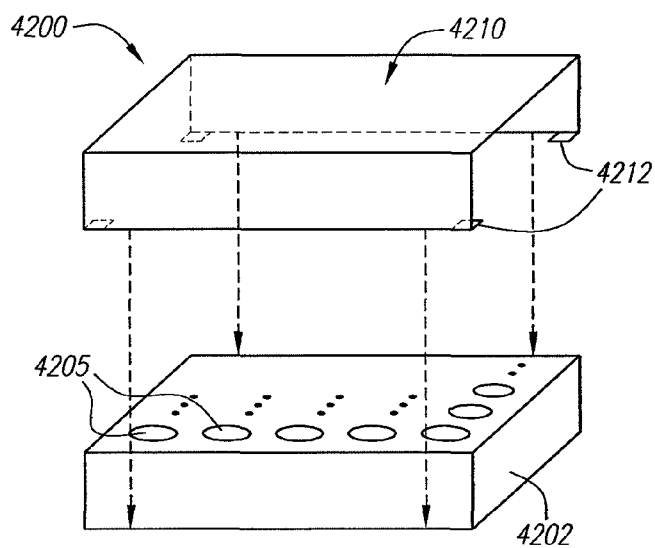
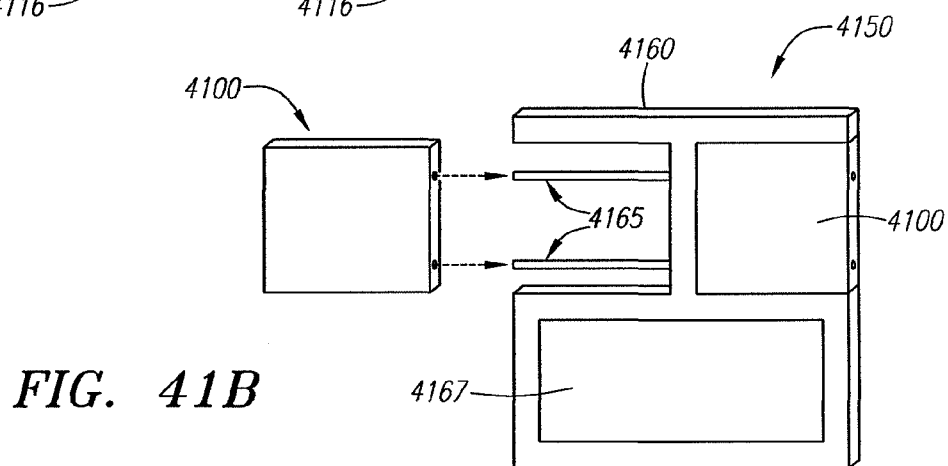
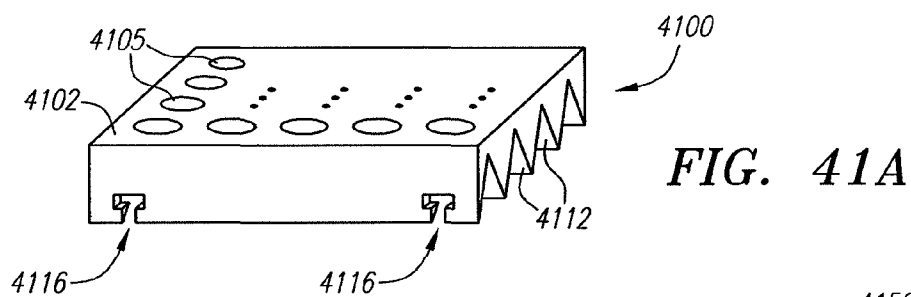


FIG. 40



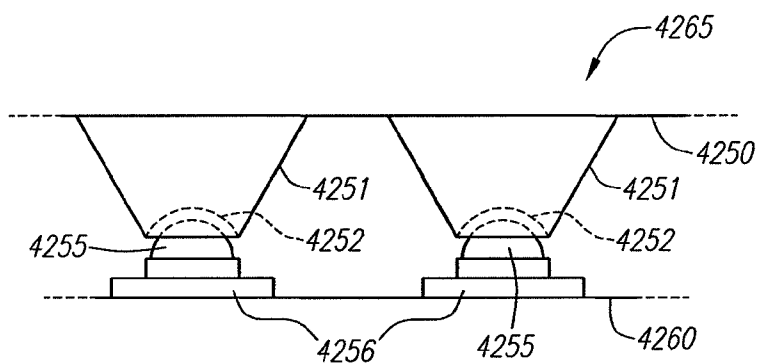


FIG. 42C

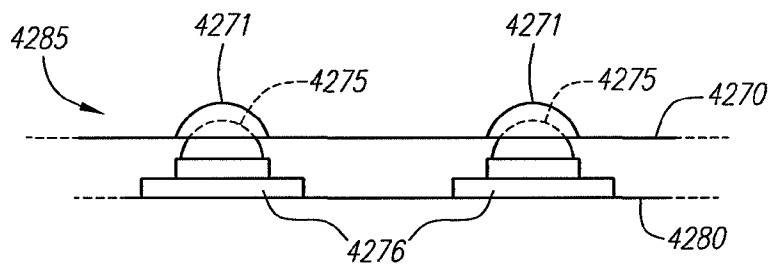


FIG. 42D

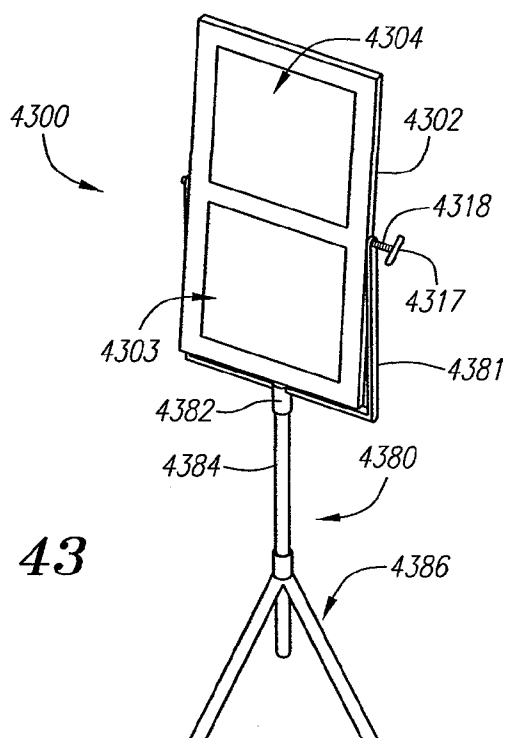


FIG. 43

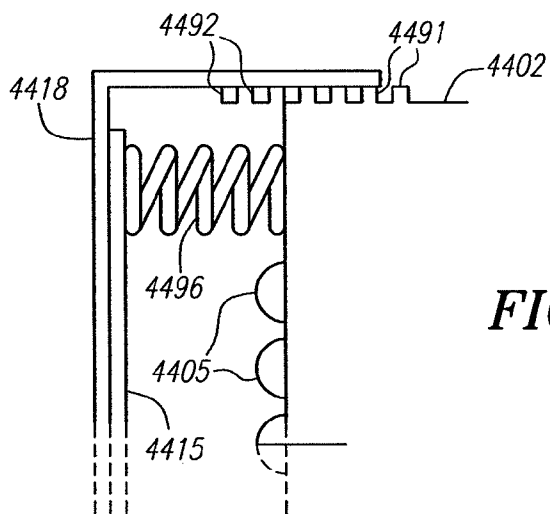


FIG. 44

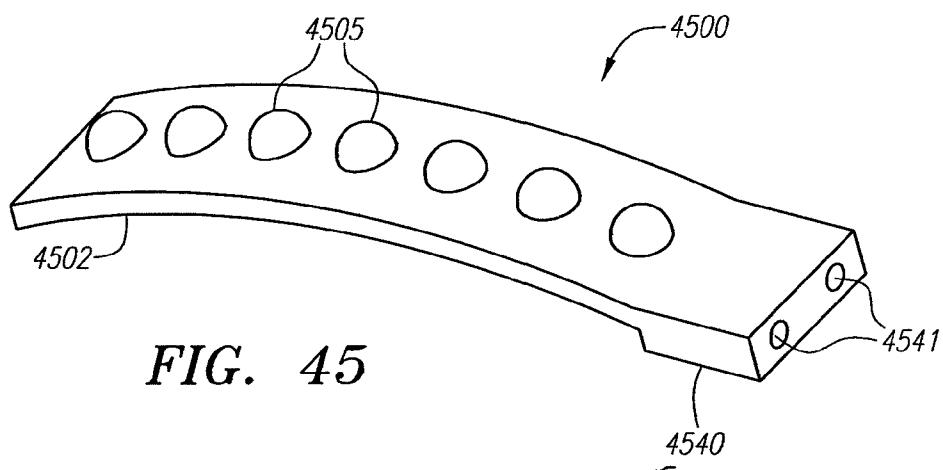


FIG. 45

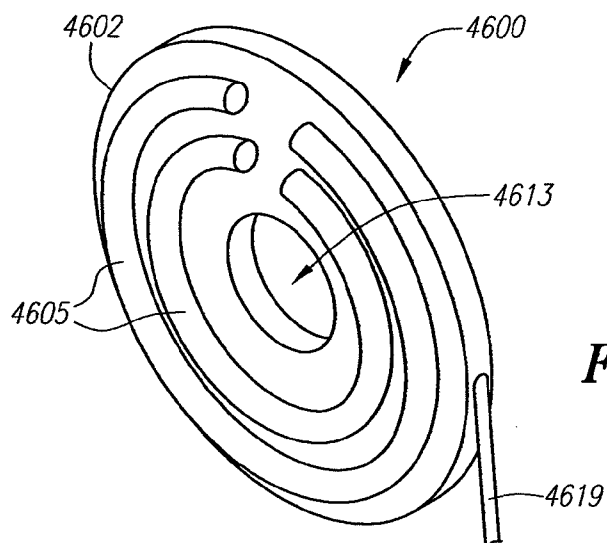


FIG. 46

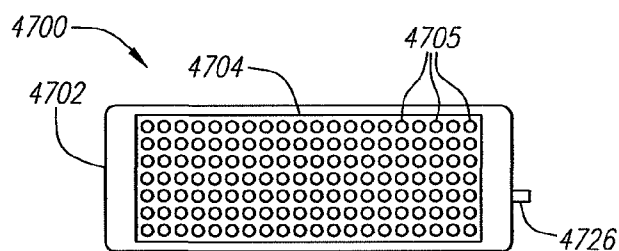


FIG. 47A

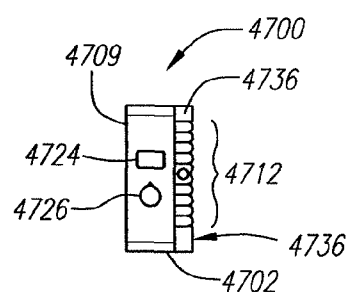


FIG. 47B

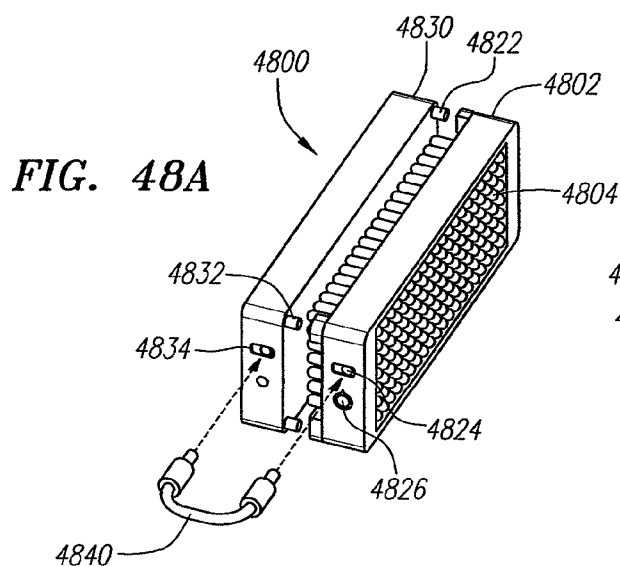


FIG. 48A

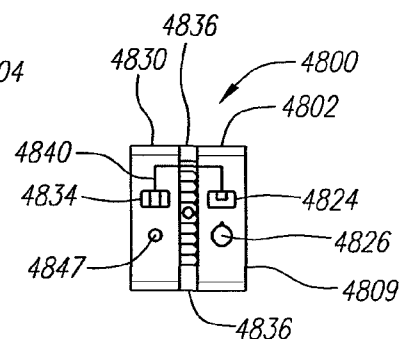


FIG. 48B

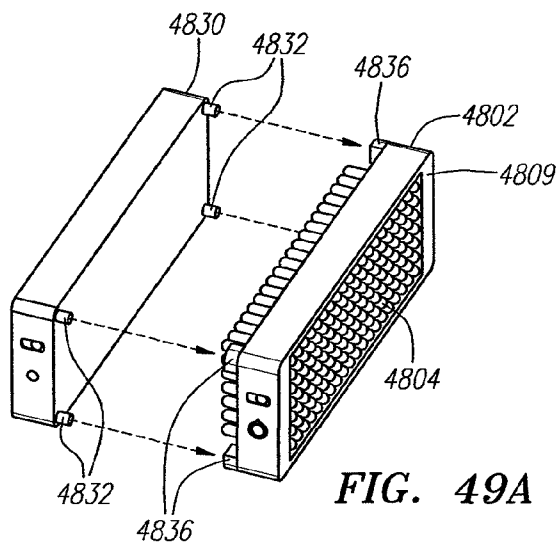


FIG. 49A

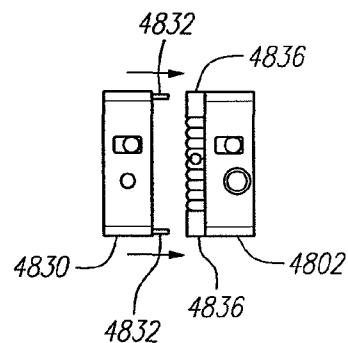


FIG. 49B

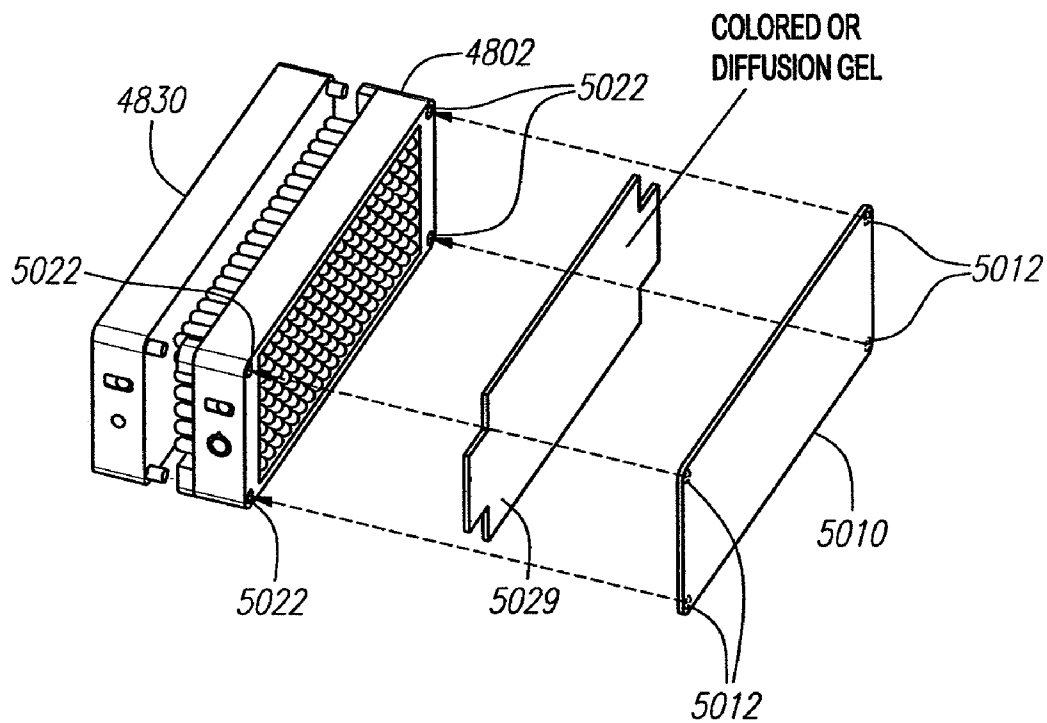


FIG. 50A

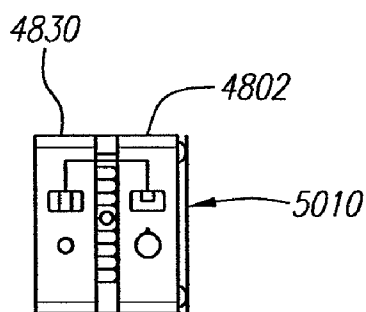


FIG. 50B

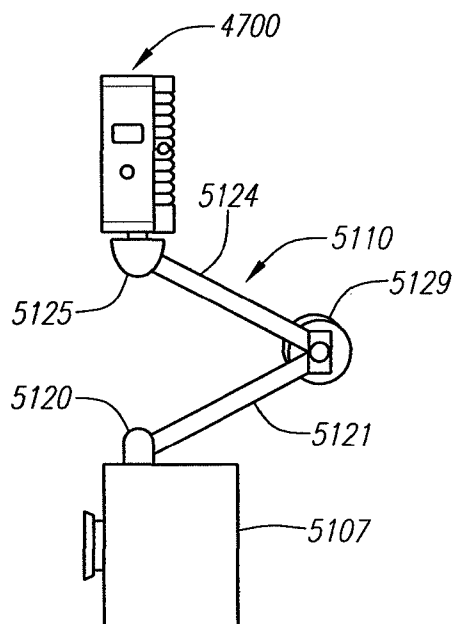


FIG. 51

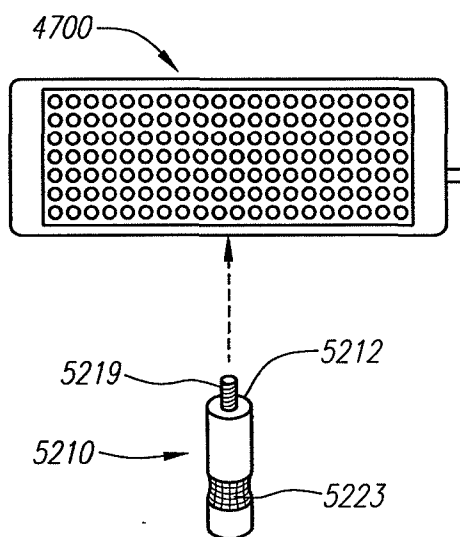


FIG. 52A

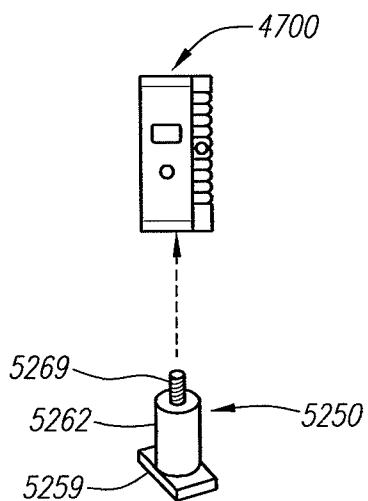


FIG. 52B

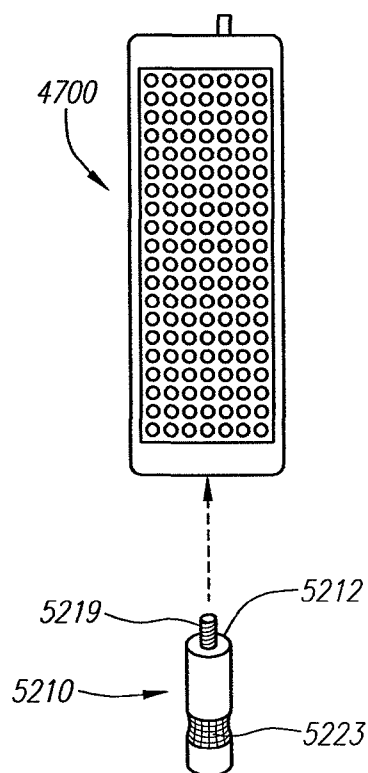


FIG. 52C

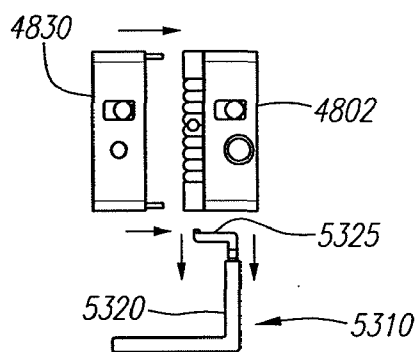


FIG. 53A

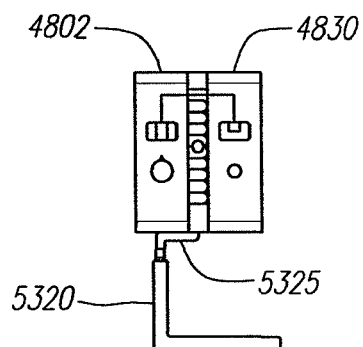


FIG. 53B

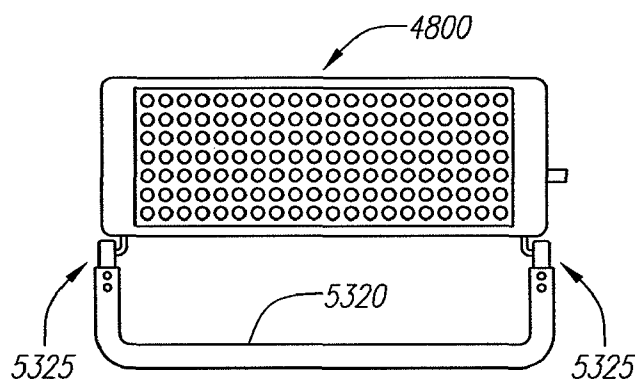


FIG. 53C

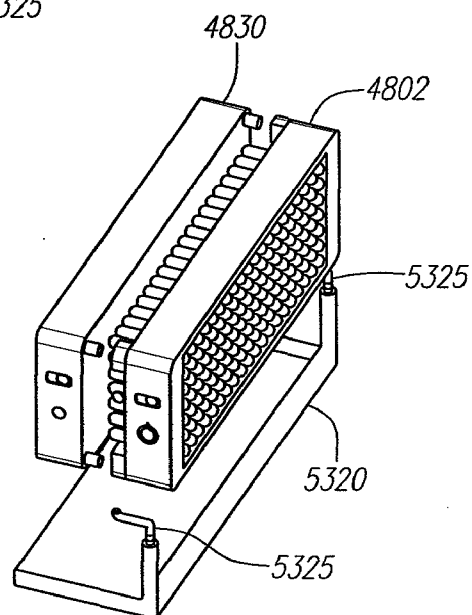
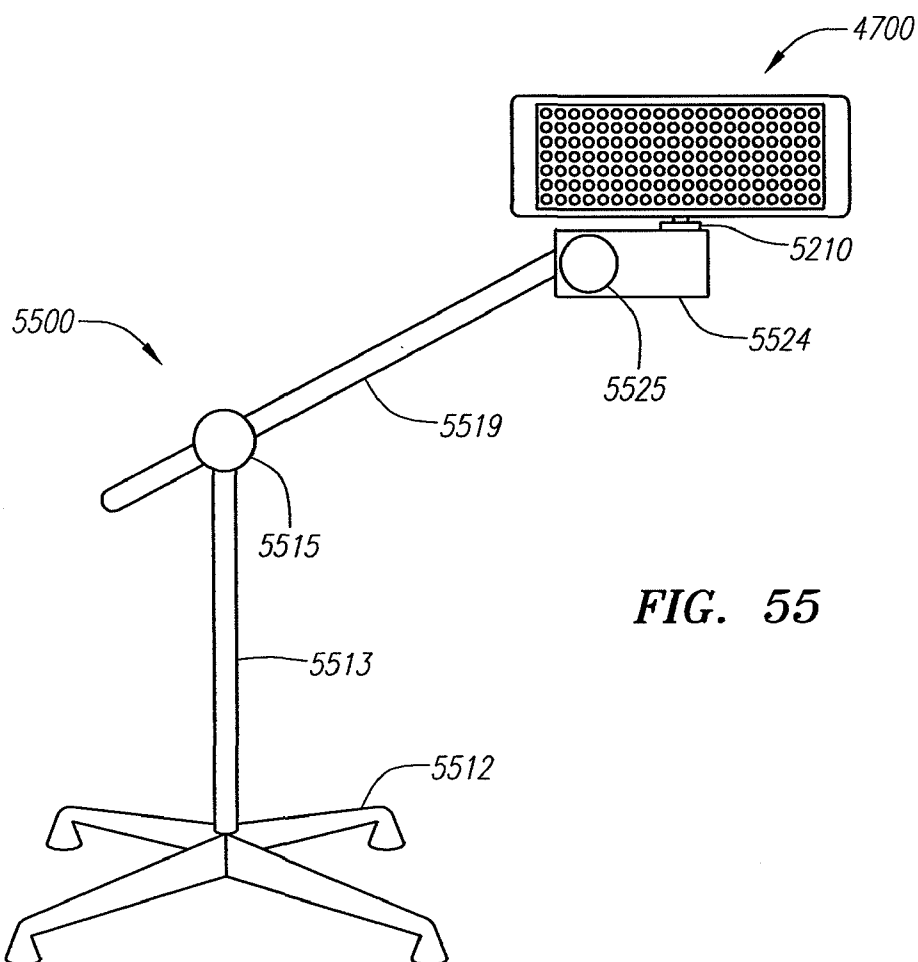
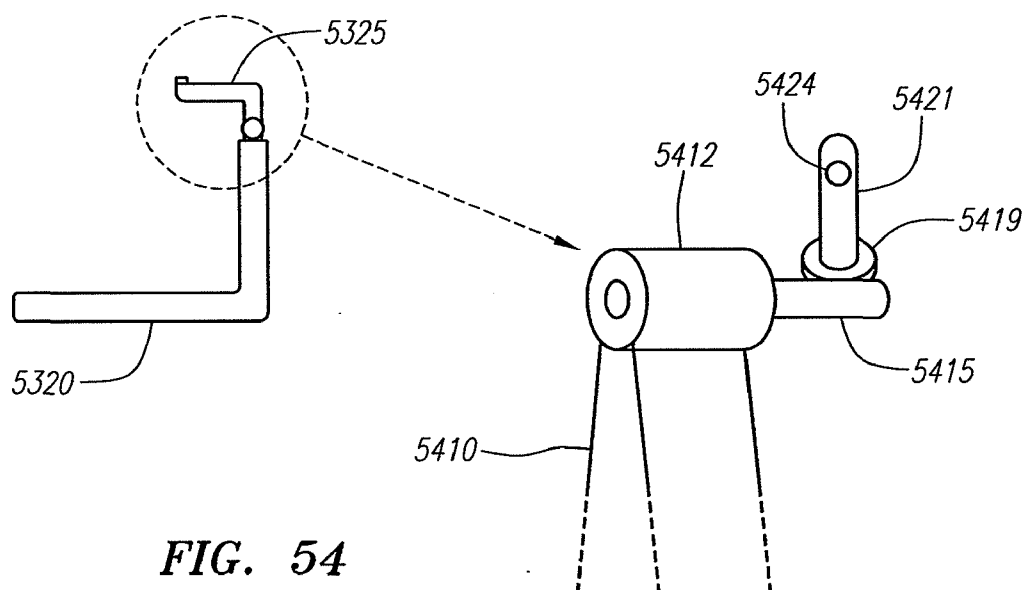


FIG. 53D



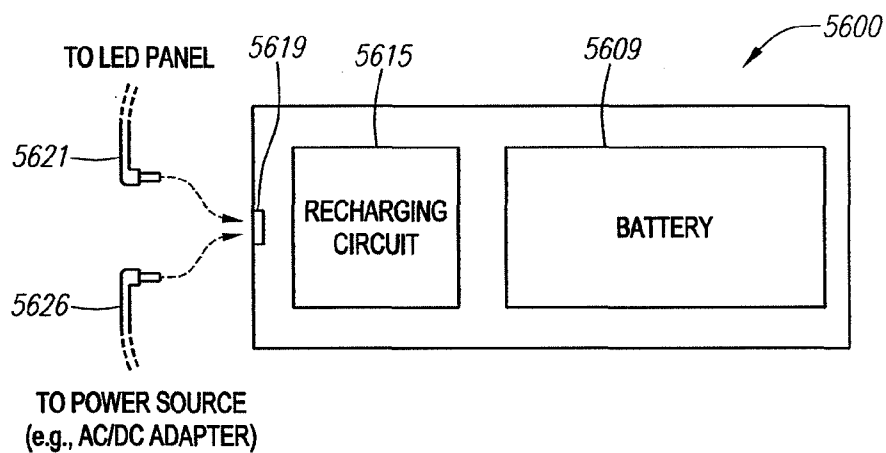


FIG. 56

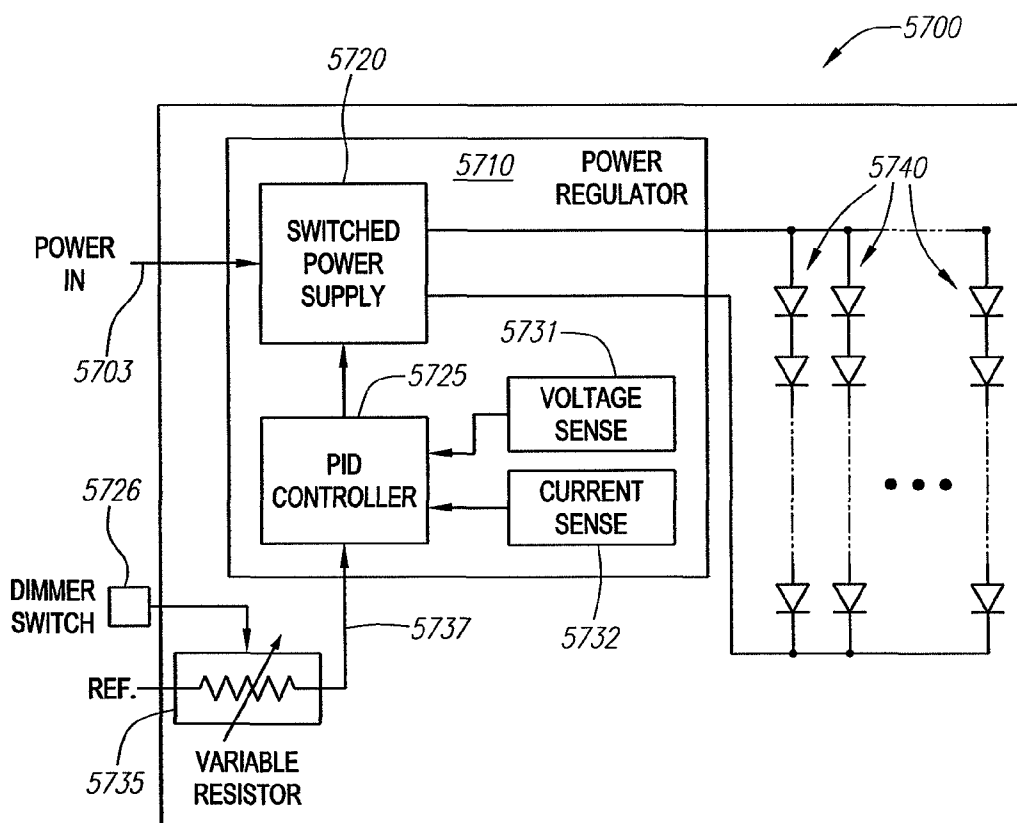


FIG. 57

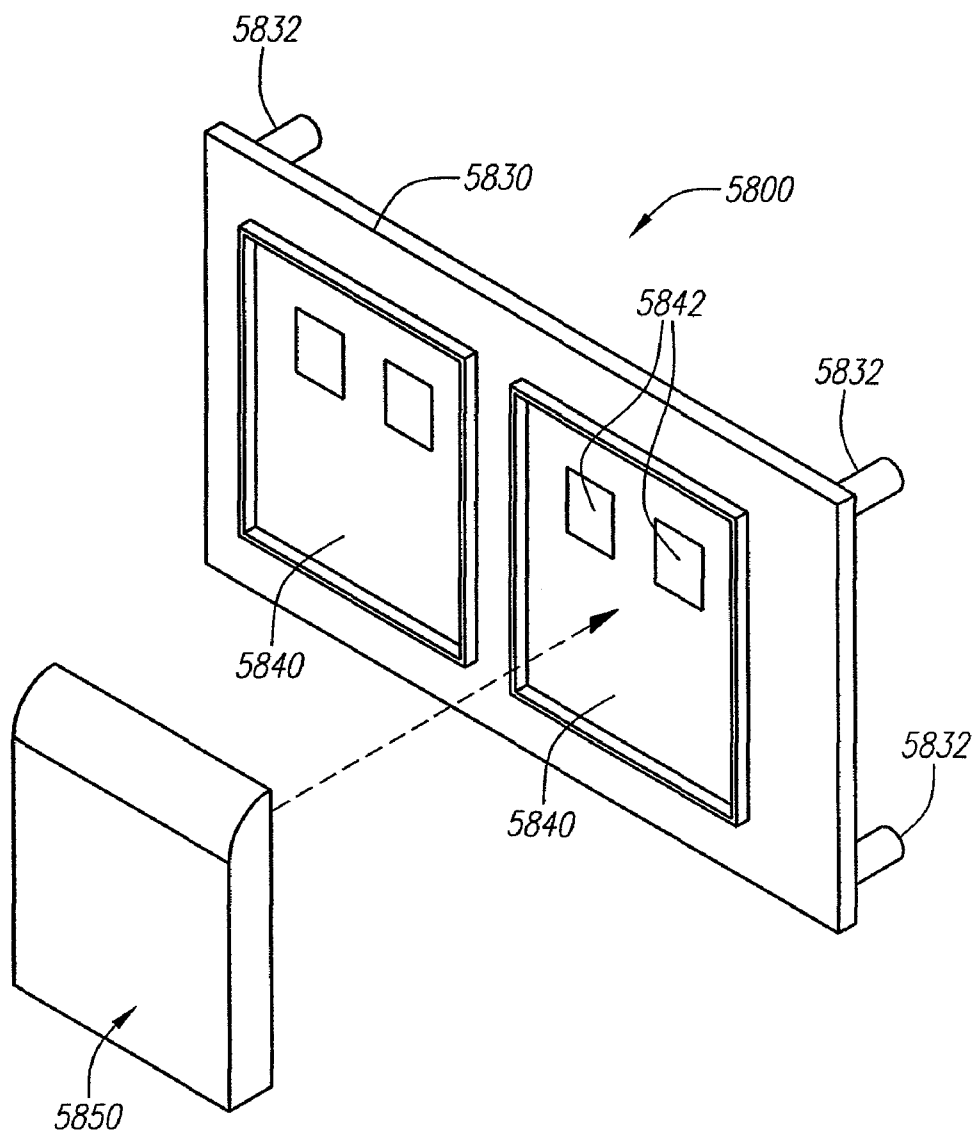


FIG. 58

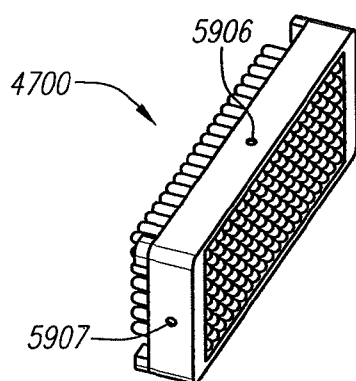


FIG. 59

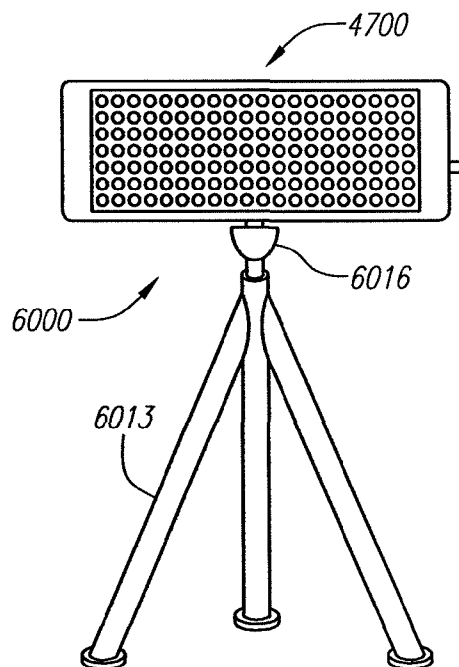


FIG. 60

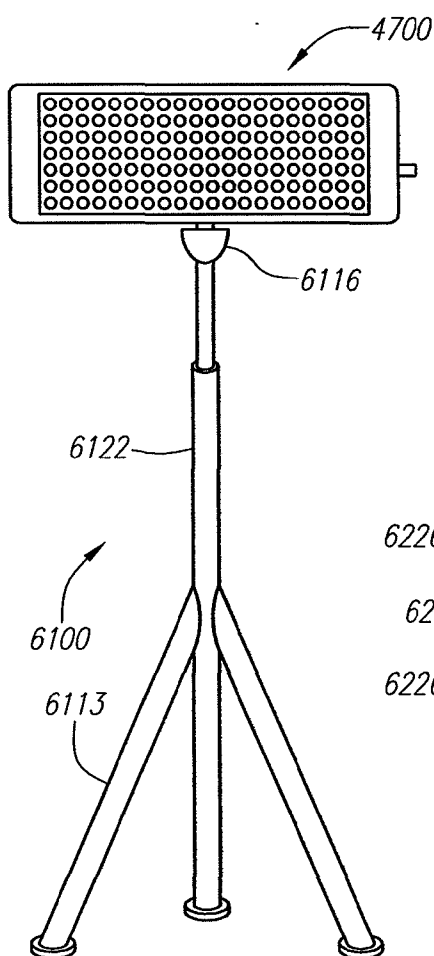


FIG. 61

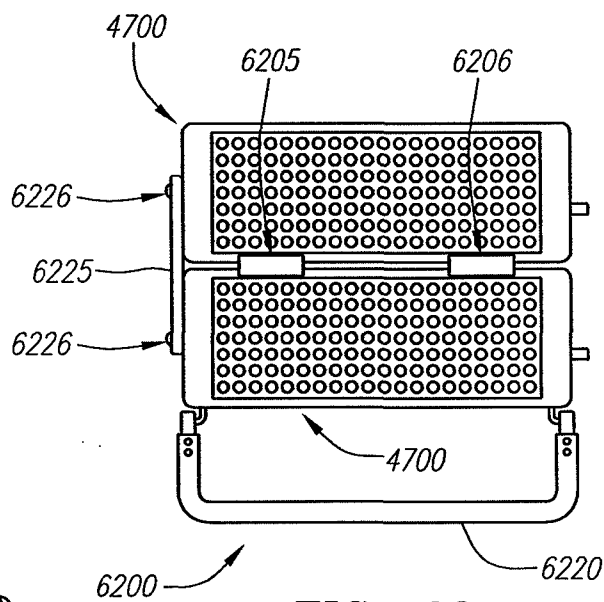
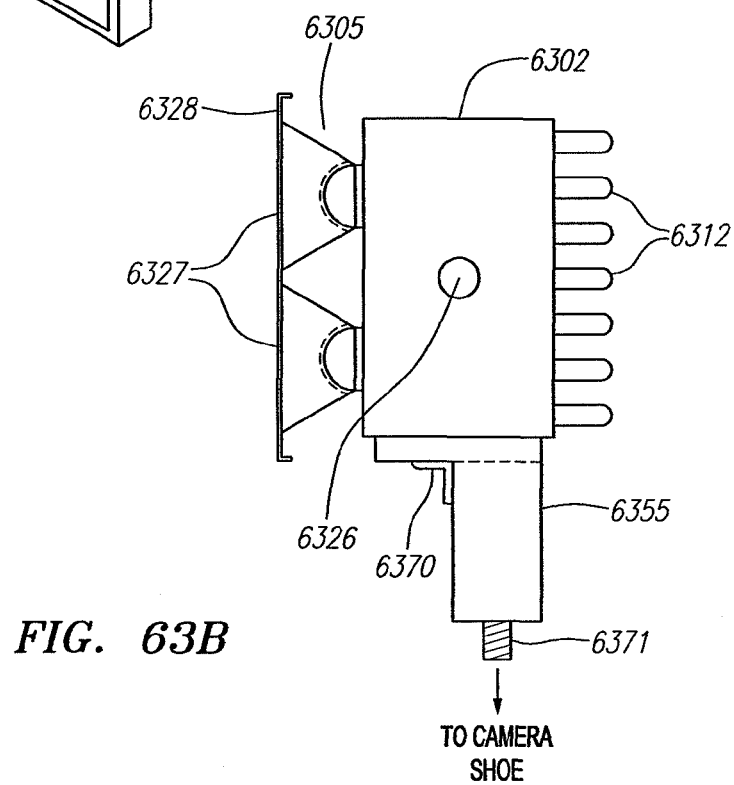
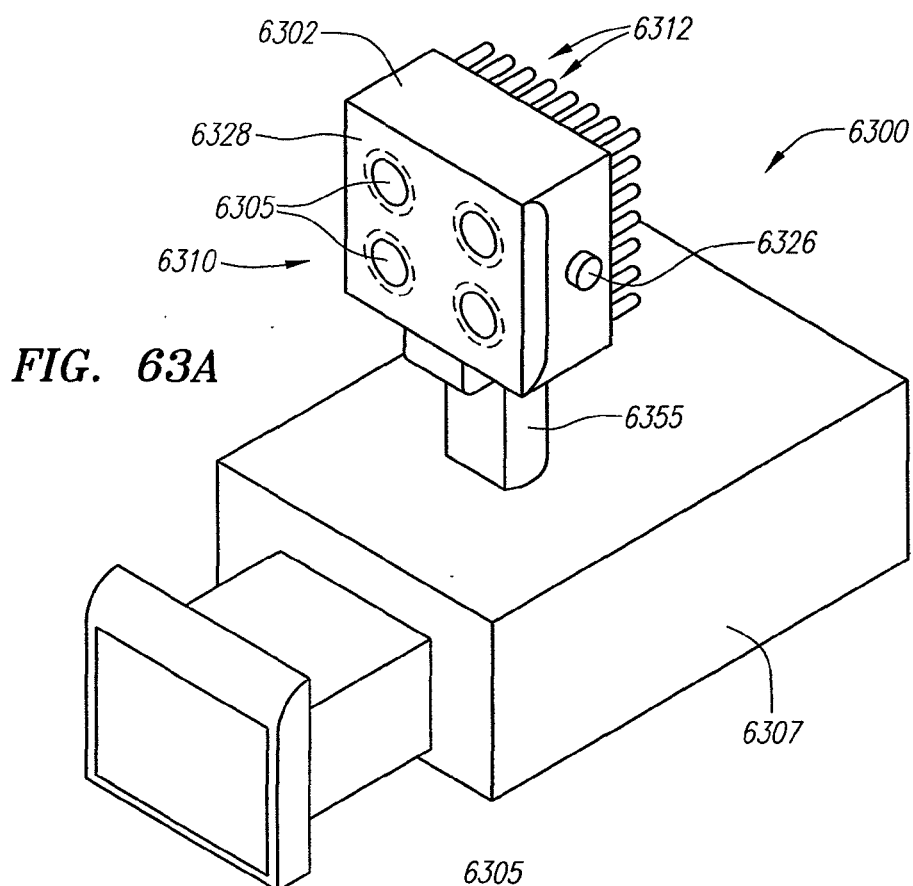


FIG. 62



STAND-MOUNTED LIGHT PANEL FOR NATURAL ILLUMINATION IN FILM, TELEVISION OR VIDEO

RELATED APPLICATION INFORMATION

[0001] This application is a continuation of U.S. application Ser. No. 11/308,004 filed Mar. 2, 2006, which is a continuation of U.S. application Ser. No. 11/005,564 filed Dec. 4, 2004, which is a continuation-in-part of U.S. application Ser. No. 10/238,973 filed Sep. 9, 2002, now U.S. Pat. No. 6,948,823, which in turn is a continuation-in-part of U.S. application Ser. No. 09/949,206 filed Sep. 7, 2001, now U.S. Pat. No. 6,749,310, all hereby incorporated by reference as if set forth fully herein.

BACKGROUND OF THE INVENTION

[0002] 1) Field of the Invention

[0003] The field of the present invention relates to lighting apparatus and systems as may be used in film, television, photography, and other applications.

[0004] 2) Background

[0005] Lighting systems are an integral part of the film and photography industries. Proper illumination is necessary when filming movies, television shows, or commercials, when shooting video clips, or when taking still photographs, whether such activities are carried out indoors or outdoors. A desired illumination effect may also be desired for live performances on stage or in any other type of setting.

[0006] A primary purpose of a lighting system is to illuminate a subject to allow proper image capture or achieve a desired effect. Often it is desirable to obtain even lighting that minimizes shadows on or across the subject. It may be necessary or desired to obtain lighting that has a certain tone, warmth, or intensity. It may also be necessary or desired to have certain lighting effects, such as colorized lighting, strobed lighting, gradually brightening or dimming illumination, or different intensity illumination in different fields of view.

[0007] Various conventional techniques for lighting in the film and television industries, and various illustrations of lighting equipment, are described, for example, in *Lighting for Television and Film* by Gerald Millerson (3rd ed. 1991), hereby incorporated herein by reference in its entirety, including pages 96-131 and 295-349 thereof, and in *Professional Lighting Handbook* by Verne Carlson (2nd ed. 1991), also hereby incorporated herein by reference in its entirety, including pages 15-40 thereof.

[0008] As one example illustrating a need for an improved lighting effects system, it can be quite challenging to provide proper illumination for the lighting of faces in television and film, especially for situations where close-ups are required. Often, certain parts of the face must be seen clearly. The eyes, in particular, can provide a challenge for proper lighting. Light reflected in the eyes is known as “eye lights” or “catch lights.” Without enough reflected light, the eyes may seem dull. A substantial amount of effort has been expended in constructing lighting systems that have the proper directivity, intensity, tone, and other characteristics to result in aesthetically pleasing “eye lights” while also meeting other lighting requirements, and without adversely impacting lighting of other features.

[0009] Because of the varied settings in which lighting systems are used, the conventional practice in the film, com-

mercial, and related industries is for a lighting system, when needed, to be custom designed for each shoot. This practice allows the director or photographer to have available a lighting system that is of the necessary size, and that provides the desired intensity, warmth, tone and effects. Designing and building customized lighting systems, however, is often an expensive and time-consuming process.

[0010] The most common lighting systems in film, commercial, and photographic settings use either incandescent or fluorescent light elements. However, conventional lighting systems have drawbacks or limitations which can limit their flexibility or effectiveness. For example, incandescent lights have been employed in lighting systems in which they have been arranged in various configurations, including on ring-shaped mounting frames. However, the mounting frames used in incandescent lighting systems are often large and ponderous, making them difficult to move around and otherwise work with. A major drawback of incandescent lighting systems is the amount of heat generating by the incandescent bulbs. Because of the heat intensity, subjects cannot be approached too closely without causing discomfort to the subject and possibly affecting the subject’s make-up or appearance. Also, the heat from the incandescent bulbs can heat the air in the proximity of the camera; cause a “wavering” effect to appear on the film or captured image. Incandescent lighting may cause undesired side effects when filming, particularly where the intensity level is adjusted. As the intensity level of incandescent lights change, their hue changes as well. Film is especially sensitive to these changes in hue, significantly more so than the human eye.

[0011] In addition to these problems or drawbacks, incandescent lighting systems typically draw quite a bit of power, especially for larger lighting systems which may be needed to provide significant wide area illumination. Incandescent lighting systems also generally require a wall outlet or similar standard source of alternating current (AC) power.

[0012] Fluorescent lighting systems generate much less heat than incandescent lighting systems, but nevertheless have their own drawbacks or limitations. For example, fluorescent lighting systems, like incandescent lighting systems, are often large and cumbersome. Fluorescent bulbs are generally tube-shaped, which can limit the lighting configuration or mounting options. Circular fluorescent bulbs are also commercially available, and have been used in the past for motion picture lighting.

[0013] A major drawback with fluorescent lighting systems is that the low lighting levels can be difficult or impossible to achieve due to the nature of fluorescent lights. When fluorescent lights are dimmed, they eventually begin to flicker or go out as the supplied energy reaches the excitation threshold of the gases in the fluorescent tubes. Consequently, fluorescent lights cannot be dimmed beyond a certain level, greatly limiting their flexibility. In addition, fluorescent lights suffer from the same problem as incandescent lights when their intensity level is changed; that is, they tend to change in hue as the intensity changes, and film is very sensitive to alterations in lighting hue.

[0014] Typically, incandescent or fluorescent lighting systems are designed to be placed off to the side of the camera, or above or below the camera. Because of such positioning, lighting systems may provide uneven or off-center lighting, which can be undesirable in many circumstances.

[0015] Because of their custom nature, both incandescent lighting systems and fluorescent lighting systems can be dif-

difficult to adapt to different or changing needs of a particular film project or shoot. For example, if the director or photographer decides that a different lighting configuration should be used, or wants to experiment with different types of lighting, it can be difficult, time-consuming, and inconvenient to re-work or modify the customized lighting setups to provide the desired effects. Furthermore, both incandescent lighting systems and fluorescent lighting systems are generally designed for placement off to the side of the camera, which can result in shadowing or uneven lighting.

[0016] A variety of lighting apparatus have been proposed for the purpose of inspecting objects in connection with various applications, but these lighting apparatus are generally not suitable for the movie, film or photographic industries. For example, U.S. Pat. No. 5,690,417, hereby incorporated herein by reference in its entirety, describes a surface illuminator for directing illumination on an object (i.e., a single focal point). The surface illuminator has a number of light-emitting diodes (LEDs) arranged in concentric circles on a lamp-supporting housing having a circular bore through which a microscope or other similar instrument can be positioned. The light from the LEDs is directed to a single focal point by either of two methods. According to one technique disclosed in the patent, a collimating lens is used to angle the light from each ring of LEDs towards the single focal point. According to another technique disclosed in the patent, each ring of LEDs is angled so as to direct the light from each ring on the single focal point.

[0017] Other examples of lighting apparatus used for the purpose of inspecting objects are shown in U.S. Pat. Nos. 4,893,223 and 5,038,258, both of which are hereby incorporated herein by reference in their entirety. In both of these patents, LEDs are placed on the interior of a spherical surface, so that their optical axes intersect at a desired focal point.

[0018] Lighting apparatus specially adapted for illumination of objects to be inspected are generally not suitable for the special needs of the film, commercial, or photographic industries, or with live stage performances, because the lighting needs in these fields differs substantially from what is offered by object inspection lighting apparatus. For example, movies and commercials often require illumination of a much larger area than what object inspection lighting systems typically provide, and even still photography often requires that a relatively large subject be illuminated. In contrast, narrow-focus lighting apparatuses are generally designed for an optimum working distance of only a few inches (e.g., 3 to 4 inches) with a relatively small illumination diameter.

[0019] Still other LED-based lighting apparatus have been developed for various live entertainment applications, such as theaters and clubs. These lighting apparatus typically include a variety of colorized LEDs in hues such as red, green, and blue (i.e., an "RGB" combination), and sometimes include other intermixed bright colors as well. These types of apparatus are not well suited for applications requiring more precision lighting, such as film, television, and so on. Among other things, the combination of red, green, and blue (or other) colors creates an uneven lighting effect that would generally be unsuitable for most film, television, or photographic applications. Moreover, most of these LED-based lighting apparatus suffer from a number of other drawbacks, such as requiring expensive and/or inefficient power supplies, incompatibility with traditional AC dimmers, lack of ripple protection (when connected directly to an AC power supply), and lack of thermal dissipation.

[0020] In the context of film and television, various attempts have been made to develop camera-mounted lighting fixtures; however, prior attempts to provide a suitable camera-mounted lighting fixture suffer from a variety of potential drawbacks. For example, conventional camera-mounted lighting fixtures using incandescent or fluorescent lighting elements suffer from the same drawbacks as described above, and can cause undesirable shadowing or other side effects. Also, camera-mounted lighting fixtures which are designed to connect to the camera's battery can cause premature depletion of the battery. Other lighting fixtures are designed to be powered by a battery pack which is worn, typically on a belt, by the camera operator. Such battery belts are often heavy and cumbersome, and may require lengthy power cords that can interfere with camera maneuverability.

[0021] It would therefore be advantageous to provide a lighting apparatus or lighting effects system that is versatile and portable, and may find use in a variety of applications. It would further be advantageous to provide a lighting apparatus or lighting effects system that is well suited for use in the film, commercial, and/or photographic industries, and/or with live stage performances, that overcomes one or more of the foregoing disadvantages, drawbacks, or limitations.

SUMMARY OF THE INVENTION

[0022] The invention is generally directed in one aspect to a novel and versatile lighting apparatus. According to one embodiment as disclosed herein, a lighting apparatus comprises a light panel having a panel frame, with a plurality of semiconductor light elements, such as LEDs, secured to the panel frame. A self-contained battery unit securably attaches to the outside of the panel frame. When attached together, the light panel and self-contained battery unit function as an integrated lighting apparatus. Optionally, the light panel may have an integrated dimmer switch, and may also be capable of receiving power from a source other than the self-contained battery unit.

[0023] In various forms and embodiments, the lighting apparatus may be adapted for being mounted to a camera or a stand, and may include adapters for such a purpose. The lighting apparatus may also be provided with a diffusion lens or color gels, which may be integrated with or detachable from the light panel. The lighting apparatus may conveniently be provided in the form of a kit, with one or more of a light panel, self-contained battery unit, compact stand, connecting cable(s), adapter(s), lenses or color gels, and so on, being provided in a single package to allow flexibility and versatility to users in the field.

[0024] Further embodiments, variations and enhancements are also disclosed herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] FIG. 1 is a diagram of an example of a lighting effects system in accordance with one embodiment as disclosed herein, illustrating placement of a camera relative to a lighting frame.

[0026] FIG. 2 is a block diagram of a lighting effects system showing various components of a preferred system.

[0027] FIG. 3 is an oblique view diagram illustrating an example of attachment of one type of camera mounting assembly to a particular type of lighting assembly frame.

[0028] FIG. 4 is a front view diagram of a lighting assembly frame with small, low-power lamps to provide illumination arranged in a preferred pattern.

[0029] FIG. 5 is a diagram illustrating aspects of the lighting effect provided by a lighting assembly such as, for example, shown in FIG. 4.

[0030] FIG. 6 is a diagram illustrating various human eye features that may be of interest in providing illumination for films, commercials or photography.

[0031] FIG. 7 is a diagram of a light segment as may be used, for example, with the lighting assembly of FIG. 4, along with filtering lens(es).

[0032] FIG. 8 is a diagram illustrating the effect of a filtering lens on an individual light element.

[0033] FIG. 9 is a graph illustrating a frequency distribution of light in accordance with one lighting effects system embodiment as disclosed herein.

[0034] FIGS. 10A and 10B are a block diagrams of two different types of electronic controllers as may be employed, for example, in the lighting effects system illustrated in FIG. 2.

[0035] FIG. 11 is an oblique view diagram of another embodiment of a lighting assembly frame as disclosed herein.

[0036] FIG. 12 is a diagram illustrating various options and accessories as may be used in connection with the lighting assembly frame depicted in FIG. 11.

[0037] FIG. 13 is a diagram of electronic control circuitry as may be employed, for example, with the lighting effects system illustrated in FIG. 11.

[0038] FIG. 14 is a graph illustrating a frequency distribution of light in accordance with another lighting effects system embodiment as disclosed herein.

[0039] FIGS. 15A and 15B are diagrams showing an oblique view and a top view, respectively, of a portion of a lighting assembly frame.

[0040] FIG. 15C is a diagram illustrating assembly of a lighting assembly frame from two halves thereof.

[0041] FIGS. 16A and 16B are diagrams showing an oblique view and a top view, respectively, of the backside of the lighting assembly frame portion illustrated in FIGS. 15A and 15B, while FIGS. 16C, 16D and 16E are diagrams showing details of the lighting assembly frame portion shown in FIGS. 16A and 16B.

[0042] FIG. 17 is a diagram of a cover as may be used in connection with the lighting effects system of FIG. 2 or the frame assembly of FIG. 4.

[0043] FIG. 18 is a diagram of a portion of a preferred camera mounting assembly.

[0044] FIGS. 19A and 19B are diagrams collectively illustrating another portion of a preferred camera mounting assembly.

[0045] FIG. 20 is a diagram of a retention clip for a camera mounting assembly.

[0046] FIG. 21 is a diagram of a plunger used in connection with attaching a mounting assembly to a lighting frame, in accordance with one technique as disclosed herein.

[0047] FIG. 22 is a diagram of a mounting assembly with components from FIGS. 18 and 19 shown assembled.

[0048] FIG. 23 is a diagram illustrating one technique for attaching a camera mounting assembly to a lighting frame.

[0049] FIGS. 24, 25 and 26 are diagram of components relating to another type of camera mounting assembly.

[0050] FIG. 27 is a diagram showing components of FIGS. 24, 25 and 26 assembled together.

[0051] FIGS. 28 and 29 are diagrams of alternative embodiments of integral or semi-integral camera mounting assemblies.

[0052] FIGS. 30A, 30B and 30C are diagrams illustrating various alternative lamp patterns.

[0053] FIG. 31 is a diagrams of an LED suitable for surface mounting.

[0054] FIG. 32 is a diagram of a lighting array mounted atop a circuit board.

[0055] FIG. 33 is a diagram of one embodiment of a lighting effects system having at least two different lamp colors.

[0056] FIG. 34 is a diagram of another embodiment of a lighting effects system having at least two different lamp colors.

[0057] FIG. 35 is a diagram of a lighting apparatus embodied as a panel having lighting arrays mounted thereon.

[0058] FIGS. 36A and 36B are side-view diagrams of two different types of surface-mount LEDs, and FIG. 36C is an oblique image of the LED shown in FIG. 36A.

[0059] FIG. 37A is a diagram of one embodiment of a lens cap for an LED, and FIGS. 37B and 37C are diagrams illustrating placement of the lens cap with respect to a particular type of LED.

[0060] FIGS. 37D and 37E are diagrams illustrating another embodiment of a lens cap for an LED, and placement thereof with respect to a particular type of LED.

[0061] FIG. 38A is a front view diagram of a ring-shaped lighting frame assembly with surface-mount LEDs arranged on the lighting frame.

[0062] FIG. 38B is a side view diagram of one embodiment of the lighting frame assembly illustrated in FIG. 36A, showing backside fins for heat dissipation.

[0063] FIGS. 39 and 40 are diagrams illustrating examples of a panel light with surface mount LEDs.

[0064] FIG. 41A is an oblique view diagram of a panel light illustrating backside fins and a groove for attachment to a multi-panel lighting assembly, and FIG. 41B is a diagram of a multi-panel lighting assembly illustrating attachment of the panel light shown in FIG. 41A.

[0065] FIG. 42A is a diagram of a detachable integrated lens sheet for a panel light, and FIGS. 42B-42D are more detailed diagrams of portions of the integrated lens sheet.

[0066] FIG. 43 is a diagram of a multi-panel lighting assembly employed on a lighting stand.

[0067] FIG. 44 is a cross-sectional diagram illustrating an adjustable lens cover of the type shown in FIG. 12, and an optional mechanism for securing interiorly positioned color gel(s) and/or lens filter(s).

[0068] FIG. 45 is a diagram of a flexible LED strip with surface mount LEDs.

[0069] FIG. 46 is a diagram of a ring-shaped lighting frame assembly with multiple fluorescent lights.

[0070] FIGS. 47A and 47B are diagrams of a lighting apparatus in accordance with one embodiment as disclosed herein.

[0071] FIGS. 48A and 48B are diagrams of the lighting apparatus in FIGS. 47A-B together with an attachable battery unit.

[0072] FIGS. 49A and 49B are diagrams showing attachment of the lighting apparatus in FIGS. 47A-B and 48A-B to the attachable battery unit of FIGS. 48A-B.

[0073] FIG. 50A is a diagram illustrating placement of a lens and optional color gel on the integrated light panel and battery apparatus of FIGS. 48A-B, and FIG. 50B is a side view diagram illustrating the lens in place.

[0074] FIG. 51 is a diagram showing one possible means for mounting an LED light panel to a camera.

[0075] FIGS. 52A, 52B and 52C are diagrams illustrating attachment of various mounting pins to the lighting apparatus shown in FIGS. 47A-B.

[0076] FIGS. 53A through 53D are diagrams showing different views of an integrated LED light panel and battery apparatus mounted on a stand.

[0077] FIG. 54 is a diagram showing details of one possible mounting arm configuration for the stand illustrated in FIGS. 53A-D.

[0078] FIG. 55 is a diagram of a light panel attached to a stand.

[0079] FIG. 56 is a simplified block diagram illustrating components of a battery unit in accordance with one embodiment as disclosed herein.

[0080] FIG. 57 is a functional block diagram illustrating circuits or components of an LED light panel in accordance with one embodiment as disclosed herein.

[0081] FIG. 58 is a diagram of an alternative embodiment of a battery unit, including an adapter panel and at least one attachable battery.

[0082] FIG. 59 is a diagram illustrating a panel light with one or more adapters for mounting or affixing the panel light.

[0083] FIGS. 60 and 61 are diagrams of a panel light mounted to different types of tripods.

[0084] FIG. 62 is a diagram of a stackable panel light, shown mounted on a stand.

[0085] FIGS. 63A and 63B are diagrams of an embodiment of a camera-mountable lighting apparatus.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT(S)

[0086] Before describing preferred embodiment(s) of the present invention, an explanation is provided of several terms used herein.

[0087] The term “lamp element” is intended to refer to any controllable luminescent device, whether it be a light-emitting diode (“LED”), light-emitting electrochemical cell (“LEC”), a fluorescent lamp, an incandescent lamp, or any other type of artificial light source. The term “semiconductor light element” or “semiconductor light emitter” refers to any lamp element that is manufactured in whole or part using semiconductor techniques, and is intended to encompass at least light-emitting diodes (LEDs) and light-emitting electrochemical cells (LECs).

[0088] The term “light-emitting diode” or “LED” refers to a particular class of semiconductor devices that emit visible light when electric current passes through them, and includes both traditional low power versions (operating in, e.g., the 20 mW range) as well as high output versions such as those operating in the range of 3 to 5 Watts, which is still substantially lower in wattage than a typical incandescent bulb. Many different chemistries and techniques are used in the construction of LEDs. Aluminum indium gallium phosphide and other similar materials have been used, for example, to make warm colors such as red, orange, and amber. A few other examples are: indium gallium nitride (InGaN) for blue, InGaN with a phosphor coating for white, and Indium gallium arsenide with Indium phosphide for certain infrared colors. A relatively recent LED composition uses Indium gallium nitride (InGaN) with a phosphor coating. It should be understood that the foregoing LED material compositions are mentioned not by way of limitation, but merely as examples.

[0089] The term “light-emitting electrochemical cell” or LEC” refers to any of a class of light emitting optoelectronic devices comprising a polymer blend embedded between two electrodes, at least one of the two electrodes being transparent in nature. The polymeric blend may be made from a luminescent polymer, a salt, and an ion-conducting polymer, and various different colors are available. Further background regarding LECs may be found, for example, in the technical references D. H. Hwang et al, “New Luminescent Polymers for LEDs and LECs,” *Macromolecular Symposia* 125, 111 (1998), M. Gritsch et al, “Investigation of Local Ions Distributions in Polymer Based Light Emitting Cells,” *Proc. Current Developments of Microelectronics*, Bad Hofgastein (March 1999), and J. C. deMello et al, “The Electric Field Distribution in Polymer LECs,” *Phys. Rev. Lett.* 85 (2), 421 (2000), all of which are hereby incorporated by reference as if set forth fully herein.

[0090] The term “color temperature” refers to the temperature at which a blackbody would need to emit radiant energy in order to produce a color that is generated by the radiant energy of a given source, such as a lamp or other light source. A few color temperatures are of particular note because they relate to the film and photographic arts. A color temperature in the range of 3200° Kelvin. (or 3200° K.) is sometimes referred to as “tungsten” or “tungsten balanced.” A color temperature of “tungsten” as used herein means a color temperature suitable for use with tungsten film, and, depending upon the particulars of the light source and the film in question, may generally cover the color temperature range anywhere from about 1000° Kelvin. to about 4200° Kelvin. A color temperature in the range of 5500° Kelvin. (or 5500° K.) is sometimes referred to as “daylight” or “daylight balanced.” Because the color of daylight changes with season, as well as changes in altitude and atmosphere, among other things, the color temperature of “daylight” is a relative description and varies depending upon the conditions. A color temperature of “daylight” as used herein means a color temperature suitable for use with daylight film, and, depending upon the particulars of the light source and the film in question, may generally cover the color temperature range anywhere from about 4200° Kelvin. to about 9500° Kelvin.

[0091] In one embodiment, a lighting effects system comprises an arrangement of lamp elements on a panel or frame. The lamp elements may be embodied as low power lights such as light-emitting diodes (LEDs) or light emitting electrochemical cells (LECs), for example, and may be arranged on the panel or frame in a pattern so as to provide relatively even, dispersive light. The panel or frame may be relatively lightweight, and may include one or more circuit boards for direct mounting of the lamp elements. A power supply and various control circuitry may be provided for controlling the intensities of the various lamp elements, either collectively, individually, or in designated groups, and, in some embodiments, through pre-programmed patterns.

[0092] In another embodiment, a lighting effects system comprises an arrangement of low power lights mounted on a frame having an opening through which a camera can view. The low power lights may be embodied as LEDs or LECs, for example, arranged on the frame in a pattern of concentric circles or other uniform or non-uniform pattern. The frame preferably has a circular opening through which a camera can view, and one or more mounting brackets for attaching the frame to a camera. The low power lights may be electronically controllable so as to provide differing intensity levels,

either collectively, individually, or in designated groups, and, in some embodiments, may be controlled through pre-programmed patterns.

[0093] FIG. 1 is a diagram of an example of a preferred lighting effects system 100 in accordance with one embodiment as disclosed herein, illustrating placement of a camera 140 relative to a lighting frame 102. The lighting frame 102 shown in FIG. 1 may be generally ring-shaped (as shown in, for example, FIGS. 3 and 4, and later described herein), and may define a central hole 103 through which the camera 140 can view. The camera 140 itself, while illustrated in FIG. 1 as a motion picture type camera, may be embodied as any type of image capture or optical viewing device, whether analog or digital in nature. For example, the camera 140 may use film or solid state image capture circuitry (e.g., CCDs), and may be a still photography camera or a motion picture camera. In a preferred embodiment, the lighting frame 102 is physically attached to the camera 140 using a camera mounting, as further described herein.

[0094] FIG. 2 is a block diagram of a lighting effects system 200 that may, if desired, be constructed in accordance with various principles illustrated in or described with respect to FIG. 1. As illustrated in FIG. 2, the lighting effects system 200 comprises a lighting frame 202 upon which are mounted or otherwise affixed a plurality of lamps 205. Preferred arrangements of the lamps 205 are described further herein. The lighting frame 202 may include a mounting assembly receptor 220 for receiving a mounting assembly 230 (preferably removable in nature), and an electrical socket 215 for receiving a cable 213 providing electrical power to the lamps 205 from a power source 210, although in alternative embodiments battery power may be used. A power controller 212 is preferably interposed between the power source 210 and the electrical socket 215, for providing various lighting effect functions described in more detail hereinafter, such as, for example, dimming, strobing, selective activation, pulsation, and so on, or combinations thereof.

[0095] In a preferred embodiment, the lighting frame 202 is ring-shaped, and the lamps 205 are arranged in a pattern around the center hole of the lighting frame 202 so as to provide the desired lighting condition—typically, the lamps 205 will be arranged in a symmetrical, regular pattern so as to provide relatively even lighting over the area of interest. The lighting frame 202 is preferably comprised of a lightweight, durable material, such as thermoplastic and/or aluminum, with a flat black finish (either paint, coating or material) so as to eliminate any reflections from the front of the lighting frame 202 that might cause ghosts to the final image.

[0096] An example of a preferred lighting frame 302 is depicted from various angles in FIGS. 3 and 4. FIG. 4 shows a front view of a lighting frame 302, illustrating the preferred ring-shaped nature thereof. In the embodiment shown in FIG. 4, a number of lamp segments 306 are arranged in a radial or arrayed pattern around the center hole 303 of the lighting frame 302. The lamp segments 306 are positioned along rays 308 emanating from a center point 307 of the lighting frame 302, and are preferably equidistant from one another (i.e., the rays 308 are preferably defined such that all of the angles between neighboring rays 308 are equal). The equidistant placement of the lamp segments 306 results in a symmetrical, even pattern that advantageously provides even lighting over an area of interest.

[0097] The density of the lamp pattern may vary, and is dictated in part by the particular lighting needs. Examples of

alternative lamp arrangement patterns are shown in FIGS. 30A-30C. FIGS. 30A and 30B show the lighting frame 302 with different pattern densities of lamp segments 306. FIG. 30C illustrates a lamp pattern in which pairs 309 of lamp segments 306 are arranged near adjacent to one another, while each pair 309 of lamp segments 306 is positioned further away from its neighboring pair 309 than from the other lamp segment 306 that is part of the lamp segment pair 309. The lamp patterns shown in FIGS. 30A, 30B and 30C are meant to be merely illustrative and not exhaustive. Other lamp patterns might involve, for example, triplets of lamp segments (rather than pairs or singles), or alternating single lamps with pairs and/or triplets, or lamp segments which have gradually increasing or decreasing spacing between them, or lamp segment clusters having the same or different numbers of lamp segments in each cluster, to name a few. The lamp pattern can thus be varied to suit the particular lighting needs, but is preferably symmetric at least in those situations calling for even lighting over the area of interest.

[0098] Each of the lamp segments 306 preferably comprises a plurality of low power lamps 305, such as illustrated, for example, in FIG. 4. The low power lamps are preferably solid state in nature and may comprise, for example, light-emitting diodes (LEDs), light-emitting crystals (LECs), or other low power, versatile light sources. Alternatively, fluorescent lamps may be used instead of lamp segments, as described later herein, for example, with respect to, e.g., FIG. 13. Fluorescent lights are power efficient and tend to have high concentrations or spikes of blue, green, and ultraviolet wavelength light. Most white LEDs have color spikes as well. These spikes of color combined with improper proportions of other wavelengths can render the colors of objects seen or photographed as incorrect or odd in hue. Slight color variations may be added relatively easily to the lenses of LEDs to compensate for these deficiencies without significantly impacting the overall light output. Colored LED lenses may also be used to generate a desired color (such as red, green, etc.), but, since colored lenses are subtractive in nature, the stronger the color, generally the more the output of the LED will be dimmed. White LEDs typically utilize clear or nearly clear lenses; however, in any of the embodiments described herein, a clear LED lens may be manufactured with slight subtractive characteristics in order to minimize any color spikes and/or non-linearities in the output of an LED.

[0099] The number of low power lamps 305 in each lamp segment 306 may be the same or may vary among lamp segments 306. If the number of low power lamps 305 is the same in each lamp segment 306 and are spaced the same (for example, equidistant from one another) within each lamp segment 306, then the resulting pattern will be a plurality of concentric circles of low power lamps 305 radiating outward from the inner circular portion to the outer circular portion of the lighting frame 302. It will be appreciated, however, that the low power lamps 305 need not be arranged in segments 306 as illustrated in FIG. 4, but may be arranged in clusters or other patterns, whether uniform or non-uniform, over the lighting frame 302. However, a symmetrical, regular pattern of low power lamps 305 is preferred, at least where uniform lighting is desired over an area of interest.

[0100] FIG. 5 illustrates the effect of a lighting frame assembly such as light frame 302 with low power lamps 305 arranged as shown in FIG. 4, in illuminating a subject 646. As shown in FIG. 5, radiating light regions 620, 621 from lamps arranged on the front surface of the lighting frame 302 (as

illustrated in FIG. 4, for example) overlap one another in a manner so as to provide lighting from multiple angles. With a radial or arrayed pattern of lamp segments 306 as shown in FIG. 4, a subject 646 may be relatively evenly illuminated from every angle. FIG. 1 illustrates a preferred placement of a camera 140 (including any type of image capture device, whether film based, solid state/CCD, or otherwise) with respect to a lighting frame 102 (which may be embodied, for example, as lighting frame 302). As illustrated in FIG. 1, the camera 140 may be positioned so that its lens or optical front-end peers through the central hole 103 of the lighting frame 102, thus allowing the lighting to be presented from the same angle and direction as the camera viewpoint.

[0101] FIG. 6 illustrates how the lighting frame assembly with the pattern of lamp segments 306 as shown in FIG. 4 may advantageously illuminate a human subject's eyes. In FIG. 6, the iris 650 of the subject's eye 654 is illustrated showing a circular pattern of reflected light segments 652 around the iris 650. A lighting pattern of a lighting system such as illustrated in FIG. 4 can illuminate the iris 650 of the subject's eye 654 from multiple angles, thus helping provide desirable "eye lights" or "catch lights" with respect to a human subject 546, as well as providing uniform, even lighting over the area of interest.

[0102] Turning once again to FIG. 3, an oblique view of the lighting frame 302 is shown illustrating an example of attachment of one type of camera mounting assembly 330 to the lighting frame 302. In the particular embodiment illustrated in FIG. 3, a mounting assembly receptor 320 is affixed to, molded as part of, or otherwise attached to the lighting frame 302. The camera mounting assembly 330 is preferably configured so as to attach securely to the mounting assembly receptor 320. The mounting assembly receptor 320 may, for example, include a socket 323 or similar indentation adapted to receive a corresponding member 335 on the camera mounting assembly 330. The member 335 may be attached to an elongated rod or arm 332, along which a camera clamp 334 may be slidably engaged. The camera clamp 334 preferably includes a generally U-shaped clamping portion 336 which may be securely attached along the housing of a camera, and may advantageously be moved along the elongated rod or arm 332 and clamped into a suitable position using a clamping screw or other fastening mechanism.

[0103] FIGS. 15A and 15B are diagrams showing an oblique view and a frontal view, respectively, of one portion of a lighting assembly frame 1502 in accordance with one or more of the concepts or principles explained with respect to the embodiment shown in FIG. 3. As illustrated in FIGS. 15A and 15B, the lighting assembly frame portion 1502 is generally ring-shaped in nature, having a central hole 1503 for allowing a camera or other image capture device to view through the lighting assembly frame. The lighting assembly frame portion 1502 may be reinforced, if desired, with ribs 1560, and may include, as noted with respect to FIG. 3, a mounting assembly receptor 1520 for receiving a camera mounting assembly (not shown in FIG. 15A), and an electrical socket 1515 for receiving a cable or wires for providing power to the lamps of the lighting assembly.

[0104] The lighting frame portion 1502 illustrated in FIG. 15A comprises one half (specifically, the backside half) of a complete lighting frame assembly. A corresponding lighting frame portion 1592 (e.g., printed circuit board), as shown in FIG. 15C, may be adapted to fit securely to the lighting frame portion 1502 (e.g., injected molded poly-carbonate), and may

attach thereto by, for example, exterior locking tabs 1564 and/or interior locking tabs 1567, which are shown in FIGS. 15A and 15B. Alternatively, other means for fastening together the lighting frame assembly 1501 may be used, such as screws, glue, etc.

[0105] Likewise, the mounting assembly receptor 1520 may comprise any suitable mechanism for securing a camera mounting assembly to the lighting frame portion 1502 of the lighting frame assembly 1501. In the example illustrated in FIGS. 15A and 15B, the mounting assembly receptor 1520 may comprise a raised, slightly tapered cylindrical housing, defining a hollow cylindrical chamber in which the camera mounting assembly may be fitted. If the lighting frame portion 1502 is formed of plastic, for example, then the mounting assembly receptor 1520 may be formed through an injection molding process. FIG. 18 depicts an example of a portion of a camera mounting assembly 1801 as may be affixed to the lighting frame portion 1502 using the mounting assembly receptor 1520. The camera mounting assembly 1801 in FIG. 18 comprises an elongated rod or arm 1832, at the end of which is affixed an attachment member 1835 having a generally circular body portion with two wing-like protruding tabs 1838. The tabs 1838 may be fitted into two corresponding indentations 1524 in the ring-shaped top surface of the cylindrical housing of the mounting assembly receptor 1520. The camera mounting assembly 1801 may then be twisted in a clockwise direction to cause the tabs 1838 to slide through the slits adjacent to the indentations 1524 in the mounting assembly receptor 1520, allowing the camera mounting assembly 1801 to be slid downward, then twisted in a counter-clockwise direction and locked into place in the mounting assembly receptor 1520. The camera mounting assembly 1801 may be disengaged from the lighting frame portion 1501 by manually applying pressure to release the locking tabs and twisting the camera mounting assembly 1801 in the opposite (i.e., clockwise in this example) direction from that originally used to bring it into a locking position. The camera mounting assembly 1801 may then be raised upwards and twisted in a counter-clockwise direction to cause the tabs 1838 to slide back through the slits adjacent to the indentations 1524 in the mounting assembly receptor 1520, thereby completely releasing the camera mounting assembly 1801.

[0106] A variety of other means may alternatively be used to affix a camera mounting assembly to the lighting frame portion 1502, but the mechanism used in the embodiment depicted in FIGS. 15A and 15B has the advantage of not requiring additional pieces (such as screws), and being relatively simple and quick to use.

[0107] A main purpose of the camera mounting assembly 1801 is to allow the lighting frame assembly to be secured to a camera or other image capture device, thus providing even lighting from all directions surrounding the camera or other image capture device, and allowing, for example, the lighting frame assembly to follow the motion of the camera or other image capture device as it is moved. An example of additional components allowing the camera mounting assembly 1801 to be secured to a camera are shown in FIGS. 19A and 19B. In particular, FIGS. 19A and 19B depict two halves 1902, 1912 of a camera clamp which may be joined together and attached to the elongated rod or arm 1832 of the camera mounting assembly 1801, arriving at a complete camera mounting assembly such as illustrated in FIG. 3 (i.e., camera mounting assembly 330) or, in more detail, in FIG. 22. The rectangular openings 1903, 1913 in the two halves 1902 and 1912, respec-

tively, of the camera clamp allow it to be slid onto the elongated rod or arm 1832. A spring-loaded retention clip, as shown in FIG. 20, may be used to help secure the camera clamp to the elongated rod or arm 1832. In alternative embodiments, the camera clamp (comprising the combination of two halves 1902, 1912) may be permanently affixed and/or integrally formed with the elongated rod or arm 1832.

[0108] An attachment member, such as pre-molded clamping member 1916 shown in FIG. 19B, may be used to slide onto an appropriate feature of the camera (such as a Panavision® type motion picture camera), e.g., a rod or other feature of the camera. Other types of attachment members may be used, depending upon the particular nature of the camera or other image capture device. The camera mounting assembly 1801, in conjunction with the preferred camera clamp illustrated in FIGS. 19A and 19B, thereby allow a lighting frame assembly to be secured to a camera or other image capture device.

[0109] FIG. 23 is a diagram illustrating one technique for attaching a camera mounting assembly to a lighting frame. As shown in FIG. 23, a lighting frame 1302 may comprise a mounting assembly receptor 1320, similar to as described with respect to FIG. 3 and FIGS. 15A-15B, for example. In connection with attaching a camera mounting assembly 2328, a spring 2305 is first positioned in the mounting assembly receptor 2320, atop of which is then placed a plunger 2308 (such as illustrated in FIG. 21). Then, the camera mounting assembly 2328 is attached, by, e.g., inserting the attachment member into the mounting assembly receptor 2320. In essence, the application of the attachment member to the mounting assembly receptor 2320 may be viewed analogously to inserting and twisting a “key” in a keyhole. The spring 2305 effectively locks the camera mounting assembly 2328 in place against the back “keyplate” surrounding the keyhole, thus allowing the camera mounting assembly 2328 to be “twist-locked” into place. The assembly structure shown in FIG. 23 allows relatively easy attachment and detachment of the camera mounting assembly 2328. Other attachment techniques may also be used.

[0110] Another embodiment of a camera mounting assembly, as may be used to attach a lighting frame to a camera or other image capture device, is illustrated in FIG. 27, and various components thereof are illustrated individually in FIGS. 24, 25 and 26. With reference first to FIG. 24, two halves 2415, 2418 of a camera clamp may be joined together to form a main camera clamp body. The two halves 2415, 2418 may be secured together by screws or any other suitable fastening means. A slot in the camera clamp body may be provided to allow placement of a thumbwheel 2604 (illustrated in FIG. 26) which allows tightening of a clamping member 2437. Several holes 2430 are provided in camera clamp portion 2415, which receive corresponding protrusions 2511 from an attachment member 2501, illustrated in FIG. 25, which has a generally circular body portion 2519 with two wing-like protruding tabs 2586. The completed camera mounting assembly 2701 appears as in FIG. 27.

[0111] The tabs 2586 of the camera mounting assembly 2701 shown in FIG. 27 may be fitted into the two corresponding indentations 1524 in the ring-shaped top surface of the cylindrical housing of the mounting assembly receptor 1520 shown in FIG. 15, as described previously with respect to the FIG. 22 camera mounting assembly. As before, the camera mounting assembly may be twisted in a clockwise direction to cause the tabs 2586 to slide through the slits adjacent to the

indentations 1524 in the mounting assembly receptor 1520, allowing the camera mounting assembly 2701 to be slid downward, then twisted in a counter-clockwise direction and locked into place in the mounting assembly receptor 1520. The camera mounting assembly 2701 may be disengaged from the lighting frame portion 1501 by manually applying pressure to release the locking tabs and twisting the camera mounting assembly 2701 in the opposite (i.e., clockwise in this example) direction from that originally used to bring it into a locking position. The camera mounting assembly 2701 may then be raised upwards and twisted in a counter-clockwise direction to cause the tabs 2586 to slide back through the slits adjacent to the indentations 1524 in the mounting assembly receptor 1520, thereby completely releasing the camera mounting assembly 2701.

[0112] As noted previously, a variety of other means may alternatively be used to affix a camera mounting assembly 2701 of FIG. 27 to the lighting frame portion 1502.

[0113] As with the camera mounting assembly 1801 shown in FIG. 18, the camera mounting assembly of FIG. 27 functions to allow a lighting frame assembly to be secured to a camera or other image capture device, thus allowing, for example, the lighting frame assembly to follow the motion of the camera or other image capture device as it is moved. An attachment member, such as pre-molded clamping member 2437 shown in FIG. 24, may be used to slide onto an appropriate feature, such as a rod or other feature, of the camera (for example, an Arri® type motion picture camera).

[0114] FIGS. 28 and 29 are diagrams of alternative embodiments of camera mounting assemblies having certain integral components. FIG. 28 illustrates a camera mounting assembly 2801 as may be used, for example, to secure a lighting frame to a Panavision® type camera. As shown in FIG. 28, an attachment member 2838 (or “key”) connects with, and integrally attaches to, a camera clamp plate 2802, in a manner similar to that shown in FIG. 18, but eliminating the elongated rod or arm shown therein. A pair of cylindrically-shaped lock lever “screws” 2851, 2852 enable the camera mounting assembly 2801 to attach to an appropriate feature of the camera. Lock levers 2855, 2856 connected to each of the lock lever screws 2851, 2852 can be flipped (e.g., a quarter turn) in order to lock the screws 2851, 2852 into place, thus securing the camera mounting assembly 2801 to the camera. The lock lever screws 2851, 2852 can be flipped the opposite direction to unlock the screws 2851, 2852 and thereby release the camera mounting assembly 2801 from the camera.

[0115] FIG. 29 illustrates a camera mounting assembly 2901 as may be used, for example, to secure a lighting frame to an Arri® type camera. As shown in FIG. 29, an attachment member 2938 (or “key”) connects with, and attaches to, a camera clamp plate 2902, by way of, e.g., screws 2940. A cylindrically-shaped lock lever screw 2951 enables the camera mounting assembly 2901 to attach to an appropriate feature of the camera. A lock lever 2855 connected to the lock lever screw 2851 can be flipped (e.g., a quarter turn) in order to lock the screw 2851 into place, thus securing the camera mounting assembly 2901 to the camera. The lock lever screw 2851 can be flipped the opposite direction to unlock the screw 2851 and thereby release the camera mounting assembly 2901 from the camera.

[0116] Additional details of the particular lighting frame portion 1501 of FIGS. 15A and 15B are illustrated in FIGS. 16A through 16E. FIGS. 16A and 16B, for example, are diagrams showing an oblique view and a top view, respec-

tively, of the backside of the lighting frame portion **1501** illustrated in FIGS. **15A** and **15B**. In FIGS. **16A** and **16B** can more clearly be seen, for example, the interior locking tabs **1567** and exterior locking tabs **1564** that can be used to secure the lighting frame portion **1501** to its corresponding half, as previously described with respect to FIG. **15C**. In FIG. **16C** is depicted a close-up illustration of the backside of the mounting assembly receptor **1520** and electrical socket **1515** illustrated from the opposite side in FIGS. **15A** and **15B**. In FIGS. **16D** and **16E** can be seen additional details of both the mounting assembly receptor **1520** (FIG. **16D**) and the interior locking tabs **1567** and exterior locking tabs **1564**. As shown in FIGS. **16D** and **16E**, the interior locking tabs **1567** may include a protruding locking member **1570** for securing the lighting frame portion **1501** to its counterpart by, e.g., snapping it into place, and the exterior locking tabs **1564** may likewise include protruding locking members **1568** having a similar function. The frame wall **1562** between the two nearby exterior locking tabs **1564** may be reinforced with a supporting rib **1569**, to provide added counter-force when the lighting frame assembly is put together.

[0117] The camera mounting assemblies shown in FIGS. **18**, **23**, **27**, **28** and **29** are merely examples of camera mounting assemblies that may be utilized in various embodiments described herein. Other camera mounting assemblies may be specifically adapted to the particular camera of interest. The mounting assembly receptor **320** (or **1520**) may in one aspect be viewed as a universal receptor, allowing different camera mounting assemblies to be connected to the lighting frame, provided that they are compatible with the mounting assembly receptor (such as the example shown in FIGS. **15A-15BB** and elsewhere). A single lighting frame may thus be used with any of a variety of different cameras or other image capture devices. Although examples have been explained with respect to certain camera types (that is, a Panavision® camera or an Arri® camera), the camera may be of any type, whether for film or still photograph, and may be based upon either analog or digital imaging techniques. Moreover, while preferred dimensions are illustrated in some of the figures, the mounting assemblies and components thereof may be of any appropriate size and shape.

[0118] Further description will now be provided concerning various preferred light elements as may be used in connection with one or more embodiments as disclosed herein. While generally discussed with reference to FIG. **3**, the various light elements described below may be used in other embodiments as well. When embodied as LEDs, the low power lamps **305** typically will emit light at approximately 7400-7500K degrees when at full intensity, which is white light approximating daylight conditions. However, LEDs of a different color, or one or more different colors in combination, may also be used. FIG. **9** is an energy spectrum graph showing a typical frequency distribution (in terms of light wavelength) of light output from white-light, low voltage LEDs, and illustrating a main peak at about 600 nanometers. A color correction mechanism, such as a color correction gel or lens filter, may be used to alter the color of the LED light. For example, the LED light could be converted to “tungsten daylight” (similar in hue to an incandescent bulb) by use of a color gel or colored lens. A diffusion lens or filter may also be used, by itself or in conjunction with a color gel or colored lens, to diffuse or soften the outgoing light. A diffusion lens or filter may be formed of, e.g., clear or white opaque plastic, and may be configured in a ring-shaped pattern of similar

dimension to the light frame **302** to facilitate mounting thereon. FIG. **17**, for example, shows a diagram of an opaque, ring-shaped cover **1701** as may be used in connection with the lighting frame assembly depicted in FIG. **3** or FIG. **4**.

[0119] FIG. **7** is a more detailed diagram of a light segment **792** (e.g., an array) as may be used, for example, in connection with the lighting frame **302** shown in FIG. **4**. The light segment **792** may correspond to each of the individual light segments **306** shown in FIG. **4**, and the various light elements (i.e., LEDs) **790** in FIG. **7** may correspond to the individual low power lamps **305** shown in FIG. **3**. FIG. **7** illustrates a straight row of LEDs **790** as may comprise the lighting segment **790**. Although fifteen LEDs **790** are illustrated in the example shown in FIG. **7**, any number of LEDs **790** may be used, subject to physical space limitations and lighting intensity requirements. In addition, a set of filtering lenses **794** (which are preferably formed as a single, collective lens comprised of individual lens elements **795** connected together) may be placed over the light segment **792** as shown, such that each lens element **795** is positioned in the light path of one of the LEDs **790**. The overall effect can be, for example, to focus or spread the light according to a specifically desired pattern, such as the exemplary light pattern **796** shown in FIG. **7**. A variety of other light filtering techniques may also be used.

[0120] FIG. **8** is a diagram illustrating the effect of a filtering lens element (e.g., wave guide) **876** on an individual light element (e.g., LED) **872**. As shown in FIG. **8**, light **874** emanates from the LED **872** in a generally even pattern, but can be focused or otherwise filtered by the filtering lens element **876**. FIG. **7** illustrates an example of collectively filtering all of the LEDs **790** of the light segment **792**.

[0121] Various embodiments of lighting apparatus as described herein utilize different color lamp elements in order to achieve, for example, increased versatility or other benefits in a single lighting mechanism. Among the various embodiments described herein are lamp apparatuses utilizing both daylight and tungsten lamp elements for providing illumination in a controllable ratio. Such apparatuses may find particular advantage in film-related applications where it can be important to match the color of lighting with a selected film type, such as daylight or tungsten.

[0122] Alternatively, or in addition, lamp elements of other colorations may be utilized. It is known, for example, to use colored lamp elements such as red, green, and blue LEDs on a single lighting fixture. Selective combinations of red, green, and blue (“RGB”) lamp elements can generally be used to generate virtually any desired color, at least in theory. Lighting systems that rely upon RGB lamp elements can potentially be used as primary illumination devices for an image capture system, but suffer from drawbacks. One such problem is that the red, green, and blue colors generated by the light elements do not necessarily mix completely. The discrete RGB lamp elements (e.g., LEDs) each project a localized “pool” of its individual primary color. This manifests as spots of color, or bands of individual or partially mixed colors. One of the only presently available solutions to correct for this problem is mixing the colors using a diffusion technique. Diffusion mixing can be accomplished by adding detractors, gratings, or white opal-appearing filters, for example. Unfortunately, these techniques end up reducing the overall output of the lighting apparatus and, more importantly, severely reduce the ability of the LEDs to “project” light in a direct fashion. Another problem for illumination systems which rely upon RGB color mixing is that not all of the LEDs are generally

used at full power for most lighting situations. One or two of the LED color groups typically have to be dimmed in order for the desired color to be generated, which can further reduce the overall light output. When these factors are considered in combination, RGB based lighting apparatus may not be well suited for providing primary illumination for image capture applications (such as film).

[0123] While the foregoing discussion has principally focused on RGB based lighting apparatus, similar problems and drawbacks may be experienced when employing lamp elements in other color combinations as well.

[0124] In various embodiments as disclosed herein, a lighting apparatus is provided which utilizes two or more complementary colored lamp elements in order to achieve a variety of lighting combinations which, for example, may be particularly useful for providing illumination for film or other image capture applications. A particular example will be described with respect to a lighting apparatus using lamp elements of two different colors, herein referred to as a "bi-color" lighting apparatus. In a preferred embodiment, the bi-color lighting apparatus utilizes light elements of two different colors which (unlike red, green, and blue) are separated by a relatively small difference in their shift or color balance. When reference is made herein to light elements of two different colors, the light elements may, for example, include a first group which provide light output at a first color and a second group which provide light output at a second color, or else the light elements may all output light of a single color but selected ones of the light elements may be provided with colored LED lenses or filtering to generate the second color. In a preferred embodiment, as will be described, the bi-color lighting apparatus uses lamp elements having daylight and tungsten hues (for example, 5200° K. and 3200° K. color temperatures, respectively). Other bi-color combinations may also be used and, preferably, other combinations of colors which are closely in hue or otherwise complementary in nature.

[0125] One possible advantage of a bi-color lighting system as will be described in certain embodiments below is the ability to more easily blend two similar colors (e.g., 5500 K and 3200 K color temperature hues), particularly when compared to a tri-color (e.g., RGB) lighting system that relies upon opposing or widely disparate colors. The blending process of two similar colors is not nearly as apparent to the eye, and more importantly in certain applications, is a more suitable lighting process for film or video image capture devices. In contrast, attempting to blend 3 primary or highly saturated (and nearly opposite colors) is much more apparent to the eye. In nature one may visually perceive the blending of bi-colors, for example, from an open sky blue in the shade, to the warmth of the direct light at sunset. Such colors are generally similar, yet not the same. Their proportion in relation to each other is a naturally occurring gradient in most every naturally lit situation. This difference is the basis of most photographic and motion picture lighting hues. These hues give viewers clues as to time of day, location and season. Allowing separate control of the two different color lamp elements (such as LEDs), through two separate circuit/dimmer controls or otherwise, provides the ability to easily adjust (e.g., cross-fade, cross-dim, etc.) between the two colors because they do not have significant color shifts when dimmed and blend in a visually pleasing manner, allowing the type of color gradients that occur in nature. In addition, virtually all still and motion picture film presently used in the industry is either tungsten or daylight balanced, such that various combinations of daylight

and tungsten (including all one color) are well matched directly to the most commonly used film stocks. These features make various of the lighting apparatus described herein particularly well suited for wide area still, video, and motion picture usage, especially as compared to RGB-based or other similar lighting apparatus. The above principles may also be extended to lighting systems using three or more lamp element colors.

[0126] FIG. 33 is a diagram of one embodiment of a lighting effects system 3300 having at least two different lamp element colors. As illustrated in FIG. 33, the lighting effects system 3300 comprises a lighting frame mounting surface 3302 having a plurality of lamp elements 3305 which, in this example, include daylight LEDs 3304 and tungsten LEDs 3303, although different lamp elements and/or different colors could be chosen. The lighting effects system 3300 further comprises various control electronics for controlling the illumination provided by the lamp elements 3305. In particular, the lighting effects system 3300 comprises an intensity control adjustment 3342, an intensity control circuit 3345, a ratio control adjustment 3341, and a ratio control circuit 3346. The intensity control adjustment 3342 and ratio control adjustment 3341 may each be embodied as, e.g., manual control knobs, dials, switches, or other such means, or alternatively may be embodied as a digital keypad, a set of digital buttons, or the like. A visual display (not shown) such as an LCD display may be provided to allow the operator to view the settings of the intensity control adjustment 3342 and ratio control adjustment 3341. Alternatively, the ratio control adjustment 3341 and/or intensity control adjustment 3342 may comprise digital commands or values received from a computer or similar device.

[0127] In operation, setting the intensity control adjustment 3342 selects the illumination level for the lamp elements 3305, while setting the ratio control adjustment 3341 selects the relative intensities between, in this example, the daylight LEDs 3304 and the tungsten LEDs 3303. The intensity control circuit 3352 and ratio control circuit 3346 may comprise analog and/or digital circuitry, and the output of the ratio control circuit 3346 modifies the incoming power supply separately for the daylight LEDs 3304 and the tungsten LEDs 3303 in a manner dictated by the setting of the ratio control adjustment 3341. Accordingly, by use of the ratio control adjustment 3341, the operator may select more daylight illumination by increasing the relative intensity of the daylight LEDs 3304 or may select more tungsten illumination by increasing the relative intensity of the tungsten LEDs 3303. To increase or decrease the overall light output intensity, the operator may adjust the intensity control adjustment 3342. The lighting effects system 3300 thereby may provide different combinations of daylight/tungsten coloration to match a wide variety of settings and circumstances, with the two colors being generally complementary in nature and thus providing a balanced, well blended illumination effect.

[0128] FIG. 34 is a diagram of another embodiment of a lighting effects system having at least two different lamp colors. As illustrated in FIG. 34, and similar to FIG. 33, the lighting effects system 3400 comprises a lighting frame mounting surface 3402 having a plurality of lamp elements 3405 which, in this example, include daylight LEDs 3404 and tungsten LEDs 3403, although different lamp elements and/or different colors could be chosen. The lighting effects system 3400, as with that of FIG. 33, further comprises various control electronics for controlling the illumination provided

by the lamp elements **3405**. In particular, the lighting effects system **3400** comprises individual intensity control adjustments **3451**, **3452** for daylight and tungsten lamp elements (e.g., LEDs) **3403**, **3404**, and individual intensity control circuits **3456**, **3457** also for the daylight and tungsten LEDs **3403**, **3404**. The tungsten intensity control adjustment **3451** and daylight intensity control adjustment **3452** may, similar to FIG. **33**, each be embodied as, e.g., manual control knobs, dials, switches, or other such means, or alternatively may be embodied as a digital keypad, a set of digital buttons, or the like. A visual display (not shown) such as an LCD display may be provided to allow the operator to view the settings of the two intensity control adjustments **3451**, **3452**. Alternatively, the intensity control adjustments **3451**, **3452** may comprise digital commands or values received from a computer or similar device.

[0129] In operation, setting the tungsten intensity control adjustment **3451** selects the illumination level for the tungsten LEDs **3403** via the tungsten intensity control circuit **3456**, and setting the daylight intensity control adjustment **3452** selects the illumination level for the daylight LEDs **3404** via the daylight intensity control circuit **3457**. The relative settings of the tungsten intensity control adjustment **3451** and the daylight intensity control adjustment **3452** generally determine the relative intensities between, in this example, the daylight LEDs **3404** and the tungsten LEDs **3403**. The intensity control circuits **3456**, **3457** may comprise analog and/or digital circuitry, and the relative outputs of the tungsten intensity control circuit **3456** and the daylight intensity control circuit **3456** generally determine the illumination level and composition. The operator may select more daylight illumination by increasing the relative intensity of the daylight LEDs **3404** or may select more tungsten illumination by increasing the relative intensity of the tungsten LEDs **3403**. The lighting effects system **3400** thereby may provide different combinations of daylight/tungsten coloration to match a wide variety of settings and circumstances, as with the FIG. **33** embodiment.

[0130] Because the two different colors of LEDs (e.g., daylight and tungsten) can be controlled separately (through common or separate circuitry), and because these particular LEDs, or other similar complementary colors, do not have significant color shifts when dimmed, it would be relatively straightforward to adjust (e.g., cross-fade, cross-dim) between the two colors and, for example, provide a variety of natural light illumination effects for various types of common film stock.

[0131] The lighting apparatuses of FIGS. **33** and **34** may, if desired, be physically embodied in a manner as described elsewhere herein; for example, the lighting apparatus may be embodied with a generally ring-shaped lighting frame as illustrated in and/or described with respect to FIG. **4**, or with a portable frame such as generally illustrated in and/or described with respect to FIG. **35**. The principles and underlying concepts associated with the embodiments of FIGS. **33** and **34** may be extended to support more than two colors of lamp elements **3305** or **3405**. Moreover, the lighting apparatuses of FIGS. **33** and **34** may utilize any number of lamp elements in a bi-color or other multi-color arrangement, in any desired pattern.

[0132] Returning now to the general diagram of a lighting effects system **201** illustrated in FIG. **2** (although the following comments will apply to various other embodiments such as the lighting frame assembly shown in FIGS. **3** and **4**), the

LEDs or other low power lamps **205** may be operated at a standard direct current (DC) voltage level, such as, e.g., 12 volts or 24 volts, and may be powered by a power source **210** controlled by a power controller **212** such as generally shown in FIG. **2**. The power source **210** can generally comprise a standard electrical outlet (i.e., nominal 110 volt AC power line), although in various embodiments the power source **210** could also be a battery having sufficient current to drive the LEDs or other low power lamps **205**. In some embodiments, the power controller **212** may be omitted, and the lighting frame **202** may be connected directly to the power source **210**.

[0133] Block diagrams of two different types of power controllers **212** as may be used in various embodiments as described herein are illustrated in FIGS. **10A** and **10B**, respectively. With reference to FIG. **10A**, a first type of power controller **1012** has an input for receiving an AC power source **1003**, and outputs a plurality of power wires **1047** preferably through a cable (e.g., cable **213** shown in FIG. **2**) for connection to the lighting frame **202**. The power controller **1012** may further comprise a power converter **1020**, the nature of which depends upon the type of power source **210**. If the power source is an AC source, the power converter **1020** may comprise an AC-to-DC converter and appropriate step-down power conversion circuitry (e.g., a step-down transformer). On the other hand, if the power source is a DC source (e.g., a battery), the power converter **1020** may comprise a DC-to-DC converter, if necessary. The design and construction of power converters is well known in the field of electrical engineering, and therefore is not described herein in detail.

[0134] The power converter **1020** is preferably connected to a plurality of switches **1022**, which may be solid state devices (e.g., transistors) or analog devices (e.g., relays), each switch controlling power delivered by the power converter **1020** to one of the wires **1047** output by the power controller **1012**. A switch selector **1042** controls the on/off state each switch (or group) in the set of switches **1022**. A manual interface **1030** is provided to allow operation of the switches **1022** according to manual selection. The manual interface **1030** may include a master power switch **1031**, switch controls **1032**, and, optionally, an effects selector **1033**. The switch controls **1032** may include an individual manual switch, button or other selection means for each individual switch provided in the set of switches **1022**, or else may comprise a control mechanism (such as knob or reduced number of manual switches, buttons or other selection means) for selecting groups of switches **1022** according to predesignated arrangements. As but one example, assuming a light arrangement such as shown in FIG. **4**, a knob provided as part of the switch controls **1032** could have a first setting to select all of the light segments **306**, a second setting to select every other light segment **306**, and a third setting to select every fourth light segment **306**, thus providing options of 100%, 50% and 25% total light output. The switch selector **1042** would then convert each knob setting to a set of control signals to the appropriate switches **1022**, which in turn would control power to the wires **1047** supplying power to the light segments **306**.

[0135] As another example, the switch controls **1032** could include an individual manual switch, button or other selection means for each light segment **306** or group of light segments **306** in the lighting arrangement.

[0136] An effects generator **1043** may optionally be included in the power controller **1012**, along with an effects selector **1033** which forms part of the manual interface **1030**.

The effects generator **1043** may provide the ability to create various lighting effects, such as, e.g., dimming, strobing, pulsation, or pattern generation. The effects selector **1043** may affect all of the switches **1022** simultaneously, or else may affect individual switches or groups of switches **1022**, depending upon the desired complexity of the lighting effects. Dimming may be accomplished, for example, through a manual control knob or multi-position switch on the effects selector **1033**. The dimming control may be electronically implemented, for example, in an analog fashion through a variable resistive element, or in a digital fashion by detecting the selected manual setting and converting it to selecting power setting through, e.g., selected resistive elements in a resistive ladder circuit. Where the switches **1022** are implemented, for example, as controllable variable amplifiers, the selectable resistance may be used to control the output of each amplifier and thereby the light output by the amplifier's respective light segment **306** (or group of light segments **306**). In other embodiments, the dimming control may optionally be applied to the output of switches **1022**. Where dimming control is applied collectively, it may be implemented by applying the selected dimming control level to the incoming signal from the power converter **1020**, which is supplied to all of the switches **1022** collectively. Other variations for implementing dimming control are also possible and will be apparent to those skilled in the art of electrical engineering.

[0137] Strobing may be accomplished by generating an oscillating signal and applying it as a control signal either upstream or downstream from the switch selector **1042**. The frequency of oscillation may be selectable via a manual knob, switch or other selection means as part of the effects selector **1033**.

[0138] Pattern generation may be accomplished by, e.g., manual selection from a number of predefined patterns, or else through an interface allowing different pattern sequencing. Patterns may include, for example, strobing or flashing different groups of light segments **306** (given the example of FIG. 3) in a predefined sequence (which may be a pseudo-random sequence, if desired), strobing or flashing different low power lamps **305** of the light segments **306** in a predefined (or pseudo-random) sequence, gradually dimming or brightening the light segments **306** (individually, in groups, or collectively), or various combinations of these effects.

[0139] Alternatively, rather than providing a separate effects selector **1033**, certain effects may be combined with the switch controls **1032**. For example, a dimmer switch (knob) could be used to both activate a light segment **306**, or group of light segments **306**, and also control light output via rotation of the dimmer switch (knob).

[0140] FIG. 10B is a block diagram showing another example of a power controller **1052** as may be used, for example, in the lighting effects system **200** of FIG. 2 or other embodiments described herein. Like the power controller **1012** shown in FIG. 10A, the power controller **1052** shown in FIG. 10B includes a power source input **1053** connected to a power converter **1060**. It further includes a set of switches **1062** receiving power from the power converter **1060**, and providing power to individual wires **1097** which are conveyed, preferably by cable, to the lighting frame assembly **201** of the lighting effects system **200**. The power controller **1052** also includes a switch selector **1072**, which may comprise, for example, a set of registers which provide digital signals to the switches **1062** to control their on/off state.

[0141] The power controller **1052** includes a processor **1074** which may be programmed to provide various lighting effects by manipulating the switch selector **1072** (for example, by changing values in registers which control the on/off states of the switches **1062**). The processor **1074** may interface with a memory **1075**, which may comprise a volatile or random-access memory (RAM) portion and a non-volatile portion (which may comprise, e.g., ROM, PROM, EPROM, EEPROM, and/or flash-programmable ROM), the latter of which may contain programming instructions for causing the processor **1074** to execute various functions. The memory **1075** may be loaded through an I/O port **1076**, which may include an electrical serial or parallel interface, and/or an infrared (IR) reader and/or bar code scanner for obtaining digital information according to techniques well known in the field of electrical engineering and/or electro-optics. An interface **1080** may also be provided for programming or otherwise interfacing with the processor **1074**, or manually selecting various lighting effects options through selectable knobs, switches or other selection means, as generally explained previously with respect to FIG. 10A. The processor-based control system illustrated in FIG. 10B may also include other features and components which are generally present in a computer system.

[0142] In operation, the processor **1074** reads instructions from the memory **1075** and executes them in a conventional manner. The instructions will generally cause the processor **1074** to control the switch selector by, e.g., setting various digital values in registers whose outputs control the switches **1062**. The programming instructions may also provide for various lighting effects, such as dimming, strobing, pulsation, or pattern generation, for example. To accomplish dimming, the processor **1074** may be programmed select binary-encoded values to load into registers of the switch selector **1072**, which in turn select a variable resistance value which controls the output from each individual or group of switches **1062**. To accomplish strobing, the processor **1074** may be programmed to turn the switches **1062** on and off according to a pre-designated pattern dictated by the programming instructions. The processor **1074** may make use of one or more electronic timers to provide timing between on and off events. The programming instructions may provide that the switches **1062** are turned on and off according to designated sequences, thus allowing the capability of pattern generation via the processor **1074**. As mentioned before, patterns may include, for example, strobing or flashing different groups of light segments **306** (given the example of FIG. 3) in a predefined (or pseudo-random) sequence, strobing or flashing different low power lamps **305** of the light segments **306** in a predefined (or pseudo-random) sequence, gradually dimming or brightening the light segments **306** (individually, in groups, or collectively), or various combinations of these effects.

[0143] Although the lighting frame **302** and lighting arrangement illustrated in FIG. 3 provides various advantages, other lighting frames and other lighting arrangements may also be used in a lighting effects system, and may be employed in connection with various techniques as described herein.

[0144] Another embodiment of a lighting frame **1101**, for example, is illustrated in FIG. 11. The lighting frame **1101** shown in FIG. 11 may be used in connection with a lighting effects system **201** such as shown in and previously described with respect to FIG. 2, and may be constructed according to general principles described previously with respect to FIGS.

15A-15C and 16A-16E. As shown in FIG. 11, a lighting frame **1101** is generally ring-shaped and has an opening **1107** through which a camera or other image capture device can view. On the lighting frame **1101** may be mounted a plurality of lamps **1112** or in some instances even a single lamp **1112**. In the embodiment shown in FIG. 11, the lamps **1112** may be embodied as slim, narrow fluorescent “cold cathode” tubes with an internal phosphorous coating emitting visible light of certain wavelength (for example, a color temperature of around 3200 deg. K or 5500 deg. K, both of which temperatures are commonly used in film and photography applications). FIG. 14 is a graph illustrating an example of a spectral distribution of light (in terms of light wavelength) in accordance with such a lighting effects system. The lamps **1112** are preferably oriented as illustrated in FIG. 11—that is, in a radial pattern, emanating from a centerpoint **1119** of the opening **1107** in the middle of the lighting frame **1101**. Where embodied as cold cathode tubes, the lamps **1112** may be of any suitable size, such as, e.g., 3 to 10 millimeters in diameter and 25 to 250 millimeters in length.

[0145] Preferably, the lamps **1112** are controllable such that they can produce higher intensity or lower intensity light, and/or can be turned on or off in selected groups to adjust the overall light level provided by the lighting system. One possible means for controlling the light intensity of lamps **1112** is illustrated in FIG. 13. As shown therein, a light control system **1301** includes a selector switch **1310** which has a plurality of settings **1312**, each of the settings **1312**, in this example, providing a different combination of lamps **1112** (shown as elements **1322** in FIG. 13). By way of illustration, a first setting may illuminate all of the lamps **1322**; a second setting may illuminate every other lamp **1322**; and a third setting may illuminate every fourth lamp **1322**, in each case providing a relatively even distribution of light but of a different overall intensity. For example, if 24 lamps were used, then the first setting would illuminate all 24 lamps, the second setting would illuminate 12 of the 24 lamps, and the third setting would illuminate six of the 24 lamps. The settings may correspond to any desired combination of lamps **1112**. For example, each setting may be designed to control an equal number of lamps **1112**, but in a different combination. The settings may be selected by any type of analog or digital input means (e.g., a manual knob, a set of switches or buttons, or a programmable interface), and any number of settings or programmable patterns may be offered.

[0146] Power for the lighting control system **1301** may be supplied by a battery **1305**, which may have a voltage rating of, e.g., 12 volts. The battery **1305** may be rechargeable in nature. Alternatively, or in addition, power may be provided from an alternating current (AC) source, such as a standard 120 volt electrical outlet, connected to an AC-to-DC power converter. The output of the battery **1305** may be controlled by a dimmer switch (not shown), to allow the light intensity level of lamps **1312** to be reduced. Alternatively, or in addition, dimming and/or pulsing can be controlled through a pulse width modulation (PWM) circuit **1317**. A first control means (e.g., a manual switch or knob, or programmable interface) (not shown) may be provided for dimming the lamps **1322**. For example, a manual knob may control the conductance of a variable resistor, thus allowing more power or less power to reach the lamps **1322**. In this way, the selected lamps **1322** may be brightened or dimmed, down to around 20% of their total light output. The PWM circuit **1317** may also, through a second control means (e.g., a manual switch or

knob, or a programmable interface) allow pulsing of the light (i.e., a strobing effect) by adjustment of a pulse width modulation frequency. For example, a manual knob may control a variable resistive element, which in turn controls the width of pulses being generated by the PWM circuit **1317**. Various techniques for generating pulses of different widths using a variable resistive element to control the selection of the width are well known in the electrical arts.

[0147] Energy is preferably delivered to the various lamps **1322** in FIG. 13 through a plurality of high frequency (HF) ballasts **1325**, which are capable of converting low DC voltage of the battery **1305** to high DC voltage (e.g., 800 to 1500 volts) for starting the lamp, and mid-level voltage (e.g., 170 to 250 volts) for sustaining lamp operation. Other techniques may also be used to deliver energy to the lamps **1322**.

[0148] While shown in a radial pattern in FIG. 13, the lamps **1322** (e.g., fluorescent tubes) may also be arranged in other patterns, such as patterns similar to those depicted, for example, in FIGS. 30A, 30B and 30C. FIG. 46 illustrates one example of a pattern of arranging fluorescent tubes (in this case, circular fluorescent tubes) on a lighting frame **4602**. In FIG. 46, a lighting assembly **4600** includes a ring-shaped lighting frame **4602** with two fluorescent lamps **4605**, an inner (small circumference) fluorescent lamp and an outer (larger circumference) fluorescent lamp. Additional fluorescent lamps (circular or otherwise) may also be added to the lighting frame **4602**, or else a single fluorescent lamp may in some cases be utilized. The lighting frame **4602** may, as previously described, be constructed of a lightweight, durable material, and it may have a bracket or other mounting mechanism for mounting to a camera frame or lens (with the camera lens preferably viewing through the generally central hole **4613** in the lighting frame **4602**), and/or a bracket or other mounting mechanism for allowing the lighting frame **4602** to be connected to a yoke or stand (such as conceptually represented by arm **4619** in FIG. 46). Energy for the fluorescent lamps **4605** may be provided as previously described herein, such that the lighting assembly **4600** can provide continuous light or, if applicable, various lighting effects.

[0149] FIG. 12 is a diagram illustrating various options and accessories as may be used in connection with the lighting assembly frame depicted in FIG. 11. As shown in FIG. 12, the lighting frame **1101** may be augmented with a diffusion filter **1205** and/or a color filter **1215**, which may, if desired, be secured into place through a cover **1218** (e.g., a clear plastic cover) which locks or snaps onto the lighting frame **1101**. Similar accessories may be utilized, for example, in connection with the lighting frame **302** illustrated in FIGS. 3 and 4. Illustrations of filtering techniques, through the use of waveguides and other means, are described, for example, in U.S. Pat. Nos. 6,272,269 and 6,270,244, both of which are incorporated by reference herein in their entirety.

[0150] FIG. 44 illustrates, among other things, an adjustable lens cover **4418** similar in general nature to the cover **1218** shown in FIG. 12. In the particular example illustrated in FIG. 44, threading **4491** is provided on the outer surface of the lighting frame **4402** (which may be generally analogous to lighting frame **1101** shown in FIG. 12), and matching threading **4492** is provided on the interior surface of the adjustable lens cover **4418**. The adjustable lens cover **4418** may be formed of clear plastic or a similar material and may be constructed with lenslike attributes (e.g., focal, diffusion) and/or may also be colorized if desired. The adjustable lens cover **4418** is secured to the lighting frame **4402** by twisting

the cover **4418** onto the lighting frame **4402** in a screw-like fashion, thereby causing the threadings **4491**, **4492** to interlock. By the number of rotations of the lens cover **4418** with respect to the lighting frame **4402**, the distance of the “top” surface of the lens cover **4418** to the lighting elements **4405** on the lighting frame **4402** may be varied, thus allowing different lens effects. As further illustrated in FIG. 44, one or more coiled springs **4492** or other similar elements may be provided atop the lighting frame **4402**, to secure one or more color gels **4415** or other filtering objects against the inner “top” surface of the adjustable lens frame **4418**, when such objects are placed within the cover **4418** in the manner shown, for example, in FIG. 12.

[0151] As an alternative to the complementary threading provided on the lens cover **4418** and the lighting frame **4402**, other adjustment means may be provided. For example, the lens cover **4418** may be secured to the lighting frame **4402** by one or more adjustable screws which dictate the distance of the “top” surface of the lens cover **4418** from the lighting frame **4402**. Also, slide-and-lock mechanisms may be used as well.

[0152] It will be appreciated that, in various embodiments, a flexible, lightweight and functional lighting effects system is provided, whereby relatively uniform light may be used in illumination of a subject or area. The lighting effects system may, in various embodiments, allow a lighting frame to be secured to a camera or other image capture device, so as to permit the lighting system to be mobile and move in tandem with the camera or other image capture device, if desired. Also, in various embodiments, the lighting effects system may provide a variety of lighting patterns, including programmable patterns by which individual or groups of lights can be controlled for different lighting effects. The lighting frame may, in certain instances, be formed in multiple sections and hinged to allow the lighting frame to fold, or else snapped apart section by section, for ease of transport.

[0153] In various alternative embodiments, the lighting frame need not be ring-shaped in nature, as shown in FIGS. 3 and 4, for example, but could have other shapes as well. For example, the lighting frame may be square, hexagonal, octagonal, or other polygonal, or could, for instance, have a partially polygonal shape. Preferably, the lighting frame is relatively thin, as compared to its overall size, although it need not be. Also, the lighting frame preferably has a hole generally centered therein to allow a camera or other image capture device to view through the frame, although in some embodiments a viewing hole may not be present. The exterior portion of the lighting frame, or at least the exterior portion thereof, is preferably made of a lightweight, durable material such as plastic and/or lightweight metal (e.g., aluminum), optionally anodized, although in various embodiments it can be made of other materials as well, including any type of metal, wood, plastic, or combination thereof. The interior lighting frame portion may advantageously comprise a printed circuit board.

[0154] Other variations may pertain to the manner of attaching the lighting frame to a camera or other image capture device. Rather than using a single mounting bracket or assembly, for example, multiple mounting brackets or assemblies may be used. Also, the mounting bracket or assembly may be permanently attached or affixed to the lighting frame, and may be, for example, retractable or foldable for convenience of transportation. The lighting frame may attach either to the camera body or to the lens portion of the camera. The

lighting frame may attach to the camera lens through any of a variety of means, such as by engaging an outer camera lens threading through a threading on the interior circular hole of the lighting frame, engaging an inner camera lens threading by providing a complementary threaded extension for that purpose, by a strap means to secure the lighting frame to the camera and/or stand, or by a “hose-clamp” type strap which grips the outer cylinder of the camera lens. Also, rather than attaching to the camera, the lighting frame may be portable, and may be outfitted with handles for lighting crew to manually carry or hold the lighting frame, or may be adapted to attach to a stand or fixture for providing stationary illumination. The lighting frame may also be adapted to attach to a machine arm or other contrivance for allowing the lighting effects system to be moved as needed for filming or other desired purposes.

[0155] Further embodiments, variations, and modifications pertain to the type of lamp elements that may be utilized in a lighting effects system and/or the manner of constructing a lighting frame particularly well suited for placing numerous lamp elements thereon. One method of construction involves the use of surface mount LEDs of the type illustrated, for example, in FIG. 31. As shown therein, a surface mount LED **3100** comprises a body **3104** having a thermal shoe on the bottom surface **3103** and a pair of soldering tabs **3102** for securing the surface mount LED **3100** to a circuit board (e.g., an aluminum core circuit board) or other suitable surface. A lens **3101** atop the body **3104** directs the light generated by the surface mount LED **3100** outwards. While the body **3104** and the lens **3101** of the surface mount LED **3100** radiate heat, the soldering tabs **3102** as well as the thermal shoe on the bottom surface **3103** assist in conducting heat to the mounting surface (e.g., circuit board) and thus may provide advantageous heat dissipation capabilities, particularly as compared to non-surface mount LEDs which tend to dissipate heat typically through their leads. Use of surface mount LEDs provides a larger and more direct heat conduction path to the mounting surface (e.g., circuit board), and may also provide advantages in ease of fabrication and improved durability.

[0156] In various embodiments as described herein, the lamp elements used in a lighting effects system or lighting apparatus may comprise high output semiconductor lights such as, for example, high output LEDs. Such high output LEDs are available from Lumileds Lighting, LLC of San Jose, Calif. under the product brand name Luxeon™. High output LEDs are presently available in white as well as colors such as green, blue, red, amber, and cyan, are fully dimmable, and generally operate at about one to several Watts (e.g., 5 Watts), outputting in certain devices approximately 24 lumens per Watt. The high output LEDs may be mounted upon, e.g., a metal printed circuit board (PCB) such as an aluminum core circuit board. High output LEDs may be used in connection with any of the embodiments previously described herein, and may provide advantages of increased lighting output with fewer lamp elements and, hence, reduced cost of construction in certain cases. However, the driving circuitry for the high output LEDs would generally need to have a higher output rating than the circuitry used for lower power LEDs.

[0157] FIGS. 36A and 36B are diagrams of two other types of high output surface-mount LEDs, both of which are commercially available from Lumileds Lighting, LLC under the brand name Luxeon™. In FIG. 36A, the surface mount LED **3600** comprises an aluminum bottom plate **3611** atop of

which is a printed circuit board (PCB) **3608** (e.g., a fiberglass board such as a standard FR4 board). A high output light source **3605** is mounted atop the PCB **3608**. The aluminum bottom plate **3611** acts as a thermal conveyance which assists in conduction of heat to a mounting surface (e.g., circuit board) for thermal dissipation. FIG. **36C** shows an oblique view of the surface mount LED **3600** shown in FIG. **36A**, illustrating, in this example, the relatively wide bottom plate **3611** relative to the size of the light source **3605**. The bottom plate **3611** and PCB **3608** preferably have notches **3615** through which screws may be placed to secure the surface mount LED **3600** to a mounting surface. FIG. **36B** illustrates another surface mount LED **3650** that is similar in certain respects to the surface mount LED **3650** shown in FIG. **36A**, with an aluminum bottom plate **3661** and printed circuit board **3658** (e.g., fiberglass board such as a standard FR4 board). However, in contrast to the surface mount LED **3600** shown in FIG. **36A**, which is Lambertian (domed) in nature, the high output light source **3655** of surface mount LED **3650** is a side emitting light source. Other alternative types of surface mount LEDs, with similar or alternative mounting mechanisms, may also be utilized in various embodiments described herein.

[0158] FIG. **37A** is a diagram of one embodiment of a lens cap **3702** for a single LED. The lens cap **3702** may act as a focusing lens to direct the light output from an LED in a forward (or other) direction. FIGS. **37B** and **37C** illustrate placement of the lens cap **3702** with respect to the surface mount LED **3600** of FIG. **36A**. As illustrated, the protruding tabs **3704** on the base of the lens cap **3702** may be used to lock the lens cap **3702** into place by snugly residing in the holes **3615** of the base of the surface mount LED **3600**. A similar type of lens cap may be used for other types of LEDs. While six tabs **3704** are shown in the example of FIGS. **37A-37C**, the number of tabs, or the nature and/or shape of other alternative securing means, may depend upon the particular size, shape, and configuration of the LED base. Also, fewer tabs may be used if there is a desire leave some holes **3615** in the LED base available for receiving securing screws to hold the LED to a mounting surface. In such a case, the lens cap **3702** may be indented or otherwise shaped to allow relatively convenient access to the holes **3615** needed for attaching screws. The lens cap **3702** is illustrated as domed, but may be of any suitable shape for focusing light in a desired manner.

[0159] The lens cap **3702** may have an advantage in providing local effects on an individual basis for LEDs. Also, where different color lighting elements are placed within a single high output LED **3600**, the lens cap **3702** may be configured to provide local blending of the different colors according to a desired mix.

[0160] FIGS. **37D** and **37E** are diagrams illustrating another embodiment of a lens cap **3752** for an LED, and placement thereof with respect to a particular type of LED **3600**. With reference first to FIG. **37E**, an illustrated embodiment of lens cap **3752** is shown from an oblique viewpoint in a generally funnel shape, with a cone-like or tapered portion **3753** and a short cylindrical portion **3754** at the apex (i.e., narrow end) of the tapered portion **3753**. The lens cap **3752**, including the cone-like tapered portion **3753**, is preferably transmissive in nature such that light travels through it substantially unimpeded. FIG. **37D**, which is a side profile diagram, illustrates preferred placement of the lens cap **3752** with respect to a particular type of LED (that is, the LED **3600** illustrated in FIGS. **36A** and **36C**). The cylindrical portion

3754 of the lens cap **3752** rests atop the LED **3600**, with the tapered portion **3753** gradually widening away from the LED **3600**. A concave recess **3755** within the cylindrical portion **3754** may be provided, and is adapted to receive the curved lens **3605** of the LED **3600**, as illustrated in FIG. **36D**. Light from the LED **3600** enters through the short cylindrical portion **3754** of the lens cap **3752**, and exits through the top surface **3759** (see FIG. **37E**) thereof. The particular shape of the lens cap **3752** in FIGS. **37D** and **37E** serves to collect light from the LED **3600** that would otherwise emanate omnidirectionally, and focus the light in a generally conical beam emanating from the top of the lens cap **3752**, thus providing a light source with greater directivity.

[0161] The lens cap **3752** may be formed of, e.g., glass, plastic, or other suitable material or compound/layers of material, with any desired refractive index(es). One type of lens cap is commercially available, for example, from Lumileds Lighting, LLC.

[0162] FIG. **32** is a generalized diagram of an array of surface mount LEDs **3202** (of the type such as shown, for example, in FIG. **31**, **36A**, or **36B**) mounted atop a circuit board **3204**, as may be used in various embodiments as described herein (for example, the lighting effects system illustrated in FIG. **4**). The circuit board **3204** may comprise rigid fiberglass or phenolic planes with electrically conductive tracks etched on them, and/or may be metallic in nature (such as aluminum core PCBs). The term "circuit board" as used herein is meant to encompass the foregoing structures as well as various other types mounting apparatus, including flexible electrical interconnects such as conductive membranes made on thin Mylar, silicone, or other similar materials. The surface mount LEDs **3202** may be connected together in series and/or in parallel by electrical traces **3203** on the circuit board **3200**. While the LEDs **3202** are illustrated in FIG. **32** as being in a straight line array, other LED patterns may also be utilized. As previously mentioned, the soldering tabs and thermal shoe on the bottom each of the surface mount LEDs **3202** generally assist in conducting heat to the circuit board **3204**, thus providing advantageous heat dissipation capabilities.

[0163] FIG. **35** is a diagram of a lighting apparatus **3500** embodied as a panel **3502** having lighting arrays mounted thereon or therewith, in accordance with various embodiments as described herein. As illustrated in FIG. **35**, the lighting apparatus **3500** comprises a panel **3502** which is preferably flat and provides suitable surface area for mounting a set of lamp elements, such as lamp elements **3505** on circuit board assemblies **3506**. The circuit board assemblies **3506** may generally be constructed in accordance with the principles described with respect to FIG. **32** above, and the lamp elements **3505** may comprise, for example, surface mount LEDs such as illustrated in FIG. **31**. In the example shown, the lamp elements **3505** are generally arranged in series in a straight array formation, but the lamp elements **3505** may be arranged in other patterns as well. Likewise, the circuit board assemblies **3606** are illustrated in FIG. **35** as being arranged in a symmetrical pattern of rows thus providing relatively even illumination in many scenarios, the circuit board assemblies **360** may be arranged in other symmetrical or non-symmetrical patterns, and may be grouped or clustered as well. Furthermore, while the panel **3202** is shown in FIG. **35** as being generally rectangular in shape, the panel **3202** may take any suitable shape, including, for example,

hexagonal, octagonal, or other polygonal or semi-polygonal, or round, oval, or ring-shaped (such as illustrated in FIG. 4 for example).

[0164] Surface mount technology for the LEDs used in various embodiments as disclosed herein may simplify replacement of the LEDs (allowing “drop in” replacements for example) or else may allow easy replacement of an entire row or array of LEDs should it be desired to change the color of a particular group of LEDs. Also, the LED arrays may be constructed such that the LEDs have screw-in bases or other similar physical attachment means, such that the LEDs can be easily removed and replaced.

[0165] Various controls, power supply, and camera mounting means are not shown in FIG. 35, but may be employed in a manner similar to the various other embodiments as described herein. It will be appreciated that the control electronics, power supply, and other electrical components may be part of the panel 3202 or else may be separate therefrom. Furthermore, the lighting apparatus described with respect to FIG. 35 may be embodied as a bi-color or other multi-color lighting system, as described with respect to, e.g., FIGS. 33 and 34.

[0166] The lighting apparatus 3500 of FIG. 35 or other various lighting effects systems and apparatuses as described herein may include means for directing light at different angles. Such means may include, for example, pivotable light arrays which physically alter the angle of the lamp elements with respect to the frame (e.g., mounting) surface. The pivoting light arrays may be either manually controllable (via, e.g., a rotatable knob or crank) or electronically controllable through standard electronic input means (e.g., buttons or control knob). Such means may alternatively include adjustable lens elements (either individual or collective for an entire lens array or other group of lamp elements) for redirecting the illumination in a desired direction. Such means may further alternatively include, for example, groups of lamp elements wherein each group has a predetermined angle or range of angles with respect to the frame surface. Each group of lamp elements may be separately controllable, so that different groups can be separately activated or de-activated, or separately intensified or dimmed. With the ability to vary the angle of the lamp elements, the lighting effects system may, for example, allow the abrupt or gradual switching from one angle of illumination to another, or from a more targeted to a more dispersive illumination pattern (or vice versa).

[0167] FIGS. 39 and 40 illustrate various panel light embodiments using surface mount LEDs. In FIG. 39, a panel light 3900 comprises one or more rows or arrays (in this example, two rows or arrays) of surface mount LEDs 3905 secured to a mounting surface 3902. Screws 3996 are used in this example to secure the bases of the surface mount LEDs 3905 to the mounting surface 3902. FIG. 40 is similar, with a panel light 4001 having, in this example, four rows or arrays of surface mount LEDs 4005 securing to a mounting surface 4002 with, e.g., screws 4096. The mounting surfaces 3902 or 4002 may comprise a circuit board, and thus LEDs 3905 or 4005 may be mounted directly to a circuit board type mounting surface. The circuit board may be attached to an outer frame of aluminum or another preferably lightweight material, to provide a solid structural support for the circuit board. Panel lights 3900 or 4001 such as shown in FIGS. 39 and 40 may be used as relatively lightweight, portable lighting fixtures that generate less heat than incandescent lighting fixtures, and may be provided with handles for manual manipu-

lation or with brackets or other means to connect to a yoke, stand, or other mechanical contraption. The panel lights 3900 and 4001 may use a ballast to supply power or, in some instances, may be directly connected to an AC electrical outlet (e.g., wall socket).

[0168] FIG. 41A illustrates a panel light 4100 of the general type shown, for example, in FIGS. 39 and 40, further illustrating a number of heat conductive fins 4112 which serve to assist with heat dissipation. The panel light 4100 may optionally include a means for facilitating attachment to a single- or multi-panel lighting assembly. In the present example, the panel light 4100 has a pair of T-shaped cutouts 4116 located in each of the fins 4112, such that the T-shaped cutouts 4116 form a pair of straight line, T-shaped grooves through the series of fins 4112. The T-shaped cutouts 4116 may be slid over a T-shaped bar to attach the panel light 4100 to a lighting assembly.

[0169] FIG. 41B is a diagram of an example of a multi-panel lighting assembly 4150, illustrating attachment of a panel light 4100 as shown in FIG. 41A to the lighting assembly 4150. In the example of FIG. 41B, the lighting assembly 4150 includes a pair of T-shaped bars 4165 which protrude from a lighting assembly frame 4160, and which are matched to the T-shaped cutouts 4116 in the lighting panel 4100 of FIG. 41A. Once the lighting panel 4100 is slid into place along the T-shaped bars 4165, they securely hold the lighting panel 4100 in place. Insulated caps (not shown), made of rubber or plastic for example, or other such means may be placed on the ends of the T-shaped bars 4165 to prevent the lighting panel 4100 from sliding out of place. In the particular example shown, the multi-panel lighting assembly 4150 is configured to receive up to two lighting panels 4100 of the type shown in FIG. 41A, although such an assembly may be configured to receive any number of lighting panels 4100 depending upon the particular needs of the application. The multi-panel lighting assembly 4150 also has another lighting panel 4167 that may be “permanently” attached to or integral with the multi-panel lighting assembly 4150, or else may likewise be attachable and detachable in the manner of lighting panel 4100. The multi-panel lighting assembly 4150 thereby provides a lighting operator with a variety of lighting configurations in a single unit. Other similar modular multi-panel lighting assemblies may be constructed according to the same or similar principles, having any number of panel lights in a variety of different sizes and/or shapes. The multi-panel lighting assembly 4150 may, in certain embodiments, be used in connection with a lighting stand such as illustrated, for example, in FIG. 43 and described elsewhere herein.

[0170] Attachment of panel lights (such as, e.g., panel lights 4100) to a multi-panel lighting assembly (such as, e.g., multi-panel lighting assembly 4150) may be accomplished by a variety of means. For example, rather than using complementary bars 4165 and cutouts 4116, the panel light 4100 may drop down and lock into an opening in the multi-panel lighting assembly 4150. In such a case, the housing or frame of the multi-panel lighting assembly 4150 may have a molded beam with traverses the outer edge of the opening in which the panel light 4100 would be positioned. Locking tabs, for example, or other such means may be used to secure the dropped-in panel light 4100 within the opening of the multi-panel lighting assembly 4150.

[0171] FIG. 38A is a diagram of ring-shaped lighting panel 3800 having surface mount LEDs 3805 (such as, e.g., the high output surface mount LEDs shown in FIG. 36A or 36B)

attached to a mounting surface of a frame **3802** which, as with the panel lights described before, may comprise a circuit board. The ring-shaped lighting panel **3800** may have a camera mounting bracket (not shown in FIG. **38A**) and generally be utilized in a manner similar to the ring-shaped lighting assembly shown in FIG. **4** and described in various places herein. The surface mount LEDs **3805** in the example of FIG. **38A** are arranged in a plurality of rows or arrays **3806** emanating from the center of the hole or cutout region **3803** of the lighting panel **3800**. While a relatively dense pattern of LEDs **3805** is illustrated in FIG. **38A**, the pattern may be less dense, and the LEDs **3805** need not necessarily be deployed in rows or arrays. Because the LEDs **1305** in this example are high output, the lighting panel **3800** outputs a greater total amount of light than with ordinary LEDs. Also, fewer LEDs need to be physically mounted on the lighting panel **3800**, which can reduce cost of construction.

[0172] FIG. **38B** is a cross-sectional view of the lighting panel **3800** showing the inclusion of optional fins **3812** on the backside of the frame **3802**, to assist with heat dissipation. The fins **3812** are shown in cross-section, and form a set of parallel members similar to the fins **4112** shown in FIG. **41A**.

[0173] FIG. **42A** illustrates an integrated lens cover **4200** which can be placed atop, e.g., a panel light **4202** for providing focusing for a plurality of LEDs simultaneously. The panel light **4202** has rows of LEDs **4205**, similar to FIGS. **39** and **40**, and the integrated lens cover **4210** may be placed atop the panel light **4202** and, e.g., snapped into place by tabs **4212**, or otherwise secured to the frame of the panel light **4202**. FIG. **42B** shows additional detail of the integrated lens cover **4210**. The integrated lens cover may be formed of any suitable lightweight, durable material (such as plastic) and preferably has a number of focal lens portions **4219** which, when the unit is placed atop the panel light **4202**, act as focal lenses for LEDs **4205** which are positioned directly beneath the focal lens portions **4219**. The integrated focal lens **4210** may thus allow the panel light **4202** to provide more directed, focused light (e.g., in a forward direction), rather than allowing the light to diffuse in an omnidirectional fashion. Alternatively, the integrated focal lens **4210** may provide other focusing effects that can be done with lenses. The focal lens portions **4219** may be domed or semi-domed, or else any other shape sufficient to serve their intended purpose.

[0174] FIGS. **42C** and **42D** are side profile diagrams illustrating further details of alternative embodiments of an integrated focal lens. FIG. **42C** illustrates an integrated focal lens **4265** with tapered focal lenses **4251** emanating from the underside of the sheet-like surface **4250** of the integrated focal lens **4265**. In the instant example, the tapered focal lenses **4251** appear as inverted cone-like projections, with small concave recesses **4252** for receiving the dome-like lenses **4255** of LEDs **4256**, which are mounted to a mounting surface **4260**. The tapered focal lenses **4251** may be constructed in a manner as generally described previously with respect to FIGS. **37D** and **37E**, and may also have a short cylindrical portion **3754** such as illustrated in those figures, for resting atop the LEDs **4256** and providing added support to the top surface **4250** of the integrated focal lens **4265**. Alternatively, separate struts (not shown) may be molded to the underside of the integrated focal lens **4265** to provide such support. The integrated focal lens **4265** may, in certain embodiments, be constructed by attaching (using glue or solvent) individual, tapered focal lenses of the type illustrated in FIGS. **37D** and **37E** to the underside of a clear plastic sheet,

and then providing securing means for the overall resulting lens device to allow it to secure to, e.g., a panel lighting fixture.

[0175] FIG. **42D** illustrates an alternative embodiment of an integrated focal lens **4285**, with bubble-shaped or domed focal lenses **4271** on the topside of the sheet-like surface **4250** of the integrated focal lens **4285**. The focal lenses **4271** may be constructed in a manner as generally described previously with respect to FIGS. **37A-37C**, and may also have one or more projecting members or struts (not shown) on the underside of the integrated focal lens **4285** to provide support for the top surface **4270** thereof. Other shapes and styles of integrated focal lenses (or other lenses) may also be utilized for an integrated focal lens.

[0176] FIG. **43** illustrates a panel lighting assembly **4300** in which a panel light frame **4302** is attached to a stand **4380**. The panel light frame **4302** may include multiple panel light sections **4303**, **4304**, or may be a single unitary panel light. The stand **4380** may be of a conventional nature, with a C-shaped yoke **4381** for securing the panel light frame **4302** crossbar and allowing it to tilt for directional lighting. A twisting handle **4317** may be used to lock the panel light frame **4302** at a particular tilting angle. The C-shaped yoke **4381** may be rotatable or pivotable by placement atop a fluid head **4382**, which in turn is positioned atop a stem **4384** and tripod **4386**. The panel lighting assembly **4300** thus conveniently provides a variety of directional lighting options for the panel light frame **4302**.

[0177] In alternative embodiments, a ball-and-socket mechanism may be used to rotate/pivot an attached lighting panel, using socket joints similar to those used for, e.g., computer monitors. Likewise, in any of the foregoing embodiments, motorization may be employed to control the movement of the lighting yokes or stands. Motorized control is well known in the art for lighting apparatus (particularly in the performing arts field), and the motorized control may be either automated or manual in nature.

[0178] FIG. **45** is a diagram of another embodiment of a lighting fixture **4500** employing semiconductor light elements. In FIG. **45** is shown a flexible strip **4502** with an array of surface mount LEDs **4505** mounted on the flexible strip **4502**. The flexible strip **4502** preferably comprises a circuit board that may be comprised, for example, of a material such as mylar or composite material, of sufficient thinness to allow the circuit board to be bent and/or twisted. The circuit board may be at least partially encased in an insulated (e.g., rubberized) material or housing that is likewise flexible and thin. Heat dissipating fins (not shown in FIG. **45**) may protrude from the backside of the flexible strip **4502**, to assist with cooling of the surface mount LEDs **4505**. While a single array of surface mount LEDs **4505** is illustrated in the example of FIG. **45**, two or more arrays of LEDs **4505** may be used, and may be positioned, e.g., side by side. An electrical connector **4540** with electrical contact receptacles **4541** is also illustrated in the example of FIG. **45**, for receiving an electrical cord (not shown) supplying power for the LEDs **4505**. Other alternative means for providing electrical power, such as a battery located in an integrated battery housing, may also be used.

[0179] According to one or more embodiments as disclosed herein, a versatile lighting apparatus in the form of an LED-based light panel is provided, preferably having a variety of mounting options or configurations, an attachable or integrated battery unit, and alternative means for receiving a

power supply input. In a preferred embodiment, the versatile LED-based light panel includes a panel frame, and a plurality of LEDs or other light elements secured to the panel frame. A self-contained battery unit securably attaches to the outside of the panel frame. The light panel may have a dimmer switch, and may also be capable of receiving power from a source other than the self-contained battery unit. The lighting apparatus can be mounted to a camera or a stand through adapters. Diffusion lenses or color gels can be integrated with or detachable from the light panel. The lighting apparatus may conveniently be provided in the form of a kit, with one or more of a light panel, self-contained battery unit, compact stand, connecting cable(s), adapter(s), lenses or color gels, and so on, provided in a single package.

[0180] FIGS. 47A and 47B are diagrams of a lighting apparatus 4700 in accordance with one or more embodiments as disclosed herein. The lighting apparatus 4700 is preferably portable and versatile in nature, as further described herein. The lighting apparatus 4700 in this example includes a panel, fixture or frame (hereinafter “panel”) 4702 having a plurality of semiconductor light elements (such as LEDs or LECs) 4705 mounted on a mounting surface 4704 of the panel 4702. As illustrated in FIG. 47A, the semiconductor light elements 4705 may be disposed in uniform arrays to provide a broad light source. The mounting surface 4704 may include one or more circuit board assemblies, generally constructed in accordance with the principles described previously with respect to FIG. 32. Although the semiconductor light elements 4705 are illustrated as being arranged in uniform arrays, they may be arranged in other patterns as well. Furthermore, while the panel 4702 is shown in FIG. 47A as being generally rectangular in shape, the panel 4702 may alternatively be of any suitable shape, including, for example, hexagonal, octagonal, or other polygonal or semi-polygonal, or round, oval, square, or ring-shaped (such as illustrated in FIG. 4, for example).

[0181] The semiconductor light elements 4705 may be surface mounted (e.g., surface mount LEDs), which may have the advantage, for example, of simplifying replacement of the LEDs (allowing “drop in” replacements for example) or else may allow easy replacement of an entire row (e.g., interconnect set, etc.) or array of LEDs should it be desired, for example, to change the color, size, shape, or other characteristics of a particular group of LEDs. The light elements or LEDs may have screw-in bases or other similar physical attachment means, such that the LEDs can be easily removed and replaced.

[0182] The panel 4702 may further include an integrated dimmer control 4726, in the form of a knob, switch, or other mechanism, to allow the intensity of the semiconductor light elements 4715 to be adjusted. As one example of an implementation, a dimmer control 4726 in the form of a manual knob may control the conductance of a potentiometer or variable resistor (similar to 5735 in FIG. 57), to adjust the amount of current reaching the semiconductor light elements 4705. More than one dimmer control 4726, and/or switches, may optionally be provided, so as to control groups of semiconductor light elements 4705, for example, or to turn on or off certain groups of the semiconductor light elements 4705. An example of electronic circuitry as may be used in connection with dimmer control 4726 is described with respect to FIG. 57.

[0183] As illustrated in FIG. 47B, the panel 4702 preferably further includes a socket 4724 or other input for receiving

a power connection (e.g., cable) to provide electrical power to the semiconductor light elements 4705. The panel 4702 may also include various heat dissipating fins 4712, which may be arranged, for example, in arrays of metal or heat conductive rods, integrated on the back side of the panel 4702, in order to efficiently dissipate heat generated by the semiconductor light elements 4705. The heat dissipating fins 4712 may generally be similar to those described elsewhere herein, for example, with respect to FIG. 38A or 41A. The heat dissipating fins 4712 may be of any suitable size or shape, and may be extended, for example, to accommodate higher wattage LEDs or light elements. Other types of heat dissipation mechanisms may also be used.

[0184] The lighting apparatus 4700 of FIGS. 47A and 47B may be particularly adapted to receive an attachable/detachable battery unit, so as to provide a self-contained unit having its own power source. FIGS. 48A and 48B are diagrams of a panel-based lighting apparatus 4802 such as illustrated in FIGS. 47A-B, together with an attachable battery unit 4830, to form a self-contained, self-powered lighting apparatus 4800. The battery unit 4830 may be attachable to the panel 4802 in any of a variety of manners. In the particular example shown in FIGS. 48A and 48B, the battery unit 4830 comprises a set of struts 4832 that attach to corresponding receptacles 4836 of the panel 4802. FIG. 48A shows a perspective view of the light panel 4802 and battery unit 4830 slightly separated, while FIG. 48B shows a side view of them attached to one another, with the struts 4832 inserted in the receptacles 4836 of the panel 4802. FIGS. 49A and 49B are diagrams showing attachment of the light panel 4802 to the attachable battery unit 4830. FIG. 49A in particular is a simplified diagram omitting certain details such as the heat dissipating fins.

[0185] A wide variety of alternative means may be used to attach the battery unit 4830 to the panel 4802; by way merely of example, the battery unit 4830 may slidably attach and engage with the panel 4802, or may have external tabs that grip the panel 4802, or may have pins or screws that engage with the panel 4802.

[0186] The battery unit 4830 preferably delivers power to the light panel 4802 through an electrical connector 4840, which may take the form of, e.g., a jumper cord, and may insert into electrical sockets 4834 (in the battery unit 4830) and 4824 (in the panel 4802). Alternatively, the front side of the battery unit 4830 and backside of the panel 4802 may be provided with a mating male/female electrical plug and socket, which automatically engage when the battery unit 4830 is attached to the panel 4802. As with the lighting apparatus 4700 of FIGS. 47A-B, a dimmer switch 4826 may be provided in a convenient location on the panel 4802, to adjust the light intensity. One or more batteries, possibly replaceable, may be integrated with battery unit 4830. The battery, or batteries, may have a nominal voltage rating of appropriate level, such as 12 volts. The battery, or batteries, of battery unit 4730 is/are preferably rechargeable in nature.

[0187] A diffusion lens or filter may also be used, by itself or in conjunction with a color gel or colored lens, to diffuse or soften the outgoing light. A diffusion lens or filter may be formed of, e.g., clear or white opaque plastic, and may be configured in a shape of similar dimension to the panel 4702 or 4802 to facilitate mounting thereon. One such diffusion filter 5029 is shown in FIG. 50A. A preferred diffusion filter/lens would be a Light Shaping Diffusor material (e.g., holographic, etc.). A color correction mechanism, such as a lens filter and/or color gel, may be used to alter the color of the

light elements of a lighting apparatus such as depicted in FIG. 47A-B or 48A-B. For example, LED light sources could, if necessary, be converted to “tungsten daylight” (similar in hue to an incandescent bulb) by use of a color gel and/or colored lens.

[0188] The lighting apparatuses 4700 and 4800 are preferably adapted to be utilized in conjunction with various lenses and/or color gels, to increase their versatility. FIG. 50A is a diagram illustrating one embodiment having a lens 5010 and optional color gel 5029 used with the lighting apparatus 4800 illustrated in FIGS. 48A-B, and FIG. 50B is a side view diagram illustrating the lens 5020 in place. The lens 5010 is preferably readily attachable to the panel 4802 of the lighting apparatus 4800, by fastening means such as complementary Velcro patches 5022, 5012. Alternatively, the lens 5010 could snap or slide on to the panel 4802, or be attached using screws, nuts/bolts, pins, or other such means. The filter/lens 5010 (as with 6327, described later herein) may comprise, e.g., a Fresnel lens, a holographic lens, or any other type of lens, or combinations thereof. The color gel 5029 is preferably inserted beneath the lens 5010 and is secured beneath it. As depicted in FIG. 50A, the color gel 5029 has cutouts on each of the corners so as not to interfere with the Velcro patches 5022, 5012.

[0189] The lighting apparatus 4700 is preferably portable in nature and can be adapted for use in a variety of ways. To facilitate mounting of the lighting apparatus 4700 (whether or not attached to a battery unit, as depicted in FIGS. 48A-B), the lighting apparatus 4700 may be provided with one or more adapters. FIG. 59 is a diagram illustrating an example of a lighting apparatus 4700 in the form of a panel 4702 with one or more adapters 5906, 5907 for mounting or affixing the panel 4702 to a camera, stand, or other object or surface. In the example depicted in FIG. 59, the adapters 5906, 5907 are in the form of receptacles suitable for receiving a mechanical pin (or a similar fastener such as a screw or bolt), allowing convenient and rapid deployment of the lighting apparatus 4700 on, e.g., a camera or stand. Other adapters or fastening means (e.g., hinged tabs, sliding/coupling members, etc.) may also be used.

[0190] Examples of ways in which the light apparatus 4700 can be mounted on a camera, stand or other object or surface are illustrated in FIGS. 51 through 55, and 60 through 63B. For example, the lighting apparatus 4700 may be mounted to a camera, directly to the camera housing or to an arm attached to the camera housing. FIG. 51 is a diagram showing one possible mechanism for mounting a lighting apparatus 4700 in the form of a light panel to a camera 5107. While the description below is explained in terms of lighting apparatus 4700, it also applies to the lighting apparatus 4800 having an attachable battery unit, as well as other possible lighting apparatuses as well. In FIG. 51, the camera 5107 includes or is configured with an attachment arm 5110 which may be used for mounting the lighting apparatus 4700. The attachment arm 5110 may, for example, be an articulated arm system of the type commercially available from, e.g., Noga of Israel, sold under the trade name “Hold-It.” The attachment arm 5110 comprises a ball joint 5120 attached to the housing (or shoe) of the camera 5107, a second ball joint 5125 attached to the lighting apparatus 4700 (via, e.g., an adapter 5906 such as shown in FIG. 59), and a pair of arms 5121, 5124 meeting at an adjustable knob interface 5129. The knob 5129 in this particular example allows the ball joints 5120, 5125 to loosen so that the arms 5121, 5124 can be positioned as

desired, and again tightened with the knob 5129. In this example, the lighting apparatus 4700 preferably includes a pin receptacle for receiving a threaded pin from the ball joint 5125 of the attachment arm 5110.

[0191] FIGS. 52A through 52C are diagrams illustrating other attachment options, using various mounting pins, in connection with the lighting apparatus 4700 of FIGS. 47A-B. FIG. 52A, for example, illustrates a mounting pin 5210 that may be used to allow the lighting apparatus 4700 to attach to a stand or tripod. The mounting pin 5210 in this example includes a threaded pin 5219, a cylindrical body 5212, and a grooved depression 5223 for providing a gripping region for a clamp or other attachment mechanism. The lighting apparatus includes a threaded receptacle (of the type shown in, e.g., FIG. 59, as adapter 5906) for receiving the threaded pin 5219. FIG. 55 depicts the lighting apparatus 4700 attached to a stand 5500 using a mounting pin such as 5210. The stand 550 has a base 5512, a main arm 5512 (possibly telescoping in nature), and an adjustable swing arm 5519 connected to a clamp member 5514. The clamp member 5524 in this example comprises a knob 5525 which loosens and tightens two opposing plates that grip the mounting pin 5210 between them. Alternatively, or in addition, the lighting apparatus 4700 may have a threaded receptacle on its shorter side instead of, or in addition to, a threaded receptacle on its longer side, to provide an alternative mounting option.

[0192] FIG. 52C illustrates attachment of the lighting apparatus 4700 to a mounting pin 5210 similar to that shown in FIG. 52A, but in this instance being coupled to an adapter on the narrow side of the lighting apparatus 4700 instead of its long side (i.e., using an adapter 5907 such as shown in FIG. 59).

[0193] In FIG. 52B, the lighting apparatus 4700 is attached to a stand or camera using a mounting pin 5250. The mounting pin 5250 in this example also includes a threaded pin 5269 and a cylindrical body 5262. In this case, the mounting pin 5250 may have a T-bar 5259 that is securably attached to the cylindrical body 5262, or else fits into a hollow receptacle to secure it to the cylindrical body 5262 of the mounting pin 5250, thereby allowing it to slide onto a camera having curved fins or other members for receiving the wings of the T-bar 5259. The mounting pin 5250 may alternatively have a pin, receptacle, or other member for mounting into a camera shoe or a stand, thus securing the lighting apparatus 4700 to the camera or stand.

[0194] The lighting apparatuses 4700 or 4800 may also be adapted to be placed on a compact stand. FIGS. 53A through 53D are diagrams showing different views of the lighting apparatus 4800 mounted on one possible type of stand 5310. In this example, the stand 5310 comprises a base plate 5320 with mounting arms 5325, one on each side, attached to L-shaped struts on the base plate 5320. The mounting arms 5325 preferably allow the lighting apparatus 4800 (comprised of the panel 4802 and battery unit 4830 in this example, although the same principles would apply to a lighting apparatus 4700 having only a panel 4702) to tilt forward and backward, thus allowing rapid adjustment of the angle of light provided. The stand 5310 is preferably of sufficient weight or bulk to keep the entire unit stable, and to prevent it from falling over regardless of the angle of tilt.

[0195] FIG. 54 is a diagram showing details of one possible mounting arm 5325 configuration for the stand 5310 illustrated in FIGS. 53A-D. As shown in FIG. 54, the mounting arm 5320 is attached to the top of the L-shaped strut 5410 of

the base plate, and includes a rotatable rod **5415** having a pin **5421** mounted on a base **5419** attached to the rotatable rod **5415**. The pin **5421** in this example includes a spring-loaded ball bearing **5424**. The lighting apparatus **4700** or **4800** preferably has a pin receptacle complementary to the pin **5421** with ball bearing **5425**, on each side of the base plate, allowing the lighting apparatus **4700** or **4800** to be slid down the pin(s) **5421**, with the spring-loaded ball bearings **5424** allowing the pins **5421** to lock into place within the pin receptacles. The lighting apparatus **4700** or **4800** can be removed by pulling it firmly while holding the base plate **5320** in place. Of course, other attachment means can be used to allow the lighting apparatus **4700** or **4800** to be attached to a stand, including mounting pins, screws, nuts/bolts, sliding tabs, snapping fasteners, and so on.

[0196] The lighting apparatuses **4700** or **4800** in certain embodiments may also be stackable to allow convenient expansion of the lighting source area. FIG. **62** illustrates an example of a stackable panel light **6200**, shown mounted on a stand **6220** (similar to stand **5320** of FIGS. **53A-D**). In FIG. **62**, two panel-type lighting apparatuses **4700** are vertically stacked, being held together by one or more front brackets **6205**, **6206** and/or one or more side brackets **6225**, which can conveniently be secured to adapters of the type shown in FIG. **59** (i.e., adapters **5906**, **5907**) using pins or screws **6226**. In the example of FIG. **62**, a side bracket is only placed on one side because of the presence of dimmer switches on the opposite side. The front bracket(s) **6205**, **6206** may be placed anywhere along the border between the two lighting apparatuses **4700** so long as they sufficiently secure them together (for example, a single bracket may be centered). Also the brackets may be placed on the backside rather than the front. In any of the embodiments using stacked light panels, power may be provided to both of the lighting apparatuses **4700** using, for example, a split cable or Y-cable that emanates from a single power source.

[0197] The lighting apparatuses **4700** or **4800** may also be adapted to be placed on a tripod type stand. FIGS. **60** and **61** are diagrams showing different types of tripod configurations. In FIG. **60**, the lighting apparatus **4700** is placed on a compact tripod stand **6013** having a ball joint **6016** allowing flexible tilting and angling of the lighting apparatus **4700**. In FIG. **61**, a tripod **6113** supports an arm (in this example, a telescoping arm **6122**) which in turn supports a ball joint **6116** similar to that of FIG. **60**, thereby allowing flexible tilting and angling of the lighting apparatus **4700**.

[0198] FIGS. **63A** and **63B** are diagrams illustrating another embodiment of a camera-mountable lighting apparatus **6310**. In FIGS. **63A-B**, the camera-mountable lighting apparatus **6310** includes a lighting frame or housing **6302** in the general nature of a panel light, and is attachable to a camera **6307** using, e.g., a mounting bracket **6355**. The lighting apparatus **6310** may include a number of semiconductor light elements **6305** arranged in a suitable pattern on a front mounting surface of the panel **6302**. The panel **6302** may, as described previously, be configured with heat dissipating fins **6312** to allow cooling of the light elements **6305** and any other resident electronics. A dimmer switch **6326** having functionality as previously described herein may optionally be provided. A lens cover **6328**, of the type generally described with respect to FIGS. **42A** through **42D**, may be placed in front of the light elements **6305**. The lens cover **6328** may be comprised of individual lenses **6327**, as illustrated in FIG. **63B**, of a type similar to that described with respect to FIG. **43C** (i.e.,

generally conical in shape). The lenses **6327** may be a focusing lens, such as a Fresnel lens, and may be positioned so as to abut one another, thereby providing a more contiguous light source as generated from the various light elements **6305**.

[0199] The mounting bracket **6355** may be hinged to allow the panel **6302** to tilt backward or forward, and may also allow the panel **6302** to swivel right or left. A mounting pin **6371** may be provided to allow it to affix to the camera **6355**, or else a T-bar may be used similar to that shown in FIG. **52B**.

[0200] A lighting apparatus may conveniently be packaged in the form of a kit that includes a number of components providing increased convenience, flexibility, and adaptability to operators in the field. For example, a lighting apparatus kit may include one or more lighting panels **4702**, as well as one or more battery units **4830** (and/or battery adapters such as described with respect to FIG. **58**), power jumper cable (for connecting the power between the panel(s) **4702** and battery unit(s) **4830**), an AC adapter and power/recharging cable, one or more lenses **5010**, a set of colored or diffusion gels **5029** of various tints and hues, or providing light shaping or diffusion (such as with a Fresnel lens or holographic lens), and/or one or more compact mounting stands **5310** (or other accessories described herein), all of which can be packaged conveniently in a portable case. The colored or diffusion gels **5029** may be integrated with the panel **4802**, or else detachable as depicted in the example of FIGS. **50A-B**.

[0201] The lighting apparatus and/or battery unit may have electronics which also provide increased performance, versatility, and/or flexibility. FIG. **56** is a simplified block diagram illustrating, for example, components of one possible embodiment of a battery unit **5600**, which may be physically constructed in accordance with the battery unit **4830** of FIGS. **48A-B** or otherwise. The battery unit **5600** illustrated in FIG. **56** includes a recharging circuit **5615** in addition to one or more batteries **5609**. A socket **5619** is provided for either receiving an output electrical connector **5612** intended to be connected to a light panel (e.g., **4802**), or an input electrical connector **5626** which provides a DC voltage source. In the latter case, the input electrical connector **5626** may be connected to a wall source via, e.g., an AC-to-DC adapter. The battery or batteries **5609** may be of any suitable type, for example, Lithium-ion, Nickel-metal-hydride (NIMH), Nickel-cadmium, or any other suitable type. The kit may also include a DC-to-DC adapter to provide a more suitable voltage (e.g., 7.2 V to 12V, which may be attached between the camera and its battery).

[0202] The battery unit **5600** may optionally include one or more LED indicators for indicating the state of charging (e.g., when the battery or batteries **5609** is/are being recharged), and/or act as a meter to indicate the remaining battery charge. For example, the battery unit **5600** may have five LED indicators—two green (e.g., full or almost full), one amber (e.g., warning), and two red (e.g., approaching empty and virtually empty), to indicate the amount of remaining battery charge as it gradually depletes.

[0203] FIG. **57** is a functional block diagram illustrating an example of circuits or components of an LED-based light panel **5700**, as may be constructed in accordance with, e.g., light panel **4702** or **4802** described elsewhere herein. The LED-based light panel **5700** in this example includes a power regulator **5710** which preferably provides a relatively constant or stabilized current output to one or more arrays or series of LEDs **5740** (or other semiconductor light elements).

Details of possible embodiments of a power regulator **5710** are described in copending U.S. application Ser. No. 10/708,717 filed Mar. 19, 2004, entitled “Omni-Voltage Direct Current Power Supply,” hereby incorporated by reference as if set forth fully herein. The power regulator **5710** preferably includes a switched power supply **5720** under control of a control circuit **5725**, such as a PIC microcontroller **5725**. The switched power supply **5720** may be a buck/boost power supply, or else simply a buck or boost power supply, or other type of power supply. A buck/boost power supply allows the most flexibility, in that the input voltage could vary over a relatively wide range; a particular example is described in application Ser. No. 10/708,717 referred to above. A voltage sense circuit **5731** and current sense circuit **5732** provide feedback information to the PIC microcontroller **5725**, which information is used in maintaining the output current to the LEDs **5740** at a stable level, and thereby reducing undesirable artifacts such as flicker.

[0204] In FIG. **57**, a dimmer switch **5726** adjusts a potentiometer or variable resistor **5735**, which in turn provides a dimming control input signal **5737** to the power regulator **5710**. In a preferred embodiment, the dimmer control input signal **5737** adjusts the level of gain in a feedback loop for the PIC microcontroller **5725**, thus allowing adjustment of the amount of output current for the LEDs **5740**. The circuitry of FIG. **57** can allow, for example, the adjustment of light intensity without a substantial change in the output color temperature of the light source (i.e., the LEDs), and again, without flicker even at relatively low light output levels. These can be significant advantages to those working in the field.

[0205] The battery unit **4830** described previously herein may take on various different forms and configurations. In alternative embodiments, for example, the battery unit **4830** may, for example, comprise one or more “standard” or conventional camera batteries, as may be obtained by companies such as, e.g., Sony, Panasonic, Canon, and the like. FIG. **58** is a diagram of an embodiment of a battery unit **5800**, including an adapter panel **5830** for receiving at least one attachable battery **5850**, such as a DV (“digital video”) battery. A DV type battery typically has a battery casing designed to be snapped directly into the camera, although DV batteries may differ from camera manufacturer to manufacturer. The adapter panel **5830** is preferably constructed to mate to a particular type or brand of battery, and thus different adapter panels **5830** may be made available, each suited to a particular battery or family of batteries. At least some DV batteries output less than 12 volts—for example, a typical output voltage is 7.2 volts. The battery unit **5800** may, as illustrated in FIG. **58**, comprise two receptor plates **5840** each adapted to securably attach a battery **5850** to the adapter panel **5830**.

Electrical contacts **5842** provide electrical connection from the battery **5830** to downstream electronics or a power output source. The two batteries **5850** may be electrically connected in series via electronics integrated in the adapter panel **5830**, thus doubling the voltage to, e.g., 14.4 volts. Alternatively, the adapter panel **5830** could include a transformer of other type of DC-DC conversion circuitry to step up the voltage to 12 volts or some other appropriate level.

[0206] The battery unit **5800** preferably includes struts **5832** or other attachment means similar to those of battery unit **4830**, in order to allow the battery unit **5800** to readily attach to, e.g., an LED based light panel **4802**, in a manner similar to the way in which battery unit **4830** may connect to the panel **4802**.

[0207] Certain embodiments have been described with respect to the placement of lamp elements (e.g., LEDs) on a “mounting surface” or similar surface or area. It will be appreciated that the term “mounting surface” and other such terms encompass not only flat surfaces but also contoured, tiered, or multi-level surfaces. Further, the term covers surfaces which allow the lamp elements to project light at different angles.

[0208] Various embodiments have been described as having particular utility to film and other image capture applications. However, the various embodiments may find utility in other areas as well, such as, for example, automated manufacturing, machine vision, and the like.

[0209] While preferred embodiments of the invention have been described herein, many variations are possible which remain within the concept and scope of the invention. Such variations would become clear to one of ordinary skill in the art after inspection of the specification and the drawings. The invention therefore is not to be restricted except within the spirit and scope of any appended claims.

What is claimed is:

1. An apparatus for illuminating a subject for film, photography or video, the apparatus comprising:
 - a frame having a front;
 - a plurality of semiconductor light elements disposed on the front of the frame and configured to provide a continuous source of illumination, said semiconductor light elements having a color temperature suitable for image capture, at least one of said semiconductor light elements individually emitting light in a daylight color temperature range or a tungsten color temperature range; and
 - a dimmer whereby an illumination intensity of said semiconductor light elements may be user adjusted;
 wherein said frame is adapted for being mounted to and readily disengaged from a stand.

* * * * *

EXHIBIT G



US006454437B1

(12) **United States Patent**
Kelly

(10) **Patent No.:** **US 6,454,437 B1**
(45) **Date of Patent:** **Sep. 24, 2002**

(54) **RING LIGHTING**

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U.S.C. 154(b) by 0 days.

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(22) Filed: **Jul. 28, 2000**

(30) **Foreign Application Priority Data**

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Dec. 13, 1999 (IE) 991032

(51) **Int. Cl.**⁷ **F21V 5/00**; F21V 21/00;
F21V 1/00

(52) **U.S. Cl.** **362/246**; 362/249; 362/235;
362/252; 359/287; 359/387

(58) **Field of Search** 362/249, 235,
362/252, 800, 326, 335, 244, 230, 231,
246; 359/287, 387

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(57) **ABSTRACT**

An illuminator has a printed circuit board supporting a ring of light emitting diodes (LEDs). An annular Fresnel lens and the board are both mounted in a housing having a central though-hole for a camera field of view. The lens mixes light from the LEDs in the tangential direction and it also controls spread in the radial direction so there is uniform illumination over a target plane. Any individual point on the target plane receives illumination from over 25% of the light sources. The illuminator is thus particularly effective, compact, and suitable for a wide range of industrial applications. Choice of lens and the spatial arrangement allows versatility. The illuminator design is easily scaleable by changing the size and spacing between the light sources.

28 Claims, 9 Drawing Sheets

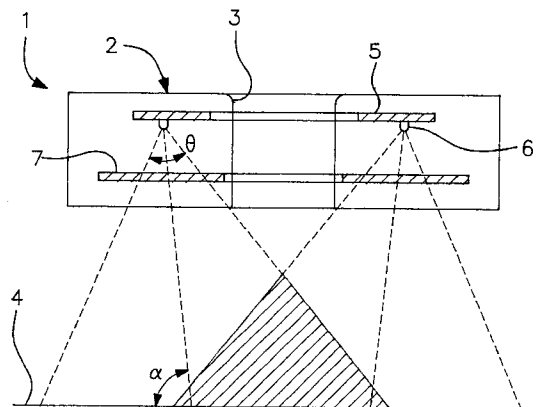
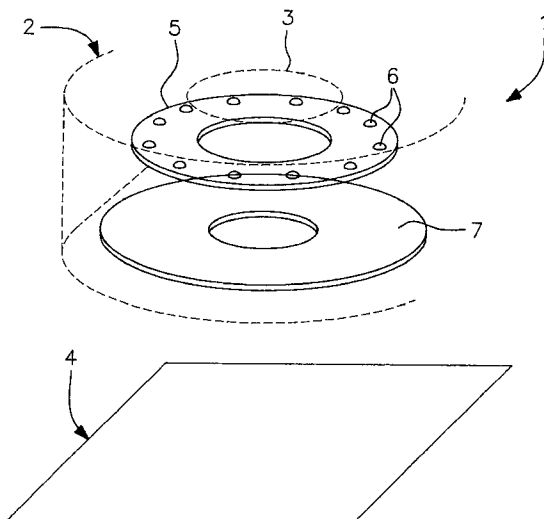


FIG. 1

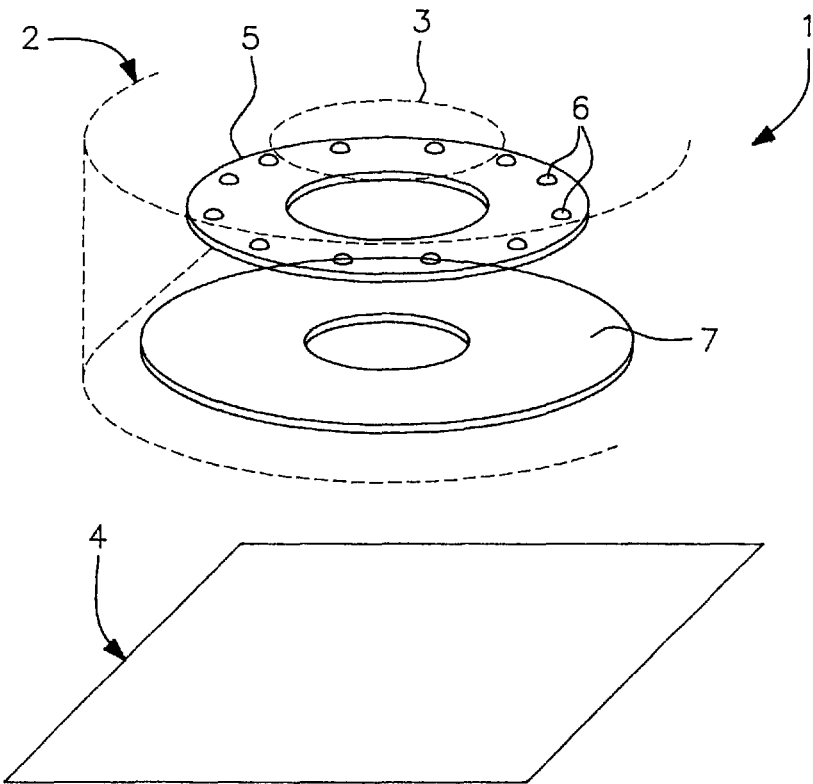


FIG. 2

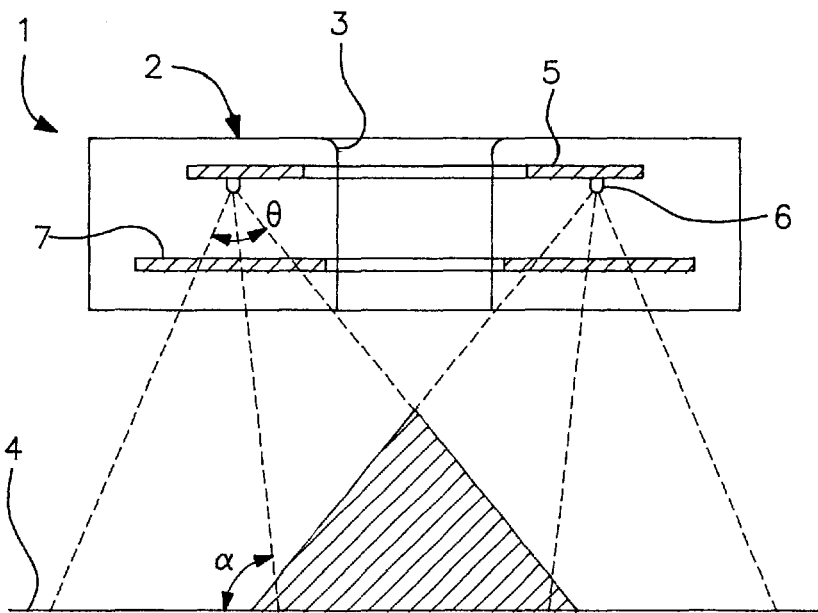


FIG. 3(a)

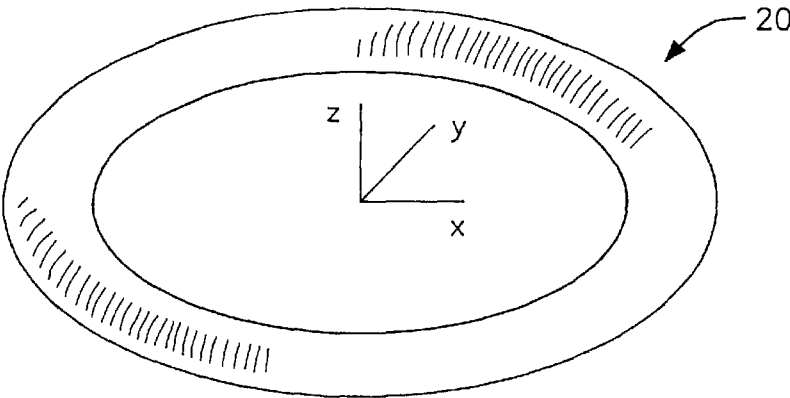


FIG. 3(b)

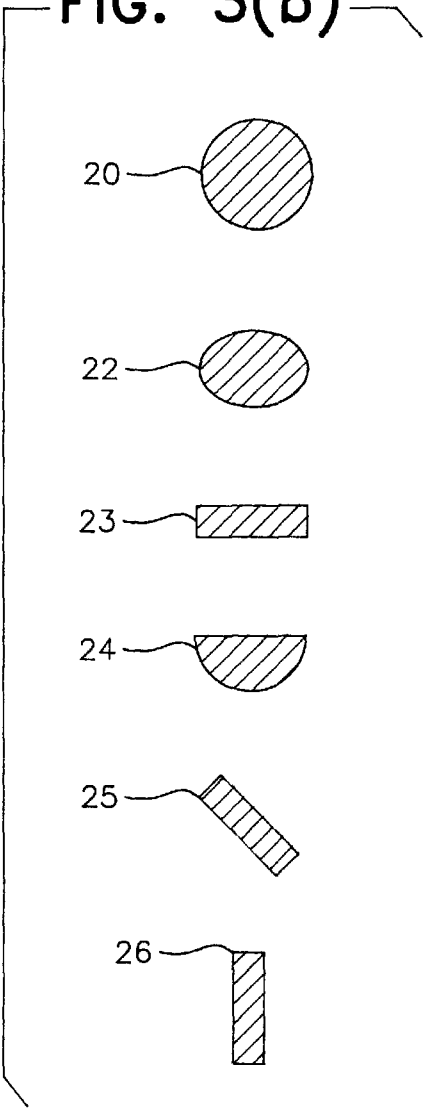


FIG. 3(c)

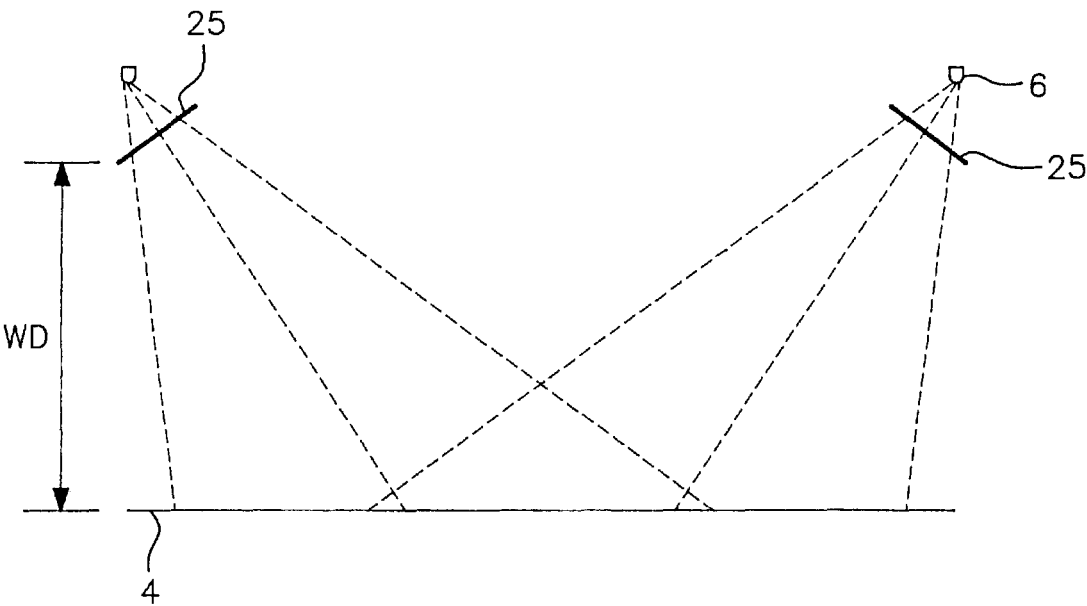


FIG. 3(d)

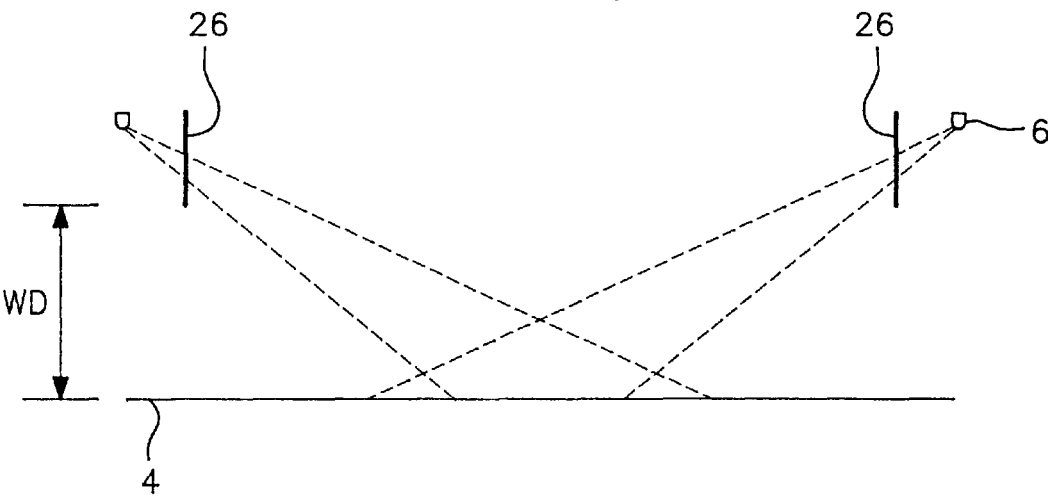


FIG. 4

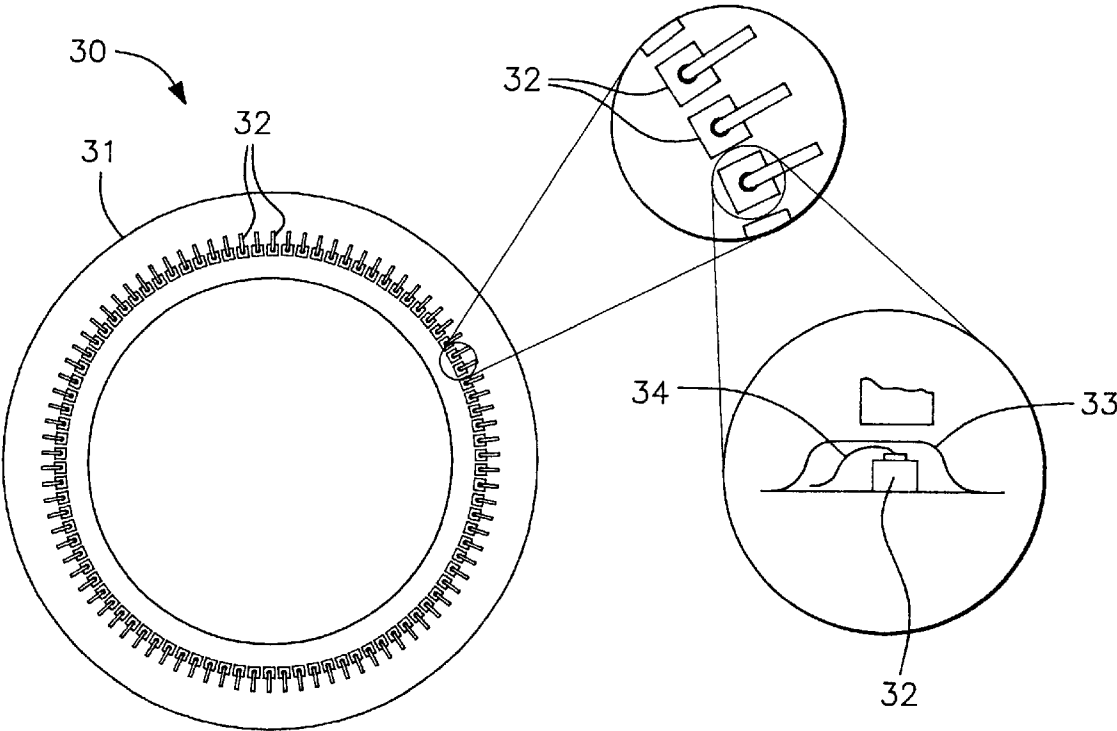


FIG. 5(b)

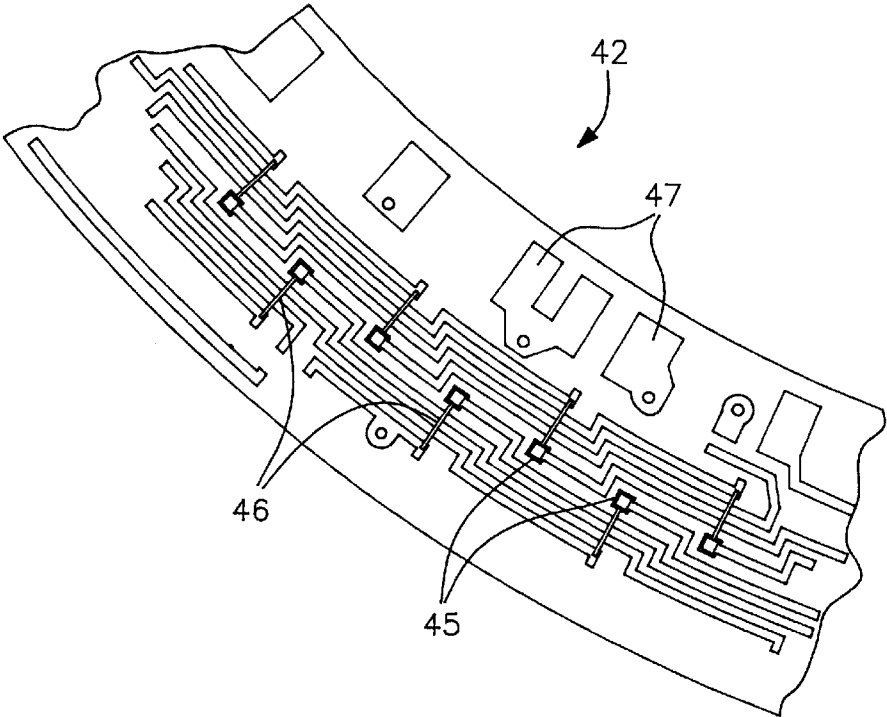


FIG. 5(a)

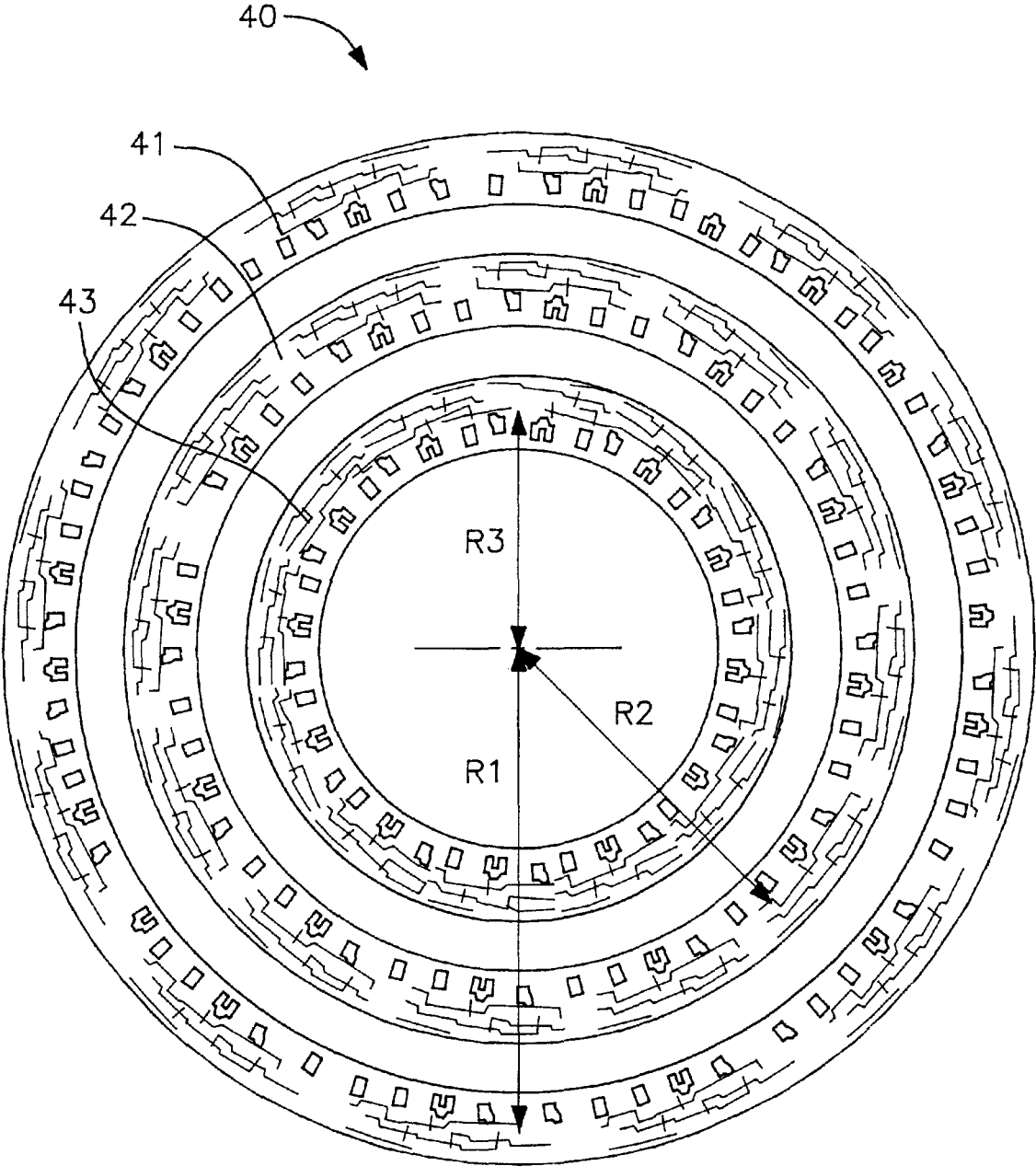


FIG. 6

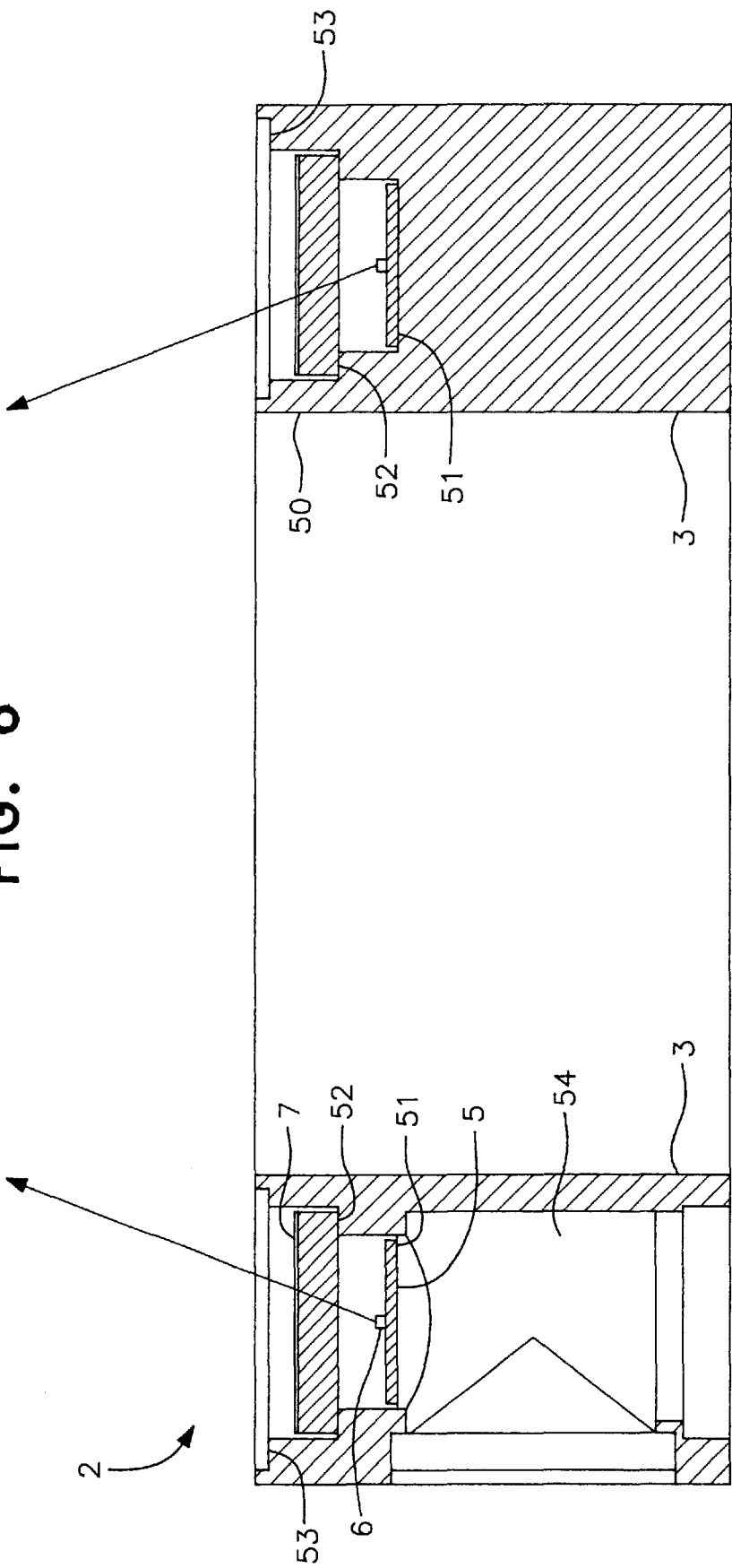


FIG. 7

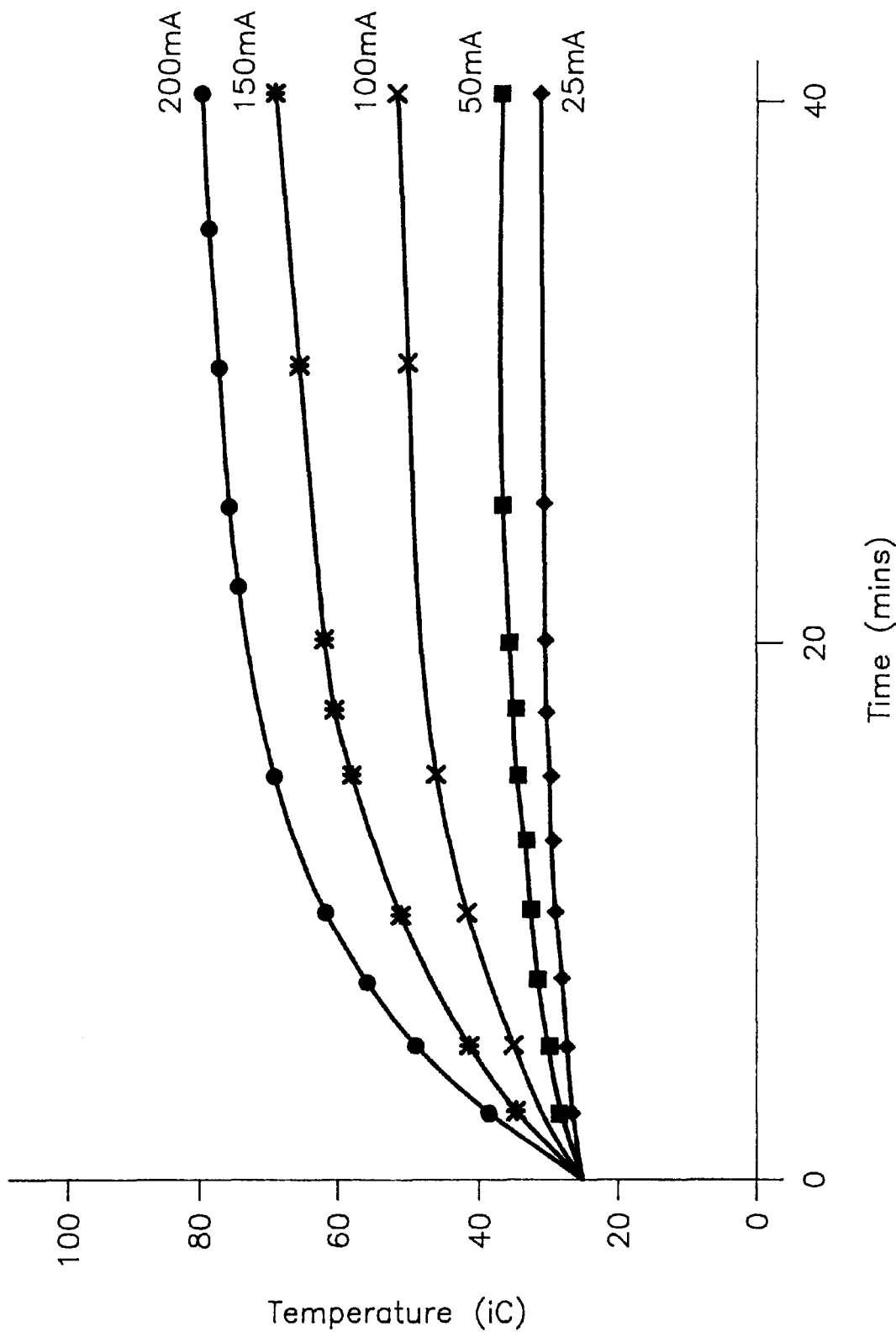


FIG. 8(a)

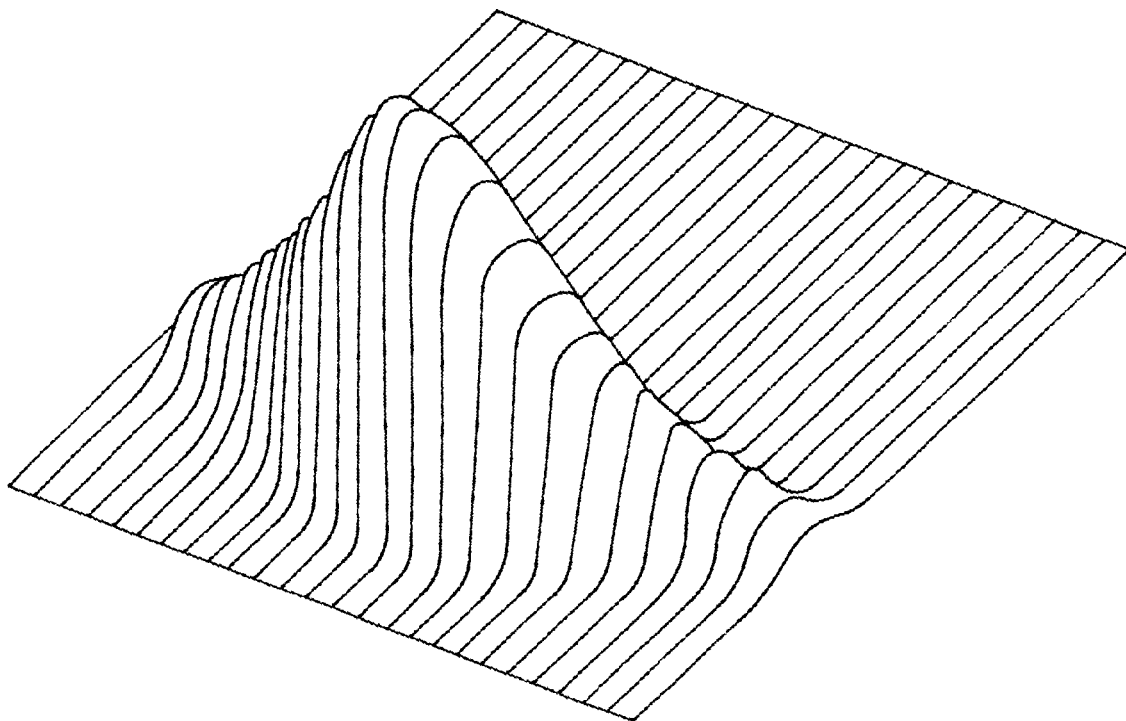


FIG. 8(b)

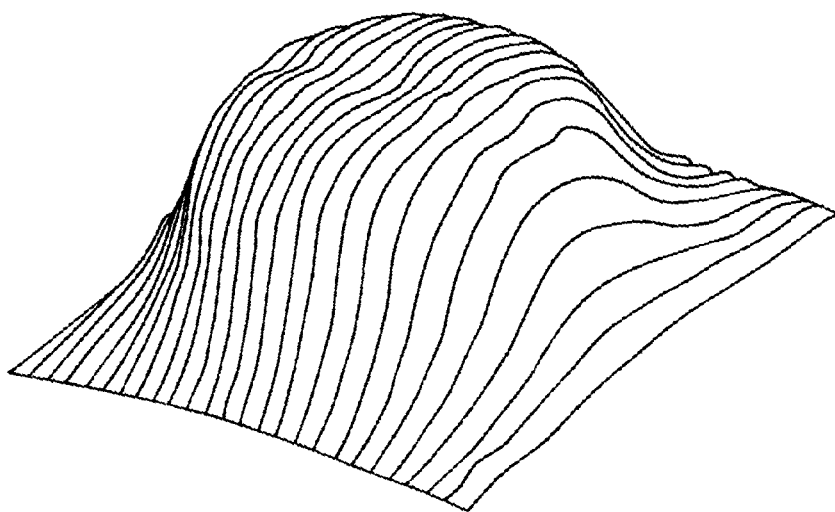
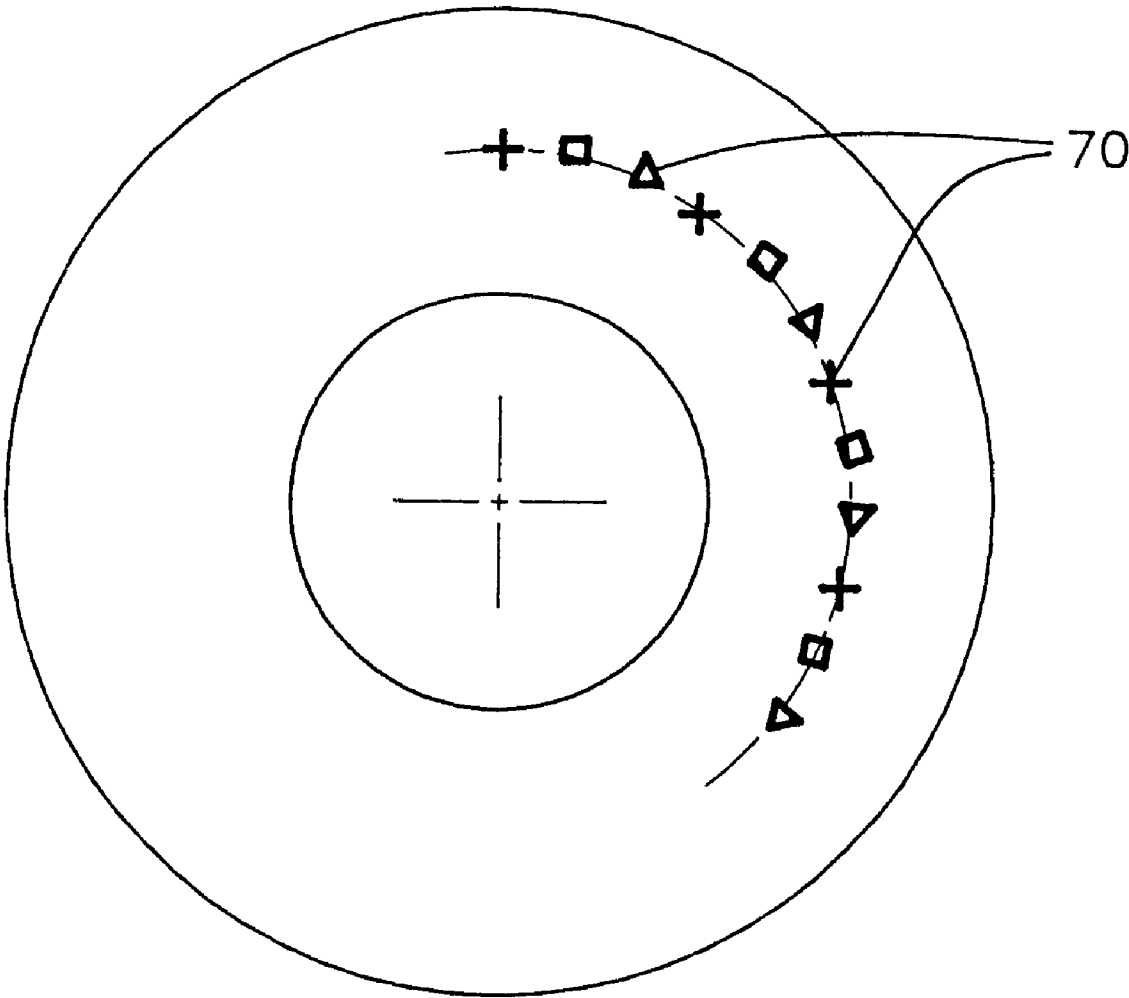


FIG. 9



+ – Colour 1

□ – Colour 2

Δ – Colour 3

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RING LIGHTING

FIELD OF THE INVENTION

The present invention relates to illuminators used in industrial instrumentation in which it is desired to illuminate an object which is being inspected by a sensor or camera. An example is the illumination of objects on a production line which are being inspected by a machine vision system.

PRIOR ART DISCUSSION

A typical machine vision system consists of an illuminator, a camera, and a control system for enabling the illuminator and camera in combination to capture an image of the object which is under inspection and for processing the image and initiating the desired action. The action may be marking the product as acceptable or rejected. The illuminator is an important part of the system, and properties of the illumination such as its brightness, its uniformity, its angle of incidence, its colour, and its degree of collimation can have a significant influence on the overall performance of the complete vision system. Additionally, the physical size of the illuminator is very important, as for some vision systems there is very little physical space available. For example, it may need to be located within a camera housing. Several types of illuminator have been used with machine vision systems, for example incandescent bulbs, fluorescent tubes, lasers, Xenon flash tubes, halogen bulbs combined with fibre light guides, and light emitting diodes (LEDs). Due to their relative cheapness, physically small size, long lifetime, fast switching speed and reasonable efficiency, LEDs have become increasingly popular.

FIG. A illustrates the main features of a typical prior art ring illuminator, such as for example displayed at the Volpi™ website, or in the Electronic Imaging Catalog of Edmunds Industrial Optics Inc™. The illuminator consists of an arrangement of light emitting diodes arranged either within a housing, or on a printed circuit board within a housing, with a hole in the centre of the housing and board through which a camera or sensor can view the objects which are being illuminated. Each LED is in its own package, usually lensed so as to provide a "viewing angle" of between 4 degrees and 120 degrees. By viewing angle is meant the full width angle measurement in the far field at the half power points of the light which is being emitted from the package. In general, the light from these packages has a cross-sectional profile which is such that it can not be described by a smooth mathematical function such as a Gaussian function, but has undesirable intensity variations caused by the structure of the LED chip and/or by the arrangement of the LED within the optical elements of the package. It can be seen additionally from FIG. A that there is the potential for a lot of structure (non-uniformity) in the illumination pattern which is produced when these packaged LEDs are used to make a ring illuminator depending upon how well the beams from the individual LEDs mix. This can be improved by adding diffuser material either within the individual LED packages or on the exterior of the housing of the illuminator, but the effect in both circumstances is to reduce the efficiency of the system. It can also be seen from FIG. A that the overall volume of the illuminator is very much determined by the size of the individual diode packages, which are typically several millimeters in diameter.

A problem with such illuminators is that the pointing accuracy of individual LEDs is poor, leading to lack of uniformity of the illuminated area. Also, the uniformity of

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the light produced by the individual LEDs is poor, and even after they mix on the target, the resulting uniformity is poor, perhaps $\pm 25\%$.

Another disadvantage is that the overall brightness of the illumination is limited by the packing density of the individual packaged LEDs, which are typically housed in 5 mm or 3 mm diameter acrylic packages. For example, a 30 mm diameter ring of 5 mm LEDs can only hold about 16 of these lensed LEDs.

In order to produce a shorter working distance it has been proposed to arrange the LEDs at an angle to the optical axis. This means that the illuminator works well at a particular working distance, which is determined by the position at which the beams from the individual LEDs coincide. However, there is no facility for adjusting the working distance.

U.S. Pat. No. 5,822,053 describes a system for improving the uniformity and for matching the angle of illumination with the field of view. This consists in essence of bending the metal legs on the individual packaged LEDs to adjust the orientation of the beam from each LED. By observing the pattern on the target plane, it can then be ensured that the uniformity is improved to the extent that is possible, given the non-uniformity of the individual LEDs to start with. Following adjustment, the LED packages are fixed in place with epoxy. This technique can only improve uniformity up to a point, and does not address the other fundamental limitations of using a ring of lensed LEDs, such as limitations of brightness, compactness, and scalability to small sizes.

U.S. Pat. No. 5,580,163, describes a mechanical adjusting system to enable the angle of incidence of the illumination from a ring illuminator consisting of the lensed LEDs to be varied. This is mechanically complex, and adds significantly to the manufacturing cost of the system and to its volume and mass. Also, it does not address uniformity and brightness problems.

Use of annular lenses has been described in the prior art. U.S. Pat. No. 4,567,551 describes a multidirectional surface illuminator which uses a Fresnel lens to redirect and focus the light from the light sources arrayed around the outside of an illuminator housing, so as to illuminate the object under inspection from a particular quadrant of the illuminator. It is very difficult to make a compact illuminator using this technique due to the arrangement of the light sources outside of the housing. Additionally, this arrangement does not achieve a desirable level of uniformity over a target area, and is not suitable for extension to very small sizes.

U.S. Pat. No. 5,690,417 describes a surface illuminator with a means for adjusting the orientation and inclination of the incident illumination, which includes light emitting diodes arranged in coaxial circles. Each coaxial circle of diodes may have their beam angles inclined at different angles to the angle of the axis of the housing. The diodes are energizable in pie-shaped sectors so that arcuate clusters of diodes may be illuminated to enable the orientation of the resultant illumination to be varied. The light emitting diodes are individually packaged so as to include a collimating lens and a Fresnel lens is used to focus and redirect the light towards the illuminated object. The illumination is similar to the prior art illuminator illustrated in FIG. A from the perspective of efficiency and uniformity. The only function of the Fresnel lens is to enable the variation of the angular inclination from the various segments, while using light emitting diodes mounted coaxially with the housing.

U.S. Pat. No. 5,897,195 describes an illuminator with a cylindrical or conical array of light emitting diodes produc-

ing collimated light beams that are redirected towards the illuminated object by a Fresnel-like diffuser. Again, this is a variation of the prior art illuminator shown in FIG. A which might have some advantages for producing particular angular inclinations. However, it is not very suitable for compactness, high uniformity or high efficiency.

These disadvantages with using discrete light sources such as LEDs have led to use of large illuminators for machine vision systems and for microscopy in order to achieve the required illumination intensity and distribution. These illuminators may, for example, comprise a ring-shaped fluorescent tube. These units are bulky and so impose design limitations on the instrument with which they are intended to be used, and they also are not efficient for producing monochromatic light. These illuminators may also comprise "cold light" sources, consisting of a fan-cooled halogen bulb providing light via a light pipe and adapter, which are bulky and expensive.

Therefore, it is an object of the invention to provide a ring illuminator which has some or all of the following advantages:

- is compact, providing a high ratio of brightness to illuminator volume,
- may have a size within a large range extending down to a compact size, for example an illuminator having 10 LEDs with a housing diameter of less than 10 mm,
- provides a uniform illumination intensity over the desired target area,
- incorporates redundancy so that failure of some sources does not result in darker areas within the illuminated area,
- has a relatively high optical efficiency,
- can be readily focused to adjust the size of the illuminated area,
- allows configuration for a required application at the design and manufacturing stages in a versatile manner.

SUMMARY OF THE INVENTION

According to the invention, there is provided an illuminator comprising a plurality of light sources mounted in a ring configuration, and an optical system for directing light from the light sources onto a target plane, characterised in that,

the properties of the optical system and the spatial arrangement of the optical system with respect to the light sources is such that light emitted by the light sources mixes to uniformly illuminate the target plane.

Thus, the optical system properties and the spatial arrangement achieve uniformity—desirable for many industrial applications—in an efficient manner without the need for a large single light source such as a fluorescent bulb.

In one embodiment, the optical system comprises an annular lens. This is a very simple, compact, and effective optical system.

In one embodiment, the separation of the light sources and the lens is less than the lens focal length. This achieves a uniform illumination area which is greater than the area encompassed by the lens, and also achieves excellent spread in the radial direction.

In one embodiment, the lens comprises means for controlling spread in the radial direction sufficient for uniformity and adequate illumination intensity across the target plane.

In one embodiment, the effective diameter of the ring of light sources is greater than that of the lens by 2% to 10%.

This helps to control the size of the illuminated area and to achieve excellent uniformity.

In one embodiment, the lens comprises means for allowing light from the light sources to spread primarily in the tangential direction so that any point on the target plane is illuminated by at least 25% of the light source. This is a very simple way of achieving uniformity and excellent brightness on the target plane.

In one embodiment, the light sources comprise means for emitting uncollimated light. This also contributes to spread of light, helping to achieve uniformity.

In one embodiment, each light source is a semiconductor die. This is a compact arrangement.

In one embodiment, the illuminator comprises a housing supporting the light sources and the optical system, said housing having a chamber for the light sources and a chamber for the optical system. This provides robustness and reliability.

In one embodiment, the light source chamber supports the light sources in efficient thermal contact with the housing. This contributes to reliability.

In one embodiment, the housing supports the optical system in a manner whereby it is accessible for adjustment by users. This allows excellent versatility.

The annular lens may have a Fresnel pattern, and preferably the Fresnel pattern comprising means for correcting for spherical aberration. The lens may alternatively comprise a diffraction pattern. The lens may have a convex shape on one side and be flat on the other side. The lens may comprise a plurality of individual lenses arranged in an annular configuration.

In one embodiment, the light sources are mounted on a circuit board. This both allows simple electronic control and provides mechanical support.

The circuit board may have electronic components to control or switch current to the light sources.

In one embodiment, the circuit board is flexible and is formed into a ring. This provides ease of manufacture.

In one embodiment, the drive circuits comprise means for providing different colour illumination. In another embodiment, the drive circuits comprise means for driving rings of light sources of different radii to electrically vary angle of illumination. These features provide excellent versatility and simple control.

In one embodiment, the circuit board comprises a plurality of separate circuits. In another embodiment, each circuit drives light sources mounted in a pattern whereby failure of a circuit has a uniform impact across the target plane. These features provides excellent fault-tolerance.

In one embodiment, the light sources are covered by epoxy, preferably applied in a continuous layer.

The epoxy layer may contain phosphorescent material.

In one embodiment, the optical axis of the lens cross-section is inclined at an angle to the normal to the plane of the annulus.

In one embodiment, the lens is inclined at 90° to the normal to the plane of the annulus.

In one embodiment, the lens is of a deformable material.

In one embodiment, the lens has a flat arc-shaped starting configuration before being bent into an overall ring configuration in plan.

According to another aspect, the invention provides a method of producing an illuminator comprising a plurality of light sources mounted in a ring configuration and an annular lens for directing light from the light sources onto a target plane, wherein,

the annular lens is chosen to have properties such that the lens mixes light from different light sources in the

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tangential direction and controls spread in the radial direction so that a target plane at a desired working distance is uniformly illuminated, and

the separation of the lens from the light sources, and the light source ring diameter: lens diameter ratio are chosen to set the desired illumination area.

In one embodiment, the light source ring diameter: lens diameter ratio is chosen within a range of 1.02 to 1.10.

DETAILED DESCRIPTION OF THE INVENTION

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more clearly understood from the following description of some embodiments thereof, given by way of example only with reference to the accompanying drawings in which:

FIG. 1 is a diagrammatic perspective view of a ring illuminator of the invention;

FIG. 2 is a cross-sectional view of the illuminator of FIG. 1, showing spread of light from the light sources;

FIG. 3(a) is a perspective view of an annular lens, FIG. 3(b) is a set of sample cross-sections; and FIGS. 3(c) and 3(d) are views illustrating illumination arising from different lenses;

FIG. 4 is a plan view of LEDs on a printed circuit board together with a detailed view showing encapsulation of a single LED;

FIG. 5(a) is a plan view showing the arrangement of LEDs in an alternative illuminator, and FIG. 5(b) is a more detailed view of the circuits of the illuminator of FIG. 5(a);

FIG. 6 is a cross-sectional view of a housing of the illuminators of FIGS. 1 to 5 inclusive;

FIG. 7 is a plot illustrating housing temperature versus driving current characteristics of the illuminator;

FIG. 8(a) is a 3-D plot illustrating the distribution of light on a target plane from a single LED in the illuminator and FIG. 8(b) is a 3-D plot illustrating total distribution on a target plane from 100 equi-spaced LEDs arranged in a ring in the illuminator; and

FIG. 9 is a plan view of an LED configuration in which there is a single ring of different coloured LEDs.

Referring to FIGS. 1 and 2 a ring illuminator 1 comprises a housing chamber 2 having a central opening 3 for a camera field of view. The illuminator 1 is for uniform illumination across a target plane 4.

The illuminator 1 comprises an annular printed circuit board 5 supporting a ring of LEDs 6. An optical system, in this embodiment an annular Fresnel lens 7, is mounted beneath the LEDs 6.

Referring to FIG. 2, the properties of the lens 7 and the spatial arrangement of the lens 7 with respect to the LEDs 6 is such that light emitted by the LEDs mixes to uniformly illuminate the target plane 4. The lens 7 spreads the light extensively in the tangential direction, perpendicular to the plane of the page. This achieves comprehensive mixing of the light. The following aspects of the spatial arrangement also contribute to uniformity across the target plane.

The separation between the LEDs 6 and the lens 7 is less than the focal length of the lens 7.

The effective diameter of the LEDs 6 is slightly greater (by 2%) than that of the lens 7. In general it has been found that if the LED effective diameter is greater than the lens effective diameter by a value in the range 2%

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to 10% there is particularly good distribution of light in the radial direction. Choice of this ratio sets the value for α , the angle of incidence of the illumination on the target plane.

The viewing angle, θ , of the LEDs 6, is partly dependent on the lens/LED separation.

Other factors such as the physical size of the lens and the presence or absence of restrictive apertures in the housing.

A combination of these aspects achieves the desired uniformity across the target plane with excellent efficiency and compactness. It is possible that the lens/LED separation be greater than the lens focal length, in which case the lens/LED diameter ratio is chosen to ensure sufficient mixing and uniformity for the illumination area on the target plane 4.

The spatial arrangement and the lens properties achieve uniform mixing of the light to the extent that at any point on the target plane light is received from at least 25% of the LEDs 6 in various proportions.

The angle of incidence of the illumination on the target plane (indicated as α) may be electronically varied if the illuminator has a plurality of rings of LEDs, in which case choice of a particular ring to be activated sets the value for α .

The LEDs 6 emit uncollimated light, again contributing to uniform illumination.

Referring to FIG. 3(a) an annular lens 20 of circular cross-section may be used. The lens has rotational symmetry about the z-axis, as shown. As shown in FIG. 3(b) the cross-sectional shape (in the x-z plane) may be:

22—bi-convex,

23—Fresnel (as for the illuminator 1 of FIGS. 1 and 2),

24—combined Fresnel and refractive,

25—Fresnel, tilted with respect to the Z axis

26—Fresnel, orthogonal to the Z axis

Other shapes which achieve uniformity across the target plane may also be used.

Referring to FIG. 3(c) operation of an illuminator with the lens 25 is shown. The target 4 is illuminated by the annular Fresnel lens 25 which is orientated in elevational view in a manner whereby it extends at an angle of approximately 45° to the (horizontal) plane of the target, particularly for relatively short working distances. The lens may be orientated up to 90°, as shown for the lens 26 in FIG. 3(d). This is particularly effective for even shorter working distances or for "dark-field" applications requiring illumination from low angles of incidence. The lenses 25 and 26 may be deformable because of choice of material or thickness. The starting configuration when the material lies flat may in this case be arc-shaped. Alternatively, the lens may be formed in rigid material by various casting or moulding techniques.

Referring to FIG. 4 a light source assembly 30 for an illuminator is illustrated. The assembly 30 comprises a board 31 supporting LED chips 32 encapsulated by epoxy resin 33 and connected to the circuit by wire bonds 34. The separation between the chips is in this embodiment 0.50 mm. As chip volume is small, the overall volume of the illuminator is small. In this case the radius on which the chips are located is only 8 mm.

As described above, the LEDs can be arranged in separate rings, each at a different effective angle with respect to the centre of curvature of the annular lens, so that the working distance of the light source assembly 40 can be adjusted electrically, by energising an alternative ring of diodes. This is illustrated schematically in FIG. 5(a), in which LEDs are

on separate circuits 41, 42, and 43 of radii R1, R2, and R3, corresponding to different values of α as defined in FIG. 2. Referring to FIG. 5(b), each circuit comprises LED chips 45 in a semiconductor die connected to a circuit by wire bonds 46. Pads 47 are provided for mounting other components such as resistors or transistors. Also, each ring may have chips with a different colour of illumination so that colour choice or mixing may be electronically driven.

If other factors are unchanged, the area which is illuminated is determined by how close the light sources are to the annular lens. The illuminated area widens as this distance is reduced. This is taken into account in the physical design of the housing. The housing can be either designed so as to provide the appropriate width of illumination at the required working distance, or else it can include a simple mechanical adjustment which enables adjustment of the source to lens separation, and thus adjustment of the area of illumination.

Referring to FIG. 6, the housing 2 of FIG. 2 is shown in detail. The body 50 is of solid aluminum construction, as shown on the right side of FIG. 6. The housing 2 comprises a seat 51 for the PCB 5, a seat 52 for the lens 7, and a further seat 53 for a diffractor or additional lens, if required. The housing 2 also comprises an opening 54 for access of cables to the PCB 5. This arrangement allows excellent heat dissipation from the PCB 5 by conduction through the body of the housing 2. The construction is also very robust and compact. The housing may be modified to incorporate a threaded fitting having the lens seat so that the LED-lens distance may be easily adjusted, or the lens may be replaced easily for different operating conditions. It is envisaged that the lens may be repositioned by an electromechanical mechanism for configuration for different applications.

The housing 2 provides excellent conductive heat dissipation, the importance of which is clear from consideration of the profiles of FIG. 7. This plot illustrates the case temperatures which are achieved by an illuminator of the invention containing 100 LED chips, which is placed on at thermally insulating surface at an ambient temperature of 22° C. These chips are arranged in 10 parallel circuits, each containing 10 light emitting diodes connected in series. Thus the current of 200 mA corresponds to 20 mA going through each chip, which is the recommended continuous current rating of these particular chips. Due to the inefficiencies of the conversion of electrical power to light power within each chip, most of the electrical power which is being supplied to the circuit is being dissipated as heat, and this heat causes the temperature of the housing to increase, as indicated in the diagram. By selecting the materials used in the circuit board and in the housing, and in the manner used to connect the board to the housing, and in the physical size, mass and shape of the housing the amount of temperature rise can be controlled. These issues must be carefully addressed, especially in using the particular advantage of this invention to use a densely packed array of sources in a physically small housing. Because, as can be seen from FIG. 6 the LED chips can be mounted in excellent thermal contact to the metal housing, it is a relatively simple matter to provide adequate heat-sinking for the housing to maintain a cool operating temperature of the LED chips, say less than 50° C. as required for reliable operation.

A particular advantage of the invention is its mechanical simplicity and compactness. The circuits shown in FIG. 5 are designed to contain 100 light emitting diode chips or packages. The illuminator may be smaller especially when using light emitting diode chips, which are typically only 0.25 mm square.

An important feature of the invention is how well the light from the various light emitting diodes mixes on the target

plane through the action of the annular lens on the light as it passes through it. This is illustrated in FIG. 8(a), which is a computer-based "Monte Carlo" simulation showing the pattern on the target plane from a single 0.3 mm square LED chip located on the source circuit with a housing of FIG. 6. The light is spread into a fuzzy segment of an arc. Clearly, in an illuminator containing a number (for example 100) of LEDs, arranged in a ring, when viewed from a point on the target plane, the light at that point will appear to come from many separate diodes, so that it will be very uniform in intensity and colour. This is due to the mixing effect, which normally exist from chip to chip.

Referring to FIG. 8(b) there are illustrated simulations of a 100 chip illuminator in which all of the chips are illuminated, for a working distance of 100 mm. These are two dimensional plots of the relative intensity of the light hitting the target plane in a 100 mm square box, from an illuminator in which the diameter of the circle of light emitting diode sources is 37 mm. The illuminator is designed so that at the desired working distance the uniformity and brightness are optimised. Experimental tests revealed that these simulations are accurate to $\pm 10\%$.

As shown in FIG. 9, LED chips 70 may be arranged in separate circuits, with LEDs of different colours in each circuit so that the colour of the uniformly illuminated area may be sequentially changed by turning on only one LED circuit at a time. Also, different circuits may be simultaneously electrically driven by different currents so that the colour of the resulting illuminated area can be adjusted and, for example, can be made white. It has been found that mixing of R (color 1), G (color 2), and B (color 3) coloured LEDs achieves excellent quality white light, which is particularly important for microscopy applications. Excellent quality white illumination may also be achieved using a mix of blue LEDs together with a phosphor, which may for example be contained in the LED-encapsulating epoxy.

The invention can also produce illuminated areas which are not rotationally symmetric, for example rectangular, by arranging the LED chips appropriately in the plane of the PCB.

The LED chips can be individual unpackaged LED chips, which are typically about 0.25 mm square. They could also be chips in surface mount packages. The chips could also be so-called micro-cavity LEDs with a narrower spectral distribution than normal LEDs. The chips could also be laser diode chips, especially vertical cavity surface-emitting lasers (VCSELs) whose geometry is especially suitable for PCB mounting as described above. They could also be chips in individually lensed packages, such as described above.

The PCB may be made from FR4, or alternatively from ceramic or other high-thermal conductivity material which would be advantageous if a lot of optical power is desired. The operating temperature of the chips may be maintained at a satisfactory temperature, either in isolation or with passive cooling by a heat sink for example, or actively cooled by a Peltier device. Alternatively, a combination of such approaches may be used. The use of a flexible PCB would be particularly advantageous for applications as shown in FIGS. 3(c) and 3(d).

The annular lens can have a variety of shapes as described above referring to FIG. 3. It can be a toroidal-shaped piece of acrylic, polycarbonate, glass, or other special material, having a generally circular cross-section at any point along the annulus. It could have a completely flat surface on one side, so that the cross-section is plano-concave or plano-convex. Very advantageous for compactness is the use of a Fresnel surface, so that the annulus is a flat ring in shape,

with Fresnel refracting rings on one or both surfaces to provide the focussing properties which are required. These Fresnel features can be designed so as to correct for spherical aberration, or in other ways to improve the properties of the illumination on the target surface, such as sharpness or uniformity. The annular ring could be made with an essentially flat ring as described above, but which has diffractively-patterned surfaces designed to provide the required focussing properties. This would be especially useful in the case where laser chips are in use as sources on the PCB, due to the narrow spectral spread of a laser, which is especially suitable for diffractive optics. The annular ring could have a convex shape on one side and a flat surface on the other side could have a Fresnel or diffractive pattern on it.

The chips on the PCB may be arranged in different circuits, insofar as possible to facilitate the correct current driving conditions, or to make it possible to have different colours illuminating the target at the same or different times, or so as to make it possible to have different effective working distances, or to minimise the reduction in uniformity if some circuits fail. The board may also contain voltage dropping resistors, as well as other circuitry for strobing the chips, if required, or for controlling the circuits. The changing of the illumination pattern of the light head could thus be implemented in various ways—either by opening the housing and making an on-board adjustment to the circuitry, or by having the circuits connected to electrical switches on the housing, or by electrical circuitry which can be controlled externally to the light head. Because of the dense arrangement of sources, the invention enables a variety of failure-tolerant features as follows. The sources can be arranged in separate circuits, in which the sources in each circuit are interleaved with sources in other circuits. For example, a 100 chip illuminator might have 100 circuits of 10 chips each in which the 1st, 11th, 21st . . . chips along the circumference are in the same circuit, the 2nd, 12th, 22nd . . . chips are in the next circuit, and so on. The effect of a circuit failure would thus be to reduce overall brightness by 10% rather than to produce a dark area in the illumination.

It will be appreciated that the invention provides an illuminator which is compact, has a low power consumption, and which achieves excellent illumination uniformity. The invention also provides these properties for short or long working distances and so allows excellent versatility for the range of applications which benefit. The illuminator of the invention is particularly suitable for industrial instruments such as used in microscopy or machine vision applications because of the above properties. The illuminator design is scaleable. Another advantage is excellent colour control, as it can provide single colour, switched R, G, or B colour, or combined RGB white illumination.

The invention is not limited to the embodiments described but may be varied in construction and detail. For example, the annular lens may comprise a number of discrete lens arranged in an annular configuration. Also, the illuminator may not have a through hole as applications such as back-lighting do not require it. It is also envisaged that the optical system may comprise an annular reflector instead of a lens. The board need not necessarily be annular even where the housing has a through hole. It may, for example be square in outline plan. It is also envisaged that a particularly compact embodiment of the invention could be achieved by having all of the sources and associated circuitry integrated onto a single monolithic optoelectronic integrated circuit. By appropriate choice of semiconductor, dielectric deposition and patterning techniques the complete illuminator (including optics and housing) could be monolithically integrated.

What is claimed is:

1. An illuminator comprising

a plurality of light sources mounted in a ring configuration, and

an optical system spaced from the plurality of light sources for directing light from the light sources onto a target plane,

the optical system including an annular lens mounted to mix light from all of the plurality of light sources and uniformly illuminate the target area, and

the properties of the optical system and the spatial arrangement of the optical system with respect to the plurality of light sources is such that the light emitted by the plurality of light sources is mixed tangentially, and radial spread of the light is controlled, to uniformly illuminate the target plane over an area at least equal to that encompassed by the ring of light sources and the illumination extending uniformly from a center to a periphery of the target plane.

2. An illuminator as claimed in claim 1, wherein a separation of the light sources and the lens is less than a focal length of the lens.

3. An illuminator as claimed in claim 1, wherein an effective diameter of the ring of light sources is greater than an effective diameter of the lens by 2% to 10%.

4. An illuminator as claimed in claim 1, wherein the light sources comprise means for emitting uncollimated light.

5. An illuminator as claimed in claim 1, wherein each light source is a semiconductor die.

6. An illuminator as claimed in claim 1, wherein the illuminator comprises a housing supporting the light sources and the optical system, said housing having a chamber for the light sources and a chamber for the optical system.

7. An illuminator as claimed in claim 6, wherein the light source chamber supports the light sources in thermal contact with the housing.

8. An illuminator as claimed in claim 1, wherein the annular lens comprises a Fresnel pattern.

9. An illuminator as claimed in claim 8, wherein the Fresnel pattern is configured for correcting for spherical aberration.

10. An illuminator as claimed in claim 1, wherein the lens comprises a diffraction pattern.

11. An illuminator as claimed in claim 1, wherein the annular lens has a convex shape on one side and is flat on the other side.

12. An illuminator as claimed in claim 1, wherein the lens comprises a plurality of individual lenses arranged in an annular configuration.

13. An illuminator as claimed in claim 1, wherein the light sources are mounted on a circuit board.

14. An illuminator as claimed in claim 13, wherein the circuit board has electronic components to control or switch current to the light sources.

15. An illuminator as claimed in claim 13, wherein the circuit board is flexible and is formed into a ring.

16. An illuminator as claimed in claim 13, wherein the light sources provide different colour illumination.

17. An illuminator as claimed in claim 13, wherein the drive circuits comprise means for driving rings of light sources of different radii to electrically vary angle of illumination.

18. An illuminator as claimed in claim 13, wherein the circuit board comprises a plurality of separate circuits.

19. An illuminator as claimed in claim 18, wherein each circuit drives light sources mounted in a pattern.

20. An illuminator as claimed in claim 1, wherein the light sources are covered by epoxy.

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- 21. An illuminator as claimed in claim 20, wherein the light sources are covered by a continuous epoxy layer.
- 22. An illuminator as claimed in claim 21, wherein the epoxy layer contains phosphorescent material.
- 23. A ring illuminator as claimed in claim 1, wherein the optical axis of the lens cross-section is inclined at an angle to the normal to the plane of the annulus.
- 24. A ring illuminator as claimed in claim 23, wherein the lens is inclined at 90° to the normal to the plane of the annulus.
- 25. A ring illuminator as claimed in claim 1, wherein the lens is of a deformable material.
- 26. A ring illuminator as claimed in claim 25, wherein the lens has a flat arc-shaped starting configuration before being bent into an overall ring configuration in plan.
- 27. A method of producing an illuminator comprising the steps of:
 - mounting a plurality of light sources in a ring configuration,

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- positioning an annular lens for directing light from the plurality of light sources onto a target plane,
- choosing the annular lens to have properties such that the lens mixes light from different light sources in the tangential direction and controls spread in the radial direction so that a center to a periphery of the target plane at a desired working distance is uniformly illuminated,
- separating the lens from the light sources by a predetermined distance, and
- choosing the light source ring diameter to lens diameter ratio to set a desired illumination area of the center to the periphery of the target plane.
- 28. A method as claimed in claim 27, wherein the light sources ring diameter: lens diameter ratio is chosen within a range of 1.02 to 1.10.

* * * * *

EXHIBIT H

PATENT ABSTRACTS OF JAPAN

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(72)Inventor : NOMURA HIROSHI

(54) FLUORESCENT PATTERN DETECTOR AND POSTAL MATTER PROCESSOR USING THE DETECTOR

(57)Abstract:

PROBLEM TO BE SOLVED: To efficiently detect a fluorescent pattern by detecting light from the fluorescent pattern of an object to be detected which is excited by excitation light with plural wavelengths and recognizing a fluorescent pattern of the object based on a detection signal.

SOLUTION: In the case of detecting the fluorescent pattern of an object 10 to be detected which is moved in an arrow X direction, an ultraviolet lamp 4 is turned on, 1st excitation light La having 1st proper excitation wavelength is emitted and exited from an outgoing window 2, a light emitting member 5 is excited by the excitation light La, and 2nd excitation light Lb with 2nd proper excitation wavelength is emitted and exited from the window 2. Thereby the fluorescent pattern 11 of the object 10 is excited by respective excitation light La, Lb and light corresponding to the pattern 11 is made incident upon a camera 6 through the window 2 and an aperture part on the center part of a partition plate 3. Consequently a large signal output and a large SN ratio can be obtained by the photoelectric conversion of the camera 6 to be a light detection element and the fluorescent pattern 11 can be efficiently recognized by a recognition part 7.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the mail processing unit which used the fluorescence pattern detection device and this fluorescence pattern detection device.

[0002]

[Description of the Prior Art] Conventionally, in the mail processing unit which processes much mail, Type accumulation of mail etc. which detected the fluorescence pattern which consists of

HAKODO printed by the print medium of an ink-jet printer (IJP) etc. with the fluorescence pattern detection device are performed.

[0003]The conventional example of such a fluorescence pattern detection device is explained with reference to drawing 5 and drawing 6.

[0004]The case 30 which the fluorescence pattern detection device shown in drawing 5 equipped the end with the radiation window 31, and was provided with the diaphragm 32 in which the center section carried out the opening to the inside. The ultraviolet ray lamp 33 which emits light in the excitation light of the fitness excited wavelengths L1 as shown in drawing 6 of the fluorescence pattern 41 of the detecting object 40 arranged between said radiation window 31 and the diaphragm 32. It is arranged in the side rather than the portion in which said diaphragm 32 carried out the opening inside said case 30. The camera 34 which detects the light from the fluorescence pattern 41 of said detecting object 40 excited by the excitation light emitted through said radiation window 31 from said ultraviolet ray lamp 33. The recognition part 35 which recognizes the fluorescence pattern 41 of said detecting object 40 as text etc. based on the detection result of this camera 34 is provided. The detecting object 40 shall move to an arrow X direction in drawing 5.

[0005]

[Problem to be solved by the invention]However, in the case of the conventional fluorescence pattern detection device mentioned above, it is what is exciting the fluorescence pattern 41 of the detecting object 40 only by the excitation light of the single wavelength L1 from the ultraviolet ray lamp 33. The problem that excitation of the fluorescence pattern of detecting objects, such as mail which had the two fitness excited wavelengths L1 and L2 since the luminosity currently adopted was increased in recent years, could not be performed efficiently occurred.

[0006]In light of the above-mentioned circumstances, this invention is a thing.

The purpose is to provide the mail processing unit using the fluorescence pattern detection device and this fluorescence pattern detection device which can detect efficiently the fluorescence pattern of detecting objects, such as mail with excited wavelengths.

[0007]

[Means for solving problem]The fluorescence pattern detection device of this invention which detects a fluorescence pattern with two or more excited wavelengths given to the detecting object is characterized by that the fluorescence pattern detection device of this invention comprises the following.

The excitation device which emits light in the excitation light of two or more wavelength corresponding to the fluorescence pattern of said detecting object.

The optical system unit which consists of a euphotic means to detect the light from the fluorescence pattern of said detecting object excited by the excitation light of two or more wavelength from this excitation device.

A recognition means to recognize the fluorescence pattern of said detecting object based on the detecting signal of said optical system unit.

[0008]Two or more excited wavelengths of the fluorescence pattern given to said detecting object are the 1st and 2nd fitness excited wavelengths, for example, and the 1st excitation part that emits light in the excitation light of the 1st fitness excited wavelengths, and the 2nd excitation part that emits light in the excitation light of the 2nd fitness excited wavelengths can constitute said excitation device.

[0009]The 1st excitation part can constitute the 2nd excitation part with an ultraviolet ray lamp by the light-emitting member which emits light in the excitation light of said 2nd fitness excited wavelengths by the excitation light from an ultraviolet ray lamp.

[0010]The fluorescence pattern detection device of this invention comprises:

The case which equipped the end with the radiation window and was provided with the diaphragm in which the center section carried out the opening to the inside.

The ultraviolet ray lamp which emits light in the excitation light of the 1st fitness excited wavelengths of the fluorescence pattern of said detecting object arranged between said radiation window and a diaphragm.

The light-emitting member which is arranged at the wall surface by the side of the ultraviolet ray lamp of said diaphragm, and emits light in the excitation light of said 2nd fitness excited wavelengths by the excitation light from this ultraviolet ray lamp.

It is arranged in the side rather than the portion in which said diaphragm carried out the opening inside said case, A recognition means to recognize the fluorescence pattern of said detecting object based on the output signal of the photo detector which detects the light from the fluorescence pattern of said detecting object excited by each excitation light emitted through said radiation window, and this photo detector from said ultraviolet ray lamp and a light-emitting member.

[0011]According to the fluorescence pattern detection device of such composition, detection and recognition of detecting objects, such as mail with two or more fitness excited wavelengths, of a fluorescence pattern are efficiently realizable with the simple composition using the light-emitting member which emits light by the excitation light from an ultraviolet ray lamp and this ultraviolet ray lamp.

[0012]Since the mail processing unit of this invention is provided with the fluorescence pattern detection device of composition of having mentioned above, for example, it is being adopted in recent years, the two fitness excited wavelengths L1 and the fluorescence pattern of mail with L2 can be detected efficiently, and it can recognize them.

[0013]Since it is ** with which the mail rework part which gives the fluorescence pattern for discernment to mail by the read station and this mail processing unit itself of the mail in which the fluorescence pattern detection device of composition of having mentioned above was already given to said fluorescence pattern was equipped according to the mail processing unit of this invention, It becomes possible to process efficiently the mail to which the fluorescence pattern for discernment was newly given with the mail which is fed into this mail processing unit, and to which said fluorescence pattern was already given, and this mail processing unit itself.

[0014]

[Mode for carrying out the invention]Below, an embodiment of the invention is described in detail.

[0015]Drawing 1 is provided with the following.

The case 1 which it is an outline sectional view showing the composition of the fluorescence pattern detection device of an embodiment of the invention, and this fluorescence pattern detection device equipped the end with the radiation window 2, and was provided with the diaphragm 3 in which the center section carried out the opening to the inside.

The ultraviolet ray lamp 4 which emits light in 1st excitation light La of the 1st fitness excited wavelengths L1 in the fluorescence pattern 11 of the detecting objects 10, such as mail arranged between said radiation window 2 and the diaphragm 3.

The light-emitting member 5 which is arranged at the wall surface by the side of the ultraviolet ray lamp 4 of said diaphragm 3, and emits light in the 2nd excitation light Lb of the 2nd fitness excited wavelengths L2 in the fluorescence pattern 11 with 1st excitation light La from this ultraviolet ray lamp 4.

It is arranged in the side (right-hand side) rather than the portion in which said diaphragm 3 carried out the opening inside said case 1, Each excitation light La emitted through said radiation window 2 from said ultraviolet ray lamp 4 and the light-emitting member 5, The optical system unit which consists of the camera (CCD camera) 6 which is a photo detector which receives and detects the light from the fluorescence pattern 11 of said detecting object 10 excited by Lb through the opening part of said radiation window 2 and the center section of the diaphragm 3, The recognition part 7 which recognizes concretely the fluorescence pattern 11 of said detecting object 10 as text etc. based on the output signal of the camera 6 of this optical system unit.

The detecting object 10 shall move to an arrow X direction in drawing 1 (conveyance).

[0016]It faces detecting the fluorescence pattern 11 of the detecting object 10 which moves to an arrow X direction according to the fluorescence pattern detection device of composition of having mentioned above, First, while making 1st excitation light La that turned on said ultraviolet ray lamp 4 and had the 1st fitness excited wavelengths L1 emit light and ejecting this 1st excitation light La from said radiation window 2, Excite the light-emitting member 5 with said 1st excitation light La, the 2nd excitation light Lb of the 2nd fitness excited wavelengths L2 is made to emit light, and this 2nd excitation light Lb is also ejected from said radiation window 2.

[0017]Thereby, the fluorescence pattern 11 of the detecting object 10 is excited by the 1st [said] excitation light La and 2nd excitation light Lb, respectively, and the light corresponding to the fluorescence pattern 11 enters into the camera 6 through the opening part of said radiation window 2 and the center section of the diaphragm 3.

[0018]As a result, a bigger signal output and S/N ratio than a conventional example are obtained by the photoelectric conversion in the camera 6 which is a photo detector, and said fluorescence pattern 11 can be efficiently recognized as text etc. by the recognition part 7.

[0019]Next, with reference to drawing 3 and drawing 4, the outline of the mail processing unit provided with the fluorescence pattern detection device (it gives mark 26 below and shown) of composition of having mentioned above is explained.

[0020]The mail processing unit shown in drawing 3 has the main part 20 of the shape of a large-scale core box, and loads into a left part the postcard 15 grade which is mail in drawing 3 of the main part 20, It had the supply system 21 which it sends out one sheet at a time, and had the Type accumulation system 22 of the long picture which classifies the postcard 15 supplied to the center section of the main part 20 from the supply system 21, and the distribution system 23 of postcard 15 grade and the rework part 24 are formed in the field of the point of the carrying path formed through the Type accumulation system 22 bottom from the supply system 21.

[0021]Said supply system 21 possesses the reading part etc. which read the variety of information of the zip code containing said fluorescence pattern detection device 26 which detects the accumulation part 25 which accumulates postcard 15 grade, and the fluorescence pattern 11 which is given to the postcard 15 grade sent out from this accumulation part 25, and which were described, an address, etc.

[0022]The ink-jet printer 27 which prints the fluorescence pattern 11a with the 1st and 2nd fitness excited wavelengths L1 according to the reading result of a zip code, an address, etc., and L2 on said rework part 24 by the reading part mentioned above, The fluorescence pattern

detection device 26 for checking the fluorescence pattern 11a printed by this ink-jet printer 27 is formed.

[0023] Drawing 4 shows an example of the postcard 15 on which the fluorescence pattern 11a was printed by the ink-jet printer 27.

[0024] According to the mail processing unit provided with the fluorescence pattern detection device 26 of composition of having mentioned above, the two fitness excited wavelengths L1 adopted in recent years and the fluorescence pattern 11 of the mail 15 with L2 can be detected efficiently, and can be recognized. According to the mail processing unit provided with the fluorescence pattern detection device 26 of composition of having mentioned above, it becomes possible to process efficiently the mail to which the fluorescence pattern 11a for discernment was newly given with this mail processing unit itself.

[0025]

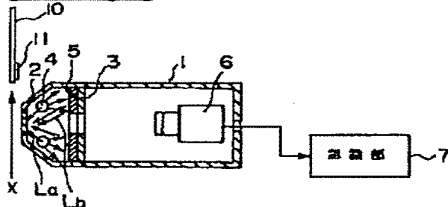
[Effect of the Invention] According to this invention, the fluorescence pattern detection device which can perform detection and recognition of a detecting object of a fluorescence pattern efficiently with the simple composition of using two or more excitation light can be provided.

[0026] It is possible according to this invention, to detect efficiently the two fitness excited wavelengths L1 and the fluorescence pattern of mail with L2, and to recognize them, for example, it is being adopted in recent years, The mail processing unit which can process efficiently the mail to which the fluorescence pattern for discernment was newly given with the mail processing unit itself can be provided.

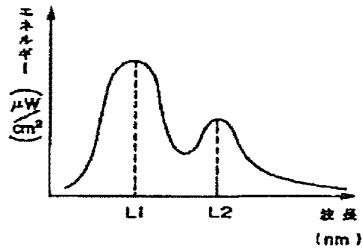
[Translation done.]

DRAWINGS

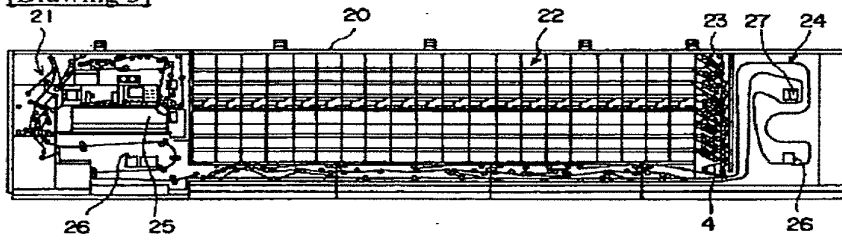
[Drawing 1]



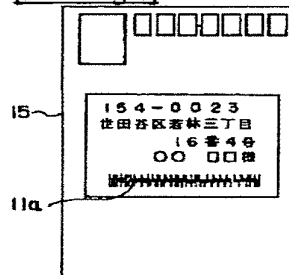
[Drawing 2]



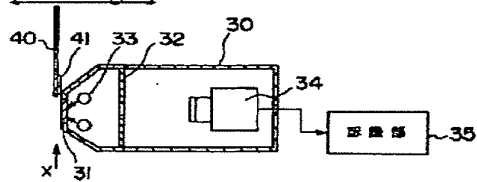
[Drawing 3]



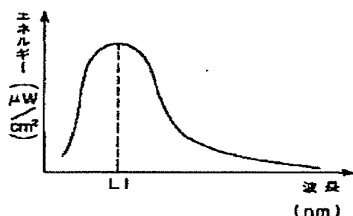
[Drawing 4]



[Drawing 5]



[Drawing 6]



[Translation done.]

[Claim 1] A fluorescence pattern detection device which detects a fluorescence pattern with two or more excited wavelengths given to a detecting object, comprising:

An excitation device which emits light in excitation light of two or more wavelength corresponding to a fluorescence pattern of said detecting object.

A recognition means to recognize a fluorescence pattern of said detecting object based on a detecting signal of an optical system unit which consists of a euphotic means to detect light from a fluorescence pattern of said detecting object excited by excitation light of two or more wavelength from this excitation device, and said optical system unit.

[Claim 2] The 1st given to a detecting object, a fluorescence pattern detection device which detects a fluorescence pattern with the 2nd fitness excited wavelengths characterized by comprising the following.

The 1st excitation part that emits light in excitation light of the 1st fitness excited wavelengths of a fluorescence pattern of said detecting object.

An excitation device which consists of the 2nd excitation part that emits light in excitation light of said 2nd fitness excited wavelengths by excitation light from this 1st excitation part.

An optical system unit which consists of a euphotic means to detect light from a fluorescence pattern of said detecting object excited by excitation light of the 1st [from this excitation device], and 2nd fitness excited wavelengths.

A recognition means to recognize a fluorescence pattern of said detecting object based on a detecting signal of said optical system unit.

[Claim 3] The 1st given to a detecting object, a fluorescence pattern detection device which detects a fluorescence pattern with the 2nd fitness excited wavelengths characterized by comprising the following.

An ultraviolet ray lamp which emits light in excitation light of the 1st fitness excited wavelengths of a fluorescence pattern of said detecting object.

An excitation device which consists of a light-emitting member which emits light in excitation light of said 2nd fitness excited wavelengths by excitation light from this ultraviolet ray lamp.

An optical system unit which consists of a photo detector which detects light from a fluorescence pattern of said detecting object excited by excitation light of the 1st [from this excitation device], and 2nd fitness excited wavelengths.

A recognition means to recognize a fluorescence pattern of said detecting object based on a detecting signal of said optical system unit.

[Claim 4]The 1st given to a detecting object, a fluorescence pattern detection device which detects a fluorescence pattern with the 2nd fitness excited wavelengths characterized by comprising the following.

A case which equipped an end with a radiation window and was provided with a diaphragm in which a center section carried out the opening to an inside.

An ultraviolet ray lamp which emits light in excitation light of the 1st fitness excited wavelengths of a fluorescence pattern of said detecting object arranged between said radiation window and a diaphragm.

A light-emitting member which is arranged at a wall surface by the side of an ultraviolet ray lamp of said diaphragm, and emits light in excitation light of said 2nd fitness excited wavelengths by excitation light from this ultraviolet ray lamp.

It is arranged in the side rather than a portion in which said diaphragm carried out the opening inside said case, A recognition means to recognize a fluorescence pattern of said detecting object based on an output signal of a photo detector which detects light from a fluorescence pattern of said detecting object excited by each excitation light emitted through said radiation window, and this photo detector from said ultraviolet ray lamp and a light-emitting member.

[Claim 5]A mail processing unit which processes mail to which a fluorescence pattern with two or more excited wavelengths was given, comprising:

An excitation device which emits light in excitation light of two or more wavelength corresponding to a fluorescence pattern of mail.

A recognition means to recognize a fluorescence pattern of said mail based on a detecting signal of an optical system unit which consists of a euphotic means to detect light from a fluorescence pattern of said mail excited by excitation light of two or more wavelength from this excitation device, and said optical system unit.

[Claim 6]A mail processing unit which processes mail to which a fluorescence pattern with two or more excited wavelengths was given, comprising:

An excitation device which emits light in excitation light of two or more wavelength corresponding to a fluorescence pattern of mail.

A recognition means to recognize a fluorescence pattern of said mail based on a detecting signal of an optical system unit which consists of a euphotic means to detect light from a fluorescence pattern of said mail excited by excitation light of two or more wavelength from this excitation device, and said optical system unit.

[Translation done.]

EXHIBIT I

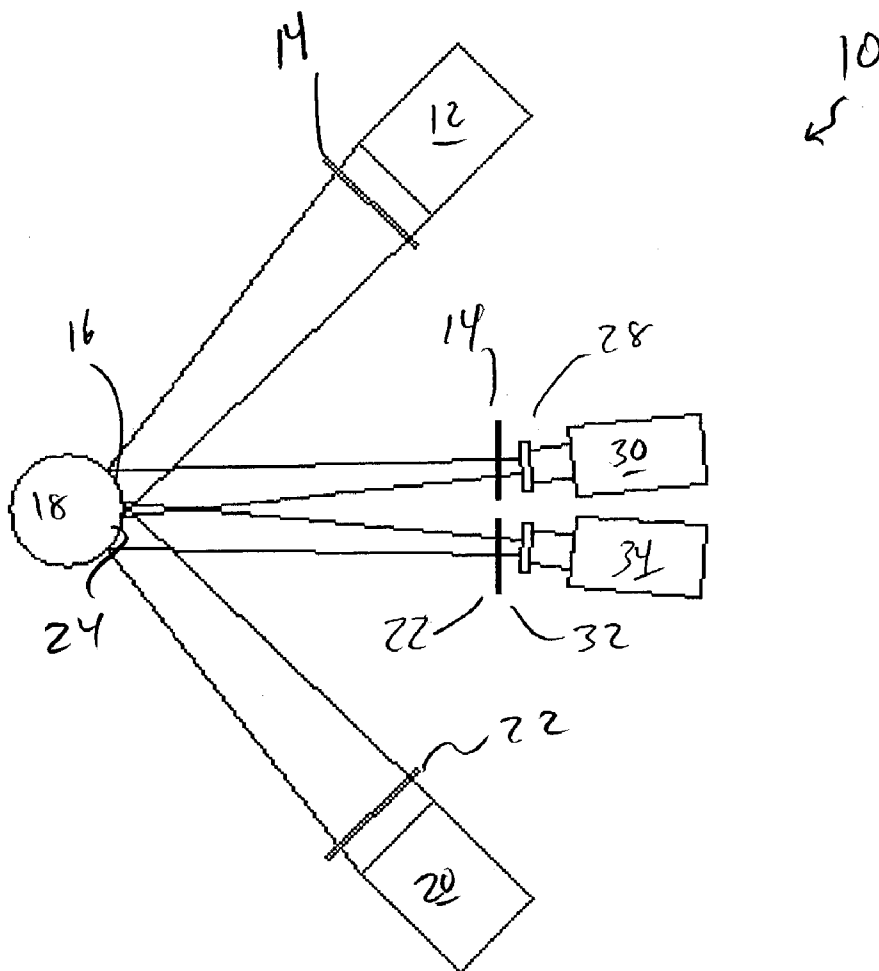


US 20040247170A1

(19) **United States**(12) **Patent Application Publication****Furze et al.**(10) **Pub. No.: US 2004/0247170 A1**(43) **Pub. Date: Dec. 9, 2004**(54) **USE OF PATTERNED, STRUCTURED LIGHT
TO DETECT AND MEASURE SURFACE
DEFECTS ON A GOLF BALL**(52) **U.S. Cl. 382/141**(76) **Inventors: Paul A. Furze, Tiverton, RI (US);
Thomas L. Mydlack, Rochester, MA
(US)**(57) **ABSTRACT**

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A method of inspecting a golf ball, comprising the steps of providing a golf ball; providing a first light source emitting a first color of light; illuminating a first area of the golf ball with the first light source; providing a second light source emitting a second color of light different from the first color of light; illuminating a second area of the golf ball with a second light; providing a first detector comprising a first filter for transmitting the first color of light and filtering out the second color of light; providing a second detector comprising a second filter for transmitting the second color of light and filtering out the first color of light; rotating the ball about an axis; and detecting a shadow resulting from illumination by the first or second light sources.

(21) **Appl. No.: 10/456,298**(22) **Filed: Jun. 6, 2003****Publication Classification**(51) **Int. Cl.⁷ G06K 9/00**

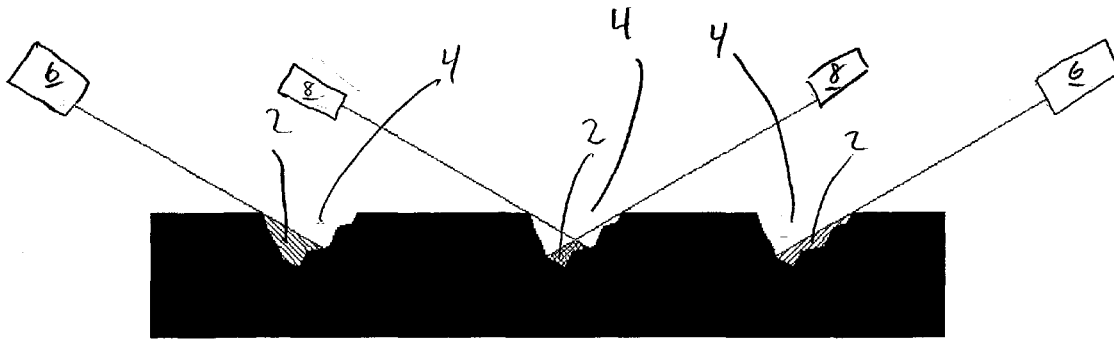


FIG. 1

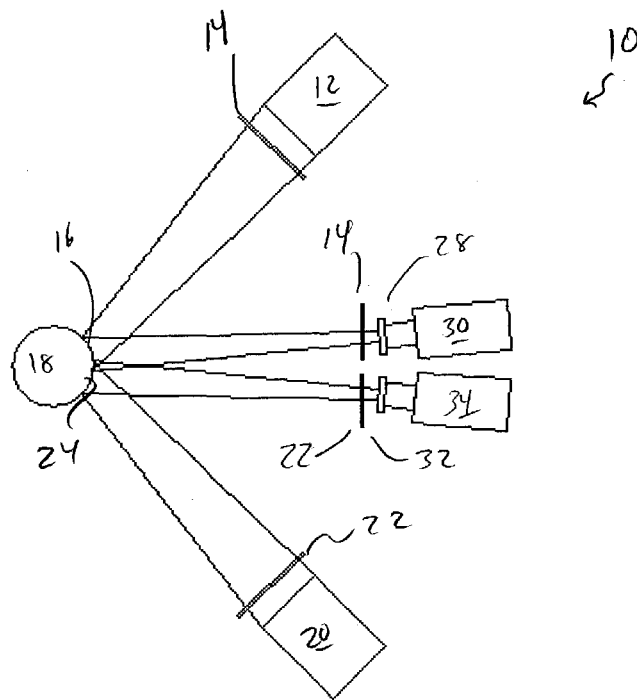


FIG. 2

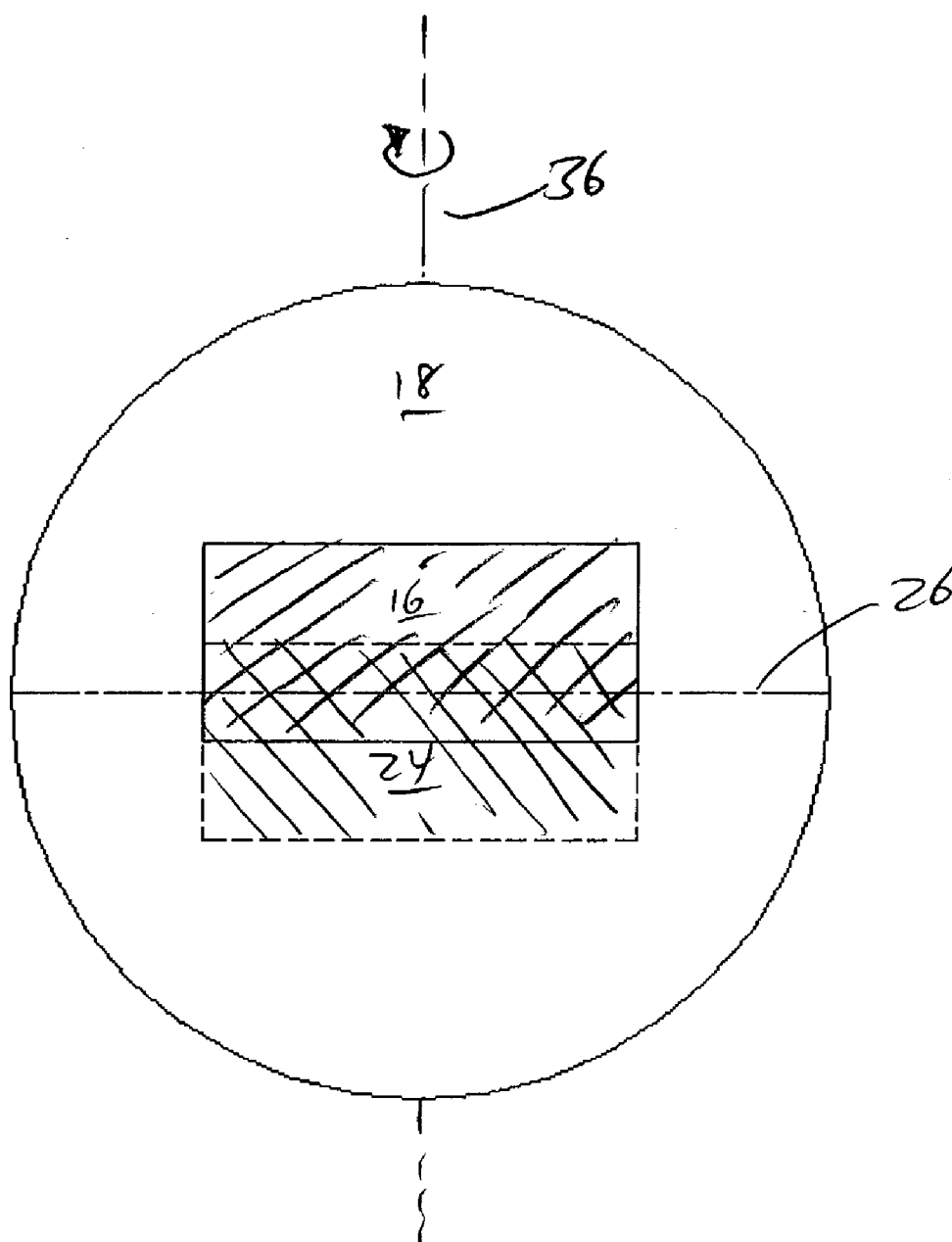


FIG. 3

USE OF PATTERNED, STRUCTURED LIGHT TO DETECT AND MEASURE SURFACE DEFECTS ON A GOLF BALL

BACKGROUND OF THE INVENTION

[0001] In the manufacture of golf balls defects, such as flow lines, excess cover material, weld marks, protrusions, gate marks, depressions, buffing lines, paint blots, stuck molding flash, blisters, and other foreign matter (i.e., dirt, particulate, etc.), can form on the surface of the golf balls for a variety of reasons. Golf balls having such defects can be aesthetically displeasing and may exhibit a loss in aerodynamic performance. As such, it is common practice within the golf ball industry to inspect, in some manner, the surface of the golf balls for defects prior to painting (if necessary), packaging, and shipping.

[0002] Conventionally, golf balls are inspected manually. But given the excessive number of golf balls produced in a year (e.g. Titleist®, the number one ball in golf, produces over 276 million golf balls per year), however, manual inspection of every golf ball is physically and logistically impossible and, additionally, is very subjective. Manufacturers have, therefore, attempted to automate the inspection process and incorporate the inspection somewhere in the golf ball manufacturing sequence. Automated golf ball surface inspection is difficult, however, because of a golf ball's unique surface topography—curved and dimpled.

[0003] A substitute for visual inspection that is commonly employed to automatically inspect the outer surface of a golf ball typically includes taking an optical image of the ball and processing the image by comparing it to a reference standard. When the object to be inspected is dimpled, such as a golf ball, the difficulties in detecting defects on the surface are greatly increased. Because dimples are distributed on a spherical surface, they can appear in the image as artifacts, such as ellipsoids having indefinite major and minor axes shadows. It is, therefore, important for a detection system to be able to detect the difference between a dimple and a defect on the curved, dimpled surface.

[0004] U.S. Pat. No. 6,031,933 discloses one such method for inspecting the outer surface of a golf ball. In the '933 patent, the outer surface of a golf ball is inspected for defects by illuminating the golf ball with a single light source, rotating the golf ball at a constant speed in one direction, and taking a series of line images of the ball surface with a line sensor camera along a line perpendicular to the rotational direction of the ball. The camera then delivers the one-dimensional line data to a computer that assembles it into a two-dimensional image, converts a brightness change in the two-dimensional image in the rotational direction of the ball into a variation per preset unit, and subjects the resulting variation data to binary processing on the basis of a threshold set between the variation associated with the dimple and the variation associated with any defects, thereby detecting whether or not defects are present. Effectively, a light threshold, based on the dynamic range of the line data, is determined—light levels darker than the threshold value are deemed a defect and light levels above the threshold value are deemed not a defect (i.e., a shadow or dark area, that does not match the intensity profile of a dimple, represents a defect).

[0005] The '933 patent, however, is limited in the 'area' of the surface that can be inspected. Because the surface of a

golf ball is curved and light does not bend, as one moves away from the equator (or center of the illumination) of the ball, the golf ball surface itself begins to appear as a shadow in a collected line (or two-dimensional) image, limiting the effectiveness of the imaging method. Because of their varying and non-discriminating nature, surface defects, unfortunately, are not limited to specific areas of a golf ball. The method of the present invention provides a novel way to address this issue by adding a second illumination source having a different wavelength (or range of wavelengths) than the first illumination source, in combination with an array of pass filters and two-dimensional area imaging (versus line imaging).

SUMMARY OF THE INVENTION

[0006] The present invention is directed to a method of inspecting a golf ball, comprising the steps of providing a golf ball; providing a first light source emitting a first color of light; illuminating a first area of the golf ball with the first light source; providing a second light source emitting a second color of light different from the first color of light; illuminating a second area of the golf ball with a second light; providing a first detector comprising a first filter for transmitting the first color of light and filtering out the second color of light; providing a second detector comprising a second filter for transmitting the second color of light and filtering out the first color of light; rotating the ball about an axis; and detecting a shadow resulting from illumination by the first or second light sources.

[0007] The second area preferably has a different geometric center than the first area, but is preferably parallel and overlapping. The area of the golf ball to be imaged is preferably on either side of its equator (or parting line) which would be disposed between the first and second imaging areas.

[0008] The method further may include the step of capturing an image of each of the first and second areas with the first and second detectors. The images may be compared or analyzed individually for defects. It is preferred that the first light source have a first wavelength range and the second light source has a second wavelength range that is substantially different from the first. In a preferred embodiment, the first wavelength range is between about 480 nm and about 530 nm and the second wavelength range is between about 600 nm and about 680 nm.

[0009] In one embodiment, a first polarizer is located between at least one of the light sources and the golf ball and a second polarizer is located between the golf ball and at least one of the detectors, the second polarizer being oriented orthogonal to the first.

[0010] The first or second detectors are preferably one of a charge-coupled device, a photomultiplier tube, an avalanche photodiode, or a video camera. The first or second filters typically include a high-pass filter, a low-pass filter, a notch filter, or a holographic notch filter. The first or second light sources generally are one of a light-emitting diode, a laser, a colored lamp, or an arc lamp.

[0011] The axis of rotation of the golf ball for imaging should be perpendicular to a plane defined by the equator or parting line of the ball. The light sources and/or detectors can be oriented in any reference frame relative to the defined

plane. In a preferred embodiment, the first and second areas are parallel and not overlapping.

[0012] The present invention is also directed to a method of inspecting a golf ball, comprising the steps of translating a golf ball for inspection, the golf ball having an equator; providing a first light source emitting a first color of light having a first wavelength range; illuminating a first area of the golf ball with the first light source; providing a first polarizer disposed between the first light source and the golf ball; providing a second light source emitting a second color of light having a second wavelength range substantially different from the first; illuminating a second area of the golf ball with a second light, the second area being parallel to and overlapping the first; providing a second polarizer disposed between the second light source and the golf ball; providing a first detector comprising a first filter for transmitting the first wavelength range and filtering out the second wavelength range; providing a second detector comprising a second filter for transmitting the second wavelength range and filtering out the first wavelength range; rotating the ball about an axis perpendicular to a plane defined by the equator; capturing an image of the first and second areas with the first and second detectors; and analyzing the image for a shadow indicative of surface defects. In one embodiment, the method further includes the step of providing at least one third polarizer disposed between the golf ball and the detectors, the third polarizer being orthogonal to the first and second polarizers.

[0013] The present invention is further directed to a method of inspecting a curved surface, comprising the steps of providing the curved surface for inspection; providing a first light source emitting a first color of light having a first wavelength range; illuminating a first area of the curved surface with the first light source; providing a second light source emitting a second color of light having a second wavelength range substantially different from the first; illuminating a second area of the curved surface with a second light, the second area being parallel to the first; providing a first detector comprising a first filter for transmitting the first wavelength range and filtering out the second wavelength range; providing a second detector comprising a second filter for transmitting the second wavelength range and filtering out the first wavelength range; rotating the curved surface; capturing an image of the first and second areas with the first and second detectors; and analyzing the images for a shadow indicative of surface defects. In one embodiment, the curved surface includes a golf ball center, golf ball core, golf ball layer, or a golf ball.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 is a cross section of a golf ball surface showing the effect of shadow cancellation;

[0015] FIG. 2 is a diagram of one embodiment of the inspection system; and

[0016] FIG. 3 is a view of the overlapped regions inspected by the inspection system.

DETAILED DESCRIPTION OF THE INVENTION

[0017] The automated inspection system of the present invention is suitable for use on the surface of any golf ball

component, such as centers, cores, core layers, intermediate layers, and cover layers or coatings. Preferably, the inspection system is used to inspect the outer surface of cores or covers.

[0018] The inspection system of the present invention typically includes at least one golf ball, a translation and rotation system, 2 light sources, 2 detectors, and 2 filters. Generally, a golf ball to be inspected is translated into a position for inspection. Although not shown, the inspection system is attached to a computer (or self-contained vision system) and for subsequent analysis and image processing. The computer and monitor may be combined into a single element or be separate elements. The computer has several algorithms and programs used by the system to make the determinations discussed below.

[0019] A first light source illuminates the golf ball at a first wavelength and a second light source illuminates the golf ball at a second wavelength, the second wavelength being different from the first. It is preferred that at least 2 light sources are used so that the region of inspection is maximized. It is well understood that a curved surface provides difficult challenges to overcome, in particular when light, varying angles, and shadows therefrom are involved.

[0020] Referring to FIG. 1, shadows 2 caused by surface defects 4 are easily 'seen' when illuminated with a single light source 6. A problem arises, however, when two light sources 8 are employed. In FIG. 1, the center defect clearly shows that the two light sources impinging on the defects 4 result in cancellation of the shadows 2. As such, these defects 4 would not be detected if the detection system were to rely solely on shadows 2 to indicate such anomalies.

[0021] Referring to FIGS. 2 and 3, the inspection system of the present invention recognizes and overcomes this problem by requiring that the light sources have different wavelengths and further including a filter (i.e., color, high-pass, low-pass, notch, holographic, etc.) between the illuminated golf ball surface and each detector. This configuration results in a system in which each of the detectors are specific to (because of filtering) the wavelength (or wavelength range) of each light source and that 'passed' by the filter. FIG. 2 shows a preferred embodiment of the inspection system 10 of the present invention and includes a first light source 12 and a polarizer 14 for illuminating a first area 16 of a golf ball 18. A second light source 20 and polarizer 22 illuminate a second area 24 of golf ball 18. The polarizers, 14 and 22, may or may not be present but can help eliminate specular glare, especially when illuminating a reflective surface. Further, the polarizers, 14 and 22, are preferably present both between the light sources, 12 and 20, and the golf ball 18, as well as between the detectors, 30 and 34, and the golf ball 18. Most preferably, the polarizers, 14 and 22, are oriented orthogonal to one another.

[0022] The first and second areas, 16 and 24, may or may not overlap. Preferably the first and second areas, 16 and 24, overlap, more preferably about the equator 26 or parting line of golf ball 18. Referring to FIG. 2, the image resulting from illumination by the first light source 12 passes through first filter 28 and is captured by first detector 30. The image resulting from illumination by the second light source 20 passes through a second filter 32 and is captured by second detector 34.

[0023] The first and second light sources, 12 and 20, can be any light source, but are preferably a light-emitting-diode

(“LED”), a colored lamp, or a laser. Additionally, a multi-wavelength light source, such as an arc lamp, may be used in combination with a filter that passes only a single (or narrow band) wavelength of light prior to striking the golf ball surface. The first and second filters, **28** and **32**, can be any filter that passes the wavelength of light of the first light source **12** but does not pass the wavelength of light from the second light source **20**. Preferably, the filters are a high-pass filter (allows long wavelengths to pass but blocks short wavelengths); a low-pass filter (allows short wavelengths to pass but blocks long wavelengths); a notch filter (allows only a narrow band of wavelengths to pass, i.e., a green notch filter might allow 500-525 nm light to pass while blocking all other wavelengths); or a holographic notch filter (allows only a single wavelength of light to pass; typically used with laser illumination).

[0024] For example, consider a first light source to be a green light, having a wavelength of about 500 nm, and a second light source to be a red light, having a wavelength of about 650 nm. In this case, the detector for the first light source would have a filter that passed only green light (but no red light) and the detector for the second light source would have a filter that passed only red light (but no green light). This combination would eliminate the shadow-canceling problem and allow twice the area to be probed for defects than were a single camera used.

[0025] While any light-sensitive detector, capable of imaging an area, is suitable for the inspection system **10** of the present invention, preferred detectors include, but are not limited to, charge-coupled device-based detectors, photomultiplier tubes, avalanche photodiodes, and digital video cameras. First and second detectors, **30** and **34**, are most preferably charge-coupled device (“CCD”) based, such as the ELECTRIM® EDC-1000U computer camera from Electrim Corporation in Princeton, N.J. CCD’s are two-dimensional silicon-metal oxide arrays that are nearly ideal for a variety of imaging needs, especially those requiring detection at low light levels. CCD detectors have a number of characteristic advantages over other multi-channel detectors, such as photomultiplier tubes, including high quantum efficiency in the visible spectrum, excellent charge-transfer efficiency, low read noise and dark current, wide dynamic range, and image plane stability. Utilization of the CCD as a detector is based on collecting and storing photon-induced charge on a continuous silicon substrate (array) divided into individual elements (pixels) by a series of electrodes which are used to manipulate the charge. Exposure of this two-dimensional imaging area leads to charge accumulation that is localized by potential wells established by electrodes on the detector surface. This two-dimensional “image” can then be transferred to a serial register by a series of potentials applied to the electrodes and on to a monitor for viewing by the user.

[0026] The detectors preferably each have a line-of-sight directed to and focused on a predetermined focal length. The focal length of the detectors can be any focal length but is preferably larger than required to image a single golf ball. The detectors are most preferably directed and focused on a predetermined field-of-view in which the golf ball moves into and out of, during which it is imaged.

[0027] The light from the first and second light sources, **12** and **20**, is preferably directly illuminating, but may also be

directed by mirrors, lenses, prisms, fiber optics, or a combination of these. It is also envisioned that UV or IR irradiation could be employed or that a single wavelength light source, in combination with a strobe or alternating time delay might be used in the inspection system.

[0028] The golf ball **18** may be delivered in any manner into the field of view of the inspection system **10**. Proper orientation of the ball is important so that the maximum area of the surface can be imaged. Preferably, the golf ball is oriented so that the field of view of the 2 detectors, **30** and **34**, is overlapping, just above and below the equator **26** of the ball **18**. This can be seen clearly in **FIG. 3**. The golf ball **18** is then preferably rotated about an axis **36** perpendicular to the plane defined by the equator **26** so that the entire circumference of the golf ball **18** can be inspected. Preferably the golf ball is rotated continuously but in an alternative embodiment, the golf ball **18** is rotated incrementally.

[0029] The inspection system **10** can be oriented at any angle relative to the equator **26** and golf ball **18**, as long as the light illuminates the proper areas of the surface and the detectors, **30** and **34**, can collect the area-scan image. In two alternative embodiments, the golf ball **18** is rotated on more than 1 axis or the combination of the light sources, filters, and detectors are rotated or translated.

[0030] In an alternative embodiment of the present invention, structured light, in the form of a Moiré pattern (or, alternatively, a grid or line scan pattern), is projected onto the surface of a golf ball. Moiré fringes are an interference pattern that is formed when two similar grids overlap each other. The result is a series of fringe patterns that change shape when as the grids are translated. While typically used to measure the profiles of flat surfaces, in this alternative embodiment it is desired that the lines of the Moiré pattern, when projected onto a curved surface, can effectively serve as “topographical” lines to map the golf ball surface and any defects thereon. Upon detection and analysis, any variations in the Moiré “topographical” pattern would indicate variations or imperfections in the golf ball surface—defects.

[0031] An additional Moiré pattern embodiment involves projecting the Moiré pattern onto the curved golf ball surface at a predetermined angle to the viewing axis. If part of the golf ball surface is raised or indented (i.e., a surface defect exists), the Moiré pattern will shift toward or away from the light source.

[0032] Alternatively, a single line could be projected onto the golf ball surface at a predetermined angle relative to the viewing axis. Any raised or indented areas (surface defects) would again shift the line toward or away from the light source. In this embodiment, the golf ball (or surface being analyzed) could be iteratively shifted and/or rotated to allow the entire surface to be mapped. In a preferred embodiment, the line projected on the curved surface is pre-curved so that it appears on the curved golf ball surface as a straight line. It is well understood that a straight line projected onto a curved surface results in an arc-shaped line—processing or analyzing the area around an arc is time consuming. Adjusting the projection as above will allow simpler and faster analysis of the golf ball surface. It is also envisioned that this method would work using a single point in place of a line.

[0033] The term “about”, as used herein in connection with one or more numbers or numerical ranges, should be understood to refer to all such numbers, including all numbers in a range.

[0034] The invention described and claimed herein is not to be limited in scope by the specific embodiments herein disclosed, since these embodiments are intended solely as illustrations of several aspects of the invention. Any equivalent embodiments are intended to be within the scope of this invention. Indeed, various modifications of the invention in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description. Such modifications are also intended to fall within the scope of the appended claims.

What is claimed is:

1. A method of inspecting a golf ball, comprising the steps of:

- providing a golf ball;
- providing a first light source emitting a first color of light;
- illuminating a first area of the golf ball with the first light source;
- providing a second light source emitting a second color of light different from the first color of light;
- illuminating a second area of the golf ball with a second light;
- providing a first detector comprising a first filter for transmitting the first color of light and filtering out the second color of light;
- providing a second detector comprising a second filter for transmitting the second color of light and filtering out the first color of light;
- rotating the ball about an axis; and
- detecting a shadow resulting from illumination by the first or second light sources.

2. The method of claim 1, wherein the second area has a different geometric center than the first area.

3. The method of claim 1, wherein the golf ball has an equator or a parting line disposed between the first and second areas.

4. The method of claim 1, further comprising the step of capturing an image of the first and second areas with the first and second detectors.

5. The method of claim 1, wherein the first light source has a first wavelength range and the second light source has a second wavelength range different from the first.

6. The method of claim 5, wherein the first wavelength range is between about 480 nm and about 530 nm and the second wavelength range is between about 600 nm and about 680 nm.

7. The method of claim 1, wherein a first polarizer is located between at least one of the light sources and the golf ball and a second polarizer is located between the golf ball and at least one of the detectors, the second polarizer being oriented orthogonal to the first.

8. The method of claim 1, wherein the first or second detectors comprise a charge-coupled device, a photomultiplier tube, an avalanche photodiode, or a video camera.

9. The method of claim 1, wherein the first or second filters comprise a high-pass filter, a low-pass filter, a notch filter, or a holographic notch filter.

10. The method of claim 1, wherein the first or second light sources comprise a light-emitting diode, a laser, a colored lamp, or an arc lamp.

11. The method of claim 1, wherein the axis of rotation is perpendicular to a plane defined by the equator or parting line.

12. The method of claim 1, wherein the first and second areas are parallel and not overlapping.

13. A method of inspecting a golf ball, comprising the steps of:

- translating a golf ball for inspection, the golf ball having an equator;
- providing a first light source emitting a first color of light having a first wavelength range;
- illuminating a first area of the golf ball with the first light source;
- providing a first polarizer disposed between the first light source and the golf ball;
- providing a second light source emitting a second color of light having a second wavelength range substantially different from the first;
- illuminating a second area of the golf ball with a second light, the second area being parallel to and overlapping the first;

- providing a second polarizer disposed between the second light source and the golf ball;

- providing a first detector comprising a first filter for transmitting the first wavelength range and filtering out the second wavelength range;

- providing a second detector comprising a second filter for transmitting the second wavelength range and filtering out the first wavelength range;

- rotating the ball about an axis perpendicular to a plane defined by the equator;

- capturing an image of the first and second areas with the first and second detectors; and

- analyzing the image for a shadow indicative of surface defects.

14. The method of claim 13, further comprising the step of providing at least one third polarizer disposed between the golf ball and the detectors, the third polarizer being orthogonal to the first and second polarizers.

15. A method of inspecting a curved surface, comprising the steps of:

- providing the curved surface for inspection;
- providing a first light source emitting a first color of light having a first wavelength range;
- illuminating a first area of the curved surface with the first light source;
- providing a second light source emitting a second color of light having a second wavelength range substantially different from the first;
- illuminating a second area of the curved surface with a second light, the second area being parallel to the first;
- providing a first detector comprising a first filter for transmitting the first wavelength range and filtering out the second wavelength range;

providing a second detector comprising a second filter for transmitting the second wavelength range and filtering out the first wavelength range;

rotating the curved surface;

capturing an image of the first and second areas with the first and second detectors; and

analyzing the images for a shadow indicative of surface defects.

16. The method of claim 15, wherein the curved surface comprises a golf ball center, golf ball core, golf ball layer, or a golf ball.

* * * * *

EXHIBIT J



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(54) **LAYERED ARTICLES HAVING
POLYOXYMETHYLENE BLEND
SUBSTRATES WITH ENHANCED SURFACE
PROPERTIES AND AT LEAST ONE LAYER
THEREON AND PROCESS FOR MAKING
THE SAME**

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(57) **ABSTRACT**

The present invention relates to layered articles comprising
(a) a substrate comprising 99.5-40 weight percent of an
polyoxymethylene polymer; and 0.5-60 weight percent of at
least one non-acetal thermoplastic polymer; and (b) at least
one additional layer deposited thereon.

**LAYERED ARTICLES HAVING
POLYOXYMETHYLENE BLEND SUBSTRATES
WITH ENHANCED SURFACE PROPERTIES AND
AT LEAST ONE LAYER THEREON AND PROCESS
FOR MAKING THE SAME**

[0001] This application claims the benefit of U.S. Provisional Application No. 60/435,090 filed Dec. 20, 2002 which is incorporated by reference herein for all purposes as if fully set forth.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates to layered articles comprising a polyoxymethylene blend substrate having at least one discontinuous or co-continuous layer adhered thereon, wherein the substrate comprises a blend of compositions that provide enhanced surface adhesion, thereby allowing the application of the at least one layer such as, for example, a coating or overmolding of paints, thermoplastic elastomers, glues and the like.

[0004] 2. Description of Related Art

[0005] Polyoxymethylene compositions are useful as engineering resins due to the positive physical properties they possess, thus allowing polyoxymethylene to be a preferred material for a wide variety of end-uses. Articles made from polyoxymethylene compositions typically possess extremely desirable physical properties such as high stiffness, high strength and solvent resistance. However because of their highly crystalline surface, such articles also have low levels of adhesion, wherein it is difficult, if not impossible to readily paint, glue, or print on such surfaces, overmold such articles with thermoplastic polymers or adhere some other type of layer to the surface of the substrate.

[0006] Polyoxymethylene compositions are generally understood to include compositions based on homopolymers of formaldehyde or of cyclic oligomers of formaldehyde, for example trioxane, the terminal groups of which are end-capped by esterification or etherification, as well as copolymers of formaldehyde or of cyclic oligomers of formaldehyde, with oxyalkylene groups having at least two adjacent carbon atoms in the main chain, the terminal groups of which copolymers can be hydroxyl terminated or can be end-capped by esterification or etherification. The proportion of the comonomers can be up to 20 weight percent. Compositions based on polyoxymethylene of relatively high molecular weight, for example 20,000 to 100,000, are useful in preparing semi-finished and finished articles by any of the techniques commonly used with thermoplastic materials, such as, for example, compression molding, injection molding, extrusion, blow molding, stamping and thermoforming.

SUMMARY OF THE INVENTION

[0007] The present invention relates to an article comprising:

[0008] a) a substrate comprising 99.5-40 weight percent of an polyoxymethylene polymer and 0.5-60 weight percent of at least one non-acetal thermoplastic polymer; and

[0009] b) at least one layer adhered to said substrate, wherein the above given weight percents are based upon the total weight of a) and b).

[0010] The present invention further relates to a process for making the above-noted article comprising the steps of:

[0011] (i) blending a matrix comprising 99.5-40 weight percent of an polyoxymethylene polymer and 0.5-60 weight percent of at least one thermoplastic polymer;

[0012] (ii) molding the matrix into a substrate; and

[0013] (iii) adhering at least one layer to said substrate.

**DETAILED DESCRIPTION OF THE
INVENTION**

[0014] The present invention relates to articles comprising (a) a substrate comprising 99.5-40 weight percent of a polyoxymethylene polymer; and 0.5-60 weight percent of at least one thermoplastic polymer on or near the surface of the substrate to promote adhesion; wherein the substrate has (b) at least one discontinuous or co-continuous layer adhered to its surface.

[0015] Typically, polyoxymethylene based substrates have low levels of adhesion at their surface, therefore it is difficult to make layered articles for commercial purposes such as, for example, "decorated" parts for the automotive industry including, but not limited to, soft touch buttons and switches; household appliances; consumer products including, but not limited to, painted ski bindings and chrome plated caps for perfume bottles; construction parts; furniture, fashion; and industrial uses including, but not limited to, high friction conveyors and sealing clips.

[0016] Additionally, utilizing pretreatments or surface modification techniques such as, for example, etching, flaming ionization, sanding, surface cleaning, UV exposure and the like further increase the adhesion between the substrate and the at least one additional layer. The improved adhesion provided by the pre-treatment may result in better test ratings in some of the more severe testing including, but not limited to, scratching with a knife blade, aging of the painted part.

[0017] The term "layer(s)" or "layered" or a derivative thereof, as used herein, is meant to refer to the overmolding layer and/or the layer of paint or glue and the like being adhered to the substrate.

[0018] As used herein, the terms "adhered," "adhesion" and derivatives thereof shall mean the adhesion that exists between surfaces in which the adhesive secures the adherents by means of interlocking forces, also known as mechanical adhesion. The level of adhesion, mechanical binding or interlocking can be determined by either the peel test or the cross-hatch test or other test appropriate for the type of adherents and its ultimate use. According to the peel test, adhered elastomers or other overmoldings must have a value of at least 2 pounds per linear inch. According to the cross-hatch test, adhered paints or other printing/decorative layers have a value of 2 or better, however the minimum for commercial utility may be higher.

[0019] The term "discontinuous" as used herein refers to a layer (as defined herein) that is adhered to the substrate in

a non-continuous or partial manner over the surface area of the substrate. For example, printing, painting, overmolding, etc. in a pattern which is not continuous and/or does not cover the entire substrate such as, but not limited to stripes, polka dots, grids, etc. are a discontinuous layer. The discontinuous layer is any layer that can not be classified as "co-continuous".

[0020] The term "co-continuous" as used herein refers to a layer (as defined herein) that adheres to the substrate (i.e. which is co-continuous with the "layer") in an uninterrupted or continuous manner over the surface area of the substrate. For example, dip-coating, painting or chrome-plating, etc. of the surface area of the substrate would form a co-continuous layer with the substrate. The co-continuous layer adheres to the surface area of the substrate and there is not a break in the layer (i.e. the layer is a solitary unit).

[0021] As used herein, the term "semi-crystalline" shall refer to a polymeric material processing a melting point when heated in a DSC, in contrast to a T_g.

[0022] Polyoxymethylene Component

[0023] The polyoxymethylene component of the substrate includes homopolymers of formaldehyde or of cyclic oligomers of formaldehyde, the terminal groups of which are end-capped by esterification or etherification, and copolymers of formaldehyde or of cyclic oligomers of formaldehyde and other monomers that yield oxyalkylene groups with at least two adjacent carbon atoms in the main chain, the terminal groups of which copolymers can be hydroxyl terminated or can be end-capped by esterification or etherification.

[0024] Typically, substrates according to the present invention comprise about 99.5-40 weight percent of a polyoxymethylene polymer, however about 99.5-55 weight percent of a polyoxymethylene polymer is preferred.

[0025] The polyoxymethylenes used in the substrates of the present invention can be branched or linear and will generally have a number average molecular weight in the range of about 10,000 to 100,000, preferably about 20,000 to about 90,000, and more preferably about 25,000 to about 70,000. The molecular weight can be measured by gel permeation chromatography in m-cresol at 160° C. using a DuPont PSM bimodal column kit with nominal pore size of 60 and 100 Å. In general, high molecular weight polyoxymethylenes segregate from the second phase material to a greater degree to the non-polyoxymethylene components, and thus addends may show greater adhesion. Although polyoxymethylenes having higher or lower molecular weight averages can be used, depending on the physical and processing properties desired, the polyoxymethylene weight averages mentioned above are preferred to provide the optimum balance of surface adhesion with other physical properties such as high stiffness, high strength and solvent resistance.

[0026] As an alternative to characterizing the polyoxymethylene by its number average molecular weight, it can be characterized by its melt flow rate. Polyoxymethylenes which are suitable for use in the blends of the present invention will have a melt flow rate (measured according to ASTM-D-1238, Procedure A, Condition G with a 1.0 mm (0.0413) diameter orifice of 0.1-40 grams/10 minutes). Preferably, the melt flow rate of the polyoxymethylene used in

the blends of the present invention will be from about 0.5-35 grams/10 minutes. The most preferred polyoxymethylenes with a melt flow rate of about 1-20 gram/10 minutes.

[0027] As indicated above, the polyoxymethylenes used in the substrates of the present invention can be either a homopolymer, a copolymer or a mixture thereof. Copolymers can contain one or more comonomers, such as those generally used in preparing polyoxymethylene compositions. Comonomers more commonly used include alkylene oxides of 2-12 carbon atoms and their cyclic addition products with formaldehyde. The quantity of comonomers will be no more than 20 weight percent, preferably not more than 15 weight percent, and most preferably about 2 weight percent. The most preferred comonomer is ethylene oxide. Generally, polyoxymethylene homopolymer is preferred over copolymer because of its greater stiffness and strength. Preferred polyoxymethylene homopolymers include those whose terminal hydroxyl groups have been end-capped by a chemical reaction to form ester or ether groups, preferably acetate or methoxy groups, respectively.

[0028] The polyoxymethylene may also contain those additives, ingredients, and modifiers that are known to be added to polyoxymethylene compositions for improvement in molding, aging, heat resistance, and the like.

[0029] Thermoplastic Polymer Component

[0030] The at least one non-acetal thermoplastic polymer may be selected from those thermoplastic polymers that are generally used by themselves, or in combination with others, in extrusion and injection molding processes. These polymers are known to those skilled in the art as extrusion and injection molding grade resins, as opposed to those resins that are known for use as minor components (i.e., processing aids, impact modifiers, stabilizers) in polymer compositions.

[0031] Generally substrates according to the present invention comprise about 0.5-60 weight percent of at least one non-acetal thermoplastic polymer, however, about 5-20 weight percent of the at least one non-acetal thermoplastic polymer is preferred. The polyoxymethylene/thermoplastic polymer blend substrate of the present invention contains a region, on or near the surface of the substrate, where the non-acetal polymer typically resides to promote adhesion. The thermoplastic polymer resides in this particular region because in a flowing mixture of immiscible fluids, the lowest viscosity liquid will tend to migrate to the region of highest shear. For example, in the case of injection molding, the wall of the mold cavity is the region of high shear, and thus, a higher concentration of the low viscosity polymer melt becomes concentrated somewhat on or near the surface of the part.

[0032] Semi-crystalline polyamides, polyesters and polyolefins can also be utilized in the present invention, either alone or in combination with one another, such that, each may be blended with the polyoxymethylene to promote adhesion. For example, polyamides having relatively low melting points retain some level of crystallinity, but their low viscosity, high polarity and hydrogen bonding lends them useful for the purpose of the present invention. Polyolefins, preferably polar co- and ter-polymers such as ethylene-vinyl acetate copolymer (EVA) and ethylene butyl acrylate carbon monoxide terpolymer (EBACO), have proven useful to develop surface adhesion between a poly-

oxymethylene substrate and various surface treatments. Semi-crystalline polyesters generally comprise those with a melting point near or below that of polyacetal, such as, polycaprolactone or polylactic acid.

[0033] The non-acetal thermoplastic polymer can be incorporated into the composition as one thermoplastic polymer or as a blend of more than one thermoplastic polymer. Blends of the thermoplastic polymers may be used to adjust properties such as, for example, toughness or the compatibility of the major resin with the polyoxymethylene. Thermoplastic polyurethanes are typically used for this purpose. Preferably, however, the substrate comprises one additional or alternative polymer such as an amorphous thermoplastic polymer or semi-crystalline polymer.

[0034] Whether it is incorporated as one thermoplastic polymer or as a blend of more than one, the weight percent of all non-acetal thermoplastic polymer(s) in the composition shall not exceed the weight percent ranges given above.

[0035] The term "thermoplastic" shall mean the polymer softens, when heated, to a flowable state in which under pressure it can be forced or transferred from a heated cavity into a cool mold and upon cooling in the mold, it hardens and takes the shape of the mold. Thermoplastic polymers are defined in this manner in the Handbook of Plastics and Elastomers (published by McGraw-Hill).

[0036] The term "amorphous," shall mean the polymer has no distinct crystalline melting point, nor does it have a measurable heat of fusion (although with very slow cooling from the melt, or with of sufficient annealing, some crystallinity may develop). The heat of fusion is conveniently determined on a differential scanning calorimeter (DSC). A suitable calorimeter is the DuPont Company's 990 thermal analyzer, Part Number 990000 with cell base II, Part Number 990315 and DSC cell, Part Number 900600. With this instrument, heat of fusion can be measured at a heating rate of 20° C. per minute. The sample is alternately heated to a temperature above the anticipated melting point and cooled rapidly by cooling the sample jacket with liquid nitrogen. The heat of fusion is determined on any heating cycle after the first and should be a constant value within experimental error. Amorphous polymers are defined herein as having a heat of fusion, by this method, of less than 1 cal/gram. For reference, semicrystalline 66 nylon polyamide with a molecular weight of about 17,000 has a heat of fusion of about 16 cal/gm.

[0037] The thermoplastic polymers useful in the present compositions must be melt processible at the temperature at which the polyoxymethylene is melt processed. Polyoxymethylene is normally melt processed at melt-temperatures of about 170° C.-260° C., preferably 185° C.-240° C., and most preferably 200° C.-230° C.

[0038] The term "melt processible" shall mean that the thermoplastic polymer must soften or have a sufficient flow such that it can be melt compounded at the particular melt processing temperature for the polyoxymethylene.

[0039] The minimum molecular weight of the thermoplastic polymer is not considered to be significant for the present blends, provided that the polymer has a degree of polymerization of at least ten and further provided that the polymer is melt processible (i.e., it flows under pressure) at the temperature at which the polyoxymethylene is melt pro-

cessed. The maximum molecular weight of the thermoplastic polymer should not be so high that the thermoplastic polymer by itself would not be injection moldable by standard present techniques. The maximum molecular weight for a polymer to be used for injection molding processes will vary with each individual, particular thermoplastic polymer. However, said maximum molecular weight for use in injection molding processes is readily discernible by those skilled in the art.

[0040] To realize optimum physical properties for the ternary blend, it is recommended that the polyoxymethylene polymer and the non-acetal thermoplastic polymer have matching melt viscosity values under the same conditions of temperature and pressure.

[0041] Amorphous non-acetal thermoplastic polymers, which are injection molding and extrusion grade, suited for use in the blends of the present invention are well known in the art and can be selected from those commercially available or can be made by processes known in the art. Examples of such suitable amorphous thermoplastic polymers include, but are not limited to, those selected from the group consisting of styrene acrylonitrile copolymers (SAN), SAN copolymers toughened with a mostly unsaturated rubber, such as acrylonitrile-butadiene-styrene (ABS) resins, or toughened with a mostly saturated rubber, such as acrylonitrile-ethylene-propylene-styrene resins (AES), polycarbonates, polyamides, polyarylates, polyphenyleneoxides, polyphenylene ethers, high impact styrene resins (HIPS), acrylic polymers, imidized acrylic resins, styrene maleic anhydride copolymers, polysulfones, styrene acrylonitrile maleic anhydride resins, and styrene acrylic copolymers, and derivatives thereof and blends thereof. The preferred amorphous thermoplastic polymers are selected from the group consisting of styrene acrylonitrile copolymers (SAN), SAN copolymers toughened with a mostly unsaturated rubber, such as acrylonitrile-butadiene-styrene (ABS) resins, or toughened with a mostly saturated rubber, such as acrylonitrile-ethylene-propylene-styrene resins (AES), polycarbonates, polyamides, polyphenyleneoxides, polyphenylene ethers, high impact styrene resins (HIPS), acrylic polymers, styrene maleic anhydride copolymers, and polysulfones, and derivatives thereof and blends thereof. The more preferred amorphous thermoplastic polymers are selected from the group consisting of SAN, ABS, AES, polycarbonates, polyamides, HIPS, and acrylic polymers. Most preferred amorphous thermoplastic polymers are SAN copolymers, ABS resins, AES resins, and polycarbonates.

[0042] Amorphous thermoplastic SAN copolymers that are useful herein are well known in the art. SAN copolymer is generally a random, amorphous, linear copolymer produced by copolymerizing styrene and acrylonitrile. The preferred SAN copolymer has a minimum molecular weight of 10,000 and consists of 20-40% acrylonitrile, 60-80% styrene. The more preferred SAN copolymer consists of 25-35% acrylonitrile, 65-75% styrene. SAN copolymer is commercially available or it can be readily prepared by techniques well known to those skilled in the art. Amorphous thermoplastic SAN copolymers are further described on pages 214-216 in Engineering Plastics, volume 2, published by ASM INTERNATIONAL, Metals Park, Ohio (1988).

[0043] Amorphous thermoplastic ABS and AES resins, which are injection molding and extrusion grade resins, that

are useful herein are well known in the art. ABS resin is produced by polymerizing acrylonitrile and styrene in the presence of butadiene, or a mostly butadiene, rubber. Preferably, the ABS resin is comprised of 50-95% of a matrix of SAN, with said matrix being comprised of 20-40% acrylonitrile and 60-80% styrene, and 5-50% of a butadiene rubber or a mostly butadiene rubber, such as styrene butadiene rubber (SBR). More preferably, it is comprised of 60-90% of a matrix of SAN, with said matrix more preferably being comprised of 25-35% acrylonitrile and 65-75% styrene, and 10-40% of a butadiene rubber. AES resin is produced by polymerizing acrylonitrile and styrene in the presence of a mostly saturated rubber. The preferred and more preferred AES resin is the same as the preferred and more preferred ABS resin except that the rubber component is comprised of mostly ethylene-propylene copolymer, as opposed to butadiene, or mostly butadiene, rubber. Other alpha-olefins and unsaturated moieties may be present in the ethylene-propylene copolymer rubber. Both ABS and AES copolymers are commercially available or can be readily prepared by techniques well known to those skilled in the art. Amorphous thermoplastic ABS resin is further described on pages 109-114 in Engineering Plastics, referenced above.

[0044] Amorphous thermoplastic polycarbonates that are useful herein are well known in the art and can be most basically defined as possessing the repetitive carbonate group —O—C(CO)—O— and in addition will always have the phenylene moiety attached to the carbonate group (cf. U.S. Pat. No. 3,070,563).

[0045] The present invention also contemplates the use of polycaprolactones and polylactic acids. Polycaprolactones are polymers of a cyclic ester. Preferably, a suitable polycaprolactone is one having a number average molecular weight of about 43,000 and a melt flow of 1.9g/10 minutes at 80C and 44 psi. Preferred polylactic acids are those having a melting point of about 155C,

[0046] Amorphous thermoplastic polycarbonates are commercially available or can be readily prepared by techniques well known to those skilled in the art. The most preferred aromatic polycarbonate on the basis of commercial availability and available technical information is the polycarbonate of bis(4-hydroxyphenyl)-2,2-propane, known as bisphenol-A polycarbonate. Amorphous thermoplastic polycarbonate is further described on pages 149-150 of Engineering Plastics, referenced above.

[0047] Amorphous or semi-crystalline thermoplastic polyamides that are useful herein are well known in the art. They are described in U.S. Pat. No. 4,410,661. Specifically, these amorphous or semi-crystalline thermoplastic polyamides are obtained from at least one aromatic dicarboxylic acid containing 8-18 carbon atoms and at least one diamine selected from the class consisting of:

[0048] (i) 2-12 carbon normal aliphatic straight-chain diamine,

[0049] (ii) 4-18 carbon branched aliphatic diamine, and

[0050] (iii) 8-20 carbon cycloaliphatic diamine containing at least one cycloaliphatic, preferably cyclohexyl, moiety, and wherein optionally, up to 50 weight percent of the polyamide may consist of units obtained from lactams or omega-aminoacids con-

taining 4-12 carbon atoms, or from polymerization salts of aliphatic dicarboxylic acids containing 4-12 carbon atoms and aliphatic diamines containing 2-12 carbon atoms.

[0051] The term "aromatic dicarboxylic acid", shall mean that the carboxy groups are attached directly to an aromatic ring, such as phenylene naphthalene, etc.

[0052] The term "aliphatic diamine", shall mean that the amine groups are attached to a nonaromatic-containing chain such as alkylene.

[0053] The term "cycloaliphatic diamine", shall mean that the amine groups are attached to a cycloaliphatic ring composed of 3-15 carbon atoms. The 6 or 12 carbon cycloaliphatic rings are preferred.

[0054] Preferred examples of thermoplastic polyamides include those with melting point less than about 180C, including co- and terpolymers of nylon 6, 610, 612 and the like.

[0055] The amorphous or semi-crystalline thermoplastic polyamides exhibit melt viscosities at 200° C. of less than 50,000 poise, preferably less than 20,000 poise measured at a shear stress of 105 dynes/cm². The amorphous or semi-crystalline polyamides are commercially available or can be prepared by known polymer condensation methods in the composition ratios mentioned above. In order to form high polymers, the total moles of the diacids employed should approximately equal the total moles of the diamines employed.

[0056] In addition free dicarboxylic acids, derivatives thereof, such as the chlorides, may be used to prepare the thermoplastic polyamide.

[0057] The polymerization to prepare the amorphous or semi-crystalline thermoplastic polyamides may be performed in accordance with known polymerization techniques, such as melt polymerization, solution polymerization and interfacial polymerization techniques, but it is preferred to conduct the polymerization in accordance with the melt polymerization procedure. This procedure produces polyamides having high molecular weights. In the polymerization, diamines and acids or cyclic amides are mixed in such amounts that the ratio of the diamine components and the dicarboxylic acid components will be substantially equimolar. In melt polymerization the components are heated at temperatures higher than the melting point of the resulting polyamide but lower than the degradation temperature thereof. The heating temperature is in the range of about 170° C. to 300° C. The pressure can be in the range of vacuum to 300 psi. The method of addition of starting monomers is not critical. For example, salts of combinations of the diamines and acids can be made and mixed. It is also possible to disperse a mixture of the diamines in water, add a prescribed amount of a mixture of acids to the dispersion at an elevated temperature to form a solution of a mixture of nylon salts, and subject the solution to the polymerization.

[0058] If desired, a monovalent amine or, preferably, an organic acid, may be added as viscosity adjuster to a mixture of starting salts or an aqueous solution thereof.

[0059] Amorphous thermoplastic polyarylates that are useful herein are well known in the art and are described in detail in U.S. Pat. No. 4,861,828. Specifically, the amor-

phous thermoplastic polyarylates used in the compositions of the present invention are aromatic polyesters derived from at least one dihydric phenol or derivative thereof and at least one aromatic dicarboxylic acid or derivative thereof. Each component from which the amorphous thermoplastic polyarylate is derived has a functional group or groups, i.e., hydroxyl or carboxyl, attached directly to an aromatic ring. The dihydric phenol can be a bisphenol as described in U.S. Pat. No. 4,187,358 as structure 1: $\text{—HO—C}_6\text{H}_3(\text{—X})\text{—OH}$.

[0060] Suitable examples of alkylene groups for X containing 1 to 5 carbon atoms include a methylene group, an ethylene group, a propylene group, a tetramethylene group and a pentamethylene group. Suitable examples of alkylidene groups for X containing 2 to 7 carbon atoms include an ethylidene group, a propylidene group, an isopropylidene group, an isobutylidene group, a pentyldene group, a cyclopentylidene group and a cyclohexylidene group. Suitable examples of alkyl groups of R_1 to R_4 and R_1' to R_4' containing 1 to 5 carbon atoms include a methyl group, an ethyl group, an isopropyl group, a tert-butyl group, and a neopentyl group.

[0061] Examples of suitable bisphenols are 4,4'-dihydroxy-diphenyl ether, bis(4-hydroxy-2-methylphenyl)ether, bis(4-hydroxy-3-chlorophenyl)-ether, bis(4-hydroxyphenyl)sulfide, bis(4-hydroxy-phenyl)sulfone, bis(4-hydroxyphenyl)ketone, bis(4-hydroxyphenyl)methane, bis(4-hydroxy-3,5-dichlorophenyl)-methane, 1,1-bis(4-hydroxyphenyl)-ethane, 2,2-bis(4-hydroxy-3-chlorophenyl)propane, 2,2-bis(4-hydroxy-3,5-dibromophenyl)propane, 3,3,3',3'-tetramethyl spirobis-1,1'-indane-6,6'-diol and 1,1-bis(4-hydroxyphenyl)-n-butane. 2,2-Bis(4-hydroxyphenyl)propane, which is bisphenol A, is most preferred.

[0062] Typical examples of the functional derivatives of the bisphenol which can be used are the alkali metal salts and diesters with aliphatic monocarboxylic acid containing 1 to 3 carbon atoms. Suitable examples of aliphatic monocarboxylic acids include formic acid, acetic acid, propionic acid, etc. Preferred functional derivatives of the bisphenols are the sodium salts, the potassium salts, and the diacetate esters.

[0063] The bisphenol can be used either individually or as a mixture of two or more. Further, mixed salts or mixed carboxylate esters may be used.

[0064] Preferably, a mixture of 60 to 0 mole % of terephthalic acid and/or the functional derivatives thereof and 40 to 100 mole % of isophthalic acid and/or its functional derivatives is used as the acid component to be reacted with the bisphenol to prepare the polyarylate used in the compositions of the present invention. More preferably, a mixture of 0 to 50 mole % of terephthalic acid and/or the functional derivatives thereof and 100 to 50 mole % of isophthalic acid and/or the functional derivatives thereof is used. The molar ratio of the bisphenol to the sum of the terephthalic acid units and isophthalic acid units is substantially equimolar, e.g., about 1:0.95 to 1.2, preferably about 1:1, most preferably 1:1. Aromatic hydroxy acids such as hydroxy benzoic or hydroxy naphthoic acid and other dicarboxylic acids (both aromatic and aliphatic) can also be incorporated into the polyarylate structure as a minor component.

[0065] Examples of functional derivatives of terephthalic or isophthalic acid which can be used in this invention

include acid halides and diaryl esters. Preferred examples of acid halides include terephthaloyl dichloride, isophthaloyl dichloride, terephthaloyl dibromide and isophthaloyl dibromide. Preferred examples of diaryl esters include diphenyl terephthalate and diphenyl isophthalate.

[0066] In the preparation of the amorphous thermoplastic polyarylate, at most 50 mole %, preferably at most 25 mole %, of a compound having a carbonate linkage such as diphenyl carbonate or an aliphatic glycol such as ethylene glycol, propylene glycol, tetramethylene glycol or neopentyl glycol may also be copolymerized therewith to improve the molding characteristics. To change the reactivity and possibly the stability of the polyarylate, monofunctional components can be included in the polyarylate to limit molecular weight or reduce the proportions of reactive ends.

[0067] Amorphous thermoplastic polyarylates useful in the compositions of the present invention are commercially available or can be prepared by any of several known methods. The interfacial polymerization method comprises mixing a solution of an aromatic dicarboxylic acid chloride in a water-immiscible organic solvent with an alkaline aqueous solution of bisphenol. The solution polymerization method comprises heating bisphenol and a diacid dichloride in an organic solvent. One melt polymerization method comprises heating a diphenyl ester or an aromatic dicarboxylic acid and bisphenol. An alternate melt polymerization method comprises heating aromatic dicarboxylic acid and a diester (e.g., the diacetate ester) of bisphenol. These methods are described in detail in U.S. Pat. Nos. 3,884,990, 3,946,091, 4,052,481 and 4,485,230.

[0068] Amorphous thermoplastic polyphenylene ethers (PPE) and polyphenylene oxides (PPO) that are useful herein are known in the art. PPE homopolymer is frequently referred to as PPO. The chemical composition of the homopolymer is poly(2,6-dimethyl-4,4'-phenylene ether) or poly(oxy-(2,6-dimethyl-4,4'-phenylene)): $\text{—C}_6\text{H}_2(\text{—CH}_3)_2\text{—O—}$. The chemical composition of PPE, which is a copolymer. PPE and PPO are further described on pages 183-185 in *Engineering Plastics*, referenced above. Both PPE and PPO are commercially available or can be readily prepared by known techniques by those skilled in the art. They are typically marketed as blends with polystyrene due to their high melt viscosity.

[0069] Amorphous thermoplastic high impact styrene (HIPS) resins that are useful herein are well known in the art. HIPS is produced by dissolving usually less than 20 percent polybutadiene rubber, or other unsaturated rubber, in styrene monomer before initiating the polymerization reaction. Polystyrene forms the continuous phase of the polymer and the rubber phase exists as discrete particles having occlusions of polystyrene. HIPS resin is further described on pages 194-199 in *Engineering Plastics*, referenced above. HIPS resins are commercially available or can be readily prepared from known techniques by those skilled in the art.

[0070] Amorphous thermoplastic polymers of acrylics, which are extrusion and injection molding grade, that are useful herein are well known in the art. Amorphous thermoplastic acrylic polymers comprise a broad array of polymers in which the major monomeric constituents belong to two families of ester-acrylates and methacrylates. Amorphous thermoplastic acrylic polymers are described on pages 103-108 in *Engineering Plastics*, referenced above. The

molecular weight of the amorphous thermoplastic polymer of acrylics, for it to be injection moldable by standard present techniques, should not be greater than 200,000. Amorphous thermoplastic acrylic polymers are commercially available or can be readily prepared from known techniques by those skilled in the art.

[0071] Amorphous thermoplastic imidized acrylic resins that are useful herein are well known in the art. Amorphous thermoplastic imidized acrylic resins are prepared by reacting ammonia, or a primary amine, with an acrylic polymer, such as polymethyl methacrylate, to form the imidized acrylic resin (also known as polyglutarimides).

[0072] The imidized acrylic resin will contain at least about 10% imide groups and preferably at least about 40% imide groups, and can be prepared as described, for example, in U.S. Pat. No. 4,246,374 and in U.K. Patent 2101139B. Representative imide polymers include imidized poly(methyl methacrylate) or poly(methyl acrylate), imidized copolymers of either methyl methacrylate or methyl acrylate and comonomers such as butadiene, styrene, ethylene, methacrylic acid, or the like.

[0073] Amorphous thermoplastic imidized acrylic resins are also described in U.S. Pat. No. 4,874,817. Amorphous thermoplastic imidized acrylics are commercially available or can be readily prepared from known techniques by those skilled in the art.

[0074] Amorphous thermoplastic copolymers of styrene maleic anhydride that are useful herein are well known in the art. Styrene maleic anhydride copolymers are produced by the reaction of styrene monomer with smaller amounts of maleic anhydride. Amorphous thermoplastic styrene maleic anhydride copolymers are further described on pages 217-221 in *Engineering Plastics*, referenced above. They are commercially available or can be prepared from known techniques by those skilled in the art.

[0075] Amorphous thermoplastic polysulfones that are useful herein are well known in the art. It is produced from bisphenol A and 4,4'-dichlorodiphenylsulfone by nucleophilic displacement chemistry. It is further described on pages 200-202 in *Engineering Plastics*, referenced above. Polysulfone is commercially available or can be readily prepared from known techniques by those skilled in the art.

[0076] Amorphous thermoplastic styrene acrylonitrile maleic anhydride copolymers and styrene acrylic copolymers that are useful herein are known in the art. They are commercially available or can be prepared from known techniques by those skilled in the art.

[0077] The amorphous or semi-crystalline thermoplastic polymers may also contain those additional ingredients, modifiers, stabilizers, and additives commonly included in such polymers.

[0078] The thermoplastic polyurethanes suited for use in the blends of the present invention can be selected from those commercially available or can be made by processes known in the art. (See, for example, *Rubber Technology*, 2nd edition, edited by Maurice Morton (1973), Chapter 17, *Urethane Elastomers*, D. A. Meyer, especially pp. 453-6). Thermoplastic polyurethanes are derived from the reaction of polyester or polyether polyols with diisocyanates and optionally also from the further reaction of such components

with chain-extending agents such as low molecular weight polyols, preferably diols, or with diamines to form urea linkages. Thermoplastic polyurethanes are generally composed of soft segments, for example polyether or polyester polyols, and hard segments, usually derived from the reaction of the low molecular weight diols and diisocyanates. While a thermoplastic polyurethane with no hard segments can be used, those most useful will contain both soft and hard segments.

[0079] In the preparation of the thermoplastic polyurethanes useful in the blends of the present invention, a polymeric soft segment material having at least about 500 and preferably from about 550 to about 5,000 and most preferably from about 1,000 to about 3,000, such as a dihydric polyester or a polyalkylene ether diol, is reacted with an organic diisocyanate in a ratio such that a substantially linear polyurethane polymer results, although some branching can be present. A diol chain extender having a molecular weight less than about 250 may also be incorporated. The mole ratio of isocyanate to hydroxyl in the polymer is preferably from about 0.95 to 1.08 more preferably 0.95 to 1.05, and most preferably, 0.95 to 1.00. In addition, monofunctional isocyanates or alcohols can be used to control molecular weight of the polyurethane.

[0080] Suitable polyester polyols include the polyesterification products of one or more dihydric alcohols with one or more dicarboxylic acids. Suitable polyester polyols also include polycarbonate polyols. Suitable dicarboxylic acids include adipic acid, succinic acid, sebacic acid, suberic acid, methyladipic acid, glutaric acid, pimelic acid, azelaic acid, thiodipropionic acid and citraconic acid and mixtures thereof, including small amounts of aromatic dicarboxylic acids. Suitable dihydric alcohols include ethylene glycol, 1,3- or 1,2-propylene glycol, 1,4-butanediol, 1,3-butanediol, 2-methylpentanediol-1,5, diethylene glycol, 1,5-pentanediol, 1,5-hexanediol, 1,2-dodecanediol, and mixtures thereof.

[0081] Further, hydroxycarboxylic acids, lactones, and cyclic carbonates, such as epsilon-caprolactone and 3-hydroxybutyric acid can be used in the preparation of the polyester.

[0082] Preferred polyesters include poly(ethylene adipate), poly(1,4-butylen adipate), mixtures of these adipates, and poly epsilon-caprolactone.

[0083] Suitable polyether polyols include the condensation products of one or more alkylene oxides with a small amount of one or more compounds having active hydrogen containing groups, such as water, ethylene glycol, 1,2- or 1,3-propylene glycol, 1,4-butanediol and 1,5-pentanediol and mixtures thereof. Suitable alkylene oxide condensates include those of ethylene oxide, propylene oxide and butylene oxide and mixtures thereof. Suitable polyalkylene ether glycols may also be prepared from tetrahydrofuran. In addition, suitable polyether polyols can contain comonomers, especially as random or block comonomers, ether glycols derived from ethylene oxide, 1,2-propylene oxide and/or tetrahydrofuran (THF). Alternatively, a THF polyether copolymer with minor amounts of 3-methyl THF can also be used.

[0084] Preferred polyethers include poly(tetramethylene ether) glycol (PTMEG), poly(propylene oxide) glycol, and

copolymers of propylene oxide and ethylene oxide, and copolymers of tetrahydrofuran and ethylene oxide. Other suitable polymeric diols include those which are primarily hydrocarbon in nature, e.g., polybutadiene diol.

[0085] Suitable organic diisocyanates include 1,4-butylene diisocyanate, 1,6-hexamethylene diisocyanate, cyclopentylene-1,3-diisocyanate, 4,4'-dicyclohexylmethane diisocyanate, isophorone diisocyanate, cyclohexylene-1,4-diisocyanate, 2,4-toluene diisocyanate, 2,6-toluene diisocyanate, isomeric mixtures of 2,4- and 2,6-toluene diisocyanate, 4,4'-methylene bis(phenylisocyanate), 2,2-diphenylpropane-4,4'-diisocyanate, p-phenylene diisocyanate, m-phenylene diisocyanate, xylene diisocyanate, 1,4-naphthylene diisocyanate, 1,5-naphthylene diisocyanate, 4,4'-diphenyl diisocyanate, azobenzene-4,4'-diisocyanate, m- or p-tetramethylxylene diisocyanate, and 1-chlorobenzene-2,4-diisocyanate. 4,4'-methylene bis(phenylisocyanate), 1,6-hexamethylene diisocyanate, 4,4'-dicyclohexylmethane diisocyanate and 2,4-toluene diisocyanate are preferred.

[0086] Secondary amide linkages including those derived from adipyl chloride and piperazine, and secondary urethane linkages, including those derived from the bis-chloroformates of PTMEG and/or butanediol, can also be present in the polyurethanes.

[0087] Dihydric alcohols suitable for use as chain extending agents in the preparation of the thermoplastic polyurethanes include those containing carbon chains which are either uninterrupted or which are interrupted by oxygen or sulfur linkages, including 1,2-ethanediol, 1,2-propanediol, isopropyl-a-glyceryl ether, 1,3-propanediol, 1,3-butanediol, 2,2-dimethyl-1,3-propanediol, 2,2-diethyl-1,3-propanediol, 2-ethyl-2-butyl-1,3-propanediol, 2-methyl-2,4-pentanediol, 2,2,4-trimethyl-1,3-pentanediol, 2-ethyl-1,3-hexanediol, 1,4-butanediol, 2,5-hexanediol, 1,5-pentanediol, dihydroxycyclopentane, 1,6-hexanediol, 1,4-cyclohexanediol, 4,4'-cyclohexanedimethylol, thiodiglycol, diethylene glycol, dipropylene glycol, 2-methyl-1,3-propanediol, 2-methyl-2-ethyl-1,3-propanediol, dihydroxyethyl ether of hydroquinone, hydrogenated bisphenol A, dihydroxyethyl terephthalate and dihydroxymethyl benzene and mixtures thereof. Hydroxyl terminated oligomers of 1,4-butanediol terephthalate can also be used, giving a polyester-urethane-polyester repeating structure. Diamines can also be used as chain extending agents giving urea linkages. 1,4-butanediol, 1,2-ethanediol and 1,6-hexanediol are preferred.

[0088] In the preparation of the thermoplastic polyurethanes, the ratio of isocyanate to hydroxyl should be close to unity, and the reaction can be a one step or a two step reaction. Catalysts can be used, and the reaction can be run neat or in a solvent.

[0089] The moisture content of the blend, in particular of the thermoplastic polyurethane, can influence the results achieved. Water is known to react with polyurethanes, causing the polyurethane to degrade, thereby lowering the effective molecular weight of the polyurethane and lowering the inherent and melt viscosity of the polyurethane. Accordingly, the drier the better. In any event, the moisture content of the blend, and of the individual components of the blend, should contain less than 0.2 percent by weight of water, preferably less than 0.1 percent, especially when there is no opportunity for the water to escape, for example during an

injection molding process and other techniques of melt processing. The thermoplastic polyurethane can also contain those additives, ingredients, and modifiers known to be added to thermoplastic polyurethane. It is noted here that the addition of any of styrene acrylonitrile copolymers, acrylonitrile-butadiene-styrene copolymers, acrylonitrile-ethylene-butadiene-styrene copolymers, and polycarbonates to polyoxymethylene alone reduces the mold shrinkage of the polyoxymethylene.

[0090] Additional Layer Component

[0091] Generally the substrate of the present invention may be coated with paints or overmolded with thermoplastic elastomers, glues and the like such these are the at least one layer adhered to the substrate. The adhesion is promoted due to the presence and distribution of the at least one amorphous or semi-crystalline thermoplastic component or polymer on or near the surface of the mostly polyacetal substrate as described above.

[0092] Examples of suitable materials for overmolding include, but are not limited to, both polar and non-polar materials. Such non-polar materials include, but are not limited to, thermoplastic olefins (TPO), Kraton®, thermoplastic elastomers (TPE-S), polyethylene and polypropylene. Such polar materials include, but are not limited to, thermoplastic polyurethanes (TPU), Surlyn®, Hytrel® and polar olefins.

[0093] Examples of suitable materials for printing/painting may include solvents, water latex, epoxy, urethane, powder coating acrylic paints or inks and the like.

[0094] Examples of suitable materials for gluing includes solvent-based glues, latex, epoxy, super glue and the like.

[0095] Generally, the at least one adhered layer of the present invention may be either co-continuous or discontinuous.

[0096] Various conventional methods may be used to adhere the at least one additional layer to the substrate including, but not limited to, wet painting, powder coating, two-shot molding, insert molding, co-extrusion, gluing and metalizing.

[0097] Wet painting methods utilize either water-based or solvent-based paints that are applied via those methods known in the art such as spraying, brushing and the like.

[0098] Powder coating methods that are well known in the art, such as, for example, dipping in a fluidized bed or electrostatic fluidized beds or electrostatic spraying use a finely divided, dry solid resinous powder that may be a paint or another plastic and can be deposited on the surface of the substrate and then cured/molten at elevated temperatures.

[0099] Two-shot molding methods are well known in the art and are typically carried out wherein one part of a cavity is filled with substrate material out of a first barrel of the 2-shot injection molding machine, then the mould opens and rotates or sliders open to modify the cavity and after closing the mold again, this new cavity is filled with layer material from a second barrel.

[0100] Insert molding methods are well known in the art and may utilize conventional molding machines, wherein the molded parts are then inserted, either manually or automatically, into another mold where the layer material is

molded “on top” or around the substrate (this technique requires that the part is ejected from the mold between the 2 steps; in the method above, the part is not ejected between the 2 shots.

[0101] Co-extrusion methods, well known to those skilled in the art, allow for the extrusion of films, sheets, profiles, tubing, wire coatings and extrusion coatings.

[0102] Gluing may be performed by any method known in the art, including manual and/or mechanical methods.

[0103] Metalizing methods include those well known in the art, such as, for example, electroplating including, but not limited to, chrome plating wherein the process utilizes a mixture of chemical and electrochemical methods for the deposition of various layers.

[0104] Method of Preparation of the Articles

[0105] The present invention further relates to a process for making the above-noted article comprising the steps of:

[0106] (i) blending a matrix comprising 99.55-40 weight percent of an polyoxymethylene polymer and 0.5-60 weight percent of at least one thermoplastic polymer; and

[0107] (ii) molding the matrix into a substrate; and

[0108] (iii) adhering at least one layer to said substrate.

[0109] The matrix may be blended using any conventionally known machine. Preferably, however, the matrix is blended using a co-rotating twin screw extruder.

[0110] The substrate may be molded according to those principals known in the art utilizing any of the conventionally known processes, for example, extrusion, co-extrusion, two-shot molding, insert molding and the like.

[0111] Adhering the at least one additional layer to the substrate may be performed according to any of the known methods, as are described above.

EXAMPLES

[0112] The present invention is further defined in the following Examples, in which all parts and percentages are by weight. It should be understood that these Examples, while indicating preferred embodiments of the invention, are given by way of illustration only. From the above discussion and these Examples, one skilled in the art can ascertain the essential characteristics of this invention, and without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usage and conditions.

[0113] Generally, the adhesion was determined using a peel test in the case of thermoplastic elastomer layers, while the level of adhesiveness of the paint/printing layers was determined using a cross-hatch paint adhesion test.

[0114] Typically, “peel” is the imposition of a tensile stress in a direction that is perpendicular to the adhesive bond line (the line where the materials are united by the adhesive). Moreover, the “peel strength” indicates the strength of an adhesive, and is defined as the average force per unit test specimen width measured along the bond line required to separate progressively of the of the bonded test specimen

and is described as pounds per inch of width (having a metric equivalent of Newtons per millimeter).

[0115] Various embodiments of the present invention made utilizing either two shot molding methods or insert injection molding methods were tested to assess the peel strength of the overmolding. Those samples made using these molding methods were peel tested using a L-type peel test (commonly referred to as a 90 degree peel test) on a conventional standard tensile testing machine, such as, an Instron tensile testing machine. Typical samples comprised a substrate having a length of about 6 inches, a thickness of about $\frac{1}{8}$ inches, and a width of about 1 inch. The additional layer adhered to the substrate had a width of about 1 inch and a thickness of about $\frac{1}{8}$ inches. Additionally, either a length of the adhered layer extended a distance past the end of the substrate or a portion of the end of the specimen is pulled up, such that a portion of the layer is not in contact with the substrate to allow its attachment to the tensile machine.

[0116] Generally the method comprises having a substrate and the adhered layer, in a fixed position on a horizontally movable sample holder (e.g. a sled, wheels or roller). The extended end portion of the adhered layer is clamped to the upper traverse of the tensile machine so that there is a 90 degree angle between the substrate and the additional layer being peeled. The traverse moves upwards and peels off the additional layer; the sample holder for the substrate moves horizontally as the traverse moves vertically to keep the peel angle constant. As the traverse begins to peel the adhered layer away from the material, the adhesion factor is progressively measured.

[0117] Typically, the cross-hatch adhesion test (DIN EN ISO2409 as well as a modified version of ASTM-D3359-83, Method B) was conducted, such that a substrate was formed and subsequently coated with a paint. One hundred small squares (about $\frac{1}{16}$ inches $\times$ $\frac{1}{16}$ inches) were cut into the adhered layer by making two cuts with a bladed device (e.g. Gardco® Model P-A-T Cutter Blades, manufactured by Gardco Corporation, at a 90 degree angle. The depth of the cuts was carefully monitored so as to ensure that the cuts penetrated only the adhered layer and did not extend to any significant depths into the substrate. A quantity of suitable tape, for example Permacel 99 Tape (manufactured by Permacel Corporation, New Brunswick, N.J.), was then applied over the area cut into squares on the coated substrate so the entire area being assessed was covered. The tape was then removed and the degree of flaking of the paint due to the tape removal was assessed. A modification to the ASTM D 3359 test was made in the classification of the adhesion test results. The tests according to the present invention used a value of “0” to classify those samples in which no flaking had occurred (i.e. even at the razor cut edges), and thus showed the greatest level of adhesion, while a value of “5” was assigned in those instances where flaking of greater than 65% had been found, thus, no other aspects of the test were modified.

Example 1

[0118] Paint Adhered to High Polyoxymethylene-content Substrates

[0119] Table 1 sets forth the compositions of the various types of substrates used in the Examples. Each substrate was painted with a single paint, either paint I or paint K, the

cross-hatch test was performed and the results evaluated. The cross-hatch test results are also shown in Table 1. Sample 1 represents the control and samples 2-8 are examples of the present invention.

[0120] The Control substrate was a substrate (Sample Type 1) comprising 100% of a polyacetal homopolymer (MW=38,000). This Control substrate was painted with Paint I to form the adhered layer and tested according to the cross-hatch test described herein. When the tape was applied and subsequently removed, a value of 2 was assessed, thereby showing a moderate level of adhesion. A second test and a third test each using a Sample Type 1 substrate were painted with Paint K and again subjected to the cross-hatch test described herein, wherein values of 2 and 3 were assessed, respectively.

[0121] Sample Type 2 was a substrate comprising 90% of a polyacetal homopolymer (MW=38,000) and 10% of a thermoplastic polyurethane with ethylene adipate soft segment and 4,4' methylene bisphenyl isocyanate. The adhered layer applied to the substrate was paint K, which when tested according to the cross-hatch test, resulted in an adhesion level of 1.

[0122] Sample Type 3 was a substrate comprising 90% of a polyacetal homopolymer (MW=38,000) and 10% of a polycaprolactone (MW=43,000). The adhered layer applied to the substrate was paint K, which when tested according to the cross-hatch test, resulted in an adhesion level of 0, meaning no flaking occurred.

[0123] Sample Type 4 was a substrate comprising 90% of a polyacetal homopolymer (MW=38,000) and 10% of a polylactic acid (having a melting point of 155° C. The adhered layer applied to the substrate was paint K, which when tested according to the cross-hatch test, resulted in an adhesion level of 1.

[0124] Sample Type 5 was a substrate comprising 90% of a polyacetal homopolymer (MW=38,000) and 10% of a thermoplastic polyurethane with butylene adipate soft segments and 4,4' methylene bisphenyl isocyanate. The adhered layer applied to the substrate was paint K, which when tested according to the cross-hatch test, resulted in an adhesion level of 0. The second test was run using another substrate having the composition of Sample Type 5, where the adhered layer was paint K, thereby resulting in an adhesion level of 2. A third test was run utilizing a substrate of Sample Type 5, wherein paint I was adhered to the substrate, and an adhesion level of 1 resulted.

[0125] Sample Type 6 was a substrate comprising 90% of a polyacetal homopolymer (MW=65,000) and 1% of a polyacetal copolymer with 4.5% ethylene oxide groups (Mn=22,000); 1% of a thermoplastic polyurethane with butylenes adipate soft segments and 4,4' methylene bisphenyl isocyanate; and 8% of a nylon 66/610/6 having a melting point of 154° C. (Mn=40,000). The layer adhered to the substrate was paint K, which when tested according to the cross-hatch test, resulted in an adhesion level of 0. A second test was run using another substrate having the composition of Sample Type 6, where the adhered layer was again paint K, resulting in an adhesion level of 0. A third test was run utilizing a substrate of Sample Type 6, wherein paint I was adhered to the substrate, and an adhesion level of 4 resulted. In this Sample as well as in sample types 7 and 8, paint I

shows a reduction in adhesion in comparison to paint K. This is believed to be the result of the different interaction of paint I with the additives used in the respective examples. Thus, the applier would need to take this into account.

[0126] Sample Type 7 was a substrate comprising 90% of a polyacetal homopolymer (MW=65,000) and 1% of a polyacetal copolymer with 4.5% ethylene oxide groups (Mn=22,000); 1% of a thermoplastic polyurethane with butylene adipate soft segments and 4,4' methylene bisphenyl isocyanate; and 8% of a nylon 66/610/612/6 having a melting point of 116° C. (Mn=18,000). The layer adhered to the substrate was paint K, which when first tested according to the cross-hatch test, resulted in an adhesion level of 0. A second test was run using another substrate having the composition of Sample Type 7, where the adhered layer was paint K, resulting in an adhesion level of 1. A third test was run utilizing a substrate of Sample Type 7, wherein paint I was adhered to the substrate, and an adhesion level of 3 resulted.

[0127] Sample Type 8 was a substrate comprising 90% of a polyacetal homopolymer (MW=65,000) and 1% of a polyacetal copolymer with 4.5% ethylene oxide groups (Mn=22,000); 1% of a thermoplastic polyurethane with butylene adipate soft segments and 4,4' methylene bisphenyl isocyanate; and 8% of a thermoplastic polyester poly ether elastomer containing 41% PBT hard segment/59% ethylene oxide-polypropylene oxide soft segment. The layer adhered to the substrate in the first run was paint K, which when tested according to the cross-hatch test, resulted in an adhesion level of 1. A second test was run using another substrate having the composition of Sample Type 8, where the adhered layer was, again, paint K, resulting in an adhesion level of 0. A third test was run utilizing a substrate of Sample Type 8, wherein paint I was adhered to the substrate, and an adhesion level of 4 resulted.

[0128] Table 1.

TABLE 1

Sample Type	% POM	% Non-acetal	% Other	I	K
1	100	—	—	2	2,3
2	90	10	—		1
3	90	10	—		0
4	90	10	—		1
5	90	10	—	1	0,2
6	90	—	10	4	0,0
7	90	—	10	3	0,1
8	90	—	10	4	1,0

[0129] Paint I=a spray enamel 1244 metallic gold paint (manufactured by Testor Corporation)

[0130] Paint K=TS-5 Olive Drab paint (manufactured by Tamiya Europe GMBH),

Example 2

[0131] Paint Adhered to Low Polyoxymethylene-content Substrates

[0132] In Table 2, the various types of substrates used in this Example are shown. The results of the cross-hatch tests for adhesion is provided in Table 3. Descriptions of the paints used are also provided below. Each substrate was

painted with only one type of paint, thus, each substrate had a single layer of paint adhered to it.

[0133] Sample Type 9 designated substrates comprising 100% of a polyacetal homopolymer (MW=65,000). Two substrates of Sample Type 9, were used, wherein the adhered layers tested with this type of substrate were paints B and F.

[0134] Sample Type 10, designated substrates comprising 100% of a polyacetal homopolymer (MW=38,000). Various substrates of this type were tested, wherein the layer adhered to each was one of paints F, G, H, I, J, K, L, M, N, P, Q, R, S, T, and U.

[0135] Sample Type 11 designated substrates comprising 100% of a nucleated polyacetal homopolymer (MW=38,000). A substrate of this type was painted with paint B to form the adhered layer.

[0136] Sample Type 12 designated substrates comprising 60% of a polyacetal homopolymer (MW=65,000); 10% of a thermoplastic polyurethane with butylene adipate soft segments and 4,4' methylene bisphenyl isocyanate; and 10% of an extrusion grade ABS (melt flow=3.9) and 20% of a styrene acrylonitrile copolymer (melt flow=25g/10 minutes with 3.8 Kg weight at 445° F. Two substrates of this type were painted, one using paint B and the other using paint F to form the adhered layer.

[0137] Sample Type 13 designated substrates comprising 55% of a polyacetal homopolymer (MW=38,000); 15% of a thermoplastic polyurethane with butylene adipate soft segments and 4,4' methylene bisphenyl isocyanate; and 30% of an extrusion grade ABS (melt flow=3.9). The layer adhered

[0140] Sample Type 16 designated substrates comprising 55% of a polyacetal copolymer with 1.4% ethylene oxide groups (Mn=20,800); 15% of a thermoplastic polyurethane with butylene adipate soft segments and 4,4' methylene bisphenyl isocyanate; and 30% of an extrusion grade ABS (melt flow=3.9). A single substrate was tested having paint K as the adhered layer.

[0141] Sample 17 designated substrates comprising 55% of a polyacetal homopolymer (MW=38,000); 5% of a thermoplastic polyurethane with butylene adipate soft segments and 4,4' methylene bisphenyl isocyanate; 10% of precipitated CaCO₃ with a particle size of 0.7 microns and a coating of 2% stearic acid; and 30% of an extrusion grade ABS (melt flow=3.9). The layer adhered to the substrate was paint F.

TABLE 2

Sample Type	% POM	% Non-acetal	% Other
9	100	—	—
10	100	—	—
11	100	—	—
12	60	10	10 + 20
13	55	15	30
14	55	15	30
15	55	15	30
16	55	15	30
17	55	5	10 + 30

[0142]

TABLE 3

Sample	Adhered Paint Layer																
Type	B	F	G	H	I	J	K	L	M	N	P	Q	R	S	T	U	
9	5	5															
10		5	5	4	2	4	2.3	5	5	5	5	5	4	5	4	5	
11	5																
12		2	0														
13		0	0	0	0	1	0.0	0	0	0	0	0	0	0	0	0	
14		0															
15		0					0										
16							0										
17		0															

to the substrates of this type that were used were one of paints B, F, G, H, I, J, K, L, M, N, P, Q, R, S, T, or U.

[0138] Sample Type 14 designated substrates comprising 55% of a polyacetal homopolymer (MW=38,000) and 15% of a thermoplastic polyurethane with ethylene adipate soft segments and 4,4' methylene bisphenyl isocyanate; and 30% of an extrusion grade ABS (melt flow=3.9). The layer adhered to the substrate in this Example was paint F.

[0139] Sample Type 15 designated substrates comprising 55% of a polyacetal copolymer with 4.5% ethylene oxide groups (Mn=22,000); 15% of a thermoplastic polyurethane with butylene adipate soft segments and 4,4' methylene bisphenyl isocyanate; and 30% of an extrusion grade ABS (melt flow=3.9). Two substrates of this type were tested, wherein the layer adhered to the each substrate was either paint F or K.

[0143] Paint Key:

[0144] B=Rust-oleum Hard Hat, spray, finish ACA-BADO safety blue V2124.

[0145] F=Aervoe-Pacific Rust Proofing Paint, spray, 303 gloss safety blue, xylene, acetone, mineral spirits, ethyl benzene.

[0146] G=spray enamel, pactra Racing Finish, RC287 bright red, for PC. (manufactured by Testor Corporation).

[0147] H=spray enamel, 1224 gloss green, petroleum distillates, liquified petroleum propellant (manufactured by Testor Corporation).

[0148] I=spray enamel, 1244 metallic gold, alcohols, toluene, petroleum propellant (manufactured by Testor Corporation).

[0149] J=spray enamel, 130030 Reffer Orange, hydrocarbon propellants, petroleum distillants, ketones & ester solvent (manufactured by Testor Corporation).

[0150] K=TS-5 Olive Drab (manufactured by Tamiya Europe GMBH).

[0151] L=Plasti-kote Trim Black 611, acetone, Xylene.

[0152] M=Plasti-kote Classic Lacquer 346 bright red.

[0153] N=Plasti-kote Flexible Bumper & Trim, 1892 light grey primer, acetone, zylene, toluene.

[0154] Each of the above listed paints were aerosol spray paints. However, these paints were used as examples and does not limit the present invention to the use of aerosol spray paints.

Example 3

[0155] Glue

[0156] In Control Samples 18-21, identical tensile bars of PVC having a length of about 6 inches and a thickness of about $\frac{1}{8}$ inches were punched from a sheet of commercially purchased PVC. One tab was cut off and the narrow central portions were glued to each other in a lap shear fashion such that there was an overlap of the samples of about 1-inch. Samples 18-21 did not utilize any primer prior to being glued. Except for the unglued Sample, all Samples were lightly sanded prior to gluing using a fine grit sandpaper until the glossy surface was destroyed. After gluing, all the Samples were clamped using a C-clamp for a period of 24 hours.

[0157] The Control Samples gluing polyoxymethylene to polyoxymethylene and polyoxymethylene to PVC resulted in such weak adhesion they could not be tested. These samples broke while being clamped into the Instron test machine, due to the lack of adhesion.

[0158] Samples 22-26 comprise 55% of polyacetal homopolymer (MW=65,000); 15% of a thermoplastic polyurethane with butylene adipate soft segments and 4,4' methylene bisphenyl isocyanate; and 30% of an extrusion grade ABS (melt flow=2.5). These Samples, when tested, were pulled at 0.2 inches/minute and were constrained from twisting by a loose sleeve during the pulling.

TABLE 4

Sample	Glue	Primer	Stress (max, Kpsi)	Strain at break
18 (Control)	None	None	8.4	54.9
19 (Control)	Type B	None	6.0	5.6
20 (Control)	Type C	None	4.2	2.5
21 (Control)	Type D	None	5.8	4.1
22	Type B	Type P	5.3	31.0
23	Type C	Type C	5.9	40.1
24	Type D	None	5.0	4.0
25	Type D	Type C	5.6	30.2
26	Type D	Type P	5.8	39.0
27	Type D	Type P	5.8	37.6

[0159] Glue:

[0160] Type B—Harvey's MP-6, #01800, Multipurpose -ABS, PVC., CPVC (manufactured by William H. Harvey Co., Omaha NE).

[0161] Type C—IPS Weld-on PVC 700, #10082 (manufactured by IPS Corporation, Gardinia, Calif.).

[0162] Type D—Oaty #31128 CPVC Cement (manufactured by Oaty Corporation, Cleveland, Ohio).

[0163] Primers:

[0164] Type C—IP Weld-on C-65 Cleaner-PVC., CPVC., ABS, Styrene #10204 (manufactured by IPS Corporation, Gardinia, Calif.).

[0165] Type P—Harvey's Purple Primer-PVC., CPVC (manufactured by William H. Harvey Co., Omaha Neb.).

Example 4

[0166] Overmolding

[0167] Sample Types 28-36 were substrates that had been molded in a plaque mold ($\frac{1}{8}$ inches $\times$ 4 inches $\times$ 6 inches). These substrates were then inserted into a $\frac{1}{4}$ inch deep mold of the same length and width dimensions to be inserted molded by the thermoplastic elastomers set forth in Tables 5, 6 and 7. The substrates having the adhered layer were tested according to the peel test described above. Subsequently, several of those substrates were tested a second time on a different tensile machine at a different location. The first location utilized an Instron Model 4202 (Instron Corporation, New Ulm, Minn.) and the second location utilized a Zwick Model Z2.5 (Zwick GMBH).

[0168] Sample Type 28 is a substrate comprising 100% of a polyacetal homopolymer (MW=38,000).

[0169] Sample Type 29 is a substrate comprising 90% of a polyacetal homopolymer (MW=38,000); and 10% of a thermoplastic polyurethane with butylene adipate soft segments and 4,4' methylene bisphenyl isocyanate.

[0170] Sample Type 30 is a substrate comprising 70% of a polyacetal homopolymer (MW=65,000); and 30% of a thermoplastic polyurethane with butylene adipate soft segments and 4,4' methylene bisphenyl isocyanate.

[0171] Sample Type 31 is a substrate comprising 95% of a nucleated polyacetal homopolymer (MW=65,000); and 5% of an ethylene vinyl acetate copolymer (with 40% vinyl acetate) having a melt index of 55.

[0172] Sample Type 32 is a substrate comprising 90% of a polyacetal copolymer with 1.3% ethylene oxide groups (Mn=28,300); and 10% of a phenol-formaldehyde thermoplastic resin (Mn=1000 and Tg=80° C.).

[0173] Sample Type 33 is a substrate comprising 80% of a polyacetal homopolymer (MW=38,000); and 20% of a high impact polystyrene (melt flow=3.5g/10 minutes with 5.0 Kg weight at 200° C., ASTM D1238).

[0174] Sample Type 34 is a substrate comprising 90% of a polyacetal copolymer with 1.3% ethylene oxide groups (Mn=28,300); and 10% of a zinc ionomer of 67% ethylene/24% n-butyl acrylate/9% methacrylic acid (melt index=25).

[0175] Sample Type 35 is a substrate comprising 50% of a polyacetal homopolymer (MW=38,000); 20% of a butylene adipate soft segments and 4,4' methylene bisphenyl isocyanate; and 30% of a styrene acrylonitrile copolymer (melt flow=25g/10 minutes with 3.8 Kg weight at 445° C.

[0176] Sample Type 36 is a substrate comprising 55% of a polyacetal homopolymer (MW=38,000); 15% of a thermoplastic polyurethane with butylene adipate soft segments and 4,4' methylene bisphenyl isocyanate; and 30% of an extrusion grade ABS (melt flow=2.5).

[0177] All of the overmolding Examples utilized substrates having the Sample Types designated above, however various overmolding materials were adhered onto the substrate and subsequently subjected to the peeling test as described above.

Example 4(a)

[0178] Overmolding with Polyester Polyether Thermoplastic Elastomer

[0179] In this Example the overmolding layer adhered to the substrate was a polyester polyether thermoplastic elastomer with 36% hard PBT segment/67% soft PTMEG segment, a melting point of 190° C., and a Shore D hardness of 40D. The results of the peel test are shown below in Table 5.

TABLE 5

Sample Type	% POM	% Non-acetal	% Other	First Adhesion Result (pounds/linear inch)	Second Adhesion Test Result (pounds/linear inch)
28	100	0	0		—
29	90	10	0		—
30	70	30	0	5-15	19
31	95	5	0		—
32	90	10	0	3-6	—
33	80	20	0	2-4	—
34	90	10	0	1-3	—
35	50	20	30	5-8	—
36	55	15	30	6-12	20

Example 4(b)

[0180] Overmolding with Thermoplastic Polyurethane

TABLE 6

Sample Type	% POM	% Non-acetal	% Other	Adhesion (pounds/linear inch)	Second Adhesion Test Result (pounds/linear inch)
28	100	0	0		—
29	90	10	0		—
30	70	30	0	8-16	22
31	95	5	0		—
32	90	10	0	2-3	—
33	80	20	0	3	—
34	90	10	0		—
35	50	20	30	10	—
36	55	15	30	3-6	6

Example 4(c)

[0181] Overmolding with Styrene Butadiene Block Copolymer

TABLE 7

Sample Type	% POM	% Non-acetal	% Other	Adhesion (pounds/linear inch)	Second Adhesion Test Result (pounds/linear inch)
28	100	0	0		—
29	90	10	0		—
30	70	30	0	23	23
31	95	5	0	24	24
32	90	10	0		—
33	80	20	0	18	18
34	90	10	0		—
35	50	20	30	20	20
36	55	15	30	23	23

What is claimed is:

1. An article comprising:

(a) a substrate comprising 99.5-40 weight percent of a polyoxymethylene polymer; 0.5-60 weight percent of at least one non-acetal thermoplastic polymer on or near the surface of the substrate to promote adhesion; and

(b) at least one layer adhered to the substrate.

2. The article according to claim 1, wherein the polyoxymethylene polymer is branched or linear.

3. The article according to claim 2, wherein the polyoxymethylene polymer has a number average molecular weight in the range of about 10,000 to about 100,000.

4. The article according to claim 3, wherein the polyoxymethylene polymer has a number average molecular weight in the range of about 25,000 to about 70,000.

5. The article according to claim 1, wherein the substrate comprises about 0.5 to about 20 weight percent of the at least one additional non-acetal polymer.

6. The article according to claim 1, wherein the at least one non-acetal polymer is selected from the group consisting of styrene acrylonitrile copolymers, styrene acrylonitrile copolymers copolymers toughened acrylonitrile-butadiene-styrene (ABS) resins, styrene acrylonitrile copolymers toughened with acrylonitrile-ethylene-propylene-styrene resins, polycarbonates, polyamides, polyarylates, polyphenyleneoxides and their blends, polyphenylene ethers and their blends, high impact styrene resins, acrylic polymers, imidized acrylic resins, styrene maleic anhydride copolymers, polysulfones, styrene acrylonitrile maleic anhydride resins, and styrene acrylic copolymers, and derivatives thereof.

7. The article according to claim 6, wherein the at least one non-acetal polymer is selected from the group consisting of styrene acrylonitrile copolymers, acrylonitrile-butadiene-styrene resins, acrylonitrile-ethylene-propylene-styrene resins, and polycarbonates.

8. The article according to claim 1, wherein the at least one non-acetal polymer is a semi-crystalline polymer selected from the group consisting of polyamides, polyesters and polyolefins.

9. The article according to claim 1, wherein the at least one layer is co-continuous with the substrate.

10. The article according to claim 1, wherein the at least one layer is discontinuous with the substrate.

11. The article according to claim 1, wherein the at least one layer is selected from the group consisting of thermoplastic elastomers, thermoplastic olefins, thermoplastic urethanes, polyethylene and polypropylene.

12. The article according to claim 1, wherein the at least one layer is selected from the group consisting of solvents, water latex, epoxy, urethane, and powder coating acrylic.

13. The article according to claim 1, wherein the at least one layer is selected from the group consisting of solvent-based glues, latex, epoxy, and super glue.

14. The article according to claim 1, wherein the substrate is pretreated with a surface modification technique selected from etching, flaming ionization, sanding, surface cleaning, and UV exposure.

15. A process for making the article of claim 1 comprising the steps of:

(i) blending a matrix comprising 99.5-40 weight percent of an polyoxymethylene polymer and 0.5-60 weight percent of at least one non-acetal thermoplastic polymer;

(ii) molding the matrix into a substrate; and

(iii) adhering at least one layer to said substrate.

* * * * *

EXHIBIT K



US005984494A

United States Patent [19]
Chapman et al.

[11] Patent Number: 5,984,494
[45] Date of Patent: Nov. 16, 1999

[54] LIGHT SHIELD FOR AN ILLUMINATION SYSTEM

FOREIGN PATENT DOCUMENTS

[75] Inventors: Mark Garland Chapman, Ontario;
Laurence Hastings Bloxham, LaVerne,
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29143 2/1925 France .

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[22] Filed: Apr. 2, 1997

[57] ABSTRACT

Related U.S. Application Data

[63] Continuation-in-part of application No. 08/522,989, Sep. 8,
1995, Pat. No. 5,685,637, and a continuation-in-part of
application No. 08/828,618, Mar. 31, 1997, abandoned.
[51] Int. Cl.⁶ F21V 13/04
[52] U.S. Cl. 362/470; 362/240; 362/241;
362/245; 362/471
[58] Field of Search 362/236, 237,
362/240, 241, 242, 243, 244, 245, 247,
248, 228, 231, 470, 471

The Dual Spectrum Illumination System (DSIS) is a modular light source having two independent emitters of optical radiation. A halogen bulb provides a high intensity visible beam. The second source of emissions is a ring of light emitting diodes (LED). The LED ring can be configured to supply area illumination, beam illumination, or a combination of area and beam illumination. The spectrum emitted by the LED is selectable from the wide range of commercially available diodes. The illumination system provides a beam and infrared area lighting using 21 high power, 6 watt, LEDs emitting at 880 nanometers mounted on the ring. Illumination control electronics are provided on a printed circuit assembly to provide the diodes with the correct current and voltage. A second embodiment of the invention is as a direct replacement for aircraft landing lights, mobile vehicle head lights, and any other situation requiring beam illumination. This embodiment of the DSIS provides high intensity beams of visible light and infrared light and is particularly suited for U.S. Air Force covert operations. The system includes a mounting plate having a plurality of receptacles that receive the LEDs. Shield are provided that each surround a portion of selected receptacles in order to block infrared light that would otherwise impinge upon the cockpit of the aircraft.

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14 Claims, 11 Drawing Sheets

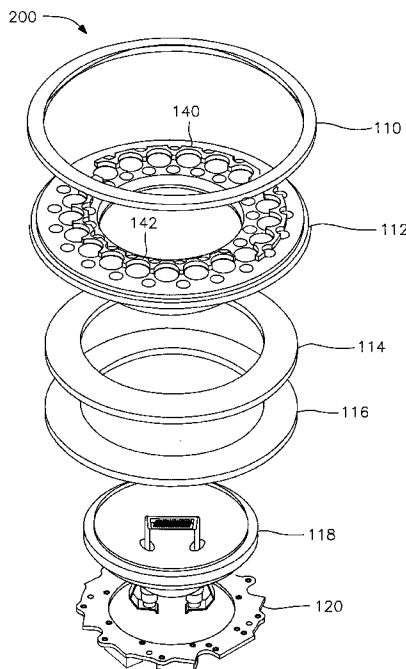


FIG. 1

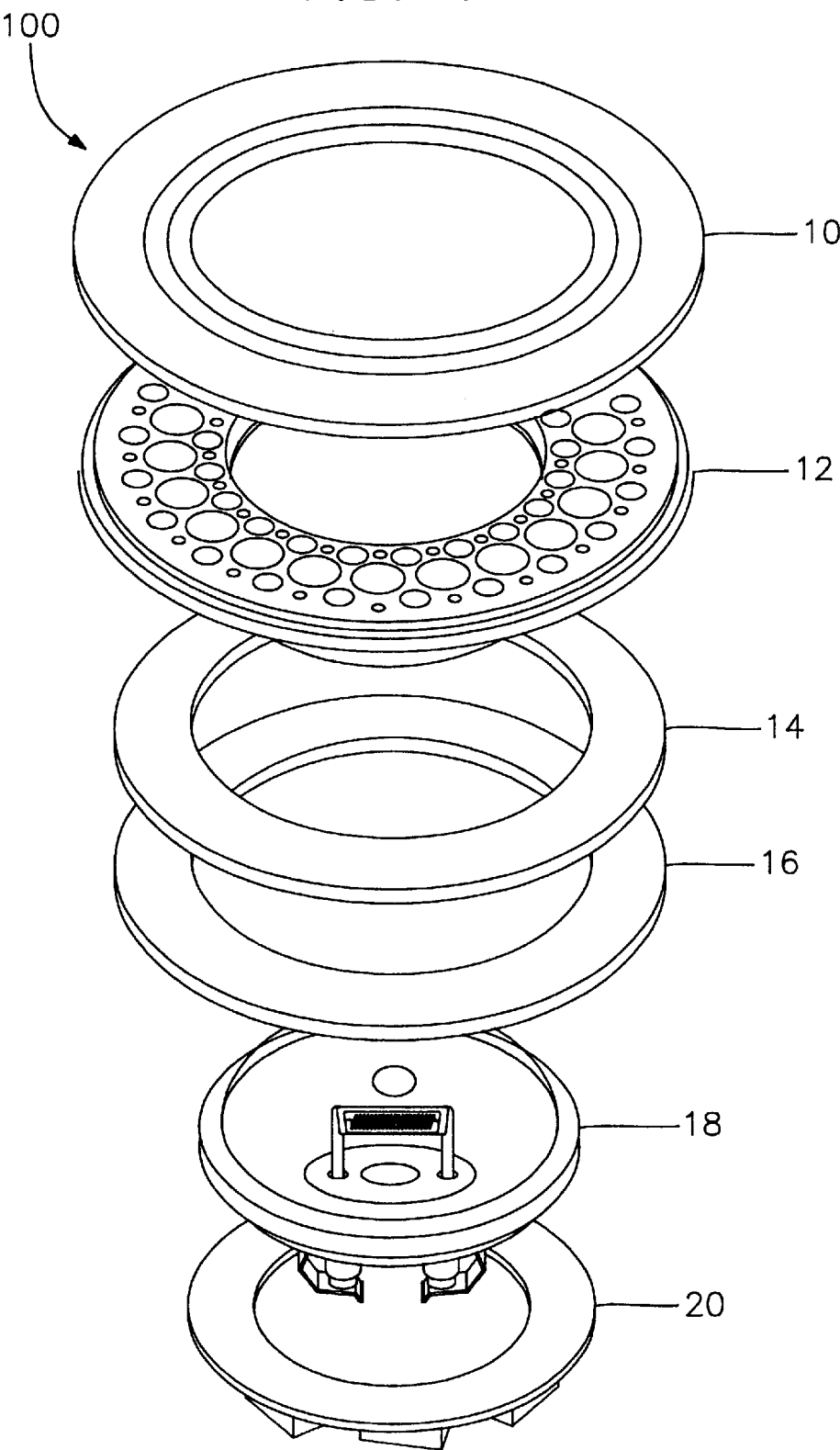


FIG. 2

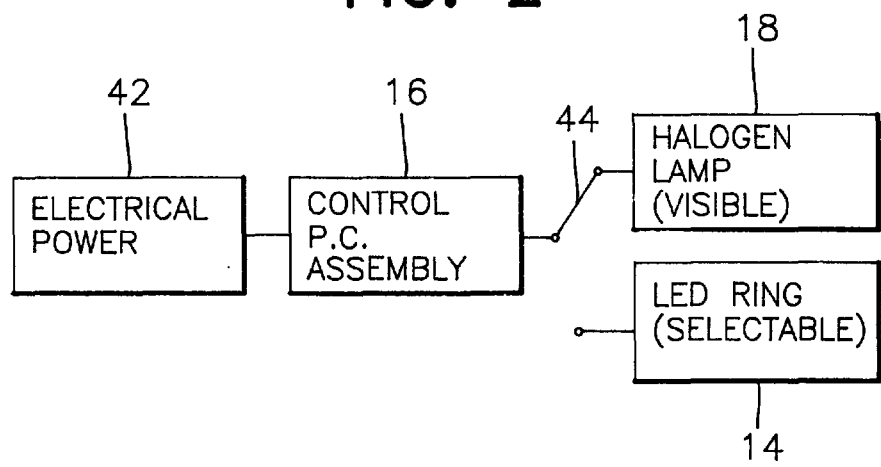


FIG. 7

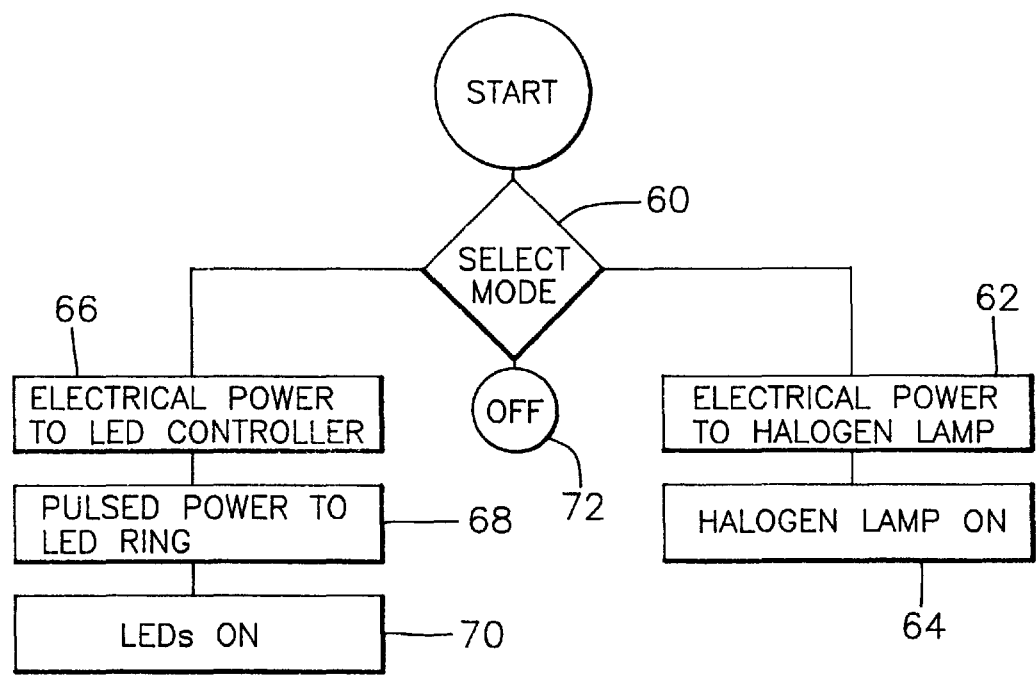


FIG. 3(a)

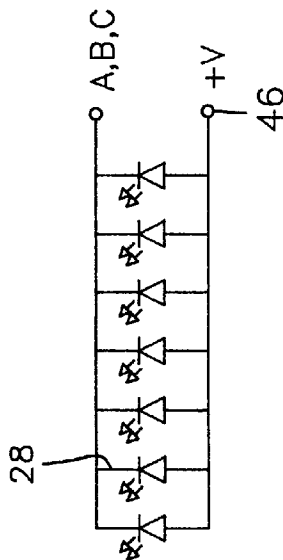


FIG. 3(b)

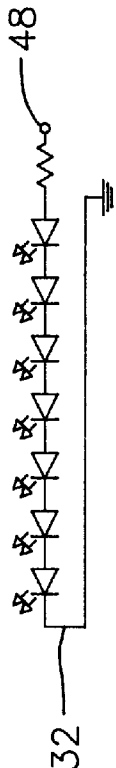


FIG. 3(c)

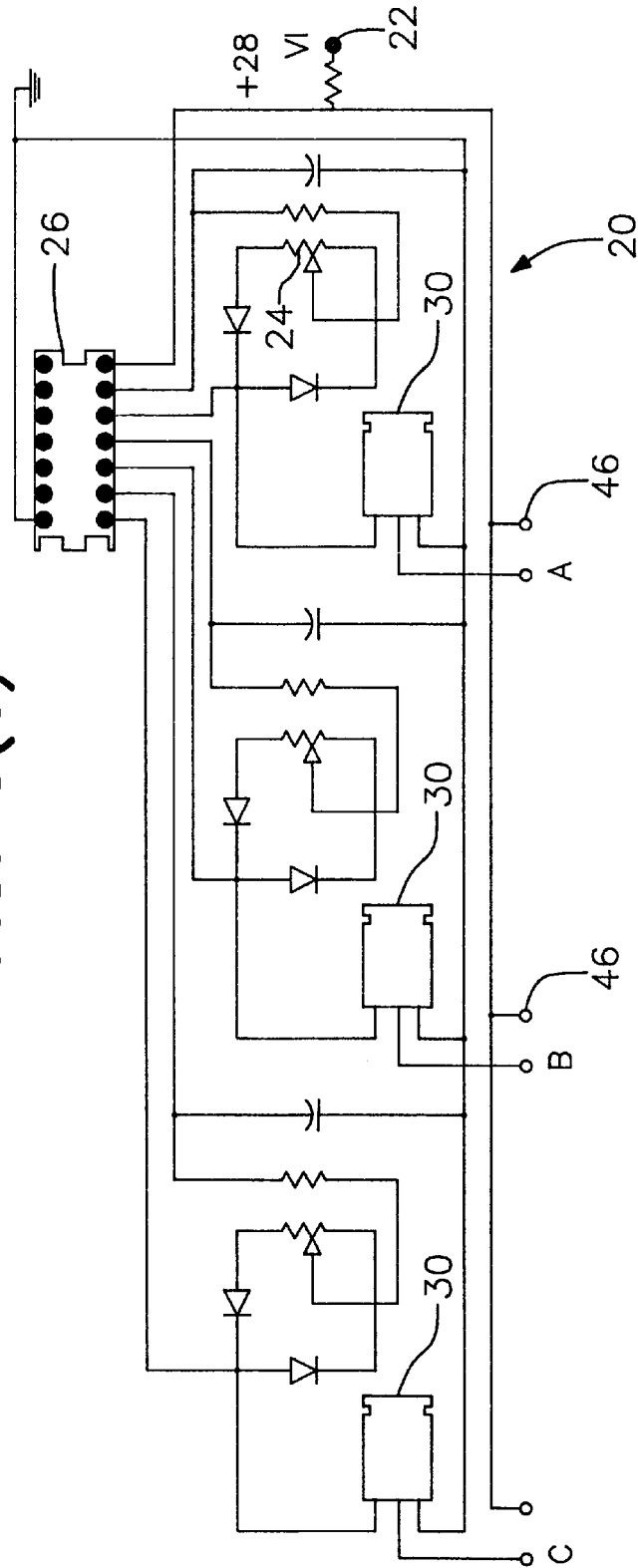


FIG. 4

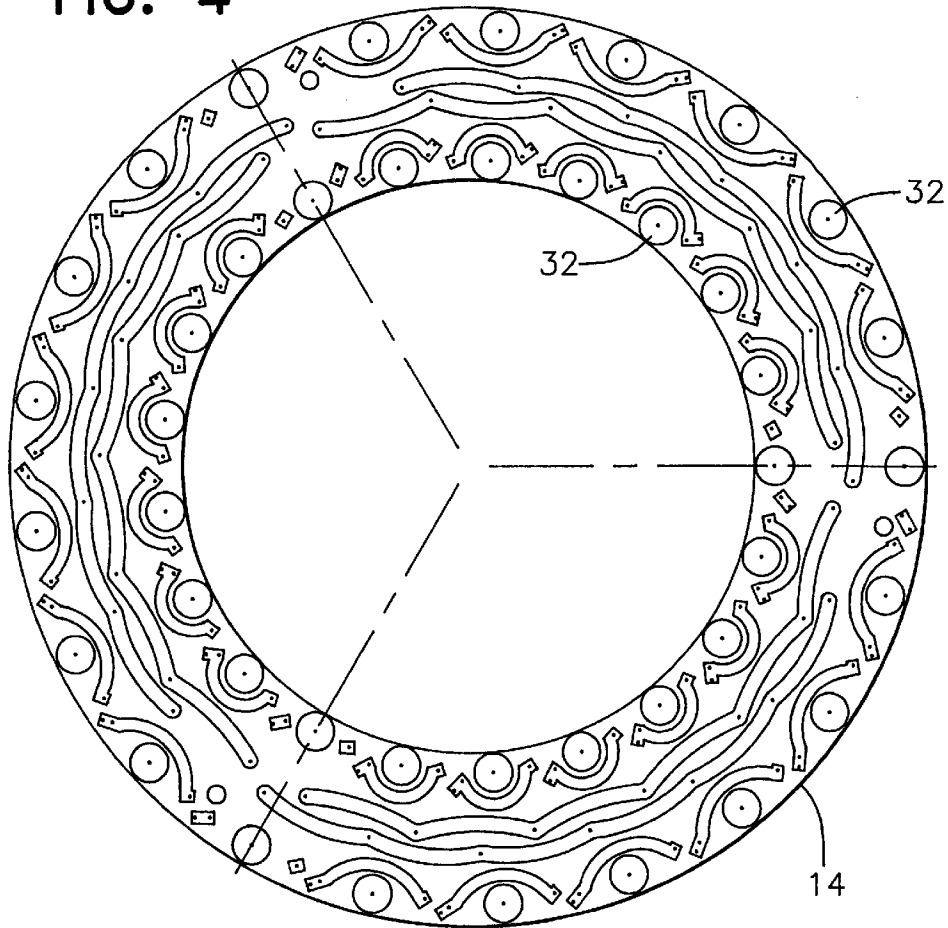


FIG. 5

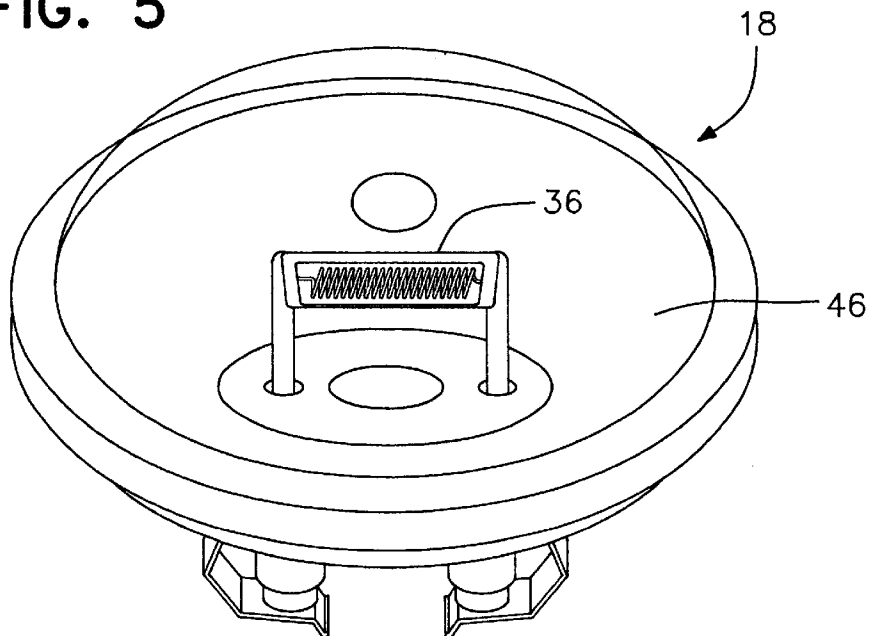


FIG. 6

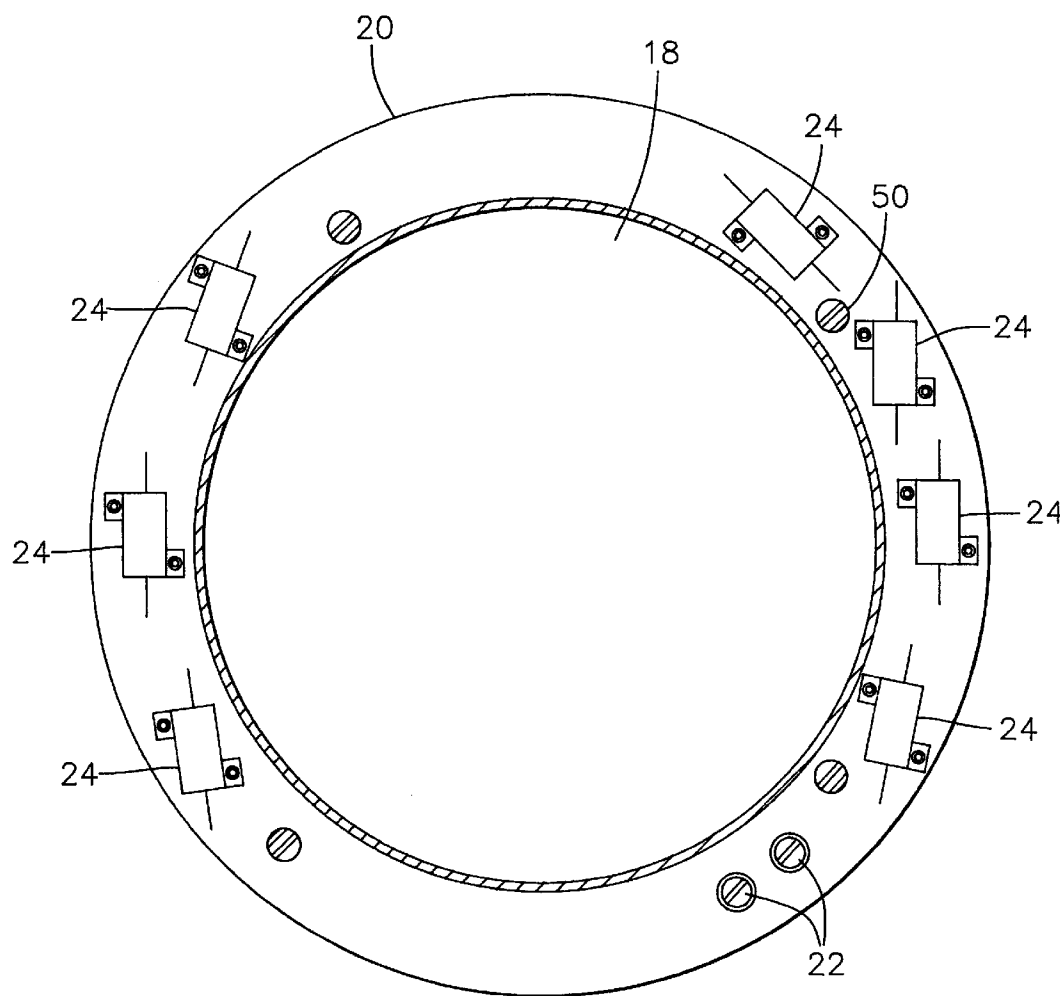


FIG. 8

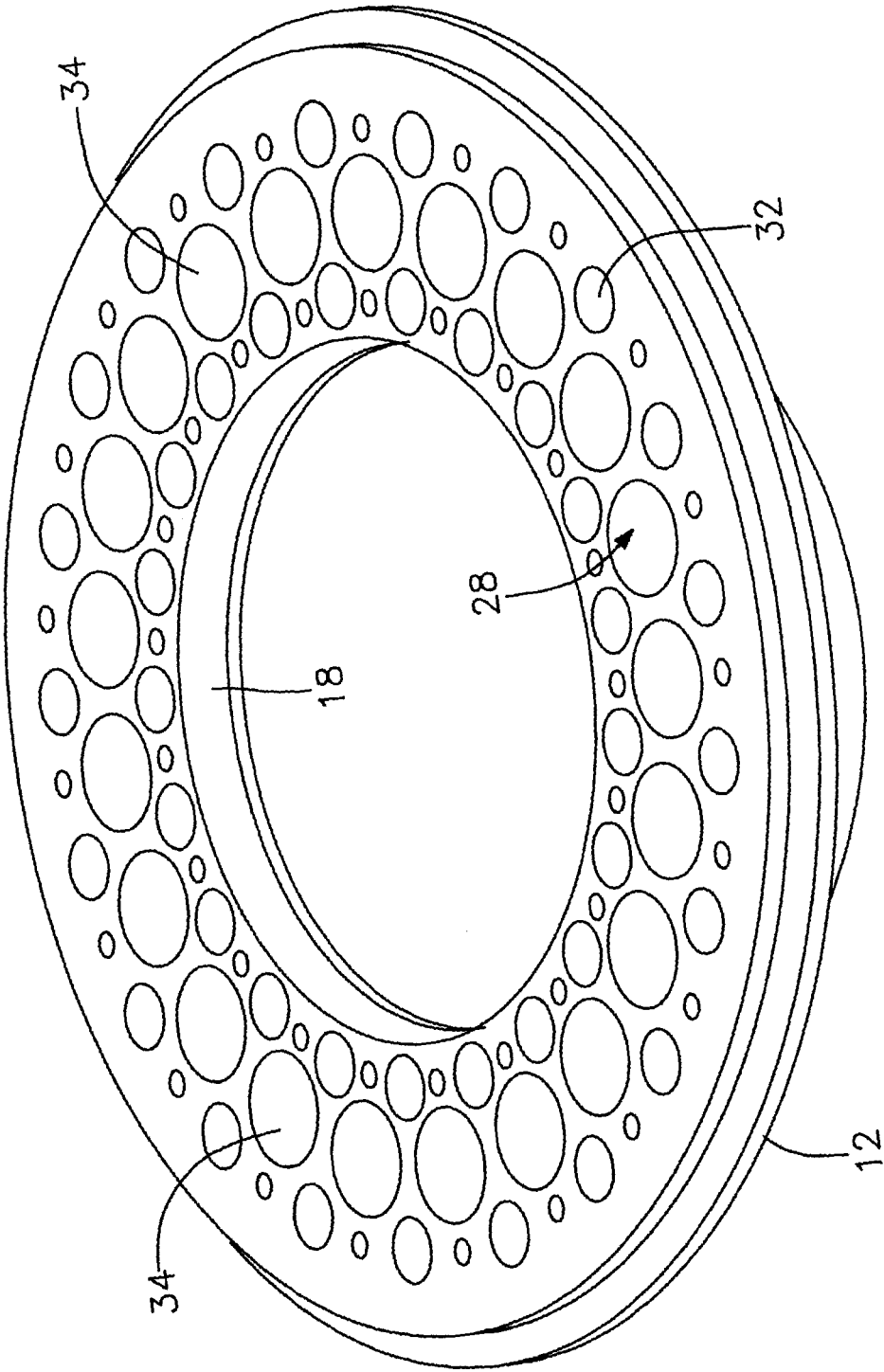


FIG. 9

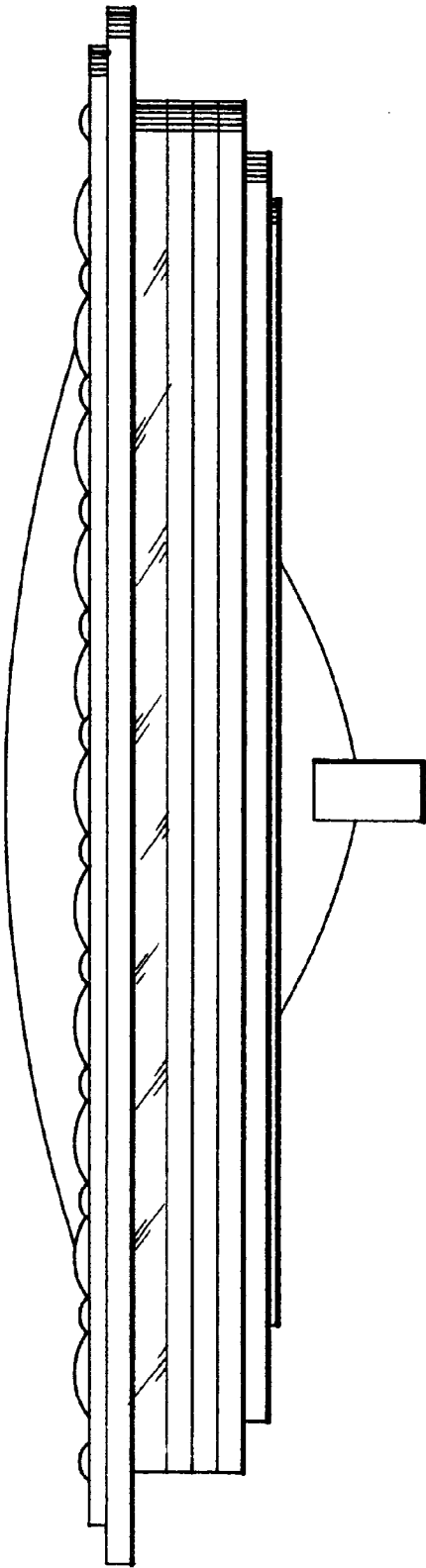
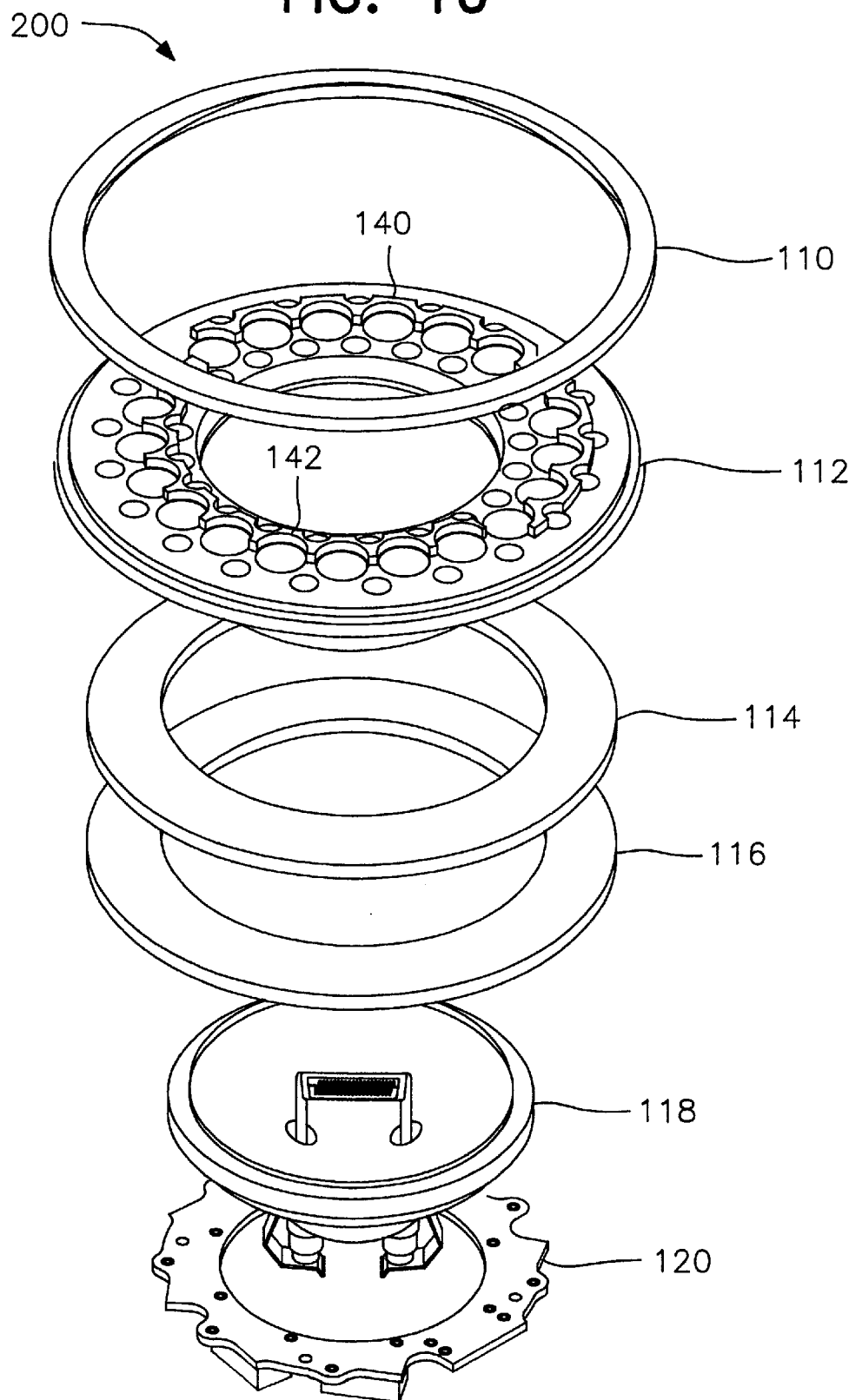


FIG. 10



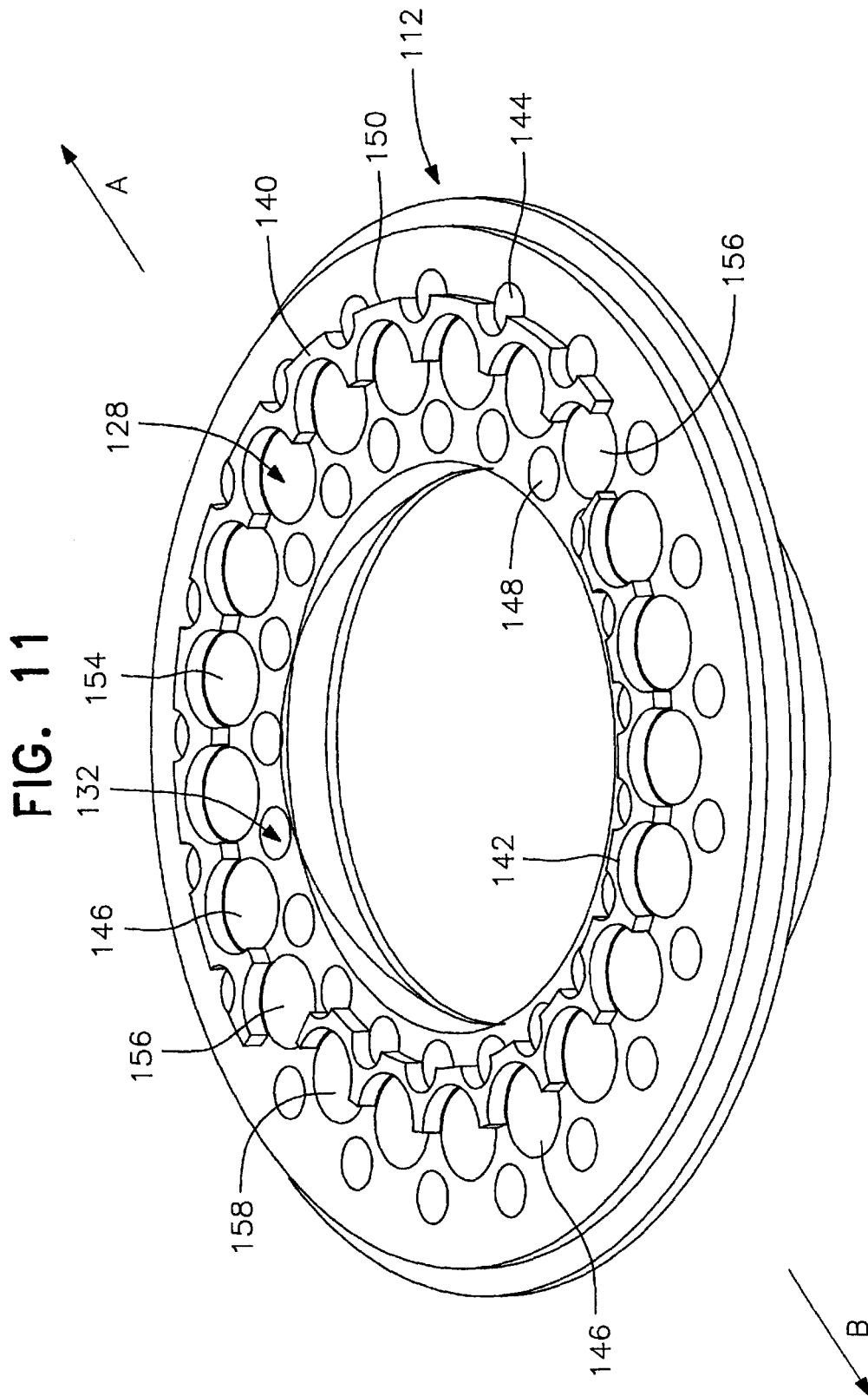


FIG. 12

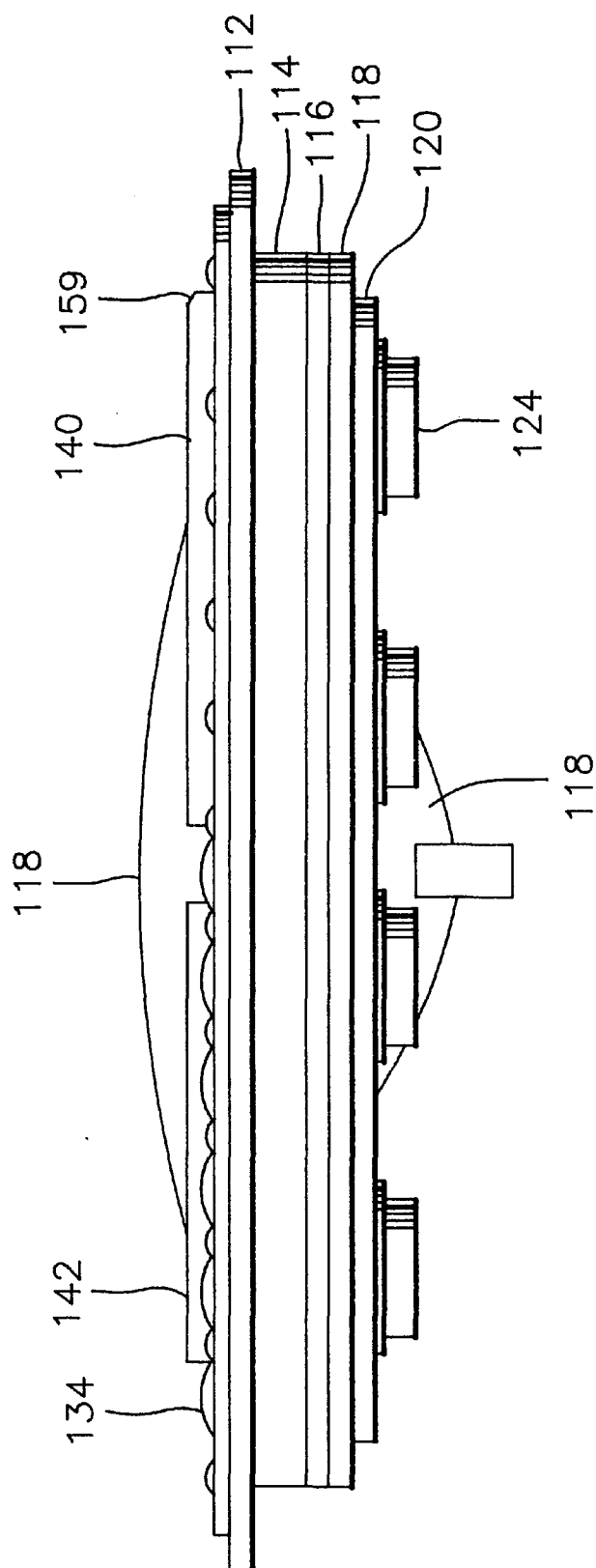
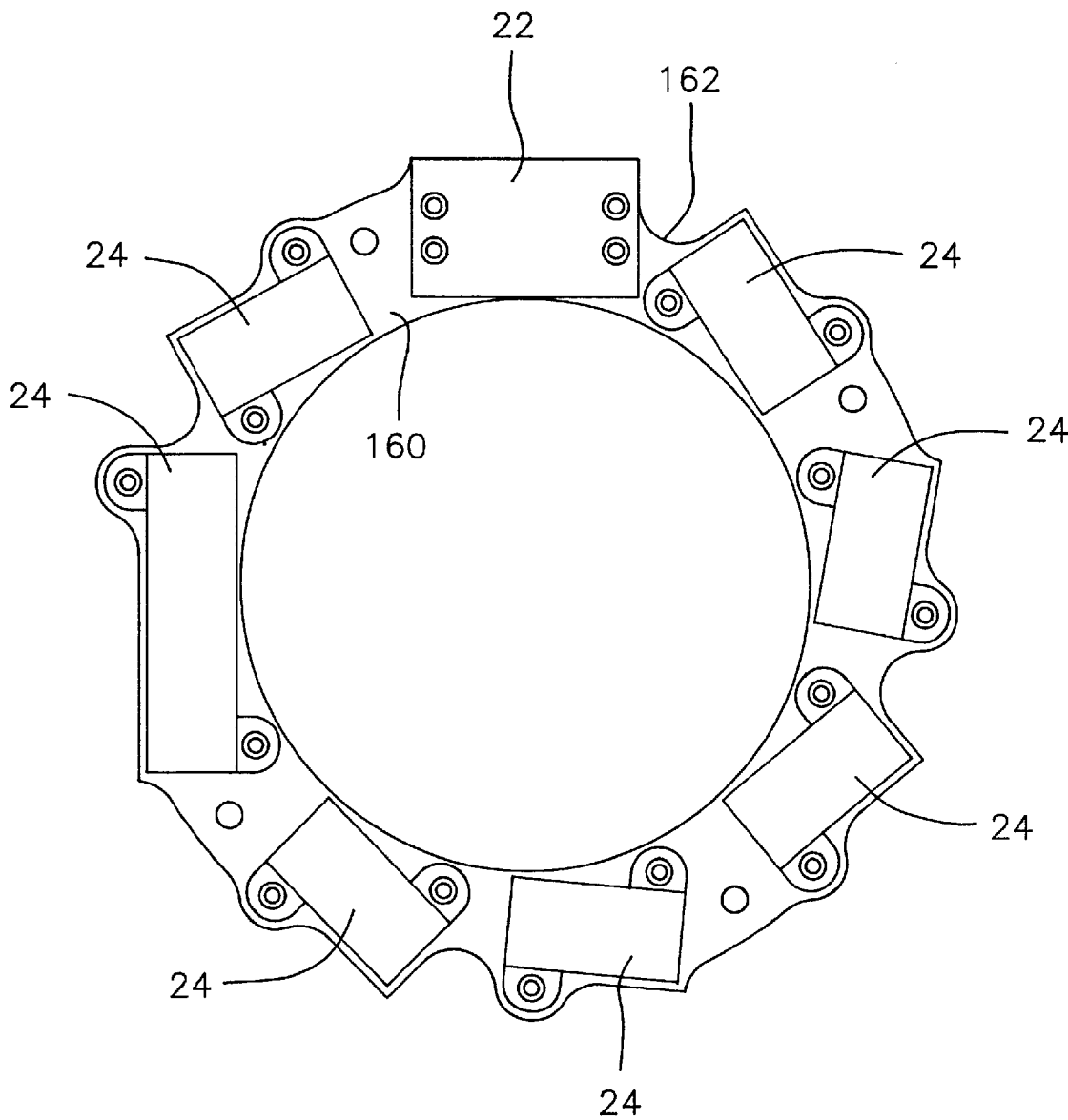


FIG. 13



LIGHT SHIELD FOR AN ILLUMINATION SYSTEM

RELATED APPLICATIONS

This application is a continuation-in-part of Ser. No. 08/522,989, filed Sep. 8, 1995, now pending, and a continuation-in-part of a U.S. application Ser. No. 08/828,618 filed on Mar. 31, 1997, entitled "Dual Spectrum Illumination System Having a Light Shield", now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to lighting, and particularly to the illumination of areas or beam lighting for use as aircraft landing lights and automobile headlights.

2. Description of the Prior Art

Heretofore, when a lamp, such as a sealed beam incandescent bulb, was used to provide a specific band of electromagnetic radiation, a filter or cold mirror was used to block the unwanted wavelengths. However, the filter or cold mirror trapped heat and the bulb operated at a temperature above the intended operating range. Consequently, the bulb burns out if operated for more than about 15 to 20 minutes and the excessive heat shortens the expected lifetime of the bulb by about 50%. In addition, changing the active spectrum required manual effort or a complex mechanical device to insert or remove the filter.

Another approach uses a dual bulb made with the reflecting surfaces pointing in opposite directions. To change the active spectrum, again a man or a complex mechanical device is needed to rotate the bulb. This approach requires a unique fixture and has relatively high cost.

Another fixture built for use on aircraft consists of four sealed beam lamps, two with cold mirrors and two unfiltered. The fixture, however, is a large complex assembly that is expensive to install on aircraft and also suffers from the bulb overheating problem described above.

Other lights are made using arc lamps, but these are also broad band and require filters with the same difficulties noted above to select specific bands of the spectrum.

SUMMARY OF THE INVENTION

Accordingly, it is a primary object of the invention to provide a modular light source particularly suited for use as aircraft landing lights, mobile land vehicle headlights, indoor or outdoor area illumination, and for use in like devices.

Another object of the invention is to provide a landing light having infrared light that does not interfere with night-vision systems, especially night-vision goggles used by a pilot.

The invention provides two independent emitters of electro-magnetic radiation. One of the emitters is a halogen bulb that provides a high intensity visible beam of light. A second source of emissions is a ring of light emitting diodes (LED). The ring can be configured to provide area illumination, beam illumination, or a combination of area and beam illumination. The spectra emitted by the LED ring is selectable from the wide range of commercially available devices. The user can easily switch between the two available spectrum with an electrical switch. This ease of spectra selection has not been previously available.

A dual spectrum illumination system is comprised of two independent modular sources of illumination. Upon activa-

tion by an operator or user, the selected light source provides a high intensity beam of visible light, preferably by a halogen lamp. Alternatively, the user may select a high intensity beam or area illumination of infrared radiation, ultraviolet radiation, or any other region of the spectrum that can be produced by light emitting diodes. The diodes are mounted on a ring that circumscribes the halogen bulb. This ring accommodates many LED configuration. The dual spectrum illumination system is manufactured to be compatible with fixtures currently in use that house sealed beam and halogen lamps that only provide visible light. The selection of a specific spectra is accomplished all electronically and no mechanical action is necessary.

The advantages are extremely significant when the dual spectrum illumination system is used as a landing light for aircraft. The invention is a form, fit, and multi-function replacement for the standard aircraft landing light 4559. The installation of the invention on an aircraft only requires adding a three position switch and a single wire from the switch to the landing light.

The pilot can select to perform a normal landing by activating the halogen lamp, or he can decide to perform a covert landing by turning on the second spectra. For example, the LED ring can be populated by high power infrared light emitting diodes ("LED"). LED light is invisible to the naked eye and night vision goggles must be used to see. The aircraft may land with the invisible landing light and cause minimal disturbance to the native population at the landing site.

The use of light emitting diodes solves the over heating problem and short operating lifetime of sealed beam lamps associated with the use of filters and cold mirrors. The LED has an expected lifetime of about 100,000 hours and will not over heat when operated with the current voltage and current.

The dual spectrum illumination system is designed to be interchangeable with landing lights currently in use on aircraft. Only one additional wire and a selection switch must be added to the current assembly. This is a significant advantage over the extensive modifications required to use mechanical filters and cold mirrors, wherein the bulb must be rotated, or the large and visible light having four sealed beam lamps, two with cold mirrors and two unfiltered.

The invention has special advantages for the U.S. Air Force. To an observer, a dual spectrum illumination system appears to be a normal aircraft landing light. The invention is less obtrusive than any prior art and is covert when used on aircraft equipped for night vision capable operations.

These together with other objects and advantages which will become subsequently apparent reside in the details of construction and operation as more fully hereinafter described and claimed, reference being had to the accompanying drawings forming a part hereof, wherein like numerals refer to like parts throughout.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an exploded perspective of the Dual Spectrum Illumination System in accordance with the preferred embodiment of the invention.

FIG. 2 is a block diagram of the system.

FIGS. 3a-3c are schematics of the electrical circuit of the invention.

FIG. 4 is a top view of the circuit side of the light emitting diode ring.

FIG. 5 is a perspective of the halogen lamp used in the system of FIG. 1.

FIG. 6 is a top view showing the power conditioning and retaining ring used in the system shown in FIG. 1.

FIG. 7 is an operational flow chart for the invention.

FIG. 8 is a perspective view of the LED mounting plate of the invention of FIG. 1.

FIG. 9 is a side view of the system shown in FIG. 1.

FIG. 10 is an exploded perspective view of an alternative embodiment of the dual-spectrum illumination system in accordance with the invention.

FIG. 11 is a perspective view of the LED mounting plate in accordance with an alternative embodiment of the invention.

FIG. 12 is a side view of the dual-spectrum illumination system in accordance with the alternative embodiment of the invention shown in FIG. 10.

FIG. 13 is a bottom view of a power conditioning and retaining ring in accordance with an alternative embodiment of the invention.

Selected Reference Numerals

- 10 a protective lens
- 12 a LED mounting plate
- 14 a LED printed circuit assembly
- 16 an illumination controller printed circuit assembly
- 18 a halogen lamp
- 20 an electrical power conditioning and retaining ring
- 22 input terminals
- 24 seven current limiting resistors
- 26 40106 hex Schmitt trigger integrated circuit
- 28 high power light emitting diodes, OD669
- 30 N-channel MOSEFETs
- 32 OD50L light emitting diodes
- 34 plano-convex lens
- 36 halogen bulb

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In describing a preferred embodiment of the invention illustrated in the drawings, specific terminology will be resorted to for the sake of clarity. However, the invention is not intended to be limited to the specific terms so selected, and it is to be understood that each specific term includes all technical and legal equivalents.

As shown in FIG. 1, a Dual Spectrum Illumination System 100 is a modular light source. The Dual Spectrum Illumination System 100 consists of a protective lens 10, a LED mounting plate 12, a LED printed circuit assembly 14, and illumination controller printed circuit assembly 16, a visible illumination module, with a halogen lamp 18 as the principal component, and an electrical power conditioning and retaining ring 20. The illumination system provides two independent emitters of electro-magnetic radiation. The illumination system is controlled by a three position switch (OFF-ILLUMINATION 1-ILLUMINATION 2) (not shown). The selection of a specific illumination is accomplished with the simple three position switch, no complex mechanical or manual operation is required. The LED mounting plate 12 and the LED printed circuit assembly 14 may be configured to accommodate many different light emitting diodes.

The Dual Spectrum Illumination System 100 is designed to be used as a direct replacement for sealed beam lamps used on mobile vehicles. The initial application of the illumination system 100 is as a replacement for the standard 4559 landing light used on aircraft. The illumination system

100 provides both conventional visible illumination, as well as night vision capable illumination. The illumination system 100 is intended to be used during take-off and landing, as well as during operations while on the ground. The Dual Spectrum Illumination System 100 is designed to be easily converted to operate with a wide variety of light emitting diodes, in anticipation of the future, when night vision goggles will respond to light at wavelengths different from the current designs.

FIG. 2 shows a block diagram of a Dual Spectrum Illumination System 100 (DSIS). Electrical power 42 is supplied through the mode selection switch 44. The selection switch 44 determines the mode of operation of the system 100 by allowing the user to select the desired spectrum of light. The selection of visible illumination causes power to flow directly from the power supply 42 to the halogen bulb 18. The selection of a second spectrum activates the illumination control printed circuit assembly 16. The illumination controller 16 generates pulsed power at the correct voltage and duration for the optimum operation of the light emitting diodes 28, 32.

Now referring to FIGS. 3a-3c, a schematic for a Dual Spectrum Illumination System 100 is shown. Construction and use will be easily apparent to those skilled in the art given the values and interconnections shown, so it will not be discussed in great detail. A power supply will be selectively matched to the available main electrical power 42. The first Dual Spectrum Illumination System 100 was built for use on an aircraft that was wired to supply 28 VDC to the landing lights.

The power conditioning ring, item 20 on FIG. 1, receives the DC power via input terminals 22 and supplies DC power through seven current limiting resistors 24. Six of the resistors 24 are each directly connected to a series circuit of seven OD50L light emitting diodes 32 at terminals 46. Only one of these identical circuits is shown in FIG. 3b. The seventh resistor 24 connects to the illumination control circuit 16. The illumination control circuit 16 uses a standard 40106 hex Schmitt trigger integrated circuit 26 to generate pulses that switch the power used to drive the twenty-one high power light emitting diodes OD669 28, on the LED printed circuit assembly 14.

The variable resistors 24 control the pulse length and duty cycle of the timer. The circuit 26 uses three identical N-channel MOSFETs 30 that each supply power to seven of the light emitting diodes OD699 28, which are wired in parallel. These three circuits 26 are indicated by the letters A, B, C on the schematic. The MOSFETs 30 switch in response to the signals generated by the 40106 trigger 26 and each MOSFET 30 supplies about 13 VDC in 10 microsecond pulses at a duty cycle of 50%. When the switch 44 is positioned to turn on the halogen bulb lamp 18, a constant 28 VDC is supplied to the halogen bulb 36.

The circuit side of the light emitting diode (LED) printed circuit assembly 14 is shown in FIG. 4. The nine circuits connecting the light emitting diodes are shown. Around the inner and outer edges are the six circuits of seven OD50L LEDs 32 connected in series. The center of the ring has the three circuits of seven OD669 high power LEDs 28 connected in parallel. The first Dual Spectrum Illumination System 100 built used these sixty-three light emitting diodes 28, 32. Twenty-one were high power OD669 LEDs 28 with power output of 6500 milliwatts each. Forty-two are OD50L LEDs 32 that emit 500 milliwatts each for a total output of 157.5 watts of infrared illumination. Each light emitting diode OD669 28 is aligned with a plano-convex lens 34 on

the LED mounting plate 12 to collimate and direct the infrared into a beam appropriate to illuminate landing fields.

The halogen lamp 18 is shown in FIG. 5. The 450 watt halogen bulb 36 is mounted near the focal point of a circular reflector 46. The reflector shapes the isotropic emissions from the halogen bulb to a beam for illuminating landing fields.

FIG. 6 shows the electrical power conditioning and retaining ring 20. The 28 VDC electrical power is connected to the terminals 22. The seven power limiting resistors 24 are mounted on the ring 20. The ring 20 is fastened to the LED mounting plate 12 by screws 50 which retain the halogen lamp 18 in position. This structure provides the necessary strength to operate in severe environmental conditions, such as are present on the wing of an aircraft.

FIG. 7 shows the sequence of operations that occur to control the Dual Spectrum Illumination System 100. The pilot has the option to select one of three options, off/visible/infrared, by setting the switch 44.

FIG. 8 is a sketch of the assembled invention in perspective view. The halogen lamp 18 with bulb 36 is mounted in the center. Surrounding the bulb 36 is the LED ring 12. Mounted on the under side of the ring 12 are the forty-two OD50L 32, and the twenty-one OD669 28 light emitting diodes. The lenses 34 for the OD669 are mounted on the top of the ring and collimate the infrared light emitted by the diodes 28.

FIG. 9 shows the side view of the assembled invention. The current limiting resistors 24 are omitted for clarity. The size, shape, weight, and electrical requirements are compatible with all lamp housing used to hold the standard aircraft landing light PAR 4559.

The operation of the Dual Spectrum Illumination System 100 will now be described. When the pilot or operator sets switch 44 to the visible illumination position, the circuit, as shown in FIG. 2, is closed, thereby activating the halogen bulb 36. The bulb 36 remains on continuously until the switch 44 is repositioned. When the switch 44 is set to the invisible illumination position, the circuit for the LED printed circuit assembly 14 is closed and current flows to the current limiting resistors 24 on the electrical power conditioning and retaining ring 20. The 42 LEDs OD50L 32 are driven directly in 6 circuits of seven LEDs each. The seventh resistor is connected to the LED control circuit, which pulses power to activate the OD669 LEDs 28 mounted on the ring. The second spectrum illumination is emitted until switched off.

Accordingly, it can be seen that, a system 100 is provided to illuminate aircraft take-off and landing fields, mobile vehicle roadways, and other areas with either of two user selectable bands of the electromagnetic spectrum. The invention is modular and can be easily reconfigured to provide different bands of illumination. A high intensity visible beam is available, as is a narrow band spectrum emitted by a ring of light emitting diodes. The diodes may be infrared emitters for use with night vision goggles, or ultraviolet emitters for use with image intensifiers. Preferably, the diodes may be red, yellow, green, blue or any other color for monochrome visible lighting. An optical system with lenses to shape the LED illumination may also be used to achieve specific intensity profiles.

Although the description above contains many specificities, these should not be construed as limiting the scope of the invention but as merely providing illustrations of some of the presently preferred embodiments of this invention. Various other embodiment and ramifications are

possible within its scope. For example, a dual spectrum illumination system could be used in a security system. At night the secure area could be flooded with invisible infrared or ultraviolet radiation. Suitable sensors would survey the area and when unauthorized entry was detected, the visible lamp would be switched on to illuminate the intruder. The dual spectrum illumination system can also be a covert broadcast transmitter. By replacing the 40106 Schmitt triggers 26 with a digital data stream using on off keying or other suitable modulation scheme, the invention can transmit digitized voice, video, or data messages.

Turning to FIG. 10, an alternative embodiment of the illumination system 200 will now be discussed. As in FIG. 1, the system 200 generally includes a protective lens 110, LED mounting plate 112, LED printed circuit assembly plate 114, illumination controller 116, halogen lamp 118, and power conditioning and retaining ring 120.

However, it has been discovered that infrared light emitted by LEDs 128 and 132 may impinge upon the cockpit of the aircraft. Though infrared is invisible to the human eye, it causes interference with the use of night-vision goggles (and like devices). Many night-vision devices, such as goggles worn by pilots, and particularly night-vision devices having auto-gain, automatically adjust sensitivity based upon ambient light conditions. Consequently, as a greater amount of infrared light emitted by LEDs 128 and 132 paints the cockpit, the sensitivity of the night-vision goggles diminishes accordingly. Thus, the sensitivity of the goggles will not accurately reflect the actual available light encountered by the pilot, thereby reducing effectiveness of the night-vision goggles.

Accordingly, system 200 is designed in order to reduce the amount of infrared light that reaches the cockpit. Inner and outer bridge members or shields 140, 142 are configured integral with the LED mounting plate 112, as best shown in FIG. 11. The inner shield 140 and outer shield 142 generally comprise a flat metal plate that extends out, preferably perpendicular, from the top surface of the LED mounting plate 112. Each of the inner shield 140 and the outer shield 142 extend around approximately one-half of the mounting plate 112.

Shields 140, 142 are particularly useful in conjunction with lenses 134, which direct and focus light emitted by LEDs 128, 132, in order to direct light away from the cockpit. Nevertheless, the lenses 134 themselves, which preferably are fitted in, and protrude slightly from receptacle 142 (as shown in FIG. 12), still leak some infrared light that reaches the cockpit. The combined use of lenses 134 and shields 140, 142 significantly reduces the amount of light that impinges on the cockpit.

The shields 140, 142 cooperate to block and otherwise collimate infrared light emitted by LEDs 128, which are fitted in the middle tier or ring of receptacles 146. The system 200 is then mounted, for instance, on the underside of an airplane wing, so that the inner shield 140 is toward the body of the aircraft (not shown), which is generally indicated by arrow A, and especially faces the cockpit. The inner shield 140 preferably encompasses the receptacles 146 that are located closest to the cockpit. More particularly, inner shield 140 is scalloped to encircle one-half of nine receptacles 154 and one-quarter of two additional receptacles 156. Similarly, the outer shield 142 is scalloped to encompass one-half of the ten receptacles 158 that are located furthest from the body of the aircraft. Thus, the outer shield 142 will be nearer to the tip of the wing (as indicated generally by arrow B), and the inner shield 140 will be nearer the body of the aircraft.

The shields **140, 142** thus reduce the amount of light that progresses toward the cockpit by blocking or otherwise re-directing light emitted from LEDs **128**. This reduces the glare of infrared light encountered by night vision devices. Preferably, the shields **140, 142** are only used to block light emitted by LEDs **128**, since those emit the greatest amount of infrared light. LEDs **132**, on the other hand, do not output a significant amount of infrared light, and do not significantly affect the use of night-vision devices. However, additional shields may also be provided about receptacles **144, 148** in order to reduce the amount of infrared light emitted by LEDs **132** that reaches the cockpit.

In a preferred embodiment of the invention, the scalloped inner shield **140** extends along a portion of the periphery of the outer ring of light receptacles **144**, as well as along a portion of the periphery of the middle ring of light receptacles **146**. Preferably, the inner shield **140** surrounds the portion of the receptacle **146** from which light is emitted that would otherwise impinge upon the cockpit. The opposite side of the receptacle **46** is left unobstructed. Comparatively, the scalloped outer shield **142** extends along the periphery of the inside ring of light receptacles **148** and the middle ring of light receptacles **146**. As with the inner shield **140**, the outer shield **142** directs or blocks light emitted from LEDs **128** located in the middle ring of receptacles **146** that would otherwise impinge on the cockpit of the aircraft.

Accordingly, inner and outer shields **140, 142** each surround about one-half of each receptacle **146**. The inner shield **140** is shown located about the half of each receptacle **146** that is furthest from the center of the mounting plate **112**. Similarly, outer shield **142** is positioned about the half of each receptacle **146** that is nearest the center of the mounting plate. However, the shields **140, 142** may also be configured to circumscribe or encircle the one-half portion of each receptacle **146** that is closest to the cockpit of the aircraft, so as to more closely block light that has the greatest probability of otherwise reaching the cockpit.

Thus, the shields **140, 142** are effective to directionally obstruct stray light, without unnecessarily reducing the effectiveness of LEDs **128, 132**. In addition, the shields **140, 142** only partially cover the top surface of the mounting plate **112**, so that there is a significant reduction in the amount of material required, and the weight of the system **200** is minimized.

In the preferred embodiment, the shields **140, 142** are metal, though may comprise any suited material that blocks light, though is able to withstand extreme temperature variations and hostile weather conditions of the particular light system application. In addition, although the shields **140, 142** are preferably integral with mounting plate **112**, they may each also be a separate metal plate that is affixed to mounting plate **112** by a commercial adhesive.

In addition, the entire top inside edge **150** of the inner shield **140** may be sloped at about a forty-five degree angle to form a beveled face **159**. The beveled face **159** prevents the shield **140** from coming into contact with the protective lens **110**. In addition, the beveled face **159** may reduce any obstruction of light that is emitted from LEDs **132**, which are located in receptacles **144, 148**. Though shields **140, 142** are shown for use about each of a plurality of receptacles, the shields may be used with any number, size and shape of light-emitting devices. In the preferred embodiment, the shields **140, 142** extend approximately one-eighth of an inch from the top surface of the mounting plate **112**.

FIG. **13** shows an alternative arrangement for the power conditioning and retaining ring **120** comprising a mounting

plate **160**. The underside of the mounting plate **160** is fitted with resistors **124** and input terminals **122**. The outer border **162** of mounting plate **160** is irregular in order to conform with the shape of the resistors **124** and input terminals **122**. The mounting plate **160** significantly reduces weight of the power conditioning and retaining ring **120**.

In addition, the protective lens **10** may be coated with a material that can be penetrated by infrared light. Preferably, a dichroic coating is used that allows infrared light emitted by LEDs **128, 132** to pass unobstructed. However, the coating is not applied in the center of the protective lens **110**, so that visible light emitted by the halogen lamp **118** may also pass through lens **110**. In addition, the dichroic coating (not shown) tints the protective lens **110** so that the internal features of the system **200** are difficult to distinguish without dismantling the system **200**. Thus, the features and capabilities of the system **200** will not be readily apparent by a visible inspection of the system **200**. Any material may be used that permits light to pass unobstructed, yet prevents persons from being able to view the internal components of the system **200**, and is able to be coated on the inside surface of a protective lens **110**.

The foregoing descriptions and drawings should be considered as illustrative only of the principles of the invention. The invention may be configured in a variety of shapes and sizes and is not limited by the dimensions of the preferred embodiment. Numerous applications of the present invention will readily occur to those skilled in the art. For example, the shields **140, 142** need not be a single continuous element. Rather, the shields **140, 142** may comprise a plurality of independent segments that each individually circumscribe a portion of a single receptacle **146**. In addition, the shields **140, 142** may encircle more or less than one-half of receptacle **146**, as desirable for the particular application. Therefore, it is not desired to limit the invention to the specific examples disclosed or the exact construction and operation shown and described. Rather, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.

We claim:

1. A mounting plate for using with an illumination system having at least one illumination source for use as a landing light on an aircraft having a cockpit, the mounting plate comprising;

at least one receptacle in said mounting plate for receiving the at least one illumination source; and,

at least one shield protruding outward from a surface of said mounting plate and surrounding at least a portion of said receptacle, wherein said shield obstructs light emitted by said illumination source that would otherwise impinge upon the cockpit of the aircraft.

2. The mounting plate of claim 1, wherein said shield is arranged to obstruct a portion of light emitted by the illumination source contained in said receptacle.

3. The mounting plate of claim 1, further comprising a plurality of receptacles and a plurality of illumination sources, each of the plurality of receptacles receiving one of said plurality of illumination sources, wherein said shield surrounds at least a portion of the plurality of said receptacles.

4. A mounting plate for use with an illumination system having a plurality of illumination sources, the mounting plate comprising:

a plurality of receptacles in said mounting plate, each of said receptacles receiving one of the plurality of illumination sources;

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at least one shield protruding outward from a surface of said mounting plate and surrounding at least a portion of said receptacle; and,

a plurality of lenses, each of said plurality of lenses received in one of said plurality of receptacles so as to be aligned with one of said plurality of illumination sources.

5. A mounting plate for use with an integrated illumination unit comprising a central opening in the mounting plate, said central opening retaining a first illumination source, said mounting plate having a top surface and a plurality of receptacles in said top surface located about said central opening, each receptacle receiving one of a plurality of second illumination sources, and at least one shield protruding outward from the top surface of said mounting plate, said shield surrounding at least a portion of said plurality of receptacles.

6. A mounting plate of claim 5, wherein said shield is arranged to obstruct a portion of light emitted by the second illumination source contained in said receptacle.

7. The mounting plate of claim 5, wherein said plurality of receptacles are symmetrically arranged, a first shield surrounding at least a portion of a first set of receptacles, and a second shield surrounding at least a portion of a second set of receptacles different than said first set of receptacles.

8. The mounting plate of claim 7, wherein said receptacles each has an inner periphery and an outer periphery with respect to a center of the symmetrically arranged receptacles, and said first shield surrounds said outer periphery of said first set of receptacles and said second shield surrounds said inner periphery of said second set of receptacles.

9. The mounting plate of claim 7, wherein the integrated illumination unit is for use as a landing light on a wing of an

10

aircraft, said first shield is located toward a body of the aircraft, and said second shield is located toward a tip of the wing.

10. The mounting plate of claim 5, wherein the integrated illumination unit is for use as a landing light on an aircraft, and said shield obstructs light emitted by said second illumination source that would otherwise impinge upon a cockpit of the aircraft.

11. The mounting plate of claim 5, further comprising at least one lens, each lens fitting in one of said receptacles so as to be aligned with one of said second illumination sources.

12. The mounting plate of claim 5, wherein the first illumination source is a different type than the second illumination sources.

13. A mounting plate for use with an integrated illumination unit having at least one illumination source, the mounting plate comprising a top surface, a plurality of receptacles in said top surface, each receptacle having an inner periphery and an outer periphery, with respect to a center of a circle of said receptacles, and receiving one of a plurality of second illumination sources, first and second shields protruding outward from the top surface of said mounting plate, said first shield surrounding the outer periphery of a first set of receptacles and said second shield surrounding an inner periphery of a second set of receptacles different than said first set of receptacles.

14. The mounting plate of claim 13, wherein the illumination system is for use as a landing light on a wing of an aircraft, said first shield is located toward a body of the aircraft, and said second shield is located toward a tip of the wing.

* * * * *

EXHIBIT L



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surround verb

[Save Word](#)

sur·round | \ sə-ˈraʊnd \

surrounded; surrounding; surrounds

Definition of *surround* (Entry 1 of 2)

transitive verb

- 1 **a** **(1)** : to enclose on all sides : [ENVELOP](#)
*// the crowd **surrounded** her*
(2) : to enclose so as to cut off communication or retreat : [INVEST entry 2](#)
- b** : to form or be a member of the entourage of
*// flatterers who **surround** the king*
- c** : to constitute part of the environment of
*// **surrounded** by poverty*
- d** : to extend around the margin or edge of : [ENCIRCLE](#)
*// a wall **surrounds** the old city*
- 2 : to cause to be [surrounded](#) by something
*// **surrounded** himself with friends*

surround noun

Definition of *surround* (Entry 2 of 2)

: something (such as a border or ambient environment) that [surrounds](#)
*// from urban centre to rural **surround***
 Emrys Jones

Synonyms **More Example Sentences** **Phrase**

EXHIBIT M

IEEE Standard Definitions for AC (52 kV and below) and DC (3.2 kV and below) Switchgear Assemblies

IEEE Power and Energy Society

Sponsored by the
Switchgear Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std C37.20.10™-2016

IEEE Standard Definitions for AC (52 kV and below) and DC (3.2 kV and below) Switchgear Assemblies

Sponsor

**Switchgear Committee
of the
IEEE Power and Energy Society**

Approved 22 September 2016

IEEE-SA Standards Board

Abstract: Terms and definitions encompassing the products within the scope of ac (38 kV and below for air insulated equipment, 52 kV and below for gas insulated equipment) and dc (3.2 kV and below) power switchgear assemblies, including components for switching, interrupting, metering, protection, and regulating purposes as used primarily in connection with generation, transmission, distribution, and conversion of electric power are included in this standard.

Keywords: definitions, IEEE C37.20.10™, metal-enclosed bus, power circuit breakers, switchgear, terms

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Introduction

This introduction is not part of IEEE Std C37.20.10™-2016, IEEE Standard Definitions for AC (52 kV and below) and DC (3.2 kV and below) Switchgear Assemblies.
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This standard constitutes a compilation of terms and definitions relating to power switchgear assemblies and should be considered to reflect common and current usage of that industry.

The size of this standard has been kept to a minimum by omitting all terms satisfactorily covered in readily available dictionaries. In many instances, terms and definitions of related products exhibiting minor variations have been combined for greater clarity.

Specifications and ratings have been excluded from definitions. This information is included in standards covering the specific products.

This standard contains, in addition to many additions and modifications, the relevant terms from IEEE Std C37.100™, which is scheduled to be withdrawn when its validity expires in 2018. IEEE Std C37.100-1992 covered the term “electric eels.” After much consideration, the working group felt this term should be at least mentioned (for historical purposes) within the Introduction of this standard.

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IEEE Standard Definitions for AC (52 kV and below) and DC (3.2 kV and below) Switchgear Assemblies

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1. Overview

1.1 Scope

The terms and definitions in this standard are intended to encompass the products within the scope of ac (38 kV and below for air-insulated equipment, 52 kV and below for gas-insulated equipment) and dc (3.2 kV and below) power switchgear assemblies for switching, interrupting, metering, protection, and regulating purposes as used primarily in connection with generation, transmission, distribution, and conversion of electric power.

1.2 Purpose

The definitions of terms and explanatory notes relating thereto contained in this standard are not intended to encompass all possible meanings of the terms. They are intended for the sole purpose of establishing only those meanings of terms used in standards for switchgear assemblies. They do not purport to encompass other meanings that the terms may properly have when used in connection with other subjects.

In some instances, terms and definitions that are not identical to those in this standard have been developed by other branches of industry. Where this situation exists, the definitions in this standard shall be used for power switchgear assemblies covered by the C37 series of standards.

2. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.¹

a auxiliary switch: *See:* **auxiliary switch** and **a contact**.

a contact: A contact that is open when the main device is in the standard reference position and that is closed when the device is in the opposite position. *See also:* **standard reference position (of a contact)**.

NOTE—For indication of the specific point of travel at which the contact changes position, an additional letter or percentage figure may be added to *a*.²

aa auxiliary switch: *See:* **auxiliary switch** and **aa contact**.

aa contact: A contact that is open when the operating mechanism of the main device is in the standard reference position and that is closed when the operating mechanism is in the opposite position. *See also:* **standard reference position**.

ac component (of a total current): *See:* **symmetrical component (ac component) (of a total current)**.

acceptance tests: *See:* **conformance tests**.

air circuit breaker: *See:* **circuit breaker**.

air magnetic circuit breaker: *See:* **magnetic (as applied to circuit breaker)** and **circuit breaker**.

air-blast circuit breaker: *See:* **circuit breaker**.

alarm switch: An auxiliary switch that actuates a signaling device upon the automatic operation of the switching device with which it is associated.

ambient air temperature: The temperature of the surrounding air that comes in contact with equipment. Note that ambient air temperature, as applied to enclosed switchgear assemblies, is the average temperature of the surrounding air that comes in contact with the enclosure.

ambient temperature: The temperature of the surrounding medium that comes in contact with the equipment.

anti-pump device: A device that prevents reclosing after an opening operation as long as the device initiating the original closing operation is maintained in the position for closing.

arc chute: A structure affording a confined space or passageway, usually lined with arc resisting material, into or through which an arc is directed for extinction after the main contacts have parted.

arcing contacts: The contacts of a switching device on which the arc is drawn after the main (and intermediate, where used) contacts have parted.

NOTE—For some interrupting technologies (e.g., vacuum), the arcing contacts may also be the main contacts.

arcing horn: One of a pair of diverging electrodes on which an arc is extended to the point of extinction after the main contacts of the switching device have parted.

¹*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>.

²Notes in text, tables, and figures of a standard are given for information only, and do not contain requirements needed to implement the standard.

arcing time (of a mechanical switching device): The interval of time between the instant of the first initiation of the arc and the instant of final arc extinction in all poles.

NOTE—For switching devices that embody switching resistors, a distinction should be made between the arcing time up to the instant of the extinction of the main arc, and the arcing time up to the instant of the breaking of the resistance current.

asymmetrical current: *See:* **total (asymmetrical) current.**

attachments: Removable auxiliaries to be temporarily connected to switchgear apparatus for short-term use, but not intended to be permanently installed.

automatic tripping: The opening of a switching device under predetermined conditions without the intervention of an attendant.

auxiliary (auxiliaries): Equipment such as voltage transformers, control power transformers, or other miscellaneous devices to be used with switchgear apparatus.

auxiliary switch: A switch mechanically operated by the main device for signaling, interlocking, or other purposes.

NOTE—Auxiliary switch contacts are classed as follows: *a*, *b*, *aa*, *bb*, etc., for the purpose of specifying definite contact positions with respect to the main device.

available (prospective) current (of a circuit with respect to a switching device situated therein): The current that would flow in that circuit if each pole of the switching device were to be replaced by a link of negligible impedance without any other change in the circuit or the supply.

available (prospective) short-circuit current (at a given point in a circuit): The maximum current that the power system can deliver through a given circuit point to any negligible impedance short circuit applied at the given point, or at any other point that causes the highest current to flow through the given point.

available (prospective) short-circuit test current (at the point of test): The maximum short-circuit current for any given setting of a test circuit that the test power source can deliver at the point of test, with the test circuit short circuited by a link of negligible impedance at the line terminals of the device to be tested.

average inside air temperature (of enclosed switchgear): The average temperature of the surrounding air that comes in contact with the parts of the apparatus within the enclosure.

***b* auxiliary switch:** *See:* **auxiliary switch** and ***b* contact.**

***b* contact:** A contact that is closed when the main device is in the standard reference position and that is open when the device is in the opposite position. *See also:* **standard reference position.**

NOTE—For indication of the specific point of travel at which the contact changes position, an additional letter or percentage figure may be added to *b*.

***bb* auxiliary switch:** *See:* **auxiliary switch** and ***bb* contact.**

***bb* contact:** A contact that is closed when the operating mechanism of the main device is in the standard reference position and that is open when the operating mechanism is in the opposite position. *See also:* **standard reference position.**

break distance (of a switching device): The minimum open-gap distance between the main-circuit contacts, or live parts connected there to, when the contacts are in the open position.

breaking operation (break operation): Opening operation while power is applied to the main circuit.

bus: A conductor, or group of conductors, that serves as a common connection for two or more circuits.

bus structure: An assembly of bus conductors with associated connection joints and supports.

calibration: The adjustment of a device to have the designed operating characteristics, and the subsequent marking of the positions of the adjusting means, or the making of adjustments necessary to bring operating characteristics into substantial agreement with standardized scales or marking.

cascading (of switching devices): The application of switching devices in which the devices nearest the source of power have interrupting ratings equal to, or in excess of, the available short-circuit current, while devices in succeeding steps further from the source, have successively lower interrupting ratings.

NOTE—Cascading of circuit breakers is no longer allowed by NFPA 70 [B3]³.

circuit breaker: A mechanical switching device capable of operating (making, carrying, and breaking electrical current) under normal and specified abnormal circuit conditions.

NOTE 1—A circuit breaker is usually intended to operate infrequently, although some types are suitable for frequent operation.

NOTE 2—The medium in which circuit interruption is performed may be designated by a suitable prefix, that is, air-blast circuit breaker, air circuit breaker, compressed-air circuit breaker, gas circuit breaker, oil circuit breaker, vacuum circuit breaker, oilless circuit breaker, etc.

NOTE 3—Circuit breakers are classified according to their application or characteristics and these classifications are designated by the following modifying words or clauses delineating the several fields of application, or pertinent characteristics:

- *High-voltage power:* Rated above 1000 V ac nominal.
- *Medium-voltage power:* Rated above 1000 V ac nominal, and less than or equal to 38 kV ac nominal for air insulated equipment, or 52 kV ac nominal for gas insulated equipment.
- *Low-voltage power:* Rated 1000 V ac nominal or below, or 3200 V dc nominal and below, but not including molded-case circuit breakers.
- Direct-current low-voltage power circuit breakers are subdivided according to their specified ability to limit fault-current magnitude by being called general purpose, high-speed, semi-high-speed, or rectifier.

clearance: *See:* **minimum clearance between poles (phases)** and **minimum clearance to ground**.

clearing time (of a mechanical switching device): The interval between the time the actuating quantity in the main circuit reaches the value causing actuation of the trip release and the instant of final arc extinction on all poles of the primary arcing contacts.

close and latch: The capability of a switching device to close (allow current flow) and immediately thereafter latch (remain closed) and conduct a specified current through the device under specified conditions.

close operation: The movement of the contacts from the open to the closed position.

NOTE—The letter C signifies this operation: Close.

³The numbers in brackets correspond to those of the bibliography in Annex A.

close-open operation: A close operation followed immediately by an open operation without purposely delayed action.

NOTE—The letters CO signify this operation: Close-Open.

close-time delay-open operation (of a switching device): A close operation followed by an open operation after a purposely delayed action.

NOTE—Typically this is shown as C- t -O, where t is the time delay.

closing and latching: *See:* close and latch

closing coil: A coil energized to initiate closing the switching device.

closing time (of a mechanical switching device): The interval of time between the initiation of the closing operation and the instant when metallic continuity is established in all poles.

compartment: Portion of a vertical section that encloses a specific component or function separated by barriers.

components: Items from which the switchgear assemblies are made.

NOTE—Some examples of components are power circuit breakers, instrument transformers, protective relays, and control switches.

conducting mechanical joint: The juncture of two or more conducting surfaces held together by mechanical means. Parts joined by fusion processes, such as welding, brazing, or soldering, are excluded from this definition.

conformance tests: Those tests made to demonstrate compliance with the applicable standards. The test specimen is normally subjected to all planned production tests prior to initiation of the conformance test program. The conformance tests may, or may not, be similar to certain design tests. Demonstration of margin (capabilities) beyond the standards is not required.

connected position: That position of the removable element in which both primary and secondary disconnecting devices are in full contact.

contact: A conducting part that co-acts with another conducting part to make or break a circuit for example.

contact position indicator: A device that is located at or near the operating mechanism to indicate whether the main contacts are in the closed or open position.

contact surface: That surface of a conductor through which current is transferred to the co-acting conductor.

control voltage: The voltage applied to the operating mechanism of a device to actuate it, usually measured at the control power terminals of the mechanism.

creepage distance: The shortest distance between two conducting parts of different electric potentials following a path along the surface of the insulating material between them.

current-carrying part: A conducting part intended to be connected in an electric circuit to a source of voltage.

NOTE—Non-current-carrying parts are those not intended to be so connected.

dc component (of a total current): That portion of the total current which constitutes the asymmetry.

dead-front mounting (of a switching device): A type of mounting in which a protective barrier is interposed between all live parts and the operator, and all exposed operating parts are insulated or grounded.

definite-time delay: A qualifying term indicating that there is purposely introduced a delay in action, which delay remains substantially constant regardless of the magnitude of the quantity that causes the action.

degree of asymmetry (of a current at any time): The ratio of the direct-current component to the peak value of the symmetrical component determined from the envelope of the current wave at that time.

NOTE—Usually expressed as a percent-dc component.

delayed release: A release with intentional delay introduced between the instant when the activating quantity reaches the release setting and the instant when the release operates.

delayed trip: A tripping means with intentional delay introduced between the instant when the activating quantity reaches the trip setting and the instant when the tripping means operates.

design tests: Tests made by the manufacturer to determine the adequacy of the design of a particular type, style, or model of equipment or its component parts to meet its assigned ratings and to operate satisfactorily under normal service conditions or under special conditions, if specified, and that may be used to demonstrate compliance with applicable standards of the industry. Design tests are made on representative apparatuses or prototypes to verify the validity of design analyses and calculation methods and to substantiate the ratings assigned to all other apparatuses of basically the same design. These tests are not intended to be made on every design variation or to be used as part of normal production. The applicable portion of these design tests also may be used to evaluate modifications of a previous design and to help ensure that performance has not been adversely affected. Test data from previous similar designs also may be used for current designs, where appropriate. Once made, the tests need not be repeated unless the design is changed so as to modify performance.

NOTE—Design tests are sometimes called type tests.

dew withstand voltage: The ability of the insulating system to withstand specified overvoltages for a specified time without flashover or puncture while completely covered with dew.

dielectric withstand voltage tests: Tests made to determine the ability of insulating materials and spacings to withstand specified overvoltages for a specified time without flashover or puncture.

disconnected position: That position in which the primary and secondary disconnecting devices of the removable element are separated by a safe distance from the stationary element contacts.

drawout-mounted device: One having disconnecting devices and in which the removable portion may be removed from the stationary portion without the necessity of unbolting connections or mounting supports. *Compare with:* **stationary-mounted device.**

dropout (of a trip device): The action of a trip device as it makes designated response to progressive decrease of input. Also used to identify the maximum value of an input quantity reached by progressive decreases that shall cause the trip device to no longer maintain pickup status.

dummy breaker: A removable element, intended for insertion into a compartment suitable for a circuit breaker (or other primary switching device), but different from such a device in that the dummy element does not have any switching capability. The dummy circuit breaker has solid conductors (normally bus bars) connected between line and load side primary disconnecting devices. When installed in a circuit breaker compartment of

a metal-clad or metal-enclosed switchgear section, the dummy circuit breaker connects the line and load side primary disconnecting devices of the circuit breaker compartment. Syn. dummy element.

duty cycle: A prescribed sequence of operations for a specific time with specified time intervals between operations.

electrical operation: Power operation by electric energy.

electromagnetic compatibility (emc): A measure of equipment tolerance to external electromagnetic fields.

electromagnetic interference (emi): A disturbance that affects an electrical circuit due to either electromagnetic induction or electromagnetic radiation emitted from an external source.

enclosure: A surrounding case or housing used to protect the contained equipment and to prevent personnel from accidentally contacting live parts.

external insulation: Insulation that is designed for exposure to the outside environment and weather.

fault: *See:* **short circuit.**

fault bus (fault ground bus): A bus connected to normally grounded parts of electric equipment, so isolated that all of the ground current passes to ground through fault-detecting means.

field tests: Tests made after the assembly has been installed at its place of utilization. These tests differ from conformance tests and production tests.

flame retardant: So constructed or treated such that flaming combustion is inhibited, prevented, or extinguished.

flush-mounted device: A device in which only a small portion of the body projects a small distance in front of the mounting surface, while the remaining portion penetrates the mounting surface.

frame size: The maximum continuous current rating of a device in amperes for all parts except any parts involving a direct-acting trip system.

functional component: A device that performs a necessary function for the proper operation and application of a unit of equipment.

general-purpose enclosure: An enclosure used for usual service applications where special types of enclosures are not required.

ground bus: A bus or bus structure to which individual components of the equipment are connected and, in turn, is connected to electrical ground (earth potential) at one or more points.

ground contact (of a switchgear assembly): A self-coupling separable contact provided to connect and disconnect the ground connection between the removable element and the ground bus of the housing and so constructed that it remains in contact at all times except when the primary disconnecting devices are separated by a safe distance.

ground overcurrent: The net (phasor sum) current flowing in the phase and neutral conductors or the total current flowing in the normal neutral-to-ground connection that exceeds a predetermined value.

ground protection: A scheme in which faults to ground within equipment are detected, triggering actions to limit the damage.

grounded parts: Parts that are intentionally connected to ground (earth) potential.

independent power operation: An operation by means of energy other than manual where the completion of the operation is independent of the continuity of the power supply.

independent-manual operation: A stored-energy operation where manual energy is stored and released, such that the speed and force of this operation are independent of the action of the attendant.

indicating control switch: A switch that indicates its last control operation.

indirect manual operation (of a switching device): Operation by hand through an operating handle mounted at a distance from, and connected to the switching device by, mechanical linkage.

indirect release (of a switching device): A release energized by the current in the main circuit through a current transformer, shunt, or other transducing device.

indirect trip: *See:* **indirect release (of a switching device)**

inorganic coating: A coating that is composed of chemical compounds that do not contain carbon as the principal element (except carbonates, cyanides, and cyanates); that is, matter other than plant or animal.

instantaneous: A qualifying term indicating that no delay is purposely introduced in the action of the device.

instantaneous phase or ground trip element: *See:* **instantaneous** and **direct-acting trip device**.

instrument switch: A switch used to connect or disconnect an instrument, or to transfer it from one circuit or phase to another. For example: ammeter switch and voltmeter switch.

insulation: A material having the property of an insulator used to separate parts of the same or different potential.

integral unit substation: A unit substation in which the incoming, transforming, and outgoing sections are manufactured as a single compact unit.

interlock: A device actuated by the operation of some other device with which it is directly associated, to govern succeeding operations of the same or associated devices.

NOTE—Interlocks are classified into three main divisions: mechanical interlocks, electrical interlocks, and key interlocks, based on the type of interconnection between the associated devices.

interlock system: A series of interlocks applied to associated equipment in such a manner as to prevent or allow operation of the equipment only in a prearranged sequence.

interrupting tests: Tests that are made to determine or verify the interrupting performance of a switching device.

interrupting time (of a mechanical switching device): *See:* **clearing time (of a mechanical switching device)**.

inverse-time delay: A qualifying term indicating that there is a purposely introduced delaying action, the delay decreasing as the operating quantity increases.

live parts: Those parts that are designed to operate at potential different from that of ground.

load: The true or apparent power consumed by power utilization equipment performing its normal function.

long-time-delay phase trip element: A direct-acting inverse-time trip device element whereby trip time decreases as current increases, frequently modeled on an I^2t curve (typically measured in seconds).

low-voltage (LV): A class of nominal system voltages for switchgear assemblies 1000 Vac or less and 3200 Vdc or less.

magnetic (as applied to a circuit breaker): A term indicating that interruption of the circuit takes place between contacts separable in an intense magnetic field.

main contacts: Contacts that carry the current of the primary circuit, not including the separate arcing contacts (if any), or primary disconnecting devices (of a withdrawable device).

main (primary) switchgear connections: Those that electrically connect devices together in the main circuit, connect them to the bus, or both.

maintenance interval: The period, defined in terms of real time, operating time, number of operating cycles, or a combination of these, during which satisfactory performance is expected without maintenance or adjustments.

maintenance operation device: A removable device for use with power-operated circuit breakers that is used for manual operation of a de-energized circuit breaker during maintenance only.

NOTE—This device is not to be used for closing the circuit breaker on an energized circuit.

make-break operation (make-break cycle): Close-open operation while power is applied to the main circuit.

making current (of a switching device): The value of the available current at the time the device closes.

making operation (make operation): Closing operation while power is applied to the main circuit.

manual lockout device: A device that holds the associated device inoperative unless a predetermined manual function is performed to release the locking feature.

manual operation: Operation by hand without the use of any other source of power.

manual trip device: A device that is connected to the tripping linkage and that can be operated manually to trip a switching device.

margin: The difference between the demonstrated capability of the equipment and that required in service for specific conditions.

mechanical switching device: A switching device designed to close and open one or more electric circuits by moving guided separate contacts with a mechanical assembly.

mechanically delayed over current release (trip): *See:* **mechanically delayed release (trip)** and **overcurrent release (trip)**.

mechanically delayed release: *See:* **mechanically delayed release (trip)**.

mechanically delayed release (trip): A release delayed by a mechanical device.

mechanically trip-free (as applied to a switching device): A term indicating that the mechanism can open even though only one of the following is true:

- a) in a manually operated switching device the operating lever is being moved toward the closed position
- b) in a power-operated switching device, such as solenoid- or spring-actuated types, the operating mechanism is being moved toward the closed position either by continued application of closing power or by means of a maintenance operation device.

mechanism (of a switching device): The complete assembly of mechanical parts that actuate the moving contacts of a switching device.

medium-voltage (MV): A class of nominal ac system voltages for switchgear assemblies greater than 1000 V and less than or equal to 38 kV for air insulated equipment or 52 kV for gas insulated equipment.

NOTE—This definition differs from the definition in other industry standards; for example, ANSI C84.1–2011 expands the scope of MV to system voltages greater than 1000 V and less than 100 kV.

mimic bus: A single-line diagram of the main connections of a system illustrated on the face of a switchgear or control panel or assembly.

minimum clearance between poles (phases): The shortest distance between any live parts of adjacent poles.

NOTE—Cautionary differentiation should be made between clearance and spacing or center-to-center distance. Spacing or center-to-center distance refers to the distance from the theoretical center of one pole to an adjacent pole. Clearance distance refers to the distance between the closest points or surfaces of adjacent poles.

minimum clearance to ground: The shortest distance between any live part and adjacent grounded parts.

mobile unit substation: A unit substation mounted and readily movable as a unit on a transportable device.

moisture resistant: Items unaffected by water or resisting the ingress of water under specified conditions.

molded-case circuit breaker: A circuit breaker that is assembled as an integral unit in a supporting and enclosing housing of molded insulating material.

NOTE 1—See NOTE 3 under circuit breaker.

NOTE 2—Molded-case circuit breakers are tested in accordance with UL 489 [B4].

nominal system voltage: A nominal voltage value assigned to designate a system of a given voltage class.

NOTE—See ANSI C84.1 [B1]

non-automatic circuit breaker: A switching device designed to open only in response to an act of an attendant.

NOTE—See NOTE 3 under circuit breaker.

non-automatic opening (non-automatic tripping): The opening of a switching device only in response to an act of an attendant.

non-automatic operation: Operation controlled by an attendant.

non-mechanical switching device: A switching device designed to close or open one or more electric circuits by means other than moving guided separate contacts with a mechanical assembly.

open operation: The movement of the contacts from the closed to the open position.

NOTE—The letter O signifies this operation: Open.

open switchgear assembly: An assembly that does not have enclosures as part of the structure.

opening time (of a mechanical switching device): The interval of time between the time when the actuating quantity of the release circuit reaches the operating value, and the instant when the primary arcing contacts have parted.

operating duty (of a switching device): A specified number and sequence of operations at stated intervals.

operating mechanism: The portion of the switching device that actuates all the main-circuit contacts of the switching device either directly or by the use of pole-unit mechanisms.

operation (of a switching device): Action of the parts of the device to perform its normal function.

outdoor: Designed for exposure to the outside environment and weather.

outdoor enclosure: An enclosure for outdoor application designed to protect against weather hazards such as rain, snow, or sleet.

overcurrent release (trip): A release that operates when the current in a particular circuit is equal to or exceeds the specified value.

overvoltage release (trip): A release that operates when the voltage in a particular circuit is equal to or exceeds the specified value.

panel: A unit of one or more sections of flat material suitable for mounting electric devices.

peak current: The instantaneous value of current at the time of its maximum value.

pickup (of a trip device): The current (or other measured quantity) level, at or above which the protective function begins to time or count toward a trip. The action of a trip device as it makes designated response to input exceeding a set threshold value.

pole (pole unit): That portion of the device associated exclusively with one electrically separated conducting path of the main circuit of the device.

power (used as an adjective): A general term, used, by reason of specific physical or electrical characteristics, to denote application or restriction or both, to generating stations, switching stations or substations. The term may also denote use or application for energy purposes as contrasted with use for control purposes.

power operation: Operation by other than hand power; that is, not manual operation.

primary (used as an adjective):

- a) First to operate; for example, primary arcing contacts, primary detector.
- b) First in preference; for example, primary protection.

- c) Referring to the main circuit as contrasted to auxiliary or control circuits; for example, primary disconnecting devices.
- d) Referring to the energy input side of transformers, or the conditions usually encountered at this location; for example, primary unit substation.

primary arcing contacts (of a switching device): The contacts on which the initial arc is drawn and is interrupted after the main contacts have parted.

primary disconnecting devices: Self-coupling separable contacts provided to connect and disconnect the main circuits between the removable element and the housing.

production tests: Tests made for quality control by the manufacturer on every device or representative samples or on required parts or materials to verify during production that the product meets the design specifications and applicable standards previously demonstrated during design tests.

NOTE 1—Certain quality assurance tests on identified critical parts of repetitive high-production devices may be tested on a planned statistical sampling basis.

NOTE 2—IEC sometimes refers to these as “routine tests.”

rate-of-rise trip device: A trip device that operates in response to a change in an operating quantity such as current or voltage, with respect to time.

rated: A qualifying term that, applied to an operating characteristic, indicates the designated limit or limits of the characteristic for application under specified conditions.

NOTE—The specific limit or limits applicable to a given device is specified in the standard for that device and included in the title of the rated characteristic, that is, rated maximum voltage, rated frequency range, etc.

rated maximum voltage: The highest rms voltage (for ac power systems) or average voltage (for dc power systems) for which the equipment is designed, and is the upper limit for operation.

rated nominal voltage class: The voltage to which operating and performance characteristics are referred.

rated short-circuit withstand current: The maximum rms current that a circuit can carry momentarily without electrical, thermal, or mechanical damage or permanent deformation. The current shall be the rms value, including the dc component, at the major peak of the maximum offset phase as determined from the envelope of the current wave during a given test time interval.

rating: The designated limit(s) of the operating characteristic(s) of a device.

reclosing time (of a circuit breaker): The time interval between energizing the trip circuit and the making of the primary arcing contacts on the reclosing stroke.

NOTE—See Figure 2 of IEEE Std C37.010™-1999 [B2].

removable element: A withdrawable device that normally carries the current-carrying and or circuit-switching components for the main circuit, as well as primary and secondary disconnecting devices.

renewal parts: Those parts that may be replaced during maintenance as a result of wear.

reverse-current trip: A trip that operates upon reversal of the direct current in the main circuit from a predetermined direction.

reverse-power tripping: *See:* **reverse-current trip.**

safe distance: A distance at which the equipment shall meet its withstand voltage ratings, both power frequency and impulse (if applicable), between line and load stationary terminals and phase-to-phase and phase-to-ground on both line and load stationary terminals with the switching device closed and in the test position.

secondary (used as an adjective): A descriptor that can denote the following:

- a) Operates after the primary device; for example, secondary arcing contacts.
- b) Second in preference.
- c) Referring to auxiliary or control circuits as contrasted with the main circuit; for example, secondary disconnecting devices, secondary and control wiring.
- d) Referring to the energy output side of transformers, or the conditions usually encountered at this location; for example, secondary unit substation.

secondary disconnecting devices: Separable contacts provided to connect and disconnect the auxiliary and control circuits between the removable element and the housing. These contacts may be either automatically or manually coupled/de-coupled during installation or removal of the removable element.

selective opening (tripping): The application of switching devices in series such that (of the devices carrying fault current) only the device nearest the fault should open and the devices closer to the source should remain closed and carry the remaining load.

semi-flush-mounted device: A device in which a significant portion of the body of the device projects a distance from the mounting surface while still penetrating the mounting surface.

series overcurrent tripping: A trip initiated by an electro-mechanical trip device by an overcurrent condition in the main circuit of the switching device.

series trip: A trip initiated by an electro-mechanical trip device by current in the main circuit of the switching device.

series undercurrent tripping: A trip initiated by an electro-mechanical trip device by a sag or loss of current in the main circuit of the switching device.

set (used as a verb): To define digitally or physically position the various adjusting devices so as to secure the desired operating characteristic.

NOTE—Typical adjustment devices are suitably marked taps, dials, levers, and scales, and rheostats and switches with numbered positions that refer to recorded operating characteristics.

setting (used as a noun): The desired characteristic, obtained as a result of having set a device, stated in terms of calibration markings or of actual performance bench marks such as pickup current and operating time at a giving value of input.

NOTE—When the setting is made by adjusting the device to operate as desired in terms of a measured input quantity, the procedure may be the same as in calibration. However, since it is for the purpose of finding one particular position of an adjusting device, which in the general case may have several marked positions that are not being calibrated, the term setting is to be preferred over the term calibration.

setting error: The departure of the actual performance from the desired performance resulting from errors in adjustment or from limitations in testing or measuring techniques.

setting limitation: The departure of the actual performance from the desired performance resulting from limitations of adjusting devices.

short circuit: An abnormal connection (including an arc) of relatively low impedance, whether made accidentally or intentionally, between two points of different potential.

NOTE—The term fault or short-circuit fault is used to describe a short circuit.

short-time current: The current carried by a device, an assembly, or a bus for a brief time duration.

short-time-delay phase or ground trip element: A direct-acting trip device element that functions with a definite- or inverse-time delayed action.

shunt trip device: A coil energized by a voltage source to initiate opening of the device.

NOTE—The voltage may be derived either from the main circuit or from an independent source.

shutter (of a switchgear assembly): A device that is automatically operated to completely cover the stationary portion of the primary disconnecting devices when the removable element is either in the disconnected position or has been removed.

NOTE—The shutters may be closed when the removable element is in the test position.

silver-surfaced or equivalent: Metallic materials having satisfactory long-term performance that operate within the temperature rise limits established for silver-surfaced electrical contact parts and conducting mechanical joints.

standard operating duty: *See: operating duty (of a switching device).*

standard reference position (of a contact): The non-operated or de-energized position of the associated main device to which the contact position is referred. Note that standard reference positions of typical devices are as shown in [Table 1](#):

Table 1—Standard reference positions

Device	Standard reference position
Circuit breaker	Main contacts open
Contactor	De-energized position
Disconnecting switch	Main contacts open
Operating mechanism	De-energized position
Relay	De-energized position
Valve	Closed position

station-type cubicle switchgear: Metal-enclosed power switchgear characterized by the following required features:

- The main switching and interrupting device is of the stationary mounted type, composed of a primary circuit compartment and a secondary or mechanism compartment; arranged with gang-operated isolating switches that are mechanically interlocked with the main switching and interrupting device.
- Each phase for the major parts of the primary circuit switching or interrupting devices, buses, and line-to ground voltage transformers are completely enclosed (or segregated) by grounded metal barriers that have no intentional openings between compartments. Specifically included are mechanically

interlocked doors in front of or a part of the primary circuit compartment of the circuit switching and interrupting device so that, when the group operated isolating switches are closed, no primary parts can be exposed by the attempted opening of the interlocked doors.

- c) All live parts are enclosed within grounded metal compartments.
- d) Primary bus conductors and connections may be bare.
- e) Mechanical interlocks are provided for proper operating sequence under normal operating conditions.
- f) Secondary control devices and their wiring are isolated by grounded metal barriers from all primary circuit elements with the exception of short lengths of wire, such as at instrument transformer terminals.
- g) The doors to the secondary or mechanism compartment of the primary switching or interrupting device are to provide access to the secondary or control equipment within the housing without danger of exposure to the primary circuit parts.

NOTE 1—Auxiliary vertical sections may be required for mounting devices or for use as bus transition.

NOTE 2—This definition is included for historical purposes. Station type cubicle switchgear was formerly included in IEEE Std C37.20.2™-1993, but was removed in the 1999 edition.

stationary-mounted device: One that cannot be removed except by the unbolting of connections and mounting supports. *Compare with:* **drawout-mounted device** and **withdrawable element**.

stored-energy indicator: An indicator which visibly shows that the stored-energy mechanism is in the charged or discharged condition.

surface-mounted device: A device in which the entire body of which projects in front of the mounting surface, with no portion penetrating the mounting surface.

switchgear: A general term covering switching and interrupting devices and their combination with associated control, metering, protective, and regulating devices; also assemblies of these devices with associated interconnections, accessories, enclosures, and supporting structures, used primarily in connection with the generation, transmission, distribution and conversion of electric power.

switchgear assembly: An assembled piece of equipment (indoor or outdoor) including, but not limited to, one or more of the following: switching, interrupting, control, metering, protective, and regulating devices; together with their supporting structures, enclosures, conductors, electric interconnections, and accessories.

switching structure: An open framework supporting the main switching device and associated equipment, such as instrument transformers, buses, fuses, and connections. It may be designed for indoor or outdoor use and may be assembled with or without switchboard panels carrying the control equipment.

symmetrical component (ac component) (of a total current): That portion of the total current that constitutes the symmetry.

terminal (terminal connector): A connector for attaching a conductor to electrical apparatus.

terminal block (terminal board): An insulating base equipped with terminals for connecting secondary and control wiring.

terminal chamber: A metal-enclosed compartment that includes all necessary mechanical and electrical items to complete the connections to other equipment.

test cabinet (for a switchgear assembly): An assembly of a cabinet containing permanent electric connections, with cable connections to a contact box arranged to make connection to the secondary contacts on an electrically operated removable element, permitting operation and testing of the removable element when removed from the housing. It includes the necessary control switch and closing relay, if required.

test enclosure: A single-unit enclosure used for test purposes for a specific frame-size circuit breaker, which conforms to the manufacturer's recommendation for minimum volume, minimum electrical clearances, effective areas and locations of ventilation openings, and configuration of connections to terminals.

test position: That position in which the primary disconnecting devices of the removable element are separated by a safe distance from those in the housing, and some or all of the secondary disconnecting devices are in full contact.

NOTE—A set of test jumpers or mechanical movement of secondary disconnecting devices may be used to complete all secondary connections for test in the test position. This may correspond with the disconnected position.

test switch (test block): A combination of connection studs, jacks, plugs, or switch parts arranged conveniently to connect the necessary devices for testing instruments, meters, relays, etc.

thermally delayed overcurrent trip: *See:* **thermally delayed release (trip)** and **over-current release (trip)**.

thermally delayed release (trip): A trip function delayed by a thermal device.

through current test: A term used to describe a short-circuit, short-time, or momentary test in which the current flowing through the test specimen is required to be maintained at or above specified levels for a specified duration.

tight (used as a suffix): So constructed that the specific material is excluded under specified conditions.

NOTE—For example: water tight.

tin-surfaced or equivalent: Metallic materials having satisfactory long-term performance that operate within the temperature rise limits established for tin-surfaced electrical contact parts and conductive mechanical joints.

total (asymmetrical) current: The combination of the symmetrical component and the dc component of the current.

track: A partially conducting path of localized deterioration on the surface of an insulating material.

tracking: The process that produces tracks as a result of the action of electric discharges on or close to the insulation surface.

tracking resistance: The quantitative expression of the voltage and the time required to develop a track under specified conditions.

trip or tripping (used as an adjective): This term is used as follows:

- a) Pertaining to a release that initiates an opening operation only.
- b) Pertaining to a complete opening operation.

trip coil (of a mechanical switching device): A coil that is part of the electromagnet that initiates the action of a release (trip).

trip setting: A calibrated point at which the trip device is set to operate.

trip-delay setting: A calibrated setting of the time interval between the time when the actuating value reaches the trip setting and the time when the trip coil operates.

trip-free: The capability of a switching device to have the moving contacts return to and remain in the open position when the opening operation is initiated after the initiation of the closing operation, even if the closing force and command are maintained.

NOTE 1—To break the current that may be established, it may be necessary for the contacts to momentarily reach the closed position.

NOTE 2—If the trip circuit is completed through an auxiliary switch, electrical actuation will not take place until such auxiliary switch is closed.

tripping delay (of a mechanical switching device): Intentional time-delay introduced into contact parting time in addition to opening time.

NOTE—In devices employing a shunt trip, the opening delay includes the operating time of protective and auxiliary relays external to the device. In devices employing direct or indirect trip system, opening delay consists of intentional delay introduced into the function of the protective device.

tripping mechanism (of a mechanical switching device): The portion of a mechanical switching device, that releases the holding means and initiates the opening of the switching device.

undervoltage protection (low-voltage protection): A form of protection that operates when voltage is less than a predetermined value.

undervoltage trip device: A trip system that operates when the voltage in a particular circuit is equal to less than a specified value.

vertical section: That portion of the switchgear assembly between two successive vertical delineations. It may contain one or more circuit breakers, auxiliary compartments, and associated primary conductors.

withdrawable element: A part of a switchgear compartment that can be moved to a position in which a safe distance or segregation between the primary circuit contacts is established while the part remains mechanically attached to the enclosure.

withdrawn position: A position in which the removable element has been moved out of the compartment. This may also be referred to as the removed position.

withstand voltage: The specified voltage that, under specified conditions, can be applied to insulation without causing flashover or puncture.

Annex A

(informative)

Bibliography

Bibliographical references are resources that provide additional or helpful material but do not need to be understood or used to implement this standard. Reference to these resources is made for informational use only.

[B1] ANSI C84.1, American Standard for Electric Power Systems and Equipment—Voltage Ratings (60 Hertz).⁴

[B2] IEEE Std C37.010TM-1999, Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.^{5,6}

[B3] NFPA 70®, National Electric Code®.^{7,8}

[B4] UL 489, Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures.⁹

⁴ANSI publications are available from the American National Standards Institute (<http://www.ansi.org/>).

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