# KURTIS KELLER

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## Research Engineer

### Medical Devices Opto-mechanical

Electro-opto-mechanical system design
Optical system design
3D Laser projection design
Projector design including stereo and IR
3D depth extraction optical design, imaging
Micro projector & HMD design

## Education:

1994 M.S. North Carolina State University, Integrated Manufacturing Systems Engineering,

1988 B.S. North Carolina State University, Mechanical Engineering.

Post grad & Business MBA *(27 of 33 credits – started company)*:

Optical Perception, UNC
Optical Mounting, U. Arizona.
Patent Law (2 classes), NCSU, UNC
Business Law, NCSU

## Professional:

2008 - Co-founder, Optical/Mechanical Eng. Director & COO, InnerOptic Technology Inc. Hillsborough, NC.

2003 - 2008 Co-founder, Optical/Mechanical Eng. Director & CEO, InnerOptic Technology Inc. Hillsborough, NC (split time with UNC).

2008 – Research Engineer, Applied Research Lab., Department of Computer Science, University of North Carolina Chapel Hill. (part-time/adjunct).

1993 - 2008 Research Engineer, Microelectronic Systems Laboratory, Department of Computer Science, University of North Carolina Chapel Hill.

2000 – 2001 3rdTech, Senior Mechanical Engineer, Chapel Hill, NC (part time).

1988 – 1993 Matrix, Inc. Mechanical Engineer. Raleigh, NC.

## Expert witness:

Provided expert witness testimony, declarations and depositions for multiple patents for both prosecution and defense for eight cases involving medical equipment and optical / electro-optical apparatuses and 20+ patents. Depositions were on location or video-taped with court recorder and attorneys; items included invalidity, infringement, claim construction, etc.

Expert witness for projectors and projection systems: Optical and optical electronic packaging and mounting US patents: 6,203,158; 5,297,005; 6,402,324; 6,527,392; 6,558,004; 6,644,817; 6,739,831; and 6,742,899. Seiko Epson Corporation, vs. Coretronic Corporation; Civil Action No. 3:06-cv-06946-MHP, Northern District of California, San Francisco Division; cases settled.

Expert witness for SAIC vs Microsoft. Augmented Reality Head Mounted display tracking technology, multiple patents. Case settled 2020.

Expert witness for MechSource for virtual reality Head Mounted Display (HMD) devices. Investigation, examinations, Infringement, invalidity contentions. Northern District of California. Case settled 2019.

Expert witness for Polycom vs. Fullview. Multi-camera single node camera system for virtual office conferencing. Infringement and invalidity contentions. US patents 5,760,826, 6,128,143, and 6,700,711. Case is ongoing 2022.

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Expert witness for endoscopic medical computer interface / display for Karl Storz - Endoscope. Ongoing, includes declarations and depositions and scheduled in-court appearance, US patent numbers 8,069,420 and 7844,657. Northern District of California, San Francisco Division; Jury. Settled 2019.

Expert witness for Axon Enterprises for body mounted cameras, mostly police use. Investigation, Infringement, invalidity contentions. Northern District of California. Case is appears settled.

Expert Witness for GoPro. Thermal and packaging patent issues. Investigation, infringement. Case is settled.

Expert Witness for Samsung, micro camera design, micro lens mounting, multiple patents. Invalidity, Case is settled.

## Major Projects, abbreviated:

Miniature laser projector design and build. For 3D depth extraction and imaging through an endoscope for surgery. Multiple versions of systems including deployed system and miniature handheld system; laser-based. UNC and licensed to InnerOptic Technology.

Laser projector design. Design and Implement micro laser projector for rear projection of 3D anatomical mannequins for Office of the future research and eventually incorporated into medical simulations and theatrical use. UNC, U of Florida.

3D Laser range depth finder and imager. Mechanical design of scanning 3D laser scanner for room-sized scans. Commercial product used in crime scene reconstruction. As seen on TV show *CSI*. UNC and Delta Sphere, Inc.

Laser projector design for HMDs. Early attempts at implementing laser projectors on Head Mounted Displays. Microvision and UNC.

3D laser scanner. Single laser with four planar outputs for very fast scanning of feet for custom orthotics. Multipass system for verification. NCSU, DARPA and NASA.

Dental Implant 3D guidance. Design and build 6DOF magnetic tracker system and mounts with graphic feedback for registration of dental implants across jaw. InnerOptic Technology.

Structured Light projectors, custom projectors for integrating IR projection with standard video for depth extraction. Imperceptible structured light. UNC.

3D depth extraction and imaging endoscope design and build: Real-time 3D depth extraction through an endoscope for medical use. Uses custom structured light projector and camera head to view subject in not only stereo but off-axis in True 3D, not just stereo; imaging-based. 2 patents. UNC and InnerOptic Technology.

Infrared Projectors. Designed and build multiple wideband infrared and laser-based narrowband projectors for imperceptible depth extraction for teleconference and medical use. Includes design of optics, beam splitters, mounts and thermal designs. UNC.

Stereo Projectors. Built and modified projectors with new optics for both passive polarization stereo (Sharp) or active stereo (TI micromirrors). Includes design of custom light wheels, collimators, exit optics, cooling and illuminators. UNC.

Four color IR projector. Uses four color wheel, custom filter design, custom lens, DMD microdisplay and custom source for combined IR and visible projector to allow imperceptible structured light inclusion . UNC and TI.

Frequency doubling, optical. Experiment with using laser to provide multiple wavelength from single laser source; in this case 532nm by using second harmonics. UNC.

Projector evaluations for depth extraction. Evaluate fleet of various projectors to determine true light intensity and chromatic accuracy across image planes for measurement, real-time integration in 3D depth . UNC.

Pinlight Display. Projector LCD for use as see-through HMD display. Used electronics and display of large cinema projector for source of HMD ultra-wide field of view display and control. UNC and continued at Microsoft.

High-speed optical cancer detection device. Design for a high-speed optical cancer detection apparatus for cancers. Optical design in the visible and IR using an array of optical filters with multiple, parallel digital cameras and computer. For cervical, prostate and throat cancers. InnerOptic Technology, Inc.

Endoscope camera head for stereo and mono endoscopes: Allows a single camera head to attach to both standard mono- endoscopes and miniature stereo endoscopes providing HD quality imagery. InnerOptic Technology, Inc.

IR camera design. Single element narrowband IR camera for tracking. Uses phosphor filter for visible image detection. Combined into a 6 camera, cross axis WFOV system. UNC.

Stereo Endoscope Design: Designed patent-pending micro, 5mm diameter dual path endoscope with wide IPD separation, single HD imager, and compact and economical camera interface for surgery use. InnerOptic Technology, Inc.

Light amplifier. Using phosphor-based imager, custom camera lens, and image intensifier tube (night vision core), used for tracked scope design for weapon system. UNC & DARPA.

Design of large aperture endoscope: Custom endoscope for very low light environments. InnerOptic.

Work with suppliers for assembling custom endoscope designs, both stereo and mono scopes. 5mm through 12mm designs. USA, Europe and South American suppliers and customers.

Design Kinect depth extraction multiple unit environment. Performed laboratory-based reverse engineering of Microsoft's Kinect device by analyzing individual operational wavelengths (to 0.1nm) to allow multiple devices to run overlapping each other. With graduate students. Also built custom mounts and other optical devices for Kinects to expand number to be used. UNC.

HiBall Ceiling Tracker. PC design, layout and mechanical design of world's largest & accurate virtual / augmented reality tracker. Six, IR shared path sensors for 5 arc minute rotation accuracy, 1400 updates/sec. Co - designed multi-sensor optical tracker. UNC and 3rdTech Inc.

Very Large Telescope Optical mounts. Designed & built mechanisms for SOAR telescope, 162" aperture. Co-designed ADC optical system of 12" and 4" optics, in Chile. UNC.

Very Large Telescope spectrum analyzer. Co-designed IFU multi pickup spectrum analyzer. Uses 240 optical fibers and 4 miniature X-Y motion platforms for SOAR telescope. Chile. UNC.

Design of magnetic and optical trackers for micro surgical tools: Designed mounts and processes for micro magnetic and optical trackers for needle sized tracking devices for human surgery. Used on human subjects, FDA approved.

InVision Computer assisted surgical system: Lead Engineer for commercial system that combined tracked ablation needles and ultrasound in a full 3D stereo, real-time display to assist surgeons. From conception to fully FDA approved computer system. InnerOptic Technology Inc.

Head Mounted Displays. Designer and co-designer of 12 HMDs including optical and video see-through and 6 display per eye very WFOV Kaiser HMD. Several medical HMD designs. Co-designed projectors for research use. UNC.

Magnetic force microscope. Lead mechanical and optical design for real-time magnetic force microscope. Includes design of microscope stages, top and lower optics including dichroic mirrors and custom optics, magnetic coils and circuit boards, optical interfaces, thermal regulation and other. From lab designs to optimized, manufacturable design. UNC.

Multiview. Designed multi-camera 180º FOV shared nodal point camera system. System has six cameras with shared, apparent virtual location by use of use of mirrors and overlapping apertures. Used for effective virtual, wide angle presence and telecollaboration. UNC.

Miniature video see-through HMD. Co-designed, built, patented and sold miniature video see-through HMD. Used from medical procedures, especially surgery. UNC and licensed to InnerOptic Technology, Inc.

## Patents *(~6 others pending):*

9,792,715, "Methods, systems, and computer readable media for utilizing synthetic animatronics"

9,675,319, "Loupe Display"

9,659,345, "System and method of providing real-time dynamic imagery of a medical procedure site using multiple modalities"

9,282,947, "Imager focusing based on intraoperative data"

8,690,776, "Systems, methods, apparatuses, and computer-readable media for image guided surgery"

8,585,598, "Systems, methods, apparatuses, and computer-readable media for image guided surgery"

8,482,606, "System and method of providing real-time dynamic imagery of a medical procedure site using multiple modalities"

8,350,902, "System and method of providing real-time dynamic imagery of a medical procedure site using multiple modalities"

8,152,305, "Methods, systems, and computer program products for full spectrum projection"

7,728,868, "System and method of providing real-time dynamic imagery of a medical procedure site using multiple modalities"

7,385,708, "Methods and systems for laser based real-time structured light depth extraction"

6,503,195, "Methods and systems for real-time structured Light"

## Publications, selected:

"Single-imager, Stereo Endoscope"; Kurtis Keller & Andrei State. SPIE Medical Imaging 2011,

"Deployable Integral Field Units, Multislits, and Image Slicer for the Goodman Imaging Spectrograph on the SOAR Telescope"; Cecil, Gerald N.; Moffett, A. J.; Cui, Y.; Eckert, K. D.; McBride, J.; Kannappan, S.; Keller, K.; Barlow, B. N.; Dunlap, B.; Bland-Hawthorn, J.. American Astronomical Society; Bulletin of the American Astronomical Society, Vol. 42, p.403, 2010.

"Head Mounted Displays for Medical Use"; Kurtis Keller, Andrei State, and Henry Fuchs; Invited Paper; Journal of Display Technology, IEEE and OSA, Vol. 4 Number 4, 2008

"Thin-foil magnetic force system for high-numerical-aperture microscopy "; Fisher, J. K., L. Vicci, J. Cribb, K. Keller, B. G. Wilde, T. O'Brien, K. Desai, , R. M. Taylor II, R. Superfine; Review of Scientific Instruments; 2006.

"Simulation-Based Design and Rapid Prototyping of a Parallax-Free, Orthoscopic Video See-Through Head-Mounted Display"; Andrei State, Kurtis P. Keller and Henry Fuchs; *Proc. International Symposium on Mixed and Augmented Reality* (ISMAR) 2005 (Vienna, Austria, Oct 5-8, 2005

“Towards Tumor Detection through Optical Tomography in a 3D Depth Extraction Endoscope”; Kurtis Keller, Adam Wax, Caroline Green, Andrei State, and Henry Fuchs; MMVR, 2005.

“3D Force Microscope: a nanometric optical tracking and magnetic manipulation system for the biomedical sciences”; Fisher, J. K., L. Vicci, J. R. Cummings, K. Keller, B. G. Wilde, T. O’Brien, K. Desai, C. Weigle, G. Bishop, R. M. Taylor II, R. Superfine; Review of Scientific Instruments; October 2004.

"Monticello Through the Window"; 4th Symposium on Virtual Reality, Archaeology and Cultural Heritage 2003, Nathanial Williams, Chad Hantak, Kom-Lim Low, John Thomas, Kurtis Keller, Lars Nyland, David Luebke and Anselmo Lastra.

“Mixed Reality HMD Design”; VR2002, Andrei State & Kurtis Keller.

“Surface Reconstruction of Abdominal organs using Laparoscopic Structured Light for Augmented Reality Applications”; Jeremy Ackerman, Kurtis Keller, Henry Fuchs; Electronic Imaging 2002 – Photonics West.

“Switched Pattern Laser Projection for Real-time Depth Extraction and Visualization through Endoscopes”; Kurtis Keller, Jeremy Ackerman, and Henry Fuchs; 2002, International Symposium on Optical Science and Technology SPIE's 47th annual meeting.

“Augmented Reality Guidance for Needle Biopsies: A Randomized, Controlled Trial in Phantoms”; MICCAI 2001”,Rosenthal, M. R., State, A., Lee, J., Hirota, G., Ackerman, J., Keller, K., Pisano, E., Jiroutek, M., Muller, K., & Fuchs, H.

“High-Performance Wide-Area Optical Tracking: The HiBall Tracking System”; Welch, Greg, Gary Bishop, Leandra Vicci, Stephen Brumback, Kurtis Keller, and D'nardo Colucci; 2001 Presence: Teleoperators and Virtual Environments 10(1): 1-21.

“Real-time Structured Light Depth Extraction”; Kurtis Keller and Jeremy Ackerman; Photonics West – Electronic Imaging, 2000.

“The HiBall Tracker: High-Performance Wide-Area Tracking for Virtual and Augmented Environments”; Greg Welch, Leandra Vicci, Stephen Brumback, Kurtis Keller, and D’nardo Colucci; VRST99, 1999.

“Real-time Anatomical 3D depth Extraction”; Jeremy Ackerman and Kurtis Keller, MMVR, 2001.

“Augmented Reality Visualization for Laparoscopic Surgery"; Fuchs, Henry, Mark A. Livingston, Ramesh Raskar, D'nardo Colucci, Kurtis Keller, Andrei State, Jessica R. Crawford, Paul Rademacher, Samuel H. Drake, and Anthony A. Meyer; MICCAI ’98, 1998.

“Perception in HMDs, what really makes them all so terrible?”; Kurtis Keller and D’nardo Colucci; Lead conference paper; SPIE Aerosense ’98, 1998.

“Cast 3D Heatsink Design Advantages”; Kurtis Keller; IEEE ITherm ’98, 1998. Transactions on Components and Packaging Technologies, IEEE press, 2000.

"Augmented Reality Assistance for Needle Biopsies: From Early Prototypes to a Controlled User Study"; IMPSE, Andrei State, Michael Rosenthal, Joohi Lee, Gentaro Hirota, Jeremy Ackerman, Kurtis Keller, Etta D Pisano and Henry Fuchs.

“Efficiency and Cost Tradeoffs Between Aluminum and Zinc Die Cast Heatsinks”; Kurtis Keller; InterPack (International Electronic Packaging conf.), Invited talk, 1997.

“PXFL Cooling Issues and Solutions for a Graphics Supercomputer”, Kurtis Keller; Colloquium “PXPL at 40”, UNC Chapel Hill, 2022.

“Video See-through HMD for Surgery Assisted by Augmented Reality”; D. Colucci, G. Hirota, K. Keller, A. State, S. Drake, R. Fish; SPIE - EI’97, 1997.

“Low Cost, High Performance, High Volume Heatsinks”; Kurtis Keller, 1998 IEMT-Europe Symposium, Berlin, 1998.

“Commercial Packaging Solutions for a Research Oriented Graphics Supercomputer,” Kurtis Keller and John Poulton; InterPack 1995.

“Video See-through Design for Merging of Real and Virtual Environments”; Emily K. Edwards, Jannick P. Rolland and Kurtis Keller; VRAIS conference, 1993.

## Principal Investigator Activities:

P.I. on NSF grant 0422102 A & B. "Phase II & Phase IIB, Three-Dimensional (3D) Laparoscope"; $430,000 & $125,000.

P.I. on NSF grant 0319710. "Phase I, Three-Dimensional (3D) Laparoscope"; $98,000.

## Reviewer & Panel Activities:

WSCG 2001, 2002, 2003, 2005, 2007, 2008, 2009 International Conferences on Computer Graphics, Visualization and Computer Vision. 2009 planning and directors committee.

ISMAR 2008, 2009 reviewer, International Symposium on Mixed and Augmented Reality.

NIH grant reviewer, 2008 onward.

NSF grant reviewer, 2005 onward.