metrically curved surfaces such as on a sphere or hemisphere of round, parabolic or elliptical shape according to the desired candle power distribution pattern. The LEDs can be mounted perpendicularly to the geometric fixture surfaces or at any other angle. When mounted perpendicularly the surface, geometry is dictated by the light distribution pattern and the LED photometrics. This is the generally assumed design case in this disclosure. However, any geometry is possible with the non-perpendicular mounting of the light sources. A flexible PC board is manufactured in the flat and then "origami" style cutouts are made allowing the PCB to be bent and shaped into the preferred form. LEDs are insertable into holes made in plastic or metal forms to secure the LEDs in the correct location at the correct aiming.

For fluorescent lamp retrofit applications, the MSLS "luminaire" would be linear with LED's mounted all around the circumference or predominantly downwards for whichever lighting effect is desired. While a fluorescent's light distribution is usually not controlled in the longitudinal direction (the reflector can't get around the long dimension of the lamp) the LED version would be spatially directed so as to give uniform light. In comparison to a fluorescent lamp, where the light is produced equally in all directions irrespective of the final distribution pattern required in the room, the DLF has the advantage of producing light directed only where it's needed. The number of SLS aimed in a specific direction at the time of manufacture is such that the proportion and angle of the light going to the ceiling and floor are calculated to produce the desired result. Louvers and reflectors are unnecessary to prevent glare or redirect the light. Up to 40% to 60% of the light produced in a fluorescent fixture goes to waste due to these considerations.

In other embodiments of a linear fluorescent replacement SLS lamp "luminaire", the position regarding the nadir (floor) of the rows of SLS are adjustable. One or more SLS strips are free to move in an arc about a long axis such that they are aimed for uplight or down light. Apparatus is provided to fix the re-positioned SLS in place. Markers along the arc can delineate the angle. Thus, the installer can adjust the amount of up-light, down-light and floor coverage in the field, (markings on the fixture would indicate standard settings) just as an adjustable reflector changes luminaire light distribution. Here again, the difference is that there are no reflector-induced inefficiencies because of operation away from the ideal design point.

A pear-shaped globe "luminaire" studded with LED's projecting light outward from the surface would give both down-light and up-light with more projection surface towards the down-light side in a typical 1 to 3 recommended ratio. Most buildings, rooms or areas to be illuminated are of a rectangular shape. The LED's on the DLF are concentrated at the 90-degree intervals. This yields a more square lighting pattern to ensure equivalent lighting in all areas of the room including the corners. This is in contrast to the chronic lack of even coverage obtained from the circular light pattern of present day light bulbs or most luminaires. At best these prior-art lamps give a circular light distribution which requires overlapping to ensure complete coverage of the area with the overlap lighting levels in wasteful excess of the requirements. A position oriented MSLS lamp has a greater concentration of LED's aimed at 90° intervals so that more light energy is directed into the far-off corners of a room to give an even illumination throughout the rectangular or square shaped area. A DLF is made with square, rectangular and even rounded light distribution if the application requires.

Typically, an incandescent or HID lamp is used in conjunction with a reflector to redirect the light to obtain a desired light pattern where more of the light is directed where it is most useful. A luminaire for area lighting will have a "bat wing" candlepower light distribution pattern, which yields equal horizontal illumination on a surface as it compensates for the "inverse square law" (a function of the cosine of the angle and the distance squared from the source). Generally, such an optical assembly has efficiency less than 80% due to losses on the reflector's surfaces. The MSLS needs no reflector to redistribute the light since each discrete SLS "digit" is aimed such that the candle power intensity varies with angle as is needed to give the optimum illumination on the room work surfaces for a given mounting height. The MSLS lamp distribution is pre-designed according to typical house or office settings. Thus, there is no need for a reflector to redirect the light and its consequent inefficiencies in order to obtain a "bat wing" distribution. The present approach by LED manufacturers is to provide single high output LEDs with optics yielding a "batwing" distribution. These batwings are usually less than optimal and are circular. The "digital" approach of this invention would yield a finer control and thus a more accurate batwing, generating a more even distribution in a rectangular/square vs. circular pattern.

In a DLF it is possible to combine a task light having a very narrow "spot" beam at the correct aiming with a general area lighting "flood" beam into one fixture. The digital lighting fixture is positioned according to recommended lighting practice near a workstation and correctly oriented such that the DLF gives a wide (though still controlled, so as not to cause glare on a computer display) general illumination distribution as well as a narrow distribution aimed at the desktop for high intensity task lighting. In a preferred embodiment a positionable task lighting spotlight located on a section of the DLF can be aimed manually or by servomotor to project onto the work area.

In another example of prior art practice, a table lamp for reading is provided with a shade. The shade is there to partially redirect the light onto the book and also prevent direct, glaring, rays from the lamp used for general lighting from reaching the reader's eyes. According to the present invention, instead of having a glaring lamp producing light which is then made non-glaring by a shade at a loss in excess of 50% the LF is built such the amounts of light directed downward at useful angles and the amount of light directed upward are in the correct ratio. The surface area, from which discomfort-glare causing rays exit, is designed such that the luminous exitance is within recommended UGR levels for home use. The fixture has no need for a shade to protect from glare; the glare was never produced at those angles to begin with due to proper geometric design. To get the desired luminous exitance expressed in terms of lumen per sq. meter or luminance in terms of candela per sq. meter, the light exiting the source of specific intensity at angles which normally reach the room occupant's eyes, is spread over an area such that the exiting light is non-glaring. These lighting design parameters serve as the product specification and are incorporated into the initial design. There is no need to add on components to achieve correct lighting.

In MSLS technology an antique style table lamp uses a MSLS "bulb" specifically designed for the application, there is no need for an additional shade other than for aesthetics. The shade is a decorative element which diffuses a small amount of light for the rustic effect. The small amount of light which would be directed between 70° to 150° (the glare zone) would cause as little discomfort glare as that which is

obtained from a shaded incandescent lamp but without the waste. This is done by sizing the area and intensity of the light source responsible for providing light at those angles such that the luminous exitance from the surface is within acceptable non-glaring luminance values. If desired, uplight to the ceiling above the glare zone is provided with light sources projecting between 150° to 180°. To maintain the aesthetics that people are used to or for the good feeling, a shade may be placed over the "digital" table lamp. A few LEDs can be dedicated for the purpose of illuminating the shade, either by projecting thru the shade and diffusing the light or projecting the LEDs into the shade as in a light guide. Colored LEDs could make the shade look yellow, pink or blue as preferred and programmed by the user.

The dimming capability of the MSLS is quite dramatic. A typical LED of today such as an Agilent® HLMP25-ED-xxxx will produce light at a tenth of a milli-Ampere and may be operated up to 50 mA. At 0.1 mA it may produce 5 milli-lumen while at 50 mA over 1000 ml. This is a hundredfold range. Another radiation output control technique is to provide pulsed power in place of constant current. LEDS are operated on DC as well as pulse power and current as well as timing in terms of duty cycle, pulse width and other signal modulations are useable by the controller to effect intensity changes.

Correct lighting doesn't only include an even light distribution and a lack of glare but a list of other factors including intensity, warmth and color rendering. Experiments have shown (IES Lighting Handbook 8th edition p. 99) a graph of preferred color temperature of light sources at various illumination levels. The graph specifies a warmer color temperature say 2,500 Kelvin for lighting levels in the 100-lux range and a cooler temperature say 3,500 for 1,000 lux. However, a typical dimming system used in a fluorescent luminaire will lower the lighting level but will not change the color temperature. A DLF of the present invention will change the balance of the different spectrum light sources in order to achieve the correct color temperature for the new lighting level. As far as dimming goes, it possible to get an instantaneous "instant on" from the SLS light source. Thus, with a built in or exterior motion detector, the DLF can be operated at emergency lighting levels, sufficient for orientation, and then immediately power up to full level when someone enters the room. Whereas a fluorescent dimmed to 50% power will give a negative return of only 10% light an LED will generally give a linear if not positive decrease in power with light reduction. Auto-dimming circuits taking sunlight into account have been touted as an energy saving technique.

In another embodiment, the electronic luminaire has a light level detector and automatically adjusts the output to the required level. If the lighting level on only one side of the room is enhanced by the sunlight, directional luminance meters, external or integral to the DLF, detect the imbalance and the controller dims only those SLS oriented to illuminate in the sunlight illuminated direction. This detailed spatial distribution intensity control is not possible with other lamp types.

The MSLS lifetime is long such that there is essentially no need for "lamp" replacement over the life of the DLF luminaire. However, power supply circuit and light source characteristics may vary over time and correct lamp color will deviate from the standard. A feedback control loop using sensors would recalibrate color based on daylight readings over the twenty-year lifetime of the fixture. Thus, a photodiode with an RGB filter is calibrated under natural light conditions. Alternately, discrete wavelength or alternately stable "white", or color, LEDs which are used only for calibration or only operated in a regime where their color is known not to shift are used as the recalibration color standard. This basis serves the dimming system in its color temperature control over its lifetime. The controller is programmed over the lifetime to seek possible recalibration opportunities. These may include using daylight or other artificial light sources available when the LSLS is not producing light. The systems can determine the accuracy of this source partially by comparing it to its previous factory or onsite calibration. Time of day analysis and initial small deviations would allow the system to evaluate whether the source was a reliable standard to use over its lifetime to correct for component color shift.

To ensure higher reliability the MSLS in the preferred embodiment will make use of large-scale integrated circuit technology where the LED junctions, Zeners and other elements are interconnected on, a chip. The chips then mounted into plane surfaces which are flat, rounded or X-hedrons.

The MSLS lifetime is long such that there is essentially no need for "lamp" replacement over the life of the DLF. This requires that the designs of the other electronic components are similarly reliable. The fixture mechanical design is again a significant departure from prior art. The fixture is sealed for life. There are no openings, gaskets, and sockets and there is no need for a mechanism to open the luminaire. All the components can be encapsulated for life to prevent water and dust ingress and thus provide a reliable, maintenance free, weatherproof and hazardous location ready lighting fixture.

The small dimensions of the light sources makes them ideal for use in conjunction with fiber optic light transmission systems. One of the primary requirements of such systems is the ability to collect the generated light into the narrow fibers. The excellent controllability of the light beam and the small source size allows for the generation of high-power narrow non-dispersing beams as would be used in flashlight, searchlight and beacons.

Multiplexing of the lamps is possible for power and lighting effect considerations. Slower duty cycles will reduce energy consumption, increase lifetime and would be used in a number of applications. Aircraft warning beacons which flash is an application, as the on-off cycling of an LED is not harmful to lamp life as it is to an incandescent lamp. Disco lighting-effect lamps are another flashing application Dimming as well as illumination color can be carried out with both the duty cycle and current being altered.

In summary, as opposed to LED industry trends of going with a single large source, the present invention provides multiple smaller sized sources of differing characteristics such that their combined effect is greater than that which could have been offered by sum of the individual parts operating separately. The added controllability offered by breaking the total light output up into discrete specifically aimable and dimmable elements, "digits", which can be addressed by control electronics to effect intensity, spectrum and distribution, yields a lighting fixture (vs. lamp) of unparalleled performance.

In order to better understand the embodiments and methods of this invention reference is now made to the following figures.

FIG. **1** is a block diagram of the elements which in combination provide a digital lighting fixture (DLF). The DLF serves as a complete luminaire solution including: power conditioning circuitry, control electronics, sensors, mechanical fixture and light source. The DLF replaces the

lighting fixture, ballast, socket, lamp, dimmers, reflector, gaskets and fasteners with a sealed for life electronic assembly. An electric power source **1**, supplies power at line Voltage 110 to 480V or at low Voltage 12-24 Volt to the DLF **2**. The DLF includes more than one light source **3**, which is preferably an electroluminescent solid-state light source but may be any other light source, such as incandescent, high intensity discharge, fluorescent, etc. such that the individual characteristics of each lamp's light are combined in operation to achieve a sum of the characteristics presenting a benefit not achievable from a single source alone. The light sources are affixed or contained within a mechanical device **4**, which may serve as containment to all of the components and facilitates affixation to building surfaces. The electric power is received in the correct waveform, voltage and current from the power source **1**, or is conditioned within the DLF **2**, by power conditioning elements and circuitry **5**. The direction of light exiting from the DLF as a whole or from each SLS individually is controllable by optical elements **6**, such as reflective surfaces and or refractors, and may be electronically variable optical elements.

The separate light sources may be of the same color and intensity characteristic or may have different color and intensity characteristics. Thus, for a 3-stage light bulb equivalent, each of three sources can have the same lumen rating or two sources are used where one is twice the output of the other. In a finely variable, digital embodiment the effect of continuous dimming effect is achieved when the differences in the lighting level is imperceptible to the people in the room. Typically, a 5% change will not be perceived. Thus, with twenty equivalent intensity LEDs as a base (one additional would add less than 5%), additional quanta could be smoothly added, or on the other hand, to in reality perform perceptible dimming (which is the objective) a greater than 5% change should be effected. The same is true for the final spectral color of the light emanating from the DLF to illuminate objects. The eye adds the radiation reaching the eye and cannot perceive the separate components, contrary to the ear's recognition of sounds where each frequency is individually resolved. Therefore, quanta of specific spectral color energy may be added to the mix without perception. For example, changes up to 200 degrees Kelvin in HID lamps are not perceived. Thus, to effect a noticeable color change, a quanta of spectral color power would need to be added or detracted from the sum.

In a preferred embodiment the DLF contains logic control electronics unit **7**. Logic control electronics unit, **7**, receives input and/or feedback from motion, intensity and/or spectral sensors **8**, or from manual control button **9** and increases or decreases or turns on or shuts off the power to one or more of the SLS to effect the desired change. That is, the control logic unit **7** has stored parameters for intensity and spectral distribution and operates the MSLS lamp within the predefined range. The control unit may include a DSP or computer with storage media, computer algorithms, signal input and output electronics, analog to digital converters, and communications elements to carry out intensity, distribution, dimming and color balance control. Computer algorithms and instruction sets **7A** are induced by the logical controller to manipulate data, calculate results generate output signals and maintain the operating parameters within the specifications. Measured parameters are checked against the stored parameters and the control circuitry adjusts the power to SLS.

Sensors **8** include any of the following: light, temperature and motion detection devices. Two types of optical detection sensors may be used: A photo detector with specific spectral sensitivity to detect a specific color. For example, a standard red, blue and green set which would then indicate how "white" the light is. Alternately, a wide spectrum photo detector that irrespective of color measures the intensity of each excited die as it is test fired, based on the eye visual sensitivity curve. The optical sensor may be lensed and capable of forming an image, that is a camera and the detector may be a detector array of photodiode pixels. The detector array may be a CMOS or CCD VSLI array and may be monochromatic or color as in a monochromatic or digital camera. Such arrays are readily available in mega-pixel resolution.

With changes in ambient lighting the light sensors detecting conditions at a specific location receive input. The detector instantaneously reads the ambient during a momentary shut off the artificial light source. The momentary shutoff is of short duration, e.g., less than one millisecond duration, at rates undetectable to the users as the eye does not discern flicker rates above 1/100th of a second. The controller then readjusts the driving circuitry to the correct power level. The sampling of multiple sensors around the DLF can be simultaneous using buffers in the controller to facilitate analysis by methods known in the art. Alternately, the light sources and coordinated detectors at specific locations are turned off, sampled, turned on again and sampled, to verify that the illumination is within recommended specifications. Interaction between DLFs, located in close proximity to each other, is avoided, by the use of the short-duration momentary shutoff controller readjusting time interval. The probability of simultaneous controller readjustment of two adjacent DLFs is very small. Further, the timer which controls the time between the controller readjusting time intervals, is preferably analog, such that there is very low probability of two DLFs having the same time between controller readjusting intervals.

In a system with feedback, changes in the light source output reflected back to the lamp such as color shift and diminishing flux over time can be compensated for. A typical fluorescent or HID source will experience serious color shift over its 10,000 to 20,000 hour lifetime. It would be a significant advantage to have a 100,000 hour life lamp with color accuracy over the complete lifetime of the lamp.

In a preferred embodiment a re-calibration system will operate as follows. The DLF is provided with a reflective rod or strip the surface of which has a wide spectrum, non-angle of incidence dependency and stable reflection characteristics over time. The reflective rod or strip is positionable so that the rod or strip can reflect light back to the outward facing photodetector based on the DLF body. In another embodiment the DLF is provided with a calibration wand on which inward facing photodetectors are placed. The calibration wand is capable being positioned such that the detectors can detect SLS performance. Both the reflective rod/strip and calibration wand can be narrow such that they can be permanently deployed about the DLF and not block light. In another embodiment the rod, strip or wand is stored and is only deployed when calibration is required. When called upon, the rod, strip or wand is rotated around the DLF to read SLS intensities. Alternately, the DLF body rotates and the rod, strip or wand remains fixed. The DLF is originally calibrated in the factory using external detectors. The spectral output of each SLS is calibrated with the power supply controller over the range of power outputs and the characteristics are stored in a memory device for recall during operation. The calibration wand or reflective rod or strip is then used by the DLF in an internal calibration where the DLF detector's readings at the initial SLS power settings are

recorded. These readings become the standard for future calibrations, where the controller will affect the power to individual junctions such that proper intensity and color is produced.

The DLF has a clock unit and/or a communication unit capable of receiving signals from the US government operated "atomic clock" which is located in Colorado. The DLF automatically searches for the signal or once a day it automatically recalibrates its time. On a periodic basis after degradation is assumed to be significant, the controller **7** invokes the calibration routine.

In another preferred embodiment the DLF surroundings are used for calibration in place of the calibration strip. A short time following installation, (after the furniture and decor has settled down), an onsite calibration is scheduled and run at the first opportunity. The purpose of this on-site calibration is to have the controller check the spectral characteristics of the illuminated area. A specific die on an SLS is fired on a timed basis and the controller reads the photo detector value. The new site-specific reading is then taken and compared to the original calibration and stored. The site-specific reading will serve as the base for the next calibration, as it is assumed to render the surroundings correctly based on still calibrated light sources. The next calibration may be scheduled for night and holidays to ensure a date when dark conditions prevail. If darkness cannot be ensured, the incremental shift in intensity above the ambient can be measured. Photo diode detectors of known field of view are placed on the DLF such that SLS output is detected. In lights-out conditions of darkness, the controller takes a base reading sample of a detector. The base reading allows the subtraction of "noise" from further readings. During the calibration the base reading may be repeated to ensure accuracy. Periodically, possibly every half a year, more or less depending on manufacturer data of how much the LEDs drift from their initial performance, a calibration routine is run. If a change in decor has been made, then the drastic change will signal the logic controller to ignore the latest reading and use the present "white" setting to recalibrate the new decor. Although photodetectors are stable devices, over a 30 year DLF lifetime it may be necessary to calibrate the photodetectors as well. Absolute intensity readings can only be recalibrated against a laboratory standard. However, daylight may be used to recalibrate color sensitive photodetectors over the 20-year lifetime. At the post installation calibration session, a day reading of photodetectors is performed and the readings analyzed for daylight sources. This is done using the clock where daylight will show a predicable spectral shift over the hours of the day. The controller will then compare the readouts of detectors over the day to identify those exposed to daylight. First during the day readings of the photodetectors are taken.

The detectors facing the daylight are assumed calibrated to read "white light. In darkness SLS units, SLS **1** in view of one calibrated daylight facing detector, detector **1** and one uncalibrated detector, detector **2**, are powered to produce white light as determined by the calibrated detector. Now detector **2** is calibrated. Moving stepwise around the DLF the process is repeated with now calibrated detector **2** used to adjust SLS **2** located between detector **2** and not yet calibrated detector **3** to produce "white" light. SLS **2**'s output is then used to calibrate detector **3**. The process continues around the DLF till other daylight-calibrated detectors are reached. For greater accuracy the process can then be performed in the other direction, moving stepwise until detector **1** is reached again. By using this nodal analysis method discrepancies propagated in the calibration process are reduced.

A power guide **10** can serve as both a power distribution and mechanical affixation device to the placement of additional DLF units **11** within an expanse. Light output **12** from one DLF may differ in distribution from another **13**, if say one MSLS is in the center of a room and the other is at the edge or one light illuminates steps between the landings and another is the last step before the landing, the last step would be illuminated in a different color.

Since an LED device is operable over a wide range of currents, when an LED serves as the light source, dimming and color balance are smoothly and infinitesimally variable.

For the purpose of illustration, a preferred embodiment of the present invention is presented in FIG. **2**B juxtaposed with a prior art solution using LEDs shown in FIG. **2**A. A typical "bulb" shape with a screw in base is provided for retrofit locations where a socket is available. The prior art design depicts LEDs spread out on the surface of what looks like a reflector lamp. It is evident from the downward facing 5 mm hole-thru type LEDs—**14** that no attempt has been made to extract a "batwing" or any other effective type of light distribution pattern. Upward facing LEDs—**15** seem intended for uplighting and again it is clear from the symmetry that no attempt has been made to provide a rectangular pattern which will give a better use of light for indirect lighting.

FIG. **2**B illustrates the teachings of the present invention. In this case, although packaged to appear as a typical "A" shaped light bulb, the device is actually a DLF and provides a complete lighting solution. Although shaped like a lamp with a screw base to facilitate replacement when the "lamp" burns out, this is not necessarily the intent. Rather, in the present concept, after 100,000 hours (over 30 years in typical use) ifs time to refurbish the room and change the fixture. The outward design is thus generated by what people expect to purchase and not what a DLF, that is not a lamp should look like. A true DLF design would not include the ceiling mounted socket and would be provided with a wiring connector and accoutrements and fasteners for attachment directly to the ceiling.

A retrofit MSLS lamp or digital lighting fixture/luminaire **16** intended to replace the lamp, fixture, reflector or shade and control-gear combination of a typical lighting fixture, includes a screw base **17**, which receives line power **18** into the electronic power conditioning circuitry **19**. In a preferred embodiment, control circuitry **20** is provided in the lamp. The input to the control is from an external source or internal logic circuit or both and in a preferred embodiment a sensor pack **21** with one or more radiation and communication sensors capable of detecting motion, day/night, spectrum, luminance etc. is provided. In external control, a control signal **22** rides on the power signal **18** and enters via the screw base **17** or an infrared or other radiation detector provided in **21** picks up the control signal. Discrete packaged light sources, e.g. Solid-state Light Source SLS **23** containing one or more junctions are mounted on the DLF lighting fixture body **24** and connected to the controlled power circuitry that determines which of the SLS **23** will operate and at what power. Each SLS with it spectral and distribution characteristic is mounted in a specific location on the surface of the DLF with an angle α, **25** from the nadir. Any angle from the nadir is possible including 180 degrees and the light flux can serve to provide uplight or illuminate a picture on a wall.

In a position oriented lamp arrangement, that is where the socket has a distinct stop point, detent or pin and is mounted substantially oriented to the room or its contents such as a work desk or wall painting, and also the DLF has a specific mounting orientation relative to the socket, then the light distribution can be nonsymmetrical and tailored to the needs of the room. The screw base **17** has a detent or pin **26** that coincides with the stop point on the socket, which is mounted in a specific location radially around the lamp at an angle β, **27** in reference to pin **26** and a design start point on the circumference of body **24**. The SLS are placed at an angle f horizontally and vertically angled a to illuminate specific areas and also have their own spatial light distribution angle θ **1** **28**A. An SLS aimed to illuminate an interior area may have a wide distribution or a distribution without a sharp cutoff **28**A while those SLS located at the edge of the area to be illuminated may be of narrow distribution θ **2** **28**B and have a sharp cutoff. This technique is similar to how a sport playing field is illuminated with multiple floodlights. Floodlights of narrow beam spreads such as a NEMA 2 are used to illuminate at the edge of the illuminated area while wider NEMA 4 beam spreads are used near the center of the playing area. The MSLS lamp will have concentrations of SLS at specific aimings to provide a wide "flood" type distribution to one part of the room and a "spot" type distribution to another such as to a painting on the wall. Each illumination target is at a different light intensity and color temperature or color rendering.

In another embodiment SLS, which perform an equivalent to a task light function with a very narrow beam, are combined with SLS performing a general background lighting function in one fixture. While general lighting recommendations in an office call for the provision of 300 to 500 lux over the working plane, specific task lighting, for example where copy work is to be illuminated by auxiliary lighting, 1,000 lux is required. To this end a section **29**, containing SLS on the DLF, provides a narrow beam of higher intensity, to provide added light flux to the working surface. In an alternate embodiment section **29** on the DLF is on a swivel and can be manually adjusted to be aimed at the worktable. In an alternate embodiment the swivel is positioned by a servomotor and controlled by a remote-control unit. In an alternate embodiment to the fixed task light section **29**, in an attempt to cut down on separate fixture types with left or right handed spot or other asymmetric orientations, the MSLS portion of the DLF body **24** is rotatable in relation to the affixing base **17**. Such an embodiment also obviates the need for a position-oriented socket and base pin **26**.

In another embodiment, modulating the output of wide distribution and narrow distribution LEDs by the controller varies the net resultant beam spread characteristics. The fixture is placed near a workstation and gives a wide distribution general lighting as well as a narrow high intensity beam for increased illumination level task lighting on demand.

In order to assure an even distribution of light from a point source over an area, it is necessary to take the effects of the angle and distance to the illuminated surfaces into account as stated in the inverse square law. Often a "batwing" type of candlepower light distribution is used. In a prior art luminaires, the reflector, which concentrates reflected rays in the higher angles, accomplishes this. In a preferred embodiment of the MSLS there are more, or more powerful, SLS over a range **1** aimed at higher angles to increase light flux at those angles in order to maintain an even light distribution. If the lamp is specifically oriented in relation to the room concentrating more light into the distant corners effects a squared distribution pattern, which would fill in the corners of a square room with equivalent illumination. An added amount of SLS are added on the DLF body **24** at 90 degree angles on β, **27** where SLS aimings will push added light into areas corresponding to the "corners". To effect uplight towards the ceiling or for indirect lighting SLS **23**A are aimed towards the ceiling such that an optimal utilization of the light is achieved.

In the preferred embodiment color of light emanating from an SLS **23** is "white" light. This is accomplished by using a "white" light producing arrangement of LEDs that is comprised of two or more spectrally differentiated junctions, which then combine their light output such that the illuminating light appears white. Other white LED technologies use phosphor or other coatings over the junction which causes a shift to longer wavelengths. The separate junctions in an SLS or separate SLS may be independently controlled. In a multi-junction SLS the total color of the illumination may be shifted to "warm" or "cool" light in correct accordance with the illumination level (see FIG. **10**) or other considerations. In another preferred embodiment, a motion detector is used to conserve energy. The room lamp is dimmable to a lighting level sufficient for safe orientation. A motion sensor **21** picks up activity and increases the illumination level to meet the activity level. This integral placement significantly reduces the wiring from sensor to power supply and again back to lamp in prior-art dimmer—motion sensor applications.

In alternate embodiment each SLS **23** may have a non-white color. The operation of many SLS in unison of different or similar wavelength may be used to create any color desired from white to monochrome in any specific region to be illuminated. A spectrum sensor **21**, inputs data to controller **20**, which maintains color at predefined level. Such a feedback mode allows for the MSLS to maintain constant color over the full lifetime of the lamp even if specific wavelength SLS shift output characteristics such as light flux and spectrum with age within bounds of the sensors calibration over age. Constant color is maintained in a room with an influx of a less desirable color temperature light on one side. Spectrum sensor **21** with a specific orientation would detect a "cool" light reflection emanating from a specific side of the lamp and will increase "warm" e.g. 2000K light to compensate. Over the long lifetime the DLF could recalibrate its spectral sensors **21** to white light based on readings of daylight where such daylight is available, and the controller has determined that the room at the time of calibration is being illuminated with white light "daylight" of a specific color temperature per orientation and time of day.

The same light distribution effect based on light source aimings could have been accomplished as in the prior-art, easy to manufacture flat pc-board configuration by simply angling the LEDs **23**B from the perpendicular as shown in FIG. **2**C. Shown is a side view of a PCB provided with standard 5 mm hole-through LEDs. The LEDs are produced with standoffs on the legs such that after soldering automatic machinery can bend the legs so that the LEDs project at the required angle from the nadir to achieve the required photometric pattern. Lead bending as is known in the art also allows for uplight as with LED **23**C. Though not as elegant as DLF **16**, this easy to manufacture configuration will accomplish much of the sought-after light distribution.

FIG. **3**A is an illustration of a prior art wall sconce for outdoor use displayed by a leading LED manufacture in at a lighting trade show in 2003. It is juxtaposed with FIG. **3**B

to highlight the difference in the design methodology as taught buy this invention. The very aesthetic prior-art wall sconce fixture encased in a curved decorative frame is portrayed in top, front and side views. It uses a multiplicity LED light sources to shine through a diffuser to produce an even glow. "White" LEDs **31** were placed on a flat printed circuit board **32** and the light was dispersed via a white diffuser **33** with the light exiting lambertianally in all directions. The good optical control initially present on the LED **31** is now squandered on the prior-art diffuser in an attempt to prevent glare from the pinpoint LED source and produce a pleasant glow on the diffuser. Light is projected evenly in all directions including uselessly upward, where it will help drown out starlight. The prior art flat PCB and optional metal heat sink **32**B facilitates manufacture and heat transfer and that is probably why the design is the way it is, with production feasibility considerations driving the design, rather than correct energy saving lighting principles.

FIG. **3**B illustrates how the same improved lighting design process can be accomplished for an outdoor wall sconce DLF intended to illuminate a walkway at night. According to the teachings of this invention, the LEDs **31**, power supply and other electrical components **34** are assembled on strips of semi-flexible printed circuit boards **35**. The LEDs can be multi-colored or monochromatic LEDs with overlapping coverage or white LEDs. As illustrated in the top view of FIG. **3**B, the LEDs **31** are mounted on a convex surface **35** such that some face to the left, some right and a smaller quantity towards the middle. The middle aimings require fewer light sources due to the inverse square and cosine law for a point source as is this DLF, where light at the angle of illumination of 0 degrees is more intense than for light at an angle greater than zero and a point closer to the DLF is more intense by the square of the distance in the denominator. The exact solution for the aimings is such that for a desired coverage and illumination level the illuminance equation 1 is used to calculate the necessary light intensity in candela at each aiming angle. The side view shows the LEDs **31**A and **31**B with varied downward angles, such that even illumination is produced on the walkway out to the prescribed distance from the wall. The PCB strips are optionally affixed onto a curved and angled aluminum heat sink **36** with electrically insulative but thermally conductive adhesive such as Dow Corning® SE 4400 Thermally Conductive Adhesive.

The diffuser **37**, is shown in the side section view to have white diffusing sections **38** and clear, fully transmissive slots **39**. The controlled angular distribution light emanating from the LEDs **31** passes through the clear slots **39** and illuminated the walkway. The diffuser **37** is illuminated by stray light emanating beyond the controlled angle of the LED **31** or one or more LEDs can be dedicated to the task and aimed into the diffuser material, using it as a light guide to spread the light within the diffuser as is practiced in the art.

FIG. **3**B illustrates how the same end result as the prior art fixture FIG. **3**A, of having a pleasantly illuminated diffuser can be accomplished while not compromising on the energy efficiency and correct lighting output of the luminaire. The fixture aesthetics can be maintained while a more physically compact design can be carried out. The components depicted in FIG. **3**B are possibly more complex and thus initially more costly. However, in a comparison of the life cycle cost per effective lux, which includes the electricity charges over the life of the fixture, the DLF is certainly superior to the prior-art.

The above design depicted in FIG. **3**B is easily adapted to a hallway application where some light to the ceiling is beneficial. To provide up light a row of LEDs **31**A is aimed towards the ceiling instead of downwards.

FIG. **4** illustrate additional embodiments of a DLF which may take on any shape be it disc shaped or linear depending on the aesthetic choice of the designer and the lighting application at hand. Thus, a preferred luminaire configuration for lighting an area from within, (using a number of lighting fixtures to prevent shadows) would be a concentrated point source design. To illuminate from the perimeter of the room or along a walkway, a linear configuration luminaire or many distributed point source luminaires are optimal. In FIG. **4** a disc shaped containment **40** would contain SLS **41** where again, the radial position of each SLS and the aiming is such as to yield a specified lighting pattern on the surfaces to be illuminated therefrom. A smooth light distribution is achieved by aiming relatively more SLS **42** in the direction of the more distant (or less perpendicular) surfaces or objects to be illuminated. One or more sensors such as motion, day/night, spectrum, luminance, are provided for in **43** or any other location as is required. A printed circuit board with power and control circuitry is provided for **44**, as are screws **45** and or adhesive on the rear **46** for affixing to a surface. Electrical connection is made via a connector or sharp prongs to a conductor **47** which are pressed against the conductors to make electrical contact. The total assembly **48** with its light sources at specific positions and aimings, its power conditioning and control equipment and connection to power source, be it integral such as with on board batteries, or external from a power line constitutes a complete lighting fixture replacement element.

Based on the disc or puck shaped integrated luminaire above an application featuring a snap on Step Light **66** used outdoors is illustrated. One or more SLS **50** are contained in housing **51** which is substantially transparent in the area in front of the SLS. The SLS light source is very long lived therefore the unit is sealed watertight for life in the injection molding process or via glue. The SLS **50** are aimed so that the distribution pattern, at standard mounting height, effectively illuminates the steps. In one embodiment the luminaire is provided in two models each specific to a right side and left side installation with opposite aimings in order to yield an even distribution along either the receding or proceeding stairs.

A two-conductor cable, which conducts power **52**, is installed along a building surface or railing along the area to be illuminated. A bracket **53** is attached to the wall **64** on which the light puck is to be placed. The slot **54** atop the puck is inserted under the top clip **55** of bracket **53**. The puck is hinged down and the bottom pivoted, catch lever **56** enters within the void of bottom clip **57**. The screw **58**, which can be a tamperproof screw to prevent removal by vandals, is tightened forcing the protruding leg of top-heavy catch lever **56** to fill the void in the bottom clip **57** of bracket **53** and lock the light puck in place. At the time of tightening screw **58** pushes contact block **59** with conductive piercing prong **60** against power cable **52**. Conductive prong **60** pieces outer insulation layer **61** of power cable **52** and makes contact with electrical conductor **62**. Further tightening of the screw **58** forces the prong on the opposite contact block **63** to pierce through the insulating layer and make electrical contact. A power cable **52** conducting current at low voltage, say 24 Volt, may be directly affixed to the wall **64** without enclosure in a conduit, and the light puck attached at points along the power cable. A bracket or clip **53** is used to affix the lighting puck fixture to the wall and has an opening **65** for the contact blocks **59** and **63** to fit through. The fixture

66 may be sealed for life during manufacture since there are no serviceable parts inside for the lifetime of the electronic components.

Other applications include stairwell lighting that is activated by motion detector or is always on due to the low power consumption or a combination of constant low level on state, with the increase to full power based on activity. Distributed along a power strip running along the stairwell are disc shaped DLF units such as luminaire **66**. A motion detector **67** in the first and last units between the floor landings is used to turn on the lamps ahead of the person using the stairs. An outdoor solar energy step light application will use a photocell or any other arrangement to turn the system on at night and a motion detector to turn the lights on for a short duration after motion is detected thus reducing the amount of energy needed to be collected in solar cells. Instead of being in a totally off state, the lighting can be partially on, such that it is visible in order to give definition to the landscape and help in orientation. This power usage is very low since even at very low current LEDs are visible at night. Upon being initiated by the motion detector it can go to full power to illuminate obstacles in the path.

Last Step or first step could be indicated by a different color of light. A motion detector could accordingly change the MSLS output color if the individual is approaching the steps say to green and to amber or red when reaching the last step.

FIG. **5** illustrates another DLF embodiment, a linear lighting fixture **70** where the similar or different SLS **71** and **72** are distributed along the area to be illuminated such as is typical with fluorescent lighting fixtures used in soffit lighting. The system may have a power conducting strip of a similar shape **73** which connects to lighting strip **70** via receptacle **74** and pin **75** set and which are attached to conductor set **76**. The two strip types, the lighting fixture strip and the power conducting strip may be adjoined together or affixed directly to the wall or attached to bracket **77** which may slide into a slot **78** in **70** and **73** and where there may also be provided matching cutouts in the lighting fixture and bracket. The matching cutouts **79** allow for a quicker, straight on insertion before sliding horizontally in the slot **78**. The bracket is thus first attached to the wall and the strips are brought up to the bracket and moved sideways to latch.

Many lengths of strips **70** or **73** up to the power capacity of the conductors can be joined together and connected to a power source with a connector **80**. Interchangeable sections of the power strip can contain LEDs of different colors for effects or alternate between power strips and lighting strips for a similar aesthetic architectural design.

The lighting/power strip may be thin and linear substantially in one or two planes or for aesthetic considerations have curves or be constructed of a flexible material and have the ability to be manipulated into curves and bends in three planes, to make such designs as an arc, wave or circle. The electrical conductors may provide the malleability to shape the strip and then hold the configuration after it is bent up, for example if they are made of copper or aluminum or alternately an additional bendable, yet shape-retaining material may be inserted in the casing **81** or the casing material itself may have such properties.

The Lighting strip **70** and Power strip **73** may also conduct light and radiate light to give a lighting effect all along its length. Alternately, the strips may be a light conductor with little light exitance from the surface and the total internal reflection is selectively frustrated to let light out along the length in a specific direction or at desired intervals. The strip lighting may come from SLS specifically aimed to project light into the strip or from light leakage from regularly placed optimally (per the main lighting application) aimed LEDs.

Another embodiment of a solid-state lighting fixture, DLF or luminaire is shown in FIG. **6**. Whereas previously described luminaires were described as incorporating LEDs in standard hole-through or SMD packages, here, a luminaire using the unpackaged solid-state light source junction is described. A multifaceted luminaire **90** is comprised of any of the following list including a mechanical affixing method to a surface **91**, an electrical connection to an outside power source **92**, a mechanical frame **93** to hold the one or more light sources **98** or lighting facets **94**. Power conditioning, heat rejection and control elements are contained on or within the interior of the structure **93**. A number of light sources, facet or many facets are placed in position radially around the lamp and angled vertically to effect the desired light distribution. Thus, while facet **94** is positioned in the frame **93** radially and angled so as to be aimed substantially downward to the left of the fixture position, facet **95** is positioned and angled to illuminate an area further out and to the right.

A detail of a lighting chip or facet is shown in front view **96** and side view **97**. In the first embodiment P/N junctions **98** of light emitting semiconductor material are placed on a thermal conducting and or light-reflecting surface **99**. Electrical connection **100** is made between the junctions often referred to in the industry as dies, such that different color junctions may be located in close proximity to each other and their combined light spectrum yielding the desired color. The power and control circuitry have access to each individual die, a cluster of dies or to a total facet. This allows for the dimming and color temperature adjustment of the illumination. To more tightly control the light intensity distribution the surface **101** beneath the light-emitting junction is formed concave to reflect and concentrate the radiation into a narrow beam. Alternately, or if additional optical control is needed, the top layer of the junction **102**, if it is light transmitting, is formed to act as a lens such as a Fresnel lens or a surface **103** above the die serves as a lens.

The level of miniaturization is irrelevant. The principal is the method of powering and controlling the light source intensity directionality and color spectrum in one integral unit by varying power signal to specifically positioned light sources of specific spectral power distribution. Device **90** contains for this purpose any or all of the following: unit **104** for effecting the power conditioning of electric current supplied to the light emitting elements, a control unit **105** to vary power to specific junctions or chips and sensor units **106** to provide input and feedback to the control elements as described earlier in devices **2** and **14**. The earlier described DLFs of FIGS. **1** through **5** are also designable using the facet light source building blocks.

In an LED, light is produced at the p-n junction of the diode. It is known that one of the major losses of light output from solid-state lamps is the absorption of light within the epitaxial layer of the chip. On a submicron level, other inefficiencies derive from defects caused by the lattice mismatch. Often LEDs are producing light at a quantum efficiency of approximately 5 percent. Depending on the chemistry and the junction molecular geometry a specific thickness of light emitting layer is required. Also, the width of the junction is important as light is absorbed in the interior.

Light extraction from AlGaInN-based LEDs is limited by the various parasitic optical loss mechanisms present within

or surrounding the AlGaInN epitaxial layers. These mechanisms include absorption at the semi-transparent metallic layer as well as absorption within many layers comprising the epitaxial portion of the LED, such as the buffer layer the active region and the heavily Mg-doped GaN contact layer. Because of the refractive index step between the multi-layered epitaxial structure (n=2.4) and the sapphire substrate (n=1.77) or the encapsulation epoxy layer (n=1.5), only approximately 25% of the light generated within the active region escapes into the epoxy or the substrate upon first encountering these interfaces. The rest of the light is trapped in a waveguide formed by the encapsulation epoxy layer above the chip and the substrate. The trapped light must travel distances on the order of the length of the chip to escape from the sides of the LED. Such distances require many passes through the various loss mechanisms within the LED structure, increasing the probability of absorption. Thus, much of this trapped light is eventually lost, decreasing the overall light output of the LED.

The LED is designed to allow the light produced to escape through an end face. However not all of the light is able to escape a diode in air because a portion is totally internally reflected at the interface between the diode and surrounding air. Due to the very high refractive index of most semiconductor materials, the portion of the light totally internally reflected is very large.

Therefore, contrary to the present trend in high flux LED design of building very large, high current diodes, it would be advantageous to build a multitude of very small diodes with relatively large surface areas relative to volume and lessen these losses.

The layout of the facet in FIG. **6** is applicable to a submicron-sized dice **102** with nano wires **107** and other subminiature connectors **108** bringing power to the junction. To prevent absorption of light by the neighboring junction the cusped reflective structure **101** of the lower surface surrounds the lower hemisphere of the junction.

The reflector as mentioned earlier for the dice on the micron level may be similar to the one described in "Semiconductor light emitter" U.S. Pat. No. 5,537,433 by Watanabe, where a semiconductor light emitter, such as the light-emitting diode or the semiconductor laser, having a structure in which a light emitting area or an active layer; a transparent layer which is pervious to light radiated from the light emitting area or the active layer; and an opaque layer or an opaque substrate which is impervious to the radiated light are arranged in order or in the inverse order. The semiconductor light emitter includes (a) total reflection layer(s) arranged between the transparent layer(s) and the opaque layer(s) so as to come into contact with the transparent layer. The refractive index of the total reflection layer is smaller than that of the transparent layer. Therefore, at least one part of the light, which has been radiated from the light emitting area or the active layer and which has been reflected by the total reflection layer thereafter, is either radiated outward from side surfaces of the transparent layer or returned to the active layer.

To carry away heat from the electronic components, a hollow center **109** will act as a thermal chimney and components are mounted on heat sinks. In compact applications, a fan or pump **110** is used in forced circulation cooling. In alternate preferred embodiment, a highly optically transmissive cooling fluid, **111** surround the chips, junctions or facets **94**. The fluid absorbs waste heat and circulates to a radiator area **112** on the body **93** where the heat can be transferred to the surroundings. The circulation can be natural thermo-siphon circulation, based on the density differences or forced, utilizing a pump **110**. An added benefit can be derived from the optical coupling of the fluid between the junctions **98** or facets **94** and the cover **103**. At an air plastic or glass interface typically 4% of the light is reflected back. With two such interfaces the loss will be 8%. The cooling fluid is selected such as to have a refractive index that it is close to the plastic, ceramic or glass used in the cover **103** and this loss mechanism is eliminated boosting efficiency.

FIG. **7** is an illustration of a typical application using the digital lamps as proposed in the present invention. A digital lighting fixture such as the puck shaped illuminating unit **66** of FIG. **4** described above shown here as **120** and **121** would be used to illuminate steps **122** by being affixed to the wall **123** or onto or within a railing **124**. A pedestrian **125** using the stairs would not be blinded by stray light reaching his or her eye's since the highly controlled light beams of the SLS **50** in FIG. **4** are aimed downward and have a sharp cut off of light distribution at an angle such that even a pedestrian coming from below and looking up the steps would not see the light source (except from a great distance on long stairways where the light intensity is weakened by the distance and does not glare). A right handed and left handed fixture design would further prevent any blinding light by always illuminating the stairs with SLS aimed toward the nadir or at angles from the nadir in the upward direction of the stairs up to 70 degree angle **126** and by having the fixtures mounted below the eye height of short adults **125** or children who walk stairs at night. A low voltage transformer **127** located within or by the outlet box or at any other power supply juncture can supply power, free from the danger of causing electric shock. A motion detector **128** could be a separate device or as propounded in this invention, be an integral part of the fixture and could cause the fixture to change color and illuminate in amber, red or green to signal the approach of the last or first step.

In a solar energy powered application, the motion detector would turn the DLFs on or alternately increase power. To conserve energy, when there is no foot traffic, it would operate in a low power mode where it is visible and gives a general outline of the terrain to warn of approaching steps. When motion is detected it would switch to a mode where it actually illuminates the steps for correct foot placement to prevent mishaps.

In another embodiment the railing **124** is an aluminum or steel extrusion **129** specially constructed to accept the lighting fixture **130** and formed with brackets **131** to carry the conductors which supply electric power. The railing is actually a combined railing lighting fixture and carries out the both functions including providing elements for the power distribution. Grooves along the extrusion accept mounting brackets **132** that facilitate attachment to the wall or upright post **133** and also have a locking mechanism such as fastener **134**. It is to be understood that any other shape or material of railing, fixture and combinations of bracket and extrusions can carry out the similar function of a combined railing—lighting fixture device.

In another embodiment the railing is a standard railing profile **135** available in the industry and the digital lighting fixture is shaped in an arced or banana shape **136** or has a bracket shaped to facilitate its merging with the railing. An insulated electrical conducting element, **137** runs along the railing to provide power to the fixtures at intervals along its length.

FIG. **8** illustrates the use of the linear packaged digital lighting fixture **70** as described earlier in FIG. **5**, here shown as **140** in a step **141** or stairwell lighting application. The

power and lighting need to be distributed substantially linear at constant distance **142** of the light source from the stairs to be illuminated and the correct light distribution for the task is designed into the SLS and or digital lighting fixture from ground up. The angle **143** of light distribution from the SLS is such that it takes the mounting height **142**, step **141** width **144** and required illumination level into account. The lighting fixture may attach to the wall **145** or onto the handrail **146**. The person's **147** presence is detectable by a motion detector **148** as he nears the last step **149** and indication by a change in color or frequency can be signaled by a segment of the lighting fixture. Alternately or in addition to, in order to save power as with a solar energy installation, the detector may cause a change in the power supplied to the DLFs.

FIG. **9** depicts a DLF **160** which can be used in pathway lighting where upon being installed at the correct orientation the SLS **161** are aimed in a controlled wide distribution **162** (but yet not in the wasteful, present-day practice of 360 degrees), such that they illuminate a section **163** along a walkway **164** of standard width **165** with equal light distribution and there is no stray light upward or to the rear. A marker, **166** situated on the fixture **160**, aids in orienting the fixture perpendicular to the path. Alternately, shrubbery **167** can be illuminated with another grouping of upward aimed SLS **168** with a more spotlight like distribution alternately of another color spectrum which may illuminate the green growth in a more aesthetic light. The group **167** may be mounted on a swivel base **169** so that it can be aimed independently of the path lighting SLS aimings. A dedicated shrubbery illuminating DLF configuration is another alternative. A stake **170** is used to install the DLF in the ground at the correct orientation and may be provided with an electrical connection box to hook up to power through piecing quick connectors as is known in the art. Alternately the DLF can be self-sufficient with an onboard power source consisting of solar cell **171** and batteries. As described in previous devices, in more embellished embodiments, onboard control logic circuitry and sensors are employed to control intensity, color spectrum and on/off switching. A motion detector **172** can control the transition from a standby mode to full operation.

FIG. **10** is a graph of the preferred parameters for lighting color temperature at different illuminance levels. It is adapted from the IES Lighting Handbook 8th edition 1993 and illustrates the Kruithof effect. It is used here as a sample of one of the recommended lighting procedure templates used by controlling logic circuitry on a DLF to keep lighting parameters such as color temperature, color rendering properties, illuminance levels and distribution in optimal bounds. Other control parameters such as switching on and off and color change used to signal critical circumstances are examples of look up, truth tables and media storage data that can be provided to a controller.

Shown in FIG. **11** is a revisited step light which incorporates the chip technology introduced in FIG. **6** into the step light application which has been used to demonstrate the general method of digital luminaire design as espoused by the present patent. The intent is to illustrate the advantages of the placement of the junctions on a facet configuration over the discrete component approach in the previously described step light design of FIG. **4**. The significant feature that stands out is the size reduction. Many junctions are packed in a facet and the facets are cast in epoxy at the correct position and angle to properly illuminate the steps. Again, the entire lighting fixture function is carried out in this properly shaped button-like device which yields the correct light distribution. A button shaped step light **170** is shown on the bottom side of the railing section **171**. A power cable **172** single wire (it can be a single conductor with the railing serving as the other conductor) supplies AC or DC power, which for safety considerations can be low voltage. The power, sensor and control circuitry package **173** makes contact **174** with the power cable **172** and distributes power to the light generating discrete LED or multiple-packaged facet elements **175**. The light facets **175** are strategically located on the relevant geometric surface of **170** such that their aimings contribute to the illumination **176** of the steps from the preferred direction and at even intensities. While facet **175** is contributing light at higher angles on the receding step surfaces facet **177** is illuminating **178**, the close face of the upward step **179**. In manufacturing such a luminaire the components must all be wired together and then positioned in their proper locations at the exact angles. This can be done with automatic machinery while the components are in the flat. Each component is placed by automated pick-and-place machinery in a hollow where it is temporarily set and where the wiring is attached as well. The hollow is actually a computer positionable setting and all the hollows are moved with the components in situ into the molding positions. An epoxy like spray is used to temporarily lay up the components until the final encapsulation into the final "button" shaped lighting fixture. This is a general lay-up method and applies to subassemblies as well, which can later be brought together before final encapsulation. Conductors that require subsequent electrical connection are mechanically or chemically covered during the spraying process.

In another preferred embodiment shown in FIG. **12** the DLF is an Adaptive Digital Lighting Fixture. As opposed to a DLF described earlier, is not pre-designed with light source aimings based on a pre-known application. Instead the DLF is equipped with a plethora of light sources ready for most of the conceivable lighting tasks in the illuminated area. The light sources are then controlled such as to adapt the lighting to the room construction and the lighting tasks at hand. The same technique applies to outdoor area lighting applications. This universal DLF is the preferred design when the cost of having an overabundance of light sources is low enough such that other economic considerations such as minimizing stocking units in inventory, repeated changing of the room tenants etc. will be more expensive. It is similar to purchasing a 100-Watt lamp where a 40 W lamp would suffice and always operating it on 60% dimming. The capacity is there but it is unwise to use it since electricity is costly.

The adaptive or intelligent DLF **190** shown in FIG. **12** has multiple light sources **191** placed about the body **192** having a geometric shape. The shape, which influences the spatial light distribution, may be of a fixed or flexible design. In a flexible design, solenoids, servo motors, actuators, pumps, controlled fluid or air pressure devices **193** are used to realign surfaces, moveable plates or expandable tubes or cylinders **194** to morph the topology of the fixture. The ADLF is equipped with an electronic power supply, computer control and communications unit **195**. One or more light sensors **196** are placed strategically to detect necessary inputs. Alternately one or more digital cameras **197** with a photodetector array which is equipped with a lens which can be a 360-degree lens, or a fisheye lens is placed with a field of view of the area to be illuminated. The geometric shape of the body **192** is such that an asymmetric lighting pattern is produced for the provision of a non-circular lighting pattern in a typically rectangular room. Because more light needs to be directed to the far corners of the room, more

surface area for projecting SLSs at that position is required. If multiple fixtures are used in a large room then squared lighting patterns will obviate the need for overlapping coverage as with circular distribution luminaires or the prior art. Concave section **198** increases the ADLF surface area available for light source mounting at the room corner orientations. In bottom view **199**, a section of the body **192** is shown with asymmetric surface cut out **198** which increases the available surface area on the ADLF.

Spatially differentiated motion detectors **200** are provided on the Adaptive Digital Lighting Fixture along with the light sources **191** and light sensors **196**. Typically motion detectors have been associated with lighting in motel rooms to shut off the lighting if there is no activity. There is another level of control that can include matching the lighting to type and amount of activity. On sport fields for example, 200 lux may be used general sport activities, 1,000 lux for night practice sessions while 3,000 lux is used in a televised game. Taken to the extreme, one or more limited field-of-view motion detectors **200**, or camera **197**, can be used to follow the whereabouts of room occupants. The DLF controller acts to provide heightened lightning to the occupants" present locations. The controller has stored look-up-tables, instruction sets and algorithms which it uses to processes the information communicated from the sensors or a camera and in response control the light provided to the illuminated area.

A special or standard remote-control unit **201** can be used to operate and program the ADLF. In one embodiment the control **201** is equipped with a laser pointer and/or light sensor **202** that is used to assist in providing positional an angular data on the location of work surfaces, room structures and dimensions. The control **201** can then pass on information concerning the visual task performed at that specific location. This data now enables the controller **195** to use stored algorithms, look-up-table templates to calculate and program the correct lighting intensities and spectrum for that room location as explained earlier in the block diagram as functionality **7** and computer processes **7**A. The photometer on the remote control **201** held at the specific location will then corroborate the illumination and spectral performance of the ADLF with the specific light source aiming being programmed at the particular instant. The communication can be optical in the visual or infrared wavelength or wireless. An antenna **203** is provided for wireless communication. The adaptive DLF is thus manually capable of being programmed with all the input parameters necessary for a computer program **7**A as is practiced in the art of lighting design, to determine the correct intensities and spectrum to carry out the visual tasks at a specific room location. This is a unique property for a single luminaire. Lighting designers are usually forced to compromise and provide the entire room or area with the highest common denominator of lighting in the room. With the ADLF nonglaring, spectrally correct lighting at minimum intensities is provided and this affords significant energy savings. The added daylight and activity related dimming functions are another significant energy savings factor with its ensuing economic and environmental benefits.

A calibration system is provided in the form of calibration element **204** constructed such that it has coverage of the light source radiation on the ADLF body **192**. The calibration element **204** is a reflective rod or strip the surface of which **205** has a wide spectrum, non-angle of incidence dependency and stable reflection characteristics over time. The reflectance of **205** is known at each wavelength and it serves as the standard reflector for the calibration routine. The reflective rod or strip is moveable so that it can reflect light back to the outward facing photodetector **196** based on the ADLF body **192**. To test SLS performance the calibration element **204** is rotated about the body **192** by actuator or motor **206**. When the reflecting surface **205** is opposite a column of SLSs **191**, the controller times the firing of each independently addressable SLS **191** location and acquires detector **196** intensity readings uniquely for each SLS. The results of the test firing are analyzed in controller **195** which has the functionality described in FIG. **1** of components **7** and software **7**A. Correction is made to the junction power supply parameters in order to maintain metametrically balanced outputs for white light and overall lumen production. The controller **195** re-powers the SLS **191** again using the updated power supply instruction set and retests for accuracy. The process continues until the SLS performance is repeatable at different power levels. In another embodiment the ADLF is provided with a calibration wand **204** on which inward facing photodetectors **207** are placed. The calibration wand is capable being positioned such that the detectors **207** can detect SLS **191** performance as the wand **204** is rotated about the body **192** and SLS **191** are independently tested as describe in the previous embodiment. Both the reflective rod/strip and calibration wand **204** are narrow such that when not in use, rod/strip/wand **204** is parked at a specific position where it does not block light sources **191**. In another embodiment the rod, strip or wand is stored and is only deployed when calibration is required. When called upon, the deployed rod, strip or wand **204** is rotated around the DLF body **192** to read SLS **191** intensities. Alternately, the DLF body **192** rotates and the rod, strip or wand **204** remains fixed.

An ADLF **190** outfitted with computer calculation, communication, calibration and other feature may be costly, such that using a number of units to illuminate a room is impractical. Correct lighting practice encourages the use of multiple point light sources to illuminate an area using a number of criteria. A single fixture cannot cover an area larger than glare and mounting height considerations allow. There is a limit on the maximum angle of light provision. Another consideration has to do with the production of shadows. Finally, due to the cosine law there is a practical maximum angle at which the lighting can be delivered. At large angles the lighting effect becomes negligible. Therefore, due to all the above considerations it is advantageous to have multiple lighting fixtures in a room. A single ADLF **190** is used in a large room. The ADLF is designed to be used with one or more satellite reflectors **220** which are strategically positioned about the room. The satellite has provision for being attached to a supporting structure such as a ceiling or light pole and being fixed with a certain orientation in relation to the ADLF **190** and the working surfaces below. The satellite's inward facing surface is a highly efficient specular, semi-specular or diffuse reflector or combinations thereof. A part of the surface **221** is provided with a full spectrum, white reflector which may be a spot or a band across the top bottom or middle or all combinations thereof used in calibrating the intensity and or spectrum photodetectors and/or light sources over the lifetime of the DLF. A part of the surface may be a special reflector **221** such as a retroreflector which will serve as a ray targeting aid useful in the installation process of the satellites. The targeting can be manual using a red laser pointer or automatic using the detectors **196** on the ADLF **190** and the retroreflector **221** on the satellite **220**. A section **222** of light sources, which may be high power light sources, is dedicated to provide sufficient light to the other areas of the room or for specific task lighting applications such as to computer terminals which require

lighting at small angles from the nadir. The section **222** may be on a swivel so as to be aimable at the satellite **220**. Section **222** projects light **223** at the satellite reflector **220**. In use, the satellite is installed substantially over the work area to intercept rays **223** from **222** so as to provide task-lighting **224**. The specular reflector **220** is positioned and angled such that it concentrates and re-directs the light rays **224** downward onto an area or worktable. The downward directed light coming at very small angles will illuminate the worktable **225** but will not cause veiling glare reflections on the computer screen **226**. To provide general lighting to room extremities, the satellite reflector is specular, semispecular or diffuse and has a surface geometry for reflecting the incident light **223** so that it spreads the light evenly over the area to be illuminated.

In place of the manual programming technique for ADLF **190**, a semi-automatic self-programming process using luminance measurement via detectors **196** is provided. The camera **197** has a view of the room its contents and occupants. Pattern recognition techniques known in the art are used to identify room occupants, furniture, office equipment such as computers etc., room structures such as walls and windows.

The intelligent lighting fixture system **190** is adaptive to the room structure, usage and occupants on a dynamic basis. In one embodiment a hand-held laser pointer and sensor on the remote control **201** is used to assist in providing positional an angular data on the work surfaces and room structure enabling the controller to corroborate program lighting for the location with the specific light source aiming being programmed at the particular instant. The room occupants also use the remote control **201** at any instant to input lighting preferences or call up stored lighting scenarios to the DLF **190**. Thus, the controller **195** or a controller **195** which communicates with a PC computer is provided with an interactive program which based on application look up tables will determine recommended light intensity and spectrum for the application at hand. Procedures useful in the lighting design process, lookup tables and specific application guidelines can be found in the IES Lighting Handbook 8th edition pages 447-903. A number of commercially available programs are available which prescribe lighting based on the application and calculate the illuminance based on the fixture. In this invention the procedure is reversed in that the recommendations are first used to generate the illuminance on or luminance from the room surfaces. The computer program **7**A is used to calculate the light intensities required at each angle in order to produce the desired illuminance or luminance results. Luminance in cd/m 2 is the reflection of the light flux lumen/m 2 from a surface having a reflectance property and is more similar to what the eye sees. The algorithms are processed onboard the ADLF **190** or run on a PC which communicates with the ADLF. Computer programming for lighting calculations and correct lighting practice recommendations is known in the prior art. Commercial programs using procedures based on IES, ILDA and other standards and professional lighting engineering and design organizations are available. Lumen Micro® and Simply Lighting® from Lighting Technologies Inc are examples of such programs which provide tools to create and simulate lighting layouts for both indoor and outdoor applications. Simply Lighting® is a suite of Windows®-based lighting analysis tools that are designed to answer the questions you need answered using a step-driven application targeted at a specific lighting application. Lighting Analysts, Inc AGI32® is a program used to predict lighting system performance for any application from one to hundreds of luminaires, interior or exterior. Users can build environments for most any electric lighting application with unlimited luminaires, calculation points, and reflective or transmissive surfaces including day lighting effects. The program used in this invention is an adaptation of a state of the art lighting programs. It is capable of receiving data inputs automatically or manually interpreting them according to correct lighting practice and calculating the candlepower distribution from the illuminance back to the luminaire. A post processor and outputs the operational instructions to the controller **195** for the application at hand.

The operation of the system is demonstrated in home use, but the method is the same for office, store and industrial applications. The input program **7**A is user friendly including the use of icons representing pieces of furniture, e.g. table, lounge chair, equipment such as TV, computer etc., and visual tasks being performed such as reading, and watching TV. The homeowner moves about the room with the remote control **201**. At a specific location the homeowner enters the furniture type, possible occupant postures, sitting reclining, standing etc, and visual tasks to be performed. The room and its surfaces is defined the by being positioned at a wall, entering into **201** that it is a wall at that position and at another position entering that it is a window. The control unit **201** is optionally outfitted with a photometer **202** which can be used to read the surface reflectance of the wall and transmit the data to the lighting program **7**A. This is the same process a lighting designer uses to enter data to the lighting analysis programs. The lighting program as known in the art then specifies the correct lighting levels, aimings and spectrum for the different locations and uses throughout the room. This is reversing the typical design process as described earlier where the lighting fixtures performance is simulated on a computer and the results calculated. Here, the required illuminance results are known first and the fixture is then programmed to make them happen. The controller **195** uses its stored performance characteristics to determine the power supply to the SLS so that it provides the required intensities and obtain the required illuminance. The lighting calculations and programming of the power supply **195** of the light sources **191** is preferably performed in real time such that the sensor **202** detects the illuminance to corroborate the performance while the homeowner is still at the location. If the lighting is not to specification, then the controller **195** readjusts the parameters so as to bring them in line. This trial and error process continues until the readings are within tolerance. The process is best carried out in the dark or when there is non-varying daylight. Alternately, the photometric reading sensors are on the luminaire and they are used to corroborate performance. Alternately, the process is automatic using feedback from the surroundings and pattern recognition to determine surroundings and applications.

Providing correct lighting for the various activities a homeowner in a room involves the use of numerous lighting regimes. Typically, he or she would move about the room performing various activities with diverse lighting requirements. First, moving from the table where work was performed on the computer to a lounge chair to read the paper and finally moving to the sofa for a little relaxation watching TV. In prior-art practice, several lighting fixtures of different design are used to carry out the different tasks. In order to conserve energy each one would have to be turned on and off or dimmed as the resident moves about the room. A glare-shielded luminaire would be used for correct illumination in the computer task, while a floor lamp may provide lighting for reading on the lounge chair. General lighting from an

overhead luminaire is sufficient for TV viewing. According to the present invention, as the room occupant moves about the room performing varied tasks, the motion detector **200** or camera **197** picks up the new location and from its stored templates which correlate location to lighting application, controller **195** provides the correct lighting regime.

According to the teachings of the present disclosure, the room lighting needs are provided by one or more DLFs or ADLFs including satellites or combinations thereof placed such that they are capable of providing lighting at the correct non-glaring angles for the lighting tasks at hand. The ADLFs are programmed as to the whereabouts of furniture, computer monitors, TVs etc. as described above. The ADLFs and DLF can communicate with each other and an ADLF can control a DLF and vise versa so that level lighting is accomplished in the room. Two or more DLFs can share in the illumination requirements of a location located between them. The DLF turns off its illumination towards a specific location, reads the ambient luminance and then correctly powers the SLS to provide the additional illumination. An oscillating "singing" feedback network incapable of settling is prevented by the provision of inexact timing. The DLF lighting assessment process occurs on a periodic basis as the controller surveys its numerous detectors and SLS, the complete cycle taking a number of seconds. The same process is occurring in the neighboring DLFs. A clock on the DSP controls the process. The DSP is programmed to randomly nudge the clock timing by a number of a multiple of milliseconds typical of the survey process from cycle to cycle. The similar timed assessment process with an independently random shift in timing occurs on the adjacent DLFs. Thus, the chance of seesaw interaction between DLFs is insignificant. Alternately, communication between neighboring DLFs can also be used to synchronize the process and prevent feedback oscillations.

The novel lighting-application oriented approach to light-source construction, as taught by this invention impacts on the method involved with marketing the DLFs. Rather than speaking of a wattage for a lamp or lighting fixture, now with DLF technology, the area covered is the determining factor, somewhat like the coverage area of a can of paint printed on the container. The customer needs only to specify the room area and what the lighting is used for in order to select the correct luminaire. In today's prior-art process of selecting by lumen or wattage, there is an additional step, that of taking the effective lumen output and dividing it by the area of the room. Instead, a DLF is packaged and marked according to the area it will cover (when mounted at the designed for), mounting height (usually standard for most residential ceilings) and the lux it will provide or the visual tasks for which it is suited. Thus, a homeowner in a store will be queried by the sales staff or be presented with instructional promotional media which allows for the determination of the room dimensions, type of room and typical activities carried out therein. The lists printed on the cartons for the various DLFs will include location types and task types. Location possibilities for consumer lighting include corridors, kitchens, bathrooms, bedrooms, play areas, garages, driveways, backyard, playing fields, steps, workrooms etc. Task possibilities which would generally be a subdivision in a location type will include reading, dining, TV viewing, exercise, sport etc. A single DLF may be suitable for more than one location and task type and be so marked. Thus, typical DLFs would come in bathroom, kitchen, garage, bedroom, hallway, and etc. models. The bedroom model comes in a 12 ft. by 12 ft. Coverage and is also the TV room model etc. An ADLF is suitable for many more locations and applications and is so marked.

Industrial and commercial lighting DLFs are similarly marked and marketed. Mounting height determines the maximum area covered according to correct lighting practice principles and adds another variant less prevalent in the consumer market. The many DLF models will not exceed the plethora of prior art luminaire designs, as they are also based on mounting height and lighting application. While prior art luminaires rely on large reflector and every variant requires new investment in tooling, in a DLF a basic carcass will support many MSLS configurations with their particular amount of SLSs and their aimings.

In non-color critical applications for example in low lighting used for orientation a further energy saving can be obtained. LED junctions are made of different materials. The blue, green, and white illuminators utilize InGaN LEDs and the amber and red utilize AlInGaP for the junction material. Some materials are more efficient at converting electrical energy to visible light than others. As an example, (in terms only relevant at the time of this writing since the efficiencies are increasing daily), while a green LED which has the advantage of high photopic eye sensitivity to its wavelength, is producing only 30 lumen per watt, a super flux red LED can produce over 50 lumen per watt. Thus, when color rendering is not important in the lighting application at hand it is possible to shift the workload onto the more efficient LEDs. This of course must also take the eye sensitivity at the specific lighting intensity into account. While a purely scotopic rod eye response at extremely low light levels, less than 0.01 lux gives added sensitivity to the 510 nano-meter green blue, photopic vision at levels above 100 lux is most sensitive to the greenish yellow 555 nm wavelength. In most illuminated cases low lighting would not be below 5 to 10 lux where the sensitivity peak is around the 550 nm yellowish green. Thus, two factors are used by **7** in **7**A to calculate the most efficient light color of the DLF; the LED radiation power per watt multiplied by the eye sensitivity curve for the present illuminance value. In a less rigorous embodiment, if the par between the LED efficiencies is large such as in the example above, then the red LED is used combined in ratios with other wavelengths, such that the color still found acceptable by the users.

In a preferred embodiment, using pattern recognition techniques the ADLF **190** is semi or fully automatic in programming itself to correctly function where installed. The DLFs or ADLFs will adapt to the seating arrangement of room occupants in real time. In the preferred embodiment, the addition of a machine vision system with pattern recognition capabilities as is known in the art, easily deduces room occupancy and usage. The camera **197** including a wide angle or fisheye lens camera is mounted on the DLF or ADLF. In an alternate embodiment, one or more cameras in communication with the lighting system controller, has coverage of all, or part of the area to be illuminated. The camera may also serve as an illuminance and spectral measuring device as the individual detectors in the array, for example as on a CCD or CMOS array, may be read for their individual stimulus. The detector array pixels are calibrated to the room coordinates. The calibration routine can be manual or automatic. A manual method includes walking a controller around the room and programming in the coordinate to the camera system or alternately using a PC CAD program to input room coordinates overlaid on the image obtained from the camera such that the lighting system coordinates and the camera coordinates are the same. An automatic routine as in **7**A uses timed firing of a coordinate-

specific light source, or array of light sources and the following reading of the camera detector of light reflected to that specific coordinates pixel, or set of pixels to corroborate action between light sources and the detectors. The detector pixels **197** can then be used to obtain images of the room which the controller **195** can assess as furniture, equipment or occupants. Pattern recognition methods known in the art, including neural networks, can provide a generalized stored application library of usages to the controller or the controller is an artificial intelligence controller and can learn the actual room usage with time. Outputs from the CCD arrays are analyzed by appropriate computational means employing trained pattern recognition technologies, to classify, identify or locate the contents. These techniques known in the art are covered in texts such as: Schalkhoff, Pattern Recognition, statistical, structural and neural approaches, John Wiley and Sons, New York, 1992 and Neural Networks for Pattern Recognition by Christopher M. Bishop, Chris Bishop, Oxford University Press; (January 1996) included herein by reference. Thus, the controller with or without human intervention will program the ADLF lighting system to carry out lighting within the realm of correct lighting practice. This includes providing the correct illumination in real-time based on occupant whereabouts, activity being performed and outside factors such as sunlight contribution, time of day factors etc. Advanced robotic vision techniques including object segmentation and selective-attention modeling (Itti, Visual attention and target detection in cluttered natural scenes in Optical Engineering, Vol. 40 No. 9, September 2001 included herein by reference) will aid in identifying various room objects and the lighting program **7**A will associate with their location the visual tasks and recommended lighting characteristics. In case if the machine settings are not acceptable to the users, provision is made for human intervention. Through the data input device **201** a user, the ultimate "sensor" corrects or customizes the lighting arrangement and reprograms the controller.

In a further ADLF intelligent lighting system improvement over prior-art practice, machine vision is used to control surrounding luminance. A prime example is an office application where a computer Visual Display Terminal is in use. This is an application where the quality of the localized task lighting is important. Contrast plays a major role in seeing and glare plays a role in producing veiling reflections as causing fatigue. The correct illuminating solution involves the control of surrounding luminances. A prior art workstation design will include partition, carpet, ceiling and desk surface reflectance which reduce the luminance in the workers field of view. Using the ADLFs ability to recognize the computer screen chair, desk and surrounding floor and ceiling, the illuminance in lux on each element is varied to obtain the optimal luminance. That now allows any color scheme to be used by the interior designer on the work cell decor. The ADLF will control the luminance by varying the spatial light intensity distribution over the different surfaces.

In another embodiment using the camera **197**, the controller **195** is instructed to identify and track a roving speaker during a video presentation. A signaling device is used by the speaker to allow the pattern recognition program to initially lock-on and recognize a target attribute as is known in the art of object tracking. The signaling device can be a laser light pointer **202** aimed at the camera or a hand held remote control **201** in communication with the camera vision system. The controller **195**, based on the camera input runs the pattern recognition routines, derives the coordinates and generates instructions to drive the specific light sources with aimings which will project light at the speaker as the speaker move about the room. It is to be understood that in a theater lighting application there is no need for a preprogrammed moving light using motors to change position. Instead a fixed DLF or ADLF with multiple light sources powers the necessary light sources to illuminate the performer as he or she moves about the stage. This actually is similar to the banks of shuttered lights used in present day stage lighting. Only now the digital aspect of discrete multiple light sources allowing for a smooth transition of aimings with instantaneous control of almost infinite variation of spectrum and intensity is accomplished. The controller, once locked-on to the performer using images from the camera **197**, will now follow the performer around the stage illuminating instantaneously in the intensities and spectrum as preprogrammed in the choreographic setup or in correspondence to the music or some other characteristic as in known in stage lighting practice.

An emerging problem with LED light sources is that with the increase in light conversion efficiency the LEDs are becoming ever brighter and for their small size present uncomfortable sources of glare. These high intensity light sources would have to be used with diffusers which would impair the light control characteristic. One solution is to construct the DLF large enough such that the area over which the light flux emanates is sufficiently large that the luminance in candela per square meter will not exceed allowed luminous exitance values or glare limits. In this solution of increasing the luminaire area over which the light emanates, the number of light sources at specific location may not be sufficient to provide the continuum of light distributions and spectral combinations necessary to carry out correct lighting practice as per the teachings of this invention. Another way of looking at the problem is, that with added lumen output, a few high-performance LEDs could provide the illumination for a room but due to even distribution and spectrum consideration many discrete SLS are required. That is, the SLS needed for the smooth continuum, digital aspect of the invention exceeds the number required for the maximum light flux.

In a preferred embodiment the DLF or ADLF is rotated about an axis such that the time any source in the glare causing zone is exposed to an observer's eye is such that it is not observed as glaring and the time the source is out of view is below the flicker rate for that intensity level. HID and fluorescent lamps operated on 50 Hz have a 100 Hz flicker rate and are not considered to flicker. For aesthetic, aerodynamic and dynamic balance reasons the DLF can appear as the globe shape **190** of FIG. **12**. However, the now reduced dimension DLF is spun rapidly on its axis **227** by motor **206**. The LEDs can be concentrated in an arc from top to bottom along the surface **192** or be located in the concave arc section **198**. The concentration of SLS in this section is sufficient to offer a large number of spectral combinations at any aiming. Two arcs of SLS **191** opposite each other for balance or one arc with counterweight can be used. With one arc a 6,000 RPM rotation rate is used to prevent flicker and with two a 3000-rpm rate. In an alternate embodiment instead of a complete globe just an arc section such as **198** runs from top to bottom. The arc is on an axis and is motorized so it rotates rapidly on its axis. The speed of rotation is such that the light source does not appear to flicker. This way a compact unit can be made since the apparent brightness is reduced. This process is possible because the eye is an integrator of light over time and persistence of vision minimizes flicker. The LEDs **191** disposed along the surface are timed to fire in the correct intensity according to the instantaneous position. The timed

operation is coordinated with room location. Thus, when the spinning light sources **191** are facing a corner more intense light at higher angles is projected so the far corner is illuminated equally to the areas near the DLF. The positionally correlated timed firings of the rotating DLF will illuminate as need per location per usage requirements in real time. The side of the room near the window receiving ambient daylight will receive less illumination than the opposing darker side. This is also possible because the controller electronic **195** operates much more rapidly than the mechanical motion and that the rise time of the SLS is extremely fast measured in single digit microseconds. In a preferred embodiment, the globe or arc can be placed in an outer jacket which is partially evacuated of gas. The globe or arc is then rotated in a partial vacuum envelope to reduce air friction losses.

In FIGS. **13**A through **13**C a streetlight fixture designed according to the teachings of this invention is shown. The design and functionality distinction as compared to prior-art streetlights is derived from the multi-light source, digital design. In FIG. **13**A the aesthetically designed DLF streetlight **240** is shown in a front view. The geometric shape is a derivation of the surface geometry for mounting the SLS perpendicularly thereon to obtain photometric light distribution compatible with the requirements of the street lighting application. These photometric distributions are expressed in terms of luminaire cutoff angle which refers to the angle beyond which rays capable of producing glare are prevented from exiting the fixture. Another type of classification used by the IES, refers to the elongation of the light pattern along the road in terms of Long, Medium and Short and another categorization, perpendicular to the roadway called "Type", describing the distance in units of mounting height (where the fixture is mounted), that is illuminated. The novel design includes SLS with over 100,000-hour lifetime allowing for the fixture to be factory sealed for life. This obviates the need for cleaning reflectors, as all the exterior surfaces are cleanable by rain and there are no light sources at the sharp bottom drip point where dirt normally accumulates. The compact design **240** shown mounted on a pole **241** in side view FIG. **13**B has a small exposure area, reducing wind induced drag force loads on the pole. This low wind factor and low weight of the electronic components allows for the use of a less expensive pole. The pole arm **242** fits into slipfitter **243** which is provided to perform the mechanical fixing means of the DLF **240**. FIG. **13**C is a side section view through the center of the fixture. The electrical power and communications connection is made to a connector block **244** mounted such that it accessible for the external wiring of the fixture during installation. The grid power is connected to power supply **245** and the data to the controller DSP **246**. A dedicated communications line is used, or the data is sent over the power line using communications protocols as known in the industry and the DLF communicate with each other or with a central control. The SLS aimings are shown in front view FIG. **13**A where the SLS aimings to the right **247** and left **248** along the roadway show how an even distribution pattern out to the maximum design distance from the pole center is obtained. This distance is a function of the fixture mounting height and cutoff angle. Hole-through SLS units have been drawn to illustrate the point but the principle the design is valid for SMD, SMT, the chip **94** design of FIG. **6** as well as other package arrangements known in the art. Many more SLS **249** are concentrated at the larger angles **250** to illuminate out to the extremes of the area covered by the DLF. Fewer SLS **251** are needed at the small angles near the pole to maintain with equal illumination. The SLS at the cutoff angle **250** have a tightly controlled beam spread **252** to maintain a sharp cutoff, minimize glare and eliminate spill light. The SLS **253** in the interior have a wider beam spread **254**. The DLF **240** projects light in a highly controlled pattern perpendicular to the roadway as well SLS **255** as seen in the side sectional view FIG. **13**C are aimed such that the cutoff angle **256** is out to the road width with or without the shoulders as designed. In applications where illumination for a sidewalk is required, "house side" illumination is provided by inward SLS aimings **257**. On a dual carriageway road where the illumination provided is limited to a single carriageway, the lighting from the roadway fixture need not be symmetric about the nadir along the roadway. While approaching the streetlight, glare is to be avoided and the cut-off angles must be small for light aimed at the advancing vehicles. However, after passing the streetlight, the lighting in the direction of travel may be provided at increased beam angle from nadir and still not cause glare. This would significantly increase pole spacing saving cost and eliminating hazardous poles.

In all stages of the SLS positioning and aiming design process which works in reverse of the normal process by engineering from the illumination required on the working surface back to the light source. Glare ratings for the design are checked to make sure they are within the acceptable limits. If the light source concentration is such that drivers or pedestrians in normal eye viewing conditions would experience glare, then the luminous exitance is lowered by design changes in the geometry or light source attributes. The ramifications of a dynamic and exact light control are numerous in a street light luminaire. First there is no spill light and no light trespass. If the position of a luminaire is such that light is shining into a house the individual SLS at that aiming is not powered by the control **246**. All the light power is placed where needed in the designed for illumination intensity, neither in deficit nor excess. While prior art luminaire show 80% of the light falling in the area designed to be illuminated, the DLF will have a near 100% utilization factor.

When artificial intelligence methods known in the art is combined with the fine control and functional flexibility of the DLF additional advantages are realized. A detector or camera **258** in concert with a logic controller **246** is capable of providing the road lighting needs to a driver or group of drivers in according to the time of day, needs of the roadway layout and usage at any moment. The detector **258** will provide signal to the controller **246** of the ambient lighting conditions. When daylight is no longer sufficient for viewing such as at dusk the DLF will add lighting. At dawn the process is reversed. In an alternate embodiment the roadway lighting can be dimmed if there are no approaching vehicles. The detector or camera **258** is capable of detecting oncoming and retreating traffic. The headlights and backlights are used, or more sophisticated pattern recognition is used to determine traffic on the roadway. When there is no traffic the luminaire will illuminate at a fraction of the power used to generate the 5 or 10 lux used in street lighting. Taken to the extreme the controllability of the DLFs or series of communicating DLF street lights allows for the lighting to precede the vehicle by the stopping distance, say 300 ft. at 65 MPH (91 meters), and dim the unused lighting behind the driver if it is not necessary for other drivers. In the late hours of the night when traffic is low this function can save significant amount of energy. A typical 250 W HPS streetlight will consume over 25,000 Kwh in its 20 yr. lifetime. On moonlit nights the dimming of the DLF can be greater as

moonlight provides up 0.10 lux. The dimming of SLS actually improves their lighting efficiency and prolongs lifetime. Dimming of HID sources has a negative return, typically 10% light at 50% power. The color spectrum of the light is also varied in the DLF to match the intensity levels. Here an additional efficiency boost is achieved when the added scotopic eye sensitivity to 510 nm bluish white similar to the pale moonlight is taken into account.

It has been shown that certain colors of light i.e. of different spectral power distribution (SPD) are perceived to be more glaring than others in night driving. Studies of drivers (Flannagan, M. J., (1999). Subjective and objective aspects of headlamp glare: Effects of size and spectral power distribution, Report No. UMTRI-99-36). Ann Arbor: The University of Michigan Transportation Research Institute) indicate that blue-white color has been found to cause more glare discomfort than yellow light. On the other hand, studies have shown that driver night vision is better under the blue-white spectral power distribution. Recent laboratory studies have also shown, for example, off-axis detection peripheral detection can be better for bluish, metal halide lamps than for yellowish, high pressure sodium lamps at the same photopically specified light level (Bullough, J. and Rea, M. S. 2000. Simulated driving performance and peripheral detection at mesopic light levels, Lighting Research and Technology, 32 (4), 194-198). In the DLF streetlight luminaire it is possible to use the blue-white SPD to illuminate most of the roadway yet increase the cutoff angle, which is determined by glare considerations, by using yellow-white SPD light at the large angles which throw the light further along the road. The higher angle lighting provides more vertical lumens and is actually more effective at illuminating objects along the roadway. The increased visibility afforded by the added vertical lumens at high angles offsets the decrease in visibility due to the yellow-white SPD. This means that the overall visibility over the roadway sections is constant. Thus, SLS near the angle **250** would have a yellow-white non-glaring SPD while interior SLS such as **253** would have the superior blue-white SPD. The higher the cutoff angle, the fewer luminaires that are required to illuminate a roadway. The same differentiation would be possible with SLSs **255** in the side view of which some illuminate the sidewalk **257**, some the right lane and others the left lane. The SPD of the SLSs at the high glare causing angles **250** facing the oncoming driver aimed to cover the near lane would be yellowish while those SLS covering the same lane but now to the rear of the receding driver, will still be of bluish-white SPD. The opposite is true for the far lane. The SPD of the SLS aimed **257** at covering the sidewalk would again be in the blue-white to aid in peripheral vision detection of pedestrians or objects approaching the roadway from the side.

As with all correct lighting practice the visual surroundings at any instant in time determine the amount of illumination required to carry out visual tasks including the luminance of background surfaces. Roadway luminance as detailed in the IES Handbook pages 751-779, is the preferred factor used in specifying required illumination levels. Freshly paved blacktop with its diffuse reflection will change over time to a mostly specular reflection. The higher luminance value pavement requires less illumination to see objects. This characteristic changes over time with wear and periodic road maintenance and illumination levels need to vary accordingly. A detection by **258** of this road luminance will provide the controller will the data necessary to set the required illumination. Roadway activity is another factor in determining illumination levels. This factor often changes over days of the week or seasons of the year. An adaptive DLF with detectors **258** and computer devices **246** capable of recording this traffic activity will provide the correct illumination for the traffic situation at hand.

Though the design of a streetlight has been detailed the same design process is valid for floodlights and other outdoor lighting applications. The use of the SLS of specific spatial candlepower distributions at particular aimings, the use of tighter beams at the edges of coverage, the non-glare design and the optional use of logical control are as applicable to DLF floodlight design as to the street light design.

FIG. **14** is a flow chart which illustrates the general design concept which allows anyone to build a multi-light source lighting fixture from the ground up, tailor made to the final application. This process differs fundamentally from prior art lighting fixture design. Rather than building a fixture around a common lamp and then coercing the usually isotropically radiating lamp to perform in a certain application, the lighting application is used to describe the light source construction. The light source construction is unique in that its flux density is spatially differentiated over its volume in concert with its final orientation when in use. The light source design then defines the supportive power, control and mechanical elements. These elements are then integrated into a single unit with shared components and packaging. The method for designing an application oriented luminaire designed according to correct lighting practice, providing the correct light intensity, spectrum, and spatial distribution of intensity and spectrum, suited to the specific lighting application, would comprise a number of steps some of which can be left out of the process while others may be added including a) determining the lighting application, and the recommended lighting practices for the application b) determining the luminaire mounting height, illumination area covered and surrounding conditions typical of the application c) determining candlepower required to effect the required illumination over the area d) selecting SLS types capable of producing required intensities and spectrum at highest conversion efficiencies at lowest economic cost e) determining SLS beam spreads f) determining SLS aimings for the required distribution pattern g) determining electronics to control and power SLS h) determining lighting fixture surface geometry and size i) testing whether the glare rating for the viewing angle is acceptable j) if the glare rating is not acceptable, then changing SLS beam spread, fixture geometries, or size, resulting in an acceptable glare rating; and, h) when the glare rating is acceptable, then designing the luminaire aesthetics for the application.

The digital lighting concept is extended to transportation vehicle applications. A headlamp for an automobile uses multiple light sources based on electro luminescence of semiconductor junctions. The proposed unique approach is to combine the lighting engineering function i.e. the correct light distribution, color spectrum and level necessary for the visual task at hand into the lamp, such that the digital lamp obviates the need for additional light controls and fixtures. The digital electronic lamp utilizes ⅓ the energy and has over 100,000 hours lifetime versus 2000 for an automotive incandescent lamp and can be rapidly switched on and off without deleteriously affecting lifetime (Quite the opposite, off time is not part of the lifetime). The multiple light-source, digital device, is an electronic headlight which provides the driver with the correct aiming, illumination level and distribution (e.g. parking lights, low beam, high beam, lighting around curves and corners) based on input from the vehicle's speed, steering wheel position, turn signal indicator and detection of approaching headlights. These

functions are carried out automatically however; the standard manual override controls are still maintained.

Headlamp glare is addressed in two alternate ways. European regulators recognize the danger presented by excessive headlamp glare, and so European cars with HID lamps must have dynamic headlamp leveling. On-the-fly headlamp vertical aim adjustment has been required by European directives for quite some time now, but dashboard dial control of the vertical aim is no longer acceptable. Recent European regulations require that the headlamp leveling of HID-equipped cars be linked to the suspension system of the car so the lamps don't glare as much to oncoming traffic when the rear of the car is loaded-down or the car is heading up a small hill. The digital headlamp solves this problem by automatically sensing the angle of the headlamp assembly and will employ in real time only the properly aimed light sources to illuminate so as not to glare oncoming traffic.

An alternate method of glare control is accomplished by rapidly switching on and off the headlamp light output or only the high beam portion thereof at such a rate that flicker is not observed by the driver. This persistence of vision is the same effect on which motion picture viewing operates using shutters to intermittently block the light while the frame changes. On the oncoming vehicle, a variable light transmitting element, an electronic shutter, located in the driver's field of view is rapidly switched to a blocking state synchronized in time with the on state of the oncoming car's headlamp. The situation is vise versa for the driver in the other vehicle such that in the instant one driver is seeing the other is not.

The Spectral Power Distribution, SPD, of the headlamp is also variable as a function of the area being illuminated. Studies by Flannagan cited earlier, have shown a preference by drivers for yellow tinted headlights on oncoming vehicles. The drivers find the yellowish colored light of an incandescent less glaring vs. the bluish "white" light of an HID Metal Halide lamp. On the other hand, recent studies by Bullough, cited earlier, on driver's peripheral night vision show the clear benefits of HID MH headlamps in detecting pedestrians and objects along the side of the road. Thus, an ideal solution is to have the SPD in that part of the beam visible to oncoming drivers be of the less glaring yellowish type while the beams headed everywhere else would be of the blue-white SPD for increased driver visibility. In fog or snow the color spectrum would also be adjusted so as to maximize visibility. Yellow colored lights are used in fog and snow conditions to prevent flashback. Thus, according to the teachings of this invention the DLF headlamps serve as the fog-lamps. The digital headlamp will automatically or manually be adjusted to the optimal intensity and SPD lighting parameters for the environmental conditions at hand.

Present advances in automobile lighting include Adaptive Frontal-lighting Systems which aid in seeing around curves and other features in the road. In these systems the light distribution pattern and color spectrum will be changed according to the instantaneous road conditions at hand. Thus, the headlamp now has much more flexibility than the high beam/low beam variation of today. At any instant in time the intensity, spectrum and beam pattern of the headlamp may be varied as a function of the driver's intent, lay of the road and environmental factors. A GPS system on the car may also let the headlamps system know of curves up ahead, one-way traffic and others factors such the headlamp may be operated in the optimal mode at that instantaneous location. With sensors sensitive to environmental surroundings such as ambient light, fog or snow conditions etc. lighting can be adapted to the optimal operating regime.

Additional features include an optional concentrated flashlight type of beam to illuminate distant overhead and roadside signs, which due to the narrow, directed beam will not blind oncoming traffic. Image recognition via a camera will allow the beam to follow the retroreflective sign as the vehicle moves or the signs will be provided with a special marker for this purpose. In this way the headlamp cutoff above horizontal except for the concentrated sign beam can be total.

FIG. **15** illustrates a preferred embodiment of a digital automotive headlamp. A headlamp is a specialty lighting application unrivaled in terms of the need for controllability and is especially suitable to the methods and devices described in this disclosure. The headlamp fixture is unique in the continuum of beam patterns, intensities and color spectrum. The number of possible control modes are: 1. Parking Lights. 2. Low Beam lights; 3. High Beam; 4. Cornering Lights; 5. Load leveling adjustment; 6. Integral turn signal indicator, 7. Programmable alternate beam spread selection so that one headlamp fulfills the different sets of legal regulations for the high and low beam in different regions of the world such as the U.S.A., Japan and Europe; 8. Driver preferential color; 9. Oncoming vehicle or vehicle-ahead driver's preferred color 10. Color of ambulances extra headlamp provides red flashes to be more easily picked up in rear view mirror; and 11. Non-Glaring pulsed headlamps.

Input data to the controller would first and foremost be in the control of the driver and would consist of an overriding manual selector switch. Otherwise headlamp control is automatic, from turning on automatically when ambient lighting levels fall to such a level where it is advantageous to have headlamps on, either to aid in illuminating the way ahead or facilitate being seen by others, to automatic dimming of high beam due to detection of oncoming vehicles and shut off when ambient lighting levels are sufficient. A possible control system for such purposes is described in U.S. Pat. No. 6,281,632 by Stam, et-al from Aug. 28, 2001 titled: A Continuously variable headlamp control incorporated herein by reference. The patent describes how continuously variable headlamps offer greater flexibility for roadway illumination but offer challenges in automatic control design. Each continuously variable headlamp has an effective illumination range varied by changing at least one parameter from a set including horizontal direction aimed, vertical direction aimed, and intensity emitted. Stam discloses a system for automatically controlling continuously variable headlamps on a controlled vehicle includes an imaging system capable of determining lateral and elevational locations of headlamps from oncoming vehicles and tail lamps from leading vehicles.

Using a control system such as that above, many driver functions are automated. With the digital headlamp, automatic control of headlight beam is a function of speed of travel, that is: when vehicle is in Park the parking lights are on, when speed is low the lamp beam is aimed sufficiently forward to give ample reaction to brake for objects in the vehicle's path per the speed it is traveling up to the intensity, angle and thus distance which is the upper legal limit for the beam. If there is no oncoming traffic, then it operates as the high beam. If there is oncoming traffic, then it acts as the regular low beam.

Additional features can include an optional very narrow flashlight type of beam. Present day LEDs come in very narrow aimings such as two half angle 8 degrees which may

not be narrow enough (a 10 meter spread for 150 meters down the road which may be sufficiently aimed to the right) but with need, smaller angles are also feasible. Such a beam at the correct narrow aiming can continue to illuminate far ahead (in high beam) without blinding oncoming traffic. Analysis by a detector or an imaging system of the oncoming vehicles position (using its headlights for example) can be used to determine which exact aiming is the maximum allowable for any given traffic situation and road layout.

Using color and pattern recognition techniques it is possible to determine what is a sign. It is then possible to provide the equivalent of "task lighting" and use the controller and properly aimed SLS to follow and illuminate distant overhead and roadside signs for a longer time, yet not blind oncoming traffic due to the narrow beam.

Wavelength specific SLSs in the infrared or near Ultra Violet spectrum, not visible to the driver by the unaided eye are used for communication between vehicles and roadway controllers or toll booths. Infrared SLS will provide radiation to be reflected from objects for night vision cameras. UV SLS are used for or illuminating UV fluorescent dyes in clothing bicycles and baby carriages to increase pedestrian visibility as is known in the art.

In FIG. **15** a headlamp **270** of a land, sea or air vehicle **271** is shown in front view **272**, side view of a section **273** and top view of a section **274**. A discrete SLS light source such as an LED **275** with specific location within the cluster **276** has a specific spatial light distribution, color wavelength and aiming relative to the vehicle, such as straight ahead, and or downwards and or off towards the right or left. The SLS may have one junction and be monochromatic or have many junctions and provide a wide spectral power distribution and the power to the SLS may be varied. An SLS can also be a "white" LED. For example, a typical "white" LED such as a Luxeon® white LED such as LXHL-XXXX will have a colder "bluish" 4,500K color temperature. LED **277** at a second location within the same cluster may have a similar or dissimilar aiming, wavelength and spatial light distribution. The concept cluster shown by the dashed lines, is used to describe a control function and is not necessarily related to contiguous placement. In general, a cluster may be deemed a separate grouping due to a function it performs, either exclusively or in conjunction with other clusters or sub-clusters, such as high beam function versus a second cluster **278** which may provide a parking light function. The same SLS may be used, albeit at different intensities, for both the above functions and thus clusters may overlap and be discontinuous. As two LEDs may be of different wavelengths, operating in unison at different power levels will yield a variable light "color". A possible combination of two or more LEDs such as a blue, 470 nanometer and an amber **590**, nanometer wavelength LED would yield a "white" light similar to the yellow tint of sunrise at the correct power intensity setting for each lamp. Coincidently aimed LEDs **275** and **277**, at the correct output intensity of each LED, with more power in the amber will accomplish this. Thus, when following another vehicle, assuming, as drivers have reported, that they find yellow incandescent colored headlamps less offending than the HID blue-white color, the external controller **279** which receives traffic data from sensors **280** would shift wavelength specific radiant power contributions of SLSs such that the resultant on the CIE chromacity diagram would be yellowish. If, however, there is no car immediately ahead or oncoming traffic, then assuming as drivers reported they see further with bluish light, then the energy of the 490 nanometer LED is increased, and the resultant color will shift to bluish white, allowing the driver to better ascertain road conditions further up ahead. The LEDs, their packages, wavelength and light source type are mentioned by way of example and it is clear that any other types of discrete light sources, such as the chip **95** of FIG. **6**, with differing aimings wavelengths and distributions could be used to accomplish the same functions.

To further illustrate the innovative DLF headlamp device, a cluster **281** would be used to illuminate around a corner. Thus, when the turn indicator has been selected or the steering wheel has been rotated by the driver, the DLF headlamp is powered by the controller to illuminate sideways at angles which according to the speed of travel is correct. (A driver can't make a 90-degree turn traveling 90 km/h but from a stop, the turn may be around a corner.) In a preferred embodiment a multitude of LEDs in **281** are differently aimed in top view **274** showing the top view of the cluster **282** with SLS **283** angled less outwards and SLS **284** angled more outward with the forward aiming (distance ahead of the vehicle) of the more angled SLS **284**, closer in for illuminating sharp turn, than that of the less angled SLS **283** for a shallow curve. Side sectional view **273** shows a general downward aiming with SLSs of front view **272** cluster **285** corresponding to cluster **286** shown from the side. The cluster **286** is the most angled downward such as for a slow driving as in a parking light type of application where the idea is not to cause glare yet to be seen. The parking light function can also be done with higher angled LEDs by just lowering the intensity to very low non-glaring intensities. Cluster **287** of the front view would be the main illuminating workhorse and is shown in side view **273** as angled SLSs in cluster **288** and top view **274** as cluster **289**. The top cluster **276** shown in side view **273**, as **290** would perform alone or in tandem with part of **287** the high beam lighting function.

Many more degrees of flexibility are possible with the digital headlamp by varying the timing of the LED operation. For example, more intense illumination of red LEDs for a fraction of time would give the effect of flashing ambulance lights if required by the type of vehicle and could be effected by programming alone without the need for a different type of headlamp greatly reducing the different types of headlights that need to be installed on a vehicle or maintained in inventory. That is the same MSLS light engine device could be placed in different aesthetic packages by different manufacturers and could provide different functions. In one embodiment the digital headlamp carries out all the functions in a single unit **270**. SLSs have different locations and aimings **291** and **292** to carry out the functions. In another embodiment **293** the spotlight sign illuminating function or corner lighting function is in a separate package **294** with its aiming **295**. The low and high beam lighting is accomplished with fixture **296** and its general aiming **297**. The separate units may be dictated by design or sales considerations and yield more flexibility but are within the scope of the overall integral digital lamp headlight device. The controller **279** will addresses the power supply of each DLF headlamp **270**, **296** and **294** independently such that each lamp performs its functions separately.

In another embodiment FIG. **16** the digital headlights **300** and **301** on vehicle **302** are also part of an anti-glare system operating between two or more vehicles **303**. The system is designed to prevent discomfort and disability glare from oncoming headlights or glaring headlights viewed in the rear view or side mirrors. The anti-headlight-glare system works based on the "persistence of vision" of the human eye-brain system and is accomplished by the synchronization of the

illuminating and light attenuating or blocking devices which intermittently enable the driver to see the night scene ahead but not the counter-timed glare of oncoming vehicles. The elimination of blinding glare will increase traffic safety, as a driver may lose vision may for a number of seconds following a glare event. It will also prevent driver fatigue caused by glaring headlights. Another of the advantages of the anti-glare system is that it increases the distance that a driver can see at night by allowing the use of more powerful headlamps aimed at higher angles, thus illuminating more of the road ahead while not blinding oncoming traffic. The anti-glare system consists of pulsed headlamps **304** and **305** on the oncoming vehicle **303** and a synchronized on/off switched light filtering or blocking element **306**A in between the driver's eyes **307** and the glare sources **304** and **305**. The light attenuating element is normally highly transmissive of light i.e., see-through. When energized, the light-attenuating element turns non-transmissive and attenuates or totally blocks the glare intensity. The attenuating element is similar in operation to the fast-acting automatic darkening welding helmets commercially available, only here the off switching is also very rapid. The glare, or light-attenuating element may be the windshield, a part of the windshield be a specific element located on or within the windshield **306**A and **308**A or on a visor located in front of the driver shown in **306**B and **308**B. The light attenuating device **306**A or **306**B is synchronized with the oncoming headlight such that when low-beam or even high beam, glare causing headlamps **300** and **301** of vehicle "one" **302** is "on" the light attenuating device **308**A or **308**B on vehicle "two" **303** is toggled into a mode which reduces or totally blocks the light beams. Conversely, in the next instant, when the headlamps **304** and **305** of vehicle "two" **303** is "on", that is, in the glare causing mode, the light attenuating device **306** on vehicle "one" **302** is switched into a mode, which reduces or totally blocks the light beams. The light-attenuating device **306**A or **306**B consists of an LCD, ferroelectric, SPD, electrochromic or any other medium that can be switched between substantially light transmitting to substantially light blocking in the form of a screen, visor or film. It may be placed on the windshield from without or within, in between the glass layers of the windshield safety glass **306**A or positioned anywhere in between the driver's eyes and windshield **306**B including being worn as eye glasses. A motorcyclist would have it installed in the visor of the helmet or on a windscreen. The speed of vision is slow relative to electronic pulsation and depending on the illumination level persistence of vision will fuse on/off levels into a constant flicker free level. Motion pictures operate at 24 frames per second. For scotopic nighttime levels 10 HZ is sufficiently flicker free while at high levels of illumination 60 Hz is required. Totally flicker-free operation is assured at 120 Hz operation even for peripheral vision which is more sensitive to movement.

LEDs are excellent light sources for a pulsed lamp since they are not damaged by on/off cycling (actually off-time adds to the overall lifetime) as are the prior-art incandescent and other cathode-based lamps. Rise time to full output is on the order of microseconds, much faster than necessary. The pulsed SLS is operated at a higher power during the on-time of the duty cycle to offset for the off-time in order to produce the required illumination. This is typical of normal LED operation which may be run in DC mode or pulsed, AC operation. Actually, HID lamps cycle on/off at twice the line frequency and the eye integrates the light intensity over time. However, it should be understood that incandescent or any other lamp switchable within the constraints of the flicker free visual requirement are acceptable for use according to the teachings of this invention. In an alternative embodiment, the lamp may be a state of the art incandescent, halogen or HID lamp and the switching is accomplished by an additional light-attenuating element placed in front of the light source. Alternately, electronic signal control circuitry can rapidly switch an HID or incandescent headlamp used in the anti-glare system. The lamp need not totally turn off, the requirement is that during the seeing portion of time when the driver's light attenuating element is letting light through un-attenuated, the light intensity reaching the eye is non-glaring. Therefore, it shall be considered that present state of the art incandescent and HID headlamps operated in a pulsed mode fall under the realm of the present invention. That is, any headlamp system where the high beam is toggled such that it is synchronized with a light-blocking element before the driver's eyes in the approaching vehicle is included within this disclosure. It is also to be understood that the headlamps when not in high beam mode may not be totally off rather they can be in a non-glaring low beam mode. This leaves the vehicle visible to oncoming traffic.

It is to be understood that for the system to work, all oncoming vehicles using high beam synchronized blocking must be working according to the same timing among them versus all the traffic headed in the opposite direction. A timing protocol based on major heading determines the synchronization. Thus, on a substantially north south route, a train of traffic headed north will all be similarly timed, and counter synchronized with all southbound traffic. The blocking screen's timing is synchronized with the oncoming high beam headlight's timing either universally, through a global clock system such as that of the global positioning system GPS or the National Institute of Standards and Technology atomic clock broadcast over radio station WWVB located in Fort Collins, Colo. or locally through communication among vehicles in proximity to being within the line of sight. A combination of directional data together with a timing protocol based on direction will determine the synchronization among proximate north/south and east/westbound vehicles. The vehicles direction data is derived from an onboard compass or gyro or GPS to eliminate the influence of roadway curves in cases of borderline directionality, the vehicle's direction for synchronization is not the instantaneous reading but rather is based on distance traveled over time and previous headings history. A stop and turn for example will change the synchronization while a smooth curve will wait for an oncoming cars synchronization to indicate that the road ahead is actually in a new heading unless sufficient elapsed time makes it clear the car is on a new course. The protocol will give benefit to the north on a 45 degree North/East heading and to the south on a 135-degree heading. GPS location and route recognition can also be used to set synchronization protocols for opposing vehicles. In one embodiment, the communication between vehicles for synchronization is effected through the headlamps themselves either through modulations in visible light LEDs of the digital headlight itself or with LEDs, radio or infrared emitters dedicated for the purpose **173**. Detectors **174** on the vehicle, pick up the signal and signal-processing equipment passes the information on to the controlling unit **175**.

Glare attenuating elements can be placed over the mirror surfaces or the side windows where the glare from the side mirrors passes. Thus, not only the glare from oncoming headlights through the windshield is blocked but also glaring beams emanating from following vehicles, reflected off the rear and side view mirrors is controlled. To eliminate glare

off the mirror **176** from reaching the driver's eyes from the side mirrors **177**, a pulsed blocking screen or film **178** is placed on the driver facing side of the mirror's the reflecting surface. Similarly, a rearview mirror **179** is embodied with a pulsed blocking screen or film. The timing of the modes in this instance is such that the light-attenuating mode occurs at the same time as the glaring or high beam headlamp mode since all cars in the same direction are in glaring mode at the same instant. All mirrors are synchronized to block the headlight glare coming from the rear which are on at the same synchronization time as that of the first lead vehicle in the traffic train.

In another embodiment additional information used to control the headlight aiming can come from analysis of the driver's eye movement and gaze. The headlight aiming system obtains information from a driver eye tracking system concerning the driver's gaze (i.e. what the driver is looking at). Analysis of saccade can be used to instantaneously predict where the driver will end up looking and the headlight intensity in that aiming changed to illuminate the area where the driver wishes to see in advance of the driver's re-accommodation. A machine vision system using pattern recognition and other object identification techniques to discern eye gaze direction, is contrived of the camera **316** with a view of the driver's eyes, infrared emitters **317** and the computer logic system **311**. The data obtained is analyzed according to eye tracking methods and algorithms known in the art of in a computer routine **7**A to adjust the light aimings of the headlamps according to the drivers gaze at required intensities. The allowed intensities at any aiming take glare considerations into account so as not to cause offending glare. In another embodiment an outward and inward facing camera **316** is used to acquire both images of the scene ahead and the driver's gaze and using both sets of data adjust the headlamp illumination.

Accordingly, it has been illustrated in the streetlight and headlamp application the benefit of a multiple-light source illuminating device. The flexible characteristics of the DLF allow for spatial variations of the intensity and spectral power distribution of the light over the area covered. When the element of variation of intensity and SPD with time over the area covered is introduced another dimension of flexibility is introduced. These properties are unique to the DLF and allow them to deal with dynamic lighting situations in a way not afforded by prior-art lighting devices. When combined with devices capable of detection changes in the surrounding environment the flexible DLF is capable of changing the illumination so as to provide the optimal lighting solution in real-time.

FIG. **17** illustrates a power supply circuit used on a DLF such as the Surface or Railing Mount Discrete **66** or Distributed 70 Digital Lighting Fixture of FIGS. **4** and **5**. The circuit controls current and illustrates the use of two disparate LED sets one red colored with specific voltage and current characteristics and the other green colored with its own voltage characteristics. When operated in this quanta and regime of voltage and current the combined output light is whitish in color according to the earlier teachings of this disclosure.

New Preferred and Additional Embodiments

Referring now to the invention in more detail, in FIG. **18**A there is shown an illuminating or irradiating device which is capable of being adjusted in situ to match the radiation output with the actual illuminating requirements of the surround where the lighting fixture has been installed. As an example, the device is a lighting fixture and the installation is in a chemical processing plant which is an open facility with piping and vessels placed in the structure with walkways, floors and stairs made of metal grating. The walkways, vessels, machinery and piping need to be illuminated at night by lighting fixtures placed on the structural support uprights along the walkways. In this lighting application example, the walkways are at the exterior edge of the structure with the piping and machinery towards the interior. Beyond the walkway safety fence there is no structure and no need for illumination. The spatial light distribution pattern of the lighting fixture shown in FIG. **18**A can be arranged so as to illuminate inwards towards the vessels, machinery and piping as well as downward along the walkways and stairs but not outward into free space.

The lighting fixture **410** is comprised of light sources **411**. The multiple light sources are referred to as LEDs, Light Emitting Diodes which is but one type of exemplary light sources used herein. Light sources referred to in this disclosure include any of a wide range of visible and non-visible electromagnetic radiation emitting or generating devices formed from organic or inorganic semiconductor materials such as LEDs, organic light emitting diodes, OLEDs and all gaseous high and low intensity discharge lamps, incandescent filament and other solid-state light sources. The light sources **411** shown in FIGS. **18**A and **18**B have means to be coupled with apparatus for modifying the light output of LED chips or arrays of chips **412** such as a reflector **413** which yields a symmetric light distribution or an asymmetric reflector **414** which yields a substantially asymmetric light distribution. An optical lens or light guide **415**, or other refractive or diffractive device may be used to modify the light output as well as phosphors or filters within the light guide **415** which may be used to add or filter out certain wavelengths. The spatial light distribution of the light source refers to the luminous flux emanating from the light source **411** at various candle power intensities as a function of the angle. The light source **411** has a characteristic angular light distribution **416** also called herein beam spread and when installed on a lighting fixture attached to the building, object therein or lighting pole with a specific orientation in the surrounding living space, the beam axis **417** will have a particular aiming towards surfaces within the living space and therefore the light source will illuminate only the specific surfaces it is intended to fall upon. In an embodiment of the invention a light source module **411** is comprised of the one or more LED chip **412**, optical modifying device **413**, **414**, or **415**, a heat dissipative element **418** such as a heat sink and a physical and/or electrical connecting element for the LED chip **412** such as a printed circuit board **419**. In one embodiment a very narrow beam laser LED is mounted in the array of chips **412** such that it shines along the optical axis of the light module **411**. In an embodiment of the LED the beam spread has been determined on the die level without the need for additional optical modifying devices as part of the light module **411**.

A preferred embodiment of the invention is a lighting fixture comprised of many light sources of which some or all can be separately aimed and powered so as to illuminate areas, surfaces or objects in a room in a most correct, efficient and comfortable manner or for a desired lighting effect. The overall luminaire **410** spatial light distribution at various angles is comprised of that of the individual light sources. Thus, when the multiplicity of light sources having their respective light distribution patterns, which are substantially directional and subtend lesser angles than those of the overall light distribution pattern are mounted and

arranged on the lighting fixture structure their respective directional light distributions combine to form a wider overall light fixture distribution pattern. The overall distribution pattern is efficiently formed directly by the multiplicity of light sources without recourse to inefficient reflectors or refractors. Using a goniophotometer to measure over space the emanating light intensity in the various directions one obtains the overall spatial light distribution pattern of the luminaire **410**.

Using commercially available LEDs such as the Artavi 10° product from Illumitex which offers 90% of the light output in 10 degrees of the beam, it is possible to generate well controlled light distribution patterns with minimal spill light. Thus, the Coefficient of Utilization (CU) or the utilization factor of the luminaire is high. That is, the ratio of the luminous flux (lumens) from a luminaire received on the work-plane to the lumens emitted by all the luminaire's light sources alone. The Illumitex LED package emits light in a uniform, highly-precise beam directly from the source. The result is that with die-level optical integration, the need for cumbersome and inefficient secondary optics to control light is obviated. Using well defined light beams to illuminate the area allows for the floor surface in the distant corners of a square room to have the same illuminance as the floor at the nadir, directly beneath the luminaire. This results in high uniformity which is a measure of variation of illuminance over a given plane, expressed as either the ratio of the minimum to the maximum illuminance or the ratio of the minimum to the average illuminance and a measure of the energy efficiency of the luminaire system.

In order to alter the spatial light distribution, the lighting fixture **410** has apparatus such as joints and flexible electrical connections giving it the ability to morph or change shape. That is, by the alteration of fixture geometry, moving structures or arms on which the light sources are mounted or by changing the LEDs' refractor or reflector geometry, the direction of the light emanating from groups or even individual light sources is modified so as to generate an overall site specific light distribution pattern. For example, LEDs are mounted on moveable luminaire structural elements such as the end of posts, on bars or curved arms which can be adjusted to provide various symmetrical and asymmetrical illumination patterns as the installation requires. In the lighting fixture **410** the arms, such as arm **420** has apparatus to swivel around the central support post **421**. In an embodiment of the invention control electronics **422** have electronic means and circuitry configured to provide different power levels to LEDs or groups of LEDs such that the light intensity in any given direction and angular aiming may be varied as needed. In an embodiment of the invention the power supply and control electronics **422** are further defined to provide power only in the amount needed using a logical controller **428**. Controller **428** performance can be further enabled with sensor **429** providing information about the surroundings. The resulting light fixture embodiment described is thus a Field Adjustable Multiple-light-source Luminaire or FAML.

Thus in FIG. **18**A the beam spread **423** of LED **411** differs from the beam spread **424** of a LED light source **425** which may have a wider area from which the light exits so that its higher angled light output will not be as bright so as not to cause glare. An accessory reflector **426** may be used to shield from glaring rays. The method disclosed for reducing the glare from concentrated high luminance light sources is the use of light guides to reduce the luminous emittance or luminance of a very bright LED. Light guides using the principle of total internal reflection redirect the light. They may in addition be used to increase the area from which the light flux is exiting and thus reduce the luminance or luminosity of the light source.

FIG. **19** shows a light guide which can be used to redirect the light from a light source and/or increase the area from which the light is exiting in order to reduce the apparent brightness. The light guide is constructed of a transparent material with an index of refraction greater than that of air. The light guide **430** will accept light rays emanating at large angles away from the beam axis and bend the rays to smaller angles from the axis thus producing a narrow beam. Light produced by the LED **412** at various angles enters the aperture **431**. The light then bends as total internal reflection contains it within the walls of the curved light guide and exits from the light guide at surface **432** with a different aiming. More than one light guide can be used and when stacked light exiting the light source at different angle can be directed outwards at different angles or the same angle. Light guide assembly **433** is shown with two light guides stacked but many similar or different beam modifying characteristic light guides can be stacked for a unique total light distribution resulting from the source. Thus in FIG. **18**B the optical device **415** can be a light guide assembly **433** as shown in FIG. **19** which has been added over a light source in FIG. **18**A aimed at a potentially glaring angle as shown covered by the light guide assembly **433**. The exit surface **432** may be a lens, a Fresnel lens or microlens whose optical features enable precise control of uniformity, exit angle and beam spread. In addition, any of the surfaces may be covered with optical substrate or films to reduce light loss on entry or exit, frustrate the total internal reflection or filter or control the light. Light guides may also be asymmetrical.

In an alternate embodiment when using a single light source in a FAML yet an asymmetric spatial light distribution is desired, light guide assembly **434** made of light guide segments **435** is designed take light from the single light source and spatially differentiate its delivery to different parts of a room. For example, if the light fixture light source is located on the ceiling in the center of a square room and the assembly **434** is turned over so the light exits downward; then when the light exits the surface **436** with a Lambertian distribution and the segments are aimed in the direction of the corners of the room, a substantially homogeneous illumination can be obtained on a work plane near the floor in the square room. More than one segment of assembly **434** can be stacked and light guides with different light exiting directions can take the light of one light source and symmetrically or asymmetrically distribute over an area. Combined with reflective control elements **437** added within, upon the surface or external to the light guide further light control can be achieved.

While light guides are known for their ability to carry and redirect light, in this disclosure another novel embodiment of a light guide used as a light control device is its use to increase the area from which the light from the LED is exiting from thus reducing the light source luminance or glare. In an embodiment where the inlet aperture **431** cross section is small and the cross section of the light guide exit surface **432** is large there will be a significant reduction in the light source luminance and it will appear less bright and cause less glare to persons viewing it. Thus, while persons in a room would find high brightness LEDs disturbing it is possible to add optical devices that while maintaining the directionality of the illuminating beams spreads them over a larger area thus reducing the luminous emittance.

The Spectral Power Distribution of the luminaire refers to the distribution of light energy emitted by the light source