



AEROSPACE RECOMMENDED PRACTICE

ARP5560™**REV. A**

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Superseding ARP5560

(R) Safety Considerations for High-Intensity Lights (HIL)
Directed into the Navigable Airspace

RATIONALE

ARP5560 Revision A is prepared in order to incorporate the state of the art in outdoor lighting, including Laser Illuminated Lighting Instruments (LILIs) and Laser Pumped Lights (LPLs). It is also updated to reflect current terminology, definitions, and applicable documents.

INTRODUCTION

On March 26, 1999, the Federal Aviation Administration (FAA) submitted a written request to SAE for assistance in developing standards and regulations concerning outdoor laser operations. Since December 1999, SAE has developed several documents, including: AS4970, "Human Factor Considerations for Outdoor Laser Operations in the Navigable Airspace," and three aerospace recommended practices: ARP5535, "Observers for Laser Safety in the Navigable Airspace"; ARP5572, "Control Measures for Laser Safety in the Navigable Airspace"; and ARP5293, "Safety Considerations for Lasers Projected in the Navigable Airspace" in support of this request. Although the number of aviation incidents involving high-intensity lights has been fewer than with laser light sources, such incidents have occurred, and the FAA has asked SAE to develop guidance regarding high-intensity light devices.

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1. SCOPE

This document applies to regulatory/approving authorities involved with decisions regarding the use of high-intensity light (HIL) directed into the navigable airspace. For the purpose of this document, lights greater than 0.25 million candlepower meet the minimum threshold of an HIL. Lights not directed or reflected into the navigable airspace are not usually considered to interfere with aircraft operations. HILs include laser-derived light sources; other laser systems are beyond the scope of this document.

This document addresses adverse effects of HILs on humans, such as visual interference. HIL effects on Unmanned Aircraft Systems (UASs) are beyond the scope of this document.

1.1 Purpose

The purpose of this document is to provide guidance to regulatory/approving authorities on issues specific to the use of HIL directed or reflected into the navigable airspace.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 1-877-606-7323 (U.S. and Canada only) or 1-724-776-4970 (outside U.S. and Canada), www.sae.org.

ARP5293	Safety Considerations for Lasers Projected in the Navigable Airspace
ARP5535	Observers for Laser Safety in the Navigable Airspace
ARP5572	Control Measures for Laser Safety in the Navigable Airspace
ARP5598	Unauthorized Laser Illuminations: Pilot Operational Procedures
AS4970	Human Factor Considerations for Outdoor Laser Operations in the Navigable Airspace

2.1.2 ANSI Publications

Copies of these documents are available online at <https://webstore.ansi.org>.

ANSI Z136.6	American National Standard for Safe Use of Lasers Outdoors
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2.1.3 Code of Federal Regulations (CFR) Publications

Copies of these documents are available online at www.ecfr.gov.

14 CFR § 91.11	Prohibition on interference with crewmembers
21 CFR Part 1002	Records and Reports

2.1.4 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

FAA AC 70-1	Outdoor Laser Operations
FAA AC 150/5345-12	Specification for Airport and Heliport Beacons
FAA Form 7140-1	Notice of Proposed Outdoor Laser Operation(s)

2.1.5 FDA Publications

Available from Food and Drug Administration, 10903 New Hampshire Avenue, Silver Spring, MD 20993, Tel: 1-888-463-6332, www.fda.gov.

FDA Laser Notice 57	Classification and Requirements for Laser Illuminated Projectors (LIPs)
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2.1.6 IEC Publications

Available from IEC Secretariat, 3 rue de Varembe, PO Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 0211, www.iec.ch.

IEC 60825-1	Safety of laser products - Part 1: Equipment classification and requirements (especially re: 4.4 on conventional lamp)
IEC 62471	Photobiological safety of lamps and lamp systems

2.1.7 TNO Publications

Available from TNO, Anna van Buerenplein 1, 2595 DA The Hague, Netherlands, Tel: +31 88 866 00 00, www.tno.nl.

TNO-DV 2009 C264	The outdoor use of lasers and other high intensity light sources in relation to air traffic safety
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2.1.8 Other Publications

Threshold Limit Values (TLVs) for Chemical Substances and Physical Agents & Biological Exposure Indices (BEIs), American Conference of Governmental Industrial Hygienists (ACGIH), Cincinnati, OH.

2.2 Definitions

The definitions of the terms listed below are based on a pragmatic rather than an academic approach. The terms defined are therefore limited to those that are specific in the context of this aerospace recommended practice. This list is not intended to constitute a dictionary of terms used in the lighting field as a whole. For some definitions, examples of typically used units are given; however, other units may also be used.

AERONAUTICAL STUDY: A study conducted by the FAA to determine the relative safety of certain proposed operations in the National Airspace System.

AFTERIMAGE: A visual interference effect that persists after the source of illumination has been removed, for example, a reverse contrast shadow image left in the visual field after an exposure to a bright light (e.g., flashblindness from a camera flash). An afterimage may be distracting and disruptive and may persist from several seconds to several minutes.

BEAM DIVERGENCE: A measure of the increase in diameter of a light beam with distance from the exit aperture.

BLACKBODY RADIATOR: A thermal source of radiant power.

CANDELA (cd): The basic unit of luminous intensity adopted under the International System of Units (SI); equal to 1/60 of the luminous intensity per square centimeter of a black body radiating at the temperature of 2046 Kelvin (K). Candela is the measurement of light at the source of illumination.

CANDLEPOWER (cp): Candlepower is a measure of luminous intensity. In general use, candlepower is considered to be synonymous with candela.

FLASHBLINDNESS: A temporary visual interference effect that persists as an afterimage after the source of illumination has ceased, e.g., from a camera flash. The afterimage from flashblindness can persist from several seconds to several minutes. Flashblindness is not associated with biological damage.

FLIGHT HAZARD ZONE: Areas within the navigable airspace defined by the FAA, usually around runways and airports, in which any visible laser light must not expose aircrews to light above specified levels for the zone, in order to prevent interfering visual effects, such as glare, flashblindness, or afterimage. See Appendix E.

FOOT-CANDLE (ft-c): A unit of illuminance on a surface that is everywhere 1 foot from a point source of 1 cd.

GLARE: A temporary disruption in an individual's field of vision caused by the presence of a bright light within an individual's field of vision (for example, an oncoming car's headlights). Glare is not associated with biological damage. Its effect only lasts as long as the light source is present within the individual's field of vision.

HIGH-INTENSITY LIGHTS (HIL): Lights exceeding 0.25 million candlepower that are projected into the navigable airspace (e.g., searchlight, handheld spotlight, etc.). These may produce visual interference effects at significant distance and may warrant hazard controls. HILs are extended sources, not point sources as in traditional laser beams.

ILLUMINANCE: A measure of the irradiance on a surface multiplied by an appropriate factor to adjust for human visual sensitivity. Measurement units are typically lumens per square foot or lumens per square meter (lux).

IRRADIANCE: The intensity of the laser beam over a given area, expressed as power per unit area, e.g., milliwatts per square centimeter (mW/cm²) or watts per square meter (W/m²). Irradiance is used for power (watts), while radiant exposure is the same concept for energy (joules).

LASER-DERIVED LIGHTING SOURCE: A family of light-emitting sources that begins with laser light and is made incoherent and modified inside the device so that the resulting emitted light is similar to conventional non-laser light sources. These types of sources "function as conventional lamps," according to IEC 60825-1, and are classified under IEC 60825-1 and IEC 62471 as appropriate. Includes these three main types:

- **Laser Illuminated Lighting Instrument (LILI):** A fixture used for lighting in entertainment, architecture, and other professional applications where the original light source is generated in part or exclusively from laser light made incoherent and modified so it can be used in a manner essentially identical to conventional high-intensity lighting. Because the original laser light is extensively modified, safety considerations for LILIs are essentially the same as for the light from HILs.
- **Laser Illuminated Projector (LIP):** A projector for video or digital motion picture applications where the light source is in part or exclusively from one or more non-scanned lasers.
- **Laser Pumped Light (LPL):** A light source or fixture incorporating a laser that optically pumps a non-laser light source (generally fluorescent) where the emissions are in part or wholly non-laser light. LPLs are used in products such as automobile headlights.

LUMEN (lm): A unit of luminous flux equal to the amount of light given out through a solid angle of 1 steradian (sr) by a point source of 1 cd intensity radiating uniformly in all directions.

LUMINANCE: Photometric measure of the density of luminous intensity per solid angle per unit area emitted from the source. The SI units for luminance are candles/cm² [lm/(cm² sr)] or candles/m² (1 ft-c = 10.8 lux and 1 lux = 0.0929 ft-c).

LUX (lx): A unit of illumination equal to 1 lm/m²; 0.0929 ft-c.

NATIONAL AIRSPACE SYSTEM (NAS): The common network of U.S. airspace; air navigation facilities, equipment, and services; airports or landing areas; aeronautical charts, information, and services; rules, regulations, and procedures, technical information, and manpower and material. Included are system components shared jointly with the military.

NAVIGABLE AIRSPACE: As defined by the FAA, navigable airspace consists of airspace that can contain aircraft. In this document, navigable airspace is usually limited to airspace that is 500 feet (152 m) above the ground or from any structure in semi-populated areas. In heavily populated areas, aircraft are required to allow more distance from structures. Near airports or heliports, navigable airspace extends to the runway. Helicopter operations may require additional considerations, since they often fly below 500 feet.

OPTICAL RADIATION: Nonionizing electromagnetic emissions in the ultraviolet, visible, and infrared wavelength ranges.

PROPONENT: A person or organization who provides the FAA with information regarding the safety of a proposed operation.

RADIANCE: Radiant flux or power output per unit area per unit source solid angle (watts per square centimeter per steradian).

RADIANT EXPOSURE: Surface density of the radiant energy received. Typical unit: joules per square centimeter.

RADIANT INTENSITY: Radiant power emitted by a source per unit solid angle (watts per steradian).

SAFETY OBSERVER: One who has been tasked with observing the airspace through which a HIL beam is being projected to ensure that the beam does not illuminate any individual or object that could be injured, impaired, or damaged as a result of such an exposure. The observer is trained and has the ability to immediately terminate the HIL.

SOURCE: Light that is emitted from a lamp or similar (such as a laser).

VISIBLE RADIATION (light): Electromagnetic radiation that can be detected by the human eye. For purposes of this document, visible radiation includes wavelengths in the spectral region of 390 to 780 nm. Light within this range can produce visual response that can interfere with the safe performance of sensitive or critical tasks.

3. BACKGROUND

3.1 Physics of Light

The pertinent characteristics of light from HIL in the navigable airspace revolve around questions of illumination intensities great enough to cause physical harm to humans or aircraft. However, the effects of HIL projected into the cockpit that can interfere with the aircrew performing their operational duties are more relevant.

Searchlights are considered a “collimated” light source. This is a column of light whose rays are projected in parallel. In the case of searchlights, the rays are approximately parallel, and the light beam may expand by 3 degrees. Searchlights within a few meters of the aircraft cannot cause physical damage without prolonged exposure times.

A laser, by comparison, can be tuned and focused so that it functionally emits only a single wavelength of light. This narrow band emission remains well focused over distance as opposed to a searchlight. This focusing improves the visibility of a laser to the aircrew and allows the deliverance of more power within a defined area. As a result, lasers may cause physical damage to both humans and aircraft at extended distances.

The major energy output of a laser is a specific wavelength. Helium-Neon lasers, for example, primarily produce energy at 632.8 nm, in a coherent beam. However, searchlights produce light across a broad spectrum. The typical searchlight bulb or carbon arc light source will produce significant energy from at least 280 nm through 1500 nm. The primary output of the searchlight is from approximately 400 to 700 nm, which is within the visible light spectrum. There may also be significant ultraviolet (UV) and infrared (IR) radiation output from searchlights, especially from older or industrial types of searchlights. However, beyond 100 m, UV and IR exposure presents virtually no risk to the human eye and skin.

3.2 Bioeffects and Physiology of Vision/Vision Effects from High-Intensity Lights

The eye consists of the cornea, anterior chamber (a fluid-filled space between the cornea and the lens), the crystalline lens, vitreous, and retina. The retina contains the photoreceptor elements that, when stimulated by light, send signals to the brain that are perceived as vision. The fovea is the part of the retina on the central visual axis and contains the highest concentration of cone receptors. Cone receptors are responsible for color vision and also fine visual acuity often exceeding the standard 20/20 measurement. This range of vision is called photopic vision. The cones function best in relatively bright light such as daylight. The more numerous rod receptors are found in the peripheral retina and are 1000 times more sensitive to dim light than the cones. This range of vision is called scotopic vision.

Intrabeam viewing of HIL can exceed exposure limits of the eye that can result in eye damage. Fortunately, the eye's natural aversion response can help to limit the potential for permanent retinal injury (i.e., blindness). At much greater intrabeam viewing distances, up to 1 mile, viewing can cause visual impairment, particularly to aircrews in subdued lighting. HIL can be so intense as to bleach the photoreceptor pigments resulting in visual impairment, such as glare, flashblindness, and afterimage. Visual interference effects are discussed further in Appendix E. These are normally temporary, although some effects can last for several minutes. Additionally, light scatter from opacities within the different structures of the eye can result in loss of visual performance.

Airports use rotating beacons, which produce flashes not unlike a lighthouse, to aid the aircrew for navigation, and these lights are operated routinely without creating additional concerns.

HIL sources are inconsequential during certain atmospheric conditions, such as rain, clouds, dust, smoke, etc. The light is rapidly dispersed by the microscopic particulates in these conditions, reducing their visibility and increasing light scattering. The illumination of a cloud by a searchlight would be visible in subdued lighting.

4. APPLICATIONS OF HIL

HIL have numerous applications that may have an impact on aircraft operations. The following are some examples of these bright light sources.

- a. **Search Lights/Advertisement Lights/Entertainment Lights:** These lights may be stationary or moving in a pattern that may be either predictable or unpredictable. These systems may project one or multiple beams of light. These lights are generally more powerful and more expensive than other lights addressed in this section and are more likely to be used by professionals in the lighting industry. The larger lights require a substantial power source.
- b. **Handheld Spotlights:** Handheld spotlights are readily available to the general public. These may be battery powered or operate on an external power source.
- c. **Portable Lighting Systems:** These systems are used for a number of activities including night construction, temporary parking lots, entertainment venues, etc. These systems are being utilized with increased frequency and include high powered, large aperture lights in arrays. These generally consist of lights on a tower and a generator mounted on a trailer.
- d. **Stadium Lights:** These lights are used to illuminate outdoor events. They are normally large arrays, fixed in location and direction.
- e. **Architectural Lighting:** These are generally pointed upward and toward a building. They are used to wash a building in light and therefore are defocused and would have a limited impact on aircraft operations.
- f. **Beacons and Lighthouses:** These lights are generally used in navigation for both aviation and maritime activities. Beacons and lighthouses are used to mark fixed hazards and to help identify airports and landmarks.

4.1 Directed HIL Sources

4.1.1 Carbon Arc

An older technology would be carbon arc searchlights, which are still in use today. Positive/negative rods are energized by direct current. When the current is passed through the rods, an arc is created in the gap between the ends of the rods.

The principle of the electric arc is still used today by many older entertainment lights and film projectors, used in entertainment facilities around the world. Modern entertainment lights and projectors now tend to rely on high-intensity discharge lamps.

4.1.2 Enclosed Arc

Depending on rated wattage and intended application, the arc length of these lamps may vary from about a third of a millimeter to 4 cm. These lamps have the highest luminance and radiance of any continuously operating light source and are the closest approach to a true “point” source. The bulb is made from optically clear quartz material of various grades and has a spherical or ellipsoidal shape. The most widely used material for the electrodes is tungsten.

Most compact arc lamps are designed for direct current operation. This results in better arc stability and substantially longer life. DC systems consist of an igniter and a regulated power supply. High voltage pulses (up to 50000 V) ionize the gas between the electrodes and heat the cathode tip to incandescence. Higher wattage lamps do not necessarily yield more light intensity. When higher illumination intensity is needed, lamps must be selected with greater brightness, and this does not always increase with lamp wattage.

4.1.3 High-Intensity Discharge

The technology in high-intensity discharge (HID) lighting is an arc established between two electrodes in a gas-filled tube that causes a metallic vapor to produce radiant energy. This process allows a combination of factors to concentrate much of the emitted energy within the visible wavelength range. The electrodes are close together and the gases in the tube may be highly pressurized. This allows the arc to generate extremely high temperatures, causing metallic elements within the gas atmosphere to vaporize and release large amounts of visible radiant energy. The main types of HID lamps are xenon, mercury vapor, metal halide, and sodium.

All of the above HIL lamps require a warm-up period prior to full illumination after which time they produce a relatively stable emission. These lamps are intended to be used in a continuous fashion. Frequently turning the lamp off and on reduces the lamp life. As the lamp ages, the light output decreases.

Low-pressure sodium, high-pressure sodium, and metal halide lamps consist of electric arcs, operating in a gaseous environment, sealed within a glass tube or bulb. HID light sources are more efficient than electric filament lamps; however, they also have limited color-rendering abilities due to their concentration of increased emission of energy at specific wavelengths in the spectrum. Many HID lamps are now provided with a phosphor coating on the inside of the bulb. This coating causes additional secondary emissions of visual radiation, providing wider bands of light and color. Typical applications include industrial, commercial, and architectural lighting.

The technology in high-intensity discharge lighting is in some ways similar to fluorescent technology: An arc is established between two electrodes in a gas-filled tube, which causes a metallic vapor to produce radiant energy. In this case, however, a combination of factors shifts the wavelength of much of this energy to within the visible range, so light is produced without the use of any phosphors. In addition, the electrodes are no more than a couple inches apart (at opposite ends of a sealed “arc tube”). This allows the arc to generate extremely high temperatures, causing metallic elements within the gas atmosphere to vaporize and release large amounts of visible radiant energy. There are four main types of HID lamps: mercury vapor, metal halide, xenon, and sodium. The names refer to the elements that are added to the gases in the arc stream, which cause each type to have somewhat different color characteristics and overall lamp efficiency.

4.1.4 Xenon and Mercury/Xenon

Mercury vapor or halide lighting is the most common HID technology. The mercury arc produces a bluish light that renders colors poorly but improves the efficiency over incandescent lamps. Many mercury vapor lamps have halide additives that improve the color rendering index (CRI).

Xenon lamps are high-pressure, compact arc lamps that typically reach 80% of final output within 10 minutes of starting. The arc color is close to daylight (6000 K). The spectrum is continuous in the visible wavelength range and extends both into the UV and near infrared (800 to 1000 nm). Xenon lamps are available for operation in either a vertical or horizontal position.

Mercury/xenon lamps contain a specific amount of mercury and a small amount of xenon added at a pressure exceeding 1 atm. The xenon is necessary to facilitate starting and to sustain the arc until the mercury is fully vaporized; it also reduces the warm-up period. Normal warm-up time is 10 to 15 minutes. Typical steady state voltage of a mercury/xenon lamp is higher than that of a xenon lamp. The output in the visible range consists mainly of four mercury lines and some continuum, due to the high operating pressure. A properly warmed lamp will show no significant trace of the xenon gas spectrum.

High-pressure mercury lamps are sensitive to cooling because the bulb temperature determines the vapor pressure. Some of the lamps may be water-cooled. Chilled water may decrease the operating voltage and interfere with the proper evaporation of mercury. In some cases, the mercury may not evaporate at all, causing unsuitable performance and shortened lamp life.

4.1.5 Metal-Halide Gas Discharge Medium Arc-Length Lamps

Metal-Halide Gas Discharge Medium Arc-Length Lamps (e.g., HMI® as the registered trademark of Osram Lighting). The “H” stands for mercury (Hg), the “M” indicates presence of metals, and the “I” refers to the addition of halogen components (iodide, bromide). Originally designed for television lighting, they are now used for location film lighting and as a source for many common entertainment lights. The modern HMI® lamp produces a spectrum similar to daylight with a color temperature of 5600 K.

4.1.6 Laser-Derived Lighting Devices: LILs and LPLs

Laser Illuminated Lighting Instruments (LILs) and Laser Pumped Lights (LPLs) both use laser emission to generate light which, when it emerges from the lighting fixture’s aperture, is equivalent in safety to conventional lamps and HILs. There are two ways to generate the light:

- RGB mixing starts with red, green, and blue laser light sources. These are combined and are made incoherent. The beam is white when all three lasers are on. By mixing the relative amount of the three laser sources, any color can be generated.
- Laser-pumped phosphors use blue laser light to illuminate a phosphor which emits yellow light. Some portion of the blue laser light which is not absorbed by the phosphor mixes with the red and green in the yellow, resulting in white light.

LILs can use either of the two techniques; LPLs by definition use the laser-pumped phosphor technique.

In a LILI, the beam emerges from the instrument about 6 inches in diameter. It can be focused to a divergence (spread) of 1 to 7 degrees (17.5 to 122 mrad). Compare this to a conventional laser with a divergence of around 0.5 to 5 mrad. The beam from a LILI is very uniform. There is no bright center and no hot spots.

Both lights are “extended sources,” not “point sources” like conventional lasers. This means that there is a limit to how concentrated LILI and LPL light can be focused on the eye’s retina. Conventional laser light appears to the eye as a point source. It can be focused by the lens of the eye to a vanishingly small spot 25 µm or less in diameter. This extreme concentration, high power density, and consequent heating of the retina is why laser light is potentially much more hazardous than conventional extended sources which include HILs, LILs, and LPLs.

4.1.6.1 Safety Evaluation as Lasers and as Light Sources

LILs, LPLs, and other laser-derived light sources are evaluated as “a laser being used as a conventional lamp source” under part 4.4 of the laser safety standard IEC 60825-1, “Safety of laser products - Part 1: Equipment classification and requirements.” Based on a laser-derived light source’s particular characteristics, its laser class designation such as Class 1, 2, 3R, 3B, or 4 is first determined.

Section 4.4 then describes when and how laser-pumped light sources are to be evaluated for safety purposes as if they were conventional lamps using the lamp safety standard IEC 62471, “Photobiological safety of lamps and lamp systems.” Under IEC 62471, all types of lamps—including conventional lamps, HILs, LILs, and LIPs—can be determined to be in one of four “Risk Groups”:

- Exempt: No photobiological hazard
- Risk Group 1: Low risk; no hazard under normal behavioral limitations
- Risk Group 2: Moderate risk; does not pose a hazard due to bright light aversion response or thermal discomfort
- Risk Group 3: High risk; hazardous for even momentary exposure

Note that these Risk Groups are for exposure close to the lamp source. Just as an exposure to a Class 4 laser can be considered safe beyond a specified distance (the Nominal Ocular Hazard Distance), a Risk Group 3 lamp can be considered safe beyond a specified distance.

Many conventional high-intensity lighting sources are classified as Risk Group 3 but historically have not posed a hazard to aircraft in navigable airspace due to the distance from the lamp.

4.1.6.2 Analysis and Control of LILs and LPLs

If a LIL or LPL is classified as Risk Group Exempt, 1, or 2, then no special controls are needed for use in the navigable airspace. Use the same controls as for lower-powered high-intensity light sources.

If a LIL or LPL is classified as Laser Class 1, 2, or 3R and is classified as Risk Group 3 and the radiance is less than $10 \text{ MW}/(\text{m}^2 \text{ sr})$, then its use in the navigable airspace can be evaluated and controlled in the same manner as conventional high-intensity light sources. This radiance value is comparable to existing conventional (non-laser) entertainment and architectural lighting instruments such as the Claypaky Mythos ($6.7 \text{ MW}/[\text{m}^2 \text{ sr}]$), Sharpy ($6.4 \text{ MW}/[\text{m}^2 \text{ sr}]$), and Supersharpy ($9.9 \text{ MW}/[\text{m}^2 \text{ sr}]$), as well as existing searchlights and spotlights.

If a LIL or LPL is classified as Laser Class 3B or 4 or is classified as Risk Group 3 and the radiance is greater than $10 \text{ MW}/(\text{m}^2 \cdot \text{sr})$, then its use in the navigable airspace should be evaluated to determine the eye hazard distance and the visual interference distances of the light source. Use the same forms and evaluations as are used in submissions of outdoor laser operations to the FAA; refer to FAA AC 70-1, “Outdoor Laser Operations,” and FAA Form 7140-1, “Notice of Proposed Outdoor Laser Operation(s)” (current versions). Submit this to the FAA for their review and to receive a letter of non-objection, if required by an FDA variance or if desired by the proponent.

Note that government agencies or private organizations may require more restrictive measures than the above. For example, per FDA Laser Notice 57 “Classification and Requirements for Laser Illuminated Projectors (LIPs),” the FDA is requiring any Risk Group 3 LIL or LPL used in entertainment or display to apply for and receive a variance. This is done using the same forms and procedures as for Class 3B or Class 4 conventional lasers used in entertainment and display. This in turn requires submission to the FAA of any outdoor use in navigable airspace. The FAA will review the forms and evaluations. If the FAA objects to the outdoor use, the FDA will not permit the entertainment or display to proceed.

4.2 Other Light Sources

Currently, sources listed in this section do not meet the criteria of an HIL. However, future technological advances may utilize some of these technologies in the creation of bright, directed lights.

4.2.1 Incandescent

An incandescent lamp is an electric lamp in which a filament gives off light when heated to incandescence by an electric current. Tungsten is a type of incandescent lamp. These lamps consist of a coiled tungsten filament mounted in a sealed glass bulb. The bulb may have a vacuum or, more commonly, be filled with an inert gas such as argon or krypton.

4.2.2 Fluorescent

A fluorescent lamp is a tubular electric lamp having a coating of fluorescent material, called the phosphor, on its inner surface and containing mercury vapor whose bombardment by electrons from the cathode provides ultraviolet light that causes the phosphor to emit visible light.

4.2.3 Light Emitting Diode

The light emitting diode (LED) is a semiconductor lamp. The emitted radiation may be either invisible (infrared) or in the visible spectrum. Visible solid state lamps used for LEDs are commonly used in lighting applications. Due to their very long life and low operating current, they are ideal replacements for incandescent lights. Red, green, amber, blue, and white LEDs have been developed.

4.2.4 Sodium Vapor

Sodium lamps can be recognized by their amber or yellow color. These lamps are used where energy efficiency and long life are the primary requirements.

4.2.5 Metal Halide

Metal halide lamps are mercury high-pressure discharge lamps that have additional metal halides in their arc tubes. Metal halide lamps provide improved efficiency and improved color rendering qualities over mercury lamps. This type of lighting is usually used indoors due to this improved color rendering and the limitations of the metal halide gases.

4.3 Reflector Design and Lamp Orientation

The orientation of the lamp and the design of the reflector influence the performance characteristics of the light source.

The obvious way to increase the optical output of a light source is to employ a bigger lamp. A higher power lamp, however, will not necessarily result in higher optical output from a light source. Since light is emitted by the lamp in all directions, the important factor is not the amount of light emitted from the lamp but the amount of light output by the device.

Designs of the reflectors are paramount to the highest optical power efficiency. Reflector designs include spherical, parabolic, and ellipsoidal. These designs collect and collimate the emitted light. The ellipsoidal reflector design is the most efficient in reflecting light from a lamp.