جامعة الملك عبدالله
للعلوم والتقنية
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Science and Technology

Guidance on Exposure to Broad Band Incoherent Light Sources

Blue light, Visible light and Infrared

Health, Safety and Environment (HSE)

Contents

1. INTRODUCTION

There has been a growing use of various high-intensity light sources in KAUST research laboratories. Depending on the application, these sources may emit a broad spectrum of electromagnetic radiation, including ultraviolet (UV), blue light, visible light, infrared (IR), or a combination of these ranges. Exposure to high-intensity light can pose health risks to the human eye and skin.

This document summarizes exposure limits established by international organizations, including the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Threshold Limit Values (TLVs) defined by the American Conference of Governmental Industrial Hygienists (ACGIH). Additionally, it discusses lamp safety standards developed by the American National Standards Institute (ANSI), which help identify the potential photo-biological risks associated with these light sources

2. SCOPE

This guide outlines the exposure limits for continuous wave (CW) emission sources in the range of 300 nm to 3000 nm, encompassing blue light, visible light, and infrared radiation sources. It applies to all laboratories across the KAUST campus.

The injury thresholds for this type of radiation are well defined; therefore, this guide does not differentiate between public and occupational exposures, with the exception of children under 2 years of age and aphakic individuals (those lacking a lens in the eye), for whom special hazard functions should be applied. These exceptions are outside the scope of this guidance. Similarly, medical or deliberate exposures are not covered by this document.

For information on ultraviolet (UV) radiation exposure, please refer to the Guidelines for Working with Ultraviolet Light Sources document.

3. RESPONSIBILITES

For responsibilities of different parties and stakeholders such as Health Safety and Environment (HSE), Primary Investigator (PI), Lab Safety Representatives (LSRs) and lab users, please refer to the Lab Safety Manual.

4. BIOLOGICAL EFFECTS:

Visible and infrared optical radiation can cause at least nine distinct types of damage to the eyes and skin. These effects vary depending on wavelength, exposure duration, and individual susceptibility.

EFFECTS ON THE EYE

1. **Thermal damage to the cornea** – occurs primarily between 1,400 nm and 1 mm.
2. **Thermal damage to the iris** – in the range of approximately 380 nm to 1,400 nm.
3. **Near-infrared thermal damage to the crystalline lens** – between 800 nm and 3,000 nm.
4. **Thermal damage to the retina** – typically between 380 nm and 1,400 nm.
5. **Blue-light photochemical damage to the retina (Type II)** – primarily between 380 nm and 550 nm.
6. **Photochemical retinal damage from chronic exposure to bright light (Type I)** – can occur with prolonged exposure to high-intensity visible light.

EFFECTS ON THE SKIN

1. **Thermal damage (burns)** – occurs in the range of 380 nm to 1 mm.
2. **Photosensitization damage** – although more common with UV radiation (<380 nm), it may extend up to 700 nm, especially as a side effect of certain medications.

3. **Photo-allergic reactions** – immune responses triggered by antigens activated through exposure to optical radiation, primarily UV.

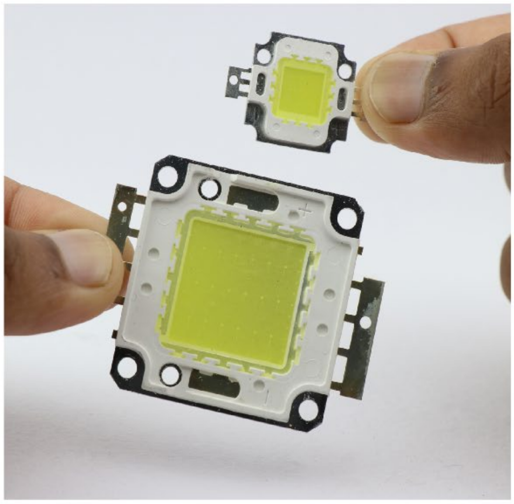
People with certain medical conditions may be more sensitive to optical radiation and can experience harmful effects at exposure levels that are safe for others.

The severity and nature of biological interactions are strongly **wavelength-dependent**. This dependence is captured through **action spectra**, which are used to apply spectral weighting to exposure quantities. The result is the calculation of **effective exposure quantities**, such as effective irradiance.

Examples of Potentially Hazardous Light Sources (see Figure 1):

- Arc welding equipment
- High-intensity lamps used for research purposes (e.g., solar simulators, photo-catalysis setups)
- High-intensity photographic flash lamps
- Infrared lamps for surveillance or heating
- Medical diagnostic devices
- Printing and photocopying systems

High intensity lamps - Photo catalysis



High intensity LEDs

High intensity xenon lamps - Sun simulators

Figure 1: Examples of high intensity light sources used in the labs

Natural and aversion response of the eye reduces potential hazard exposure, and thermal dis-comfort of the skin and cornea triggers aversion response. The risk for photo chemically induced photo retinopathy may be evaluated by applying the blue-light photochemical exposure limits given in these guidelines. Evaluation of the potential hazards of broadband conventional light sources requires spectro- radiometric data to apply several different photo biological action spectra, as well as knowledge of the exposure geometry. Damage of the cornea is only possible if intense radiation is focused onto the cornea. For the lens, chronic exposure to high levels of IR potentially causes cataract. Chronic elevation of skin temperature (not only caused by optical radiation) is known to induce a fixed reddening of the skin, erythema-ab-igne.

5. QUANTITIES DEFINITIONS AND MEASURING UNITS

- Electromagnetic wavelengths from 100 nm to 1mm is optical radiation:
  - Ultraviolet-UV (100-400 nm),
  - Visible light (400-700 nm),
  - Infrared-IR (A:780-1400 nm, B:1400-3000 nm, C:3000 nm-1mm)
- Exposure limits are expressed in radiometric quantities. See Table 1.

Table 1. Radiometric quantities.

Quantity	Symbol	Unit
Power	Φ	W
Energy	Q	J
Irradiance	E	$W\ m^{-2}$
Radiant exposure	H	$J\ m^{-2}$
Radiance	L	$W\ m^{-2}\ sr^{-1}$
Radiance dose/Time-integrated radiance	D	$J\ m^{-2}\ sr^{-1}$

- Where:
  - **Φ (Radiant flux or Power),** measured in **W** (Watt),
  - **Q (Energy**), measured in **J** (Joule),
  - **E (Irradiance),** measured in power per area (**W/m²**):
    - It is the quotient of the radiant flux (Φ) or power (W) incident on an element of a surface A (cm²), see Figure 2.

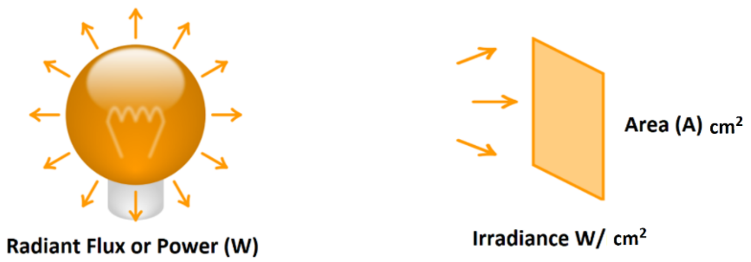


Figure 2: Irradiance

- **H (Radiant Exposure),** measured in energy per area (**J/m²**)
- **L (Radiance),** measured in power per area per solid angle (**W/m².sr**)

- It is the power incident on a given area of detector from a given part of space (i.e. from a certain solid angle defined by the field-of-view of the detector) divided by that area and that solid angle, as shown in Figure 3.

- **D (Radiance Dose),** also defined as time integrated radiance**,** measured in energy per area per solid angle (**J/m².sr**)
- **Solid Angle,** measured in steriadian (**sr**)

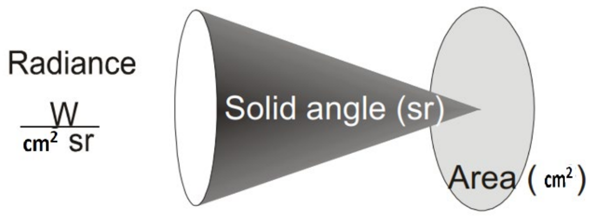


Figure 3: Radiance and solid angle

- Exposure to skin, anterior part of the eye (cornea and lens), retinal photochemical injury under small sources, are expressed in: Irradiance and Radiant Exposure. See Figure 4 for the human eye.

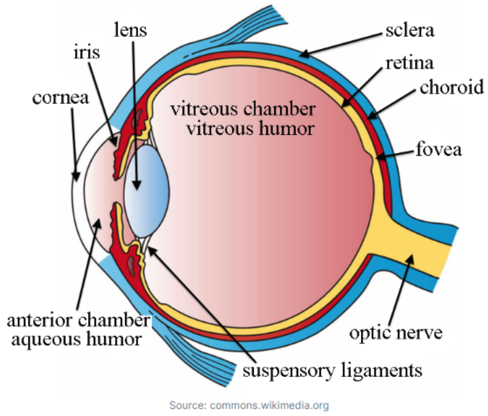
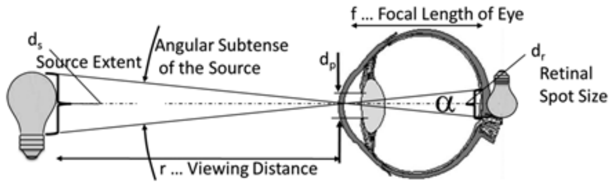


Figure 4: Human eye anatomy (cross section)

- Exposure to retinal injury from extended sources is expressed in : Radiance and Radiance Dose
- A source is considered a point source if the angular subtense is less than or equal to 1.5 mrad, which corresponds to a retinal spot size of 25 µm. see Figure 5.
- Continuous wave (CW) source where the exposure duration is greater than 0.25 s.
- Angular subtense of the source (α), also known as source size:
  - Measured in radian, and for circular sources, it is the ratio between the diameter of the source (d_s) and the distance (r) between the source and the eye, that is d_s/r. see Figure 5.
  - Small sources or point sources has α_{min} = 1.5 mrad

- Large sources has α_{max} = 100 mrad
- Intermediate sources α is in between α_{min} (1.5 mrad) and α_{max} (100 mrad)
- The value of α used in the formulas should not be less than 1.5 mrad, or more than 100 mrad,



$$\alpha = \frac{\text{Source Diameter } (d_s)}{\text{Viewing Distance } (r)}$$

Figure 5: Imaging of a broadband source on the retina showing the planar angular subtense, α, of the source, where d_s source extent, d_p: pupil opening, d_r: retinal spot size, r: viewing distance

6. ICNIRP EXPOSURE LIMITS

The exposure limits are set well below the damage thresholds, incorporating a safety reduction factor of at least two orders of magnitude. In general, exposure levels below these limits are not expected to cause adverse health effects. Because injury thresholds are well defined, this guidance does not distinguish between public and occupational exposures, except in the case of children under 2 years of age and aphakic individuals (those lacking a natural lens in the eye), for whom special hazard functions are required. These exceptions are beyond the scope of this document.

Exposure assessments may be limited to wavelengths below 3000 nm, as non-laser light sources typically do not emit sufficient power beyond this range to pose significant health risks, apart from potential heat stress.

It is important to note that there is limited data available on threshold levels for long-term, chronic exposure. Therefore, the guidelines provided here are based on available threshold data for damage with short onset delays—typically within 48 hours of exposure.

6.1 Basic retinal thermal limit (380 - 1400 nm)

Table 2 summarizes the retinal thermal exposure limits for different source sizes and exposure durations. In the formulas, the source size (α) has to be in radians and the time (t) has to be in seconds.

- If the source size is less than α_{min} then set $\alpha = \alpha_{min}$ in the formulas
- If the source size is more than α_{max} then set $\alpha = \alpha_{max}$ in the formulas, and consider that α_{max} has different values for different exposure durations as indicated in Table 2.

Table 2: Retinal thermal exposure limits

Source size α	Exposure time t in s	Radiance **(L)** W/(m^2.sr)	Radiance Dose **(H)** J/(m^2.sr)
Intermediate sources $\alpha_{min} \leq \alpha \leq \alpha_{max}$	$t < 10^{-6}$ s	--	$0.63 \times \alpha^{-1}$
	10^{-6} s $\leq t < 625\times10^{-6}$ s ($\alpha_{max} = 0.005$ rad)	$2\times10^4 \times \alpha^{-1} \times t^{-0.25}$	2×10^4 s $\times \alpha^{-1} \times t^{0.75}$
	625×10^{-6} s $\leq t < 0.25$ s ($\alpha_{max} = 0.2\times t^{0.5}$ rad)	$2\times10^4 \times \alpha^{-1} \times t^{-0.25}$	2×10^4 s $\times \alpha^{-1} \times t^{0.75}$
	$t \geq 0.25$ s	$2.8\times10^4 \times \alpha^{-1}$	--
Small sources $\alpha \leq \alpha_{min}$	$t < 10^{-6}$ s	--	420
	10^{-6} s $\leq t < 0.25$ s	$1.3\times10^7 \times t^{-0.25}$	$1.3\times10^7 \times t^{0.75}$
	$t \geq 0.25$ s	1.3×10^7	--
Large sources $\alpha \geq \alpha_{max}$	$t < 10^{-6}$ s	--	130
	10^{-6} s $\leq t < 625\times10^{-6}$ s ($\alpha_{max} = 0.005$ rad)	--	$4\times10^6 \times t^{0.75}$
	625×10^{-6} s $\leq t < 0.25$ s ($\alpha_{max} = 0.2\times t^{0.5}$ rad)	--	$10\times10^4 \times t^{0.25}$
	$t \geq 0.25$ s	28×10^4	--

Special limit for an infrared heat lamp or any near-IR source that provides no strong visual stimulus, a conservative limit is:

- Radiance limit = $6300 \times \alpha^{-1} = 0.57 \times 10^6$ W/(m^2.sr), for α = 0.011 rad, and exposure time more than 100 s.

6.2 Blue-light photochemical retinal hazard (300 - 700 nm)

- Radiance dose limit **(H)** = 10^6 J/(m^2.sr), for exposure time 0.25 s $\leq t \leq$ 10000 s.
- Radiance limit **(L)** = 100 W/(m^2.sr), for exposure time >10000 s (2.8h).
- Note that when the source size is smaller than the eye field of view such as point sources where α ≤ 1.5 mrad, and for simplicity, the limit is converted to equivalent irradiance, and in that case:
  - Irradiance limit **(E)** = 1 W/(m^2), and maximum exposure time 30000 s (8h).

6.3 Cornea and lens limit (780 nm – 3000 nm)

To avoid thermal injury of the cornea and possible delayed effects on the lens of the eye (cataract-genesis)

- Irradiance limit **(E)** = 100 W/(m^2), and maximum exposure time 1000 s.

6.4 Visible and infrared limit for thermal injury to the skin up to 3000 nm

- Irradiance limit **(E)** = 3.5×10^{3} W/(m^{2}), and maximum exposure time 10 s.

Important notes:

- No limit is provided for longer exposure durations, as normal avoidance behavior will impose limits on duration of exposure.
- Much longer exposure durations are dominated by concerns of heat stress.
- Thermal pain is induced by skin temperatures greater than $\sim 45^{0}$, which are lower than the temperatures needed to produce a thermal burn, and this pain would limit the exposure so that a thermal injury is prevented by avoidance reactions.
- For all arc and incandescent light sources, the contribution made by the IR-C spectral region (3000 nm to 1 mm) is normally of no or little practical concern. In addition, the contribution of this part of the spectrum to the physical exposure is counted for in the limit below 3000 nm, that is 100 W/m^{2}.

7. ACGIH TVLs

Threshold Limit Values (TLVs) refer to exposure limits for incoherent, non-laser visible and infrared (IR) radiation in the wavelength range of 305 to 3000 nm. These values represent levels to which workers may be exposed without experiencing adverse health effects, based on the best available data from experimental studies. The TLVs for occupational exposure to broadband light and near-infrared radiation apply specifically to eye exposure over the course of any 8-hour workday.

7.1 Blue-light photochemical retinal hazard (305 - 700 nm)

- Radiance limit **(L)** = $100 \times t^{-1}$ W/(cm^{2}.sr), for maximum exposure time less than 10^{4} s (2.8h) in a day.
- If Radiance exceeds 0.01 W/(cm^{2}.sr), the maximum exposure time is $t_{max} = 100 \times \alpha^{-1}$ s
- When the exposure time exceeds 10^{4} s, the Radiance limit is 0.01 W/(cm^{2}.sr)

7.2 Cornea and lens limit (770 nm – 3000 nm)

- The Irradiance limit **(E)** = $1.8 \times t^{-0.75}$ W/(cm^{2}), for maximum time less than 10^{3} s
- When the exposure time exceeds 10^{3} s, the Irradiance limit is 0.01 W/(cm^{2})

7.3 Retinal thermal limit for IRA (770 - 1400 nm)

- Radiance limit $< 3.2 \times t^{0.25} \times \alpha^{-1}$ W/(cm^{2}.sr), for maximum exposure time less than 810 s (2.8h), and $\alpha = 0.011$ rad.
- When the exposure time exceeds 810 s, the Radiance limit is $0.6 \times \alpha^{-1}$ W/(cm^{2}.sr)

7.4 Retinal thermal limit for visible light and IRA (380 - 1400 nm)

- For large sources, where α greater than 0.1 rad
  - Radiance limit **(L)** = $640 \times t^{0.25} \times$ W/(cm^{2}.sr), for exposure time 1 μs to 630 μs
  - Radiance limit **(L)** = $16 \times t^{0.75} \times$ W/(cm^{2}.sr), for exposure time 630 μs to 0.25 s

- Radiance limit **(L)** = 45 W/(cm^2.sr), for exposure time greater than 0.25 s
- For intermediate sources where 0.0017 < α < 0.1 rad
  - Radiance limit **(L)** = 640 × $t^{-0.25}$ × W/(cm^2.sr), for exposure time 1 μs to 630 μs
  - Radiance limit **(L)** = 3.2 × α^{-1} × $t^{-0.25}$ × W/(cm^2.sr), for exposure time 630μs to 0.25 s, and α = 0.2 × $t^{0.5}$ rad.
  - Radiance limit **(L)** = 4.5 × α^{-1} W/(cm^2.sr), for exposure time greater than 0.25 s.

8. SUMMARY OF LIMITS AND COMPARISON BETWEEN ICNIRP AND ACGIH

Table 3: Comparison between ICNIRP and ACGIH limits

Hazard	ICNIRP, for occupational and public	ACGIH, for occupational
Basic retinal thermal limit **Radiance (L)** (380 - 1400 nm)	28 W/(cm^2.sr) Exposure time ≥ 0.25 s.	45 W/(cm^2.sr) Exposure time ≥ 0.25 s
Blue-light photochemical retinal hazard **Radiance (L)** (300 - 700 nm)	0.01 W/(cm^2.sr) When the exposure time ≥ 10^4 s	0.01 W/(cm^2.sr) When the exposure time ≥ 10^4 s
Cornea and lens thermal limit **Irradiance (E)** (780 nm – 3000 nm)	0.01 W/(cm^2) Maximum exposure time 10^3 s	0.01 W/(cm^2) Exposure time ≥ 10^3 s
Visible and infrared limit for thermal injury to the skin up to 3000 nm **Radiance (L)**	0.35 W/(cm^2.sr) Maximum exposure time 10 s	N/A

The data provided in Table 3 are conservative values and chosen for limited scenario conditions. The ICNRIP report does not differentiate between occupational or public. The ACGIH TLVs are for occupational exposure and it is applied for any 8 working hours per day. The limits and TLVs should be used as guidance only, not to be used as fine lines between safe and hazardous exposure levels.

8.1 Example on how to identify the exposure limit

The following example demonstrates how to identify/calculate the exposure limits using ICNIRP and ACGIH TVLs.

Example: consider the following scenario, for an exposure duration of 8 hours/day (~30000 s), what is the maximum exposure level that should not be exceeded to protect the retina from thermal injuries, consider the lamp diameter of 15 cm, and is placed at distance of 1.5 m from the eye. What is the permitted exposure levels according to the ICNIRP and ACGIH TVLs?

Solution:

1. By dividing the source diameter (assuming circular) by the distance, the source subtends an angle (α) by the eye equals to 0.1 rad, and this can be considered a large source.
2. As per the ICNIRP retinal thermal limits, Table 2, and for large sources and exposure duration t ≥ 0.25 s, the irradiance levels emitted by this lamp, should not exceed 28 W/(cm^2.sr)
3. As per the ACGIH retinal thermal limits for large sources, and exposure duration t ≥ 0.25 s, the irradiance levels emitted by this lamp, should not exceed 45 W/(cm^2.sr)
4. Information about the irradiance emitted by the lamp is expected to be provided by the manufacturer, along with the safe exposure durations incase the irradiance emitted exceeds the standard permitted values.

Note that the ACGIH TVLs are considered for occupational exposure, i.e. for 8 working hours per day, while the ICNIRP does not differentiate between occupational and public exposure (except for children less than 2 years old and aphakic individuals).

9. PRODUCT (LAMP) SAFETY STANDARDS AND RISK GROUPS

Lamp safety standards have been developed using a risk group classification scheme that enables the implementation of appropriate control measures based on the potential hazard posed by the light source. The emission limits outlined in these product safety standards are generally derived from guidelines established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the American Conference of Governmental Industrial Hygienists (ACGIH).

The American National Standards Institute (ANSI), in collaboration with the Illuminating Engineering Society of North America (IESNA), has published a technical standard—ANSI/IESNA RP-27 (2007)—to assess the photo-biological risk associated with lamps and lamp systems. This standard has also been adopted internationally by the International Electro-technical Commission (IEC) under the designation IEC 62471.

Table 4 outlines the definitions of risk groups, which are categorized, based on the maximum permissible exposure durations for a given source.

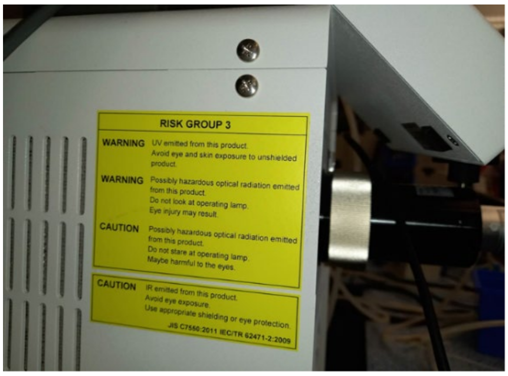
Table 4: IEC lamp risk groups

Type of hazard	Exempt No Hazard	Risk Group 1 Low-Risk	Risk Group 2 Moderate-Risk	Risk Group 3 High-Risk
	Exposure limit not exceeded for exposure durations up to: (i.e. exceeded for exposure durations beyond:) (s)			Exposure limit exceeded within: (s)
Actinic UV (skin and eye)	30,000	10,000	1,000	<1,000
UVA (lens)	1,000 (~16 min)	300	100	<100
Photochemical (retina)	10,000 (~2.8 h)	100	0.25 (natural aversion)	<0.25
Thermal (retina)	10	10	0.25 (natural aversion)	<0.25
Infrared (cornea, lens)	1,000	100	10	<10

[a] NOTE: The IEC (IEC 2006) exempt group regarding the un-weighted UVA limit was based on the ACGIH integration duration of 1,000 s (ACGIH 2009) and exposure to such lamps from a distance of 20 cm for longer than 16 min might lead to exposures above the limit as recommended by ICNIRP, where the integration duration is 8 h.

Two different distances of measurement are defined in the standard for the risk group classification depending on the intended use:

1. The distance where the luminance level equals 500 lux for general lighting service lamps and;
2. 20 cm for non-general lighting service lamps. Note that most lamps that emit a relevant amount of UV are non-general lighting sources.



RISK GROUP 3
WARNING Possibly hazardous optical radiation emitted from this product CAUTION Possibly hazardous optical radiation emitted from this product NOTICE UV emitted from this product

RISK GROUP 2
CAUTION Possibly hazardous optical radiation emitted from this product

Figure 6: Sample Risk Group warning labels on the equipment, identifying the risk group class and the potential hazards of the installed lamp

Users should always verify the risk group classification of any lamp used in research activities to identify potential photo-biological hazards and implement appropriate protective measures and safety controls. This classification is essential for ensuring safe use, particularly when working with high-intensity light sources.

Manufacturers are expected to provide this information in product catalogs, technical specifications, and on equipment labels (see Figure 6). Proper labeling and documentation help users assess risks effectively and comply with relevant safety standards.

10. PROTECTIVE MEASURES

Protective measures should be implemented in accordance with general **risk management principles**. The **hierarchy of controls** outlines five levels of safety interventions, arranged in order of effectiveness, to mitigate and reduce risks to acceptable levels.

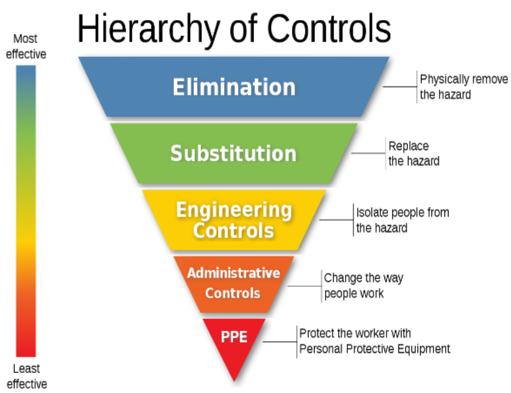


Figure 7: the hierarchy of controls diagram showing the orders of the controls from the most effective “Elimination”, to the least effective “PPE”.

These controls should be applied in sequence, starting with the most effective:

1. **Elimination** – Physically remove the hazard
2. **Substitution** – Replace the hazard with a less dangerous one
3. **Engineering Controls** – Isolate the user from the hazard. This is the most desirable control, and it can be achieved using engineering-designed safety features to prevent the hazard such as enclosures, barriers, interlocks and so.
4. **Administrative Controls** – Change the way people work, examples:
    - Training and education (technical, safety, hands-on)
    - Using access/entry and user log control
    - Procedures and SOPs, warning signs
    - Supervision
5. **Personal Protective Equipment (PPE)** – This control is to be added to the engineering and administrative controls, and it can be achieved by wearing the correct and approved PPE.
    - Always used standard, approved and marked eye and face protection (e.g. compliance with ANSI Z87.1)
    - Important marking factors that will provide information about the protection level must be provided by the lamp/source manufacture. Example of the ANSI Z87.1 markings related to this guide:
        - **W** Shade: welding filter lens, ranges from W1.3 to W16
        - **U** scale number: UV filter lens, ranges from U2 to U6
        - **R** scale number: IR filter lens, ranges from R1.3 to R10
        - **L** scale number: visible light filter lens, ranges from L1.3 to L10
    - For protecting the eye and face from UV, refer to the Guidelines for Working with Ultraviolet Light Sources

Refer to **Figure 7** for a visual representation of the hierarchy of controls.

ADDITIONAL ENGINEERING CONTROLS:

If the hazard cannot be eliminated or substituted, the most effective remaining control measure is the use of engineering controls, such as the total enclosure of the light source and its emissions (see Figure 8). These enclosures can be fitted with interlocks that automatically switch off the light source when the enclosure is opened, enhancing user safety.

The enclosure material must be suitable for the specific working environment—accounting for factors such as temperature, humidity, chemical exposure, and fumes. Special considerations are also required when the enclosure must support ventilation systems, power connections, or other integrated equipment and utilities.

Engineering controls also may include:

- Beam reflectors and fiber optics to guide and confine light emissions to the sample
- Shielding using opaque materials (e.g., aluminum foil), ensuring compatibility with the environment and resistance to high temperatures, moisture, and chemical exposure

For UV-specific shielding materials, refer to the Guidelines for Working with Ultraviolet Light Sources.

In situations where full containment is not feasible, partial enclosures, administrative controls, restricted access, and the use of eye and/or skin protection may be required to ensure adequate safety.

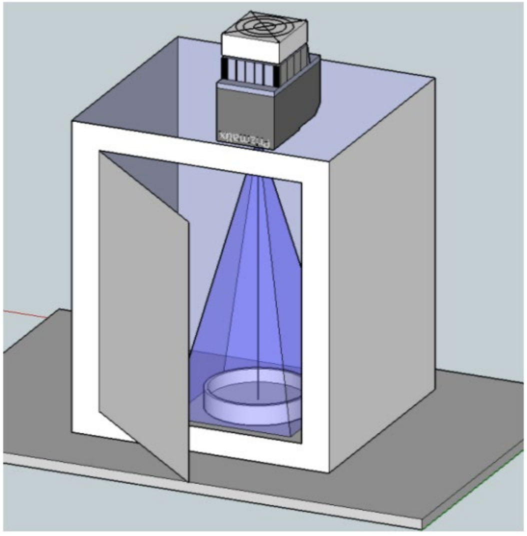


Figure 8: Sample enclosure for high intensity light source

ADDITIONAL GUIDELINES FOR SAFE HANDLING

Safety Precautions:

- Avoid direct eye and skin exposure, and note that also chronic exposures may lead to adverse health effects to the eye and the skin.
- Avoid touching the bulb: the bulb becomes very hot and can cause burns.
- Proper disposal: see section 12 for the proper disposal.

Usage Guidelines:

- Avoid prolonged/unnecessary use: Turn off lamps immediately after use to extend lifespan.
- Adjust usage time: Avoid frequent on/off cycles to prevent premature wear.
- Avoid overusing time: Avoid exceeding the working time recommended by the manufacturer which is usually indicate in hours. Exceeding the working time of the lamp increase the risk of fire.
- Preheat and cool down: Allow proper preheating and cooling periods for safe operation.
- Follow manufacturer’s recommendations: Adhere to specific usage instructions for your lamp model.

Electrical & Power Considerations:

- Appropriate power supply: use suitable high-voltage power sources and avoid under/overvoltage.
- Use proper power controllers: when the setup is assembled, where the lamp is purchased as an individual module, ensure compatible controllers are used to avoid damage.
- Check cables and connectors: regularly inspect for wear or loose connections.

Temperature & Ventilation:

- Proper cooling: most of the units contains a built-in cooling fan, and for assembled setups where the lamp is purchased as a single module, use fans or cooling systems to prevent overheating.

* Ensure adequate ventilation: keep air circulation unblocked around the lamp. Also this is necessary in case the lamps is not an ozone free lamp.

Installation & Maintenance:
* Secure installation: ensure stable mounting to prevent accidental detachment of the lamp.
* Regular cleaning: use soft cloths and appropriate tools to clean bulbs/lenses, and always follow the manufacture user manual for the correct and proper cleaning material and method respectively.
* Regular inspection & maintenance: check for wear, damage, cracks or damage to filters or coating (specially for ozone free lamps and UV filters), or operational issues, and notify lab equipment and maintenance LEM

Handling & Storage:
* Avoid touching or vibrating the bulb or the tungsten electrodes.
* Prevent vibration and impact: handle carefully to avoid internal damage.
* Prevent moisture and contamination: store in a clean, dry, and ventilated area.

11. EXPOSURE ACCIDENTS

In an effort to identify and manage workplace hazards, any work-related exposures, illness and injuries must be reported. Employees must inform their supervisors of any work-related exposures, injuries or illnesses as soon as possible and report by end of the shift and report the incident via HSE incident reporting portal (SALUTE portal).

Collaborate with HSE for investigation and medical follow up, with the Laser Safety Specialist/Research Safety Team (RST) to investigate the causes of the incident, and with Occupational Health Specialist (OH) for any medical follow up and GOSI reporting. For more information, please refer to Exposure Response Protocol & Exposure Response, under KAUST Occupational Health.

12. DISPOSAL OF MERCURY CONTAINED EQUIPMENT

Some high intensity light sources (lamps) might contain hazardous material such as mercury, and it must be disposed of as hazardous waste. Refer to the Lab Safety Manual and hazardous waste manual for hazardous waste and mercury-containing equipment. If the mercury lamp original packing box is still available, it can be utilized for disposal, since it is already designed for transportation and shipping, and it contains also the proper lining material for absorbing shocks. Seal the box properly with tape, and deface all the markings, and label with the standard hazardous waste label.

High intensity light sources that does not contain any hazardous material, can be also packed in its original packing box, and it can be disposed of in the special Universal waste bins available at the campus buildings entrances. Also the user may contact recycling team at recycle@KAUST.EDU.SA for large quantities. In case that the original packaging box is not available, the lamp can be packed in cardboard box with the proper lining material for shock absorbing (e.g. polystyrene and Styrofoam), and seal the box properly with tape.

13. REFERENCES

KAUST, HSE, NIR Safety Webpage

Guidelines for Working with Ultraviolet Light Sources

ICNIRP Guidelines: On Limits of Exposure to Incoherent Visible and Infrared Radiation

IEC 62471: Photo-biological safety of lamps and lamp systems

ANSI/IES RP-27-20, Recommended Practice: Photo-biological Safety for Lighting Systems

ANSI/IES RP 27.1-22, Recommended Practice: Risk Group Classification and Minimization of Photo-biological Hazards From Ultraviolet Lamps and Lamp Systems

ANSI/ISEA Z87.1-2020: Current Standard for Safety Glasses

ACGIH TLVs

University of Washington, NIR Safety Manual