Guidelines for Working with Ultraviolet Light Sources

1. Purpose

The purpose of this document is to provide guidance to laboratory users, the Laboratory Safety Representative (LSR), and the Principal Investigators (PIs) or Center Director in the safety precautions required when using ultraviolet light sources.

2. Scope

This document applies to all laboratories on the KAUST campus, including the KAUST Research and Technology Park and the Innovation Cluster.

3. Responsibilities

3.1. Health, Safety and Environment

- Determine the specific hazards and identify the hazardous areas.
- Review and provide advice on safety precautions.
- Provide training.

3.2. Principal Investigator

- Ensure personnel are trained to safely perform the task assigned.
- Ensure all protective control measures are maintained.

3.3. Laboratory Safety Representative (LSR)

- Ensure that all users work in a safe manner and follow all the safety precautions.
- Ensure that non-laboratory users are accompanied and received.
- **Immediately** notify the PI or Center Director and Research Safety Team of unsafe conditions, and all known or suspected incidents.

3.4. Laboratory Staff

- Have completed all required training.
- Follows all precautionary measures
- **Immediately** notify the LSR, PI or Center Director and Research Safety Team of unsafe conditions, and all known or suspected incidents.

4. Introduction

Ultraviolet light (UV) is a type of non-ionizing radiation in the 100 to 400-nanometer wavelength region of the electromagnetic spectrum. The ultraviolet radiation spectrum is commonly divided into the following three regions:

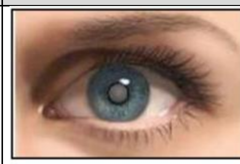
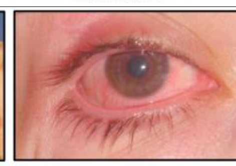
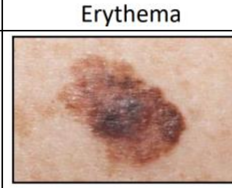
Region	Region Name	Wavelength (nm)
UV-A	Black Light	315 - 400
UV-B	Erythermal	280 - 315
UV-C	Germicidal	100 - 280

For most people, the main source of UV exposure is the sun. Exposure from the sun is typically limited to the UV-A region since the earth's atmosphere protects us from the more harmful UV-C and 97-99% of the UV-B region. However, UV radiation in all three spectral regions can be generated by man-made sources found in most research laboratories. If used without the appropriate shielding and personal protective equipment, these man-made radiation sources can cause injury with only a few seconds of exposure.

5. Hazards and Bio-Effects of Ultraviolet Radiation

There are no immediate warning symptoms to indicate overexposure to UV radiation. The critical organs which are affected by the UV radiation are the skin and the eye. The hazards of man-made UV radiation sources are greater than that of natural sources of UV radiation because the level of UV radiation in man-made sources greatly can exceed the level found in nature. A summary of the hazards and bio-effects of UV radiation is presented in Table 1.

Table 1. Hazards and bio-effects of UV radiation.

Band	Wavelength (nm)	Hazard Potential	Description	Biological Effect
UV-A	315 – 400	Lowest	Accounts for up to 95% of UV radiation. Penetrate deeper into skin layers.	 Cataract  Sunburn
UV-B	280 – 315	Mid to High	Biologically active but cannot penetrate beyond the superficial skin layers. Most solar UV-B is filtered by the atmosphere.	 Erythema  Photokeratitis
UV-C	100 – 280	Highest	Most damaging. Completely filtered by the atmosphere and does not reach the earth's surface; however, this does not apply for man-made sources.	 Skin cancer  Conjunctivitis

5.1. Skin Injury

UV radiation damage collagen fibers in the skin, which accelerates the changes due to aging and plays a major role in production of wrinkles. UV-B is responsible for erythema (i.e. skin reddening or sunburn) and together with UV-A, they are associated with skin cancers. Erythema consists of redness ulcerations that can vary in severity and can occur from only a few seconds of exposure.

Symptoms can vary with one's genetic background; darkly pigmented skin is much less susceptible to sunburns than pale/fair skin. Additionally, certain food or medications (tetracycline antibiotics, sulfa drugs, antihistamines, non-steroidal anti-inflammatory drugs and even certain herbal remedies) can increase one's photosensitivity to UV radiation.

5.2. Eye Injury

UV radiation exposure can cause injury to the cornea (the outer protective coating of the eye). The main clinical effects are photokeratitis or conjunctivitis, which appear 2 – 24 hours after exposure. Photokeratitis is a painful inflammation of the eye mainly caused by UV-B and UV-C. Symptoms include a sensation of sand in the eye that may last several days; however, there is no permanent damage since the corneal cells grow back. In very severe cases or due to chronic exposures to acute high-energy UV radiation, the cornea may become clouded and corneal transplant may be needed to restore vision. The absorption of UV-A in the lens of the eye is thought to produce yellowing with time and may contribute to the formation of cataracts, causing partial or complete loss of transparency. Chronic exposure to UV radiation can also lead to the formation of cataracts.

5.3. Other Hazards

5.3.1 Lamp Explosion

UV lamps containing high-pressure gas may explode if not handled properly; i.e. if there is presence of dust, fingerprints, powder, grease, smoke, etc. These must be cleaned thoroughly, and the glass section of the lamp should not be scratched. Fingerprints should be wiped off with isopropyl alcohol and a clean soft tissue; otherwise they will weaken the lamp envelope. It is also recommended to use cotton gloves for handling the lamp and to avoid stressing the glass part when connecting the UV lamp and tightening electrical connections.
It is important to replace the lamp when it reaches its lifetime limit. An old lamp having a darkened glass envelope has a high likelihood of exploding and should be replaced.

5.3.2 Mercury (Hg)

Some of the solar simulators use mercury-based arc lamps (Hg or HgXe). Mercury contamination can occur if a lamp breaks or explodes. A mercury spill kit should be available when such lamps are used in the laboratory. Consult with the Research Safety Team for advice on proper handling of mercury contamination.

5.3.3 Ozone (O_3)

Triatomic oxygen or ozone is formed when oxygen is exposed to short-wavelength UV light (i.e. less than 240 nm). Ozone produced by lamps with high UV output can be a major irritant to the user respiratory system. It can cause chest pain, coughing, throat irritation, and airway inflammation. It can also reduce lung function and harm lung tissue.
Ozone formation can be reduced by using ozone-free lamps in which certain dioxides are added to the quartz of the lamp to absorb the short wavelengths that produce ozone. A nitrogen atmosphere can also be used to eliminate the presence of oxygen in the area and therefore the production of ozone; however, this can be costly. Another solution consists in eliminating the ozone by exhausting the air from the system outside the building. This is often the preferred choice and is very effective.

5.3.4 Electrical shock

During normal operation, the user is protected from contact with any energized electrical connections. However, electrical shock danger can occur if interlocks are defeated or the power supply section is opened with the unit still plugged in. Unplug the unit before replacing the lamp or servicing the power supply section.

5.3.5 Heat

An arc lamp envelope reaches extremely high temperatures during normal operation and can cause severe burns if touched. It is recommended to let the lamp cool at least 15 minutes before opening the lamp compartment door or power supply.

6. Risk Assessment

Currently, there are no regulatory exposure limits for UV radiation. Threshold Limit Value (TLVs) have been published by the American Conference of Governmental Industrial Hygienists (ACGIH). These refer to incoherent ultraviolet (UV) radiation with wavelengths between 180 and 400 nm and represent conditions under which all healthy workers may be exposed repeatedly without suffering adverse effect or noticeable risk of delayed effects.

In order to minimize exposure, a risk assessment is required when operating a UV equipment outside the scope of the manufacturer's recommendation or if the user may be exposed to UV (i.e. the UV lamp is not shielded).

7. Control Measures

To prevent overexposure to UV radiation, it is recommended that control measures are put in place.

7.1. Engineering Control Measures

- ***Containment*** **–** ideally, the equipment should be placed in a separate room or low traffic area of the laboratory. In addition, it is recommended to avoid placing the equipment in the direct vicinity of desk areas or other equipment.
- ***Enclosures, screens, shields, or filter*** should be used to contain UV radiation. UV can easily be shielded by materials such as UV-blocking polycarbonate, metal, cardboard, and wood. Ordinary glass blocks most UV light of wavelengths less than 330 nm; however, it may transmit most of the UV for longer wavelengths (i.e. above 330 nm). As a result, glass should not be relied upon for UV protection unless UV shielding is verified. Please check your safety equipment to ensure that it is rated for the wavelength in use.
- ***Safety interlocks*** **–** some equipment come with interlock devices that prevent operation of the equipment if they are activated. Interlocks should not be tampered with and should be replaced or repaired when damaged.
- ***Eliminate reflections*** **–** if the emitted UV radiation cannot be shielded the surfaces around the equipment must be made to avoid reflections.
- ***Exhaust*** **–** if the system can produce large quantity of ozone gas, an exhaust should be installed.

- ***Spill kit*** **–** if the UV lamp contains mercury, a mercury spill kit should be available in the laboratory.

Note that it is strictly prohibited to remove, disable or alter any protective shield or interlocks. Failure of any individual to comply with these requirements can cause injury and may have repercussions.

7.2. Administrative Control Measures

- ***Room access*** **–** access to the room/equipment should be limited to authorized users only. In addition, risk of injury due to UV exposure can also be minimized by limiting the exposure time and increasing the distance between the users and the UV source.
- ***Training*** **–** all users of equipment emitting UV radiation must have been trained and familiar with the correct/safe way of using the equipment. At minimum laboratory personnel must:
  - Complete the UV Safety Training in the online system
  - Be familiar with the correct/safe operation of the UV light producing equipment
  - Be familiar with the warning signs
  - Be familiar with the symptoms in case of exposure

  If experiments using the UV radiation are conducted in shared spaces, all occupants must receive prior notification and warning signs be must be clearly posted.
- ***Warning Signs*** **–** any equipment that emits UV radiation must be clearly labeled with a caution label with language similar to the one shown in Figure 1. The laboratory door sign must have the UV radiation hazard warning and if the equipment is placed in a separate room within the laboratory, a warning sign should also be posted on entrance to the laboratory/room (Figure 2.).
- ***Warning Lights*** **–** it may be necessary to install warning lights and to limit exposure time, if necessary, this will be discussed with the Research Safety Team.
- ***Regular Testing*** **–** the equipment should be tested regularly as per manufacturer's recommendations.
- ***SOP*** **–** SOP must be available if the device is not equipped with safety interlocks that prevent exposure.

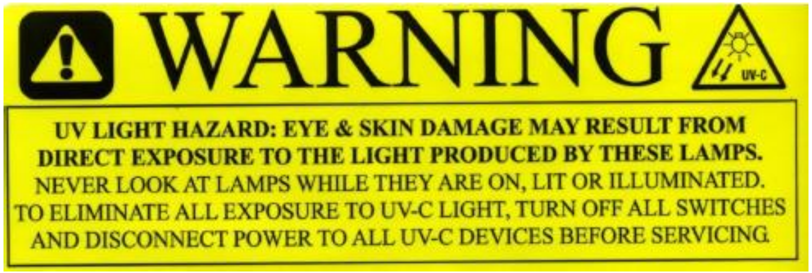


Figure 1. Example of a caution label for equipment producing UV radiation.

Lab Safety Representative	Name	054 – XXX – XXX
Lab Safety Representative (Alternate)	Name	054 – XXX – XXX

Figure 2. Example of a door sign to indicate UV radiation hazard.

7.3. Personal Protective Equipment (PPE)

In addition of all the administrative and engineering control measures, personal protective equipment (PPE) may be recommended. The Research Safety Team is available to recommend appropriate personal protective equipment suited for the UV radiation source.

7.4. Protective Clothing

When in the laboratory, all laboratory users must wear standard laboratory apparel including a fully buttoned laboratory coat, long trousers, and closed toe shoes. While working with UV radiation sources which are not fully shielded, laboratory workers must wear the following:

- Laboratory coat with elasticated arm bands.
- Gloves to cover the hands - prefer nitrile gloves as they attenuate more the UV radiation. Do not use vinyl gloves, which can transmit significant amounts of actinic UV.
- Long trousers and closed-toe shoes
- Gaps in protection at wrist and neckline must be covered.

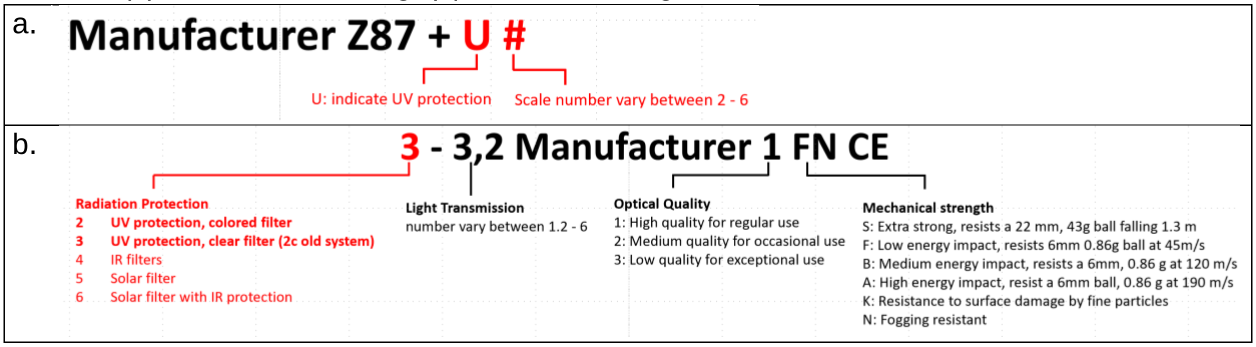
Note: If working outside – use a large area hat and put on sunscreen if required.

7.5. Eye/Face Protection

UV certified face shields are preferred as they provide protection to the eye and face. Alternatively, users can also wear UV certified goggles and safety glasses; however, it is common for laboratory workers to suffer facial burns in the areas not covered by the goggles or glasses.

All eye and face protection must be stamped with either certification ANSI 87.1-2015 (American Eye Protection Standard) or EN 166 (Personal Eye Protection European Standard). The filters must be marked as indicated in Table 2.

Table 2. (a) ANSI 87.1 marking, (b) EN166 marking.



Note that the general laboratory safety glasses that use polycarbonate or prescription glasses are often inadequate against the UV radiation unless they have the makings as indicated in Table 2.

8. Common Ultraviolet Radiation Sources

There are several examples of man-made sources of UV radiation in the laboratory including germicidal lamps in biological safety cabinets, nucleic acid transillumination boxes, nucleic acid crosslinkers etc. (Figure 3).

UV Light Box/UV Transilluminator

UV Crosslinker

Germicidal Lamps

Figure 3. Example of man-made Ultraviolet sources.

8.1. UV/Ozone cleaning device

UV/Ozone cleaning system use a high-power UV light source emitting short UV wavelengths (below 240 nm). The UV lamps then generate ozone gas which then breaks down surface contaminants into volatile compounds. These volatile compounds evaporate from the surface leaving no trace. This method can produce near-atomically clean surfaces without causing damage to the sample. This device is commonly used for surface cleaning and surface treatment.

Safety Precautions:

- The device should be equipped with safety interlocks.
- The system should be connected to an exhaust.

8.2. Hand-Held UV lamps

UV hand-held lamps are often used in research laboratories for visualizing nucleic acids following gel electrophoresis and ethidium bromide staining or for other purposes.

Safety Precautions:

- Personal Protective Equipment (PPE) include UV face shields (to protect eyes and face), long-sleeved, tightly woven clothing that covers much of the body and gloves (with no gaps between the cuff and the glove). PPE should be worn at all time when there is potential for UV exposure.
- Be aware of reflective surfaces which can reflect UV radiation to unprotected parts of your skin.
- Never look directly at the beam.
- Limit the exposure time and maximize the working distance.
- Enclosed beam paths wherever possible.
- Use a manual or electronic shutter to close the beam when the source is idle, is possible.
- Restrict access to area/laboratory where the UV source is used.
- Post warning signs at the entrance to areas using UV sources.

8.3. UV Light Box/UV Transilluminator

This device is commonly used for visualizing nucleic acids (DNA and RNA) that has been stained with ethidium bromide or sybr green. This device contains a UV lamp under the clear glass top which allows the light to illuminate the gel while potentially exposing the user. To reduce the risk of exposure, most models come equipped with a shield to filter excess light. For older models, there are various types of shields that can be attached that provide equal protection.

Safety Precautions:

- Checks the shields regularly for cracks or damages. Shields must be kept clean and replaced when damaged. Make sure that the shield is always in place and the interlock operating before using the device.
- When operating the device, never remove the protective shield to get a closer look at the material being visualized with the transilluminator or hand-held unit.
- Personal Protective Equipment (PPE) include UV safety eyewear or face shields, long-sleeved, tightly woven clothing that covers much of the body and gloves (with no gaps between the cuff and the glove). PPE should be worn at all time when there is potential for UV exposure.
- Access to rooms with transilluminator should be controlled and posted with a warning sign indicating face and other skin protection is needed to enter when the transilluminator is in use.

Note that there are transilluminators currently available that do not use UV radiation.

8.4. UV Crosslinker

This device is used to attach nucleic acids to a surface or membrane following blotting procedures. Crosslinkers are equipped with door safety interlocks, like a household microwave, preventing operation of the machine when the door is open. If the interlock system is not functioning correctly, please refrain from using and contact the manufacturer.

Safety Precautions:

- Do not use the device if the door's safety interlock mechanism is not working properly. Discontinue use until it is serviced.
- Do not attempt to override the internal safety interlock.
- Do not expose unprotected eyes or skin to UV radiation.

8.5. Germicidal Lamps

This device is typically used in biosafety cabinets, laminar flow hoods or other areas for sterilization/decontamination purposes. It emits UV-C around 254 nm. Many factors affect the germicidal effect of UV bulbs, such as maintenance, regular bulb cleaning, and monitoring to ensure germicidal activity. ***Due to these limiting factors and lack of testing criteria for performance, UV lights are not recommended for use in biosafety cabinets.*** If you are using UV inside your biosafety cabinet, you should check the bulbs weekly with a UV meter to ensure the light intensity is sufficient. If you have questions concerning UV lights inside biosafety cabinets, contact HSE@kaust.edu.sa.

Safety Precautions:

- Do not work in or around the safety cabinet or other areas while the UV lamp is on or avoid using the room when the UV lamp is on.
- Always close the sash completely when the UV lamp is on.
- Ensure the UV light is switched off before working at the cabinet or room.
- Control access to the room/cabinet while the UV lamp is operating to prevent exposure.
- Personal Protective Equipment (PPE) include UV safety eyewear or face shields, long-sleeved, tightly woven clothing that covers much of the body and gloves (with no gap between the cuff and the glove) should be worn at all times when there is potential for UV exposure.

8.6. UV Curing Lamps

UV curing lamps are used to initiate a photochemical reaction to instantly cure UV-light activated inks, bonds, adhesives, and finishes (lacquers, glazes and varnishes), etc. The UV curing process is adaptable to printing, coating, decorating, stereolithography, and in the assembly of a variety of products and materials.
The UV lamps are usually kept inside a cabinet but in some cases substantial UV radiation can escape and expose the user.

Safety Precautions:

- The device should be equipped with safety interlocks.
- The system may be connected to an exhaust if fumes can be generated.
- Personal Protective Equipment (PPE) include UV safety eyewear or face shields, long-sleeved, tightly woven clothing that covers much of the body and gloves (with no gaps between the cuff and the glove). PPE should be worn at all time when there is potential for UV exposure.
- Control access to the area/laboratory while the lamps is operating to prevent exposure.
- Post warning signs at the entrance to areas using UV sources.

8.7. Light Emitting Diodes

Light-emitting diodes (LEDs) have recently been used in research laboratories to construct solar simulators or to catalyze chemical reactions or to study algae/coral, etc. These can emit bright light and some of it may be in the UV range.

Safety Precautions:

- Never look directly at the beam.
- If possible, enclose the LED system.
- Wear adequate Personal Protective Equipment (i.e. wear UV certified a face shield or protected helmet rated for UV protection, cover all exposed skin).
- Limit the exposure time.
- Restrict access to area/laboratory where the device is used to avoid exposing others.
- Post warning signs at the entrance to areas.

8.8. Electric Arc Welding

Welding arcs and flames emit intense visible, ultraviolet, and infrared radiation. UV radiation in a welding arc will burn unprotected skin just like UV radiation in sunlight.

Safety Precautions:

- Wear adequate Personal Protective Equipment (i.e. wear a UV certified face shield or protected helmet rated for UV protection, cover all exposed skin).
- Never look directly at the beam.
- Limit the exposure time.
- Restrict access to area/laboratory where the device is used to avoid exposing others.
- Post warning signs at the entrance to areas.

9. Protection from Sun

Outdoor workers can minimize their UV exposure by:

- Avoiding outdoors between 10 a.m. and 2 p.m. when UV rays from the sun are the greatest.
- Staying in the shade when possible.
- Wearing tightly woven clothing that covers your arms and legs.
- Wearing a hat with a wide brim to shade your face, head, ears, and neck.
- Wearing sunglasses that wrap around and block UV rays.
- Using sunscreen with sun protection factor (SPF) 30 or higher.

For more information on protection from the Sun, please refer to the Field Research Safety Program.

10. UV lasers

Please refer to the Laser Safety Program.

11. Disposal of UV lamps

Many UV-generating devices have UV light bulbs that can be replaced. **DO NOT dispose of UV bulbs in the regular trash.** Disposal of these bulbs must be handled through Research safety Team because the bulbs may contain mercury and are considered hazardous. They are subject to certain regulatory requirements for disposal.

12. Emergency Procedures

In case of injury, the other users in the laboratory must:

- Stay with the injured person (if it is safe to do so);
- Call 911 (KAUST landline) or 012-808-0911 (mobile phones) and indicate the location of the incident and if an ambulance is needed. Do not hang–up until you are told to do so;
- Immediately contact the PI or LSR;
- The injured person must go to the KAUST Health Emergency Room as soon as possible and in any case within 24 hours;
- Log the incident in the reporting system;
- Collaborate with the RST to investigate the cause of the incident.

Reference

[1] ACGIH, 2020 TLVs and BEIs

[2] Ultraviolet Safety Sheet, University of Washington, https://www.ehs.washington.edu/system/files/resources/UV_Safety_Sheet-revised.pdf (July 2020)

[3] Ultraviolet Safety, University of Nottingham, https://www.nottingham.ac.uk/safety/documents/uv.pdf

[4] University of Pennsylvania, Factsheet: Ultraviolet Radiation https://ehrs.upenn.edu/health-safety/lab-safety/chemical-hygiene-plan/fact-sheets/fact-sheet-ultraviolet-radiation

Document History

REV	DATE	PREPARED BY	DESCRIPTION
01	2018	D. Darios	Initial Document
02	2020	D. Darios	Use new template, added section 1, 2, 3, 8 and modified sections 5, 6 and 7.