Workplace Safety ACADEMY

Battling a Virus with GUV Lighting

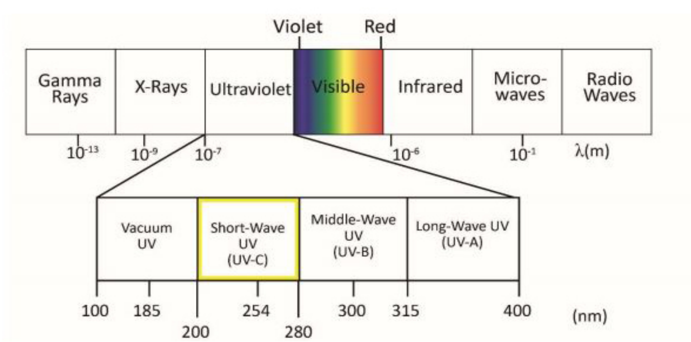
Ultraviolet radiation can be a powerful weapon in fighting COVID-19.

By Joe Knisley

COVID-19, which was declared a pandemic on March 11, 2020, by the World Health Organization (WHO), continues to affect the economies of the world. This scourge, however, has energized some industries — especially the lighting community — to research and develop programs to combat, mitigate, and eventually control the viruses.

Various types of germicidal ultraviolet lamps (GUVs) have been used over the years to disinfect water and surfaces by killing bacteria/mold spores and inactivating viruses. These lamps are now also being used to sterilize the air inside a room, room surfaces, and personal protection equipment (PPE), such as N95 masks. Scientists usually refer to ultraviolet (UV) as radiant energy, but UV light has become commonly accepted. Measured in nanometers (nm), or a millionth of a millimeter, UV radiation embraces wavelengths between 100 nm and 400 nm, which is just beyond the violet portion of the visible light spectrum and thus invisible to the human eye. The UV spectrum is divided into the UV-A, UV-B, and UV-C regions, which are 315 nm to 400 nm, 280 nm to 315 nm, and 200 nm to 280 nm, respectively. The UV-C band of ultraviolet radiation from the sun does not reach the earth's surface, being blocked by the ozone layer in the upper atmosphere, but it is created by several different lamp types for germicidal use.

Light sources in the UV-A and UV-B region have been used to destroy bacteria, fungus, and other germs; however, the photobiological ultraviolet spectral band UV-C, ranging from 200 nm to 280 nm, is considered the only one capable of fighting the COVID-19 pathogens because the photons (particles of light) in these wavelengths are the most photochemically active in the optical spectrum (see the **Figure,** below).



The ultraviolet portion of the electromagnetic spectrum.
Source: IES Committee Report CR-2-20V1a Page 5 of 24

Photons in the UV-C region are absorbed by the RNA of a virus; then the photons break apart the RNA strands in the virus, preventing the damaged RNA from reproducing.

Most GUV lamps operate predominantly at 254 nm, which is close to the peak germicidal wavelengths of 265 nm to 270 nm; however, other wavelengths are also used, especially the 222-nm region. To be effective, the UV energy must reach a pathogen for a specific amount of time at a specific power density to achieve a lethal dose. The required dose depends on both the pathogen species and the degree of reduction desired. In the United States, the radiation dose (irradiation multiplied by exposure time) is expressed in millijoules per square centimeter.

Research on efficiency and safety

Only months after the breakout of the pandemic, organizations in the lighting industry assembled research panels to generate timely information. In April 2020, The Photobiology Committee of the Illuminating Engineering Society (IES) issued a free, 24-page guide to GUV disinfection techniques and its usefulness in combating the SARS-CoV-2 virus, which causes COVID-19, providing answers to commonly asked questions about disinfecting methods, GUV applications, lamp technologies, and safety concerns. In June 2020, the IES also created an 8-hr webinar involving eight speakers and covering the same subjects. Additionally, the IES and the International Ultraviolet Association (IUVA) are partnering to develop new standards for UV-C lighting equipment.

In December 2020, the Lighting Research Center at Rensselaer Polytechnic Institute issued a 55-page publication on the safety, efficiency, and effectiveness of UV disinfection products and currently available codes and regulations. The report also includes test results on 12 UV disinfection luminaires.

Finally, since improperly designed, installed, or operated GUV lighting can harm a person's health, several government agencies and standards-making bodies, such as Underwriters Laboratories (UL), National Electrical Manufacturers Association (NEMA), Centers for Disease Control (CDC), and the National Institute of Health (NIH) have recently issued new certifications, guidelines, and safety recommendations.

Lamp types

Lamps producing UV-C radiant energy include:

The *low-pressure mercury lamp,* operating at 254 nm, is identical to a regular fluorescent lamp, except that the lamp's interior surface lacks a phosphor coating and uses quartz glass. Some types of this lamp also produce radiation at other wavelengths. Still, other types of this lamp emit a broad range of UV wavelengths, along with visible and infrared radiation.

The *far-UV-C lamp,* called an "excimer lamp," is physically like the low-pressure mercury lamp, except that it does not contain mercury. Specific gas combinations form chemical compounds called excimers when excited. Every excimer emits at a specific wavelength. This lamp uses krypton and chloride to produce light at a peak emission of about 222 nm, which appears to be the safest UV wavelength for prolonged human exposure, since the energy does not penetrate the top layer of the skin or the cornea of the human eye. All the light energy is absorbed by proteins in the outer layers of the skin without penetrating in the way the 254-nm wavelength does. Similarly, the 222-nm energy is absorbed almost entirely by the tear layer of the eye.

Exposure of mice — and more recently of humans — to the 222-nm wavelength in experiments indicate that the excimer lamp has the potential for wide use. However, the International UV Association has been recommending more research before using this lamp, which is an area source, in occupied spaces.

The *pulsed xenon lamp* emits a short pulse of broad spectrum (including UV, visible, and infrared light), but some xenon lamps are filtered so that only the UV energy for disinfection is emitted. Maintenance and service should be performed by authorized personnel.

The *UV-C light emitting diode (LED)*, made from alloys of aluminum nitride, has several advantages over mercury lamps – durability, long life, instant-ON operation, a range of wavelengths, and no mercury. However, while visible light chips can have a useful life of 50,000 hr or more, UV solid-state chips have an expected life of about 9,000 hr. At this stage in its development, the UV LED is relatively expensive and has a higher power requirement compared to visible light LEDs, but improvements in performance are continuous. LEDs have been expanding into lower wavelengths; however, in the region below 250 nm, 240 nm, and 230 nm, the efficiency of the source falls off dramatically.

Two main applications

The application of UV-C equipment is challenging because the air in a space along with the surfaces and equipment in that space should be treated. Upper-air circulation luminaires that are mounted high on the upper walls or ceiling of a room to disinfect all of the air in a room are a specific category. Their application has been very successful in the health care industry since the 1960s. Upper air GUV has several design methods, but, in general, these luminaires are mounted at a height of 7 ft or 8 ft (or higher) on the wall or suspended from the ceiling **(Photo 1).**

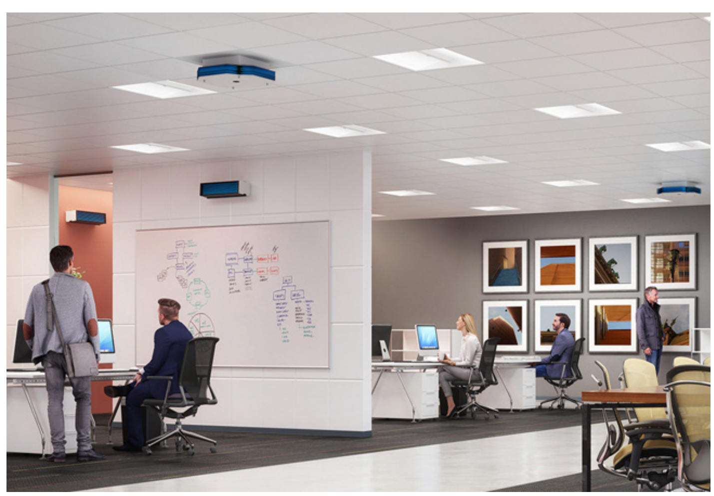


Photo 1. This office space uses two types of upper air GUV luminaires. The ceiling-mounted and wall-mounted units are located well above a 7-ft height for safety.
Source: Cooper Lighting

Luminaires should be at least 2 ft from the ceiling to allow for the spread of the light and create a large enough disinfection zone. Non-reflective louvers to direct the UV light upward are sometimes added to the unit. Natural convection, air from HVAC vents, and human movement cause the air in the room to circulate. Air entering the disinfection zone is exposed to the UV-C light, destroying the airborne viruses. In high-bay areas, high-ceiling warehouses, big-box retailers, and similar spaces, a more efficient open-lamp luminaire with fewer or no louvers can be mounted on a wall or suspended from the ceiling.

Although mounting GUV fixtures in HVAC air ducts are another method that ensures that recirculated air does not have viable pathogens, these units do relatively little to prevent person-to-person transmission in a room where both an infected person and other susceptible persons share the same air.

Luminaires for treating the surfaces of a room can be wall- or ceiling-mounted high-bays, louvered or parabolic troffers, under-cabinet, and strip units. In general, surface disinfecting luminaires should only be used when the room is vacant (this restriction may be lifted in the future for the 222-nm source). Both types of GUV luminaires — but especially those for treating surfaces — are usually considered to be supplementary because the radiation does not reach shadowed recesses of surfaces and does not penetrate dusty surfaces. Since these two disinfecting methods cannot do the task of eliminating the virus in a space, regular cleaning of surfaces with a liquid disinfectant should also be used on a continuing basis.

Design and application safety

Exposure to UV-C radiation can cause damage to the eye and to the skin. Two similar eye conditions that occur from exposure are:

- Photokeratitis, which is an inflammation of the cornea.
- Photo conjunctivitis, which is an inflammation of the conjunctiva (the membrane lining the inside of the eyelids and eye socket).

The effect is essentially like getting a sunburn on the eye. The symptoms, which can include pain, blurry vision, headaches, a gritty sensation, and temporary loss of vision, arrive within a day or so and usually last up to 48 hr. Damage to the skin, called erythema, or transitory sunburn, similarly lasts about 48 hr.

To assist the lighting community in evaluating the safety of commercial UV-C germicidal systems, some industry organizations have created brochures, videos, and webinars to help in the design and operation of these systems. For example, UL issued a document in September 2020 called UL 8802 Outline of Investigation for Germicidal Systems, which deals with permanently mounted equipment that could accidentally expose a person to damaging UV radiation. The installation of equipment and operating instructions are covered in this document, which also includes the labeling of equipment, personal protective equipment (PPE), and training for operators and service personnel.

Using this UL document, lighting manufacturers are developing UV-C germicidal lamp systems with control systems that incorporate dedicated occupancy sensors, audible and visual alarms, emergency stop buttons, magnetic door sensors, and other measures that prevent operation of the germicidal luminaires if a person enters a room or space **(Photo 2).**

Since the safe application of this equipment is extremely important, industry experts are urging all applicable governing bodies to formulate detailed and accurate information on the installation and maintenance of these systems, so as not to tarnish this emerging industry.

Because occupied spaces contain lighting systems, having a luminaire that also incorporates UV-C technology could be economical. Several luminaire makers are adding a UV-C system, operating autonomously

Photo 2. Some UV-C germicidal lamp systems feature control systems that incorporate dedicated occupancy sensors, audible and visual alarms, emergency stop buttons, magnetic door sensors, and other measures that prevent operation of the germicidal luminaires if a person enters a room or space.

and independently, to a standard lighting fixture. One manufacturer combines a ceiling troffer with a long, narrow visible light strip of LEDs centered in the luminaire and 12 UV-C LEDs enclosed inside a HEPA air circulating system to disinfect the air in a room (see **Three Ways to Fight the Viru**s below).

Shortcomings

While the technology continues to be promising, UV-C systems have some shortcomings. For example:

- All electromagnetic radiation interacts with matter. In the UV region, this radiation has sufficient energy to cause molecular damage (fading) to building materials, finishes, and fabrics. Many types of materials slowly degrade with extended exposure to UV-C radiation. If this factor is considered important, more research aimed at UV-resistant paints, plastics, and other materials may be needed.
- UV-C radiometers, used to measure the output of GUV systems, are expensive, require frequent recalibration, and may not provide an accurate reading. A less expensive way to verify germicidal UV effectiveness is with a single-use card (called a dossier) that is printed with color-changing UV-C-sensitive ink.
- The low-pressure mercury lamps have a much short life than the corresponding visible light lamps: 10 hr to 15,000 hr. Also, the efficiency of these systems goes down as humidity increases.
- Currently, manufacturers are doing the work of engineering the GUV systems. The luminaires come factory calibrated from the calculations done at the time of specification, using software programs that utilize UV spectral power distribution graphs and UV radiometric distribution graphs.

What the future holds

The virus has been mutating since it was identified a year ago, and there is increasing consensus that globally SARS-CoV-2 is likely to remain endemic for at least a decade. It is also possible that the virus will be seasonal, with predictable annual peaks. It could also mutate to become even more virulent. Electrical contractors, electrical engineers, and specifiers interested in GUV technology should study the latest developments and work with manufacturers that provide a range of products, offer instruction, and are committed to safety.

SIDEBAR: Three Ways to Fight the Virus

Lighting equipment manufacturers have responded to the pandemic by developing a variety of germicidal ultraviolet (GUV) systems. Although this equipment is expensive to install and maintain, the unit cost per system goes down with an increase in sales.

One major lighting equipment manufacturer recently introduced three product areas or strategies for fighting the virus:

1. *Continuous Air and Surface Disinfection Technology* (222 nm) – Designed to neutralize pathogens with people present while meeting safety guidelines.
2. *Intense Air and Surface Disinfection Technology (Pulsed Xenon - Broad Spectrum)* – This technology rapidly reduces pathogens while a space is unoccupied, using UV-A, UV-B, and UV-C wavelengths.
3. *UV Onboard Air Disinfection Technology* – Using a luminaire with UV light, this is the newest approach to UV germicidal upper air room treatment. Since the air chamber is sealed, no UV light enters the space.