The Invisible Light Revolution

Paul BLANC, Sales Director at Bolb

This article provides an overview of the most important parameters to consider when discussing UVC LEDs as well as background on the main disinfection applications of this technology. It is not intended as a scientific review of UVC LEDs. If you are looking for detailed technical information, then webinars, articles, and white papers from experts such as Mike Krames (Arkesso LLC.), or Ling Zhou and Jianping Zhang (Bolb Inc.) [1], or articles previously published in LED professional Review or on the LED professional website (https://www.led-professional.com/) are a good place to start.

"The COVID pandemic has awakened the world to the need for safe, effective, on-demand, point-of-use germicidal/virucidal solutions that do not involve poisonous chemicals that also cause logistical burdens. Bolb's UVC-LEDs as well as reference designs are tested and certified and demonstrate technology's scalability for air disinfection from large rooms to automotive cabins."

JERRY ZHANG, CTO BOLB

If you are a reader of LpR, there is a good chance that you witnessed the rise of visible light LEDs in the early 2000s. And if not, when was the last time you did not use LEDs in your lighting projects? Who would have imagined that this comparatively expensive and inefficient electronic component would replace proven, efficient, and cheaper conventional light sources? LEDs are now predominant in many applications: from TV backlighting, street lighting, and automotive lighting to entertainment and stadium lighting, commercial and residential lighting, to horticulture – the list is long. 20 years later, new developments in UVC LEDs are now showing very promising results. Yet conventional light sources like mercury lamps are still far ahead in terms of performance. Do you have a strong feeling of "déjà-vu"? This time though, the situation is different.

The LEDification of the visible lighting market has put LEDs in the spotlight. More importantly, the global pandemic over the last two years has shown the urgent need for innovative and environmentally friendly technologies that can make the world a safer and healthier place. Thanks to their compact dimensions, UVC LEDs are now paving the way for new designs. These LEDs offer optimal beam control thanks to optics and reflectors that improve how radiated energy is focused. They do not contain mercury or generate ozone. They start instantly and do not have a warm-up phase, making them ideal for applications with high switching cycles. And finally, UVC LEDs are not made of glass. This makes them more resistant to impact and vibrations, eliminating the risk of mercury leakage that can occur when conventional lamps break.

The Main Parameters When Discussing UVC LEDs

What are the most important criteria when starting a UVC project? Specific requirements will vary depending on the application, but there are some general parameters that always apply.

The first parameter is wavelength. UV light is in the 100–380 nm range of the spectrum. The main types of UV light are UVA (320–400 nm), UVB (280–320 nm), and UVC (200–280 nm). The UVC region is the most important for disinfection as it offers the highest ultraviolet germicidal effect. Mercury lamps have a peak wavelength at 254 nm – that's it. LEDs, on the other hand, can be produced with specific wavelengths, for example 275 nm, or 265 nm. LEDs in the 260–270 nm range offer the highest rate of disinfection. Germicidal effectiveness in individual cases will vary, however, depending on the target medium, surface, and microorganisms.

The next parameter is the Wall Plug Efficiency (WPE) of the light source, also known as Power Conversion Efficiency (PCE). The WPE or PCE is the ratio between the optical power and the electrical power of the emitter. Currently, UVC LEDs typically deliver 260–280 nm with efficiencies ranging from ~ 1% to ~ 10%.

Optical output is another essential factor. It is not quantified in lumen like conventional LEDs but in milliwatts or watts. Manufacturers will normally specify the output at the typical driving current and forward voltage. To increase the optical output of an LED, you can simply increase the driving current.

LEDs can also be easily collimated using optics or reflectors. However, not every material is compatible with UVC light. For example, standard glass can block UVC rays and standard optics degrade when they are exposed to UVC light. That's why optics made of quartz glass or silicone are recommended.

The next point to consider is lifetime. The lifetime of LEDs can be at least 50% shorter than that of standard linear light sources. This strongly depends on the conditions in which the LEDs are used.

- LEDs are driven at the typical current, and if the driving current is reduced or increased, the lifetime will increase or decrease. The following formula can be used to calculate the lifetime based on the driving current: the lifetime is ex-

Germany and Other Countries
Laser Components Germany GmbH
Tel: +49 8142 2864–0
Fax: +49 8142 2864–11
info@lasercomponents.com
www.lasercomponents.com

France
Laser Components S.A.S.
Tel: +33 1 39 59 52 25
Fax: +33 1 39 59 53 50
info@lasercomponents.fr
www.lasercomponents.fr

United Kingdom
Laser Components (UK) Ltd.
Tel: +44 1245 491 499
Fax: +44 1245 491 801
info@lasercomponents.co.uk
www.lasercomponents.co.uk

Nordic Countries
Laser Components Nordic AB
Tel: +46 31 703 71 73
Fax: +46 31 703 71 01
info@lasercomponents.se
www.lasercomponents.se

USA
Laser Components USA, Inc.
Tel: +1 603 821 – 7040
Fax: +1 603 821 – 7041
info@laser-components.com
www.laser-components.com

tended or shortened by the inverse of the current ratio to the power of 1.5.

- Temperature also has an important influence on lifetime and optical output. Exceeding the ambient, solder, or junction temperature recommended by the manufacturer will have a negative impact on the lifetime of an LED. UVC LEDs must be properly cooled to avoid accelerated optical power and loss of lifetime. The use of an appropriate combination of cooling solutions, for example metal core PCBs, thermal pastes, heat sinks, or heat pipes and fans, is prerequisite, particularly in applications where significant optical power is required and where the LED density is high.

Exposure to UVC light is also an important aspect. UVC light can be harmful to living organisms and can damage DNA and RNA. Depending on the irradiance and on a person's skin type, for example, exposure lasting just a few hours can already irritate the skin and eyes, with long-term exposure increasing the risk of cancer. It is therefore essential that users are not exposed to UVC light for long periods of time. The fact that UVC light cannot be seen (or in some cases only as a dim purple light) makes it even more important to ensure that UVC-based systems are safe for the people who use them.

So how can you make sure that UVC systems are safe? Here are some recommendations:

- Install LEDs in an enclosure to avoid leakage of light.
- If LEDs are not placed in an enclosure, users of UVC light technology must wear appropriate personal protection equipment.
- Use smart solutions such as sensors, control timers, and connectivity to limit exposure.
- Place appropriate warnings on the packaging and device.
- Educate and train users.

No matter what wavelength of UVC radiation is used, the safety of the LED system is paramount.

Last but not least, it is essential to look at the UVC dose that is required. The dose depends on the type of microorganism that you want to target (several studies include UVC radiation tables), and on the type of application. Is the target medium a surface, an object, or a fluid? What are the characteristics? What is the distance to the target? How quickly should disinfection be completed?

UVC Disinfection Applications

Water Disinfection

There are two main areas where UVC light can be used to disinfect water: at Point of Use (PoU) and at Point of Entry (PoE). Compared to chemical options, UVC disinfection does not alter the taste, temperature, or pH of water.

PoU was one of the first applications for UVC LEDs. Thanks to the compact dimensions of LEDs, companies can develop single LED disinfection systems for water faucets, fountains, and water bottles where conventional light sources cannot be used. Moreover, most of these systems only run for a few hours a day at most, which is ideal given the current limitations on the lifetime of UVC LEDs. These kinds of solutions can be found in laboratories that produce ultra-pure water, in homes, and in mobile water disinfection systems. PoU systems that use LEDs also help to reduce the use of plastic bottles and improve access to safe drinking water.

Figure 2: Water faucet (PoU) disinfection.

PoE is a much more demanding application, primarily due to the high flow of water and use around the clock. Nevertheless, early adopter companies have already begun installing high-flow water disinfection reactors. These systems can be found for example in municipal water treatment plants, swimming pools, fish farming, ballast water treatment systems on ships, and in many industrial applications. The main motivation here is to avoid the use of mercury and replace fragile glass arches with robust solid state semiconductors. And as the lifetime of these reactors can be up to 20 years, intelligent retrofit solutions can be developed in the meantime to easily upgrade the system with the latest generation of UVC LEDs during recurring maintenance.

An example of water faucet (PoU) disinfection is shown in **Figure 2**. The device is mounted directly at the outlet of the water faucet. It is equipped with one LED with 100 mW (typical) optical power. Water flow rates of 1.5 to 5 L/min were tested with this device, achieving a kill rate against E. coli > of 99.999%.

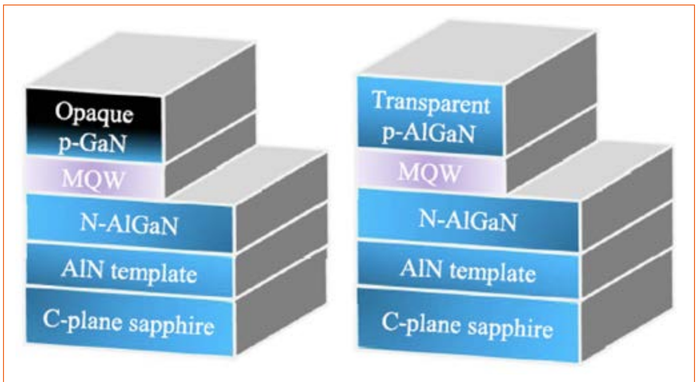

Figure 1: The difficulty for UV-C LEDs is the requirement of a high UVC transparency and an efficient hole injector layer: The traditional design is based on a non-transparent p-layer with a poor $\eta_{ext} < 6\%$ (left). The Bolb epi consists of a transparent p-layer and an efficient hole injector resulting in a higher efficiency of η_{ext} 14% now, and η_{ext} 75% in the near future (right).

Air Disinfection

As airborne virions play a dominant role in the rapid spread of the COVID-19 virus and all its mutations, air disinfection using UVC light has a significant impact in preventing transmission. New legislation is already encouraging schools to install air disinfection systems in classrooms. Organizations are using this technology to make offices a safe place for their employees. And public transportation operators are looking at new ways to offer a safer travelling ex-

Germany & Other Countries
Laser Components Germany GmbH
Tel: +49 8142 2864 – 0
Fax: +49 8142 2864 – 11
info@lasercomponents.com
www.lasercomponents.com

France
Laser Components S.A.S.
Tel: +33 1 39 59 52 25
Fax: +33 1 39 59 53 50
info@lasercomponents.fr
www.lasercomponents.fr

United Kingdom
Laser Components (UK) Ltd.
Tel: +44 1245 491 499
Fax: +44 1245 491 801
info@lasercomponents.co.uk
www.lasercomponents.co.uk

Nordic Countries
Laser Components Nordic AB
Tel: +46 31 703 71 73
Fax: +46 31 703 71 01
info@lasercomponents.se
www.lasercomponents.se

USA
Laser Components USA, Inc.
Tel: +1 603 821 – 7040
Fax: +1 603 821 – 7041
info@laser-components.com
www.laser-components.com

perience to commuters. Air disinfection devices already come in many forms, for example mobile units, air troffers, air ducts, and upper air disinfection solutions. With UVC LEDs, new, innovative solutions for clean and healthy air are possible, from retrofitting of existing systems to development of completely new applications.

Figure 3: Testing of a 3,000 LPM air disinfector at the Guang Zhou Institute of Microbiology, achieving a 99.96% single pass kill rate against aerosolized staph aureus.

The "single pass kill rate", in other words the amount or percentage of virus that will be killed in one pass through a disinfection device has always been considered a key parameter. With LEDs, increasing the air flow rate of a device makes it even more efficient. And this can be done quickly and cost-effectively. LED systems have been developed that can disinfect an air flow of 10,000 liters per minute and achieve a 99.96% kill rate in a single pass against aerosolized Staphylococcus aureus. This is with just one 25-LED module with 2.5 W of optical power.

Surface Disinfection

Surface disinfection is a simple way to disinfect objects and surfaces that need to be kept free of viruses, bacteria, or mold. This can be useful in hospitals, for medical equipment, in forensics, and where objects are regularly touched by different persons, for example door handles, handrails, ATMs, restaurant menus, etc. At the same time, system designers must take care here to ensure safety because this is where users face the highest risk of exposure to UVC radiation. **Figure 4** shows a disinfection chamber for masks with a four-LED module (0.4 W of optical power) that achieves a 99.9996% kill rate against SARS-CoV-2.

Figure 4: Disinfection chamber for masks.

Food Disinfection

Although it is essentially a combination of water and surface disinfection, food disinfection is worth mentioning separately, as food loss due to bacteria or fungus can be crucial. In addition, food poisoning is a well-known risk for end users, as we hear increasingly so about recalled salad, vegetables and meat after treatment with unsafe and contaminated water in the process.

From seeds, to plants, to fruit and vegetables, as well as in livestock breeding, UVC LEDs can be used in many applications. They can also be put to good use in disinfecting farms, greenhouses, vertical farms, food processing factories, and kitchens, as well as in food transport, storage, and retail.

Not only do they help to prevent food waste, UVC LEDs can also significantly reduce the use of pesticides, chemicals, and antibiotics in the farming industry.

"We are proud and glad at the same time that our UVC LEDs are the critical building blocks for such timely applications to provide clean and safe air for healthcare workers, patients, operators of restaurants, retail stores, office buildings, automotive and public transportation."

DR. LING ZHOU, CEO OF BOLB

Summary

The COVID-19 pandemic is demanding urgently for new, innovative solutions to make the world a safer and healthier place. UVC LEDs may need further innovation before they can fully replace conventional UVC light sources, however, they are already on the right road to achieving a success story similar to that of visible LEDs. Not only are they environmentally friendly, UVC LEDs also enable new designs thanks to their compact dimensions. The lessons learned from the last two decades and recent technical breakthroughs in the field of UVC LEDs show that they have the potential to surpass the performance of mercury lamps in the next five to ten years. Some high WPE UVC LEDs from existing suppliers enable already today a more efficient disinfection in air purifiers due to their significant higher surface brightness (etendue). What's more, as the evolution of UVC LEDs continues, new applications are set to emerge too. It's time to join the invisible light revolution! ■

Author: Paul BLANC
Paul Blanc joined Bolb, Inc in July 2021 as Sales Director for Europe. Passionate about LED lighting and customer success, Paul has proven experience in the industry with major lighting companies such as Philips Lighting, Osram, and Samsung. He has built a solution and service-oriented mindset in a variety of roles including Application Engineering, Business Development, and Product Management, and deepened his expertise in Distribution and Management at Arrow Electronics. Paul was awarded a Master of Science in 2007 from ESIEA in Paris, an engineering school specialized in information, technology and electronics. He is 38 years old and lives near Munich, Germany.
mailto:p.blanc@bolb.co

Bolb, Inc. was founded in 2014 and is based in Livermore, California. Bolb, Inc. has developed and patented breakthrough UVC LED technologies to enable 'never before possible' disinfection systems for air, water, surfaces, and food to scale on a global basis to benefit human health and increase productivity in key verticals with the objective to preserve valuable resources.

References

[1] https://bolb.co/

First published in LED professional Review (LpR), Issue March/April 2022, Issue #90 / www.led-professional.com

Germany & Other Countries
Laser Components Germany GmbH
Tel: +49 8142 2864 – 0
Fax: +49 8142 2864 – 11
info@lasercomponents.com
www.lasercomponents.com

France
Laser Components S.A.S.
Tel: +33 1 39 59 52 25
Fax: +33 1 39 59 53 50
info@lasercomponents.fr
www.lasercomponents.fr

United Kingdom
Laser Components (UK) Ltd.
Tel: +44 1245 491 499
Fax: +44 1245 491 801
info@lasercomponents.co.uk
www.lasercomponents.co.uk

Nordic Countries
Laser Components Nordic AB
Tel: +46 31 703 71 73
Fax: +46 31 703 71 01
info@lasercomponents.se
www.lasercomponents.se

USA
Laser Components USA, Inc.
Tel: +1 603 821 – 7040
Fax: +1 603 821 – 7041
info@laser-components.com
www.laser-components.com