Are UVC LEDs an alternative to UVC tubes?

Efficiency and challenges compared

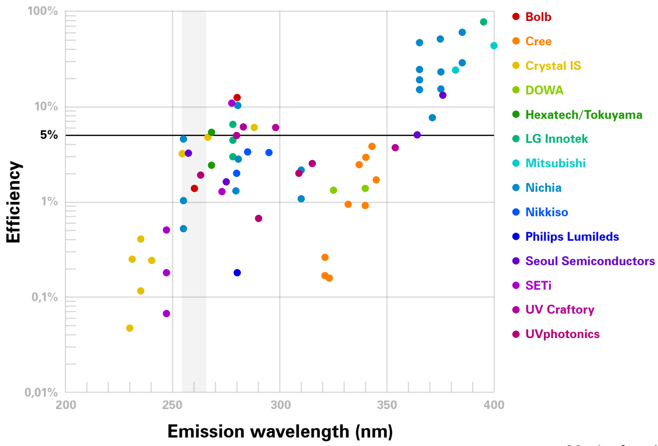
Today's High Power LEDs achieve about $100mW_{uvc}$ in the germicidal UVC range and have an energy efficiency of around 5%.[1] This is significantly less than that of conventional low-pressure UVC tubes. UVC LEDs face challenges such as high temperatures, a severely limited lifespan, and high power losses[2] – they therefore do not offer the well-known advantages of LEDs for lighting purposes. Technically and ecologically, UVC LEDs are not an equivalent alternative to conventional UVC emitters, especially not for industrial continuous use.

Characteristics of UVC LEDs

The efficiency of an LED is highly dependent on the crystalline semiconductor material and its specific doping to emit defined electromagnetic frequencies. In the case of UVC LEDs, these frequencies lie in the germicidal wavelength range of ~260nm.

Current High Power LEDs in the UVC range only achieve an efficiency of about 5%[1], partly due to the semiconductor material aluminum gallium nitride (AlGaN) required for very high frequencies.

The most powerful LEDs today initially generate around **$100mW_{uvc}$ @350mA** under laboratory conditions. This is no comparison to the **$18{,}000mW_{uvc}$ @225mA** of a conventional low-pressure UVC tube. The continuous increase in performance by increasing current is technically limited in UVC LEDs due to a reverse voltage of ~7V. Additionally, the high current leads to significant heat stress on all connected components. Operating temperatures of up to 90°C are common, preventing the formation of high-density LED arrays.



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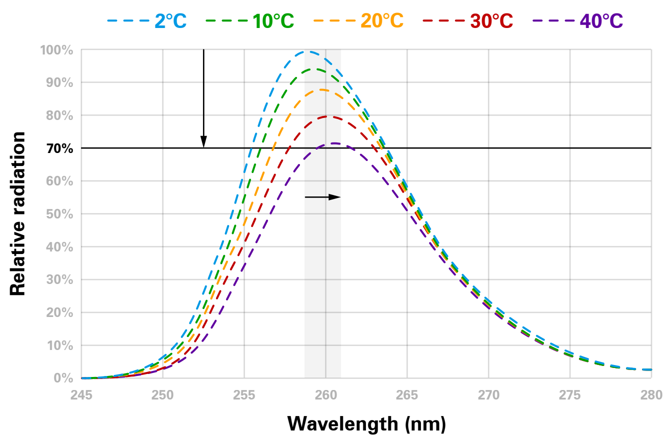

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High temperatures in UVC LEDs

Efficient cooling of the highly heated LEDs is not guaranteed as the ambient temperature rises, extensive research by the DVGW-Technologiezentrum Wasser (TZW) has documented. The performance of a UVC LED drops by almost 30% when the temperature increases from 2°C to 40°C; at the same time, a so-called **temperature shift** occurs (a wavelength shift of up to ±3nm).[2] In order to ensure sufficient cooling, High Power LEDs must also be soldered directly to the carrier board. Replacement is only possible by **exchanging the entire carrier board**, leading to increased electronic waste.

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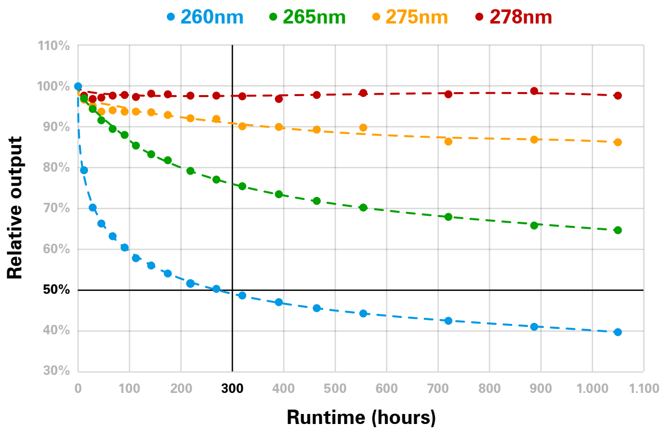
Lifespan of UVC LEDs

Unlike lighting LEDs, High Power UVC LEDs exhibit a **significant aging-related performance decline**. This is more drastic, the shorter the peak wavelength of the LED. Depending on the manufacturer and peak wavelength, the emission of UVC LEDs can **decrease by up to 50% within the first 300 operating hours.**[2] However, wavelengths >265nm reduce the germicidal effect: at 278nm, it is already almost 30% less.[3] Furthermore, LEDs, like low-pressure tubes, do not handle frequent switching well, even if they reach their respective performance level immediately.



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Mercury vs. Rare Earth Elements

A key argument for LEDs is their mercury-free nature. While this is technically correct, it falls short from an environmental perspective: LEDs contain high amounts of aluminum, antimony, arsenic, chromium, copper, gallium, gold, indium, iron, lead, nickel, phosphorus, silver and zinc. **They can only be recycled partially or not at all.** The extraction of rare earth elements needed for their production, such as europium (Eu), terbium (Tb), and yttrium (Y), also poses a significant environmental burden.

No price advantage

As an example, consider the Oslon UV 3535 LED (88mW @2.1W). To achieve the laboratory performance of a conventional low-pressure tube, 204 LEDs plus heat sinks and driver boards would be required. As of summer 2024, the unit price was approx. $23.00.[4] The total power loss sums up to 428W, more than seven times that of a low-pressure tube. **No ecological or economic advantage is apparent.** The high heat output also requires sufficient spacing between individual LEDs, making it impossible to irradiate large areas homogeneously with high intensity.

sterilAir actively monitors technical developments and is part of ongoing research. However, conventional UVC emitters based on gas discharge will not be replaced by UVC LEDs in the near or foreseeable future, nor are they suitable for industrial use.

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D. Koller
(R&D, **sterilAir** AG)

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1. D. Prakashchandra Patel, Temperature Dependence of Electroluminescence and Current-Voltage Characteristics of Arrays of Deep Ultraviolet Algan Micropixel LedMicropixel Led, University of South Carolina, 2021. **2.** DVGW-Technologiezentrum Wasser, Why and how to characterize LEDs, ICULTA Berlin, April 2018, p. 8+11. **3.** CIE Technical Report Ultraviolet Air Disinfection 155:2003, March 2020, p. 12, fig. 5. **4.** https://www.digikey.com/en/products/detail/ams-osram-usa-inc/SU-CULEP1-VC-MHMM-57-1-350-R18/18667032 (last opened: September 2024).

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