of AlGaN quantum wells predict a slight increase in threshold current density for shorter emission wavelengths, even devices operating in the UV-C spectral range (<280 nm) should exhibit threshold current densities below 5 kA cm^{-2}, which the team says could be sufficient to allow stable continuous-wave operation. Kneissl warned, however, that realizing deep-UV laser diodes will require a number of remaining challenges to be resolved, including efficient current injection and the successful p-doping of AlGaN with a high aluminium mole fraction.

Motoaki Iwaya from Meijo University in Japan reported on a joint effort with Nagoya University to improve the efficiency and extend the wavelength range of UV LEDs. The researchers used current-density-dependent electroluminescence and excitation-density-dependent photoluminescence measurements to clarify how internal quantum efficiency, injection efficiency and light extraction efficiency individually impact the overall performance of a UV-emitting LED. UV-B and UV-C LEDs both demonstrated very high internal efficiencies, which indicates that the performance of deep-UV LEDs could be significantly improved in the future by the enhancing light extraction efficiency. The team also reported the realization of a deep-UV LED that has an internal quantum efficiency of over 85%.

One of the most popular commercial uses of UV light sources is for neutralizing pathogenic organisms and removing chemical contaminants from air and water. Although mercury arc vapour lamps are commonly used for such tasks, the wavelength-selective nature of solid-state sources can be used to maximize the efficacy of sterilization, as well as achieve higher electrical efficiency and improve device lifetimes. Solid-state sources also avoid environment problems associated with mercury release and lamp disposal.

Gordon Knight from the Canadian firm Trojan Technologies reviewed recent advances in the production of UV light sources, and also summarized the necessary validation procedures for verifying the operation of water disinfection systems. He noted that the output power of deep-UV LEDs in the 250–300 nm region has increased from less than 1 mW to around 5 mW (at a current of 100 mA) for a single chip, which corresponds to an output power of more than 80 mW for a multichip device.

"The main challenges when fabricating deep-UV LEDs are the mismatch of the AlGaN epitaxial material to the sapphire substrate, which can result in more than 10^8 defects per square centimetre, the incorporation of oxygen into AlGaN, and efficient light extraction from the semiconductor structure without the use of standard encapsulants, which cannot be used at deep-UV wavelengths," Knight told *Nature Photonics*. "Total powers of more than 250 mW per chip are desired in the deep-UV, and such powers are already available for 365 nm LEDs."

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Ultraviolet LEDs received significant attention at CLEO 2011. Applications such as sterilization require solid-state UV light sources with significantly higher efficiencies and output powers than those already widely used for curing ink and testing for counterfeit money.

"UV LEDs are far lighter in weight and more energy-efficient than traditional mercury vapour light sources."

Max Shatalov from Sensor Electronic Technology also focused on the applications of UV LED devices for water purification. Shatalov pointed out that recent innovations in the design, fabrication and assembly of UV LEDs have allowed lab-based prototypes to achieve a 100% increase in efficiency over today's commercially available products. Power levels of over 100 mW in the spectral range of 270–280 nm have been demonstrated by Shatalov and his team. Shatalov also described the company's high-power UV-LED-based prototype water disinfection system, which has been shown to reduce bacteria by 99.9999% in water flowing at a rate of one litre per minute. Shatalov and his team hope that these developments will pave the way for UV LEDs to be used for water purification in military, humanitarian and consumer applications.

Ke-Xun Sun from Stanford University and National Security Technologies in the USA discussed physically robust and radiation-resilient AlGaN optoelectronic devices for use in space exploration and high-energy-density physics. Sun and his team use AlGaN UV LEDs and photodiodes manufactured by Sensor Electronic Technology using 65 MeV proton beams comprising up to 3×10^{12} protons per square centimetre. The devices have passed a demanding set of space qualification standards that involve vibrational and thermal cycles. Operational lifetime tests of these UV LEDs have been running for five years, and are still ongoing. As for applications in space, Sun told *Nature Photonics* that deep-UV LEDs emitting at a wavelength of 255 nm can excite photoelectrons from gold surfaces, and that this process can be used for charge management in gravitational reference sensors for precision space interferometry measurements.

"UV LEDs are far lighter in weight and more energy-efficient than traditional mercury vapour light sources," explained Sun. "Teams from Stanford University, NASA Ames Research Center and the King Abdulaziz City for Science and Technology are currently building a satellite to demonstrate the suitability of UV LEDs and photodiodes for space flights, and to demonstrate UV LED a.c. charge management in a space environment."

Radiation-resilient UV photodiodes have significant potential for next-generation high-energy-density physics experiments, in which the high particle fluxes involved can cause radiation damage to conventional optical detectors. Such progress, particularly with respect to the efficiency of deep-UV LEDs and low-threshold lasers grown on low-defect-density AlN substrates, suggests that further performance enhancements may be just around the corner. ❐

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Correction

The News & Views 'Backwards Doppler shifts' (*Nature Photon.* **5,** 199–200; 2011), should have cited a relevant manuscript that was published in October 1997:

Liu, W. F., Russell, P. St. J. & Dong, L. *Opt. Lett.* **22,** 1515–1517 (1997).

The manuscript describes positive and negative Doppler shifts at optical frequencies in an acousto-optic superlattic modulator using a fibre Bragg grating. Associated amendments have been made to the text and the references have been renumbered accordingly.

This revision has been made to the HTML and PDF versions.