UV-LEDs: An emerging technology
It took less than five years from the fundamental breakthroughs in gallium-nitride (GaN) materials technologies to the first demonstration of candela-class blue light emitting diodes (LEDs). Just a few years later, GaN-based white LEDs entered the markets, and today high-efficiency white LEDs are about to completely transform the lighting market. A similar transformation can be expected from UV optical sources in the near future. Up to now, we have only accessed a very narrow sliver of the emission spectrum that is reachable through semiconductor LEDs. By alloying aluminium-nitride (AlN) and gallium-nitride (GaN) materials in AlGaN-based LEDs the emission can be tuned to cover any wavelength in the UV-A (400nm-320nm), UV-B (320nm-280nm), and UV-C (280nm-200nm) spectral range. Compared to conventional sources UV-LEDs are compact, robust, and environmentally friendly; they can be rapidly switched on and off, are operated at moderate voltages, and exhibit very long lifetimes. Although the technological development of UV-LEDs is still at the very beginning, there is no doubt that this new technology offers immense economic potential. And UV-LED devices are the key enablers for a wide range of new applications including water purification, UV curing, environmental sensing and life sciences, medical diagnostics, and therapy. All in all, the development of UV-LED technologies provides significant leverage for a wide range of applications. Its economic potential is therefore by far greater than the mere commercialization of semiconductor UV components.

Fig. 1: Applications of AlGaN-based LEDs emitting in the UV-A (400nm-320nm), UV-B (320nm-280nm), and UV-C (280nm-200nm) spectral range. Source: FBH

Fig. 2: Covering the entire value chain from materials growth to device fabrication and systems integration.
Contributions to Key innovations

UV-LEDs: The challenges ahead
Despite the great progress in the development of UV-LEDs over the past few years their performance levels still lag behind their blue wavelength counterparts. Although there seem to be no fundamental limitations that would prohibit the development of high-efficiency, high-power UV-LEDs, there are a number of challenges ahead. One is the relatively high defect density in AlGaN materials limiting the internal quantum efficiencies of UV emitters. Hence, low defect density AIN substrates and advanced deposition methods, like lateral epitaxial overgrowth are being developed. Current UV emitters also suffer from low light extraction efficiency. Therefore, new approaches such as nanopixel contact designs and laser-induced substrate lift-off technologies are being explored. For high-power LEDs advanced thermal management techniques like flip-chip mounting on AIN ceramics and wafer-level packing are being investigated. Pushing the wavelength limits towards the lower end of the UV-C spectral range and developing custom solutions for UV-LEDs, e.g. UV-LED point sources for sensing applications, are additional challenges.

Advanced UV for Life: Linking up devices and applications
In order to accelerate the development of UV-LED technologies and their applications, research institutions, universities, and industrial partners joined forces within “Advanced UV for Life”. The network is funded by the German Federal Ministry of Education and Research within the “Zwanzig20 – Partnerschaft für Innovation” initiative. The consortium, headed by the Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, brings together more than 30 interdisciplinary partners from research and industry to develop high-efficiency UV-LEDs, UV modules, and systems. The “Advanced UV for Life” consortium cross-links partners along the entire value chain, starting with materials research and UV-LED fabrication through to system integration and the respective application. The wide range of applications involves medicine, like phototherapy, blood analysis, and detection of multi-resistant germs, as well as the purification of drinking water in point-of-use systems and water treatment in home appliances like washing machines. UV-LEDs can also be used in UV-curing equipment for 3D-printing, water duct renewal, gas detection systems, for environmental monitoring, and in life science applications like plant growth lighting.

Thus, the economic and societal benefits resulting from the development for a wide application range that require UV-LED technologies are perfectly obvious. Latest market studies predict rapid technological advances in the development of semiconductor-based UV-LED sources. For the world market of UV-LED components alone an annual growth rate of 43% is being forecasted, reaching a total volume of US$ 270 million by 2017.

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Fig. 3: UVB-LED module for plant growth lighting. The exposure to UV-B light significantly increases the secondary plant metabolites in broccoli, which reduce the risk of cancer and cardiovascular diseases.
Source: Leibniz Institute of Vegetable and Ornamental Crops Großbeeren/Erfurt e.V.