

Breaking new ground in photonic fields of the future

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Laser technology is entering a new phase. The first ultrashort-pulse (USP) lasers now achieve average powers in the double-digit kilowatt range, while continuous-wave (cw) lasers are approaching three-digit kilowatt levels. As a result, laser processes are becoming viable in markets that photonics could not previously address. In the future, lasers may break rock in mining or tunnels and deep drilling without tool wear, cut and join centimeter-thick steel plates for ships or wind-turbine towers, and functionalize surfaces at previously unattainable speeds. High-power lasers are also attracting growing interest in defense research.

In USP material processing, these new beam sources enable a further leap in productivity. Engineers can split a single laser into dozens of individual beams and run processes in parallel. At the same time, new beam-shaping approaches allow beam profiles to be tailored precisely to components and processing steps. Optical neural networks now make it possible to realize almost any three-dimensional beam profile.

But that is not the only breakthrough in photonics fields of the future. Laser technology is also moving into focus as a key enabler for fusion power plants and advanced secondary radiation sources. Both fields depend on the development of high-energy laser systems. In collaborative projects with industry partners, our institute is developing compact neutron and X-ray sources that can analyze the contents of containers and barrels through their walls for security applications. In the future, high-pulse-energy lasers will not only enable neutron, X-ray, and EUV generation in confined spaces, but will also play a central role in laser-driven inertial fusion (IFE).

IFE systems place extreme demands on laser technology. They require high pulse energies – from hundreds of kilojoules to beyond one megajoule – precisely defined pulse shapes, short wavelengths in the ultraviolet range, excellent beam quality, high efficiency, and repetition rates of around 15 hertz. Only under these conditions can the fusion plasma be compressed and heated sufficiently for deuterium and tritium nuclei to overcome the Coulomb barrier and fuse into helium, releasing energy. Meeting these requirements is a

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formidable challenge, which consortia from industry and research have already begun to address. In projects funded by the German Federal Ministry of Research, Technology, and Space, researchers are developing high-power diode lasers, robust optical components, resilient wall materials, and automated manufacturing processes suitable for large-scale production.

Beyond laser sources and optics, fusion itself offers a wide field of opportunity for photonics. Laser-based processes are needed to manufacture key components for both inertial and magnetic fusion facilities. In addition, advanced simulations support subsystem development and the modeling of complete fusion power plants. Data science and artificial intelligence play a crucial role here – and far beyond fusion alone.

High-performance laser applications increasingly depend on digital solutions that ensure reliable, precise operation. This applies to surface technology, optical system design and manufacturing, beam-source development, quality-assured laser cutting and joining, as well as laser medical technology, microelectronics, and quantum technologies.

This breadth of topics is reflected in the program of AKL'26, which will take place from April 22 to 24 in Aachen. Celebrating its 30th anniversary, the International Laser Technology Congress brings together strategic decision-makers from six application industries with pioneers from photonics research. Let us discuss technologies with real prospects for the future. We look forward to your ideas, inspiring presentations, and lively discussions.