Unique geometry

Many of the advances in fibre-laser technology are thanks to work by Andreas Tünnermann, now head of the Fraunhofer Institute for Applied Optics and Precision Engineering in Jena, Germany. **Nadya Anscombe** spoke to him about developments in the area and his views on its future.

Why are fibre lasers provoking so much interest at the moment?
Many of the advances needed to develop high-power fibre lasers took place in the 1980s, driven by demand from the telecoms industry. Huge investments were made in fibre and transmission technology, and when this market collapsed a few years ago, former telecoms companies identified novel markets for fibre-laser and amplifier technology in marking, welding and cutting. Although some types of heavy industry, such as the automotive industry, were initially slow to adopt this technology, they soon realized the advantages, and today we are seeing rapid growth in fibre-laser sales. The main selling point for fibre lasers in this market is that they have a wall-plug efficiency of up to 30% compared with typically less than 5% for conventional solid-state lasers and 20% for diode-pumped solid-state lasers. This is important now that energy saving results in a significant cost reduction. Fibre lasers also have excellent beam quality, are very reliable and they are ideal for remote welding, giving manufacturers great freedom on the production line. These and other advantages have resulted in annual growth rates for fibre-laser sales of around 30%.

What have been the most important technological advances in the past few years?
The fibre laser's unique geometry has enabled significant advances in scaling the power of their light output up to power levels in the multikilowatt range. Because of the fibre's huge surface area with respect to its volume, cooling is very efficient and this enables efficient operation, even at higher power levels, with excellent beam quality. Over the past two years the output power of ultrafast laser systems has been increased considerably by applying fibre technology. Until recently, femtosecond and picosecond lasers were complex devices, so that applications of these devices were limited to fundamental research laboratories. Now, with average output powers increasing from one watt to several hundred watts, many new avenues have opened. For years it has been well known from laboratory research that the use of ultrafast lasers for ultraprecision machining is advantageous when compared with traditional machining techniques because the heat-affected zones surrounding the work area are significantly reduced. This has implications for applications such as drilling injection nozzles, the manufacture of displays and even brain surgery and ophthalmology. Owing to the recent progress in scaling up the power of ultrafast fibre lasers, real-world applications in production and medicine are now feasible. Impressive results have been achieved using so-called photonic-crystal fibres. These fascinating structures give laser manufacturers an additional degree of freedom in the control of light. For example, they can be designed to only propagate the fundamental mode, thus providing a diffraction-limited beam. This means that the diameter of the fibre can be increased and the fibre will remain a single-mode fibre. The use of larger fibres is important for scaling the power because the intensity of the interaction of the laser with the optical material can be reduced, avoiding unwanted effects that degrade performance.


Fibre laser pioneer: Andreas Tünnermann.

What are the remaining challenges?
There are still issues to be addressed regarding the reliability and lifetime of fibre lasers, especially in pulsed operation. The brightness of the pump diodes used to realize the population inversion in the active fibre has to be further improved to enable a more efficient excitation of the fibres in high-power operation. In addition, nonlinear effects in the fibre, which limit the transmittance of the fibre in high-power operation, have to be minimized by optimization of the material properties and the design of the fibres. A challenge for the fibre-laser industry of today is also the passive beam-delivery system. Customers from the production industry want high-power beam delivery systems, which could be operated like optical networks. Integrated laser sources, optical fibres, fibre-optical combiners, splitters and switches can be configured into a flexible energy-delivery system enabling cutting and welding at different stations using just one laser. These systems have to handle high power densities within the optical waveguide, and the light has to be transmitted up to several hundreds of metres without affecting the beam quality. The components of this flexible energy-delivery system are not available today. We have to develop techniques for steering and guiding light at the highest power levels.

What do you feel are the future applications for fibre lasers?
The fibre laser's versatility means it can address the requirements of almost any market that uses laser technology, from high-power lasers used in the defence industry to the low-power devices used in biophotonics or quantum-limited light sources used in interferometric gravitational wave detection. Fibre-laser technology could replace cumbersome high-power chemical lasers in the airborne laser, which is being developed to shoot down missiles in flight. It could revolutionize laser microscopy by replacing sophisticated white-light lasers in the real-time non-destructive identification of living cells. In fact, the possibilities for this unique laser geometry are endless.

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