PRESS RELEASE

More efficient and brilliant diode lasers thanks to fiber Bragg gratings

Whether they are needed for medical technology, telecommunications or aerospace: the demand for high-power lasers is increasing in many industrial sectors. Users are focusing on how cost-effective and stable the systems are. The Fraunhofer Institute for Laser Technology ILT has now made significant progress in the development of efficient and stable high-power diode lasers. In principle, it has transferred the writing of fiber Bragg gratings from the world of fiber lasers to that of diode lasers. Dr. Sarah Klein developed the process as part of her dissertation and recently won 3rd place in the prestigious Hugo Geiger Prize.

The complexity of fiber laser systems can be reduced enormously with fiber Bragg gratings (FBGs). If the optical gratings are written directly into the fiber, they can replace external resonator mirrors. This eliminates the need for time-consuming mirror alignment. Not only does direct fiber integration reduce system complexity, susceptibility to interference and costs, but the brilliance of the emitted laser radiation also increases significantly.

Concept for fiber integration

In 2019, within the BMBF-funded EKOLAS project, Fraunhofer ILT took part in developing a process that had already been established for inserting FBGs into the interior of optical fibers, in this case for single-mode fibers with a core diameter of six micrometers. Coordinated by Laserline, the consortium succeeded in writing the fiber Bragg gratings into quartz fibers with a core diameter of 100 micrometers using USP lasers: The material melts briefly under the influence of the ultrashort laser pulses, cools down again very quickly and changes its optical properties in the bulk material processed in this way. The structure introduced is based on an interference pattern of superimposed light waves designed for this purpose.

A single FBG with a diameter of 100 micrometers is sufficient to relocate the previously external resonator mirrors into the fiber and optimize multimode fiber lasers in many respects. As part of her doctoral thesis, the Fraunhofer researcher also transferred this process, which she continued to develop, to fiber-coupled diode lasers. For her innovative research, she was awarded third place in the prestigious Hugo Geiger Prize on February 19, 2025, a prize that is awarded annually by the Free State of Bavaria and the Fraunhofer-Gesellschaft.

Same concept - new objective

In her work, Klein focused not only on multimode fiber lasers, but also on optimizing diode lasers, which are needed to pump solid-state lasers. This changes the objective. In contrast to fiber lasers, the FBGs are used in this application to improve the spectral properties of the diode laser radiation. Some background: In order to raise the energy level of the laser-active medium during optical pumping, the medium is excited with a specific wavelength. Only then can the medium optimally absorb this radiation.

However, diode lasers emit broadband radiation. For this reason, the researcher developed a concept to specifically reduce the bandwidth and stabilize the wavelength of the laser radiation. Once again, a directly inscribed fiber Bragg grating is central to this approach. It ensures that the high-power diode lasers used only emit the desired wavelength. Thanks to this increase in brilliance, the energy input into the solid-state laser is many times more efficient and, therefore, more cost-effective: an enormous advantage for industrial applications in which cost-effectiveness and energy efficiency are playing an increasingly important role!

Complex integration

Klein continued to develop the process as part of an in-house project at the Fraunhofer-Gesellschaft. Here too, as in the EKOLAS project, her aim was to inscribe the optical gratings in multimode fibers used as waveguides for diode lasers. "Normally, laser technology is all about miniaturization. In my research work, it was exactly the opposite," she explains. She had to transfer the USP process, developed for a core diameter of six micrometers, to a diameter of 100 micrometers. The difficulty lay in the details: It was extremely complicated to seamlessly and precisely align the FBG segments; furthermore, energy management was very challenging. In order to inscribe the many gratings in the much larger multimode fibers in a single step, she would theoretically have had to multiply the energy input. However, this option was ruled out from the very beginning.

Klein mastered the challenge by lining up over a dozen of the FBGs, which are only six micrometers in size, in several exposure processes. It was important to work seamlessly. "The writing process would have been much easier with an angular core geometry," she reports. Writing the FBG up to the outermost edges was enormously complicated in terms of the required precision. However, there was no alternative to this seamless precision – in terms of maximum reflectivity of the grating – to generate efficient resonator structure of the fiber laser.

When transferring this concept for the frequency stabilization of diode lasers, she focused on designing the FBG properties in such a way that the diode laser only emits a desired wavelength. Klein no longer pursued the goal of maximizing the FBG reflectivity. Instead, she specifically adapted the FBG properties to optimize the spectral properties of the diode laser radiation for pumping applications, for example.

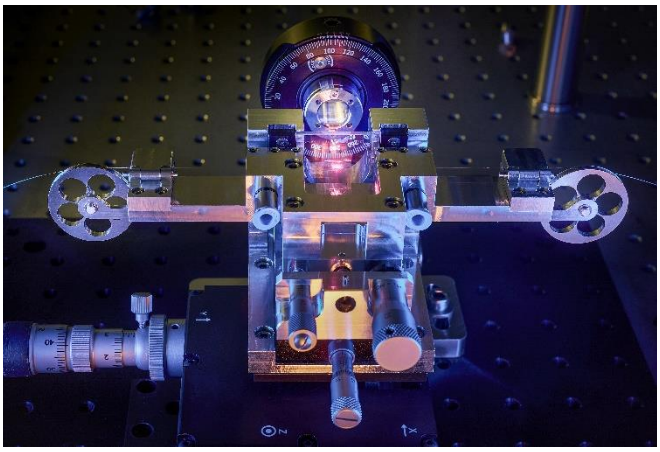
Awarded the Hugo Geiger Prize

For multimode lasers, the optical design of FBGs and their direct inscription in the USP laser process had hardly been researched until now. The recent Hugo Geiger Award winner has changed this once and for all with her dissertation "Fiber Bragg gratings for the frequency stabilization of multimode high-power laser diodes and fiber lasers." She says, "I am delighted to receive this important award! It shows me that I was right with my idea of transferring the concept established for single-mode fiber lasers to other laser beam sources."

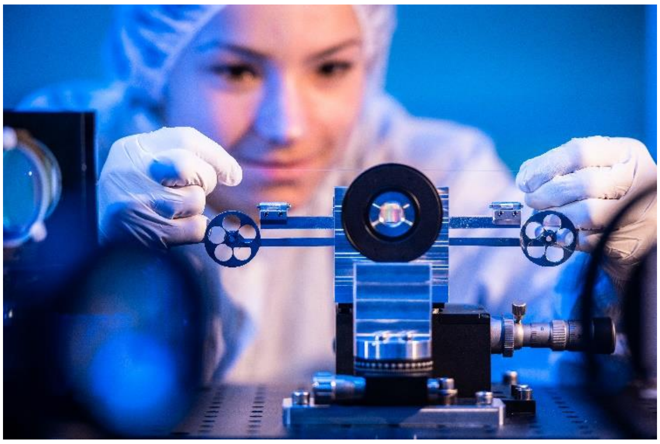
In addition to the affirmation this prestigious prize bestows, she has also received full recognition for her research at her institute. Dr. Jochen Stollenwerk, acting director of the Fraunhofer ILT, says, "We congratulate Dr. Sarah Klein on this award, which underscores the high scientific quality of her work. Based on the knowledge gained, external optical elements can be omitted from multimode diode lasers in the future, thereby reducing system complexity, assembly effort, susceptibility to failure and costs. At the same time, the new possibility of spectrally stabilizing these beam sources expands their application potential – whether as highly efficient pump sources or as beam sources for communication technology, sensor technology and direct laser material processing in industrial production."

WORLD of PHOTONICS CONGRESS 2025 in Munich

Interested parties can find out more about the latest developments in high-power diode lasers at the WORLD of PHOTONICS CONGRESS from June 22 to 27, 2025 in Munich. Dr. Klein will be moderating the application panel "High-power diode lasers - new milestones in power, spectrum and efficiency" on June 26 from 3 pm.



Picture 1:
Exposure process: a USP laser writes a fiber Bragg grating into a fiber with a core diameter of 100 micrometers.



Picture 2:
Dr. Sarah Klein clamping the fiber for the exposure process.

FRAUNHOFER INSTITUTE FOR LASER TECHNOLOGY ILT

Picture 3:
Dr. Sarah Klein was awarded 3rd place in the Hugo Geiger Prize on February 19, 2025 in Munich for her doctoral thesis at Fraunhofer ILT.
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Picture 4:
Presentation of the Hugo Geiger Prize to Sarah Klein in Munich on February 19, 2025. From left to right: Hubert Aiwanger, Deputy Prime Minister of Bavaria, Dr. Sarah Klein, Fraunhofer ILT, Prof. Dr.-Ing. Holger Hanselka, President of the Fraunhofer-Gesellschaft.
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Picture 5:
The winners of the Hugo Geiger Prize 2025. From left to right: Hubert Aiwanger, Dr. Patricia Erhard, Dr. Sarah Klein, Dr. Kerstin Müller, Prof. Dr.-Ing. Holger Hanselka.
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