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PRESS RELEASE

New and robust anti-reflective solutions for laser inertial fusion for the clean energy supply of the future

New nanoAR research project launched

Jena / Halle (Saale) / Freiburg (Germany)

In order for future laser fusion power plants to work efficiently and reliably, current laser technologies must be adapted to the extreme requirements of high power and continuous operation. In the new "nanoAR" research project, nine project partners from industry and research are working on methods for structural antireflection solutions and reducing sub-surface damage of the optical components used. Their approaches could also be transferred to other fields of application for high-power optics.

In laser inertial fusion, high-precision and high-energy laser beams are used to compress and heat fuel capsules. The temperature and pressure in the capsules increase to such an extent that atomic nuclei fuse, releasing a large amount of energy. "If the amount of energy gained is greater than that expended, laser inertial confinement fusion can be a valuable source of clean energy for the future. For this to succeed, however, the laser technologies used must be further developed to meet the extreme challenges," says Dr. Christian Rieck from Glatt Ingenieurtechnik GmbH in Weimar. He is coordinating the joint project, which is scheduled to run until 2027 and is being funded by the German Federal Ministry of Education and Research (BMBF) with six million euros as part of the "Basic technologies for fusion - on the way to a fusion power plant" program.

Innovative anti-reflective coatings and structures to optimize laser beam transport

The laser beams must be aligned extremely precise in order to hit the fuel capsule evenly and ensure symmetrical compression. Their path is controlled by various materials and atmospheres that act like lenses. This leads to optical losses, which are higher the more lenses are used. Energy is also lost when the laser beam hits the fuel capsule because its material reflects some of the energy. Last but not least, the high energy of the laser causes thermal expansion, which varies depending on the material properties and can lead to cracks or other damage and thus have a negative impact on the precision and service life of the systems.

The project partners are therefore focusing on the anti-reflective coatings that are used to reduce reflection losses. For example: when a laser hits fused silica glass, the reflection losses are around 4 percent per interface. If the beam is directed 50 times by a glass lens,

Press contact Fraunhofer IOF
Desiree Haak | Fraunhofer Institute for Applied Optics and Precision Engineering IOF | Phone +49 3641 807 - 803 |
Albert-Einstein-Straße 7 | 07745 Jena | www.iof.fraunhofer.de | desiree.haak@iof.fraunhofer.de

only 1.7 percent of the output power passes through the last interface. For this reason, lenses are already equipped with extremely thin, multi-layer anti-reflective coatings that effectively reduce losses.

"However, these solutions hardly seem suitable for use in future petawatt laser fusion reactors. This is because the significantly higher laser power increases the thermal load: if the substrate and the anti-reflective coatings expand to different degrees, there is a risk of defects," says Dr. Nadja Felde from the "Functional Surfaces and Coatings" department at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena. In addition, difficult to detect subsurface damage (SSD), which may occur during the manufacturing process and is less significant at lower laser powers, can become critical in laser fusion applications - especially in continuous operation at repetition rates of around 10 Hz.

Combination of anti-reflective coatings and nanostructured materials

In order to pave the way for viable solutions here, the project partners are focusing on nanostructured or nanoporous anti-reflective coatings based on materials with a high band gap, which should ensure the required laser damage threshold. On the other hand, they are testing a subtractive approach: instead of a combination of a substrate material and multi-layer anti-reflective coatings, they are relying on lenses made from a single material, which is to be given the desired anti-reflective properties by suitably nanostructuring its surface. Using the example of two materials with a large band gap (fused silica glass and calcium fluoride), large-area demonstrators are to be developed for different wavelengths and pulse lengths.

"We want to prove that the approach with anti-reflection structures can be specifically optimized for high-power laser applications such as laser inertial confinement fusion and achieve the best possible anti-reflection effects below 0.5 percent residual reflection. The technology also offers further exploitation opportunities in the field of high-power optics," says Prof. Dr. Thomas Höche, head of the "Optical Materials and Technologies" business unit at Fraunhofer Institute for Microstructure of Materials and Systems IMWS in Halle (Saale).

Partners from industry and research in the "nanoAR" project

In the "nanoAR" project, the project partners are pooling their expertise from substrate manufacturing and processing methods for the effective reduction of SSD, to technology-open process development for nanostructure generation, including the use of simulations and modeling, to high-resolution material characterization and the development of new methods for quality assurance.

The following companies and research institutes are involved in the project "Antireflective metasurfaces on wide bandgap materials (nanoAR)": Glatt Ingenieurtechnik GmbH (Weimar), POG Präzisionsoptik Gera GmbH (Löbichau), FLP

Microfinishing GmbH (Zörbig), Trionplas Technologies GmbH (Leipzig), Fraunhofer IOF (Jena), Fraunhofer IMWS (Halle/Saale), the Fraunhofer Institute for Mechanics of Materials IWM (Freiburg), the Leibniz Institute for Surface Modification IOM (Leipzig) and the Ernst Abbe University of Applied Sciences (Jena).

About Fraunhofer IOF

The Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena conducts application-oriented research in the field of photonics and develops innovative optical systems for controlling light - from its generation and manipulation to its application. The institute's range of services covers the entire photonic process chain from opto-mechanical and opto-electronic system design to the production of customer-specific solutions and prototypes. At Fraunhofer IOF, about 500 employees work on the annual research volume of 40 million euros.

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About Fraunhofer IMWS

The Fraunhofer Institute for Microstructure of Materials and Systems IMWS offers microstructure-based diagnostics and technology development for innovative materials, components and systems. Building on its core competencies in high-performance microstructure analysis and microstructure-based materials design, the Institute investigates questions of functionality and application performance as well as the reliability, safety and service life of materials used in various market and business areas with major importance for social and economic development. For its partners in industry and the public sector, Fraunhofer IMWS enables the accelerated development of new materials, increases material efficiency and cost-effectiveness, and helps to conserve resources. In doing so, the Institute contributes to ensuring the innovative capacity of key future fields and to sustainability as the greatest challenge of the 21st century.

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About Fraunhofer IWM

The Fraunhofer Institute for Mechanics of Materials IWM provides companies with research and development services to improve and ensure the functionality, energy efficiency, safety and durability of technical components and systems. The institute supports industrial and service companies in overcoming material technology challenges in all life phases of components and systems by creating the necessary information and knowledge base to enable experts from development, production and operation to use materials with their behavior and properties as adjustable, controllable and programmable systems. To this end, the Fraunhofer IWM develops methods for evaluating and predicting the properties and behavior of materials in components as well as material solutions and manufacturing processes.

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Scientific contact at Fraunhofer IOF

Dr. Astrid Bingel
Fraunhofer IOF
Department Functional Surfaces and Coatings

Phone: +49 3641807 - 279
Mail: astrid.bingel@iof.fraunhofer.de

Press images

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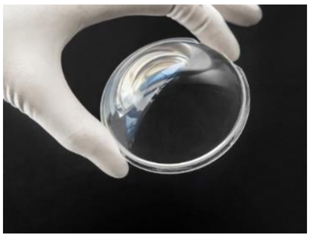
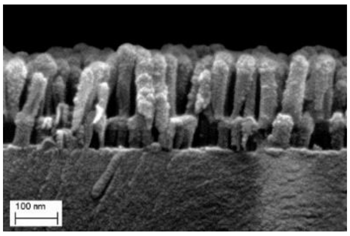


An example of a partially anti-reflective optical component. © Fraunhofer IOF

With high-resolution equipment, small surface defects can be detected. © Fraunhofer IMWS



Scanning electron image of a nanostructure. © Fraunhofer IOF