PRESS RELEASE

Target tracking for nuclear fusion

New measurement method for determining fuel capsule positioning

Researchers at Fraunhofer IPM have developed a measurement method that determines the trajectory of rapidly moving small objects with micrometer precision in real-time. This method might provide a solution for target tracking, one of the unresolved issues in laser-based inertial fusion.

Laser-based inertial fusion is a pivotal concept in nuclear fusion. In this process, fuel capsules (targets) just a few millimeters in diameter are irradiated with high-energy lasers, compressing them to initiate a fusion reaction. In December 2022, a significant breakthrough was achieved at the U.S. National Ignition Facility (NIF) at Lawrence Livermore National Lab: for the first time, more energy was released in laser-based inertial fusion than was put in by the lasers. Despite this milestone, there is still a long way to go from this proof-of-physics to a fully operational power plant. In the NIF experiment, 192 lasers targeted a single fuel capsule precisely positioned within a reactor chamber. For a functional power plant, approximately ten fuel capsules must be ignited per second. The capsules must be launched into the reactor at high speeds and hit by the lasers at exactly the right moment. To achieve this, the target must withstand the acceleration, and its position must be determined with micrometer precision immediately before ignition.

Spectrally coded target tracking from distances of several meters

In the Star Track project, funded by the state of Baden-Württemberg under the VwV Invest BW – Praxissprints program and in collaboration with Fraunhofer EMI, researchers at Fraunhofer IPM made a significant breakthrough. They successfully demonstrated the proof-of-principle for a novel optical measurement method that enables precise tracking of an object's trajectory within the typical size range of a fusion target. This method is based on the principle of chromatic confocal distance measurement, where the measurement area is spectrally encoded across a broad bandwidth. The approach has been further refined to allow for measurements over greater distances and lateral detection of objects. By using three discrete laser light sources in the red, green, and blue spectral ranges, the target's position is encoded and determined based on the reflected light, specifically by calculating the color centroid.

Editorial notes
Holger Kock | **Communications and Media** | Fraunhofer Institute for Physical Measurement Techniques IPM | Georges-Köhler-Allee 301 | 79110 Freiburg, Germany | www.ipm.fraunhofer.de/en | Phone +49 761 8857-129 | holger.kock@ipm.fraunhofer.de

The goal: measurement accuracy in the lower micrometer range

In the laboratory at Fraunhofer IPM, researchers conducted promising initial measurements using a sensor prototype based on the new measurement method. "We hope that this innovative approach will help us tackle one of the key challenges in laser-based inertial fusion," says Dr. Alexander Bertz, project manager at Fraunhofer IPM. However, the requirements for the measurement technology in a real reactor environment are extremely demanding: the position of the fusion target, which can move at speeds of up to 400 meters per second, must be determined from a distance of several meters – with an accuracy of up to 25 micrometers, a repetition rate of 10 Hz, and under challenging conditions typical of a fusion reactor, such as extreme stray light and limited accessibility. "We are confident that we can improve the measurement accuracy to single-digit micrometer levels," Dr. Bertz adds. This improvement is essential for accelerating the derivation of the control signal for laser operation. Furthermore, this powerful measurement method has potential applications in other industries, including robotics.

As part of the joint project, researchers at Fraunhofer EMI optimized the acceleration technology for the fuel capsules and analyzed potential damage during the acceleration process. This involved numerical simulations, CT analyses, and high-speed recordings of the millimeter-sized objects, which were accelerated to speeds of over 200 m/s.Through their close collaboration, the Fraunhofer institutes made significant progress in overcoming the challenges of target tracking in inertial fusion, thereby making an important contribution to the development of future fusion power plants.

Further informationen

Star Track project
The Star Track project (Spectrally coded target tracking in laser-based inertial fusion) was funded by the Ministry of Ministry of Economic Affairs, Labor, and Tourism of the State of Baden-Württemberg as part of the VwV Invest BW – Praxissprints program.

Project term Mar. 1, 2025 to Sept. 30, 2025
Project partners: Fraunhofer EMI, Fraunhofer IPM

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Other contacts
Dr. Alexander Bertz | Group Manager Geometrical Inline Measurement Systems | Phone +49 761 8857-362 | valexander.bertz@ipm.fraunhofer.de| Fraunhofer Institute for Physical Measurement Techniques IPM | www.ipm.fraunhofer.de/en