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THRILL

TECHNOLOGY FOR HIGH-REPETITION-RATE INTENSE LASER LABORATORIES

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About THRILL

The THRILL project deals with providing new schemes and devices for pushing forward the limits of research infrastructures (RI) of European relevance and ESFRI landmarks. To do so, the project partners have identified several technical bottlenecks in high-energy high-repetition-rate laser technology that prevent it from reaching the technical readiness level required to technically specify and build the needed devices, and guaranteeing sustainable and reliable operation of such laser beamlines at the partnering RIs. Advancing the technical readiness of these topics is strategically aligned with the long-term plans and evolution of the ESFRI landmarks FAIR, ELI (-BL) and Eu-XFEL, and RI APOLLON, bringing them to the next level of development and strengthening their leading position.

The project is focused and deliberately restricted to three enabling technologies, which require the most urgent efforts and timely attention by the community: high-energy high-repetition-rate amplification, high-energy beam transport and optical coating resilience for large optics. To reach our goals, the major activity within THRILL will be organized around producing several prototypes demonstrating a high level of technical readiness. Our proposal is addressing not yet explored technical bottlenecks - such as transport over long distances of large-aperture laser beams via relay imaging using all-reflective optics - and aims at proposing concrete steps to increase the performances and effectiveness of the industrial community through the co-development of advanced technologies up to prototyping in operational environments.

The project is not only pushing technology, it is also offering an outstanding opportunity to train a qualified work force for RIs and industry. With this in mind, the structure of THRILL promotes synergetic work, fast transfer to industry and integrated research activities at the European level. Access to the RIs will be granted as in-kind contribution.

Executive summary

Traditional wavefront control methods in high-energy, high-intensity laser systems usually lack real-time capability and fail to address dynamically evolving aberrations. With advancing laser technology, this became a limiting factor, where shot-to-shot fluctuations decrease the conclusiveness of experimental findings and long cool-down phases are employed to limit the impact of thermal aberrations. These shortcomings are underlined by the need for higher repetition rates, e.g. in the frame of Inertial Fusion research.

Within T5.2a, we developed and implementation a real-time adaptive optics (RTAO) system at the Apollon laser facility with the goal to address this issue. Drawing inspiration from astronomical adaptive optics technology, the system employs a fiber-coupled laser diode at 905 nm as a pilot beam to avoid the limitations of pulsed laser sources. A GPU-based real-time controller, utilizing the open source CACAO framework, manages the adaptive optics loop, which includes a bimorph deformable mirror and a high-speed Shack-Hartmann sensor. Initial testing demonstrated excellent short-term stability and effective aberration correction. At the same time, integration into the Apollon laser system revealed critical, laser-specific challenges that still need to be addressed for the safe operation of RTAO with amplified shots.

1 Report

12/2024 - The full report is available on arXiv:

https://arxiv.org/abs/2412.08418

02/2025 – The manuscript with the main results has been published

Ohland JB, Lebas N, Deo V, et al. Apollon Real-Time Adaptive Optics (ARTAO) - Astronomy-Inspired Wavefront Stabilization in Ultraintense Lasers. *High Power Laser Science and Engineering*. Published online 2025:1-15. doi:10.1017/hpl.2025.16