

Goal 10

Realization of a dynamic society in harmony with the global environment and free from resource constraints, through diverse applications of fusion energy, by 2050.

Development of Inertial Fusion Modules Powered by Blue-Violet Semiconductor Lasers

Project manager

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Summary of the project

In this project, we apply Japan's strength in blue-violet semiconductor laser technology to the field of fusion, with the aim of establishing a highly efficient laser driver for inertial fusion. Through this approach, we seek to reduce the electrical power required to generate the high-intensity laser pulses necessary for compressing fusion fuel. Furthermore, we challenge the long-standing requirement of approximately 100-fold fusion energy gain for future fusion power plants, with the objective of lowering this requirement to around 20-fold, thereby advancing the practical realization of fusion energy systems.

Specifically, the project will first pursue nanosecond-pulse operation and high-output performance of blue-violet semiconductor lasers. While such lasers can, at the device level, achieve continuous-wave efficiencies exceeding 50%, stable generation of high-power nanosecond pulses at a repetition rate of around 10 Hz has not yet been achieved.

To overcome this challenge, the project will adopt a Vertical Cavity Surface Emitting Laser (VCSEL) architecture and develop a 10-J-class, 1-nanosecond, 10-Hz blue-violet semiconductor laser capable of stable operation. Using this 10-J-class laser, the project will demonstrate compression of fusion fuel while suppressing laser-plasma interactions, thereby achieving fusion reactions at a repetition rate of 10 shots per second.

Furthermore, to realize a compact inertial-fusion reactor capable of self-preservation and autonomous operation even under harsh fusion-reaction environments involving X-ray and plasma-debris heat and particle loads, the project will develop key technologies such as regenerative low-melting-point metal mirrors and debris-shielding structures, and demonstrate their effectiveness. These technologies are expected not only to contribute to inertial-fusion power systems but also to enable applications in the space domain, including space-debris removal and space propulsion.



Milestone by 2034

- To stably operate a 10-J-class, 1-ns, 10-Hz blue-violet semiconductor laser and demonstrate fusion reactions via laser-driven fuel compression.
- To develop and validate, under fusion-reaction conditions, key technologies for a self-preserving, autonomously operated, compact inertial-fusion reactor—such as regenerative low-melting-point metal mirrors and flying-debris armor—and to develop reactor-design concepts aimed at future power-plant deployment.
- To develop application scenarios beyond fusion energy, including space application such as space debris removal.

Milestone by 2029

- To integrate key enabling technologies—vertical stacking, array integration, thermal management, wavefront control, and beam focusing—to establish chip-level performance of blue-violet semiconductor lasers and achieve millijoule-class, 1-ns, 10-Hz operation.
- To demonstrate solid-surface ablation using semiconductor lasers.
- To complete a conceptual design for a self-preserving, autonomously operated compact inertial-fusion reactor, assuming the availability of a high-efficiency laser driver, and to clarify the technical requirements for commercial reactors and space applications.

Project structure

In this research and development project, the initial objective is to achieve short-pulse operation, high-repetition operation, and high-focusing capability in stacked blue-violet semiconductor lasers. The project focuses on five key technical challenges (Fig. 1).

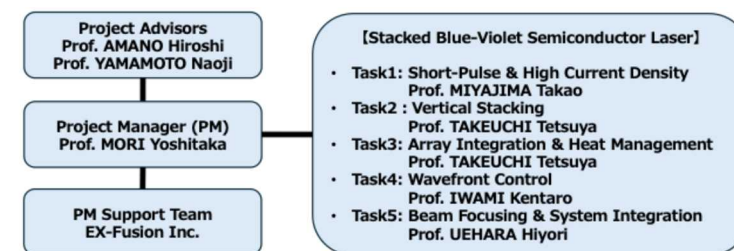


Fig. 1. R&D Framework