11th Annual Meeting
Innovation for Cool Earth Forum
Tokyo, Japan, Oct. 9-10, 2024
Technology Session 4: Future of Nuclear Energy

Realizing Nuclear Fusion Energy with High Energy Density Science

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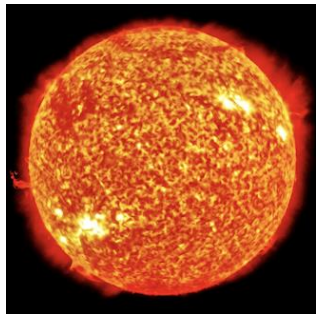
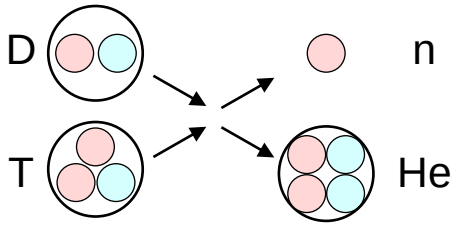
Nuclear fusion energy - The energy source of stars





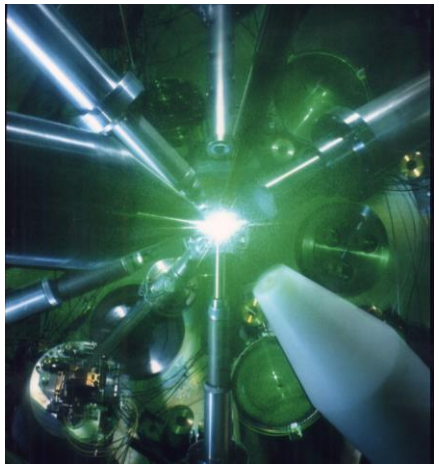
D-T fusion: One of the fusion reactions considered for fusion energy applications.

High power laser at Institute of Laser Engineering (ILE), Osaka University.

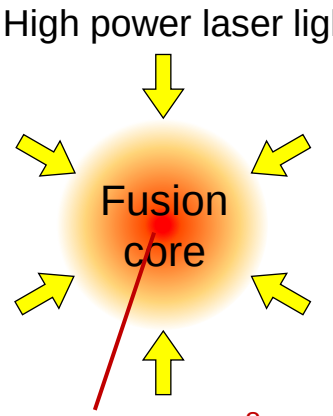
- Nuclear fusion energy, the energy that makes stars shine, is anticipated as one of the future energy sources for humanity with minimal environmental impact.
- High power lasers can create fusion plasma with an energy density equivalent to that at the solar core. Researchers succeeded in obtaining fusion energy greater than the input energy delivered to the fusion target by the laser, i.e., target gain > 1, in 2022[1].

  [1] NIF at Lawrence Livermore National Laboratory, Abu-Shawareb *et al*., Phys. Rev. Lett. **132**, 065102 (2024)
- Fusion burning plasma is an exotic state of matter, currently existing only in stars. Physics of this unique state of matter will bring deeper understanding of nature, and various technological applications.
- An essential scientific question for the fusion energy application is how we can increase the energy gain.
- To answer this question, researchers are exploring basic sciences, and technologies such as new laser and target systems.

Laser fusion



Target chamber for laser fusion experiment (ILE, Osaka Univ.)



- In laser fusion, the energy is produced by compressing the fuel repeatedly in the same way as automobile engines.

  This is because the high pressure core plasma can be hold only in nanoseconds.

- In current experiments, the fusion energy generated in a single compression cycle is less than 10 MJ. To achieve several hundred MW like a small module reactor, laser operation at a rate of about 10 Hz is required.

Challenge 1 To increase the repetition of the operation.

Currently operated
A few shots per day
(~ 10^{-4} Hz)

→

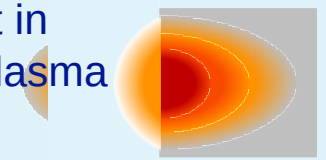
Required
> 10 Hz (for several hundred MW fusion energy output)

Lasers of 10 J / 100 Hz become available recently.
Target supply systems for the required operation have been developed in academic institutes and companies.

Challenge 2 To increase the energy gain in 1 cycle.

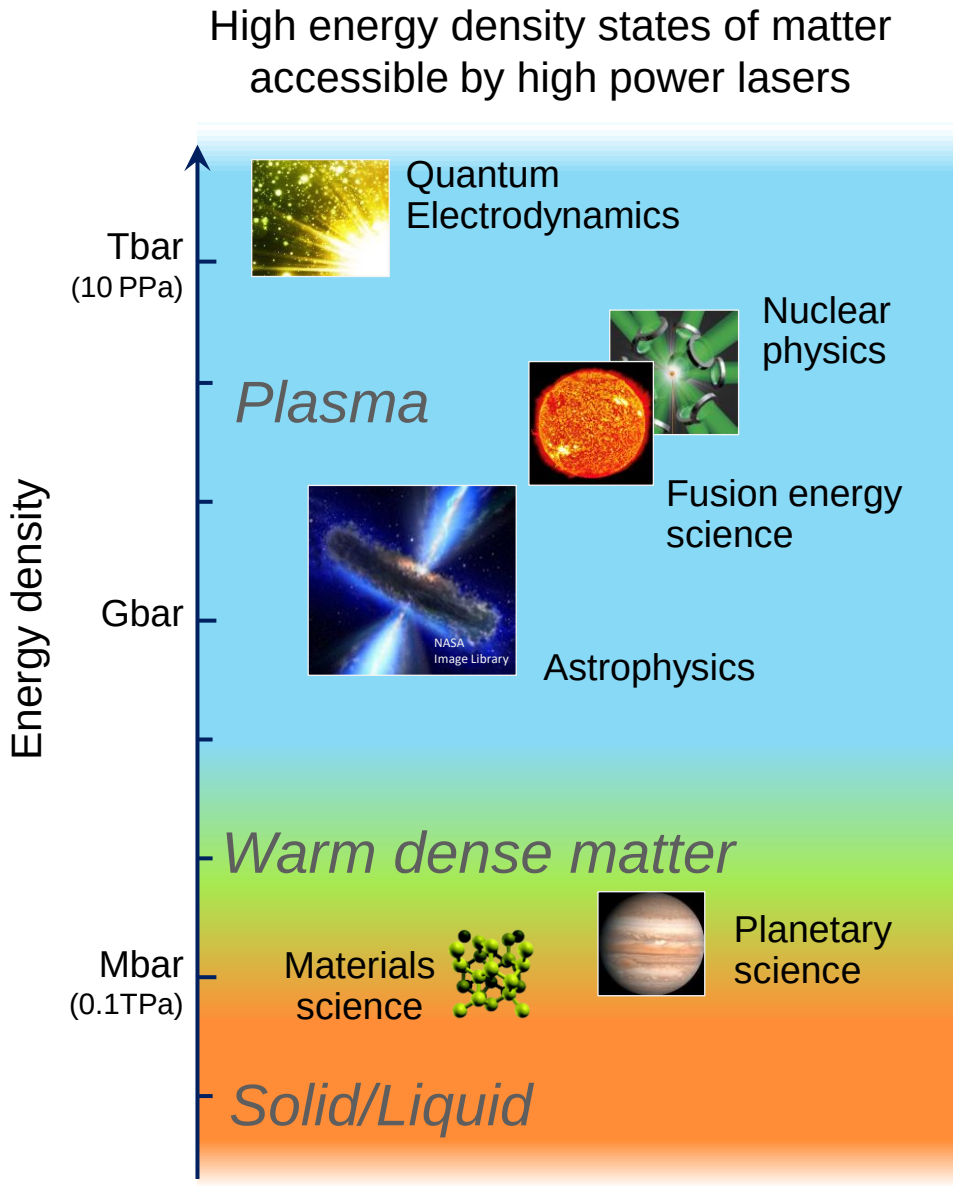
Burning fraction of the fuel is still about 3 %.
To increase it, deeper understanding of high energy density plasma physics is necessary.

Heat transport in the extreme plasma condition



Energy transfer among fusion generated particles and bulk plasma particles

Fusion energy realization will be accompanied by a vast expanse of academic and technological advancements.



- Basic understandings of plasma, the most ubiquitous state of matter in universe, is essential for space utilization.
- Novel material processing technologies have been opened up with the advancement of high energy density science.
- High power lasers have various applications, including particle accelerator, intense x-ray/ion/neutron sources and their applications to medical treatment and non-destructive radiography.