Hydrodynamic Instability of High-Energy-Density Plasmas under Laser-Produced Strong Magnetic Field

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In recent years, magnetic fields have been used actively in laser-fusion. One of the motivations for this approach is to confine alpha particles, which are the products of deuterium-tritium nuclear fusion reactions, by a strong magnetic field to make self-heating more efficient and to relax the conditions for the fusion ignition. Furthermore, in the fast ignition scheme of the laser fusion, the heating efficiency of the plasma can be increased by applying a magnetic field to guide the relativistic electron beam generated by an intense laser [1]. In both cases, it is necessary to compress the fusion fuel under an externally applied magnetic field, and it is essential to understand the hydrodynamic instability of the fuel in a strong magnetic field. We have performed experiments on the hydrodynamic instability of laser-produced plasmas under a strong magnetic field. Two laser-driven coils were placed in the experiment, and a 16 μm-thick plastic plate was placed in the gap between the coils. The magnetic field strength at the position of the plastic plate is 215 +/- 21 T, and the direction of the magnetic field lines is parallel to the normal of the plastic plate. The growth of the perturbation amplitude on the surface after laser irradiation has been measured. The application of an external magnetic field is found to accelerate the growth of the amplitude compared to the case without an external magnetic field. Since the magnetic pressure is more than an order of magnitude weaker than the plasma pressure, the magnetic pressure does not change directly the growth of the hydrodynamic instability. It has been found that the application of the magnetic field reduces the heat conduction in the transverse direction (along the surface of the plate) and reduces the thermal smoothing, called fire polishing [2]. This study reveals the essential role of the isotropic electron thermal condition in the fire-polishing effect of the hydrodynamic instability, which is vital in laser fusion. An experiment to elucidate this effect at a laser intensity equivalent to the ignition has been accepted by LMJ-PETAL facility in France, and the first campaign will be performed in early March 2022 as a collaboration between Japanese and European researchers.

[1] S. Sakata *et al.*, Nat. Commun. **9**, 3937 (2018).

[2] K. Matsuo *et al.*, Phys. Rev. Lett. **127**, 165001 (2021).