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Generation of Kilo-Tesla Magnetic Field with High-Power Laser and Its Applications to Plasma Science
高出力レーザーを用いたキロテスラ級磁場の発生とプラズマ科学への応用

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Laboratory generation of strong magnetic fields opens new frontiers in plasma and beam physics, astro- and solar-physics, materials science, and atomic and molecular physics. We will present recent experimental results with the strong magnetic field on GEKKO-XII (Japan) [1] and LULI2000 (France) [2] , Sheng-Gang-II (China) facilities. Our prospects are also presented based on the discussion in the symposium entitled with "Frontiers of plasma science open with kilo-tesla magnetic field =Fusion energy to Universe=", which will be held on 19th November 2014 in PLASMA2014 conference.

1. Introduction

Laboratory generation of strong magnetic fields opens new frontiers in plasma and beam physics, astro- and solar-physics, materials science, and atomic and molecular physics. Although kilotesla magnetic fields have already been produced by magnetic flux compression using an imploding plasma shell, accessibility at multiple points and better controlled shapes of the field are desirable. Here we have generated kilotesla magnetic fields using a capacitor-coil target, in which two metal disks are connected by a coil. We will present recent experimental results with the strong magnetic field on GEKKO-XII (Japan) [1] and LULI2000 (France) [2] , Sheng-Gang-II (China) facilities.

2. High-energy-density-plasma hydrodynamics in strong magnetic field

Hydrodynamic instability of high-energy-density plasma under the strong magnetic field is an interesting research subject relevant to inertial confinement fusion and astrophysics. A Helmholtz-type coil target was designed to generate spatially uniform magnetic field in 1 mm^3 volume for benchmarking computations by magneto-hydro-dynamic codes. In the recent years, several authors reported interesting and important HED plasma phenomena under strong magnetic field. Chang *et al.,* reported [4] that electron radial heat losses from the hot-spot to the surrounding cold fuel were suppressed by embedding axial magnetic field in plastic capsules. Perkins *et al.,* found [5] that application of strong magnetic field to fusion targets relaxes ignition requirements in two-dimensional (2D) hydrodynamic simulations. Strozzi *et al.,* show [6] guiding of relativistic electrons generated by intense laser-plasma interactions with kilo-tesla magnetic field by 2D hybrid simulations. Sano *et al.*, found [7] critical strength of magnetic field to suppress Richtmyrr-Meshkov instability in 2D-MHD simulation. Although hydrodynamics of the HED plasmas under strong magnetic field is one of the most essential processes in these studies, there is no basic experiment to focus this.

Experiment was performed to measure trajectory of a laser-driven 15 μm-thick polystyrene foil. We have generated relatively uniform 200 T of magnetic field with Helmholtz type capacitor-coil target. Velocity of the polystyrene foil is clearly changed by the application of the external magnetic field. When the direction of the magnetic field is parallel to the direction of the plasma motion, velocity of the plasma is two times higher than that without magnetic field. The experimental results are compared with two-dimensional radiation magneto-hydrodynamic (2D-rad-MHD) code. A preliminary analysis shows that thermal transport along the foil surface is suppressed owing to the trap of thermal electrons by the magnetic field lines.

2. Guiding of relativistic electron beam by magnetic field

Relativisitc electrons generated by the laser-plasma interactions have a large divergence angle (>100 deg.) and the energy flux of the electron beam decreases significantly during transport from the generation point to a target. External magnetic field parallel to the direction of electron beam propagation can guide the relativistic beam to the target.

Thin planar metal foil was located in the coil, and the the foil surface was irradiated with intense laser. Relativistic electron beam was generated by laser-plasma interactions, and the pattern of the electron beam was observed as coherent transition radiation from the rear side. By the application of the external magnetic field, size of the electron beams was reduced, and intensity of the electron beam increased significantly. This is the first demonstration to guide laser-generated electrons with external magnetic field.

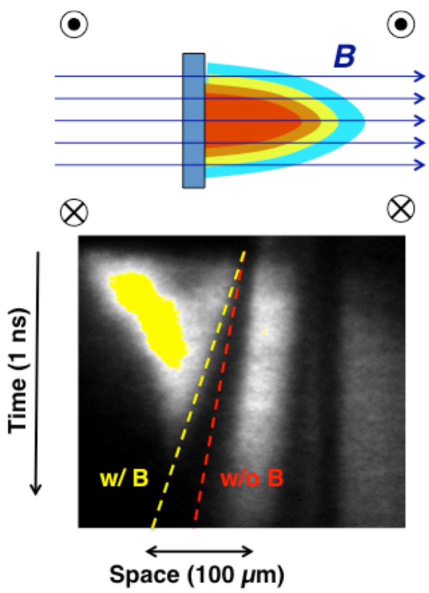

Fig. 1 Trajectory of a 15 μm-thick polystyrene foil driven by intense laser in 200 T magnetic field. Velocity of the polystyrene foil is clearly changed by the application of the external magnetic field.

3. Other applications

It is no doubt that laser-matter interactions and plasma dynamics under the strong magnetic field contains a lot of unexplored physics in the field of atomic physics, nuclear physics, and astrophysics. We will discuss our prospects based on the discussion in the symposium entitled with “Frontiers of plasma science open with kilo-tesla magnetic field =Fusion energy to Universe=”, which will be held on 19th November 2014 in PLASMA2014 conference.

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