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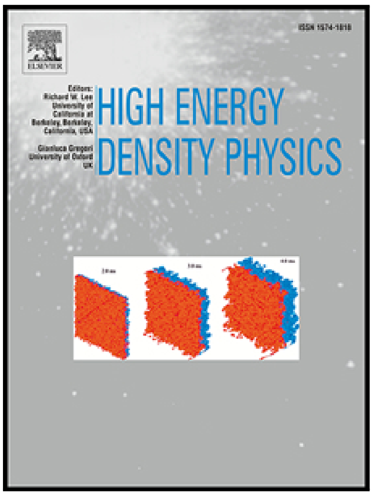

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Spatial and temporal plasma evolutions of magnetic reconnection in laser produced plasmas

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Abstract

Magnetic reconnection is experimentally investigated in laser produced plasmas. By irradiating a solid target with a high-power laser beam, a magnetic bubble is generated due to the Biermann effect. When two laser beams with finite focal spot displacements are utilized, two magnetic bubbles are generated, and the magnetic reconnection can take place. We measure the spatial and temporal plasma evolutions with optical diagnostics using framing camera. We observed the plasma jets, which are considered to be reconnection out flows. Spatial and temporal scales of the plasma jets are much larger than those of laser. The magnetic reconnection time has been estimated from the expansion velocity, which is consistent with the Sweet-Parker model.

Keywords: magnetic reconnection, plasma, laser, laboratory astrophysics

1. Introduction

In the universe, magnetic reconnections play essential roles in various astrophysical phenomena, such as solar or stellar flares, coronal heating, solar or stellar wind, aurorae, and pulser magnetospheres [1, 2] When the magnetic field lines break and reconnect, the global topology of field lines is changed. After magnetic reconnection, the magnetic energy is converted to heat, kinetic energy, and fast particle energy [3]. There are many physical quantities cannot be measured directly in the universe. In laboratories we can measure some of the key parameters in magnetic reconnection and also control plasma and magnetic field parameters. Laboratory astrophysics provides an alternative, experimental approach to investigate space and astrophysical phenomena in laboratories [4, 5, 6, 7].

A magnetic bubbles can be generated due to the thermal baroclinic effect or the Biermann effect by irradiating a solid target with a high-power laser beam, associating with plasma flow [8, 9]. The ablated plasma expands in the direction normal to the target surface as in Fig. 1(a) [10]. The Biermann effect arises because of $\nabla T \times \nabla n$, where T is plasma temperature and n is the electron density of ablation plasma [11, 12]. There will be a magnetic field surrounding the focal spot, when a laser beam focused on to a solid target. If multiple bubbles are created with multiple beams with small focal spot separation, the bubbles expand into one another, squeezing the opposing magnetic field together and driving reconnection [13, 8, 14, 15]. The spatial and temporal scales of these reconnection are relatively small, as the order of those of lasers. Here we show large spatial and temporal scale plasma evolutions with optical diagnostic and using a multi-framing camera. A series of self-emission images provides the time evolution of plasma structures where the transverse plasma jets clearly seen. Our experimental results strongly indicate that the self-generated magnetic fields reconnect and release the magnetic field energy as plasma kinetic energy. In the following section, we describe the experimental setup in Section 2. In Section 3, we explain the experimental results. Finally in Section 4 we discuss the results and give a summary.

2. Experimental setup

The experiment was performed with Gekko XII (GXII) laser facility at Osaka University. Irradiating a thin CH plane (10 μm thick) with a main laser beam (energy 120 J, wavelength 351 nm, pulse duration 500 ps, focal spot 300 μm at FWHM, intensity on the target 4×10^{14} W/cm^2), a burn through plasma is created on the rear side of the target as shown in Fig. 1. When a laser beam is focused on a solid target, the ablated plasma expands in the direction normal to the target surface while the temperature gradient is mostly along the target surface. Due to the Biermann effect, the magnetic fields are generated surrounding the laser-produced plasma as shown in Fig. 1 (a).

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