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Laser astrophysics experiments for studying collisionless shock and magnetic reconnection

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Laser-produced laboratory plasmas can be scaled to the astrophysical phenomena considering dimensionless parameters and can be alternative ways to investigate astrophysical high-energy phenomena[1]. Many researches on various astrophysical phenomena, such as collisionless shocks, magnetic reconnection, magnetic field generation and amplification, and hydrodynamic instabilities, have been performed using high-power lasers. These research methods using high-power lasers have been attracting many attentions recently. Laboratory experiments have an advantage in that various plasma diagnostics can be used simultaneously both for microscopic and macroscopic phenomena. High-speed plasmas can be easily generated by irradiating a solid surface by a laser, and the interaction between counter-propagating plasmas are considered as collisionless interaction. Under this condition, collisionless shocks, which play important roles as the origin of particle acceleration, can be studied by using high-power lasers as reported in many papers recently. Another important phenomenon is a magnetic reconnection which is universally observed in space and astrophysical contexts. A laser-produced plasma spontaneously generates strong magnetic fields in it and it can be applied to the study of a magnetic reconnection relatively in high-beta condition. Despite of these attractivenesses, time and space resolved diagnostics of laser-produced plasma and electric/magnetic fields are difficult because of small spatial scale and fast time-evolution of laser-produced plasmas.

Here, we report recent progress of the experiments for collisionless shocks and magnetic reconnection with high-power laser, Gekko-XII at Osaka University. We apply strong magnetic fields by a pulse-powered device [2,3] in laser-produced plasmas and investigate shock wave and magnetic reconnection experimentally. This device generates a quasi-stable strong (1-10 T) magnetic field in various structure (parallel, perpeneicular to plasma expansion, or anti-parallel field structure).

We also achieved spatially and temporally resolved measurements of plasmas by using laser Thomson scattering (LTS) and various optical diagnostics[4,5] simultaneously. LTS measures ion and electron temperatures, electron density, and flow velocity, and it reveals a Mach-number of a shock[6]. Also, when it is applied to a diffusion region of a magnetic reconnection, important plasma flows from magnetic reconnection (inflow and outflow) can be detected. In addition, we developed small-scale magnetic probe which can measure the deviation of magnetic field even in large electric noise. The probe consists of two magnetic loops to subtract electric noise. Using this probe, we successfully measured the magnetic fields advected by a plasmas accelerated by a magnetic tension force resulting from a magnetic reconnection.

References

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