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記

日　時 ：　２０２２年2月１０日（木）１６：５０～１８：２０

場　所 ：　Ｈ７０１号室
　　　　　オンラインでの聴講も可能。
　　　　　URL 等については下記を参照。
　　　　https://www.phys.sci.osaka-u.ac.jp/naibu/info/detail.php?id=8691

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題　目 ：Ultrafast Diagnostics for Relativistic Laser-Plasma Interaction （相対論的レーザープラズマ相互作用の超高速計測）

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論文要旨 ：

Laser-plasma experiment is becoming one of the methods to understand astrophysics. Laser-generated fast plasmas can generate the fundamental plasma dynamics in the universe such as collisionless shock, which is one of the most promising candidates for cosmic-ray acceleration. Previous research made a big progress in understanding for the collisionless Weibel shock, which is believed to be generated in relativistic astrophysical plasma flows (e.g., gamma-ray burst afterglows, active galactic nuclei, and pulsar wind nebulae), using a long-pulse (nanosecond) high-power laser system. The specific features of the Weibel shock were confirmed: the filamentary structure of plasmas and the non-Maxwellian energy spectrum of accelerated electrons. However, the long-pulse laser experiments have a few problems including the small shot numbers and the low laser intensities, which hinders the detailed parameter search and the ion acceleration, respectively. The latter problem is critical for the understanding of the cosmic ray (ion) acceleration.

We apply a relativistic short-pulse (sub-picosecond) high-intensity (HI) laser to the collisionless Weibel shock experiment to solve the problems mentioned above. Numerical simulations demonstrated that the fast electrons generated through the laser-matter interaction trigger the return currents inside a bulk of the plasma. Counterstreaming electrons (fast electrons and return currents) result in the Weibel shock. It is indispensable to develop ultrafast (sub-picosecond) diagnostics to understand the real plasma dynamics. To obtain the Weibel filament structure and temporally resolved charged particle energy spectrum, we develop the small-angle x-ray scattering (SAXS) and the electro-optic (EO) sampling methods, respectively. In short, the former is a diffraction at a small scattering angle, and the latter converts the information of an electric field (e.g., the strength and the temporal evolution) into a modulation of a polarized laser pulse via a nonlinear crystal. The SAXS measurement using the x-ray free-electron laser (XFEL) is promising to obtain the evolution of the Weibel filaments with nanometer and femtosecond spatiotemporal resolution. Applying the EO sampling method to a detector of the accelerated charged particles in a setup of a charged particle spectrometer, in principle, it is possible to obtain the temporal evolution of the energy spectrum with sub-picosecond resolution. Moreover, the developed ultrafast diagnostics are versatile and provide a platform to conduct laser experiments in a relativistic regime.

The SAXS diagnostics is developed at SACLA XFEL in Japan. We conduct the pump-

probe experiment using a HI short-pulse laser pulse and the XFEL beam. To evaluate the performance of the SAXS for the laser-generated plasmas, we used the silicon wire assembly targets, which emulates the Weibel filaments. We ionized the wires by injecting the HI short-pulse laser pulse into them and obtained the temporal evolution of the columnar plasma expansions. We confirmed that the SAXS method is applicable to the three-dimensionally structured plasma. We introduced a layered filter system, which attenuates a part of the XFEL beam profile, instead of a beamstop. This system allows us to access the SAXS signal around the original XFEL beam, which contains important information on the plasma structures such as the Weibel filaments.

We succeeded in conducting single-shot spatiotemporal EO sampling of an electric field around a relativistic electron beam using an echelon mirror for the first time. The echelon mirror has a step-like mirror surface and an injected probe pulse is divided into multiple beamlets with certain delays after the reflection, which enables the temporal measurement. This technique is promising for a temporally resolved charged-particle energy spectrometer. The obtained spatiotemporal electric field profile shows the contraction of the electric field in the beam propagation direction, which demonstrates the Lorentz transformation (LT) of electromagnetic potential vectors. The estimated electron beam sizes in the transverse and longitudinal directions are obtained by the electric field profile; the longitudinal size is much smaller than the transverse one, which implies the Lorentz contraction of the beam itself. These results are novel experimental evidence of special relativity and one of the rare experimental visualizations.