# Small angle X-ray scattering of sub-micron rod-assembly target at SACLA

M. Ota[1], M. Rodel[2], S. Egashira[1], T. Izumi[1], T. Pikuz[1,3], A. S. Pirozhkov[4], A. Laso Garcia[2], A. Morace[1], T. Minami[1], Y. Fukuyama[1], Y. Maeda[1], B. Albertazzi[5], M. Koenig[5], T. Yabuuchi[6,7], T. Togashi[6,7], Y. Inubushi[6,7], K. Sueda[7], T. Matsuoka[1], N. Ozaki[1], N. Uehara[8], R. Matsui[8], Y. Kuramitsu[1], H. Habara[1], K. Shigemori[1], Y. Sentoku[1], H. Takabe[2], T. E. Cowan[2], M. Nakatsutsumi[9], T. Kluge[2], Y. Fukuda[4], K. Fukami[8], Y. Kishimoto[8] and Y. Sakawa[1]

*1)Osaka University, Japan 2)Helmholtz-Zentrum Dresden-Rossendorf, Germany 3)JIHT RAS, Russia 4)National Institutes for Quantum and Radiological Science and Technology (QST), Japan 5)LULI, France 6) Japan Synchrotron Radiation Research Institute, Japan 7)RIKEN SPring-8 Center, Japan 8)Kyoto University, Japan 9)European XFEL, Germany*

*E-mail; ota-m@ile.osaka-u.ac.jp*

Collisionless shock is considered as one of the possible candidates of the sources of cosmic rays, or high-energy charged particles travel through space. It is formed in fast plasma flow created by gamma-ray bursts, active galactic nuclei, and supernova remnants. Theories and simulations predict that electromagnetic turbulence in front of the shock can result in stochastic charged particle acceleration and the high-energy and non-thermal energy spectrum of cosmic rays.

Weibel-instability mediated shock (Weibel shock) is one of the collisionless shocks associated with current filamentation and turbulent magnetic field. Laser plasma experiments on the Weibel shock is conducted and the filamentary structure which indicate Weibal-instability [1] and non-thermal electron energy spectrum [2] are measured in plasma created by high-power laser with ns pulse width. On the other hand, Weibel filaments with typical spatial scale of 0.1 to 10 μm and shock can be produced by irradiating a high-intensity (HI) laser with sub-ps pulse width on sample, and their pico-second plasma dynamics can be observed by using X-ray Free Electron Laser (XFEL) at SACLA, in Japan. At the moment, the driving laser intensity available at SACLA is not yet high enough to produce Weibel shock. As a preparation step, we mimic the Weibel filaments by using a target consists of Si rod-assembly (diameter 0.5 μm, length 13 μm, 15×15 or 15×3 array, interval 1.0 μm) and observe the cold rod structure with Small Angle X-ray Scattering (SAXS) using the XFEL (spot size ~ 2.7×3.4 $\mu m^2$ (FWHM), pulse duration < 10 fs (FWHM), photon energy 7.0 keV, photon number per pulse $4\times10^{11}$) [3].

Observed SAXS diffraction pattern and peaks of the XFEL from the cold rod-assembly targets show a good agreement with our calculation. We then added the HI driving laser (central wavelength 800 nm, spot size ~100 μm (FWHM), pulse duration 50 fs (FWHM), intensity $7\times10^{17}$ $W/cm^2$) to heat the targets. By varying the temporal delay between the driving laser and the XFEL probe, the time evolution of the expansion of the rod surface was successfully observed via SAXS. This successful proof-of-principle experiment can be extended to the future Weibel shock visualization at SACLA and other XFEL facilities.

**References**

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