9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

Development of a Diagnostic Method for Non-Equilibrium Plasma Using Thomson Scattering

K. Iida[1], K. Sakai[2], T. Morita[3], S. Isayama[3], K. Tomita[4], K. Kuramoto[1], Y. Toyoda[1], F. Nikaido[1], Y. Nakamura[1], H. Kusano[1], K. Yamanaka[1], Y. Esaki[1], Y. Naito[1], H. Kato[1], A. Morace[1], N. Ohnishi[5], A. Mizuta[6], R. Yamazaki[7], S. J. Tanaka[7], T. Takezaki[8], J. Zhong[9], Y. Zhang[9], J. Li[9], C. Li[9], Y. Xu[9], J. Peng[9], Y. Lu[9], Y. Guo[9], T. Hoshi[2], A. Nakano[2], S. Matsukiyo[3], Y. Sakawa[1], Y. Kuramitsu[1]
1) Osaka Univ., Japan,2) NIFS, Japan, 3) Kyushu Univ., Japan, 4) Hokkaido Univ., Japan, 5) Tohoku Univ., Japan, 6) RIKEN, Japan, 7) Aoyama Gakuin Univ., Japan, 8) Univ. Toyama, Japan, 9) Beijing Normal Univ., China
e-mail (speaker) : kaichi.iida@eie.eng.osaka-u.ac.jp

Collective Thomson scattering (CTS) is a unique diagnostic technique for measuring local plasma parameters in laser-produced plasmas, and it has been widely applied to experiments such as collisionless shocks and magnetic reconnections [1]. The theoretical framework for analyzing CTS spectra assumes linear, stationary, equilibrium, and stable plasmas.
However, no established method exists for analyzing CTS spectra in nonlinear, nonstationary, nonequilibrium, and unstable systems, such as those observed in collisionless shock experiments. Although theoretical and numerical studies have analyzed the spectral features under such conditions, experimental analysis that systematically address CTS spectra in nonequilibrium plasmas remain limited. In our previous work, we conducted experiments using a small-scale laser system to observe CTS spectra in counter-streaming plasma, as an example of nonequilibrium plasmas. However, measurements of electron feature alone in a counter-streaming plasmas, consisting of an ablation plasma from a solid target and an ambient gas plasma, did not show clear evidence of counter-streaming plasmas [2].

In the present study, we used the large-scale Gekko XII laser at the Institute of Laser Engineering, Osaka University. Two thin-foil targets were irradiated with focused laser beam from one side, generating expanding plasma flows from each target. These flows interacted to form a counter-streaming plasma system.
We simultaneously measured spatiotemporal evolution of both the electron and ion features at the region of counter-streaming plasmas. At 15 ns after laser irradiation, plasma flows from each target expanded freely into vacuum without interaction, thereby forming a collisionless counter-streaming plasma. At 35 ns, the two plasmas relax and merge into a single plasma. Because collision mean free path between the two plasmas was longer than the system size, the CTS spectra show the collisionless relaxation process of the counter-streaming plasma.

References

[1] D. H. Froula et al., "Plasma scattering of electromagnetic radiation: theory and measurement technique" Academic Press (2011).
[2] K.Sakai et al, “Collective Thomson scattering in non-equilibrium laser produced two-stream plasmas” Phys. Plasmas 27, 103104 (2020).