Exploring high energy density plasmas sustained over inertia time by the interaction between high intensity laser and structured medium

Y. Kishimoto[1,2,3], S. Masuno[4], M. Hashida[4,5], K. Fukami[6], H. Sakaguchi[3], K. Matsuda[3], S. Sakabe[2,4], S. Tokita[4] and R. Matsui[1,2]

[1] *Graduate School of Energy Science, Kyoto University*
[2] *Non-linear/ Non-equilibrium Plasma Unit (NPU), Kyoto University*
[3] *Institute of Advanced Energy (IAE), Kyoto University*
[4] *Institute for Chemical Research (ICR), Kyoto University*
[5] *Research Institute of Science and Technology (RIST), Tokai University*
[6] *Graduate School of Engineer, Kyoto University*

By irradiating a matter with a high-power laser with the peak intensity of $I > 10^{18}$ W/cm^2, a high energy density (HED) plasma with the pressure of several G bar is produced. Such plasmas open-up a variety of applications. However, the plasma is spatially localized in a limited region of the laser focal spot and then expands within the inertia time defined by L/C_s with L the typical plasma scale length and C_s the sound speed. This indicates that if the plasma is maintained (confined) on a longer timescale as a bulk plasma beyond the inertia time, we can extend the range of applications. An example is the proton-boron thermonuclear fusion, where the confinement time is of specific importance.

In order to study such a state, we developed the silicon rod assembly having high aspect ratio of 10~50 (height/diameter) by using semiconductor manufacturing technology [1,2]. Also, we used the assembly of aligned carbon nanotube (CNT) with the height of 300 μm. As a first step, we performed interaction experiments using T^6 laser at ICR, Kyoto University and measured the electron energy distribution using two sets of the electron spectrometer (ESM) from two directions, one is side (~22.5 degree) and the other is normal (90 degree) to that of rod. In the case of the CNT, a clear anisotropic feature is observed that the average electron temperature for the side case is approximately double compared to that of the normal case. Moreover, the spectra from the side show a flat pedestal region which connects lower energy part and that of high energy. These features are not seen for the slab geometry, indicating that the laser sensitively reacts the nm-ordered surface structure of the CNT. We present a possible mechanism to explain the measured ESM data from the PIC simulation, which results from the potential structure produced near the target surface.

We are now planning to experiments using silicon rod assembly targets to study the anisotropy nature as the first step for generating HED bulk plasmas beyond the inertia time incorporating with a back-light system as well as interferometry system for the density distribution measurement, which directly investigate the dynamics and structure of produced plasmas. We also planning to the scheme to generate plasmoid and high-speed ejection for the approach to make an FRC type plasma.

[1] Y. Kishimoto et al., IFSA 2017, St Malo France and IFSA2019, Osaka, Japan.
[2] R. Matsui et al., HEDS2022, April 21th, 2022, R. Matsui et al., JSPS conference, September 9th, 2022.