§51. Plasma Channel Formation in Imploded Plasmas

Habara, H., Iwawaki, T., Yabuuchi, T., Nakaguchi, S., Uematsu, Y., Yoshida, Y., Hayashi, Y., Tsujii, A., Murakami, R., Yahata, K., Tanaka, K. (GSE, Osaka Univ.), Arikawa, Y., Fujioka, S., Shiraga, H. (ILE, Osaka Univ.), McGuffey, C., Beg, F.N. (UCSD, US), Wei, M.S., Stephens, R. (General Atomics, US), Lei, A.L. (SILP, China), Sakagami, H.

We performed an integrated experiment for "super-penetration" fast ignition[1], at LFEX-GXII laser facility in the Institute of Laser Engineering, Osaka University. The ultra intense laser pulse irradiated on a spherically imploded plasma at the maximum compression timing. The laser propagation in the dense plasma was observed via Cu-Kα emission inside the plasma by adding a small amount of dopant of copper ions in the CD shell. The LFEX is focused at the positions corresponding to the critical density of imploded plasma based on the previous experimental results. The Cu-Kα emission image was observed with a crystal imager with 6.2 times magnifications and the absolute emission intensity was detected with the calibrated HOPG spectrometer. Simultaneously, escaped electron energy distributions and emission angular distribution were measured with the magnetic spectrometer and stack of imaging plates.

In this experiment, Cu-Kα image is the prime diagnostics to investigate the laser propagation inside the dense plasma. However in the previous campaigns conducted for last two years, our refractive imager suffered strong background noise coming from the plasma directly. In order to eliminate this noise, we introduced a beam blocker into the pass between the plasma and the detector. The beam blocker consists of 3-cm lead block and carefully designed not to interrupt the GXII 12 beams and LFEX. Fig. 1 shows the Cu-Kα image with and without the beam block. Clearly, the left hand side emission was almost disappeared by the block and the noise successfully reduced down to 5% of the noise without the block.

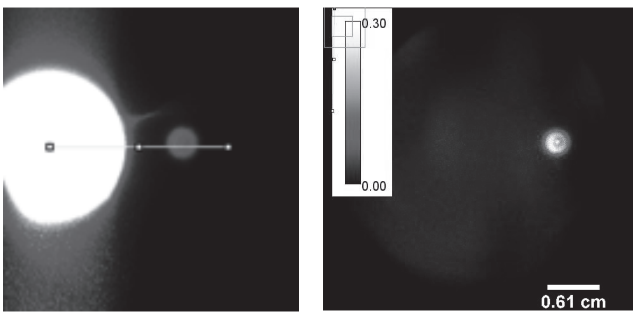

Fig. 1. Cu-Kα images without (Left) and with (Right) beam block. The left side circular emission represents the direct light from the plasma, and the right emission in both images are the refracted signal.

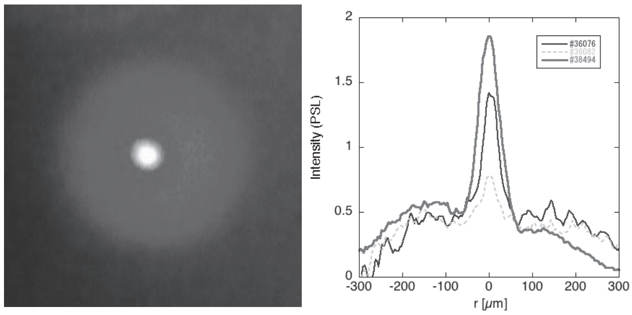

Fig. 2. (Left) Emission from the core region. (Right) Lineouts from the different shots. Red, blue, and green lines represent the data for joint shot 2014, joint shot 2012, and GXII only, respectively.

Left image of Figure 2 represents the emission from the imploded plasma when LFEX was injected. The center strong emission indicates the core. The right figure shows the line profiles of the images detected in different shots. The red, blue, and green lines indicate the data for the joint shot (2014), the previous joint shot (2012), and GXII only shot (2012), respectively. In 2012 experiment, the LFEX energy was restricted within 800 J because only 2 segments of LFEX beam could be available whereas full beam was used in 2014. As the results, the peak intensity of line profile was proportion to the LFEX energy. This fact implies that the emission at the core region is derived from the LFEX injection and the created fast electrons. We estimated the possible electron beam energy that can emit the observed Cu-Ka intensity, resulting in about 20-30% of the LFEX beam energy.

We also observed significantly collimated electron beam. The electron emission distribution was estimated with the spatial distribution of hard X-rays detected on the imaging plates, located at the outer surface of the interaction chamber with several viewing angles. In the case of cone-in-shell experiment, the emission angle was typically 40-50 degrees, whereas the angle from super-penetration was less than 20 degs. This could be because of magnetic collimation of electron beam[2]; when the laser propagates in the plasma, the plasma channel is created through the ponderomotive evacuation. Initially the fast electron created in the underdense regions creates the electrostatic and magnetic fields around the channel, and then the magnetic fields enhance the beam collimation. Because the propagation speed of laser light should be slower than the relativistic electron current, the electrons created at the critical position by the laser light are influenced by the preceding magnetic fields. This collimated beam can effectively hit the core plasma, and can be expected to lead the efficient heating of the core plasma.

1) Lei, A.L et al.: Phys. Rev. E **76** (2007) 066403; ibid, Phys. Plasmas **16** (2009) 056307.
2) Iwawaki, T. et al.: Phys. Plasmas **21** (2014) 113103 (2014); ibid, Plasma. Fusion Res. **10** (2015) 1304005.