§46. Ultra Intense Laser Propagation in Implosion Plasma Created by Cu-doped CD Shell

Habara, H., Yabuuchi, T., Iwawaki, T., Tanaka, K. (GSE, Osaka Univ.),
Shiraga, H., Nakai, M., Fujioka, S., Arikawa, Y. (ILE, Osaka Univ.),
Jarrot, C., Beg, F.N. (UCSD),
Wei, M.S., Stephens, R. (General Atomics),
Sawada, H., Sentoku, Y. (Univ. Nevada, Rino),
Lei, A.L. (Shanghai Institute of Laser Plasma, CAS)

In the recent progress of fast ignition, direct heating scheme by a single ultra intense laser beam is one of an attractive approach to obtain the fusion power[1]. In this scheme, the ultra intense laser light is focused into the underdense region of imploded plasma due to relativistic self-focusing, making increase of laser intensity during the propagation. Then the laser pulse can propagate exceeding classical critical density into overdense plasma. At later time, laser hole boring also plays an important role to bring the laser energy into overdense region efficiently.

In this research, we conducted an integrated experiment of direct heating fast ignition at GXII-LFEX laser system in Institute of Laser Engineering, Osaka University. The 1kJ/2ps intense laser light is irradiated onto imploded plasma by 2kJ/1.3ns/2ω GXII beam. In order to observe electron transport inside the dense plasma, Cu-doped CD shell is utilized as a target in order to measure Cu-Kα emission created via inner shell excitation by fast electrons. The diameter of shell is 472μm with 6.5μm thickness in average. The dopant of Cu ions is 1.6 at%. We changed focusing position of LFEX for 220μm (N_c), 430μm ($N_c/4$), and 670μm ($N_c/10$) to optimize the heating efficiency[2]. We used several imaging detector such as Cu-Kα imager, KB microscope, X-ray Pin-hole camera (XPHC), and X-ray streak camera (XSC) to measure the spatial distribution of X-ray emission. HOPG X-ray spectrometer is also utilized to measure the Kα photon numbers. The fast electron energy spectra were measured with magnet spectrometer on LEFX laser axis and 20° from the axis.

At first we calculated the electron density distribution by using ILESTA-ID code. Due to strong radiation loss from Cu ions or increase of plasma temperature, achievable maximum densities are nearly 10-20% of that of pure CD shell. In the experiment, XPHC image shows strong emission at the acceleration phase. XSC also shows slower acceleration speed of shell surface, which quantitatively agree with the calculation.

Figure 1 shows Cu-Kα intensities as a function of LFEX focusing position. When the laser focusing position becomes closer to the core, higher Kα emissions are observed, ex. 2.4 times enhancement at N_c focusing compared with $N_c/4$.

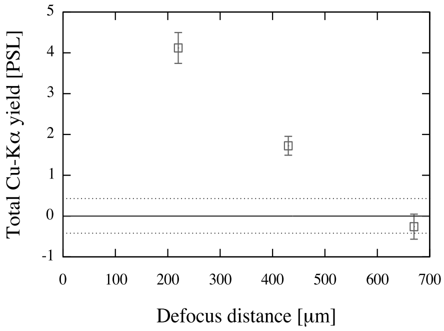

Fig. 1. Cu-Kα intensity as a function of LFEX focusing position from the core center.

Left image in Fig. 2 indicates the image taken with Cu-Kα imager. Although the emission during the implosion can be shown, strong emission is observed at the core region. The right figure of Fig. 2 shows the line profile of image taken from N_c (red), $N_c/4$ (blue), and GXII only (black). When the laser is focused on N_c, Cu Kα emission is strongly enhanced to be nearly twice. The enhancement occurs at the core, not the whole region. This fact strongly indicates that the ultra intense laser energy is actually delivered near close to the core, and effectiveness of direct heating scheme at the first time. Note that the KB microscope which also observe 8keV X-ray shows similar dependence.

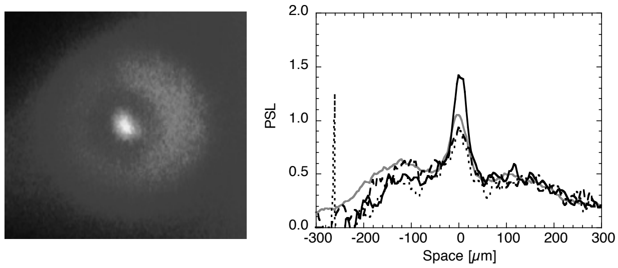

Fig. 2. (left) Cu-Kα image. (right) line profiles of image taken from N_c (black), $N_c/4$ (dashed), and GXII only (gray).

In summary, we investigate laser propagation in an imploded plasma by using a Cu-doped CD shell target. Due to strong radiation loss, the peak density of implosion plasma is nearly 1/10 of that of non-doped shell. When LFEX is irradiated on 220μm from the core center, Cu-Kα emission at the core is increased. Even within Rayleigh length, the focusing position condition can affect the laser propagation in plasma. In this experiment, closer focusing condition creates higher intensity of Kα emission. However, for longer or denser plasma, the focusing condition must be optimized for penetrating into deeper regions.

1) Tanaka, K.A., et al.: Phys. Plasma **7** (2000) 2014; Lei, A.L.: Phys. Plasma **16** (2009) 056307.
2) Matsuoka, T. et al.: Plasma Phys. Cont. Fusion **50** (2008) 105011.