§63. Super-penetration in Integrated Implosion Experiments with Cu Foam Sphere Targets

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Integrated implosion experiments were conducted at LFEX-GXII laser facility in the Institute of Laser Engineering (ILE), Osaka University, to study the super-penetration of the high-intensity laser and the deposition of the produced fast electrons inside the high-density core region. Cu foam spheres (with a diameter of 200μm and a density of 1g/cc) coated with 18μm thick CH are used as the targets due to the following two reasons. Firstly, experiments at ILE indicate that solid spheres can produce a denser core region than shells when the targets are irradiated by the twelve lasers. Secondly, Cu-Kα emission is used to detect the deposition of fast electrons inside the plasmas. Pure Cu targets rather than Cu doped targets are used because the concentration of Cu in doped solid targets is not high enough due to fabrication issues.

The targets are irradiated by the GXII lasers. Each of the 12 beams operates at 2ω with an energy of ~300J. The pulse shape is Gaussian with a FWHM of 1.3ns and the diameter of the spot at the target surface is around 160μm. The LFEX (1.4kJ/1ω/1.5ps/Φ80um) is focused 220μm away from the target center, which corresponds to the critical density when maximum compression is reached according to the simulation results. An X-ray pinhole camera and an X-ray streak camera (XSC) are used to detect the self-emission of the targets. A Kα-imager and a HOPG are used to detect the Kα emission. Three electron spectrometers are used to detect the energy spectra of fast electrons from different directions (0, 21, 42 degree with respect to the LFEX axis). Since the exact hydrodynamic evolution of this new target is unknown, we varied the delay of LFEX relative to the peak of GXII laser pulse to explore the timing of maximum compression.

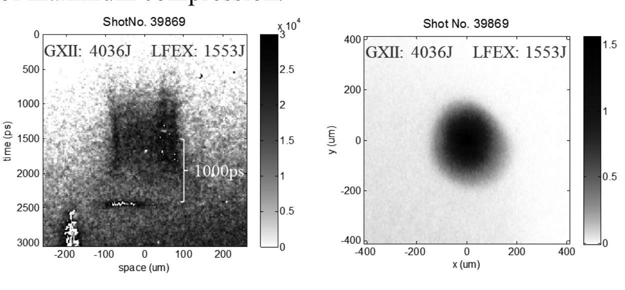

Fig. 1. Typical experimental results from X-ray streak camera (left) and Kα imager (right).

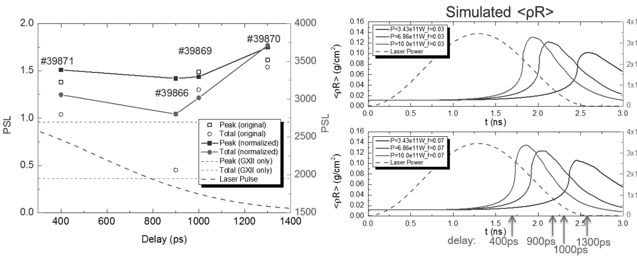

Fig. 2. (Left) The dependence of both peak (blue) and total (red) intensity of Kα emission on the delay of LFEX. The solid dots are obtained by normalizing the original data (open) with the LFEX energy (1500J). The dashed horizontal lines are the corresponding results without LFEX. The grey dashed line is the pulse shape of GXII lasers. (Right) Preliminary simulation results with MULTI1D code.

Typical experimental results from XSC and Kα imager are shown in Fig. 1. The edges of the self-emission stay at almost the same positions during the ablation and no obvious variation of the center part of the emission is observed. The size of the Kα emission region is around the initial size of the target and no significant enhancement is observed at the central region. All of these features indicate that there is almost no inward movement of the plasmas in this process and that the increase of the density at the core region for Cu foam sphere targets is not as significant as that for the previous Cu doped CH shell targets.

Quantitative analysis of the target compression can be performed according to the dependence of Kα emission on the delay of LFEX, as shown in Fig. 2. To eliminate the effect of fluctuation of LFEX energy on the production of fast electrons, the intensities of Kα emission are normalized by the LFEX energy, as shown by the solid dots. Relative to the case without LFEX, the intensity of Kα emission increases more than 50% when LFEX is applied, which demonstrates the production of fast electrons by LFEX. Since the intensity of Kα emission is related to both the number of fast electrons and the areal density of the target (<ρR>), <ρR> can be characterized by the normalized intensity of Kα emission if the number of fast electrons is assumed to be linear with the LFEX energy. As a result, both the peak and the total normalized intensities of Kα emission in Fig. 2 imply that <ρR> will increase when the delay exceeds 1000ps. Consistent behavior is also detected by the HOPG. It means that the targets are indeed compressed, although this process is difficult to be detected by XSC. We conducted a series of simulations with MULTI1D code using the same laser and target parameters as the experiments. The preliminary results indicate that the evolution of <ρR> is consistent with the experimental data if one assumes that only 50% of the energy of GXII lasers is absorbed (blue solid lines in Fig. 2).

The energy spectra and the angular distribution of the fast electrons indicate that more electrons with narrower divergence are produced when 1) more intense LFEX or 2) a larger delay of LFEX is applied in this campaign.