§58. Investigation of Fast Electron Heating of Solid Cu Wire Pertinent to Fast Ignition

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Transport efficiency of fast electrons from the source to the fuel plasma core is important in the fast ignition (FI|) laser fusion. The core heating after the fast electron transport through the cone tip has been studied via the increase of the thermal fusion neutrons in integrated experiments of FI. [1] In our study, the fast electron transport has been studied by using a cone-wire target placed inside of the imploded plasma to investigate the effect of the target-surrounding plasma on the fast electron transport in the cone-wire target. The results will be important database to benchmark simulation codes to study the fast electron transport to the plasma core in the full-scale fast ignition.

The fast electron energy spectrum and the coupling efficiency have been studied using cone-wire targets after the electrons propagate through the cone tip.[2] Past studies have been performed using the cone-wire target in vacuum, so that the fast electrons are guided along the cone-wall and the wire. This guiding effect can enhance the efficiency of fast electrons traveling in the wire, therefore, the estimated efficiency could be higher than the one expected to heat the plasma core in FI. In order to estimate the efficiencies of fast electrons reaching to the core, the cone-wire target is placed inside the imploded plasma in this study.

In the presented experiments, the cone-wire target was surrounded with high-density plasma, which is produced by a plastic shell implosion with the GXII laser pulses at the Institute of Laser Engineering, Osaka University. An intense laser pulse from the LFEX laser was focused into the cone at various timings. The cone was made of 7 μm thick gold with an opening angle of 45̊ and an inner tip of 30 μm in diameter. A 50-μm-diameter copper wire was glued on the cone tip. The wire length was 250 μm, which is equivalent to the radius of the plastic shell. The gap reduces the shockwave propagation in the wire due to the GXII pulse irradiation on the shell. The shell thickness was 7 μm. The shell implosion was performed with 9 beams of GXII with an energy of ~250 J/beam in 2ω with a pulse duration and a focused spot of 1.3 ns and 500 μm, respectively. The LFEX laser energy was changed from 0.5 to 0.9 kJ in 2 ps. The fast electrons produced by the LFEX pulse interact with the wire and produce the Cu K-alpha x-rays (8.05 keV). The spatial profile of the K-alpha x-rays along the wire was measured with a Bragg crystal imager. The x-ray energy spectrum was also measured with a spectrometer using a HOPG crystal. The energy spectra of fast electrons were measured on and off the wire axis, as well as various x-ray diagnostics including pinhole cameras and streak cameras.

As our previous study shows, in the case when the LFEX was injected at the maximum compression timing, the observed results and simulations indicate; 1) the coupling efficiency into the wire was significantly reduced (down to ~20%) compared to the case without the surrounding plasma, 2) the wire was partially heated and could be disturbed due to the shock compression caused by the imploded plasma. Since the fast electron transport could be affected by the shock compression and/or heating of the wire, the LFEX injection timing was carefully tuned to prevent the side effects of the compressed plasma in this study. The wire could remain cold with its solid density in the original shape but the cone-wire is surrounded by plasmas. Figure 1 shows the intensity of K-alpha x-rays measured with the x-ray spectrometer normalized by the LFEX laser energy. Clear signal reduction down to ~30% is still seen at ~500-640 ps before the maximum compression of the shell. Please note that hydrodynamics simulation indicates that the wire is not affected by the imploded plasmas at the timing. The signal reduction can be explained with the electron beam divergence at the source. Our preliminary hybrid simulations studying the fast electron behavior in wire surrounded with plasma show that a significant number of fast electrons escape from the wire quickly after they are produced. In contrast, the simulation confirms that the fast electrons are confined within the wire if it is in vacuum.

In summary, the fast electron transport in cone-wire targets in plasmas has been investigated using an intense laser pulse with the energy up to sub kJ in order to estimate the effect of imploded plasmas on the electron transport to the fuel core in the cone-guided FI laser fusion. The fast electrons appear widely spread into the plasma resulting less coupling to the wire. The results agree well with simulation results on fast electron transport. This work was performed with the support and under the auspices of the NIFS Collaboration Research program (NIFS11KUGK055).

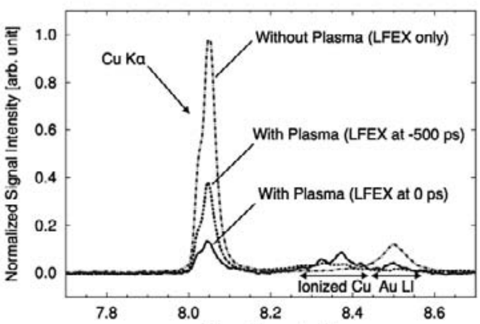

Fig. 1. X-ray spectra emitted from cone-wire targets

1) Kodama, R. et al.: Nature **412** (2002) 933.
2) Ma, T. et al.: Phys. Rev. Lett. **108** (2012) 115004.