Systematic Study of Fast Electron Transport in Solid and Warm Dense Plasma

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We report on experiments to study fast electron transport in a large volume (~300 µm) of warm dense plasma, which was created by shock heating of 200 mg/ cm^3 CH foam by 1.2 kJ, 3.5 ns laser and was characterized with a Sm x-ray backlighter. Radiation hydrodynamics simulations show about 40-50 eV plasma with electron density of 10^{22} /cm^3. Fast electrons created with OMEGA EP short pulse laser (1 kJ, 10 ps) interacting with a Au foil on one side of plastic cube were collected on the opposite side on a Cu foil to give information about the dynamics and energy deposition of fast electrons.

1. Introduction:

Understanding of relativistic electron generation and transport in solid and warm dense plasma is a fundamental issue pertinent to relativistic high energy density plasmas and intense particle beams. We have performed two experiments on the OMEGA EP laser to address this important issue. The goals of the experiments were: i) to characterize plasma to be used as the transport medium using the x-ray line absorption spectroscopy, and ii) to study the fast electron transport in the characterized plasma.

2. Experimental Setup and Results:

In the first experiment, a shock-wave-heated foam target was used to create warm dense plasma. The foam target package consisted of 200 mg/cm^3 plastic foam doped with aluminum inside a solid plastic container. A long pulse laser (1.2 kJ/3.5 ns in UV) irradiated onto a plastic foil to launch a shock wave into the foam target. The other three lasers were focused onto a samarium (Sm) dot target to produce an x-ray point source for the absorption spectroscopy. The Sm x-ray spectrum (1.4 – 1.6 keV) was transmitted through the Al-doped foam target and recorded with an x-ray streak camera. The spectral analysis using a detailed atomic physics code Prism SPECT [1] show the electron temperature of 40 ± 5 eV and the mass density of 30 ± 10 mg/cm^3 at 7 ns after the drive laser. Two-dimensional DRACO simulation [2] shows the foam plasma peak temperature and density of 30 - 50 eV and 110-180 mg/cm^3 respectively at about 7 – 8 ns. The low density in experiments was due to reduced energy in driver laser beams.

In the second experiment, fast electrons generated by an OMEGA EP short pulse were transported into the characterized foam plasma. The EP beam interacted with a gold foil on one side of the package target to generate the fast electrons. The electron transport was studied by measuring 8.0 keV Kα x-ray from a Cu foil attached to the other side. The Kα x-rays induced by the electrons were recorded with an x-ray spectrometer and a spherical crystal imager. Fig. 1 shows the Kα images from the three transport media: (a) a solid plastic, (b) an un-driven foam, and (c) the laser-driven foam plasma. A small Kα spot was observed in the cold plastic target; however, no clear structure was found in the foam targets, indicating a large divergence of the relativistic electron beam in both driven and un-driven foam. The comparison of the total Kα yields in the foam targets shows a reduction of the yield by factor of 20 in the driven foam (Fig. 1d). Low signal in the warm foam target could be attributed to interface field effects and relativistic electron beam instability exiting the gold layer into warm dense plasma.

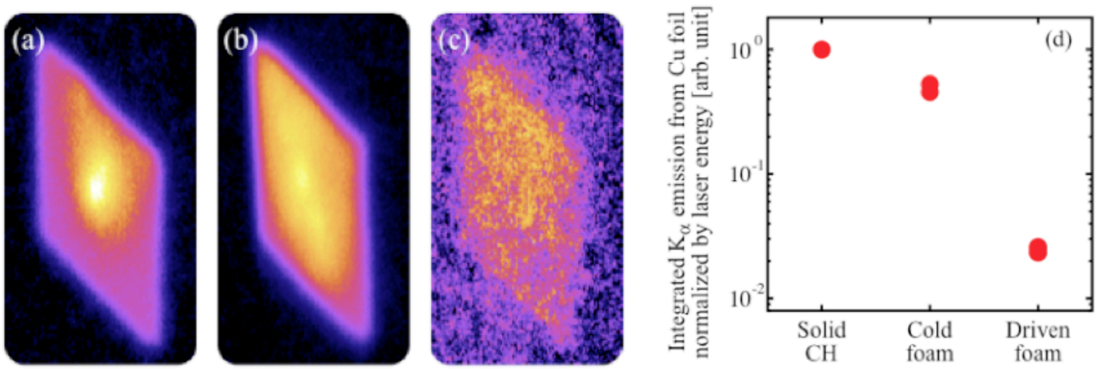

Fig. 1. Cu Kα images observed with spherical crystal imager when the transport medium was: (a) 50 µm solid CH, (b) 250 µm cold foam, and (c) 360 µm driven foam. Integrated Kα x-ray yield measured with the x-ray spectrometer for three cases (d).

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