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§50. Areal Density Measurements of Imploded Cone-in-shell Targets with High-energy K-alpha X-ray Backlighters

Sawada, H. (Univ. Nevada, Reno),
Fujioka, S., Hosoda, T., Zhang, Z., Arikawa, Y., Nagatomo, H., Nishimura, H. (Institute of Laser Engineering, Osaka Univ.),
Sunahara, A. (Institute for Laser Technology),
Theobald, W. (Univ. Rochester),
Patel, P.K. (Lawrence Livermore National Laboratory),
Beg, F.N. (Univ. California, San Diego)

Fast Ignition (FI)[1),2)] is one of the advanced laser fusion concepts in inertial confinement fusion (ICF) to achieve high gain with smaller laser energy than conventional ICF schemes by separating a compression and ignition phases: 1) a deuterated plastic (CD) shell with a re-entrant cone is compressed by long pulse lasers to form a high density fuel core and 2) the core near the peak density is rapidly heated with an ultraintense, sub-picosecond ignition laser to the ignition temperature. Formation of a high density core is a crucial step for FI to efficiently deposit the electron energy to the core. 2-D Radiation-hydrodynamic codes have been used to simulate a laser-driven implosion core, however the simulation results have not been thoroughly benchmarked against experimental measurements. The key benchmarking parameters are areal density, core size and standoff distance of the core from the cone tip. The goal of this project is to develop a 2-D monochromatic imaging diagnostic for 4.51 keV Ti K-alpha x ray to obtain a radiograph image of an imploded cone-in-shell target. Narrow x-ray backlighter spectrum (monochromatic) has an advantage for accurate density measurements because of photon energy dependence of x-ray attenuation by an object. The progress of the project is shown in the following sections.

For this project, a spherically bent quartz crystal was chosen as an x-ray optic. The quartz crystal has 20 mm diameter, 2023 mirror indices, 2d spacing of 2.749 Å, and a radius of curvature of R = 260 mm. It was operated at 1.0° off normal incidence at the 1st order reflection and magnification of 11.5. The spatial resolution with this crystal and 25 μm imaging plate scanning condition can be achieved to be ~ 15 μm. The bandwidth of the crystal is narrower than the Ti K-alpha line spectrum to produce nearly monochromatic x-ray source with ~10 eV. The temporal resolution of the diagnostic is determined by the pulse duration of the LFEX short-pulse laser, enabling to record a flash radiograph image of fast implosion dynamics.

The radiography experiment was conducted at the Institute of Laser Engineering at Osaka University using 9 beams of the Gekko XII nano-second laser and high-power, picosecond LFEX laser. Figure 1 shows a schematic of the experimental layout and two types of targets: 200 μm diameter CD sphere with a Diamond-like Carbon (DLC) cone (called cone-sphere target) and 500 μm diameter CD shell with a Au cone (called cone-in-shell target). The target placed at the target chamber center (tcc) was irradiated by ~2 kJ, 9 GXII beams in 1.3 ns Gaussian pulse to form a high density core. Near the peak compression, ~500 J, 1.6 ps LFEX laser irradiated on a Ti foil positioned at 2 mm away to generate 4.51 keV Ti K-alpha x ray. The LFEX beam was defocused to 300 μm spot to generate uniform backlighter emission. The backlighter x-ray was transmitted through the imploded core and reflected off with the spherically bent crystal to an imaging plate (IP) detector. The timing of the short-pulse irradiation was varied around the peak compression based on the shell trajectory measurement recorded with an x-ray streak camera. A cone-sphere target allowed us to obtain a radiograph of the target independent to the injection time since the initial areal density of the sphere is 0.02 g/cm^2 at the center.

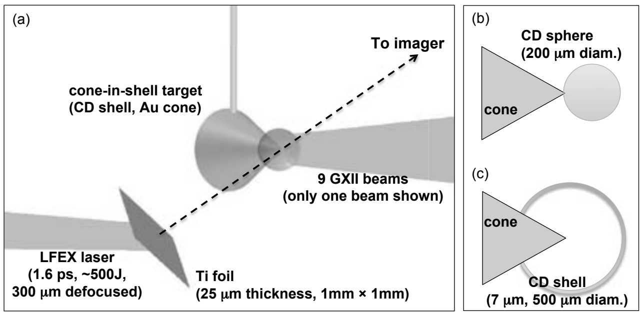

Fig. 1. (a) Experimental layout, schematics of (b) a CD sphere with a cone and (c) CD shell with a cone

Figure 2 shows the radiographic images of undriven CD shell target (s37514) and driven cone-sphere target (s37625). As shown in Fig.2 (a), a shape of the 1.0 mm by 1.0 mm Ti foil at projected angle and the Kα emission by the defocused laser beam on target were observed. The sharpness of the foil edge is used to estimate ~ 18 μm spatial resolution. Figure 2 (b) shows a radiograph of imploded cone-sphere target with a DLC cone. The shape of the imploded core was observed in front of the shadow of the cone. Preliminary analysis shows that the core size is ~ 100 μm in diameter and the separation between the core and cone tip is ~ 80 μm. Inference of the areal density and detailed image analyses are underway.

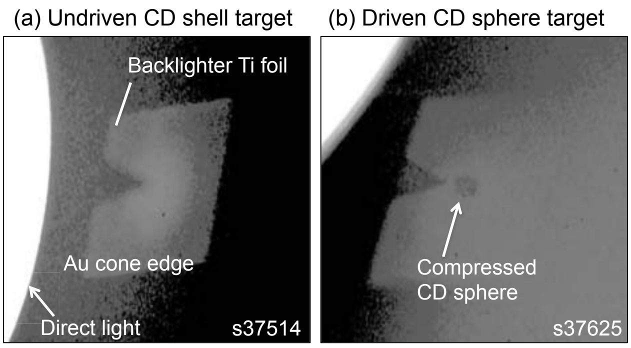

Fig. 2. Monochromatic x-ray images of (a) undriven CD shell and (b) driven CD sphere targets.

1) Tabak M. *et al.*, Phys. Plasmas **1**, 1626 (1994)
2) Kodama R. *et al.*, Nature **412**, 798 (2001)