Spherical Crystal Imager (SCI) – reported by Hye-Sook Park

A monochromatic crystal imager will be very useful for a variety of research topics such as fast-electron dynamics in fast-ignition experiments and spatial characterization of self-emitting K-α backlighters. This diagnostics was requested by the Omega Users in 2010. The key features are the operational wavelength is at Cu Ka 8.05 keV line, spatial resolution of ~10 μm, and light collection with f/10 optics. As of Sep. 30, 2011, two SCIs are completed: one on Omega EP and the other on Omega. Both were utilized for the user's physics experiments and started producing scientific results.

This diagnostic was commissioned by C. Stoeckle and G. Fiksel from LLE. The unique capabilities of a crystal imaging system using two-dimensionally bent Bragg crystals are a narrow spectral width (< 2 pm), a high throughput (up to 100 fold improvement over pinhole imaging) and potentially a high spatial resolution (< 2 μm)[1]. Crystal imaging has been frequently used on small to medium scale

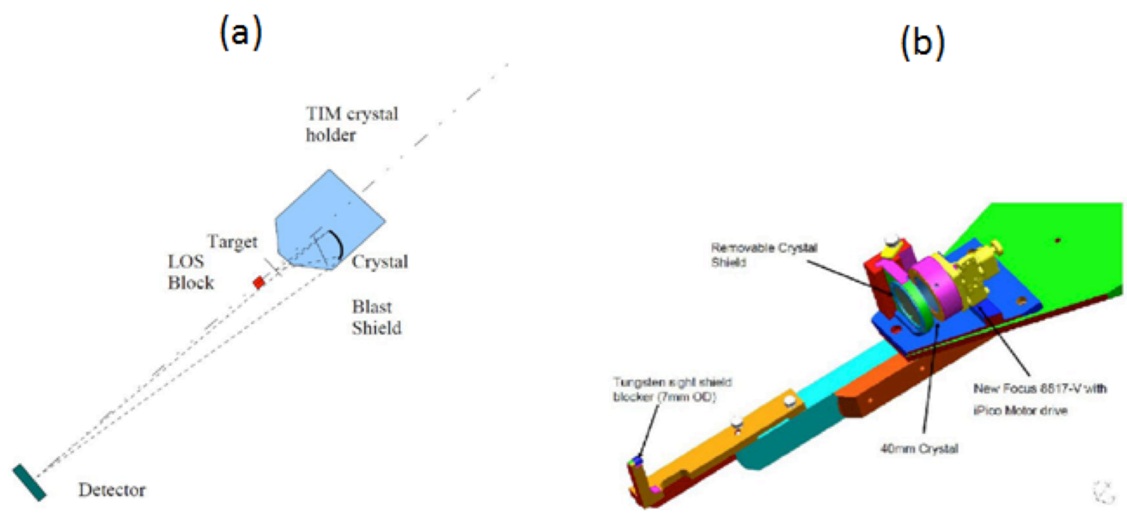

Figure 1. (a) Schematic drawing of the Spherical Crystal Imager (SCI) hardware. One Ten-Inch-Manipulator (TIM) houses the crystal holder, a second the image plate detector housing. Both TIMs are on a common centerline indicated by the dashed dotted line in the drawing. A blast shield is placed in front of the spherical bent crystal, which images the target onto the detector (dashed lines). A direct Line Of Sight (LOS) block is placed opposite the crystal mount beyond the target. (b) CAD design of the SCI. The crystal is mounted on a motorized tip-tilt stage. A blast shield protects the crystal from target debris. The blast shield can be removed for alignment. A direct line of sight block made of tungsten protects the image plate detector from x-ray background emitted by the target.

facilities, where the target chamber is vented between shots, and direct operator access to the target chamber makes the alignment relatively easy[2,3]. On larger scale facilities such as OMEGA, where the target chamber stays at vacuum between shots, fully remote alignment of the crystal imager is required. For first experiments using the Spherical Crystal Imager (SCI) implemented on OMEGA EP, a Quartz crystal was used, cut along the 2131 (211) planes for a 2d spacing of 0.3082 nm, to image the Cu Ka lines at ~8 keV. The crystal has a radius of curvature of 500 mm and was placed 285 mm from the target, for a magnification of ~ 10x. The image is recorded on Image Plate (IP) located ~2.7 m from the target. The SCI system uses two opposing Ten-Inch-Manipulators (TIM) in its shot configuration, as sketched in Fig 1. The crystal is mounted on a motorized tip-tilt stage that sits on a TIM-mounted frame, and is inserted close to the target. A removable blast shield protects the crystal from target debris. A direct line of sight block made out of tungsten is mounted on an arm between the target and the detector to block any x-rays emitted by the target that are not reflected by the Bragg crystal from reaching the detector.

The SCI on EP was used by H. Sawada and his team from UCSD to characterize the MeV electron coupling to the Cu wire for fast ignition applications. The experiment varied the short pulse laser widths measuring hot electron conversion efficiencies. The schematic of their experimental setup is shown in Fig 2. The targets were either a stand-alone Cu cone or an Al cone with a Cu wire. The cone was 1 mm long with a 34° full opening angle, a 10 µm tip thickness and a 20 µm wall thickness. The 1.5 mm long Cu wire was glued onto the tip of the Al cone. The 1-kJ and 10-ps EP beam with the average intensity of ~$5x10^{18}$ W/cm^2 was focused onto the cone tip. The SCI successfully imaged Cu K-α brightness as shown in Figure 3. The top panel is a stand-alone Cu cone and the bottom is with a Cu wire. Their brightness, shape and falloff emission profile was compared with the particle-in-cell LSP simulations to infer the electron energy distribution and laser-to-electron conversion efficiency. The initial experimental work is accepted for a publication[4].

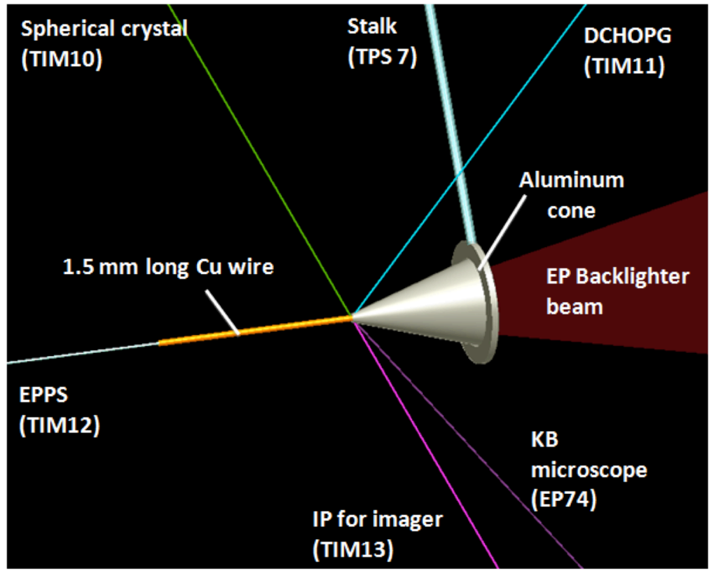

Figure 2. Experimental setup to study hot electron transport using the Spherical Crystal Imager. This experiment was performed by H. Sawada's team from UCSD.

The other experiment was performed by P. Nilson from LLE. His experiment was to measure the Cu K-α backlighter source size. He measured that the Cu K-α source was bigger than the laser spot size[5] likely from the hot electron refluxing as observed in the previous experiments[6].

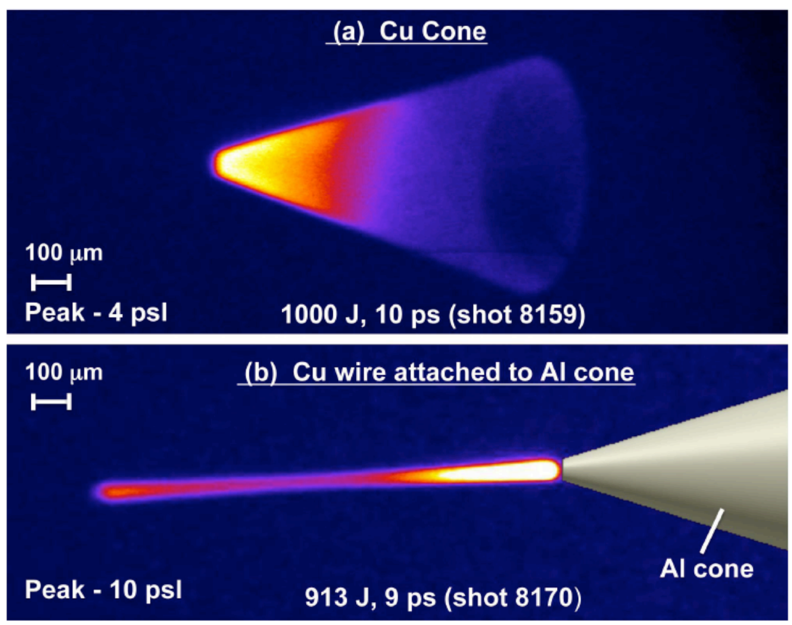

Figure 3. A Cu-Kα SCI image of the Cu-cone and Cu-wire targets used to study hot electron transport. The electron energy distribution and laser-to-electron conversion efficiency are inferred from the brightness, shape and fall-off profile. [From Ref. 4]

The SCI on Omega was utilized by Mingsheng Wei and her team from General Atomics and UCSD on a Joint shot day. In this experiment, the SCI image plate was, unfortunately, completely swamped by the background with EP beam of

>1 kJ[7]. Improvement of the background shielding and test shots will be needed to resolve the issue.

Future improvement on the may be that use of a CCD camera instead of the image plate. A complementary crystal imager is being constructed by Gennady Fiksel from LLE that will image 1.8 keV Si line. This imager will work with the existing hardware fixtures and will be available to the user community.

References

[1] Y. Aglitsky, Appl. Opt., **37** 5253 (1998).
[2] J. Koch et al., Rev. Sci. Instrum. **74**, 2130 (2003).
[3] S. LePape et al., Rev. Sci. Instrum. **79**, 106104 (2008).
[4] H. Sawada et al., IEEE Transactions on Plasma Science, Accepted for publication (2011).
[5] P. Nilson, private communication (2011).
[6] H. Park et al, Phys. Plasmas, **13**, 056309 (2006).
[7] M. Wei, private communication (2011).