§61. Study of Hot Electron Propagation in Hot Dense Matter with a High Energy X-ray Imaging and Spectroscopy

Zhang, Z. (Institute of Physics, CAS),
Nishimura, H., Yogo, A. (ILE, Osaka Univ.)

The physics of energy transport in the cone-guided fast ignition plasma by way of laser-produced hot electrons from the interaction region have been expected for many years. The results will provide important information about the basic physics of laser plasma interaction and are closely related to its applications, such as laser-based particle acceleration, fast ignition and laboratory astrophysics.

X-ray, especially high-energy Kα lines are used as a powerful diagnostics for laser plasma interaction. For the fast ignition on LFEX, the hot electron temperature exceeds a MeV level. Higher-Z materials which provide stronger stopping for the MeV-hot electrons are preferred as the tracer. Furthermore, the Kα emission from high-Z materials have a higher energy and a longer mean free path compared with the Kα from a low-Z material, which allows a thicker tracer layer than the low-Z case, and the information derived for hot electron propagation is more accurate. In the past few years, a Laue spectrometer has been applied for quantitative spectroscopy of Ta and Au Kα lines [1]. In order to provide more information about the hot electron propagation, in particular propagation behavior, a new Laue imager dedicated for Ta or Au Kα monochromatic image was designed. It is proposed to observe the hot electron trajectory with this new instrument. This will be the first direct observation of the hot electron propagation inside a solid target.

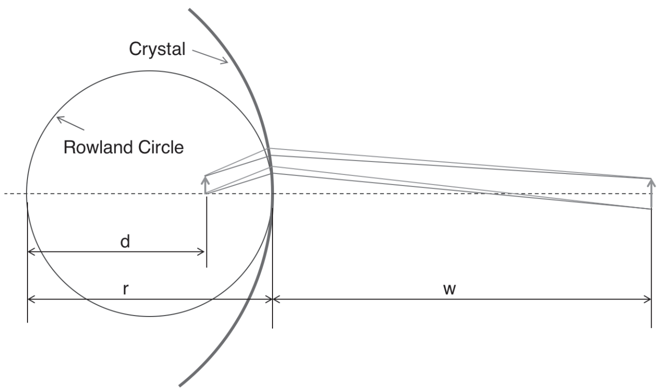

Fig. 1. Schematic drawing of the Laue imager.

The schematic drawing of the Laue imager is shown in Fig. 1. The setting is based on the geometry proposed by Cauchois [1]. The spatial magnification is calculated by: (w+r-d)/d, where r is radius of the crystal, (r-d) is the distance from the crystal surface to TCC and w is the distance from the crystal to the detector. In this design, the total distance from TCC to detector is given by w+r-d. The distance is fixed to about 1 m, which allows the imager be easily installed on the LFEX chamber. In order to observe a clear image, a magnification of about 5 is preferred. In this way, the value of w, r and d is chosen to be 900 mm, 350 mm and 205 mm, respectively. In order to increase the signal intensity, the Kα and Kβ lines are focused on the image, illustrated as blue and red lines in Fig. 1.

Based on the design, the Laue imager is fabricated as shown in Fig. 2. In front of the crystal, there is a W slit with an adjustable width, which is set to 50 μm now. A 2D goniometer behind provides a fine alignment for the crystal. The direct emission is blocked by a W block with a thickness of 50 mm, which is sufficient to cut most of the hard x-rays generated from the target. The detector plane is located outside the target chamber in air. There are two choices of detectors, Imaging plate or hard x-ray CCD. The detector can be easily changed during the experiment based on the results. The image of x-ray is a quasi-2D image. One dimension is imaged by the crystal, with a magnification of 5.1; while another dimension is imaged by the W slit, with a magnification of 6.7.

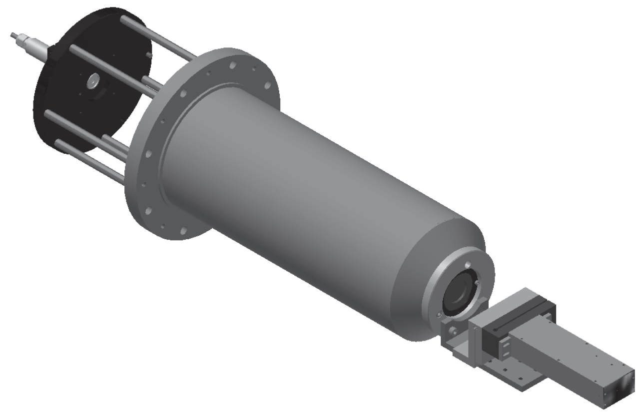

Fig. 2. The Laue imager.

The research is planed to conduct at LFEX laser facility, Institute of Laser Engineering. A Ta cube of 0.5x0.5x1 mm3 with or without a cone will be adopted as a tracer. The well-characterized Laue spectrometer and the new designed Laue imager will be used simultaneously. The information of Kα photon number and hot electron divergence can be achieved with a single-shot-based experiment. For the experiment, the 4 LFEX beams will be operated at varies of energy and pulse duration, together with other fast ignition experiments. Besides, an ESM (electron spectrometer), HEXS (high energy spectrometer for bremsstrahlung) and Comp-G (Compton x-ray spectrometer) will be needed for the hot electron temperature.

[1]. Z. Zhang, et. al., High Energy Density Physics, (15):78–81, 2015.

[2]. Y. Cauchois. Journal de Physique et le Radium, 3(7):320–336, 1932.