Measurements of soft X-ray emission from laser-irradiated gold foils

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Soft X-ray (SXR) has been considered a powerful tool for diagnostic technology as it contains ultrashort wavelengths with unique scattering and interacting properties. Several microscopy applications based on SXRs as radiation sources have been developed now, such as X-ray photoelectron microscopy, X-ray holography, transmission X-ray microscopy, and X-ray contact microscopy [1].

In particular, the SXR in the water window (WW) region (wavelength: 2.3 nm-4.4 nm) provides a high transmission rate for oxygen atom, while leaves a high absorption rate for carbon constituents. This contrast makes it possible to observe cells' nanoscale structures under high-spatial resolution, because water and carbon are the two main constituents of living organisms. More importantly, there are no necessary invasive pretreatments for a sample, keeping them still alive during its observation, which makes it more favorable when compared with an electron microscope (chemical fixation and dehydration). However, the spatial resolution of the X-ray microscopy is highly related to the photon flux [2]. In general, large and expensive facilities are required to generate considerable amounts of SXR, and the repetition rate of the driving laser is also limited. Therefore, it is necessary to construct a practical affordable, compact tabletop X-ray microscope, with a reasonable higher repetition rate (>100 Hz).

One of the simple methods to obtain SXRs is to use a laser-produced plasma. Recently, it has been found that when a commercial Nd:YAG laser (1064 nm, 7 ns, 1 J) irradiated a gold foil target under a low-pressure nitrogen gas atmosphere, the WW X-ray emission has dramatically increased [3].

In order to improve the conversion efficiency from Au laser plasma to the WW X-ray contributing to SXR lithograph light source, an appropriate thickness of the irradiation target is of significant, because the Au substance (maybe, tape target) is too expensive. Therefore, in this study, we investigated the optimal thickness of the Au foil target for the future applications.

A Nd:YAG laser pulse (1064 nm, 7 ns, 800 mJ) was tightly focused onto a spot (FWHM: ~15μm) on the target by an *f*=10 cm lens, giving an intensity of $\sim 10^{13}$ W/cm^2. The target and focus lens were mounted on six-axis motorized stages in vacuum, which enabled us to align the laser focus precisely and to choose the SXR observation region. Four diagnostic tools were employed to comprehensively evaluate the WW X-ray emission, as shown in FIG. 1. A grazing incidence spectrometer having a toroidal mirror and a 2400 grooves/mm flat field grating was installed to observe the SXR in the WW

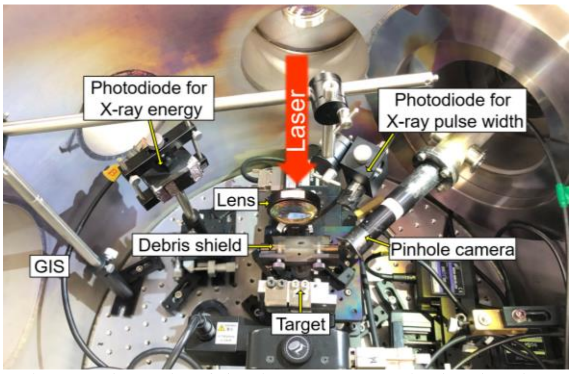

Fig. 1: Schematic of the detectors set up in the chamber.

region. Meanwhile, a pinhole camera (pinhole size 25 μm) with two Ti foils (thickness: 0.5 μm and 1.2 μm) was set at 45 degrees with respect to the target surface to obtain the SXR plasma image. The SXR pulse width and integrated emission energy were measured by two Si photodiodes.

For preliminary experiments to check the detectors work well, carbon and aluminum bulk targets were irradiated with the laser beam. Fig. 2 shows the comparison of the irradiation laser pulse with the SXR pulse duration signal, obtained by using an Al target with a 2.0 μm-thick Ti filter to block unnecessary radiation. A 9 ns SXR pulse duration have been detected.

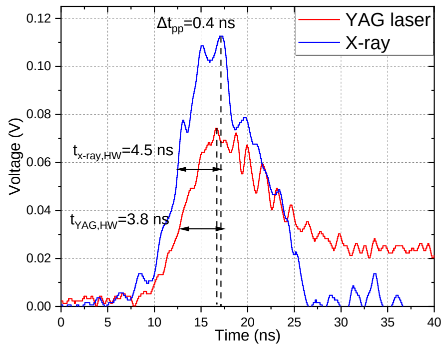

Fig. 2: Temporal profiles of laser and X-ray pulses. The X-ray signal might be broadened by longer wavelength light, due to the transmission of Ti filter at ~40 nm.

In this presentation, we will talk about the spectroscopic results on Au foil laser plasma (thickness varies from 0.42 μm to 300 μm) to evaluate a suitable thickness for generating WW X-ray.

References

[1] T. Hara, Rev. Laser Eng. Vol. 27, p. 9-13 (1999).
[2] D. Sayre et al., Ultramicroscopy 2, 337 (1977).
[3] C. John et al., Opt. Lett. **44,** pp.1439-1442 (2019).