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X-ray Generation by Irradiation of High Intensity Laser Light on Thin Film Target for Non-destructive Diagnosis

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1. Introduction

The interaction of high-intensity ultrashort laser pulses with plasmas is currently a hot issue, because there are many potential applications to various fields such as electron accelerators[1], inertial fusion[2], proton therapy[3], and non-destructive diagnosis[4,5]. X-ray generation, hard x-rays with energy over 100 keV in particular, using lasers is expected to be a very useful non-destructive diagnostic tool because of its possible high spatial-resolution, compactness, and easy control.

Here, we propose a radiographic testing (RT) system which consists of a compact x-ray generator using fs-laser-plasma and a compact x-ray imaging system, as is shown in Fig.1, for facility diagnosis in a very narrow space (-10 cm). In order to realize our proposal, we carry out the x-ray generation by irradiation of high intensity laser light on thin film targets and estimate the number of x-ray photons. We also report a development of compact x-ray imaging system.

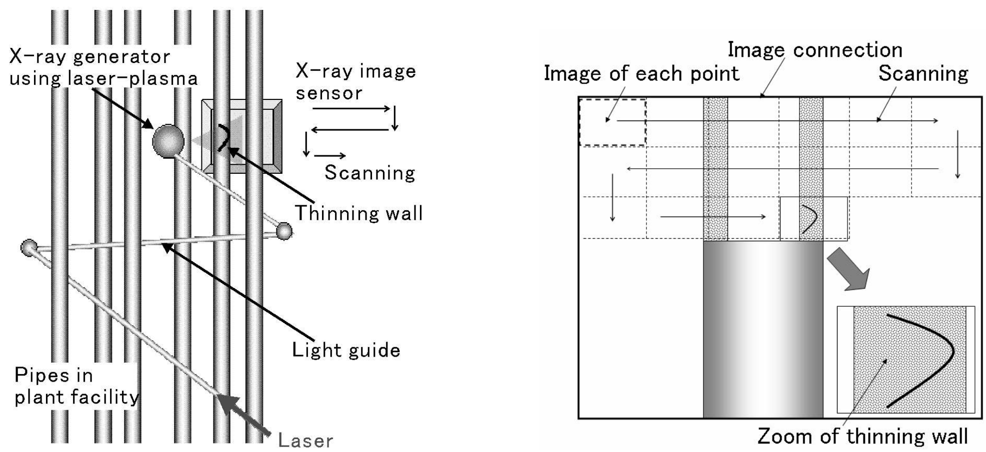

Fig. 1 (a) Concept of radiographic testing in a very narrow space and (b) for wide regional diagnosis.

2. Experimental setup

Figure 2 shows a schematic drawing of the experimental setup. The experiments were carried out using a Ti:Al_2O_3 laser (THALES LASER, Alpha 10/US-20TW)[5] and is able to deliver up to 1 J, 50-fs pulses at a fundamental wavelength of 800 nm. In this study, the delivered energy to the experimental chamber was 290 mJ, the pulse duration was 70 fs. The p-polarized laser beam was focused using a f/3 off-axis parabolic mirror, and was incident at an angle of 45 degree to the target surface. The focused spot on the target and the size of the main spot on the target was 8x3 μm^2 in full width at half maximum (FWHM), which included approximately 80% of the total energy. Therefore, the laser energy focused on the main spot was estimated to be 230 mJ, which led to I=1.3x10^{19} W/cm^2. Thin film tapes of 10 μm thick Cu and Ta were used as the target[7], and was translated for every shot so that a fresh surface was irradiated.

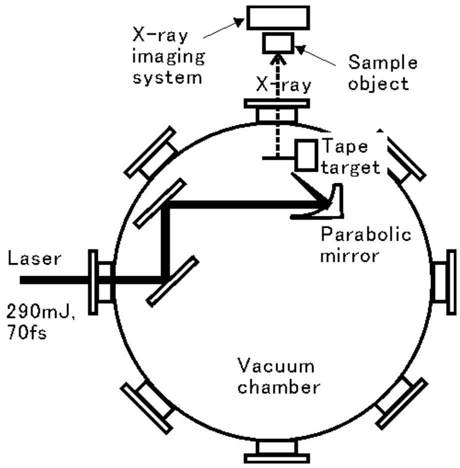

Fig. 2 Schematic drawing of experimental setup

As for an image sensor, as is shown in Fig. 3, we customized a commercial CsI CCD sensor (Hamamatsu Photonics Co. Ltd., S8985-02) by thickening CsI 0.1 mm to 1.0 mm in order to increase sensitivity for high-energy x-rays, and attached a cooling system to the sensor for reduction of thermal noise. Since the outward size of the sensor including the cooling system is 65x45x29 mm^3, it is applicable to facility diagnosis in a narrow space.

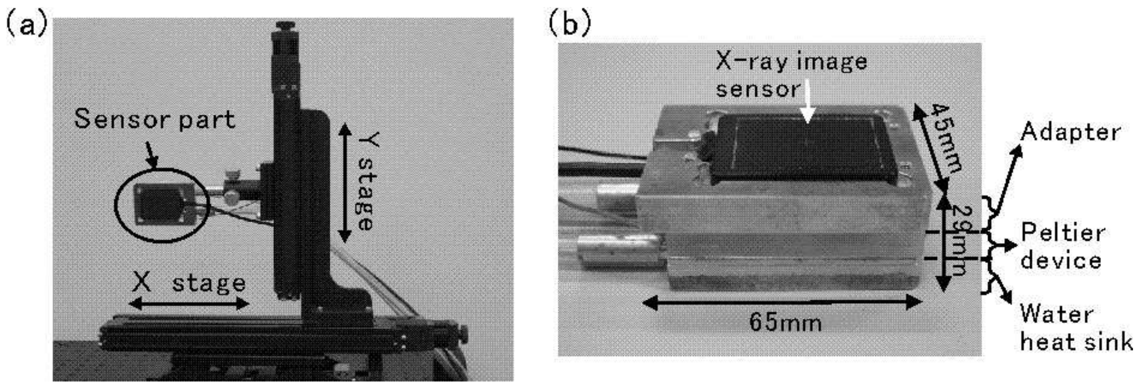

Fig. 3 (a) Prototype of x-ray imaging system applicable to a narrow space and (b) magnification of the sensor part.

Figure 4 shows comparison of sensor signal between 0.1 mm and 1 mm thick CsI for some different thick SUS304 plates using an ^{192}Ir radioactive isotope. Each plot in the figure is the average count, which is also normalized by the recording time, around center of the sensor. From this figure, we can see that the sensitivity increases approximately 7 times by the CsI thickening.

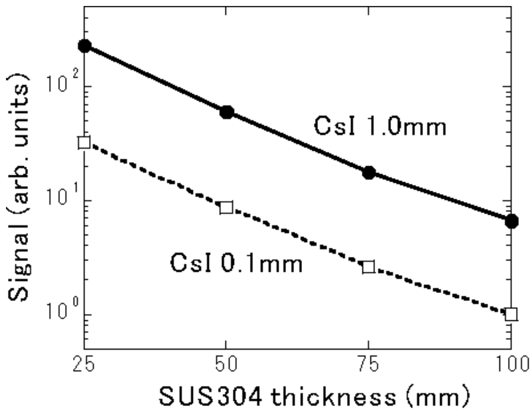

Fig. 4 Comparison of sensor signal between 0.1 mm and 1 mm thick CsI.

3. Results

A typical signal of Ta target is approximately two times as high as that of Cu target. Comparing with ^{192}Ir radioisotope irradiation, which is usually used in radiographic testing, the number of x-ray photons generated by a single laser shot is roughly estimated to be approximately 1/700 of the ^{192}Ir with a dose of 10 Ci . We also conducted a demonstration of an x-ray image of a SUS 304 pipe (outer diameter ϕ34mm with 4.5mm thickness, namely, 25A, Sch80) with elbow, which is shown in Fig. 5 (a), using the laser plasma x-ray and the sensor. To obtain a wide regional image of the sample, the sensor was scanned at intervals of 20 mm in horizontal direction and 15 mm in vertical direction, which caused overlap regions 14 mm in horizontal, and 9 mm in vertical direction between neighboring images. Figure 5 (b) shows the result of x-image connection consisting of 4 x 3 images. Each image was obtained by 300 laser shots accumulation. Image connection was automatically executed by a program soft in which image processing of linear image synthesis was conducted in order to reduce discontinuities. From this x-ray image, a mock thinning wall is, although slightly, recognized.

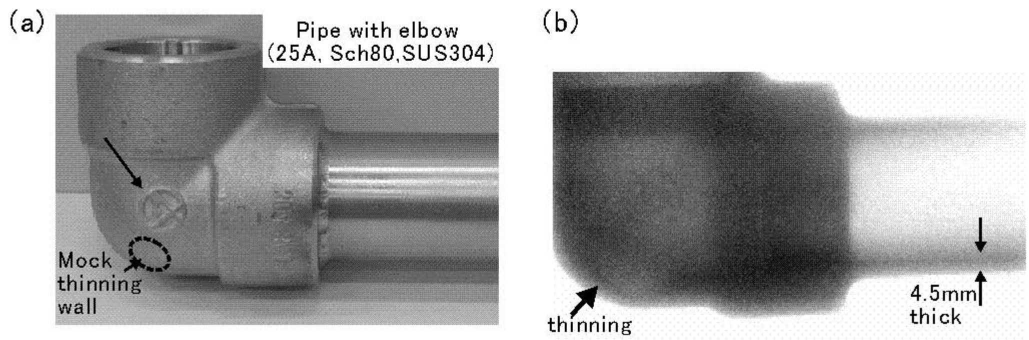

Fig. 5 (a) Photograph of a sample object and (b) the x-ray image obtained laser-plasma x-ray.

4. Summary

In summary, we have proposed the RT system, consisting of a compact x-ray generator using laser-plasma and a compact x-ray imaging system which can be applicable to a very narrow space (-10 cm) in plant facilities. For realization of our proposal, the x-ray imaging system consisting of a small x-ray image sensor and an x-y stage for sensor scanning was developed as a prototype. Using the developed sensor, we have carried out the x-ray generation by irradiation of high intensity laser light on thin film targets and estimated the number of x-ray photons. Furthermore, we have also demonstrated x-ray imaging of a SUS304 pipe with an elbow.

References

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