DIRECT HIGH POWER LASER DIAGNOSTIC TECHNIQUE ON FOCUSED ELECTRON BUNCH.

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Abstract

In laser produced plasma (LPP) EUV source, high intensity pulse CO2 laser is essential for plasma generation. To achieve high conversion efficiency and stable EUV power, we would like to measure a laser profile in the interaction point. However, there is no way to measure directly the laser profile of such a high intensity laser at the focus point. Therefore, we have been developing the direct high power laser diagnostic technique based on laser Compton scattering (LCS). LCS signal by using focused electron beam shows 1D laser profile. 2D laser profile can be reconstructed by one-dimensional laser profiles from various angles using computer tomography (CT). This method is suitable for high intensity laser, but very small spot size of electron beam is required. To obtain small spot size, we used S-band Cs-Te photocathode RF-Gun and specially designed solenoid lens at Waseda University. We already succeeded in observing minimum beam size of about 20μm rms and this is adequate to scan the CO2 laser. In this conference, we will report the result of the laser Compton scattering with pulse CO2 laser, the preparatory experiment in measuring a metal wire cross section and the present progresses.

INTRODUCTION

Recently, the ArF Excimer Laser is widely used for semiconductor exposure with Resolution Enhancement Technology (RET) [1] and Optical Pattern Correction (OPC). However, the semiconductor miniaturization with ArF Excimer Laser reached their performance limits. Extreme ultraviolet lithography (EUVL) is expected to be the next generation lithography. The wavelength of EUV light is 13.5nm and it is one-tenth of the wavelength of ArF Excimer Laser. Therefore, EUV light is expected to improve lithography techniques. In EUVL, EUV light is generated based on Sn plasma produced by CO_2 laser, and required CO_2 laser performances are shown in Table1. In order to achieve high conversion efficiency and stable EUV power, we would like to measure a laser profile in the interaction point. However, there is no way to measure directly the laser profile of such a high intensity laser at the focus point. We suggested the way of measuring laser profile directly for the first time and have been developing laser profiler based on Laser Compton Scattering (LCS). When the laser collide an electron bunch generated a photocathode RF Gun with 90-degree collision angle, the laser is scanned by focused electron bunch and Compton scattering signal is measured. If electron bunch and laser have a gaussian distribution, the measured profile of

Table 1: Required CO_2 Laser Performances

Repetition rate	100kHz
Energy	200mJ/Pulse
Spot size	100μm (rms)
Pulse duration	10ns

Compton scattering signal as a function of electron position is a gaussian distribution. Measured rms is written down as;

$$\sigma = \sqrt{\sigma^2{}_{laser} + \sigma^2{}_{electron}} \quad (1)$$

where σ_{laser} is the spot size of laser, $\sigma_{electron}$ is the beam size of electron bunch. If the electron beam size is much smaller than that of laser, the observed profile would be equivalent to the laser profile. To scan with electron bunch from various directions and use CT technique for reconstructing image, we can obtain 2D laser profile. In addition, a smaller electron beam size cause to higher resolution laser profiler. For these reasons, to achieve smaller electron bunch is one of the most important issues. We used low emittance electron beam and special design solenoid lens to achieve small beam spot. We already observed electron bunch with 20μm (rms) spot size at minimum by using Gafchromicfilm [2]. It is small enough beam size for laser profiler. In this paper, we show the accelerator systems in Waseda University and then discuss about the experimental results of CT profile measurement and LCS.

ACCELERATOR SYSTEMS

In Waseda University, the Cs-Te phtocathode RF Gun can produce the high quality electron bunch and it is applied various research experiments, such as pulse radiolysis [3] and X-ray generation [4]. The cavity structure was based on the design of BNL type, which has a 1.6 cell structure. The cavity can produce low emittance beam with 5MeV beam energy. The RF frequency is 2856MHz. Our accelerator adopts Cs-Te photocathode, with high quantum efficiency and achieve 1nC/bunch. The seed laser is Nd:YLF mode lock oscillator with 119 MHz frequency. We use LN intensity modulator to pick pulse train, with the desired number of pulses from 1 to 100. The pulses are amplified by Yb fiber amplifier and LD pumped rod amplifier. This IR pulses are converted to UV wavelength by two nonlinear frequency doubling crystals. Accelerator performances in Waseda University are summarized in Table2.

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Table 2: Accelerator Performance in Waseda University

Cathode	Cs-Te
Laser	262nm
Laser repetition rate	119MHz
Energy	~5MeV
Charge	~1nC/bunch
Bunch length	10ps (FWHM)
Bunch number	1~100/train

METAL WIRE PROFILING WITH CT TECHNIQUE

Experimental Setup

The experimental setup for metal wire profiling is shown in Fig. 1. Metal wire is placed between Solenoid2 and Solenoid3 and shape of the cross-section is circle (φ:450μm). Electron bunch is focused to about 50μm (rms) by Solenoid2, and collide with metal wire. Scanning electron bunch across the wire provides the cross sectional profile of wire. The bremsstrahlung signal from electron beam is measured by Photomultiplier Tube (PMT).

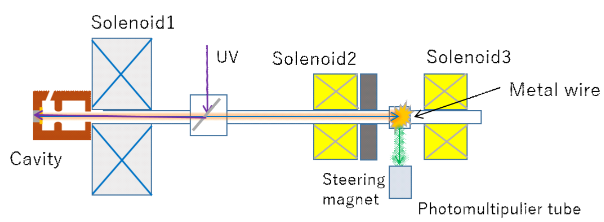


Figure 1: Schematic of experiment setup.

Results and Discussion

The calculated thickness distribution of circle shape (a) and the experimental result (b) are shown in Fig. 2. It is clear that the experimental result agrees with the calculated result. In comparison with calculation, tail of the wire profile is shaper in calculation, which is influenced by electron bunch size. By rotating the metal wire, we collect many 1D profiles with different angles, and then we can obtain 2D metal wire profile by using CT technique for reconstructing image. Fig. 3 is reconstructed wire profile by CT technique and Fig. 4 is picture of wire cross-section observed by laser microscope. Because of the insufficient amount of 1D profiles for the reconstruction, this image is not very clear. However, the size of reconstructed wire profile (Fig. 3) agrees with that of picture of laser microscopy (Fig. 4). We consider that this CT technique is quite useful to the laser profiler with Laser Compton Scattering.

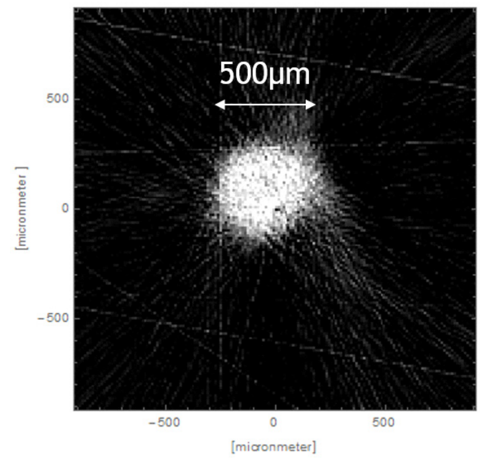


Figure 3: CT reconstructed wire profile.

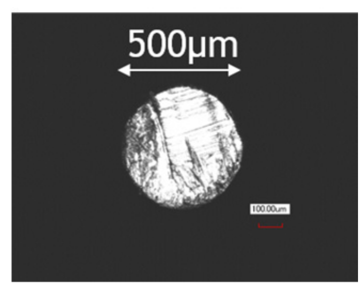
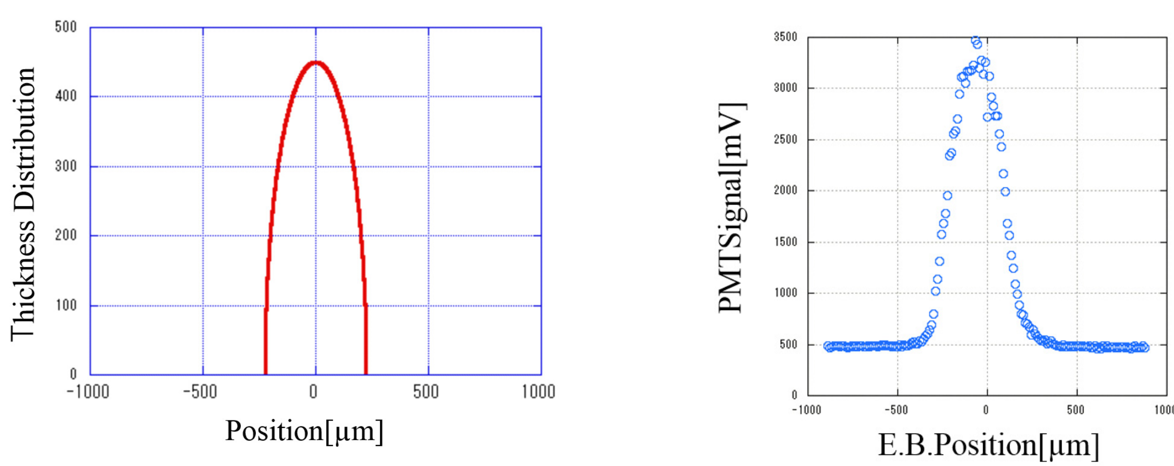


Figure 4: picture of metal wire by laser microscopy.



(a) (b)

Figure 2: The thickness distribution of circle shape (a) and the result of collision (b).

LASER COMPTON SCATTERING FOR LASER PROFILING

Experimental Setup

The experiment setup for laser profiling is shown in Fig. 5. Electron beam setup is similar to metal wire setup. Target laser is GAM LASER EX350 TEA CO_2 Laser and parameters are show in Table3. CO_2 Laser is transferred to collision point and collides with electron bunch. Scattered LCS photon is detected by MCP (Micro-Channel-Plate) and spectrometer with PMT. We have already found this MCP is not sensitive for background signal, so MCP is quite useful for detecting. However, we cannot measure energy spectrum with MCP. For this reason, spectrometer with PMT is also tested.

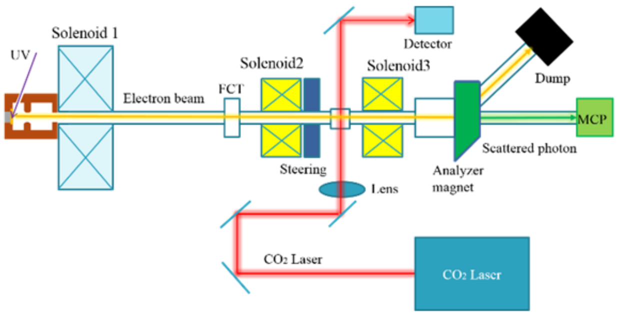


Figure 5: Schematic of experiment setup.

Table 3: CO_2 Laser Parameter

Energy	800mJ/Pulse
Pulse length	70ns (FWHM)
Spot size	117μm (rms)

Result and Discussion

The result of scattered signal by MCP and spectrometer with PMT is shown in Fig. 6 and Fig. 7 respectively. In Fig. 6, the peak of “Laser ON” slightly shifted to right side than that of “Laser OFF”. This difference would be the LCS signal. However, due to the low signal-to-noise ratio, we cannot confirm this signal is really come from LCS. On the other hand, in Fig. 7, we can find the peak around 10~16 [eV], which is expected LCS scattered photon energy of 13.8 [eV]. Therefore, according to Fig .6 and Fig. 7, we observed the LCS signal using two types of detectors. However, as mentioned above, the S/N ratio was too small to measure 1D profile of CO_2 Laser.

CONCLUSIONS

At Waseda University, we have been developing laser profiler based on LCS. Laser profile can be measured by scanning electron beam while measuring Compton scattering signal. We have achieved a small beam size of 20 μm measured by using Gafchromicfilm. Metal wire 2D profile was reconstructed by CT technique, and this CT technique is quite useful to laser profiler with LCS. In the LCS experiment, we observed the LCS signal with MCP and spectrometer. However, S/N ratio was too small to measure 1D profile of CO_2 Laser. In order to improve S/N ratio, we should suppress the background and improve the CO_2 Laser system. We will try these improvements then perform the 2D profile measurement of CO_2 Laser in near future.

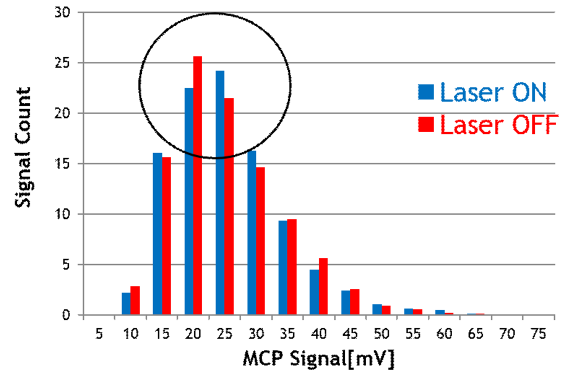


Figure 6: The result of scattered signal by MCP.

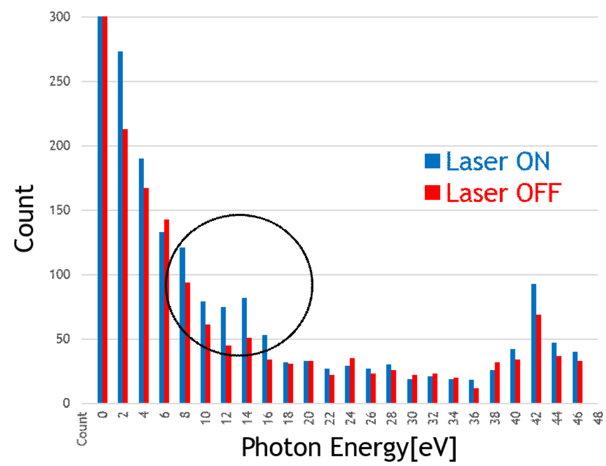


Figure 7: The result of scattered signal by spectroscope with PMT.

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