24P065-P

Durability to repeated pulse laser irradiation for laser transmission mirrors in ITER

ITERにおけるレーザ伝送用ミラーへのパルスレーザ照射耐久性

Masaya Sato[1], Shin Kajita[2], Noriyasu Ohno[1], Ryo Yasuhara[3], Masayuki Tokitani[3], and Yuzuru Tawara[2]

佐藤雅也, 梶田 信, 大野哲靖, 安原 亮, 時谷政行, 田原 譲

[1]*Department of Engineering and Science, Nagoya University, Fro-cho, Chikusa-ku, Nagoya, Aichi 464-8603, Japan*

名古屋大学工学研究科, 〒464-8603 名古屋市千種区不老町

[2]*EcoTopia Science Institute, Nagoya University, Fro-cho, Chikusa-ku, Nagoya, Aichi 464-8603, Japan*

名古屋大学エコトピア研究機構, 〒464-8603 名古屋市千種区不老町

[3]*National Institute for Fusion Science 322-6, Oroshi-cho, Toki, GIfu, 509-5292, Japan*

核融合研究所 〒509-5292 岐阜県土岐市下石町322-6

In ITER, laser transmission mirrors will be used for Thomson scattering diagnostics. For the laser transmission mirrors, which transmit laser pulses to plasma, high reflectivity at 1064 nm, high multi pulse LIDT (Laser induced damage threshold) and high durability for sputtering by plasma are needed. If the surface of mirror is damaged by laser irradiation, reflectivity of the mirror decreases seriously. In this study, the effects of the multi pulse LIDT on OFHC (Oxgen - Free High thermal Conductivity) - copper and polished pure copper are experimentally investigated up to 7.3×10^4 pulses and 5.0×10^3 pulses, respectively.

1. Introduction

In ITER (International Thermonuclear Experimental Reactor), plasma diagnostics requires metal mirror. For Thomson scattering diagnostics, laser transmission mirrors and a neodymium - doped yttrium aluminum garnet (Nd:YAG) laser at 1064 nm will be used. The required specification for the laser include a pulse energy 5 J with a repetition frequency of 100 Hz and pulse width of ~10 ns [1].

The mirrors, which transmit laser pulses to plasma, high reflectivity at 1064 nm, high multi pulse LIDT (Laser induced damage threshold) and high durability for sputtering by plasma are needed. A leading candidate material is Au, Ag, and Cu.

It is necessary to maintain its optical properties for more than 10^7 laser pulses [2]. If the surface of the mirrors is damaged by laser irradiation, reflectivity of the mirror decreases seriously. Therefore, to investigate multi pulse LIDT is important.

In this study, the effects of the multi pulse LIDT on OFHC - copper (KUGLER Co.) and polished pure copper are experimentally investigated up to 7.3×10^4 pulses and 5.0×10^3 pulses, respectively. Experimental results predicted the expected multi pulse LIDT for 10^7 pulses.

2. Experiments

The mesurement of multi pulse LIDT for OFHC - copper mirror and polished pure copper mirror were done with the set up shown in Fig. 1. Our experiment is based on the principle that once the surface of the mirrors are damaged by laser irradiation, reflectivity of the mirrors significantly decrease.

The experimental measurement system consists of pulsed Nd: YAG laser, 1064 nm wavelength, 10 Hz repetition rate, 5-7 ns pulse duration (FWHM), ND (Neutral Density) filter, and focus lens which have a focal length of 307 mm at 1064 nm. The laser beam has a Gaussian intensity profile. Spot size at metal mirror is 7.0×10^{-3} cm^2, measured with CCD camera and lase view, free software.

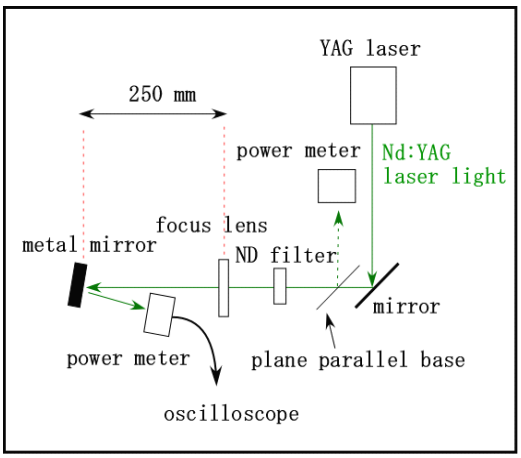

Fig. 1. Experimental measurement system

3. Results

Single shot LIDT and multi pulse LIDT of copper mirrors were investigated. The single shot LIDT was 4.8 J/cm^2 for OFHC - copper mirror and 1.1 J/cm^2 for polished pure copper. In this study, single shot LIDT was defined by visible damage on the copper mirror surface. Value of the former is about four times that of the latter.

Experimental result of multi pulse LIDT is shown in Fig. 2. The effects of the multi pulse LIDT on OFHC - copper and polished pure copper are experimentally investigated up to 7.3×10^4 pulses and 5.0×10^3 pulses, respectively. OFHC copper mirror, multi pulse LIDT was 1.5 J/cm^2 for 7.3×10^4 pulses. Polished pure copper mirror, multi pulse LIDT was 4.5×10^{-1} J/cm^2 for 5.0×10^3 pulses.

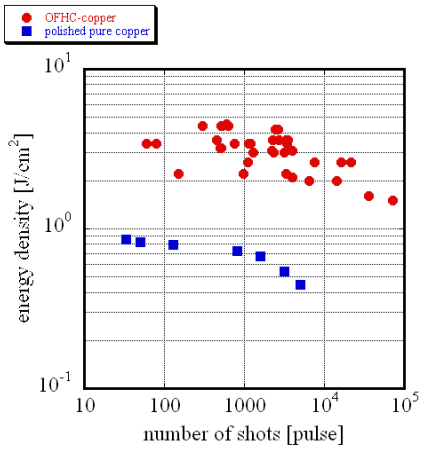

Fig. 2. Multi pulse LIDT on OFHC - copper and polished pure copper mirror.

Power of reflected light from the copper mirror decreases seriously if the mirror surface is damaged by laser irradiation. Temporal evolution of reflected laser power the that was measured by power meter and oscilloscope is shown in Fig. 3. When the energy density was low, the power of the reflected light decrease very slowly. This trend is also seen in OFHC - copper and polished pure copper.

Strange emission was observed on the surface of the copper mirror at the knee appeared in the temporal evolution.

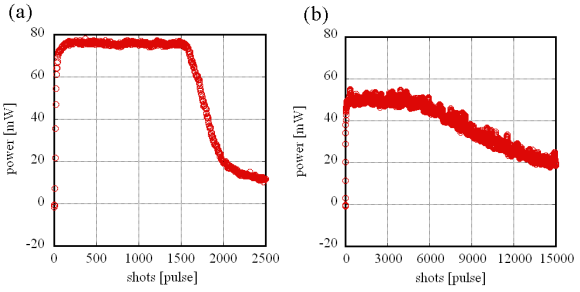

Fig. 3. For polished pure copper, energy density is 6.8×10^{-1} J/cm^2 for (a), 4.5×10^{-1} J/cm^2 for (b).

4. Discussion

Value of single shot LIDT on OFHC - copper mirror was higher than the predicted value in ref [1]. However the value of polished pure copper mirror was about the same value. This difference is thought to be related to the roughness of the surface. Roughness of OFHC - copper mirror is less than 3 nm.

Experimental data on single shot LIDT and multi pulse LIDT and regression curve for more than 10^3 pulses are shown in Fig. 4. Multi pulse LIDT on OFHC - copper mirror is averaged over the same energy density. It is seen that the slope of the graph changes between 10^3 - 10^4 pulses for both mirrors. This graph predicted that the expected multi pulse LIDT for 10^7 pulses is ~ 6.5×10^{-1} J/cm^2 on OFHC - copper mirror and is ~ 2.9×10^{-2} J/cm^2 on polished copper mirror.

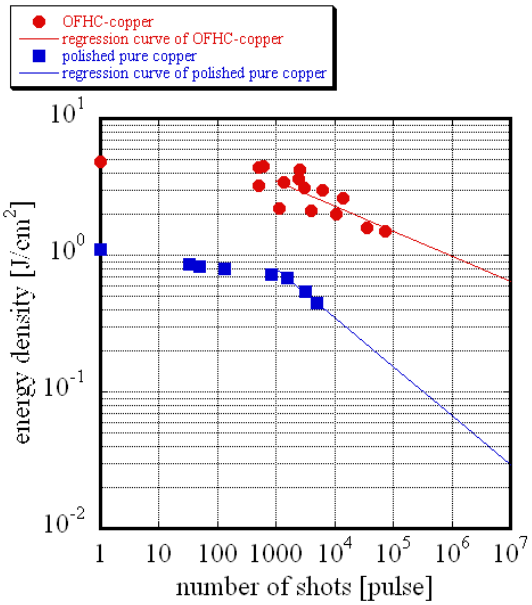

Fig. 4. Single shot LIDT, multi pulse LIDT and regression curve for more than 10^3 pulses on OFHC - copper and polished pure copper mirror.

References

[1] S. Kajita, T. Hatae, and V.S. Voitsenya: J. Plasma Fusion Res. Volume 3, 032 (2008)

[2] A. Gorshkov, I. Bel'bas, V. Sannikov, and K. Vukolov: Fusion Eng. Des. 74 (2005) 859-863

[3] J.F. Figueira and S.J.Thomas: IEEE J. Quantum Electron VOL. QE-18, NO. 9, 1982