

## §26. Irradiation Effects of Helium and Laser Pulses to In-vessel Mirror Material

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In ITER (International Thermonuclear Experimental Reactor), plasma diagnostics require metallic mirrors. 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  $\sim 10$  ns. 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. 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  $7.3 \times 10^4$  pulses and  $5.0 \times 10^3$  pulses, respectively. Experimental results predicted the expected multi pulse LIDT for  $10^7$  pulses.

The measurement 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 is damaged by laser irradiation, reflectivity of the mirrors significantly decreases. 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  $7.0 \times 10^{-3}$  cm<sup>2</sup>, measured with CCD camera and laser view, free software.

Single shot LIDT and multi pulse LIDT of copper mirrors were investigated. The single shot LIDT was  $4.8$  J/cm<sup>2</sup> for OFHC - copper mirror and  $1.1$  J/cm<sup>2</sup> 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.

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 that was measured by power meter. 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. Value of single shot LIDT on OFHC - copper mirror was higher than the predicted value. 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 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  $7.3 \times 10^4$  pulses and  $5.0 \times 10^3$  pulses, respectively. OFHC copper mirror, multi pulse LIDT was  $1.5$  J/cm<sup>2</sup> for  $7.3 \times 10^4$  pulses. Polished pure copper mirror, multi pulse LIDT was  $4.5 \times 10^{-1}$  J/cm<sup>2</sup> for  $5.0 \times 10^3$  pulses. In Fig. 2, fitting curves for more than  $10^3$  pulses are shown. 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  $\sim 6.5 \times 10^{-1}$  J/cm<sup>2</sup> on OFHC - copper mirror and is  $\sim 2.9 \times 10^{-2}$  J/cm<sup>2</sup> on polished copper mirror.

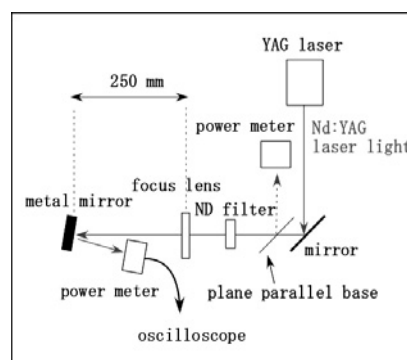


Fig. 1. A schematic of the experimental setup.

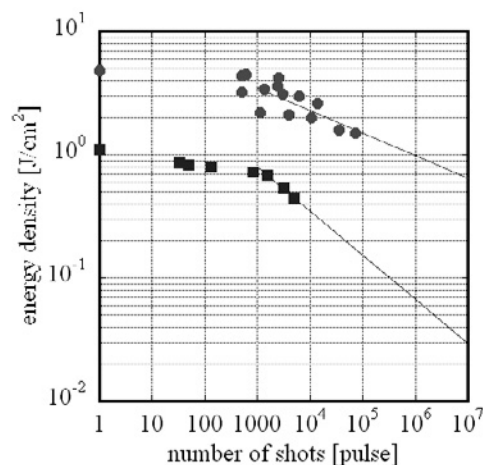


Fig. 2. Single shot LIDT, multi pulse LIDT and fitting curve for more than  $10^3$  pulses on OFHC - copper (up) and polished pure copper mirror (down).