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ITER周辺トムソン散乱計測装置用ビームダンプの開発
Development of beam dump for the Edge Thomson Scattering in ITER

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The beam dump of the Edge Thomson Scattering (ETS) in ITER needs to absorb numerous (~10^9) and extremely high power density (~5 J, ~40 mm diameter and <10 ns FWHM) laser pulses under harsh thermal (pulsed laser of greater than 400 GW/m^2 (peak), radiation from plasma of ~100 kW/m^2 and nuclear heating of 5 MW/m^3) and electromagnetic loads (~10 T, 100 T/s) within a tight allocated space (~60 mm width x 110 mm height x 125 mm depth). In order to withstand numerous incident laser pulses, it is necessary to avoid not only the ablation but also the fatigue due to cyclic thermal expansion. Fatigue causes laser-induced damage on the beam dump surface. Molybdenum was employed as the material because of its high melting point and thermal conductivity. As a simple estimation, incident energy of 5 J and exposure area of 12.6 cm^2 (4 cm diameter) corresponds to 0.4 J/cm^2. Laser-induced damage threshold (LIDT) for 10^9 pulses was extrapolated as 0.2 J/cm^2 from experimental data (12 ns pulse duration) from Ref. [1]. Since incident energy density exceeds allowable limit, a method to spread the load is necessary.

A new beam dump, the chevron beam dump, was designed to overcome the damage threat [2]. A number of sheets with three bends are aligned in parallel in the chevron beam dump (see Fig. 1). As shown in Figure 2, injected beam is gradually absorbed through multiple reflections between the sheets. Since the thermal expansion is the cause of fatigue, the absorption energy density rather than the incident energy density was used as the indicative parameter. Because of the 70% of reflectivity, absorption energy density of 0.06 J/cm^2 is acceptable for the 10^9 pulses injection to molybdenum. Effective area for laser pulse exposure was increased by injecting the laser with large angle of incidence. Number of sections and bending angles are determined to be able to absorb the laser beam within the allowable depth. The chevron beam dump has been designed for a maximum absorption energy density of 0.016 J/cm^2, giving a margin of 4 against experimental uncertainty.

It was also shown that the chevron beam dump can withstand the thermal and electromagnetic loads in ITER. The heat is removed from one of the two side plates of the beam dump. In that case, the expected maximum temperature is approximately 500 degrees including the instantaneous temperature increment during the laser pulse exposure. Strain and induced stress during major disruption (15 MA extinction in 36 ms) were also evaluated, and induced von-Mises stress is well within the yield strength of the molybdenum.

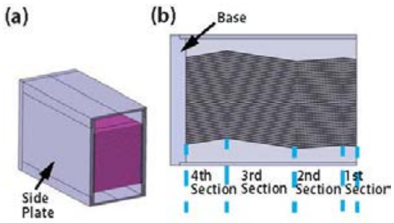

Fig. 1. Shape of the chevron beam dump. (a) Diagonal and (b) side view.

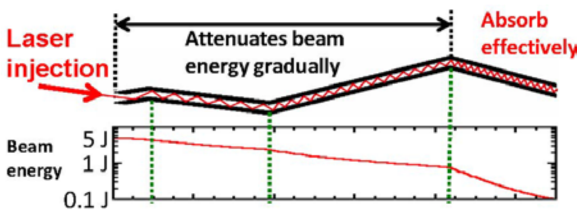

Fig. 2. Beam energy absorption in the chevron beam dump.

[1] A. Gorshkov *et al.*, Fus. Eng. Des. **66-68**, 865 (2003).
[2] E. Yatsuka *et al.*, Rev. Sci. Instrum. **84**, 103503 (2013).