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Development of high energy laser resistance beam dump for the ITER Edge Thomson Scattering

ITER周辺トムソン散乱計測装置用高レーザー耐力ビームダンプの開発

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Beam dump for the ITER edge Thomson scattering (ETS) is being developed. The key concept of the beam dump is to reduce laser energy absorption per unit area and to absorb the laser beam gradually. A new type of beam dump called the chevron beam dump was designed. Manufacturability of the complicated structure of the chevron beam dump was confirmed via prototyping. In addition, the laser irradiation tests for validating the design of the chevron beam dump were carried out. The threshold number of incident pulses before the laser-induced damage onset would be more than 10^4 times larger relative to conventional one.

1. Introduction

Thomson scattering is the primary diagnostic system for measuring the electron temperature and density profiles in ITER. Since approximately 10^{-14} of incident photons can be detected as signal in ITER, it is crucial to absorb the laser beams effectively, so that the electron temperature and density are accurately measured with high S/N.

Since the beam dump for the ITER edge Thomson scattering (ETS) is integrated on the central I-beam of the blanket, harsh electromagnetic and thermal loads are applied to the beam dump. From the point of view of ductility and thermal properties, molybdenum is one of the most promising materials for the beam dump. Since 10^9 laser pulses will be injected throughout the 20-year operation of the ITER, multiple-pulse laser-induced damage should be overcome. A new type of beam dump called chevron beam dump was designed for ITER [1], so that the beam dump has high energy laser resistance for numerous laser pulses injection while its allocated space is only 60-mm wide, 100-mm high and 77-mm deep.

This paper aims to verify the feasibility of the chevron beam dump against the severe condition of use in ITER. The chevron beam dump structure is explained in Sec. 2. Laser irradiation tests onto the molybdenum specimen are summarized in Sec. 3. Finally, conclusions are reported in Sec.4.

2. Structure of the chevron beam dump

It is considered that the laser-induced damage with multiple-pulses injection is caused by fatigue due to the cycle of thermal expansion and contraction. Therefore, the key concept of the chevron beam dump design is to reduce laser energy absorption per unit area on the surface and to absorb the laser beam gradually. As shown in Fig. 1 (b), the chevron beam dump contains multiple bent sheets 0.5-mm thick, so that the laser beam is injected with a large angle of incidence and s-polarization. At the first section of the beam dump, absorption coefficient is 6% while it is 64% if the incident laser has p-polarization. The absorption energy density of the chevron beam dump was expected 12.5 times lower than that of the conventional beam dump (see Fig. 1).

Since multiple reflections are needed to absorb

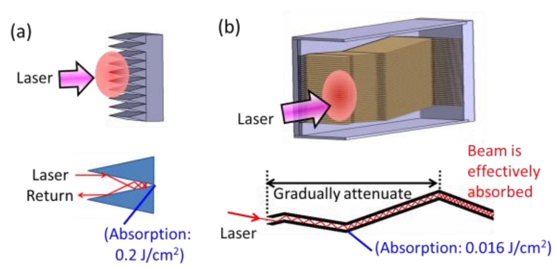

Fig.1. Structure of (a) conventional beam dump, (b) chevron beam dump

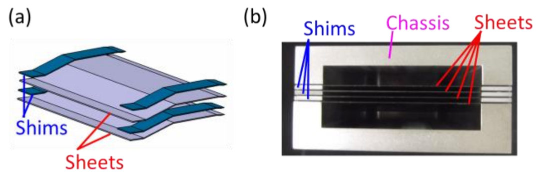

Fig.2. (a) Exploded drawing of chevron beam dump, (b) photograph of its prototype

the incident laser energy with s-polarization, a number of molybdenum sheets are aligned densely and parallel. Manufacturability of such complicated structure was confirmed by prototyping. Figures 2 (a) and (b) show the exploded drawing of the chevron beam dump and a photograph of its prototype, respectively. Chassis, sheets and shims were welded by diffusive bonding.

3. Laser irradiation tests

The structure of the chevron beam dump was optimized to reduce the absorbed beam energy density, so that the lifetime of the beam dump could be extended drastically. In order to verify this idea, the laser irradiation effects onto the molybdenum samples were investigated. Figure 3 shows the configuration of the laser irradiation tests. The polarization and pulse energy of the incident laser were adjusted by the 2 polarizers and the rotation of the half-wave plate, respectively. In order to inject the laser beam with high energy density, the incident laser beam was focused by the lens. The laser-induced damage was detected by monitoring the level of the specular reflection. As shown in Fig. 4 (a), the specular reflectivity decreased after a threshold number of incident pulses. Figure 4 (b) shows the scan-electron microscope (SEM) photos of the damaged surface, illuminated with angle of incidence θ of 75° and s-polarization. The laser-induced damage threshold (LIDT) with 3 configurations (θ=5°, s-polarization and θ=75°, p-polarization and θ=75°) were investigated.

Figure 5 shows the LIDT as a function of threshold number of incident pulses. In Fig. 5 (a), the LIDT is represented vs. the incident energy density. The s-polarization with a large angle of incidence clearly enhances the LIDT relative to the case of a small angle of incidence or p-polarization. In Fig. 5 (b), the LIDT is represented vs. the absorption energy density. In the 3 configurations shown in Fig. 5 (a) the LIDT can be fitted by the same function, i.e. the LIDT is proportional to $N^{-0.26}$ with same constant of proportion, where N denotes the threshold number of the incident pulses. Since the absorption energy density of the chevron

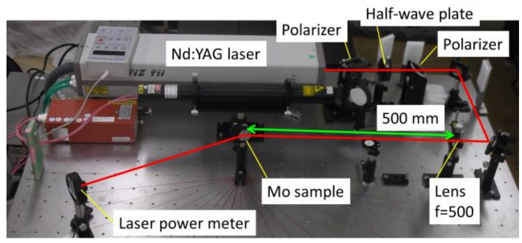

Fig.3. Configuration of the laser irradiation tests

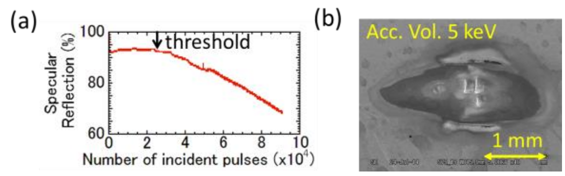

Fig.4. (a) Temporal variation of the reflectivity, (b) SEM photograph

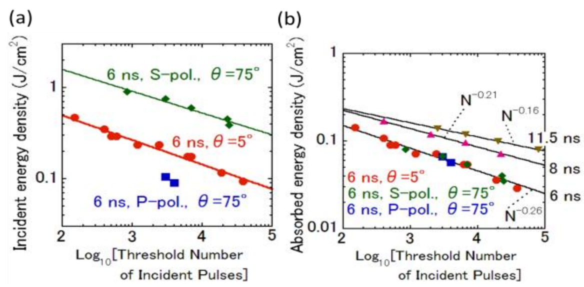

Fig. 5. LIDT represented as (a) incident energy density, (b) absorbed energy density

beam dump is 12.5 times lower than that of the conventional beam dump (see Fig. 1), the threshold number of incident pulses for the chevron beam dump is 17,000 times higher relative to the conventional beam dump when the pulse duration is 6 ns. In addition, it was clarified that not only the value of the LIDT but also its dependence on the threshold number of incident pulses N was governed by the pulse duration.

4. Conclusions

The key concept of the chevron beam dump, that is to reduce laser energy absorption per unit area on the surface and to absorb the laser beam gradually, was validated via the laser irradiation tests. The expected threshold number of incident pulses for the chevron beam dump would be more than 10^4 times larger relative to the conventional one.

Reference

[1] E. Yatsuka, T. Hatae, G. Vayakis, M. Bassan and K. Itami: Rev. Sci. Instrum. **84**, (2013) 103503.