§19. Research and Development of Cooling Faraday Rotator for High Energy Laser Systems for Plasma Diagnosis and Heating

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To prompt the deuterium experiments and the Large Helical Device (LHD) project for fusion research, higher performance plasma diagnosis and heating systems are required. Especially in Thomson scattering diagnostics, a high average power laser system which has both high pulse energy and high repetition rate is necessary. To develop such high average power laser systems, thermal- and damage problems in optics in the systems have to be addressed.

A Faraday rotator (FR) is an important optical device used for polarization rotator and optical isolation of laser light. This component is necessary for control the laser polarization for light amplification and to avoid breaking of pre-amplifier due to high-energy laser back light. However, commercially available FR cannot be used for kilo-watts class laser systems due to thermal effects such as thermal lensing and thermal-induced birefringence.

The purpose of this work is to develop a FR which can be applied to kilo-watts class pulse laser systems. For achieving this, a magnet-optic material which possesses high thermal properties, large size, and high Verdet constant, is necessary. Recently, Terbium gallium garnet (TGG) ceramics which has high Verdet constant of 36 rad/Tm [1] at a wavelength of 1 μm, large aperture size of 10 cm diameter, and a high thermal conductivity of 4.9 W/mK [1] can be manufactured. These characteristics are suitable for high average power pulse lasers.

In this work, we are developing a novel FR device for high average power pulse lasers. Figure 1 shows a photograph of the sample. TGG ceramic has disk type configuration (ϕ16 mm x 4 mmt) and the one surface is actively cooled. By using this concept, we can dramatically reduce thermal distribution in the material. We have studied thermally-induced birefringence for this sample when average power of 100 W laser is irradiated. For comparison, we performed the same experiment with rod-type TGG ceramic (5mm x 5mm x 25 mmt), and the results have been reported [2].

Figure 2 shows the depolarization ratio as a function of irradiated laser power. As seen in Fig. 2, the depolarization ratio increased exponentially with the laser power. The initial degree of polarization was 1×10^{-4}, and it degraded to 4×10^{-4} at 140 W laser power. Figure 3 shows the leakage pattern of the probe beam at the laser power of 140 W. The leakage pattern looks like clover as well as rod-type birefringence. A detailed analysis of this shape has not been conducted yet.

In the near future, we will perform similar experiment for different thickness with active cooling by a water flow. Also, we will apply strong magnetic field, and try to obtain appropriate polarization rotation. Furthermore, 1 kW class pulse laser irradiation will be performed.

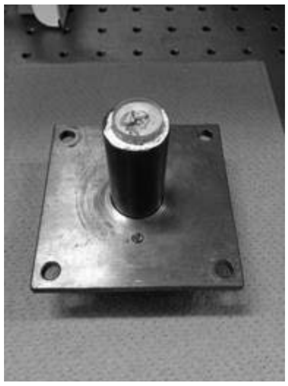

Fig. 1. A photograph of the TGG ceramic and cooling system.

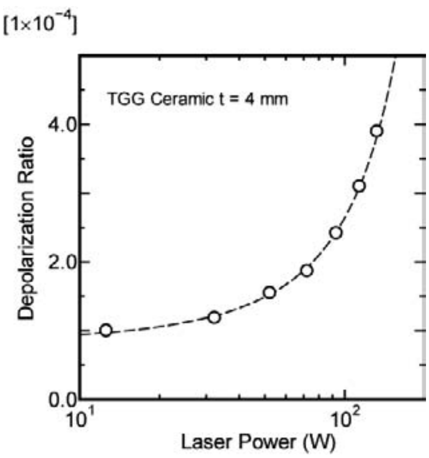

Fig. 2. Experimental results of depolarization ratio as a function of irradiated laser power.

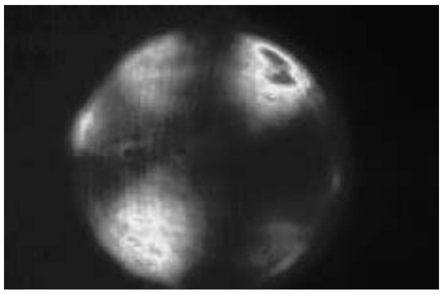

Fig. 3. The leakage pattern of thermally induced depolarization at 140 W laser power.

1) R. Yasuara, et al.: Opt. Exp. **15** (2007) 11255.
2) R. Yasuhara and H. Furuse: Opt. Lett. **38** (2013) 1751.