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

Furuse, H. (Kitami Institute of Technology),
Yasuhara, R.

Higher performance plasma diagnosis and heating systems are necessary for promotion of the deuterium experiments and the Large Helical Device (LHD) project for fusion research. Especially in Thomson scattering diagnostics, a high average power laser system with high pulse energy and high repetition rate is required. To develop such high average power lasers, damage and thermal problems such as thermal lensing, thermally induced birefringence and thermal stress fracture in optics should be resolved.

A Faraday rotator (FR) used for polarization rotator and optical isolation of laser light is one of the most important optical elements in high performance laser systems. The terbium gallium garnet (TGG) single crystal is the most widely used material in Faraday rotators for high average power lasers because it has a high Verdet constant of 35-40 rad/Tm for a 1 μm wavelength [1]. However, commercially available FR cannot be used for kilo-watts class laser systems due to thermal effects. Recently, large aperture size of 10 cm diameter ceramic TGG can be manufactured and its thermal effects have been actively studied beyond the range of 100 W [2]. In the near future, the ceramic TGG Faraday rotator will be replaced by current materials in high-average power lasers.

The goal of this work is to develop a FR which can be applied to kilo-watts class pulse laser systems using ceramic TGG. In the last year, we proposed a disk type FR and studied its depolarization characteristics [3]. We observed the depolarization ration of 4 x 10^{-4} and its leakage profile at 140 W laser irradiation power from 4 mm-thick ceramic TGG sample. For detail thermal analyses, the fundamental thermal properties such as thermal expansion α and thermo-optic coefficient *dn/dT* are necessary. In this year, we studied the temperature dependencies of these parameters at 300–500 K temperature range for detail analyses.

Figure 1 shows the experimental setup of α and *dn/dT* measurement. The details of the specimens along with the experimental setup can be found in [4]. We formed two Fizeau interferometers with the reflected He-Ne laser light of the sample, and the shift in the fringes due to temperature variation were recorded using photodetectors. From the values, α and *dn/dT* were evaluated as follows:

$$\alpha = 1 / L_1 \cdot dL_1 / dT \tag{1}$$

$$1 / nL_2 \cdot d(nL_2) / dT = \alpha + 1 / n \cdot dn / dT \tag{2}$$

where L_1 and L_2 are the vacuum and TGG path, respectively, and n is the refractive index of ceramic TGG.

Figure 2 shows the experimental results of measuring α and *dn/dT*, respectively. The open circles and triangles represent the results of α and *dn/dT*. For ceramic TGG, the experimental values of α and *dn/dT* at 300 K were 7.0 x 10^{-6} K^{-1} and 17.5 x 10^{-6} K^{-1}, respectively. As can be seen in Fig. 2, these parameters increase with temperature. This suggests that thermal effects increase with temperature, thus temperature dependence of α and *dn/dT* should be addressed especially in high-power laser applications. The detailed discussion can be found in [4]. We believe that these experimental values will be useful for developing and designing a new Faraday rotator that can be used for over 1 kW average power and high pulse energy laser systems.

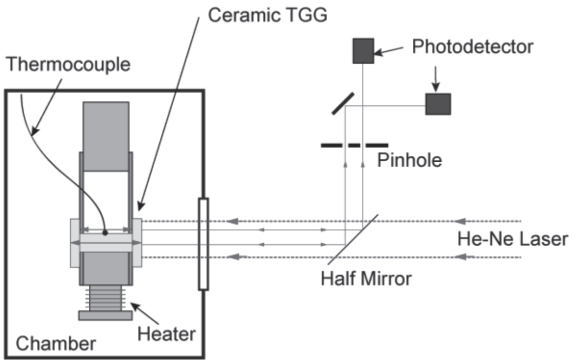

Fig. 1. Experimental setup of the α and *dn/dT* measurement of ceramic TGG.

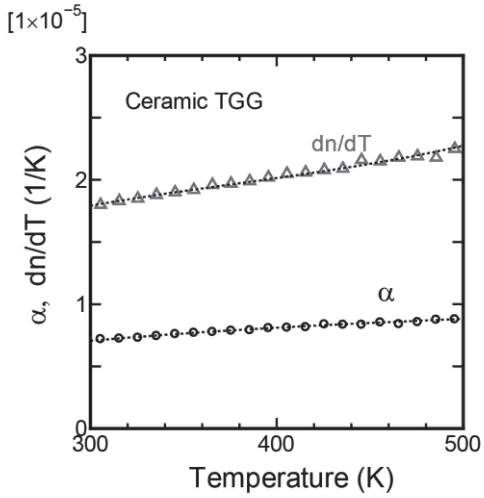

Fig. 2. Temperature dependence of α and *dn/dT* of ceramic TGG in the 300-500 K temperature range.

1) Yasuhara, R. et al.: Opt. Express **15** (2007) 11255.
2) Yasuhara, R. and Furuse, H.: Opt. Lett. **38** (2013) 1751.
3) Furuse, H. et al.: Ann. Rep. NIFS (2013-2014) 468.
4) Furuse, H. et al.: Opt. Mat. Express **5** (2015) 1266.