§3. Development of a Coaxial Laser Beam Combing Device Based on TGG Ceramics for the High Repetition Rate Thomson Scattering System

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A laser Thomson scattering system is one of the reliable methods for measuring the electron temperature and electron density in fusion plasma. Thomson scattering diagnostics needs high energy probe lasers to increase the probability of the interaction between photons and electrons due to the small Thomson cross-section: σ_{ts} = 6.65 x 10^{-21} m^2. However, repetition rate of the flash lamp pumped high energy laser which produce over 1 J pulse energy in 10 ns pulse duration is limited because of the heat generation in the optical component in the laser system.

The method to increase the repetition rate of the Thomson scattering measurement is the multi-laser system. Laser pulses emitted from several number of laser amplifiers are combined by beam combiner in multi-laser system. In this case, we can increase the repetition rate of Thomson scattering system as the number of the laser system. The problem of this system is thermo-optic effects in the beam combiner. Electro-optic and Magneto-optic effects based on polarization switching co-axial beam combiners are proposed in previous studies (1-3). Those beam combiner show the large thermo-optic effects at the high repetition rate operation due to the heat generation in the optical medium.

In this study, we propose the TGG ceramics based Faraday rotator for the beam combiner of the Thomson scattering system.

TGG ceramic material is the recently developed transparent ceramics which have large magneto-optic coefficient. Also this material have the good thermal properties supporting the high average power laser operation. Thirdly, large size TGG ceramics can be fabricated by recent ceramics technology. Those three factors are suitable for the high average power beam combiner.

In this report, we show the characteristics of the thermally induced depolarization (a kind of the magneto-optic effect) in TGG ceramics based Faraday rotator. Suppression of the thermally induced depolarization is the most important issue for this type of beam combiner.

Figure 1 shows the experimental set up for the measurement of the thermally induced depolarization in TGG ceramics based Faraday rotator. We used the cw fiber laser with a linearly polarized power of up to 300 W as a radiation source. The beam diameter at the TGG ceramic rod and the wavelength of the laser are 2.4 mm and 1076 nm, respectively. A calcite wedge and Glan prism were set in the crossed-Nicols arrangement. Fused silica wedges were used to attenuate the laser radiation into the Glan prism polarizer. The intensity distribution of depolarized and polarized radiation transmitted through the second polarizer was measured by the CCD camera.

Figure 2 shows the experimental results (circles) of the depolarization ratio as a function of the laser power in TGG ceramics with magnetic field. From this result depolarization ratio is proportional to power square of the laser power (solid curve). The maximum depolarization ratio with magnetic field for 45 degree Faraday rotation was 5.48×10^{-4} at input laser power of 257 W. This means that the extinction ratio of 33 dB under 257 W laser power radiations was demonstrated.

In LHD, we use the 1.6 J x 30 Hz laser. The average power is 48 W. By using TGG ceramics based beam combiner, we can combine five 1.6 J x 30 Hz lasers coaxially.

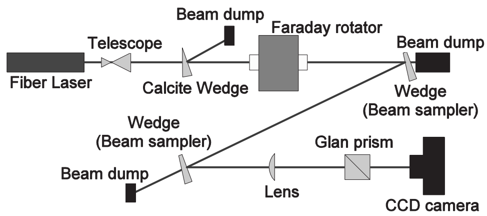

Fig. 1. A schematic diagram of the experimental set-up for the thermal birefringence measurement in TGG ceramics based Faraday rotator [4].

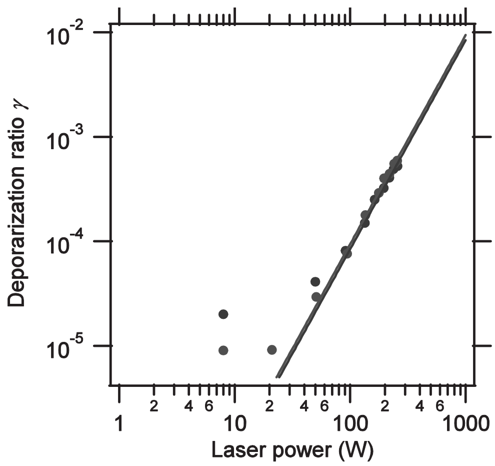

Fig. 2. Experimental results of depolarization ratios as a function of the laser power[4].

1) Yoshida H., et al., Rev. Sci. Instrum. 66 143 (1995).
2) Walsh M. J. et al., Rev. Sci. Instrum. 75 3909 (2004).
3) Yasuhara R., et al., Plasma and Fusion Research, 7, 2402030 (2012).
4) Yasuhara R., Optics Letters, **39** 1145 (2014).