§25. Faraday Rotation Densitometry for LHD

Tsuji-Iio, S., Murayama, H., Sato, E., Nozawa, T. (Tokyo Inst. of Tech.)
Kawahata, K.

A polarimeter is being developed to measure the Faraday rotation of CO_2 laser beam in the plasma[1]. The Faraday rotation angle is about a degree even along the tangential chords of LHD plasmas when we use CO_2 laser beam to avoid refraction effects. The frequency-shift heterodyne techniques with the use of acousto-optic modulators (AOM) are adopted to measure the angle with high resolution. The method is insensitive to beam ellipticity and laser power fluctuations and robust against common-mode refractive effects.

The Faraday rotation of the CO_2 laser beam through LHD plasmas was numerically evaluated as a function of the tangent radius to optimize the position of the beam path. We used the MHD equilibrium database of LHD computed by Dr. K. Watanabe with the VMEC code. Fig. 1 plots the distribution of the Faraday rotation angle divided by the line electron density with a tangent radius of 3.8 m in the two cases of volume averaged plasma betas of 0.32% and 1.76%. We assumed the electron density profile as $n_e = n_{max}(1-S)^j$, where S stands for the toroidal magnetic flux normalized to that at the outermost flux surface.

The dependence of the normalized Faraday rotation on the electron density profile shape is so weak that the Faraday rotation angle is a good measure of the line electron density when we choose a beam path with a tangent radius of around 3.8 m. On the other hand, the normalized Faraday rotation along inner chords with a tangent radius of around 3.4 m is sensitive to the electron density profile shape. Accordingly we can draw information of the electron density profile from the polarimetric measurements along two tangential beam paths.

We developed a retro-reflector with a clear aperture of 70 mm to displace the returning beams by 40 mm vertically so that the detector optics are separated from the probe beam optics. The retro-reflector was manufactured from aluminum alloy (A6063) and its mirror surface was coated with gold. It weighs only 540 g. Although mirror blocks were screwed on a base plate avoiding the use of resin or adhesives to be installed in the vacuum vessel, a retro-reflector accuracy of less than 0.5 mrad was achieved.

The total beam path length from the CO_2 laser (MPB GN-802-MES) to detectors was designed to be about 30 m. The beam path in the vacuum vessel to and from the retro-reflector is about 20 m. To reduce the beam diameter at the retro-reflector to about 10 mm, a beam expander with a beam expansion ratio of 3 will be placed at a path length of 2.5 m from the laser.

The polarimeter resolution was tested on an optical bench with a half-wave plate which simulates the Faraday rotation by plasmas. Digital complex demodulation[2] was employed to improve the accuracy of phase measurements of the beat signal at 100 kHz. Preliminary results indicate that the phase resolution can be raised to about 0.02 deg., which corresponds to a resolution of the line averaged electron density at 3 T of 3×10^{17} m^{-3}, in combination of digital band-pass filtering from 99.9 kHz to 100.1 kHz.

References

1) Murayama, H., et al., Proc. of 1998 ICPP & 25th EPS Conf. on Control. Fusion and Plasma Phys., Vol. 22C (1998) 1482.
2) Choi, D.W. et al., Rev. Sci. Instrum. 57 (1986) 1989.

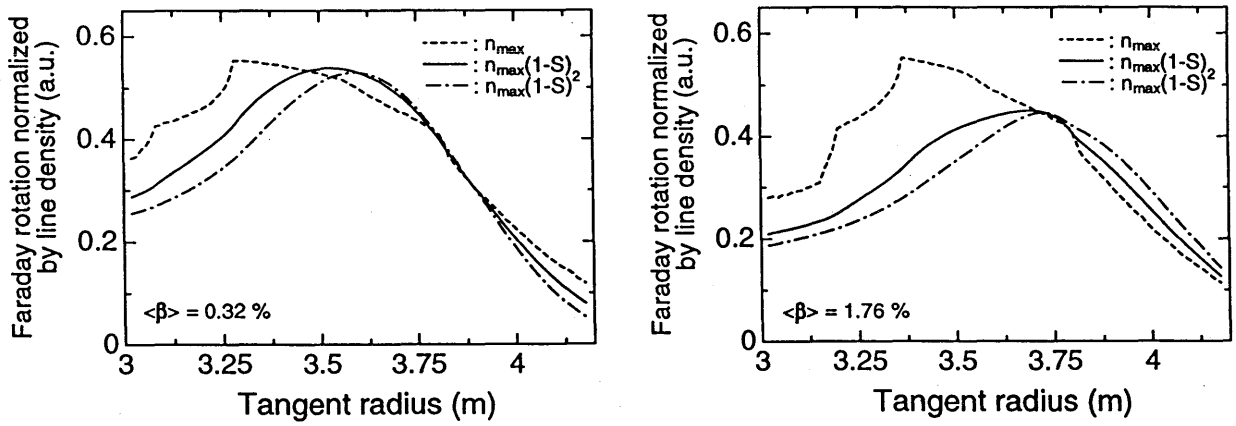

Fig. 1 Variation of the normalized Faraday rotation angle as a function of the tangent radius with three electron density profiles.