§34. Faraday Rotation Densitometry for LHD

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Tangential polarimetry in the midplane has been proposed to monitor the electron density in large tokamaks[1]. This technique has several advantages over interferometry. The polarimetric measurement does not depend on the past history of the discharge since the Faraday rotation angle can be designed to be less than 2π with a proper choice of the probe beam wavelength. Hence the polarimetry is suited for long-pulse operations of fusion devices.

An accurate measure of the rotation angle would enable us to monitor the electron density of stellarator/heliotron plasmas, where the confining magnetic field can be computed at least for low plasma pressure. The Faraday rotation angle is, however, less than a degree except high density discharges even along the tangential chords of LHD plasmas when we use CO_2 laser beam to avoid refraction effects. The frequency-shift heterodyne technique with the use of acousto-optic modulators (AOMs) was adopted to measure the angle with high resolution[2]. The method is insensitive to beam ellipticity and laser power fluctuations and robust against common-mode refractive effects.

Two optical tables for the polarimeter were installed on LHD in August, 1999. Counter-rotating circularly polarized beam components are generated on optical table 1, and launched into the plasma along three chords using polarization insensitive beamsplitters on optical table 2. Retro-reflectors with a clear aperture of 70 mm are used to displace the returning beams by 40 mm vertically so that the detector optics are separated from the probe beam optics. The phase difference between the reference and probe signals is four times the Faraday rotation angle owing to the double beam path in the plasma.

The total beam path length from the CO_2 laser on optical table 1 to detectors on optical table 2 was designed to be about 30 m. To focus the beam diameter at the retro-reflector to about 10 mm, a beam expander with an expansion ratio of three was placed at a path length of 2.5 m from the laser. Two retro-reflectors which correspond to tangent radii of 3.72 m (ch 2) and 3.90 m (ch 3) were fixed in the vessel in May, 1999. The installation of another retro-reflector for inner chord measurement (ch 1) was postponed until the next vacuum vent.

An example of the 2-channel polarimeter measurement of an NB heated discharge at 2.75 T is shown in Fig. 1. The beat signals at 100 kHz were digitized in 12 bits at a sampling rate of 1 MS/s. Digital complex demodulation[3] was employed to improve the accuracy of phase evaluation. The trace of the vertical interferometer measurement is shown by broken line for comparison. The observation that the rotation angle of ch 3 is almost the same as that of ch 2 in the early phase of the discharge is only explained by a hollow density profile.

The results indicate that the resolution of the Faraday rotation is about 0.02 degrees, which is equivalent to a resolution of the line averaged electron density of about 1×10^{18} m^{-3}, with the use of digital band-pass filtering from 99.99 kHz to 100.01 kHz.

The stability of the phase measurement was examined on discharges with pulse durations of several tens seconds with the use of lock-in amplifiers. The rotation angle sometimes fluctuates with an amplitude up to 0.05 degrees in several seconds. Although no cause for seemingly common mode noise is identified, an improvement in the long-term stability of the phase measurement is required to monitor the line electron density of long-pulsed operations.

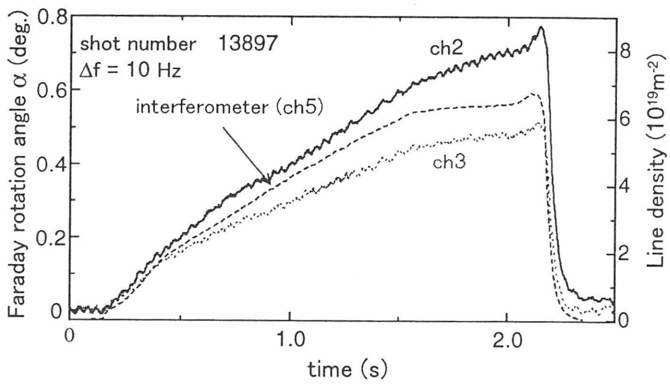

Fig. 1 Comparison of the time evolution of the Faraday rotation angle with that of the interferometer data.

References

1) Jobes, F.C., Mansfield, D.K., Rev. Sci. Instrum. **63** (1992) 5154.
2) Murayama, H., et al., Proc. of 1998 ICPP & 25th EPS Conf. on Control. Fusion and Plasma Phys., Vol. **22C** (1998) 1482.
3) Choi, D.W. et al., Rev. Sci. Instrum. **57** (1986) 1989.