§46. Faraday Rotation Densitometry for LHD

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Tangential polarimetry in the midplane has several advantages over interferometry. 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 measurements of rapid density variations in long-pulsed fusion devices.

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 polarization rotation method using frequency-shift heterodyne technique was adopted to measure the angle with high resolution[1, 2].

Retro-reflectors installed inside the vacuum vessel were displaced with new ones made of S.S. encapsulated in protective cylinders in 2000. The third channel (ch 1), with a tangent radius of 3.38 m was added to two channels at 3.71 m (ch 2) and 3.90 m (ch 3). The beat frequency was dropped from 100 kHz to 90 kHz before the fourth experimental campaign to utilize the aliasing effect at a data sampling rate of 100 kS/s for long-pulsed discharges.

To evaluate the phase difference with a high angle resolution we adopted the digital complex demodulation combined with digital band-pass filtering. Figure 1 shows the Faraday rotation angle resolution that is defined as the standard deviation of 2-s long phase difference signals without plasma as a function of the response time. The resolution of the Faraday rotation angle was found to be 0.01 degrees, which corresponds to a line-averaged density of 5.0×10^{17} m^{-3} at $B = 3$ T, with a response time of 3 ms.

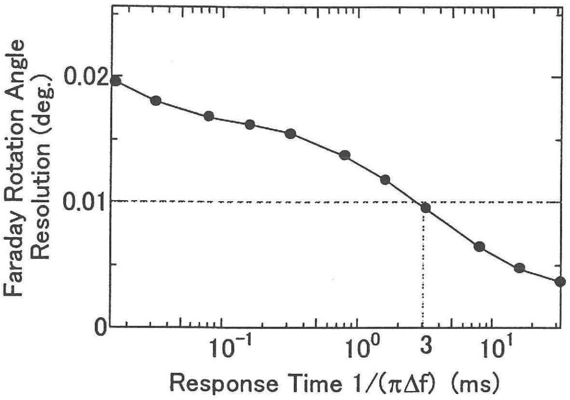

Fig. 1 The Faraday rotation angle resolution improves with widening filter band-width.

Measured Faraday rotation angles were compared with calculated ones using density profiles from 13-ch FIR interferometer data in Fig. 2. The rotation angle of each channel was shown to be consistent with the interferometer data within error bars. The reason why the error bars of ch 3 is larger than the other ones is that the probing beam of ch 3 passes the region where the path length in the plasma sharply decreases against the tangent radius of the probing beam.

Even in the case of pellet injected plasmas, where FIR interferometers often suffer from fringe jumps, it was demonstrated that the polarimeter could measure the time evolution of the Faraday rotation successfully as shown in Fig. 3. Rapid changes in the Faraday rotation angle were measured reliably with enough resolution.

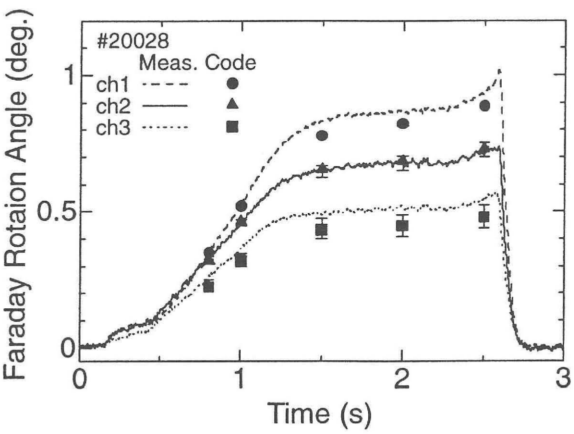

Fig. 2 Comparison of the time evolution of the Faraday rotation angle with calculation from interferometer data.

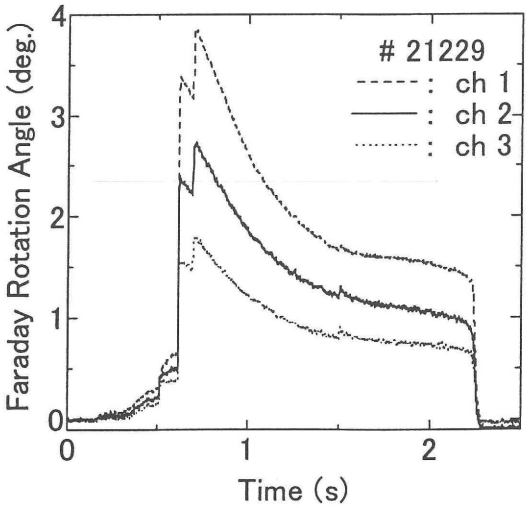

Fig. 3 The measured Faraday rotation angle of a pellet injected plasma.

References
1) Tsuji-Iio, S. *et al.*, Plasma Fusion Res. SERIES, Vol. 3 (2000) 415.
2) Akiyama, T. *et al.*, Rev. Sci. Instrum., **72** (2001) 1073.