§19. Faraday Rotation Densitometry for LHD

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

We develop a polarimeter to measure the line integral of the electron density times the magnetic field based on the Faraday rotation of CO_2 laser beam in the plasma. The polarimetry is free from the miscount of fringes from which interferometers often suffer so that it is suited for long-time operation of fusion reactors. It has another advantage of being insensitive to vibration of optical components, by which the system becomes simpler. An accurate measure of the rotation angle would enable us to monitor the electron density of stellarator plasmas, where the confining magnetic field can be computed at least for low plasma pressure.

The Faraday rotation angle, however, is about several degrees even along the tangential chords of LHD plasmas when we use CO_2 laser beam to avoid refraction effects. Thus sophisticated techniques are required to measure the angle with a resolution of about 0.01 degrees. The frequency-shift heterodyne techniques[1, 2)] are being tested under the optical setup shown in Fig. 1. The method is insensitive to beam ellipticity and laser power fluctuations and robust against common-mode refractive effects. The laser beam passes through an acousto-optic modulator (AOM), operating at about 40 MHz, which splits off a component from the main beam. This component is Doppler shifted by the AOM, and is then recombined with another diffracted beam such that the two slightly frequency offset components of the reconstituted beam are polarized perpendicularly to each other. These are then passed through 1/4 wave plate to generate counter-rotating circularly polarized beam components and launched into the plasma. A retro-reflector displaces the returning beams horizontally so that the detector optics are separated from the probe beam optics. The beam emerging from the plasma is passed through a polarizer and detected to give an oscillating signal at the beat frequency that suffers a phase retardation proportional to the Faraday angle.

The polarimeter resolution without plasmas was tested with a digital lock-in amplifier (EG & G Princeton Applied Research Model 5302). Preliminary results shown in Fig. 2 indicate that the resolution at a beat frequency of 100 kHz or higher drops below 0.1 deg. with a time constant of the lock-in amplifier of not shorter than 10 ms.

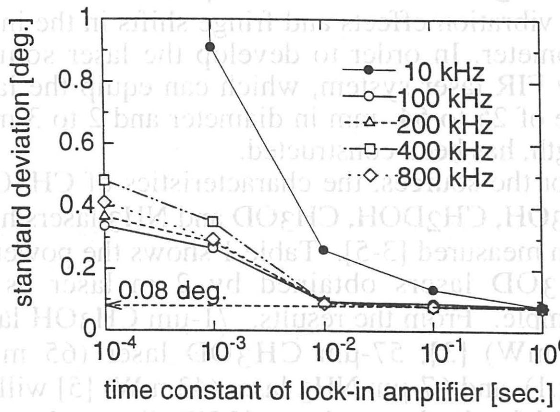

Fig. 2. Polarimeter resolution at different beat frequencies as a function of the lock-in amplifier time constant.

1) G. Dodel and W. Kunz, Infrared Phys. **18**, (1978) 773.
2) J.H. Rommers and J. Howard, Plasma Phys. Control. Fusion **38**, (1996) 1805.

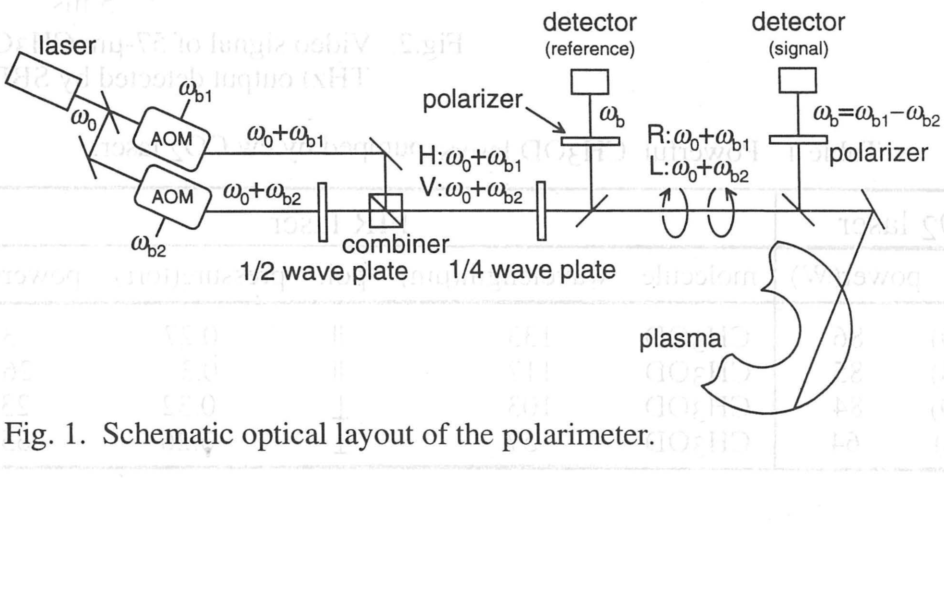

Fig. 1. Schematic optical layout of the polarimeter.