Abstract

Faraday rotation and electron line density spatial profiles have been measured simultaneously on the Microtor tokamak using the phase modulation scheme originally proposed by Dodel and Kunz [1]. Presently, a single channel system is spatially scanned across the complete plasma profile at 1 cm intervals. The extension of this technique to a 20 channel interferometer/polarimeter system using microbolometer imaging arrays is briefly described together with an assessment of the importance of such a system on fusion plasmas.

Introduction

An accurate knowledge of the current profile in a tokamak plasma is crucial to the understanding and control of MHD stability. The "tailoring" of the current profile via neutral beam injection, for example, offers the possibility of major improvement in stability control. In addition, the study of current penetration during the start-up phase is important from both the physics and engineering standpoint in future and existing tokamak fusion plasmas.

A promising, nonperturbing method of determining the magnetic field profile generated by the tokamak current is to measure the Faraday rotation of the polarization of a beam of electromagnetic radiation passing through the plasma. However, in order to accurately determine the current profile a number of criteria must be satisfied. First, a simultaneous measurement of the line density profile is necessary in order to deconvolve the poloidal field profile from the Faraday rotation signals. Second, it can be simply demonstrated from sampling arguments that 5-10 channel systems are inadequate to resolve anything but the simplest profiles. Hollow current profiles, for example, would be virtually impossible to detect with such systems. In order to resolve such features, 20 spatial sampling chords can be shown to be sufficient in most cases, although higher spatial frequencies obviously require greater sampling resolution. Third, it is highly desirable to acquire the spatial profiles of line density and Faraday rotation on a single tokamak discharge in order to eliminate difficulties associated with plasma irreproducibility.

Previous experiments [2,3] have measured the Faraday rotation produced by a tokamak plasma. However, these systems relied upon amplitude dependent measurements, which could be affected by noise from a variety of sources. In this paper an amplitude independent method [1] which simultaneously measures line density and Faraday rotation is applied for the first time to a tokamak plasma.

Experimental Arrangement and Results

The optical system is displayed in Fig. 1. It is based on the scheme suggested by Dodel and Kunz [1]. The idea is simply to measure the difference in phase velocity produced between two collinear circularly polarized beams of opposite handedness when passed through a plasma. The phase shift measured by the polarimeter detector is twice the Faraday rotation angle which is given by

\[ \alpha = 2.5 \times 10^{-17} \int_0^{\infty} n_e(r) B_r(r) \beta \, dr \]  
(c.g.s. units)

where \( B_r \) is the projection of the B-field onto the direction of propagation of the beam.

In order to produce rotation angles large enough to be easily detected, it is necessary to operate in the FIR spectral region. The source adopted in the present work was a 400 GHz (\( \approx 800 \mu \text{m} \)) carcinotron and the detectors were quasioptical GaAs Schottky diode mixers. Figure 2 indicates the calculated rotation angle profile for typical Microtor parameters assuming parabolic electron density and current density profiles (toroidal effects are neglected). A maximum rotation angle of \( \approx 40^\circ \) is expected with a reversal in sign at the plasma center.

The single channel system displayed in Fig. 1 was scanned across the plasma on a shot-to-shot basis to produce the line density and Faraday rotation spatial profiles indicated in Figs. 3 and 4, respectively. The profiles are clearly asymmetric. The line density peaks approximately 2 cm inside the vessel center. In order to obtain the density profile, the inversion method of Yasutomo, et al. [5] is utilized which allows for asymmetries in the direction transverse to the incident beam. The resultant inverted density profile is shown in Fig. 5.

The Faraday rotation profile can be similarly treated as asymmetric. The data is first fitted with an 8th order polynomial which is then inverted and divided by the density profile to obtain the poloidal B field profile. The current density is obtained from the B-field using Ampere's law.

As illustrated in Fig. 4, the shot-to-shot irreproducibility presently prevents an accurate determination of current profile. However, the data reverses sign as expected near the plasma center and possesses a maximum rotation angle of \( \approx 40^\circ \). The signals were confirmed as true Faraday rotation signals by sending two right hand circularly polarized beams through the plasma: the signal level was negligible in this case, as expected.

The shot-to-shot plasma variation can be eliminated by adopting the imaging approach described in a separate paper at this conference. This requires relatively simple modifications to the existing system. Cylindrical beam expansion optics are used so that an elliptical cross section beam passes through the entire plasma profile. The Schottky diode mixers are then replaced with microbolometer detector arrays [4] thereby allowing a 20 channel polarimeter/interferometer system to be constructed. Work is underway to implement such a system on the Microtor device. The system will fully satisfy the earlier stated requirements necessary to provide an accurate measurement of current profile in a tokamak plasma.

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References


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Figure 1 Optical system adopted for simultaneous measurement of Faraday rotation and line density.

Figure 2 Calculated Faraday rotation spatial profile for typical Microtor parameters \( n_0 \sim 5 \times 10^{13} \text{ cm}^{-3} \), \( I_T \sim 50 \text{ kA} \). Parabolic density and current profiles are assumed. Toroidal effects are neglected. The maximum rotation angle is \( \sim 40 \)°.

Figure 3 Measured line density spatial profile in Microtor obtained by scanning the single channel system shot-to-shot. Each point represents the mean of \( \sim 5 \) separate discharges. Note the observed asymmetry.

Figure 4 Measured Faraday rotation spatial profile obtained by scanning single channel system at 1 cm intervals. The scatter in the data is partly due to plasma irreproducibility.

Figure 5 Inverted electron density profile in Microtor.

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