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FAR-INFRARED INTERFEROMETRY/POLARIMETRY ON THE ISX-B TOKAMAK*

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Theoretical analyses have shown that the current density distribution in a tokamak plasma can be obtained indirectly by the measurement of the poloidal magnetic field created by the current flowing in the plasma discharge. The distribution of this field may be determined by projecting linearly polarized far-infrared (FIR) laser beams through the plasma and measuring the Faraday rotation of the polarization (1,2). Since the rotation angle of the polarization vector is proportional to the line integral of electron density times the poloidal magnetic field along the path, the electron density profile must also be measured simultaneously in order to unfold the current distribution. The amount of Faraday rotation expected in a typical plasma experiment is calculated to be on the order of 5-10 degrees. Therefore the authors have constructed a multichord modulated FIR polarimeter/interferometer that measures both the phase delay of four laser beams passing through a plasma discharge and the instantaneous polarization of these same beams. The phase shift of each of the beams is directly proportional to the line-averaged electron density and the polarization rotation is directly proportional to the line-averaged density times poloidal field.

The polarimeter/interferometer system uses two optically pumped methyl iodide FIR lasers operating at a power level of approximately 50-75 mW at a wavelength of 0.447 mm. The laser beams are propagated to and from the tokamak plasma by means of 2.54 cm i.d. dielectric waveguide. Thin mylar films of various thicknesses are used to equally distribute the FIR power among the four chords. The linearly polarized radiation of one of the lasers is passed through an rf-driven polarization modulator and then into the dielectric waveguide for transport to the plasma. Upon emerging from the plasma chamber, the beams re-enter the waveguide system and are directed to a bank of room temperature Schottky-barrier diode heterodyne detectors. The beam from the other laser is also divided by a series of mylar beamsplitters and directed to the detectors to serve as a local oscillator for the mixers. The signal derived from the detectors consists of a carrier wave with a frequency equal to the frequency difference of the two lasers and two sidebands at the frequency of the polarization modulator. The frequency difference of the lasers is set to 1 MHz by mechanically de-tuning the laser resonators. The polarization modulator was designed to operate at a frequency of approximately 100 kHz. After leaving the detectors the signal is split into two parts for processing. The first part of the signal is sent to a limiting circuit to remove the sidebands and then to a phase detection circuit where a voltage is derived that is directly proportional to the phase shift and, hence, the line-averaged electron density. The other part is sent to an amplitude demodulator and then a lock-in amplifier. The output of the lock-in amplifier, which uses a portion of the modulator drive frequency as a reference, is a voltage proportional to the polarization rotation of the laser beam. The sensitivity of the interferometer is 1/30 of a fringe and the average fringe count on a typical ISX-B tokamak plasma discharge is on the order of five fringes. The noise level of the polarimeter measurement is approximately 1 mrad and a typical measurement would yield a rotation of the order of 100-200 mrad.

In order to convert the multichord measurements into radial density profiles, a computer inversion code has been developed (3). The program, although not a rigorous abel inversion, has proven very successful in providing fast profile inversions very quickly after the plasma discharge. The profiles produced by the inversion code agree with the profiles as measured by the Thomson scattering diagnostic to within a few percent. Work is continuing on an inversion technique for the Faraday rotation measurements as well.

The polarimeter/interferometer system has been in operation on the ISX-B tokamak for several thousand discharges where it has been used to study a variety of plasma conditions including solid hydrogen pellet injection, neutral beam heating and impurity gas injection. The system has proven to be a reliable and accurate diagnostic and is considered to be an integral part of tokamak operations.

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