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ITR/P5-32: Electron Kinetic Effects on Interferometry, Polarimetry and Thomson Scattering in Burning Plasmas

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Several major optical diagnostics are under development for plasma parameters, magnetic field and current control in ITER: Thomson scattering (TS), toroidal interferometer/polarimeter (TIP) and poloidal polarimeter (PP). Since these diagnostics are needed for basic machine operation as well as physics studies, accurate measurements are required to meet the ITER goals. Each of these measurements is based on the electron response to laser light propagating in plasma. At anticipated ITER plasma conditions, the effects of electron thermal motion will be significant and must be accurately treated or the diagnostics will fail to meet the measurement requirements for ITER operation. The primary focus of our work is to examine the effects of electron thermal motion on the refractive indices and polarization of high-frequency electromagnetic waves (specifically laser light, both directed and scattered). We calculate (1) thermal corrections to the interferometric phase and polarization state of the wave propagating in the direction of the incident laser beam (Faraday and Cotton-Mouton polarimetry) and (2) perform analysis of the degree of polarization for incoherent TS. Our earlier linear in electron temperature Te calculations predicted 10–30% corrections for the interferometric phase, Faraday rotation, and Cotton-Mouton effect at Te = 30 keV. Knowing electron temperature from the Thomson scattering, the thermal effects can be corrected. This has already been included in the error analysis and design projections of the ITER TIP and PP systems. The new findings are: (1) The precision of the previous lowest order linear in Te model may be insufficient; we present a more precise model with quadratic corrections to satisfy the high accuracy required for ITER TIP and PP diagnostics. The importance of these results and their practical application for the ITER TIP and PP systems are discussed. (2) The degree of polarization of incoherent Thomson scattered laser light is calculated accurately without approximation for the full range of incident polarizations, scattering angles, and electron thermal motion from non-relativistic to ultra-relativistic. The results are discussed in the context of the possible use of the polarization properties of Thomson scattered light as a method of Te measurement relevant to ITER operational scenarios.

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