Multi-channel far-infrared HL-2A interferometer-polarimeter

Y. Zhou, Z. C. Deng, Y. G. Li, and J. Yi
Southwestern Institute of Physics, P.O. Box 432, Chengdu, Sichuan 610041, China

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An HL-2A interferometer is upgraded to a multi-channel interferometer/polarimeter, which includes four chords for the interferometer and four chords for the polarimeter. The far-infrared lasers (at \( \lambda = 432.5 \, \mu \text{m} \) and 30 mW power) are used to probe plasmas horizontally in the midplane of HL-2A. A conventional heterodyne technique is used for the interferometer. Two counter-rotating circularly polarized waves are used to measure the Faraday rotation effect. A fast-phase comparator with temporal resolution of 1 \( \mu \text{s} \) and phase resolution 0.1\(^\circ\) is developed. Further, the distortion of the polarization caused by the beam-splitters and the other optical components is also investigated.

\[ \alpha = 2.62 \times 10^{-13} \lambda^2 \int_{z_1}^{z_2} n_e(z) B_{P(z)} dz. \]  

(1)

The HL-2A is a mid-size tokamak (major radius \( R = 1.65 \, \text{m} \), minor radius \( a = 0.4 \, \text{m} \)) with a closed divertor. The plasma cross section is nearly circular. The previously multi-channel interferometer was a Michelson-type interferometer with eight measurement chords and a symmetrical distribution relative to the equatorial plane in the vertical direction. To obtain the electron density and the Faraday rotation angle information synchronously, in this paper, we demonstrate an HL-2A eight-channel interferometer that has been converted into a four-channel interferometer below the equatorial-plane and a four-channel polarimeter above the equatorial-plane.

The measurement principle is shown in Fig. 1. The lower part of the measurement chord was used to measure electron density and the upper part to measure the Faraday rotation angle. We used two HCOOH lasers optically pumped by two separate CO2 lasers with slightly offset frequencies. The two laser beams were divided into two parts. One part is for the interferometer. The other part is for the polarimeter. In the polarization measurement part, two collinear input beams were generated by combining two orthogonal, linearly polarized components. The combined beams were passed through a quarter-wave plate, generating two counter-rotating, circularly polarized waves. Then the two counter-rotating, circularly polarized beams passed through the plasma. Because of the birefringence effect, each of the beams was result in a phase delay during propagation through the plasma. This phase difference is related to the Faraday rotation angle, which can be directly determined by measuring the mixing product of the two beams and evaluating the phase difference with respect to a reference beam.

Figure 2 shows the optical arrangement of the HL-2A multi-channel interferometer/polarimeter system. To make full use of the existing optical components, one laser beam, with its polarization rotated 90\(^\circ\) by a half wave plate, is combined with a second laser beam at a wire grid \( M_{m1} \). The combined beams are passed through two glass waveguide tubes (\#8 and \#1) into the interferometer/polarimeter system. Then using the wire grid \( M_{m2} \), the beams are separated into probe and reference beams. Because the wavelengths of HCN laser and the HCOOH laser are similar, we set two plane mirrors \( M_{N1} \) and \( M_{N2} \) in front of the grating, and otherwise our...