§37. Electron Density Measurement System for DEMO-relevant Helical Plasmas

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The electron density measurement has to be accurate and reliable even on future DEMO reactors because it will be a reference signal of fueling control. However, conventional interferometers suffer from measurement errors caused by mechanical vibrations. Fringe jump errors significantly degrade the reliability of the density measurement. A dispersion interferometer (DI) [1] is insensitive to the mechanical vibrations. Since there is no phase error due to the vibrations, the phase shift due to a plasma smaller than 1 fringe is allowed from the view point of signal to noise ratio (SNR). If the total phase shift is surely smaller than 1 fringe, the line density can be determined uniquely. This means the DI is free from fringe jump errors. Hence the DI is one of candidates of reliable density measurement on future DEMO reactors.

So far, we have been developing a CO_2 laser (10.6 μm) dispersion interferometer [2] for LHD. Here, we suppose the size of a helical DEMO reactor is four times larger than that of LHD (the major radius R=3.6×4=14.4 m, the minor radius a=0.6×4=2.4 m) and the line averaged electron density and the central magnetic field strength are 3×10^{20} m^{-3} and 5 T, respectively. On this device, the numbers of the fringe shift of the DIs with the CO_2 laser, a YAG laser (1.064 μm) and a He-Ne laser (0.633 μm) are shown in Fig. 1 (a). Since the expected path length of a line of sight will be 2×4=8 m, the line integrated density of the DI will be $(3\times10^{20})\times8=24\times10^{20}$ m^{-2}. Then, No wavelength can satisfy the phase shift smaller than 1 fringe. In addition, the power of the He-Ne laser is too small to generate the second harmonic component, which is necessary for the DI. Although the fringe shift is slightly larger than 1 fringe, the candidate of laser source is the YAG laser. In order to correct the fringe jump errors, a back-up density measurement is necessary. Candidates are polarimeters which use the Faraday effect or the Cotton-Mouton (CM) effect. Both polarimeters had already been demonstrated on fusion devices [e.x., 3,4]. The Faraday rotation angle or the Cotton-Mouton phase shift should be from 1-10 deg. from the view points of SNR and a coupling error between these two optic-magnetic effects. Figure 1(b) and (c) show the rotation angle and the CM phase shift. The candidates of the laser sources are the YAG laser and a H_2O laser, respectively. However, there is less number of optical components for the H_2O laser light. Therefore the realistic back-up system is the Faraday polarimeter with the YAG laser. Since the laser source is common, combination system of the DI and the Faraday polarimeter is possible as shown in Fig.2.

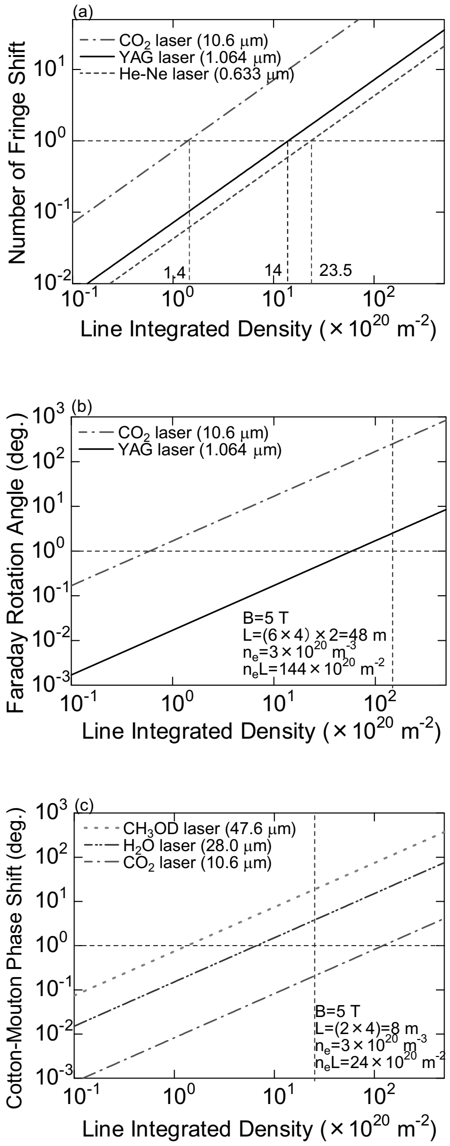

Fig. 1: Phase shifts of dispersion interferometer (a), the Faraday rotation angles (b) and the Cotton-Mouton phase shift (c) on a helical DEMO reactor, which is four times larger than LHD.

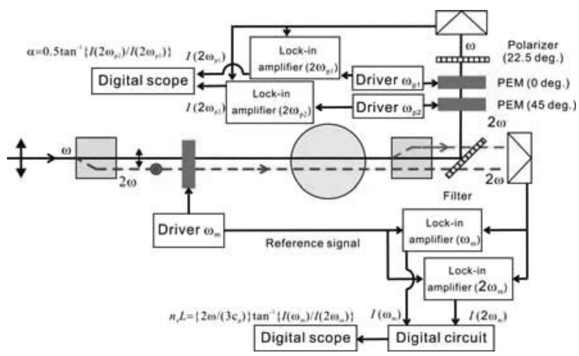

Fig. 2: Combination system of the DI and the Faraday polarimeter

1) Drachev P., V et al.: Rev. Sci. Instrum. **64**, 1010 (1993).
2) Akiyama, T. et al.,: Plasma and Fusion Res. Journal of Instrumentation **7**, C01055 (2012).
3) Akiyama, T. et al.,: Rev. Sci. Instrum. **74**, 2695 (2003).
4) Akiyama, T. et al.,: Rev. Sci. Instrum. **77**, 10F118 (2006).