Conceptual Design of dispersion interferometer using ratio of modulation amplitudes

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High reliability and resolutions are required for electron density measurements in fusion devices. A conventional interferometer is widely used for the electron density measurement and has a high density resolution. It is, however, suffered from fringe jump errors, which degrade reliability of the interferometer, in a high density range. While a short wavelength laser can reduce risks of the fringe jumps, phase errors caused by mechanical vibrations become significant. They should be suppressed with a vibration isolator or be compensated by adopting the two-color interferometry, in which two probe beams with different wavelengths (light sources). Even so, it is difficult to eliminate the vibration components completely and an optical system becomes complex and expensive.

A dispersion interferometer [1] uses the fundamental wave and the second harmonic generated with a nonlinear optical crystal as a probe beam. After passing through a plasma, the frequency of the fundamental wave is doubled again with the other nonlinear optical crystal and then the interference signal between the two second harmonics are detected. Accordingly, the detected signal contains the phase determined by only the dispersion of the plasma and that due to mechanical vibrations is cancelled out automatically. Hence it is free from mechanical vibrations even with a short wavelength laser.

One of problems in the dispersion interferometer is that variations of the detected intensity lead to phase errors, similarly to a homodyne interferometer. The phase modulation method [2] with an electro-optical modulator can reduce the influence of the intensity variations. Now we are designing a dispersion interferometer with a use of a photoelastic modulator (PEM), whose modulation frequency is stable. In this configuration, the interference signal $I(t)$ is as follows:

$$I(t) = A + B\cos\left(2\rho_0 \sin\omega_m t + \frac{3}{2}\frac{c_p \overline{n}_e L}{\omega}\right)$$

where A and B are constant determined by the detected intensity, ρ_0 is the maximum of the retardation of the PEM, ω_m is the modulation frequency of the PEM, $\overline{n}_e$ is the line averaged electron density, L is the path length in a plasma, ω is the frequency of the light source and c_p is constant. Then, the following amplitudes of fundamental and the second harmonic components $I_{\omega m}$ and $I_{2\omega m}$ of the modulation frequency ω_m can be measured with lock-in amplifiers.

$$I_{\omega_m} = -2BJ_1(\rho_0)\sin\left(\frac{3}{2}\frac{c_p \overline{n}_e L}{\omega}\right),\quad I_{2\omega_m} = 2BJ_2(2\rho_0)\cos\left(\frac{3}{2}\frac{c_p \overline{n}_e L}{\omega}\right)$$

From the ratio of these amplitudes, the line averaged electron density $\overline{n}_e$ is obtained (ρ_0=1.3).

$$\overline{n}_e = \frac{2}{3}\frac{\omega}{c_p L}\tan^{-1}\left\{\frac{I_{\omega_m}}{I_{2\omega_m}}\right\}$$

This new method of the phase extraction is simpler than that in Ref [2] and suits to real time measurements. In addition, it is completely free from variations of detected intensities A and B.

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