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SPECTROSCOPY OF AXISYMMETRIC PLASMA SOURCES

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INTRODUCTION

The importance of an angular deviation of the light ray through inhomogenous plasma has been assessed in the field of interferometry. for quite a long time.[1] The schlieren technique is based on measurements of the deviation of the light ray in the presence of refractive index gradients. However the same effect was utterly neglected in spectroscopic measurements.

The aim of this paper is to draw attention to the possible causes of systematic error in spectroscopy measurements due to the refraction of radiation in an optically thin, circularly symmetric plasma source.

NUMERICAL PROCEDURE

The angular deviation of a ray in an inhomogenous medium can be estimated from the radius of the curvature R of the deflected path given by[2]

$$\frac{1}{R} = \frac{1}{\mu} \nabla \mu \cdot \vec{n} \qquad (1)$$

where μ is the local phase refractive index, and n is the local unit vector perpendicular to the ray. Since this work deals with axial investigations of plasmas only, deflections of the ray for a cylindric geometry are considered. For this two dimensional model "X" axis coincides with the plasma axis and is assumed parallel to the incident ray. It is possible, in this case, to obtain the differential equation of the ray trajectory through plasma from eq. 1

$$\frac{dy}{dx} = \left(\frac{\mu}{\mu_o}\right)^2 - 1 \qquad (2)$$

and the radius of its curvature

$$R = \frac{\mu^2}{\mu_o \left(\frac{d\mu}{dy}\right)} \qquad (3)$$

where μ_o is the refractive index at the point of incidence of the ray. On the other hand the radial distribution of the plasma refractive index can be represented approximately by the following relationship

$$\mu = \mu_a - b\, e^{-cy} \qquad (4)$$

where μ_a is the refractive index at the plasma axis and b and c are constants. Since it is not possible to solve eq. 2 analytically, it is necessary to employ an approximate method in order to obtain the ray trajectory. Therefore, the ray path is determined from the equation of the corresponding curvature circle at the starting point of the trajectory. The next point on the trajectory is computed from this equation and the whole procedure repeated for the other points. This can be easily understood from the following equations and the notation given in Fig. 1. The coordinates of some point on the trajectory are

$$X_{n+1} - X_{cn} = h + R_n \sqrt{1 - \left(\frac{\mu_o}{\mu_n}\right)^2} \qquad (5)$$

$$Y_{n+1} = Y_n + R_n \frac{\mu_o}{\mu_n} \sqrt{R_n^2 - \left[h + R_n \sqrt{1 - \left(\frac{\mu_o}{\mu_n}\right)}\right]^2} \qquad (6)$$

where h is the step length.

From the eq-s 2,3,4 and 6 it is possible to obtain each point of the ray path with an accuracy determined by the magnitude of the step length h.

RESULTS

The radial distribution of refractive index is evaluated from[1]

$$\mu = 1 - \frac{1}{2}\left(\frac{\omega_p}{\omega}\right)^2 + 2\pi \sum_i \alpha_i N_i \qquad (7)$$

where [illegible] $\omega_p^2 = \frac{N_e e^2}{\varepsilon_o m}$, [illegible] is the permeability of vacuum, N_e electron density e and m are the electronic charge and mass, N_i is the number density of atoms or molecules in the i- th quantum state and [illegible] is the polarizability of this electronic state. For these calculations the wavelength dispersion of [illegible] and the contribution of excit[illegible] [illegible] been neglected.

For further examinations of the refraction of the radiation the plasma of a wall stabilized hydrogen arc at atmospheric pressure has been chosen. Radial variation of the refractive index at λ = 5000 Å and 6500 Å were evaluated using the temperature profile of Wiese et al.[3] for 40 A arc burning in 3 mm diameter hole and the composition data of hydrogen at atmospheric pressure[4]. From the radial distribution of refractive index, the ray trajectory through the plasma has [illegible] 2 [illegible] the [illegible] of the light is given as a function of the plasma length. In Fig. 3 the distortion of the radial light intensity distribution (at 6500 Å) by 6 cm plasma length of 40 A hydrogen arc in a 3 mm diameter tube is shown.

CONCLUDING REMARKS

It is shown that the refraction of radiation in the plasma may introduce a systematic error in spectroscopic end-on measurements. The magnitude of this error depends on the refractive index gradients and the plasma length. Also the mathematical procedure for evaluation of this effect is given. Although it has been applied to the hydrogen arc it can be used for any axisymmetrical plasma.

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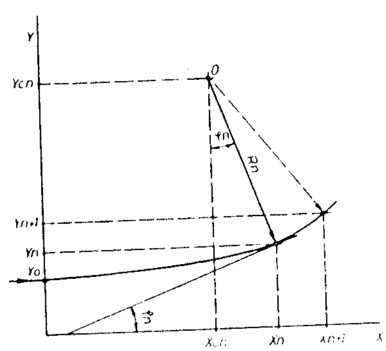

Fig. 1

Ilustration of the numerical procedure

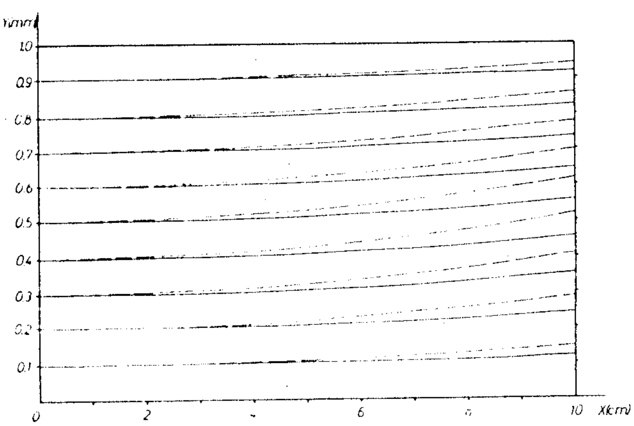

Fig. 2

Ray trajectories through the plasma in a 40 A arc[4] at — 5000 Å and -- 6500 Å

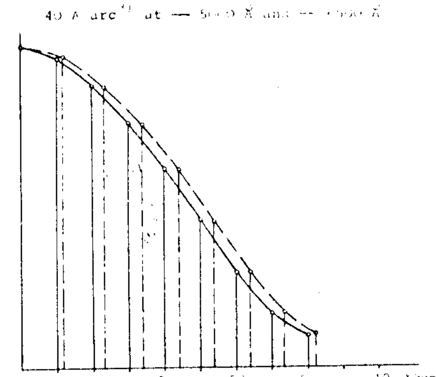

Fig. 3

Distortion of radial light intensity distribution at 6500 Å by 6 cm of plasma in a 40 A arc[3]