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REFRACTION TECHNIQUES APPLIED TO MULTIFREQUENCY SUBMILLIMETER DIAGNOSTICS OF THE MOVING UHF DISCHARGE

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Abstract

Two refraction techniques applied to active diagnostics of the plasma of a filamentary discharge in deuterium rotating around the axis of ~~an~~ UHF cavity are described. Simultaneous four-frequency transverse probing is employed for determination of the electron density distribution function. The density profiles with an abrupt jump of concentration near the axis are observed.

A refraction technique has been previously proposed [1] for the determination of the electron density profile of the moving inhomogeneous plasma cylinder probed with a narrow microwave beam perpendicular to its axis. The function of transmission T, at various impact parameters ρ (for the experimental installation shown in Fig.1), has two minima at $\rho = \pm \rho_1$, corresponding to the maximum angles of refraction. Dependence of ρ_1 on the frequency of incident radiation is specific for different types of density profiles. So it is possible to find the theoretical profile best suited to the one being studied. For this purpose one should compare the experimentally measured frequency dependence of the distance between two minima of transmission with the theoretical ones. This technique has been used to study the plasma column the dimensions of which were nearly trebled as compared to the size of the previously described UHF discharge [2, 3]. The ratio of the plasma diameter to the beam width $2a/\Delta$ increases from 3 - 5 at the small plasma installation [2] up to 10 - 15 at the greater one. Evidently it provides a higher accuracy of the density profile measurements.

A schematic representation of a diagnostic installation for probing of the plasma discharge at four different frequencies is given in Fig.1. Quasioptical elements and electronics are the same as those described earlier [3]. Two carcinotrons and submillimeter laser have been used as microwave sources. Radiation of carcinotrons modulated at 40 and 70 kc is formed into parallel beams by teflon lenses L_1 and L_2 and directed by the mirror M and electroformed nickel mesh G_1 (period 0.25 mm) to the teflon lens L_3, which is the window of a discharge chamber. Radiation transmitted through plasma is gathered by the identical lens L_4, reflected from the one-dimentional wire-grid G_3 (period 0.06 mm) and registered by the n-InSb detector (III). Two narrow bandwidth amplifiers tuned to 40 and 70 kc, respectively, separate the signals of the two wavelengths.

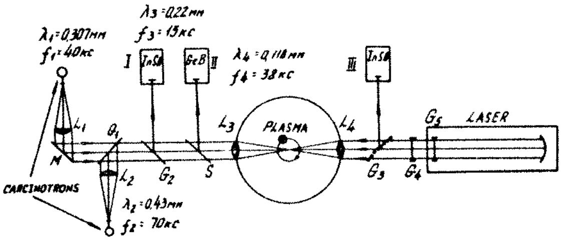

Fig.1 Experimental arrangement

Radiation of submillimeter laser on water vapours with $\lambda = 0.118$ mm and $\lambda = 0.22$ mm is guided along the same optical axis from the other side of the UHF cavity. This radiation is registered by detectors (I) and (II). The signals from the detectors have an amplitude modulation at frequencies of 38 kc and 15 kc, respectively, due to beating of two ortogonal linearly polarised modes of laser oscillations. These modes result from slight geometric anisotropy of the two-dimentional wire-mesh G_5, which is a mirror of the laser cavity [4]. Ortogonal modes interfere at the detectors due to presence of the one-dimentional wire polarizer G_4 (period 0.06 mm). The radiation that has been transmitted through plasma is divided by lavsan splitter S toward GeB detector (II). It has maximum spectral sensitivity near $\lambda = 0.1$ mm and is insensitive to emission with $\lambda = 0.22$ mm. The n-InSb detector (I) registers merely a long-wave component (0.22 mm) of the transmitted radiation which is reflected by the one-dimentional wire-grid G_2 (period 0.06 mm). This grid reflects the laser light almost completely and transmits pretty well the carcinotron's radiation which has perpendicular polarisation.

Continuous registration of plasma coordinates has been perfomed by the system that is based on the two single-line semiconductor optical convertors - scanners. This provides good accuracy of measurements of the distance between the minima of the transmission signals as a function of frequency since the function $T(\rho)$ has been registered at four frequencies in the course of a single passage of plasma across the microwave beams. A typical oscillogram of the transmission signals for the discharge in deuterium is presented in Fig.2 (gas pressure 1.5 atm, input UHF power 21 kwt).

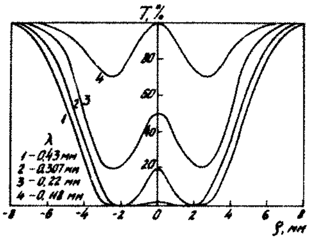

Fig.2 Signals of transmission at four frequencies

Another refraction technique of the density profile measurements has been developed for the installation under study. It is based on the calculation of the profile from the refraction angle θ as a function of the impact parameter ρ [5]. The plasma diameter being sufficiently large the function $\theta(\rho)$ can be obtained from the signal $T(\rho)$ by using the calibration function of the diagnostic installation $T(\theta)$, which has been found in model experiments. Then the profile can be calculated by Abel inversion for $\theta(\rho)$. Both of the refraction techniques are employed yelding adequate results.

The discharge in deuterium has been measured at the pressures of 1 to 5 atm and the input UHF power of 10 to 40 kwt. The maximum electron concentration within these ranges varies from $2 \cdot 10^{15}$ cm^{-3} at high power and low pressure to 10^{17} cm^{-3} at the pressure of 4 to 5 atm and the input power of 10 to 20 kwt. The effective diameter of the discharge, that corresponds to the 10 % density level, increases from 6 to 20 mm almost linearly with the input power and somewhat decreases with the pressure growth.

The transmission signals with three and four minima (see Fig.3) have been observed for plasmas of a sufficiently large diameter (15 - 20 mm) at short wavelengths, when the beam width ($\Delta \simeq 6\lambda$) is significantly less than the plasma diameter. They correspond to a model of the plasma cylinder with step rise of density in the center region [1] .

Treatment of these signals with the second refraction technique has demonstrated that the profiles exibit a drastically increased density at the radius that constitutes nearly one third of the effective radius of the plasma. The distribution function of the density calculated from the curve (a) in Fig.3 is shown in Fig.4.

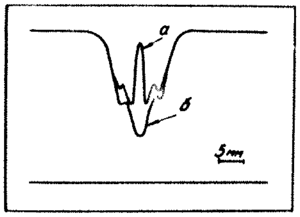

Fig.3 Signals of transmission with four and three minima

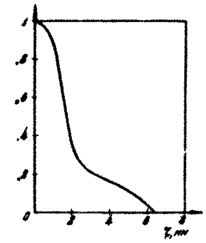

Fig.4 Calculated profile of density

The profiles, that are determined by the frequency dependence of the distance between the minima of the transmission signals, also exibit a marked rise in the density at the radius of the order of 40 to 50 % of the effective one. These results are in agreement with the proposed discharge model [2] , which suggests that there is a step rise in the profile of density near the plasma axis.

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