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MEASUREMENT OF THE COMPLEX TRANSMISSION COEFFICIENT IN SUBMILLIMETER DIAGNOSTICS OF THE MOVING PLASMA FILAMENT BY THE CONVERGING WAVE BEAM

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The short wavelength diagnostics of the moving plasma filamentary UHF discharge [1] under conditions of strong refraction is described. This diagnostics is based upon the measurement of the module and phase of the transmission coefficient for wave beam focused at the filament as a function of its impact parameter. The treatment of the experimental results is performed in a more accurate wave approach, taking into account real resolution of the diagnostic equipment [2], as distinct from one-ray approximation used previosly [3].

1. The diagnostic installation for measurement of the plasma complex transmittivity $g(\rho)=|g(\rho)|e^{-i\Psi(\rho)}$, when discharge crosses the probing submillimeter beam along the irregular trajectories, involves the geterodyne phasemeter, system for registration of the signals proportional to the module $|g|$ and phase Ψ and electro-optical device for measurement of the impact parameter ρ.

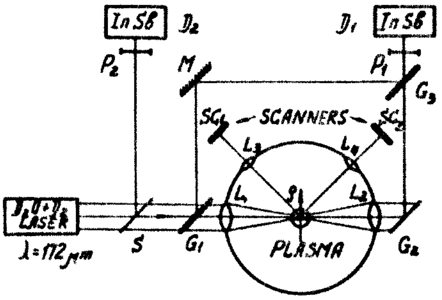

Fig. 1 Optical scheme of the experimental installation

The submillimeter laser on D_2O+D_2 [4], generating at the wavelength 172 μm two ortogonally polarised modes with a frequency shift of the order of 30 kc, was used as a source of radiation for phasemeter. The reference channel of phasemeter consists of the lavsan splitter S, mode mixer from the one-dimensional wire grid P_2 and detector D_2. Two-beam interferometer with an ortogonal polarization of beams works as a signal channel of phasemeter. Separation of polarizations is produced by the one-dimensional wire grids G_1, G_2 and G_3. Oscillations are mixed at the output of the interferometer with the one-dimensional grid P_1 and detector D_1.

Radiation is registered with the n-InSb crystals cooled to 4.2 K. Laser beam is focused onto the axis of the discharge chamber with the teflon lenses L_1 and L_2. The diameter of the beam at the waist is about 1 - 1.5 mm along the length of 20 mm.

The signals with a beat frequency arise at the output of mixers as a result of interference between two parallel components of radiation, transmitted through the grids. The signal at the interferometer output (neglecting the constant terms) is of the form $|g(\rho)|\cdot\cos[\Omega t+\Psi(\rho)]$, i.e. the interferometer transfers the information about the amplitude of the transmitted wave and phase shift between the oscillations in the signal and reference channels onto the beat frequency Ω. Narrow bandwidth amplifier with the linear detector was used to select the signal, proportional to the module of transmittivity. Phase Ψ was measured by a fast "phase-voltage" converter [5] providing the single-valued readings of the phase shift between oscillations in signal (D_1) and reference (D_2) channels up to 8π (accuracy-1%).

The device for selecting the suitable plane of the transverse probing and fast registration of the impact parameter was an opto-electronic system based on the semiconductor scanners. The diminished images of the plasma discharge were projected with the lenses L_3 and L_4 onto the scanners SC_1 and SC_2 (Fig.1). They converted images into the electrical signals used to form the pulses corresponding to the centers of images. These pulses were used to start the sweep and brightness modulation of the double-beam storage oscilloscope, which registered the signals $|g(\rho)|$ and $\Psi(\rho)$. Pulses formation was produced in such a manner, that time distance between the moments of sweep beginning and brilliance modulation was proportional to the impact parameter ρ . Measurements of ρ were performed every 200 μs ; plasma discharge crossed the beam at 20-40 ms. Typical oscillograms of the module and phase of the transmitted signal registered in the course of a single passage of plasma across the beam are presented in Fig.2.

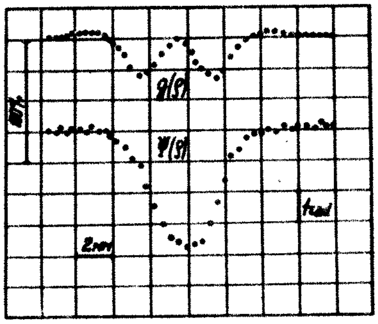

Fig.2 Module (upper curve) and phase of the transmitted signal. D_2 pressure P= 1.8 ata; input UHF power W=9.8 kwt

2. Data processing is done by the numerical solution of the integral convolution equation (7) and Abel equation (3) (see [2]), which give the relationship between the radial distribution of the complex dielectric permittivity and measured functions $|g(\rho)|$ and $\Psi(\rho)$. An apparatus function of the diagnostic installation was measured by a 0.5 mm slit. It has approximately Gaussian form $K(\rho-y)=\sqrt{D+iC}\,\exp[-\frac{1}{2}(D+iC)(\rho-y)^2]$, where D = 3.8 mm^{-2} and C =-1 mm^{-2} . For a sufficiently narrow wave beam eq.(7) can be reduced to a pair of differential equations of second order relating function $\Psi(\rho)$ to $\Phi(y)$ and $g(\rho)$ to $\Theta(y)$ [2] . An example of density profile calculations for one of the plasma regimes is shown in Fig.3.

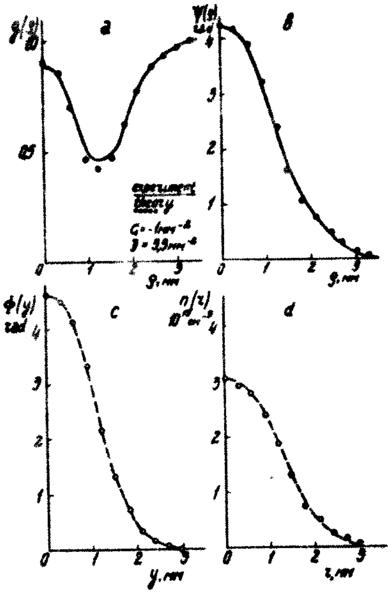

Fig.3 Determination of the electron density profile (P=2 ata, W=6.8 kwt); a) and b) - module and phase of the transmittivity; c)-ray phase; d)-density profile

Apparatus function was excluded in a narrow beam approximation. Abel equation (3) was solved by the expansion technique using Meler integrals.

This method with due regard to real resolution of the diagnostic installation provides a possibility for transverse probing at the near-critical frequencies to raise the sensitivity and accuracy while measuring the radial distribution of the plasma permittivity.

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