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EXPERIMENTAL AND THEORETICAL STUDY OF PLASMA ANTENNA *)

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A non-invasive voltage standing wave ratio (VSWR) method for electron density measurement in the surface layer of mercury plasma glow discharge is studied. The method is based on determination of resonant frequencies between the plasma layer and the radio frequency signal by the unit standing wave ratio (SWR) [1] combined with the calculation of the dielectric permittivity and Langmuir frequency. A simplified fluid plasma model is developed and validated by emission spectroscopy for comparing the method's results. The method can be used for measuring electron number density in plasma volume.

To validate the proposed optical emission spectroscopy (OES) method [2] in combination with plasma modeling based on a hydrodynamic model. The study was performed using plasma generated in a mercury lamp with a diameter of 24 mm with an interelectrode distance of 36 cm at a pressure of 60 Pa. A RF-frequency voltage source and a VSWR meter (SARK-110 antenna analyzer) were connected to the tube using metal connectors with a length of $l_{metal} =$ 60 cm for an average electron energy in the range from 4 to 10 W. The glow discharge was ignited with a ballast resistor with a resistance of 3.52 kOhm, the voltage on the resistor was 572 V, the voltage on the plasma tube was 62 V. Thus, the maximum discharge power is estimated at approximately 10 W. The VSWR method is based on determining the resonant frequencies between the plasma layer and the high-frequency signal. The basis of the VSWR can be described by the relations (1):

$$\omega_{res} = \frac{\omega_p}{\sqrt{1+\varepsilon_r}}, \quad n_e = \frac{8\pi^2 \varepsilon_0 m_e}{e^2} f_{res}^2, \tag{1}$$

where ω_{res} is the resonant frequency, ω_p is the plasma frequency, ε_r is the relative permittivity of the discharge tube, n_e is the plasma density, $f_{res} = \omega_{res}/2\pi$ is the resonant frequency of standing waves.

To validate the experimental data, a simplified numerical model of plasma was developed using the COMSOL Multiphysics software. The model is considered the main elementary processes: ionization by direct electron impact and stepwise ionization, recombination of charged particles, excitation and deactivation of excited states, and allows calculating the spatial distributions of the concentration of charged particles, excited atoms and electron temperature.

Comparison of the results obtained by VSWR and OES showed good agreement between the experimental data and numerical models. The study showed that the VSWR method can be effectively used to measure the electron density in plasma antennas.

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