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HOMOGENOUS DENSE PLASMA FLUXES FORMATION FROM HIGH FREQUENCY ECR DISCHARGE

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Abstract

Formation of ion beams with wide apertures and current at level of tens and hundreds Amperes is required in a wide range of studies. Usually plasmas of arc or high-frequency discharges are used for such applications. In this paper the possibility of using of an ECR discharge sustained by powerful millimetre wave gyrotron radiation for these purposes is considered. A high plasma density is required to solve the problem of obtaining high values of ion beam current density. The use of gyrotron as a source of millimetre wave radiation in the ECR discharge makes it possible to obtain plasma with high density and high ionization rate, close to 100%. Earlier at the IAP RAS the possibility of dense plasma fluxes production on the basis of ECR discharge in a magnetic field of one solenoid was demonstrated. In this paper, the characteristics of the outgoing plasma flux (density and homogeneity) were investigated. Estimations of the prospects for using such systems for high-current ion beams formation are presented.

INTRODUCTION

Electron-cyclotron resonance (ECR) ion sources are one of the most widespread types of systems for producing ion beams. Previous experiments in IAP RAS were aimed at creating sources of multiply charged ions with a high plasma density in such magnetic field configurations as open magnetic trap and cusp. It was demonstrated that in such systems the electron concentration can reach values 10^{13} cm^{-3}, electron temperature at the level of 100 eV, and the ion beam current has record values up to 500 mA [1-3]. System which is based on the ECR discharge in one solenoid magnetic fields has prospects for producing sources of singly charged ions and formation of plasma fluxes with large apertures as an alternative to existing magnetic plasma confinement systems. This paper is con-cerned with an experimental investigation the transversal plasma fluxes distribution and measurements of plasma pa-rameters obtained in the ECR discharge in a single mag-netic coil sustained by a powerful millimeter-wave gyro-tron radiation.

EXPERIMENTAL RESULTS

The experiments were carried out at the IAP RAS on fa-cility SMIS 37 (see Fig. 1), partly modified the single coil studies. Gyrotron radiation at the frequency of 37.5 GHz with the power up to 100 kW and pulse duration up to 1.5 ms was used for electron heating and discharge ignition. The microwave radiation is launched through a quasiopti-cal system into the discharge chamber with diameter of 68 mm and 250 mm long placed inside pulsed magnetic coil. Magnetic field in the center of the coil varies from 1 to 4 T. ECR value of magnetic field for the frequency of exter-nal electromagnetic radiation 37.5 GHz is 1.34 T.

The operating gas (hydrogen) was inlet into the dis-charge chamber in pulsed mode along the axis of the mag netic system through a gas-entry system integrated into the electrodynamic system for microwave radiation injection. To control neutral gas inlet the pressure in the gas buffer chamber above the gas valve was varied from 0.25 atm. up

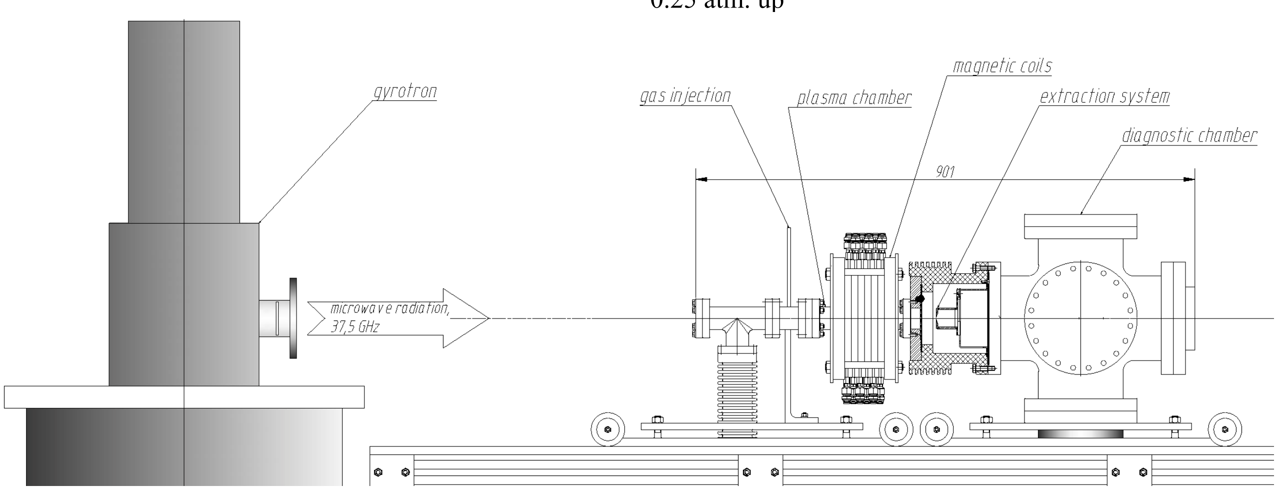

Figure 1: The experimental facility SMIS 37.

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to 0.92 atm. The first experiments were aimed to determine breakdown conditions in this system. At the first step experiments with a constant neutral gas injection were performed to study the possibility of the discharge ignition and to determine a threshold microwave power for it at various pressures. Breakdown curve plotted according to the experimental data is shown in Fig. 2. Also it was demonstrated that discharge could be realized only if maximum magnetic field in the chamber is above ECR value.

The second part of the experiments was aimed to measurements of transverse profile of the plasma flux outgoing along the axis of magnetic system. During the experiments, the parameters of the system were optimized in such a way as to achieve the most homogeneous plasma flux radial distribution. The measurements were carried out using a Langmuir probe moved both in the radial and in the axial directions. As a result of experiments, the plasma flux profiles were measured at various distances from the center of the magnetic coil.

Example of the radial plasma flux distribution at the distances from the center of the magnetic coil of 31 cm, 21 cm, 12 cm, 10 cm and 8 cm at gyrotron power Q = 100 kW and at the value of magnetic field at the center of the probe $B_c = 2.16$ T is shown in Fig. 3. The vertical axis represents the density of the plasma flux, the horizontal axis represents the radial coordinate.

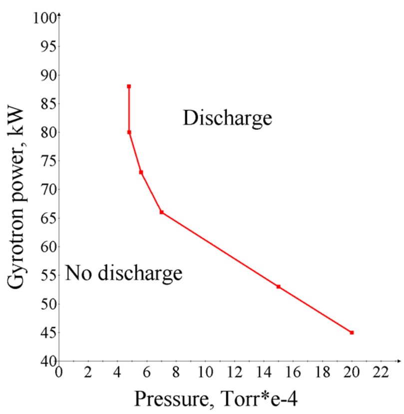

Figure 2: Breakdown threshold curve for hydrogen

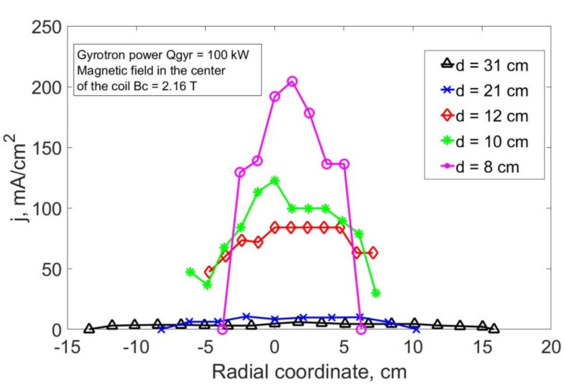

Figure 3: Plasma flux distribution in a cross section, d-distance between the probe and the centre of the coil.

The third part of the experiments was devoted to measuring the plasma parameters obtained as a result of the ECR discharge in the magnetic field of a single solenoid. During the experiments, the plasma density was measured at a distance of 31 cm from the center of the magnetic coil at different gyrotron powers, result is presented in Fig. 4. It is clearly seen from the dependence that the plasma density in the discharge increases with the microwave power and reach values $10^{10} cm^{-3}$. Measurements of the plasma density at various magnetic fields were also done. It is clear from the Fig. 5 that plasma density increases with the growth of the magnetic field.

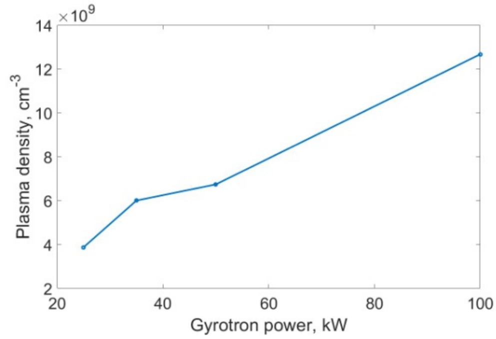

Figure 4: Dependence of plasma density on the gyrotron power, d = 31 cm

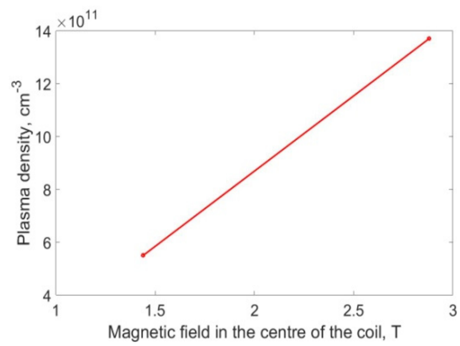

Figure 5: Dependence of plasma density on magnetic field.

The final part of the experiments was concerned with optimization of system parameters on purpose to obtain the maximum electron density in the discharge and to measure the current density of the ion beam. The maximum electron density in the center of the magnetic coil obtained in the experiments was $Ne_{max} = 2 \cdot 10^{13} cm^{-3}$, and the electron temperature was in the range $10 - 30\ eV$. The ion beam current reached 15 mA through a hole with a diameter of 1 mm, which corresponds to the ion current density of $j_{max} \approx 1.5\ A/cm^2$.

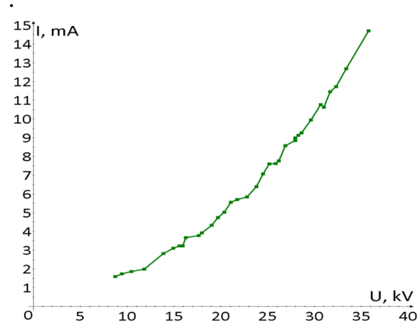

Figure 6: Ion beam current dependence on the extraction voltage.

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CONCLUSION

Experimental results obtained during the investigation of ECR discharge in one solenoid magnetic field demonstrated the possibility of producing wide-aperture plasma fluxes with a homogeneous radial distribution at different distances from the magnetic coil. It was also demonstrated that the plasma density increases with gyrotron power and magnetic field. As a result of the experiment parameters optimization plasma density of $\mathrm{Ne_{max}} = 10^{13}\mathrm{cm^{-3}}$ and the electron temperature at the level of $\mathrm{Te} \approx 10 - 30$ eV were obtained. Density of ion current extracted through the 1mm hole reached record values $\mathrm{j_{max}} \approx 1.5\ \mathrm{A/cm^2}$. Thus, these experimental results demonstrate that such system has clear prospects for producing of a wide-aperture plasma fluxes with high current density.

ACKNOWLEDGEMENTS

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