Study of Coupling of 2.45 GHz Electromagnetic Waves with Dense Plasma in Strong Magnetic Field

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Helicon discharge is one of the most suitable way for production of high-density low-temperature plasma. Helicon plasma sources, operating in the MHz frequency range and respectively low magnetic fields (0.01-0.1 T), capable to create plasma with density up to 10^{13} cm^{-3}. At the same time, next generation of linear plasma facilities for fusion requires production of plasma with density above this limit. Theoretical studies predict that such increasing of density can be achieved by application of powerful microwave sources of GHz range frequency. The paper presents first results of studies of coupling of 2.45 GHz radiation with low-temperature plasma column, created in strong magnetic field by external plasma source. Coupling efficiency (reflected-to-direct wave ratio) were measured for several types of antennas, and values of magnetic field and plasma density.

1. Experimental setup

Interaction of EM waves with plasma were studied on the GOL-3 facility, that represents 8-meter long solenoid with a magnetic field arranged from 0.3 to 4.5 T. Arc plasma gun, attached at the one end of the facility, produces plasma column with density up to 10^{14}cm^{-3}. Diameter of the plasma can be varied from 0.5 to 4 cm by changing of relation between magnetic fields on the plasma gun and in the solenoid.

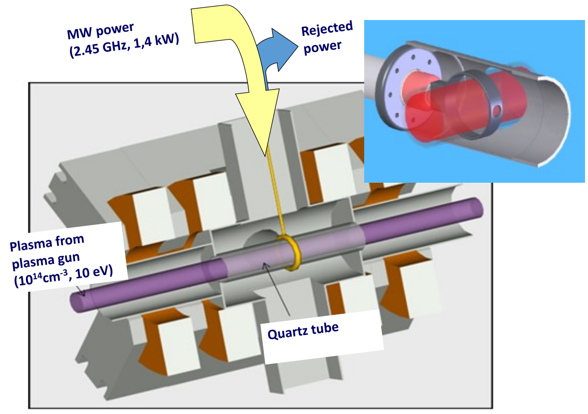

Fig.1 Configuration of the experiment. In the inset - screened ring antenna

Experimental study of EM wave interaction with plasma was performed in the special cell in the center of the facility. Microwave power was produced by 1.4 kW household 2.45 GHz magnetron, mounted in the R26 square waveguide. Magnetron is separated from antenna unit by ferromagnetic isolator to avoid influence of coupling efficiency to generation of microwave power. Direct and reflected power are measured by DD112 detectors from S-Team lab, mounted in the waveguide after isolator. Magnetron unit is connected to antenna by coaxial transfer line via specially designed waveguide-coaxial coupling unit.

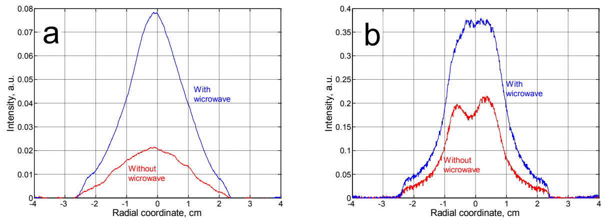

Fig.2 Profiles of plasma radiation in visible range with and without microwave power; a – magnetic field 0.3 T, b – magnetic field 1.7 T.

2. Results of experiments

Several types of antennas, including ring and horseshoe antenna with capacitive coupling, and screened ring antenna (fig.1, inset) were studied in experiments. Screened ring demonstrated best coupling efficiency – up to 30% for plasma density 10^{14} cm^{-3} and more than 60% for low-density (below 10^{14} cm^{-3}) plasma. Influence of microwave power to plasma was indentified on the images of plasma radiation taken by CCD camera. Profiles of plasma radiation across the plasma column are shown in Fig.4 for magnetic field 0.3 T (Fig. 3a) and 1.7 T (Fig.3b). Despite captured microwave power sufficiently less than power, released in the plasma gun, microwave cause valuable increasing of light emission and also transformation of the radial profile of emission.

3. Acknowledgments

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