

Turbulent Fluctuations of Plasma Injected in Open Magnetic Trap from Independent UHF Source

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We investigate on the linear plasma device – OMT-2 the methods of plasma heating by electromagnetic waves, interaction of electromagnetic waves with magnetoactive plasma and plasma turbulence and transport processes in the trap. We use ultra-high frequency (UHF) contactless method to fill the open magnetic trap by plasma. We have proposed new method of open magnetic trap filling with plasma – plasma is injected in the trap along the magnetic field from independent stationary UHF source. The source is located outside the trap and plasma formation in it takes place in strongly non-uniform magnetic field, in electron cyclotron resonance (ECR) regime by means of the UHF power. In this paper we present the physical characteristics of plasma accumulated in the trap and the results of investigation of plasma turbulent fluctuations.

1. Introduction

Different methods of filling open magnetic trap with plasma are used in various experiments. From all existing methods contactless methods are used most frequently. Among these methods lately UHF methods of plasma accumulation in a trap were most widely spread. As a rule, plasma formation takes place in the trap itself in ECR regime (see e.g. [1-5]). However, this method has various disadvantages. In particular, the range of magnetic field variation in the trap is strictly limited by the existence of UHF discharge in the magnetic field. With change of magnetic field discharge regime and plasma parameters change and the most important is that "hot" region of UHF wave absorption in plasma is in the trap itself, which is often undesirable. Therefore, application of independent plasma source with controllable parameters which is far from trap and from which the "target" plasma is injected in the trap is of great interest. The present work deals with this problem. Independent stationary UHF plasma source is described, its characteristics and possibility of filling open magnetic trap with uniform field by plasma injected from the source as well as properties of plasma and its turbulent characteristics in the trap are investigated.

2. Experimental set-up

Experiments were carried out on a stationary installation, the diagram of which is presented in Fig.1. It consists of two main parts: an independent UHF plasma source and open magnetic trap, in which plasma is injected.

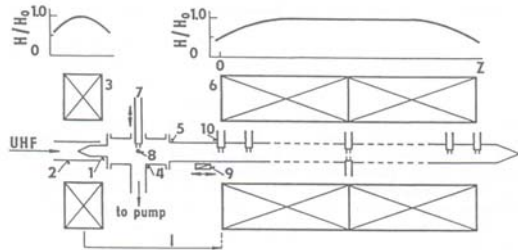


Fig.1 The scheme of experimental setup.

1 -discharge chamber, 2 – rectangular waveguide,
3 – coil forming the magnetic field in source,
4 – diagnostic section, 5 – volume under investigation,
6 - solenoid, 7,10 – double electric probes,
8,9 - semiconducting light sensors.

In the UHF source plasma is formed in a quartz tube 1 with inner diameter 2.6 cm and length of 10 cm. Stationary UHF power (2400 MHz, 150 W) is supplied to the discharge chamber by standard rectangular waveguide 2 in which TE_{01} is excited. The discharge chamber with the waveguide is located into the stationary magnetic field, created by a short coil 3. Magnetic field in the center of the coil can be continuously changed from zero to the maximum value of 2000 Oe.

The discharge chamber of the UHF plasma source is connected with the cylindrical section 4, made of stainless steel and being a diagnostic section [4].

The investigation volume 5 with plasma is placed into the stationary magnetic field, created by solenoid 6 with inner diameter of 19.5 cm and the length of 90 cm. By solenoid we obtain the uniform magnetic field, as well as the field of mirror and multimirror configuration with controllable mirror ratio and also the trap with cusp configuration. The maximum field along the axis of the solenoid can be varied smoothly from zero to maximum value of 5000 Oe. The results presented in this paper deal with the plasma injection into the trap with uniform magnetic field.

The distance between UHF plasma source and main investigation volume (the trap) can be varied in the range $\ell = 30 - 90$ cm. In this experiments $\ell = 45$ cm. In the described experiments a glass tube with the inner diameter of 6 cm and the length of 90 cm has been used as investigation volume 5. During experiments in order to determine the conditions of discharge existence in the UHF plasma source semiconducting light sensor 8 has been used. This sensor records the plasma integral light emission. Besides, injected plasma parameters - density of charged particles, temperature of electrons and their distribution over the radius - were measured by movable double electric probe 7.

In order to determine the efficiency of filling the magnetic trap with plasma and study its

characteristics in the trap (density and temperature of electrons) semiconducting light sensor 9 moving along the chamber 5 and double electric probes 10 introduced on the chamber axis in 8 locations with 7.5 cm step were used. In our case plasma is weakly ionized. As it is well known integral emission of plasma depends on its particle density. We have verified this experimentally. At the same time, electric probes can also be used for local determination of the spectrum of plasma oscillations.

During experiments described above Argon and Helium were used as working gas. Plasma in the UHF source was created at working gas pressure in the range 10^{-5} - 10^{-2} Torr.

3. Results and discussion

1) UHF plasma source - discharge in the source can be obtained in the investigated range of working gas pressure by means of stationary UHF power only if the condition of electron cyclotron resonance is fulfilled in the region of UHF field interaction with plasma, $\omega_0 = \omega_{He} = eH/mc$, i.e. when magnetic field equals to that of cyclotron ($H_c = 850$ Oe).

After the appearance of discharge plasma exists even under the change of magnetic field in certain limits the value of which depends on the pressure of neutral gas and UHF power supplied to plasma. As experiments show, at low pressure of gas plasma exists at magnetic fields not significantly different from cyclotron field. With increase of pressure the region of discharge existence broadens significantly towards the magnetic fields less than cyclotron. This is in good agreement with the results of investigations of UHF discharge in the magnetic field (see e.g. [1]). In this region UHF power absorption is determined by linear transformation of the wave in the upper hybrid resonance. The measurements by double electric probe 7 have shown that by changing supplied UHF power, neutral gas pressure and magnetic field of coil 3 one can change in wide range the density of plasma injected from the source. Under our experimental conditions plasma density can be changed from 10^8 to 10^{12} cm⁻³ with plasma electron temperature $T_e = 2 - 3$ eV. These changes are quite controllable and well reproducible.

2) Plasma injection in magnetic trap - plasma with above given parameters has been injected from UHF source into uniform magnetic field and magnetic trap of mirror configuration formed by a solenoid 6 (Fig.1). Filling of open magnetic trap with plasma has been studied experimentally in wide range of parameters of the injected plasma, neutral gas pressure, magnetic field strength in the trap and also the distance between plasma source and solenoid. Typical results of experimental determination of the efficiency of open magnetic trap filling by plasma under different pressure are presented on Fig.2 (1 - $p = 2,3 \cdot 10^{-4}$ Torr;

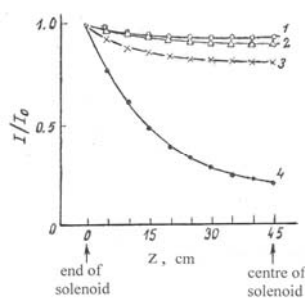


Fig.2

2 - $p=4,6 \cdot 10^{-4}$ Torr; 3 - $p=7,6 \cdot 10^{-4}$ Torr; 4 - $p=2,3 \cdot 10^{-3}$ Torr) .

Our experiments showed that for pressure $p < 5 \cdot 10^{-3}$ Torr, magnetic field in the trap $H_t < 400$ Oe and distance between the plasma source and solenoid $\ell < 80$ cm the filling of the trap is very effective and rather quiescent plasma with controllable density within the range $10^8 - 10^{12} \text{ cm}^{-3}$ and temperature 2 - 3 eV is accumulated in the trap.

3) Turbulent characteristics of plasma in magnetic trap - under the above mentioned

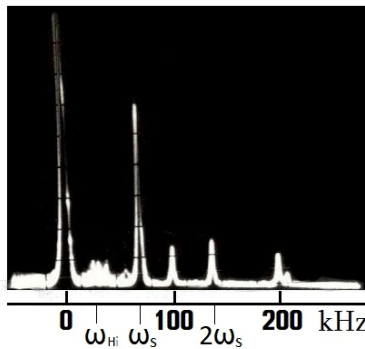


Fig.3

experimental conditions we have not found any noticeable turbulent fluctuations of neither ion saturation current, nor floating potential.

On the other hand we found that near the UHF plasma source and also in the trap first and second harmonics of ion sound wave together with ion cyclotron oscillations are reliably detected (see the Fig.3).

4. Conclusion

The presented experimental results allow to conclude that the method of magnetic trap filling with plasma proposed by us allows to accumulate quiescent target plasma in open magnetic trap.

Acknowledgments

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