MULTISLIT ELECTROMAGNETIC TRAP “JUPITER 2M3”

O.A. Lavrent’ev, V.A. Maslov, , M.G. Nozdrachov, V.P. Oboznyj, S.A. Golyuk, N.A. Krutko

Institute of Plasma Physics, NSC Kharkov Institute of Physics and Technology, Kharkov, Ukraine, e-mail: lavr@ipp.kharkov.ua

With the purpose of plasma confinement improvement the reconstruction of a multislit electromagnetic trap «Jupiter 2M» is realized. The most acceptable variant of installation with three magnetic slits - «Jupiter 2M3» is chosen. By means of multielectrode probes the exact adjustment of electrostatic locking systems of magnetic slits is carried out. The planes of the locking system symmetry are located relatively the planes of a magnetic field symmetry in slits with accuracy ~ of 0.1 - 0.2 mm. Results of the first experiments on plasma accumulation and confinement in installation «Jupiter 2M3» are presented.

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The experimental researches of plasma accumulation, heating, confinement, spatial distributions of plasma parameters and the calculations of a magnetic field configuration in a multislit electromagnetic trap “Jupiter 2M” [1] have shown, that at plasma density less than $2{\cdot}10^{12}$ cm^{-3}, the region of the superseded magnetic field in the central part of the trap represents separate islets under magnetic slits along the axis of the trap. It was shown, that plasma density in the islets with the superseded magnetic field is higher than in the central part of the trap, where plasma is magnetized [2].

With the purpose of improvement of plasma parameters, the decision on reconstruction of magnetic system was undertaken so that the volume of the superseded field was located at the centre of a trap, and the relations of this volume to a complete volume and volume of movement of injected electrons were maximal. The calculations of various variants of magnetic system were carried out, and the most acceptable variant with three ring slits “Jupiter 2M3” was chosen. The complexity was that under the reconstruction the magnetic coils, the vacuum chamber, and other elements of the “Jupiter 2M” device were used.

Fig. 1 shows the magnetic field lines in "Jupiter 2M" and "Jupiter 2M3" installations, and the spatial volumes limited by fixed intensity of magnetic field (20 Gs, 40 Gs, 60 Gs) for magnetic field value in slits H_{sl} = 8.5 kGs. It is seen that the spherical-like volume of the superseded magnetic field of "Jupiter 2M3" installation is located at the centre of the trap. This volume is much exceeds the volume in the installation “Jupiter 2M”, especially at small density. The geometrical sizes of installation “Jupiter 2M3” (in brackets similar sizes for “Jupiter 2M” are specified):the length of magnetic system between axial holes 0.8 m (1.3 m), the diameter of a ring magnetic slit in the central part – 0.5 m (0.5 m), the diameter of axial apertures 0.028 m (0.026 m), the plasma volume inside the magnetic surface limiting volume of plasma accumulation ~ 24 l (50 l), the area of a surface limiting the volume of plasma accumulation ~ 1.3 m^2 (5 m^2).

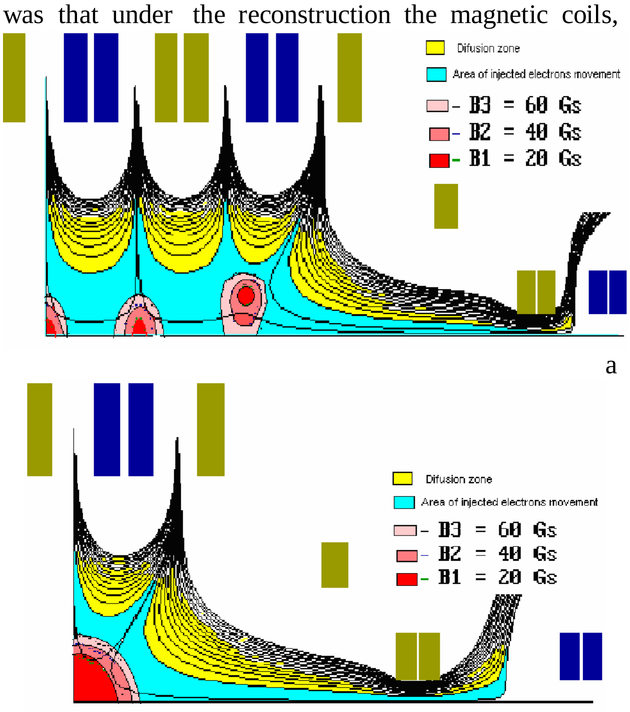

Fig. 1. Magnetic field lines and the spatial volumes limited by fixed intensity of magnetic field in (a)"Jupiter 2M" and (b) "Jupiter 2M3" installations

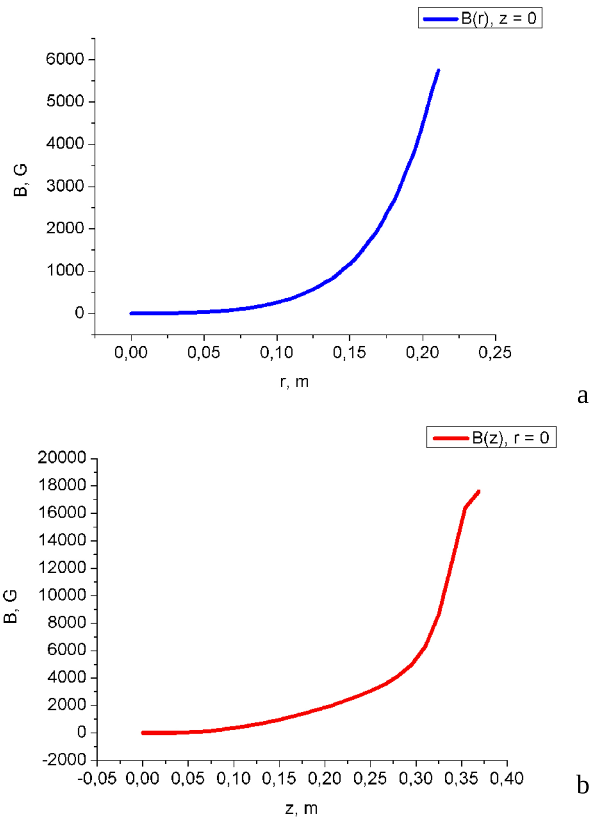

Fig. 2

In Fig. 2 the spatial dependences of magnetic field intensity on radius in the central ring slit (a) and along the axis of installation (b) of “Jupiter 2M3” are presented. The magnetic field intensity is equal to zero in the central part of the trap and increases to the periphery much steeper, than in the installation "Jupiter 2M".

The important advantage of the new configuration is that the increase of the relation of the superseded magnetic field volume to the volume of circulation of injected electrons should result in the growth of factor of energy transfer from injected electrons in nonmagnetized plasma, and the increase of the relation of the superseded magnetic field volume to the entire plasma volume will allow to increase the particles life time. The almost spherical form of the nonmagnetized plasma region, will probably allow to carry out spherical focusing particles, and plasma density increase near the centre of the trap.

In an electromagnetic trap the increased requirements to an arrangement of electrostatic locking system in magnetic slits are made. The width of a diffusion zone in a ring magnetic slit is 2 mm, therefore the plane of symmetry of magnetic slits’ locking system should coincide with high accuracy with the plane of the magnetic field symmetry in a slit. The displacements of the central plane of electrostatic system in each slit were determined from the results of calculations. According to these calculations the blocks of electrostatic locking system in every magnetic slit were displaced.

The exact adjustment was made with the help of multielectrode probes disposed through 120^0 along every anodic slit. The probe represented five isolated plates, assembled in a package with thickness of each 4 mm. The width of one plate 0.5 mm. The energy of injected electrons and intensity of magnetic field in a slit were selected so that Larmor electron radius in a slit was approximately equal to the half-width of the plate. By measuring the electron current to every plate of probes, the electrostatic system was displaced with the help of adjusting screws in such a way that the maximum of the current was registered by the central plate. Thus it was possible to fix the planes of symmetry of the locking system relatively to the plane of symmetry of the magnetic field in slits with accuracy 0.1- 0.2 mm.

Fig. 3 shows the oscillograms of magnetic field pulse (1), the current of electron injection (2), the ion losses through the all three ring magnetic slits (3), the electron losses to the limiting diaphragms (4), the signal of the microwave interferometer phase shift (5) which is proportional to the linear plasma density, and the plasma potential (6). In fig. 4 the time dependence of the plasma density found as a result of the microwave interferometer oscillogram processing is presented.

The negative plasma potential in an electromagnetic trap is installed self-consistently for alignment of the ion losses with the losses of electrons. This is well visible from Fig. 3 where the plasma potential (6): (i) decreases with growth of electron losses (4), giving an increase of ions losses (3), and (ii) increases with growth of plasma density, Fig. 4, when electron losses decrease, what results in the reduction of ions losses.

The reduction of electron and ion losses from the trap (Fig. 3) with growth of plasma density (Fig. 4) is the result of replacement of the magnetic field in the central region of the trap with growth of plasma density. The collisions of particles in the volume of the superseded magnetic field do not provoke electron losses across a magnetic field. Only particle collisions in a thin (of the order of Larmor radius) transitional layer allow electrons to pass in diffusion volume. With growth of plasma density the volume of the superseded magnetic field increases, and the width of a Larmor layer decreases because of an increase of the magnetic field intensity at the border of transitional layer. This effect does also cause the reduction of particles losses with growing plasma density.

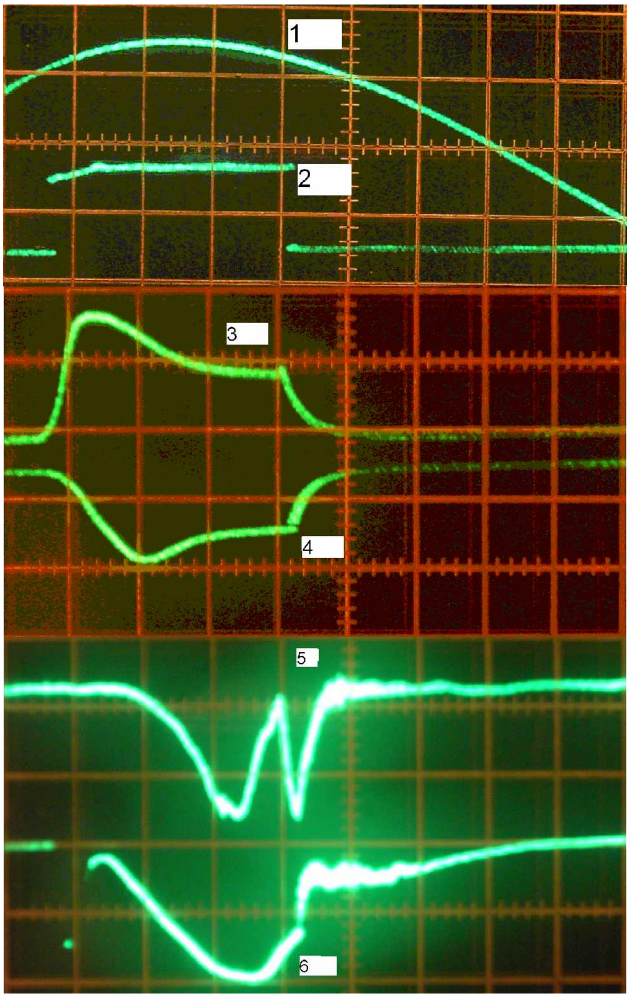

Fig. 3. Temporary sweeping 2 ms/div

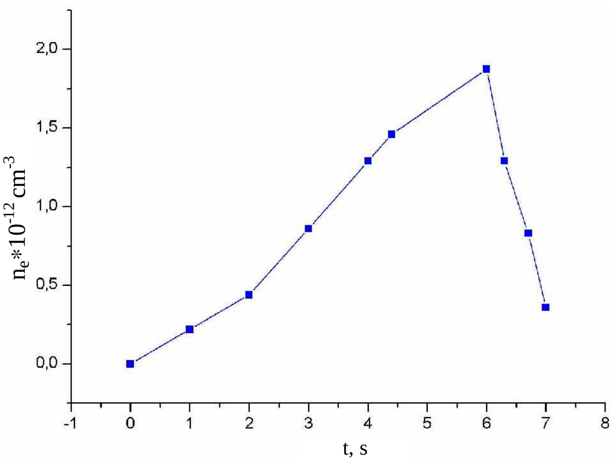

Fig. 4

Similar effect should be observed also with an increase of the sizes of electromagnetic trap.

For determination of the character of electrons cross-transfer through the magnetic field, the dependence was found of the electron cross-field flux on the plasma density. The obtained dependences were compared with the ones calculated in the assumption of classical electron diffusion. In Fig. 5 are presented experimentally the

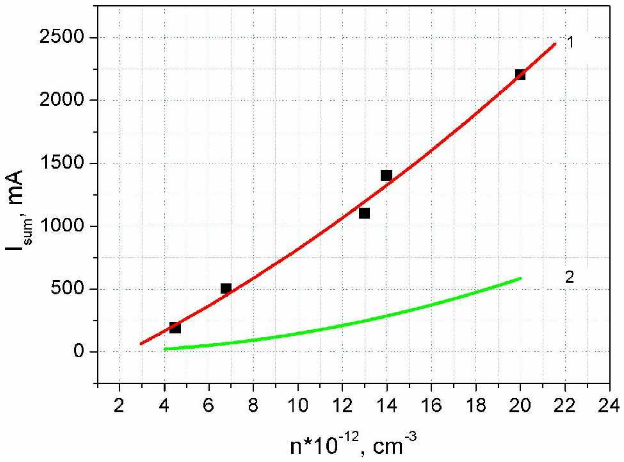

Fig. 5

measured dependence of electron losses across the magnetic field on plasma density (1) and the theoretical dependence under the assumption of classical electron diffusion (2). The experimental dependence of the electron flux on the plasma density is qualitatively similar to the theoretical dependence, but the experimental flux exceeds approximately 3 times the theoretical value. Such a rather small difference can be caused by discrepancy of manufacturing the electrostatic locking system of magnetic slits and by the influence of the neutral gas incoming into the trap as a result of bombardment of surfaces by charged particles coming out from the plasma.

The particles life time in the trap, estimated from the ratio $\tau = N_e / I_{e\perp}$ is τ = 2 ms. Here N_e – is the number of particles in the trap, and $I_{e\perp}$ - is the cross- transfer flux of electrons.

REFERENCES

1. S.A. Vdovin, O.A. Lavrent'ev, V.A. Maslov, M.G. Nozdrachov, V.P. Oboznyj, N.N. Sappa. Plasma storage in the multislit electromagnetic trap "Jupiter 2M" // *Voprosy Atomnoj Nauki i Tekhniki. Series "Termoyadernyj Sintez"*. Moscow. 1989, N 3, p. 40-45 (in Russian).
2. O.A. Lavrent'ev, V.A. Maslov, S.V. Germanova, M.G. Nozdrachev, V.P. Oboznyi, B.O. Shevchuk, N.O. Skoryk. Electrons cross transfer in multislit electromagnetic trap "Jupiter 2M" // *Problems of Atomic Science and Technology. Series "Plasma Physics" (11).* 2005, N 2, p.32-34 .

МНОГОЩЕЛЕВАЯ ЭЛЕКТРОМАГНИТНАЯ ЛОВУШКА «ЮПИТЕР 2М3»

О.А. Лаврентьев, В.А. Маслов, М.Г. Ноздрачов, В.П. Обозный, С.А. Голюк, Н.А. Крутько

С целью улучшения удержания плазмы проведена реконструкция многощелевой электромагнитной ловушки «Юпитер 2М». Выбран наиболее приемлемый вариант установки с тремя магнитными щелями – «Юпитер 2М3». С помощью многоламельных зондов проведена точная юстировка системы электростатического запирания магнитных щелей. Плоскости симметрии запирающей системы выставлены относительно плоскостей симметрии магнитного поля в щелях с точностью ~ 0.1 - 0.2 мм. Приведены результаты первых экспериментов по накоплению и удержанию плазмы в установке «Юпитер 2М3».

БАГАТОЩІЛИННА ЕЛЕКТРОМАГНІТНА ПАСТКА «ЮПІТЕР 2М3»

О.О. Лаврентьєв, В.О. Маслов, М.Г. Ноздрачов, В.П. Обозний, С.А. Голюк, Н.О. Крутько

З метою покращення утримання плазми проведена реконструкція багатощілинної електромагнітної пастки «Юпітер 2М». Вибрано найбільш прийнятний варіант установки с трьома магнітними щілинами – «Юпітер 2М3». За допомогою багатоламельних зондів проведена точна юстировка системи електростатичного запирання магнітних щілин. Площини симетрії запираючої системи виставлені відносно площин симетрії магнітного поля в щілинах з точністю ~ 0.1 - 0.2 мм. Приведено результати перших експериментів по накопиченню та утриманню плазми в установці «Юпітер 2М3».