INFLUENCE OF END POTENTIAL PLATES ON PLASMA CONFINEMENT

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Hot target plasma was obtained in an open trap AMBAL-M from arc source located behind the mirror [1]. Longitudinal electron current in a plasma was found and investigated [2]. In paper [3] the model of longitudinal electron current generation and the model of effective electron heating were presented and discussed. In this paper, two processes concerning the electric field are considered. The first one is the effect of positive radial electric field at plasma periphery on transverse ion current. The second process under study is the influence of non-equilibrium radial electric field on longitudinal electric field and on current transfer.

The scheme of the experiment is shown in Fig. 1. The plasma is generated by the arc source [4] located behind the mirror. The source generates a narrow ring dense cold plasma jet. Another feature of the source is that the arc source electrode potentials form a non-equilibrium radial electric field (Fig. 2).

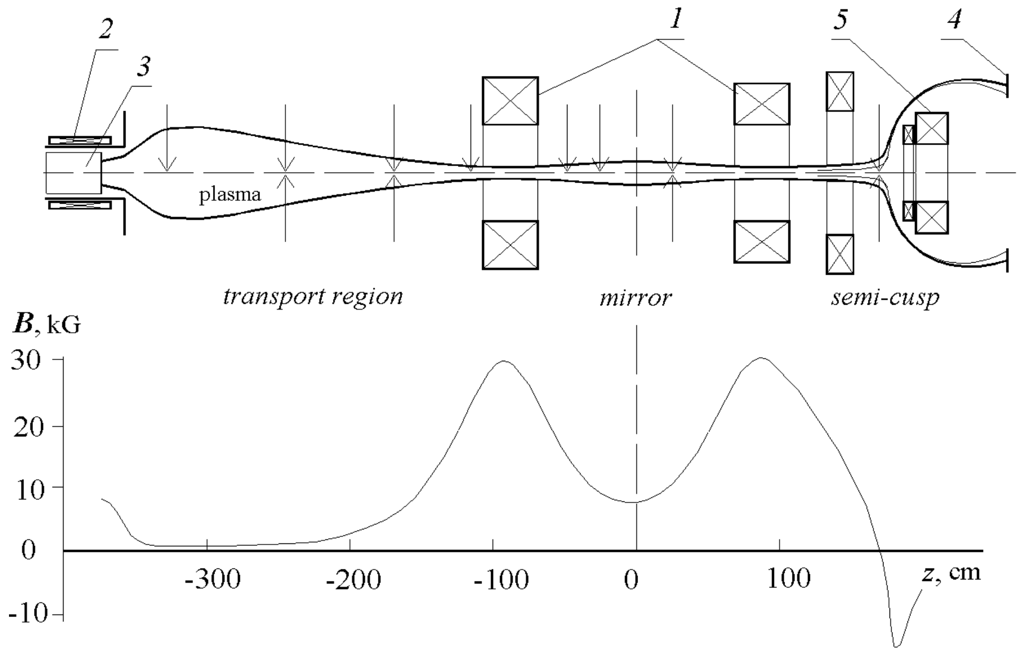

Fig. 1. Scheme of AMBAL-M experiments. 1— mirror coils, 2 — gun solenoid, 3 — plasma gun, 4 — plasma receiver, 5 — semi-cusp coil. The arrows of the cross sections where Langmuir probes were measured, from below — magnetic probes.

Assume that plasma is magnetized and it takes certain volume in the transporting region. Let us consider processes resulting in occurrence of transverse current through the surface which separates the body of plasma (contacting with the isolated gun at the left) from the outer volume of plasma (contacting with ground at the left). Choosing this surface is determined by the possibility to exclude the effect of shorting by conducting ends due to boundary conditions (the Simon's effect [5]). The longitudinal transfer from the inner volume through the right boundary, or the mirror entrance, depends on this transfer. The plasma density decreases outward ($\partial n/\partial r < 0$) and electric field is directed outward ($E_r > 0$) on this separating surface.

Nonambipolar transverse diffusion from ion-ion collisions was determined to result in marked ion current outward.

$$I_\perp^{dif} = \int 0.5\frac{e\rho_i^2}{\tau_{ii}}\frac{\partial n}{\partial r}2\pi r dz \propto S\frac{e v_{T_i}^2}{2\omega_{-i}^2\tau_{ii}}\frac{n}{L_\perp} = 280\text{A}.$$

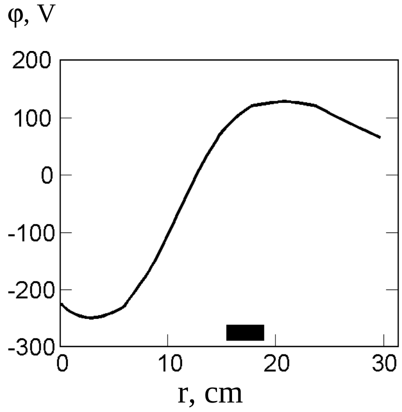

Fig. 2. Radial profile of plasma potential in the transport region (z = -243cm). Position of the gas-discharge channel is marked with the bold line segment.

The large value of current is due to a large area of the limiting surface (3.7×10^4 cm^2) and a large ratio of the Larmor radius to the density scale length $\rho_i/L_\perp \sim 1/4$. To illustrate the main reason of this strong transverse current, let us consider a rough model of the transporting region as a big mirror, and a gun generates a plasma jet of I_{pl} into it. Denote the plasma lifetime in the mirror as τ_{life}. Then, plasma density is $n = I_{pl}\tau_{life}/er^2L_{\backslash\backslash}$; taking into account that $\tau_{ii} \propto n^{-1}$, we may have the following relationship of the transverse current $I_\perp^{dif} \propto S\frac{n^2}{B^2 L_\perp} \propto I_{pl}^2\tau_{life}^2\frac{r}{L_\| L_\perp}$. The transporting region is intended for transportation of plasma jet into the main mirror. We accomplished the transportation of all the plasma jet generated by the gun by realization of collision subsonic flow [6]. The lifetime τ_{life} was equal to the flow time for the region with the ion velocity, and the longitudinal current was negligible. In this very case, through sufficiently fast arising of the magnetic field and ion heating into transverse degree of freedom [7] non-collision flow is realized in front of the throat, and the major part of the flow (~ 0.9÷0.95) becomes reflected by the increasing magnetic field. The plasma lifetime τ_{life} in the transporting region increases considerably from the previous case. As the longitudinal confinement of plasma is improved than the transverse losses become important.

As there is no limit for both longitudinal current (due to the contact with the system's end of conducting vacuum chamber), and Hall's current (due to plasma cylindricity), the conductivity current $j_\perp = \frac{\sigma_\perp}{1+(\omega_{ce}\tau_e)^2}E_\perp$ flows along the direction of the transverse electric field applied, and the current is suppressed significantly by strong magnetic field. The current is $I_\perp^E = \int\frac{\sigma_\perp E_\perp}{(\omega_{-e}\tau_e)^2}2\pi r dz \propto S\frac{e^2 n}{m\omega_{-e}^2\tau_e}E_\perp = 200$A.

Note that even small heterogeneity in conductivity of strongly magnetized plasma hinders the Hall's current flow and may cause a considerable increase in current along the transverse electric field. This effect was reported in [8] and then studied in [9].

To understand these two processes, let us advance a simple consideration. Ions are more mobile at the cross direction, and to keep them from going outward a negative radial electric field is to be established. We have a positive one, that, on the contrary, favours the transverse ion flow outward.

So, an ion current of about 1 kA flows across the magnetic field in the transporting region. As there can not be any runoff on the isolated gun, electrons flow out along the field into the mirror to provide quasineutrality.

The electron flow is also peculiar. Its peculiarity is related to the radial profile of the potential. 3 processes influence the longitudinal electric field formation: 1) potential decrease as the throat is approached that is typical for thermobarrier realization, 2) diffusion of potential nonequilibrium transverse profile as a result of transverse plasma diffusion, and 3) necessity of longitudinal electron current flow in low density plasma. They lead to formation of a longitudinal electric field in certain part of inner region. The field accelerates electrons as they leave the transporting area. A fast electron flow is formed, and these fast electrons transport the current in the mirror [3]. They go through the mirror almost collisionlessly, but they heat the trapped electrons effectively.

Conclusions

The transverse ion current has been found to be due to the following processes at plasma periphery in transporting region: 1) nonambipolar transverse diffusion from ion-ion collisions; 2) transverse current suppressed essentially by magnetic field in positive radial electric field from electron-ion collisions, which is increased due to conductivity fluctuations; 3) longitudinal current from the extending outward grounded frame of a solenoid to the anode of the gun.

Longitudinal electron current from transporting region into the mirror flows to provide quasineutrality. Non-equilibrium radial electric field in plasma favours the formation of the longitudinal electric field accelerating electrons at the output of the transporting region. The population of fast electrons is formed that transfer the current and heat the trapped electrons in mirror effectively.

One can see that the non-equilibrium radial electric field in plasma, given by the arc source electrode potentials has a determining effect on the favourable processes that take place. This fact shows the possibility of change in plasma confinement by control of potential radial profile using end potential electrodes.

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References

[1] T.D. Akhmetov *et al.*: Plasma Phys. Reports **23**, 911, 1997.

[2] T.D. Akhmetov *et al.*: Plasma Phys. Reports **24** (No. 11), 1998.

[3] S.Yu. Taskaev: Proc. *1998 ICPP & 25th EPS Conf. on Controlled Fusion and Plasma Physics*, ECA Vol. 22C (1998), p. 1265, Prague.

[4] G.I. Dimov *et al.*: Sov. J. Plasma Phys. **8**, 970, 1982.

[5] A. Simon: Phys. Rev. **100**, 1557, 1956.

[6] A.A. Kabantsev, V.G. Sokolov, S.Yu. Taskaev: Plasma Phys. Reports **21**, 735, 1995.

[7] A.A. Kabantsev, S.Yu. Taskaev: Sov. J. Plasma Phys. **18**, 635, 1992.

[8] S. Yoshikawa, D.J. Rose: Phys.Fluids. **5**, 334, 1962.

[9] B.B. Kadomsev: Reviews of Plasma Physics, Moscow: Gosatomizdat, **4**, 314, 1964.

[10] S.Yu. Taskaev: Plasma Phys. Reports **25** (No. 1), 1999.