PA06

PLASMA JET EMITTER: MECHANISM OF ION BEAM FORMATION WITH LOW EMITTANCE

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Abstract

Plasma emitter, which has been developed in Novosibirsk[1)] for diagnostics in Tokamak type plasma, is investigated conceptually in order to apply the source to a high intensity particle generation with long range focusing. The effect of thermodynamic cooling in the expansion of charged particles is examined as well as the effect of the restriction of radius in phase diagram of expanded collisionless plasma. The magnetic field is calculated for designing the geometric parameter of the plasma jet emitter.

1. Introduction

A charged particle emitter has been developed for high brightness ion and atomic beam formation by Davydenko et al.[1)]. The emitter can supply beams with high brightness because of significant reduction of the transverse ion temperature in the plasma. The normalized brightness of 1keV proton beam arrived in $3x10^8$ A/cm^2rad^2 by using a sophisticated extraction lens system. The source should be useful for applications which need a dense and focused beam. As a mechanism of the ion beam formation, the effect of thermodynamic cooling is expected to make the beam emittance lower. The cooling should be investigated to realize a new performance for low emittance beam, as well as optimization of the plasma electrodes and nozzle.

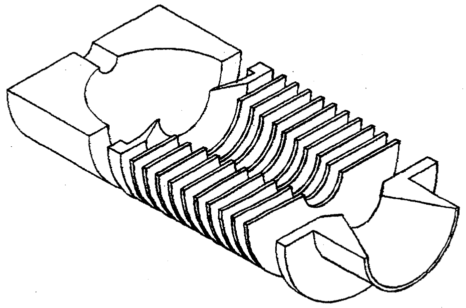

Fig. 1 Schematic drawing of Electrodes of the plasma emitter.

2. Ion beam formation for low emittance

The schematic drawing of the electrodes of the plasma emitter is shown in Fig. 1 for a half part divided by the section.

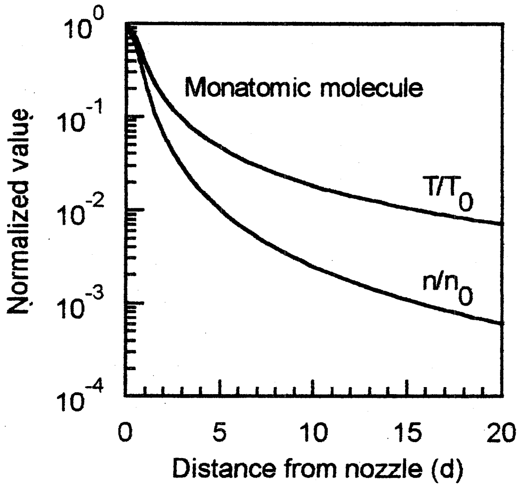

Fig. 3 Ideal thermodynamic cooling in a free jet.

The construction involves a cathode, an anode and floating electrodes between the biased electrodes. The discharge is excited just after the expansion of the gas generated by a specially designed pulse valve which is connected to the cathode. The beam formation has been explained originally by the effect of the expansion of collisionless plasma[1)]. The mechanisms of ion beam formation are drawn in Fig. 2 schematically. The transverse effective temperature of the ions is reduced by a factor X^2/d_0^2 (>>1), where X is the distance from nozzle to the extraction system, and d_0 is the diameter of particle quitting surface. In the figure, it is shown that the fluctuation of the transverse ion velocity dV_t is mainly depend on the solid angle of ion quitting surface.

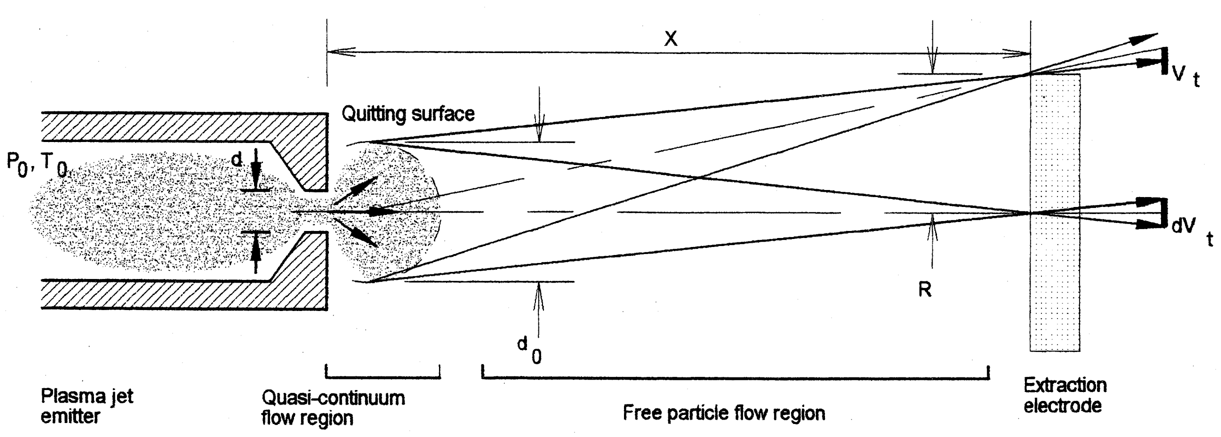

Fig. 2 Ion beam formation by the plasma emitter.

By considering quasi-continuum flow region at the nearest point to the aperture of the nozzle, thermodynamic cooling should come into effect. The ideal thermodynamic analysis of a neutral gas expansion gives changing of the temperature and the particle density as shown in Fig. 3[2]. This effect appears only for a dense region of the plasma. Experiments using small PIG source plasma, show the optimum gas pressure of less than 10 mTorr for intense beam extraction from the plasma. On this condition, the mean free pass of the ion is over 1 cm. Therefore, the discharge should be examined at about 50 mTorr gas pressure in order to realize the quasi-continuum flow. The study of the plasma formation for high pressure is needed by experimental and computational works for the effective cooling.

3. Calculation of the magnetic field

The magnetic field components H_z and H_r are calculated by using integral expressions for the field of the plasma emitter. The expressions are included complete elliptic integral. The values are evaluated by numerical integration. Iron pieces are taken into account by assuming infinite permeability and by representing the magnetization by Ampere's currents on the surface of these pieces. The boundary problems are solved directly by Gauss Jordanian elimination. The ratio of the values of magnetic field should be 8.0 for cathode region and anode region, according to the information from Novosibirsk. By some modification of the shape of the iron yoke, the ratio can be achieved in the final shape of the yoke shown in Fig. 4. The calculated fields are shown in Fig.5 for the axial strength H_z and the radial strength H_r.

4. Conclusion

In order to achieve the adiabatic cooling in the expanding plasma, dense discharge should be generated initially in the plasma emitter. A discharge in high magnetic field is one of the solutions for the requirement. The mechanism of ion beam formation of plasma jet emitter should be confirmed by experimental method and simulations.

Acknowledgement

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Reference

1) V.I. Davydenko, G.I. Dimov and G.V. Raslyakov, Sov. Phys. Dokl. 28(8), (1983) 685.

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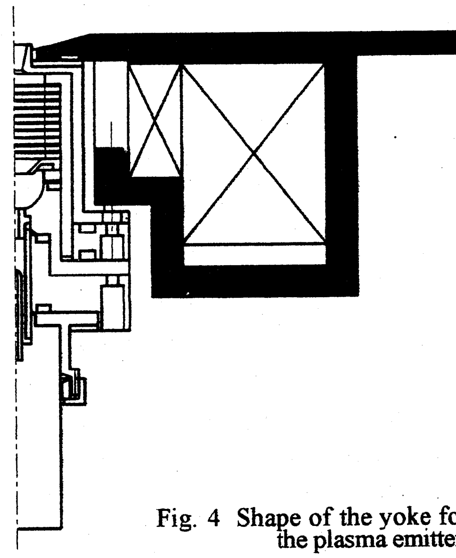

Fig. 4 Shape of the yoke for the plasma emitter.

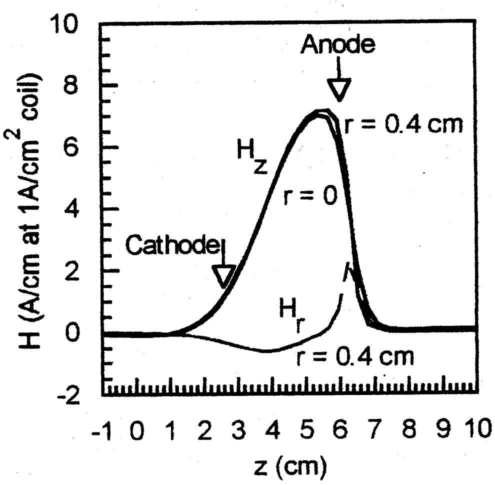

Fig. 5 Magnetic field in the plasma emitter.