UDC 533.9

HEAVY ION BEAM INJECTORS FOR THE PLASMA POTENTIAL AND ELECTRON TEMPERATURE MEASUREMENTS

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Introduction

Heavy ion beam probing is an important diagnostic to measure fusion plasma parameters – plasma potential (φ_{pl}), density (n_e), electron temperature profiles as well as their fluctuation.

The local electron temperature measurements by means of the heavy ion beams with different masses are based on the difference of ionization cross-section dependence on plasma electron temperature. These measurements, in particular, were carried out on ISTTOK by means of Xe^+ and Hg^+ ion beams [1]. Unfortunately this method did not allowed to lead ion beams of different masses and energies through fusion device plasma during the same pulse.

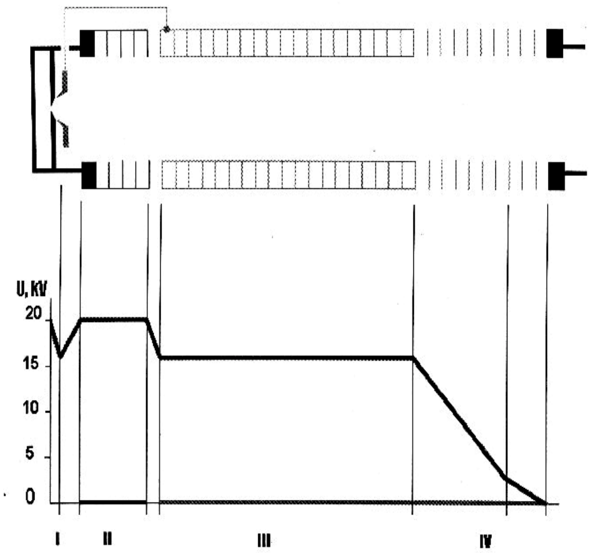
The first aim of the present work is to describe the using of a shaping-focusing system for primary ion beam [2]. This system includes quasipierce extracting system, three-electrode focusing lens, an acceleration tube and an active beam control system.

The second aim of this work is to propose the new types of double beam ion injectors for electron temperature measurements, based on elaborated shaping – focusing system.

Experimental results and discussion

Up to now in the HIBP ISTTOK diagnostic complex has been used an ion injector with plasma-arc ion source (Xe^+, Cs^+, Hg^+). An ion current on the exit of a three-electrode ion source extracting system is about 200 – 300 μA with an angular divergence 36 mrad. A cross section of ion beam in operation area (1300 mm from ion source) has defined by some apertures situated inside the injector. The secondary beam current to the detector plates is about 1 – 10 nA, if the primary beam current after apertures 1,5 **μA** [1]. This low level of a current signal leads to well-known difficulties of the secondary beam current detecting against a background of plasma loading noise. The increasing of the secondary beam current may be achieved by increasing of ion source exit current or by means of applying a focusing system.

A shaping – focusing system, based on a quasipierce extracting system, three-electrode focusing lens, a 32 electrode acceleration tube and an active beam control system was elaborated in IPP NSC KIPT and tested in CFN/IST with two types of ion sources: solid-state Cs thermo-ionic source and Xe plasma-arc ion source. This system with the potential distribution is presented in Fig.1.



I – quasipierce extracting gap
II – focusing electrode
III – flight space
IV – acceleration space with a distributed potential

Fig.1

The experimental optimization of these systems with a SIMION 3D code assistance allowed to obtain the following ion beam parameters:

	I_{beam}	E_{beam}	U_{ex}	$\varnothing_{beam}$	P_{inj}
Cs^+	16 μA	22 keV	3 kV	0,5/2 mm	$2 \cdot 10^{-6}$ Torr
Xe^+	40 μA	22 keV	3 kV	1,5/2 mm	10^{-5} Torr

The ion current / accelerating voltage dependences for plasma ion source are represented in Fig. 2.

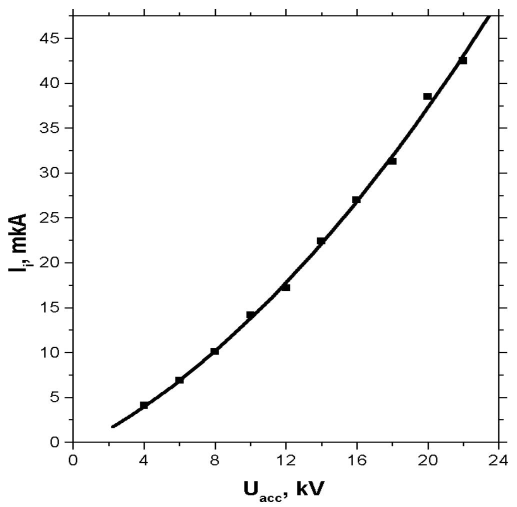


Fig.2

The design of the shaping-focusing system gives a possibility to change the thermoionic source to plasma ion source very easily in order to work with a broad spectrum of ion species.

Only Chaild-Lengmour law limits the ion current experimental value in bough extracting systems for given extracting gap without ion current losses on the focusing system electrodes.

For electron temperature measurements during the same pulse it is necessary to have two ion beams with different masses and energies along one trajectory. In order to lead two ion beams with different masses along one trajectory across the fusion device magnetic field it is necessary to have same Larmor radiuses in each point of the magnetic field:

$$\rho_{i1} = \rho_{i2}$$

where $\rho_i = 1{,}02 \cdot 10^{2} \dfrac{\sqrt{E_i \cdot \mu_i}}{H \cdot z_i}$

E_i – beam energy, μ_I – ion mass, z_i – ion charge, H - fusion device magnetic field.

$$E_{i2} = E_{i1} \frac{\mu_{i1}}{\mu_{i2}}$$

for Cs^+ and Tl^+ ion beams we have

$$E_{Tl} = E_{Cs} \frac{\mu_{Cs}}{\mu_{Tl}} = 0{,}65\, E_{Cs}$$

It is proposed two versions of double ion beam injector – ion beams, produced by these injectors will have different masses, energies and one trajectory in the fusion device magnetic field.

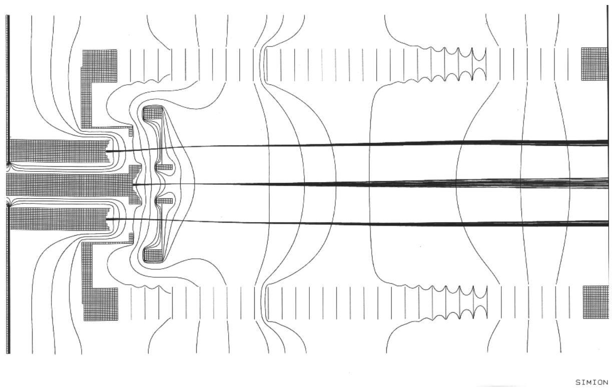


Fig.3

The first version is based on combination of two solid-state thermoionic emitters: a ring emitter and axial one with shaping-focusing system. This version allows carrying out local and simultaneous electron temperature measurements along defined trajectory (see Fig.3).

The second version is based on plasma-arc ion source and a shaping–focusing system with modulating power supply. This modulating power supply will give a possibility to have different beam energy levels with defined frequency, about 10^{3}– 10^4 Hz. In this system ion beams may be transported along defined trajectory several times during fusion device pulse.

Conclusion

This report represents two versions, which are very different from the points of view of technology and scientific realization. The first version has more difficult technical realization, but may be used to measure an electron temperature in each point and any time moment of plasma discharge. The second version is easier in technology realization, but in this case we can measure the electron temperature in different time moments. The time divergence of these measurements depends on frequency of a beam energy modulation. Now on base of these versions, the calculations and technical design of two injector types for ISTTOK (Lisbon, Portugal) are carried on in Institute of Plasma Physics (Kharkov, Ukraine). Calculations of these versions were carried out by means of SIMON 3D program. The beam energies are about 22 keV for Cs^+, Xe^+ and 14,4 keV for Tl^+, Hg^+. Calculations showed a possibility to obtain ion beam current about of several dozen microamperes.

Referenses

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2. I.S.Bondarenko, A.A.Chmyga et al. 3rd Europhysics Workshop, Budapest, June 18-19, 2000, p.14.