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PLASMA LENS
FOR MEV HEAVY ION BEAM FOCUSING

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The investigations of heavy ion beam focusing and governing that were carried out at the accelerator of heavy ions «UTI-1». are represented. The focusing of continuous ion beam of Mo^{+4} (0.9 MeV, 25 μA) by plasma lens (PL) was investigated. PL was produced by ion beam itself due to ionization processes at hydrogen leak-in (0.5—1cm^3/min) and confinement of electrons by applyed magnetic field of intensity 0.8 kOe. Beam focusing was estimated from measuring of beam diameter decreasing and corresponding current density increasing.

1. INTRODUCTION

For deep implantation technology and material modification the ion beams of metals and gases of more high energy are needed than in known ion sources with plasma lens using [1-6]. The application of plasma/electron cloud for focusing and governing of ion beams has been started from Gabor proposal [1], later in the development of Morozov's plasma optics [2] and has been widely investigated by Goncharov et al [3] both theoretically and experimentally. The attempts to apply such type of plasma lens for focusing of high-energy ion beam have been undertaken by Lefevre [4] for nuclear microprobe and Onishchenko et al [5,6] for intense proton beam of 5 Mev energy.

In NSC KIPT the source of multicharged heavy ions was created and electrostatic accelerator was put into operation to obtain ions of MeV-range energy [7]. By means of 2 quadrupolar lens initially strip beam of Mo^{+4} with cross-section 5 cm × 0.4 cm was transformed into cylindrical beam of diameter 2 cm. .

In this report the experimental investigations are represented on plasma lens using for focusing and governing of heavy and multicharged ions of high energy. The necessity of such ion beams manipulating is caused by its application in semiconductors technologies [8], surface hardening, radiation damage simulation, etc. In Sec. 2 the experimental setup is described. Sec 3 represents the results of continuous ion beam of Mo^{+4} (0.9 MeV, 25 μA) focusing by plasma lens that was produced at hydrogen leak-in (0.5—1 cm^3/min) and applying magnetic field of intensity 0.8 kOe. Beam focusing was evaluated from measuring of beam diameter decreasing (2 times) and corresponding current density increasing. In the last Sec. 4 the experimental results are summarized.

2. EXPERIMENTAL SETUP

The investigation of heavy ion beam focusing was carried out at the accelerator of heavy ions «UTI-1». This accelerator (Fig.1) consists of the following units: the ion source of metals and gases (1,2), Vacuum chamber of mass-analyzer (3), mass-analyzer (4), the system of beam governing (7), quadrypolar lenses(8), accelerating system (10), system of ion beam focusing (13), target complex(17). The ion source that is used in the accelerator produces strip beam (5 cm × 0.4 cm) of multicharged ion s of various metals and gases. The quadrupolar lens was used to form cylindrical ion beam of diameter 2 cm from strip one. The accelerating process has two stages - firstly to the energy $E_1 = ZU_1$ in ion optic system , and secondary in accelerating tube to the energy $E_2 = ZU_2$, where U_1 and U_2 are the accelerating voltages of ion source and accelerating tube, correspondingly, Z is ion charge. The total energy of accelerated ion is $E = Z(U_1 + U_2)$. Magnetic separation was performed at low ion energy (U_1 = 25 - 125 kV). The accelerating tube voltage was U_2 = 200 eV. In particular the maximum energy of Mo^{4+} reaches 0,9 Ì eV, and current 25 μA.

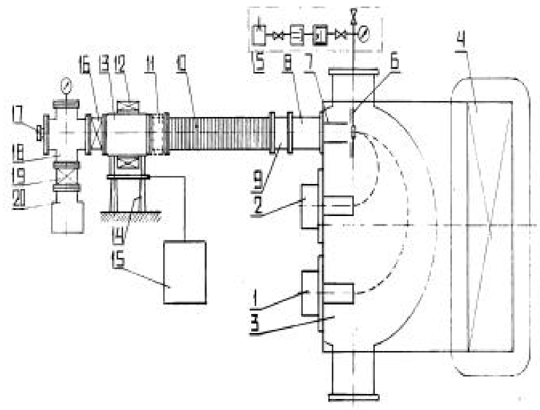

Fig. 1. Experimental installation. 1, 2 - ion sours of metals and gases, accordingly , 3 - vacuum chamber of mass analyzer, 4 mass - analyzer , 5 - system for vacuum measuring, 6 - unit for beam current measuring, 7 - system of beam declining, 8 - quadrupolar lens, 9, 11 - silphones, 10 - accelerating system, 12 - magnetic field coil, 13 - PL chamber, 14 - insulator, 15 - rectifier on 200 kV. 16, 19 - vacuum valve, 17 - target complex, 18 - vacuum chamber, 20 - magnetic discharged pump.

The hydrogen leak-in was regulated by the pin value. The gas amount was chosen so (0.5-2 cm^3 /min) that the beam current had a maximum value.

3. EXPERIMENTAL RESULTS

During ion beam propagation through the hydrogen the gas ionization and plasma production takes place. In magnetic field (0-0.8 kOe) plasma ions are nonmagnetized and they leave the system. At the same time plasma electrons are confined in magnetic field and create plasma lens as an electron cloud (noncompensated plasma). Its electric field is focusing one for ion beam.

At hydrogen leak-in 1cm^3 /min and more, and for Ì î$^{4+}$ ion energy less 350 keV the current decreasing in several times and changing of charge state and energy spectrum were observed. It can be explained by recombination and charge exchange processes of multicharged Mo ions on hydrogen atoms.
At ion energy growth to 1 MeV and gas leak-in of 0.5-1 cm^3 /min the capture cross-section decreases considerably and the probability of charge exchange falls down. Under these conditions the ion beam current increasing and its transversal size lessening was oserved.

For this case the changing of the beam crossection shape was measured on the beam imprint at the collector of diameter 3 cm, that was placed at distance 30 cm from plasma lens and 45 cm from accelerator exit.

The dependence of the beam cross-section lessening on the magnetic field value is represented in Fig.2. It is seen that in process of beam focusing by electron cloud its diameter decreases with magnetic field growth and for 0,8 kOe it is 0,8 cm.

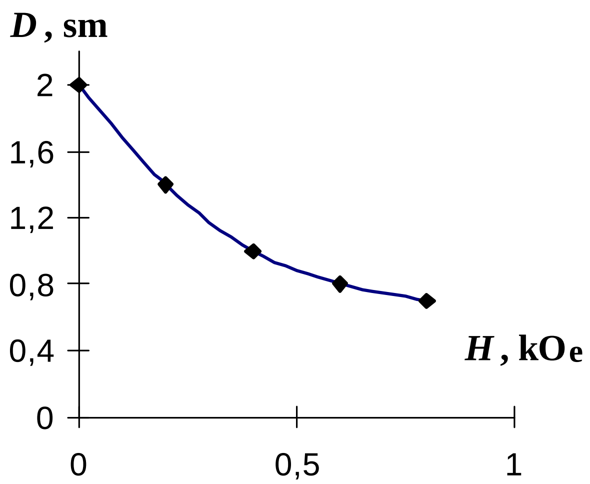

Fig. 2. The dependence of Mo^{+4} beam diameter on magnetic field value.

Simultaneously with beam cross-section measurements the beam current density were measured by Faraday microcup with inner diameter 3 mm. In Fig.3 the dependence of the beam current on this microcup on magnetic field value is shown. During focusing the beam current grows in 2 times. It is additional evidence of focusing process. However incomplete correspondence of these two measurements is probably connected with considerable decreasing of the total beam current under beam charge exchange on gas target. On this reason in further investigations it is proposed to create electron cloud by means of electrons injection into magnetic trap instead of gas ionization.

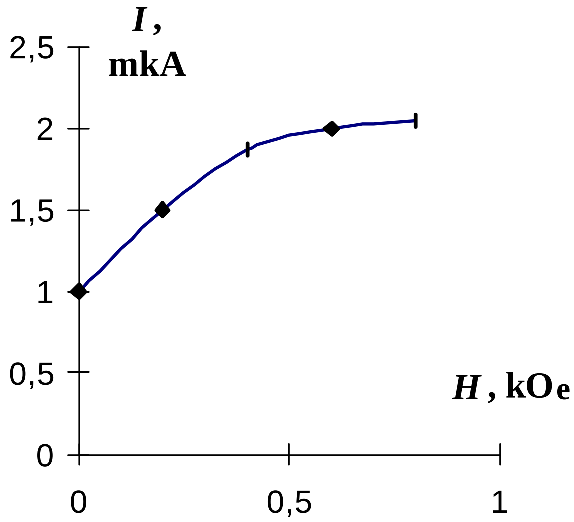

Fig. 3. The dependence of Mo^{+4} beam current density on magnetic field value

4. SUMMARY

Therefore the experimental investigations have shown that multicharged heavy ions of metals can be focused by plasma lens which is created during ion beam propagation in hydrogen gas with magnetic field applying for electrons confinement.

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