METHOD OF POTENTIAL OPTIMIZATION IN MAGNETOELECTROSTATIC PLASMA LENSES

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In magnetoelectrostatic plasma lenses the strength and spatial distribution of the magnetic and electric fields were optimized for maximum beam current density in the focal plane. Experimental implementation of the optimization is difficult because it is necessary to control the electric field strength within the lens volume by measuring the electric field in the plasma with sufficiently high precision. Here with the help of the computer model, it is proposed and tested the method of determining optimum potential distribution on the reference electrodes, by sequential increasing of a focused ion beam radius from zero to maximum value determined by the lens aperture.

PACS: 52.40.Mj

In [1] optimal spatial distributions of the electric and magnetic fields were calculated which give maximal density of the particles current in the focal plane of the lens. In particular, at the near optimal potential distribution, the ion trajectories have the view represented on Fig. 1.

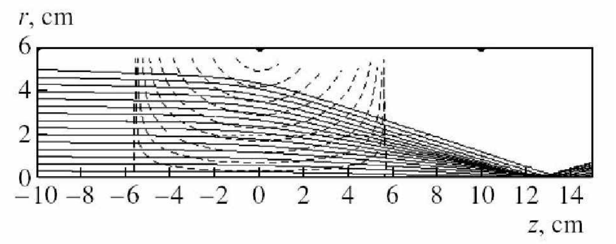


Fig. 1. Trajectories of Ta^{+3} ions in a lens with the potential distribution proportional to B_z

An experimental implementation of the calculated optimal distribution is difficult because it is necessary to control the distribution of the electric field strength within the plasma lens volume with sufficiently high precision. For the avoidance of these difficulties in this work it is proposed and checked with the help of the computer model the method of adjustment of optimal distribution of the potentials on the reference electrodes by the way of step-by-step focusing of the ion beam layers from smaller radius to larger one. The relative position pattern of magnetic lines of force and trajectories of ions being focused drawn on Fig. 1 directly leads to the way.

Let us consider the Morozov plasma lens with 15 narrow electrodes assuming linear changing of the potential between them (Fig. 2). The potential is transferred by the magnetized plasma into the lens volume in such way that the magnetic surfaces coincide with the equipotential surfaces of the electric field. So the potential of each point of the lens volume is governed by two electrodes pairs. While moving through such lens the focused ions penetrate from the region of zero potential into the region of higher potential with depth of particle penetration being in a monotone fashion related to the initial radius. The more initial radius of the ion, the higher maximal lens potential it achieves. This fact is conditioned by a variety of reasons. Firstly, the electrodes potential is in a monotone manner related to the distance from the center of the lens. Secondly, magnetic surfaces are nested; the current lines of a beam being focused without aberrations have the same property. On Fig. 3 the value of the potential along the trajectory is represented for protons with various values of initial radius. An ion with the certain initial radius is got into a region of influence only those electrodes which potential is not more than the maximal potential for given trajectory. On the ground of this fact we propose the method of experimental choice of the electrodes potentials.

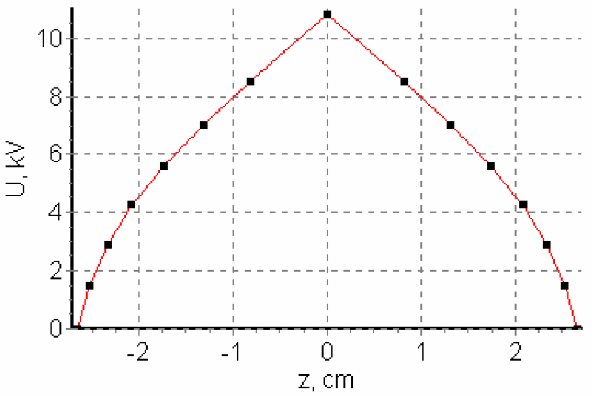


Fig. 2. Distribution of the potential on the electrodes surface

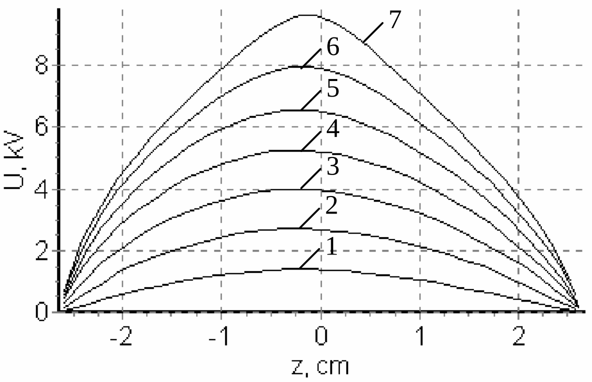


Fig. 3. The value of the potential along the protons trajectory with energy 20 keV for various values of initial radius R: 1) R = 2.3 cm, 2) R = 3.2 cm, 3) R = 4.0 cm, 4) R = 4.6 cm, 5) R = 5.1 cm, 6) R = 5.6 cm, 7) R = 6.0 cm

A wide plane collector with a thing central hole 3 is placed into the focal plane (Fig. 4). Behind the hole cylindrical collector 4 is disposed to measure an ion current density at the focus. First, outside couple of electrodes is grounded and another ones are connected together. They are supplied by a potential at which the current of second collector is maximal. This potential is kept on second pair of electrodes and the potential of the rest electrodes is chosen by the same principle. On Fig. 5 the stages of the potentials fitting are represented for 15-electrodes Morozov lens.

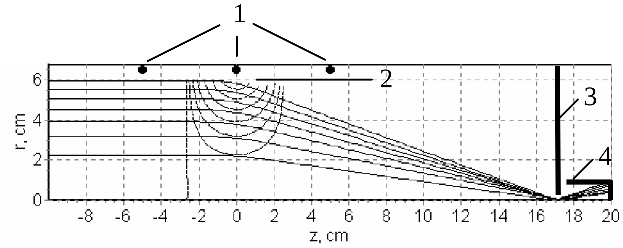
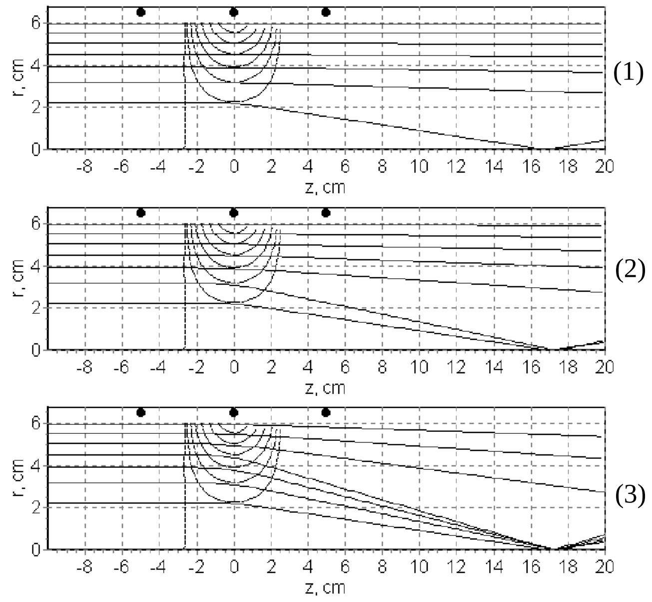


Fig. 4. Scheme of the proposed experiment



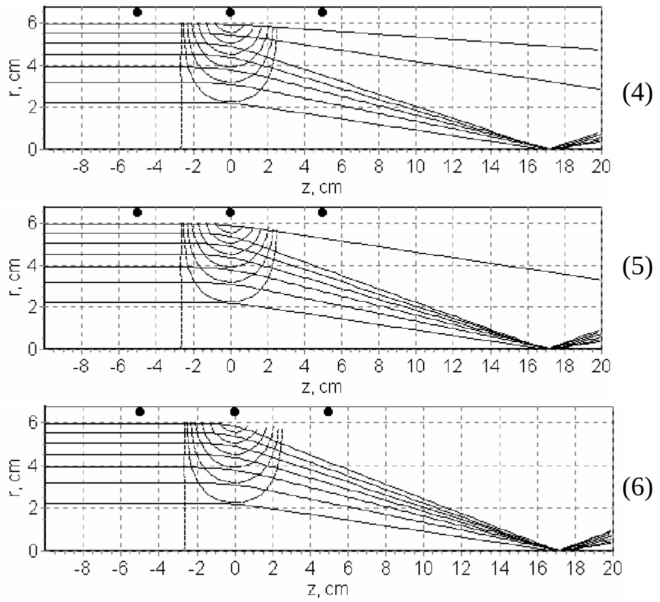


Fig. 5 Stages of fitting of the potentials for 15-electrodes Morozov lens: 1) U_1 - U_7 = 1.50 kV; 2) U_1 = 1.50 kV, U_2 - U_7 = 2.91 kV; 3) U_1 = 1.50 kV, U_2 = 2.91 kV, U_3 = 4.27 kV, U_4 - U_7 = 5.62 kV; 4) U_1 = 1.50 kV, U_2 = 2.91 kV, U_3 = 4.27 kV, U_4 = 5.62 kV, U_5 - U_7 = 7.00 kV; 5) U_1 = 1.50 kV, U_2 = 2.91 kV, U_3 = 4.27 kV, U_4 = 5.62 kV, U_5 = 7.00 kV, U_6 - U_7 = 8.50 kV; 6) U_1 = 1.50 kV, U_2 = 2.91 kV, U_3 = 4.27 kV, U_4 = 5.62 kV, U_5 = 7.00 kV, U_6 = 8.50 kV, U_7 = 10.5 kV

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МЕТОД ОПТИМИЗАЦИИ ПОТЕНЦИАЛОВ В МАГНИТОЭЛЕКТРОСТАТИЧЕСКИХ ПЛАЗМЕННЫХ ЛИНЗАХ

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В магнитоэлектростатических плазменных линзах рассчитаны оптимальные пространственные распределения электрического и магнитного полей, приводящие к максимальной плотности тока частиц в фокальной плоскости линзы. При их экспериментальной реализации возникают трудности ввиду необходимости контролировать с большой точностью распределение напряженности электрического поля в объеме плазменной линзы. Во избежание этих трудностей, предложен и опробован на компьютерной модели метод подбора оптимального распределения потенциалов на опорных электродах линзы путем последовательного увеличения радиуса фокусируемого ионного пучка от нуля до максимального значения, определяемого апертурой линзы.

МЕТОД ОПТИМІЗАЦІЇ ПОТЕНЦІАЛІВ У МАГНІТОЕЛЕКТРОСТАТИЧНИХ ПЛАЗМОВИХ ЛІНЗАХ

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В магнітоелектростатичних плазмових лінзах розраховані оптимальні просторові розподіли електричного та магнітного полів, що призводять до максимальної густини струму частинок у фокальній площині лінзи. При їхній експериментальній реалізації виникають труднощі через необхідність контролювати з великою точністю розподіл напруженості електричного поля в об'ємі плазмової лінзи. Щоб уникнути цих труднощів, запропонований та випробуваний на комп'ютерній моделі метод підбору оптимального розподілу потенціалів на опорних електродах лінзи шляхом послідовного збільшення радіуса іонного пучка, що фокусується від нуля до максимального значення, обумовленого апертурою лінзи.