SCHEME FOR FLATTENING OF ION DENSITY DISTRIBUTION ON A TARGET

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Abstract

A scheme for flattening of the ion density distribution on a target is considered. The Xe ion beam extracted from a cyclotron has the following parameters: mass-to-charge ratio is 4.4, the kinetic energy is 4.2 MeV per nucleon, the beam current is 1 μA and the beam emittance is equal to 40 π mm mrad. The ion beam line consists of quadrupoles doublet and octupole lens. After passimg through two quadrupoles the ion beam has large horizontal and small vertical dimensions. After that the octupole makes the ion beam density distribution on the target uniform withing the nessary demands. The geometry of the beam line, the quadrupole and octupole lens parameters are found during simulation. The simulated final beam density distribution on the target is also given.

INTRODUCTION

One of the important tasks is to obtain the heavy ion density distribution with deviation from the medium level not more than ±5% on the target having rather big dimensions (up to ~60 cm in width and ~30 cm in height) [1-3]. Such kinds of targets are required for some technological purposes. In this work the uniform density distribution on the target is obtained with the help of magnetostatic elements.

Getting the uniform distribution of the ion beam on the target was tested in the cyclotron IC-100 [4] with $^{+15}Kr^{86}$ ion beam having the kinetic energy of 1 MeV/a.u. Only two quadrupoles were used in this experiment. The ion density non-uniformity of about ±12% was obtained at the moving film when the channel length was equal to ~800 cm and irradiation window was 200×300 cm. At this the beam losses were about 70%. These losses are too large. Therefore it was suggested to use an octupole in the irradiation scheme.

BEAM PARAMETERS

The considered beam of $^{131}Xe^{30+}$ ions has the following parameters:

- ion beam current (I) ~1 μ A,
- mass-to-charge ratio (A/Z) 4.4,
- kinetic energy (W) 4.2 MeV/a.u.,
- ion beam diameter (D) 50 mm,
- emittance ($\varepsilon_x = \varepsilon_y$) 40 π mm mrad.

It was assumed also that the particle density in the beam has the Gaussian distribution

$$\rho(r) = \frac{N_i}{2\pi\sigma^2} \cdot e^{\frac{-r^2}{2\sigma^2}} \qquad (1)$$

Here N_i is number of the ions per unit beam length, σ^2 is dispersion of the particle distribution in the beam cross-section. The horizontal dimension of the irradiated target was equal to 600 mm.

BEAM LINE SCHEME

The beam line scheme is shown in Fig. 1. Here Q1 and Q2 are the standard quadrupoles (with the effective length equal to 350 mm, the aprture equal to 100 mm, and maximum gradient ~6 T/m), Q3 is the octupole, T is the target.

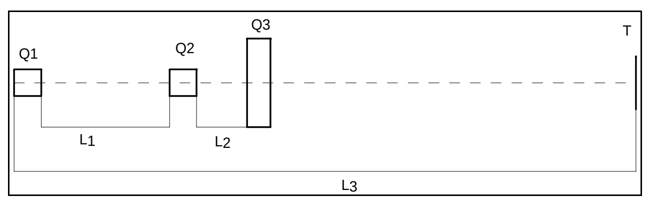

Figure 1. Scheme of the heavy ion beam line

The density distribution of the particles on the target smooths out owing to the nonlinear dependence of the oqtupole magnetic field on its radius (~r^3).

The first quadrupole Q1 defocuses the ion beam in the horizontal plane and focuses it in the vertical plane. Second quadrupole Q2 is located in the point where the horizontal beam dimension has minimum value. In this point the quadrupole Q2 continues to defocus the beam in the horizontal plane and does not act on the vertical beam dimension. As a result the beam has big horizontal and small vertical dimensions.

If the octupole is shut down we obtain the beam envelopes shown in Fig. 2.

In this case the length of the drift spaces L_1 = 45 cm, L_2 = 65 cm and L_3 = 600 cm (see Fig.1). The gradient value in both quadrupoles is equal to -4.8 T/m. As one can see from Fig. 2, horizontal half-dimension of the ion beam on the target is about ~300 mm and its vertical half-dimension is equal to ~77 mm.

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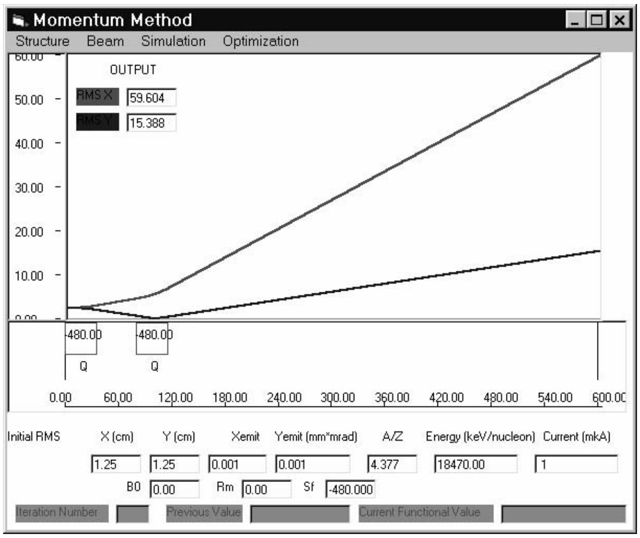

Figure 2. The ion beam envelopes. The upper curve shows horizontal half-dimension of the beam, the lower one shows vertical half-dimension of the beam

RESULTS OF SIMULATION

The work of the scheme shown in Fig. 1 was checked by the macro-particle simulation. The particles 10^5 in number were arranged in the phase space taking into account the dispersions and emittances of the ion beam. The initial particle distribution is shown in Fig. 3.

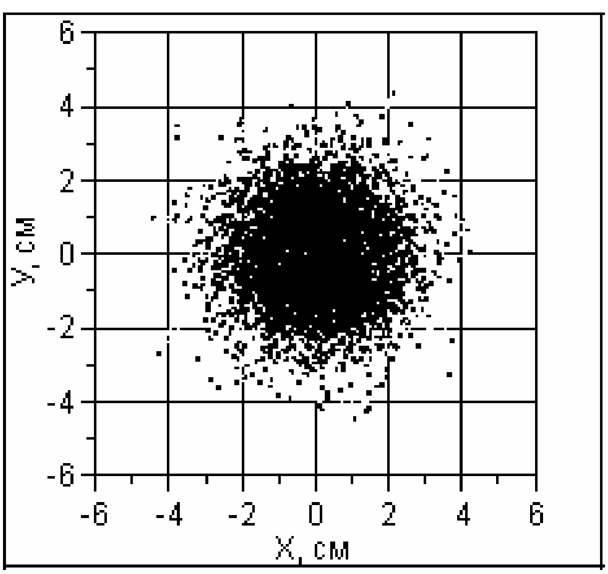

Figure 3. Initial particle distribution

The final particle distribution on the target when the oqtupole is switched on is shown in Fig.4.

Analysis of the obtained particle distribution on the target (see Fig. 4) showed that the central region of the immovable target with dimensions -30 cm ≤ x ≤ +30 cm and -7.5 cm ≤ y ≤ +7.5 cm is irradiated with uniformity of ±5%. Corresponding graph is shown in Fig. 5. About 65% of particles are found in this region.

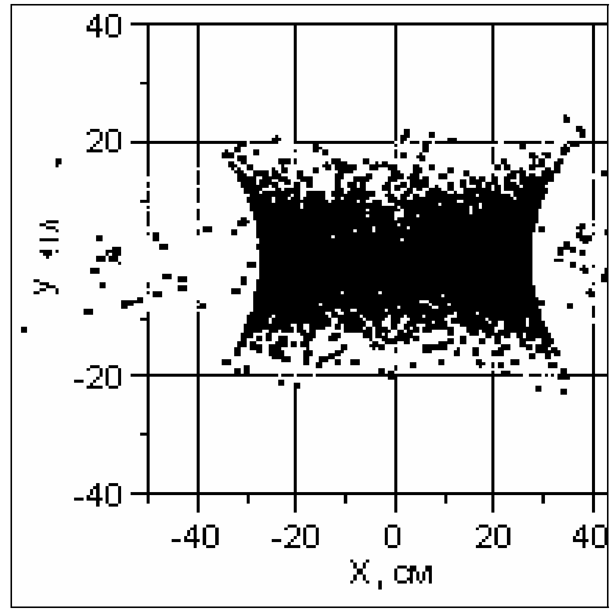

Figure 4. Final particle distribution on the target

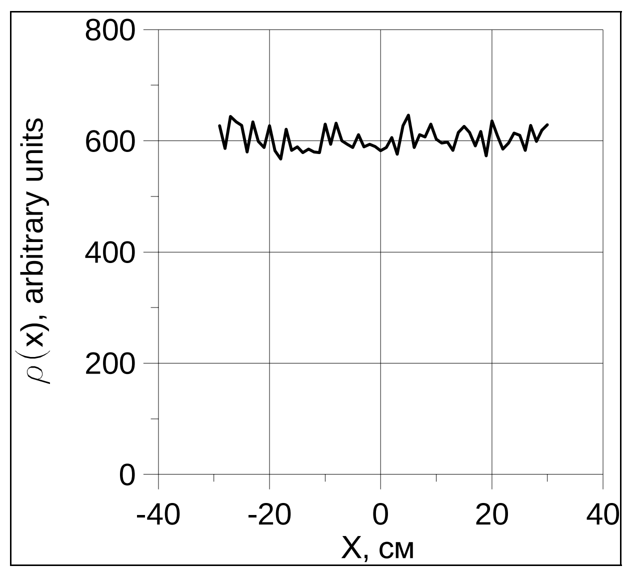

Figure 5. The particle distribution on the target (at y = 0)

The following parameters of the octupole were obtained:

- effective length 300 mm,
- aperture 360 mm,
- magnetic field induction at the pole 0.2 T

CONCLUSION

The carried out simulation of the target irradiation process by the heavy ion beam for getting high particle distribution uniformity showed that one can stretch the beam in the horizontal plane with the help of two standard quadrupoles so that it could fill up the target region of -60 cm $\leq$ x $\leq$ 60 cm. The distance from the first quadrupole entrance to the target is about ~600 cm.

The octupole with mentioned above parameters located after the quadrupole doublet allows to move the particles from the external part of the ion beam on its inner part so that the region of 600×300 mm on the immovable target turns to be irradiated with uniformity ~$\pm$5%. The particle losses are about 35% in this case.

One can control the horizontal ion beam dimension on the target by changing the gradient values in the quadrupoles and control the uniformity of radiation level by changing the magnetic field value in the octupole.

The targets with much more greater square may be irradiated by moving a film with constant velocity in the vertical direction.

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