Preliminary Design of a New Central Region for the RIKEN AVF Cyclotron

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Abstract

The central region of the AVF cyclotron at RIKEN has been newly designed for operation with higher injection voltages in the future. This upgrade plan is aimed to attain higher beam intensities in a stand-alone mode of the cyclotron as requested by nuclear science users. The design is preliminary, but main design requirements seem to be met by the current work.

1 Introduction

The AVF cyclotron at RIKEN has been used as an injector to the RRC and also in a stand-alone mode for atomic physics experiments [1]. Beams extracted from 10 GHz ECR source are axially injected, and then inflected onto the median plane by means of spiral inflector. Detailed design parameters and operation status of the cyclotron can be found such as in refs. 2,3.

Increase of the injection voltage for instance from 10 kV to 20 kV for a beam of N^{5+} has been conceived to achieve higher beam intensities. The higher voltage will enable extraction of higher beam currents from the source according to the well-known Child law, and also help reduce space charge effects during the beam transport along the injection line. A first step toward this upgrade is to redesign the inflector and central region.

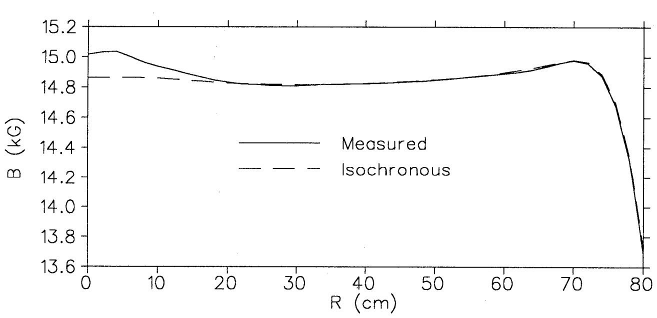

Fig. 1 Radial distributions of measured and isochronized magnetic fields which are azimuthally averaged for a beam of N^{5+} accelerating to 7 MeV/u.

In the original design of the central region, the electric fields were calculated assuming analytic distributions of the fields [2]. Thus practical effects such as field penetrations into the dees were not fully considered. In the new design the fields were calculated with a relaxation code RELAX3D [4]. First, to make orbit computations for comparison with previous results, the electric fields were computed for the existent geometry. The design ion is N^{5+} accelerating to 7 MeV/u for which measured magnetic fields are available.

For acceleration of other nuclei, a constant orbit mode can be applied in operation with the injection voltages varied according to the ratios of $\frac{Z}{A}B_0^2$.

2 Electromagnetic fields

The electric fields of the central region were calculated using RELAX3D for 3-d electrode geometries. The horizontal meshes were sized to be 1 mm, and the grid was 201 × 201 × 21. The magnetic field employed, on the other hand, is a measured data for the N^{5+} beam. Figure 1 shows azimuthally averaged distributions of measured and isochronized fields. The central corn field extends to 20 cm to enhance the axial focusing.

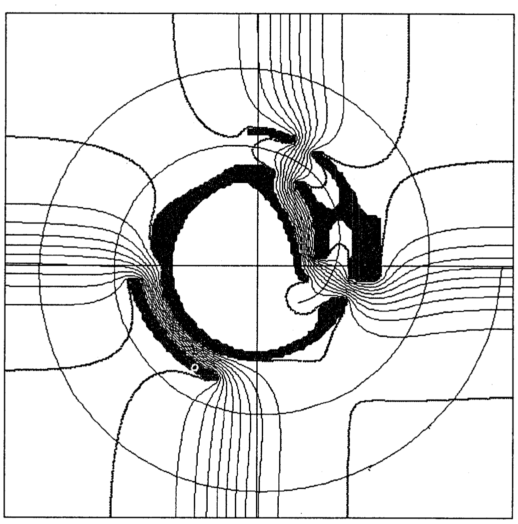

Fig. 2 Orbit trajectory of a N^{5+} ray starting at τ_0=-35° with an injection voltage of 10 kV, which is drawn on the equipotential map of the original central region.

3 Central region design

To calculate the orbits the code Z3CYCLONE [5] was used. The code utilizes the magnetic fields on the median plane, and a linear expansion in z for the horizontal fields to calculate verical motion.

Orbit trajectories have been first computed for the present central region to compare with results already available. In Fig. 2 is shown a trajectory on equipotentials for the N^{5+} beam which is injected at τ= -35° at the exit of the inflector (rf voltage is in sine wave). This result agrees with that of the original design.

When the injection voltage is doubled, the magnetic bending radius of the injected beam becomes larger by the square root of two. The new geometry was found with trial and error on the basis of the original geometry. One restriction was that the radial location of the beam exiting from the inflector is limited by 3 cm radius of the existing center hole. It turned out that major modifications are needed in the location of injection beam and in the azimuths of extraction electrodes. The centering error which is a main design consideration is tried to be maintained less than ±1 mm. The orbit trajectories traced with a beam emittance of 250 π mm·mrad are plotted in Fig. 3.

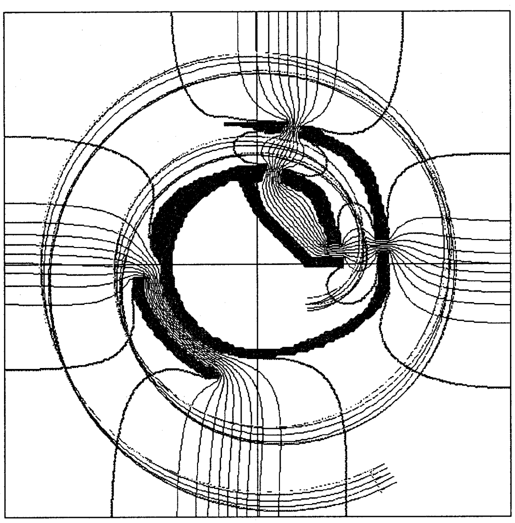

Fig. 3 Orbit trajectories on the newly designed central region for a beam with emittance of 250 π mm·mrad.

The initial conditions of injected beams were attained using analytic equations of motion in a spiral inflector. But studies have indicated that orbit trajectories are slightly different from the results which involve more realistic inflector electric fields [6]. The present design did not consider this effect, but it appears that the stray field effect can be readily handled.

The vertical motion has been computed also with Z3CYCLONE, and trajectories are plotted in Fig. 4 for two linearly independent initial conditions. The vertical acceptance is expected to be about the same as in the present design.

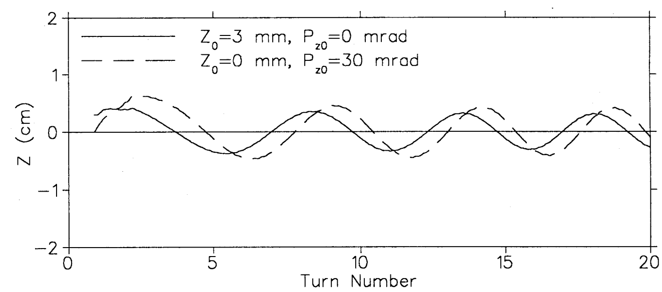

Fig. 4 Vertical motions for two different initial conditions.

4 Current status

A preliminary design of the central region was carried out, which can accept the beams injected with higher voltages. This is a first step to improve the beam currents extracted from the RIKEN AVF cyclotron. Works will continue as the project is initiated in the future.

References

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