BEAM DYNAMICS STUDY OF HIGH INTENSITY COMPACT CYCLOTRON FOR NEUTRON GENERATOR AT KIRAMS

C.S. Park, J.S. Kang, D.H. An, J.S. Chai, M. Sekiguchi
Cyclotron Application Lab., Korea Institute of Radiological & Medical Sciences, Seoul, Korea

Abstract

The compact cyclotron has been designed as a neutron generator for neutron radiography at KIRAMS. Since the intensity of the extracted beam is limited in proton acceleration, the acceleration of the negative hydrogen ion beam is proposed. A maximum energy of the beam is chosen to be 5 MeV, and the beam current is about 2 mA. For neutron generator, the high intensity beam is required. To obtain the high intensity beam, beam dynamics studies at the injection have been performed. In this paper, the design of the spiral inflector and the particle motions at the inflector have been studied to optimize the injection efficiency.

INTRODUCTION

The compact cyclotron has been developed as a neutron generator for the neutron radiography. The low energy and high current H^- ion beam is extracted. To obtain the high current H^- ion beam, the external multicusp ion source was chosen. The axially injected beam from the source is bent into the median plane of the cyclotron by the spiral inflector. This paper describes the design and the optical properties the spiral inflector.

INFLECTOR DESIGN

Design parameters of the spiral inflector

To design the spiral inflector, there are two leading parameters which are the inflector height A and the tilt parameter k'. And the conventional parameter K [1,2] is defined as

$$K = \frac{A}{2R_m} + \frac{k'}{2}.$$

The important thing to consider in design of the inflector is orbit centering at the exit of the inflector. The centering should be satisfied for beam to be accelerated correctly to central region of the cyclotron. If central magnetic field is not enough to make beam well-centered, higher spiral inflector or more tilted spiral inflector should be introduced. The height of the inflector is the same as the electric radius. It is proved that off-centering is reduced when A or k' increases [3]. Since the height of inflector is limited by space problem of the cyclotron. A and k' may be compromised.

Orbit calculations and Inflector design

The FORTRAN code CASINO[4] was used to design the inflector. CASINO uses the inflector height A and the tilt parameter k' to calculate both the central ray and the paraxial ray motion. The magnetic field map of the cyclotron is calculated by OPERA-3D TOSCA solver[5]. The boundary file for RELAX3D calculations are made by using program INFLECTOR[6] form results of CASINO. After the calculations of RELAX3D[7], the electric potential map is applied to CASINO simulation.[8,9]

Table 1: Inflector Input Parameters

Parameters	Values
Central magnetic field	8.0 kG
Charge	-1
Injection voltage	50 kV
Magnetic radius	4.04 cm
Electrode spacing	1.2 cm
Electrode width	1.5 cm

Table 1 shows input parameters of the spiral inflector. The injection energy of the ion beam is 50 keV. The central magnetic field is 8.0 kG and the magnetic radius is 4.04 cm. Gap between the electrodes are 1.2 cm width of the each electrode is 1.5 cm.

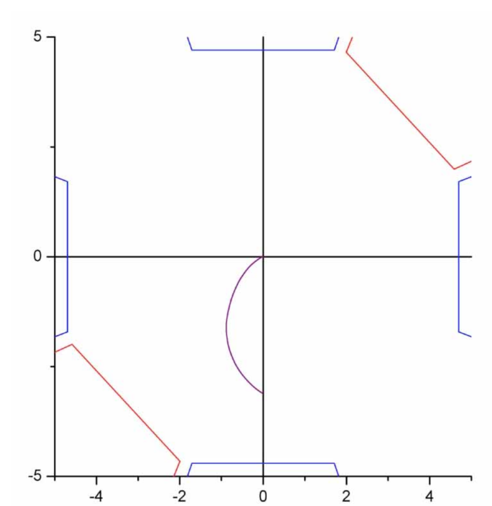

Figure 1 Central ray of the ion – xy projection.

With these values, both central and paraxial rays are calculated. Figure 1 shows the horizontal projection of the central ion trajectory in the inflector. The exit of the spiral inflector could be found at $z = p_z$ =0. Three dimensional orbit of the central ray of the ion is shown in Figure 2.

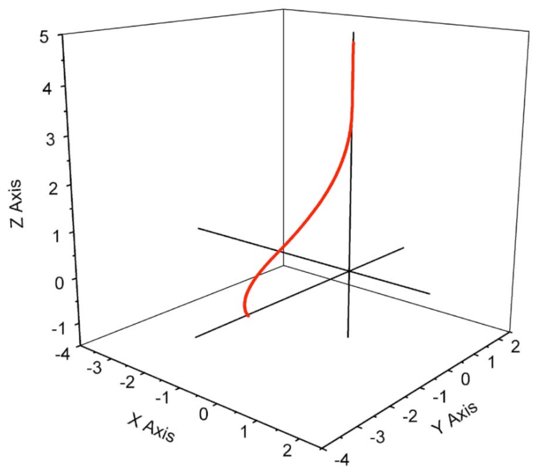

Figure 2 Central ion trajectory.

The boundary information is estimated by the program INFLECTOR which uses the output of CASINO. And shapes of two electrodes and two ground plates are calculated. The central ion trajectory and three dimensional shapes of two electrodes are displayed of Figure 3. And Figure 4 shows the grids of ground plates which need for RF shielding and are located at the entrance and exit of the inflector.

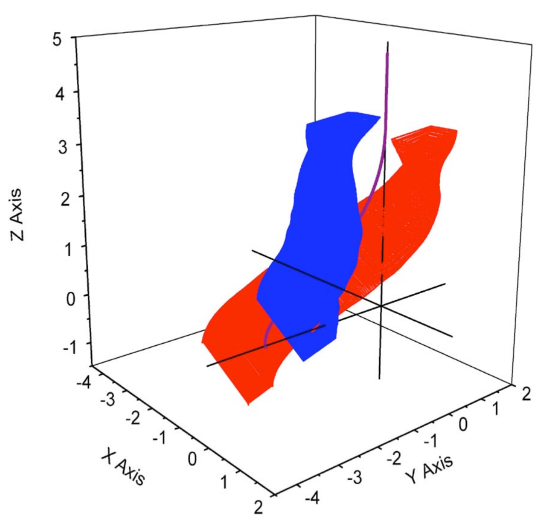

Figure 3 Central ion trajectory (the purple line) through the spiral inflector.

Table 2: Inflector Parameters

Parameters	Values
Inflector height (A)	3.5 cm
Tilt parameter (k')	-1.37
K	-0.25
Off-centering at exit (ρ_C)	1.63 cm
Exit point (r, θ)	(3.03 cm, -87.34 deg.)

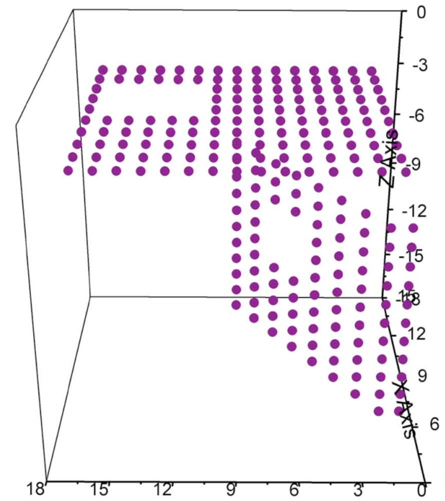

Figure 4 Grids of two ground plates

Using the output of the program INFLECTOR, RELAX3D is executed and the electric potential map is calculated. Using this map, CASINO is executed again, and central trajectory and fringe field effects are investigated. Table 2 shows optical properties of the inflector. The inflector height is A = 3.5 cm and the tilt parameter is k' = -1.37. These values are chosen to modify the beam centering. At the exit, the off-centering, ρ_C is 1.63 cm. The biased voltage of electrodes of the inflector is -17 kV. The shape of the spiral inflector is shown in Figure 5.

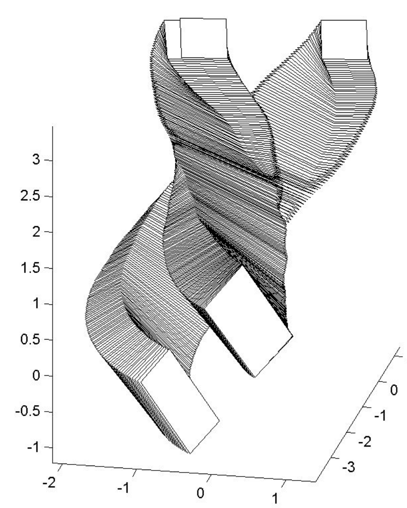

Figure 5 Two biased electrodes of the spiral inflector.

CONCLUSIONS

The spiral inflector simulations are executed using several programs. We put inflector height A = 3.5 cm to considering center gap of magnet and put tilt parameter

k' = -1.37 to modify the beam centering at the exit of spiral inflector. The central region design will be conducted with these results. And the space charge effects will be also considered.

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