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DESIGN OF ECR ION SOURCE INJECTION SYSTEM FOR JAERI CYCLOTRON

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Abstract

An ECR ion source injection system for the AVF cyclotron in JAERI was designed using a beam optics calculation code 'TRANSPORT'. The system acceptance of about 400 π·mm·mrad was obtained in the first order calculation including the second order correction for fringing fields of dipole magnets. The layout and the beam optics are discussed in detail.

Introduction

The injection system with an ECR ion source(OCTOPUS [1]) and a duoplasmatron ion source is introduced for the AVF cyclotron of Sumitomo Heavy Industories Ltd.(K=110) in the ion beam irradiation facility to be constructed at JAERI Takasaki [2] . Ion beam optics has been calculated to design the system using computer program 'TRANSPORT' [3] .

Emittance of ion sources which was measured after the extraction lenses and the analyzing magnet has been reported to be less than or around 200 π·mm·mrad in recent years [4,5,6] . However, it is desirable to assume emittance larger than the reported values to maximize the transmission of desirable the injection system, because there are intrinsic difficulties to optimize design parameters of the extraction lens system under the strong magnetic mirror field around the ion source yoke for ion beams of M/Q(mass to charge ratio), 2.0 to 6.5. The first order calculation was made based on an assumed value of 550 π·mm·mrad around the extraction hole of the ion source.

Magnetic lenses have been used to reduce space charge effect in the system except for the extraction lens. In this report, comparison between solenoid and quadrupole magnetic lenses was made by observing the calculated beam envelopes.

Layout of Injection System

Figures 1 and 2 show the injection system for the ECR and duoplasmatron ion sources. After extraction from the ECR ion source the beam passes an analyzing magnet(ANAI1), an inflection magnet(IMI), along a horizontal transport line in the basement. It is bent upward into the center of the cyclotron through an axial injection system. The transport line for duoplasmatron ion source is connected with the inflection magnet. An additional ECR ion source is planned to be installed for rapid change of ion species and easy maintenance of the ion sources.

Condition of Calculation

The calculation was made for five divided sections of the injection system, i.e. the analyzing section for the ECR ion source from the extraction hole to the beam slit(SLI1), the transport section for the ECR ion source from SLI1 to SLI2, the injection section for the duoplasmatron ion source from extraction hole to SLI2, the horizontal transport section from SLI2 to SLI4, and the axial injection section from SLI4 to the inflector of the cyclotron. The beam radius and

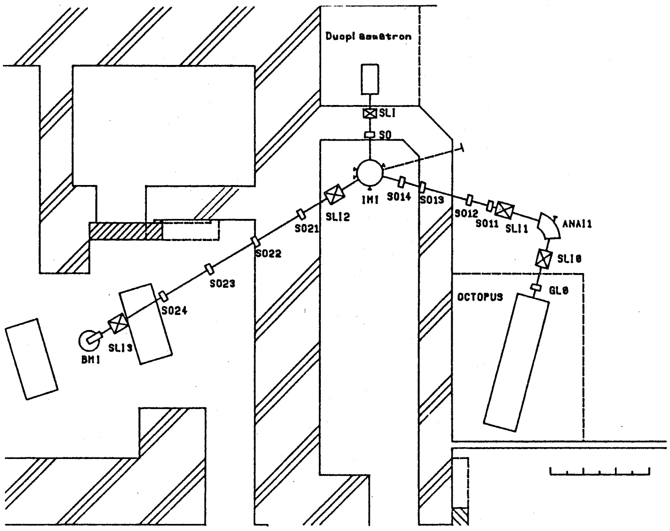

FIg. 1 Top View of the Injection System.

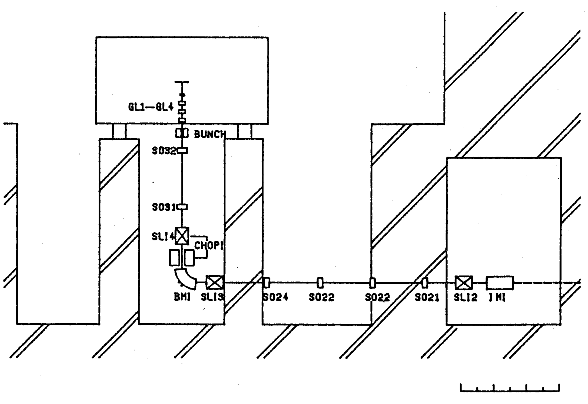

Fig. 2 Side View of the Injection System.

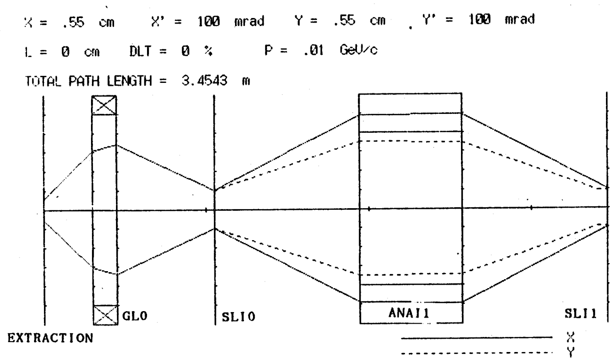

Fig. 3 Beam Envelopes for the Analyzing Section.

the divergence as the initial conditions of ion beams were assumed to be 5.5 mm and 100 mrad, respectively. Those of the duoplasmatron ion source were assumed to be 0.5 mm and 50 mrad, respectively. The acceleration voltage and the charge to mass ratio of ion beams were fixed to be 10 kV and 2.0, respectively for both ion sources. Details of the calculation are discussed in the following.

Results of Calculation

Analyzing Section of ECR Ion Source

This section is to select ions with any mass to charge ratios, and the system acceptance is determined here. As shown in Fig. 3, a Glaser lens(GL0) focuses the ion beams to a slit(SLI0) with a magnification factor of about 2. There is an extraction lens between the hole and the Glaser lens used to extract ion beams from ECR plasma surface in actual situation. However, we took the Glaser lens to be an only focusing element of this region in our calculation. Although divergence of ion beams is reduced by half at SLI0, the narrow inner clearance of the magnet chamber(3.5 inches) results in the beam loss of 30 % in the vertical plane. The acceptance of the section is evaluated to be 385 π mm-mrad in the calculation. The reduction of the emittance was simulated by multiplying the divergence at SLI0 by factor of 0.7 in the calculation.

Transport Section for ECR Ion Source

Figure 4 shows beam envelopes from SLI1 to SLI2. This section has four solenoid lenses(SO11, SO12, SO13 and SO14) and a inflection magnet(IM1). The deflection angle at the inflection magnet is 44 degree and ion beams are focused to SLI3.

Horizontal Transport Section

The transport line from SLI2 to SLI4 consists of plural focusing magnets and a 90 degree double focusing bending magnet(BMI). The single dipole system is used here, instead of an achromatic bending system, because momentum spreads of the analyzed ion beams were reported sufficiently small [7].

We calculated for two kinds of transport systems, one using four solenoid lenses(SO21, SO22, SO23 and SO24) and another using two triplet quadrupole magnets(TQI1 and TQI2). The results are shown in Figs. 5 and 6, respectively. Comparing them, the solenoid is better because of axial symmetry of focusing and of less operation parameters. Therefore, we adopted the solenoid lens for the beam transport in spite of the large amount of electricity consumption.

Axial Injection Section

Figure 7 shows beam envelopes of the axial injection section from SLI3 to the inflector, of the cyclotron consisting of two solenoid lenses(SO31 and SO32) outside the cyclotron yoke and four Glazer lenses(GL1, GL2, GL3 and GL4) inside. The slit(SLI4) is at the focusing point for a beam chopping with rectangular voltage pulses, and ion beams are also focused at a beam buncher located around the entrance of the cyclotron yoke. Ion beams are transported inside the yoke with a smaller profile by four Glazer lenses and focusing field in the center region. Distribution of the magnetic field around the pole gap shown in Fig. 8 approximated superimposing two solenoid fields. A complex field around the inflector was not considered here. Further calculation for this region will be necessary using other computer programs.

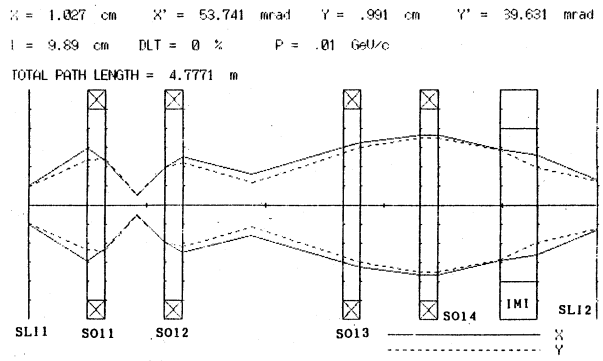

Fig. 4 Beam Envelopes for the Transport Section of the ECR Ion Source.

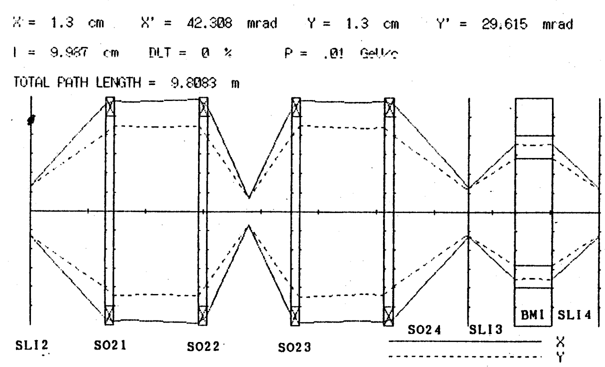

Fig. 5 Beam Envelopes for the Holizontal Transport Section Using four Solenoid Lenses.

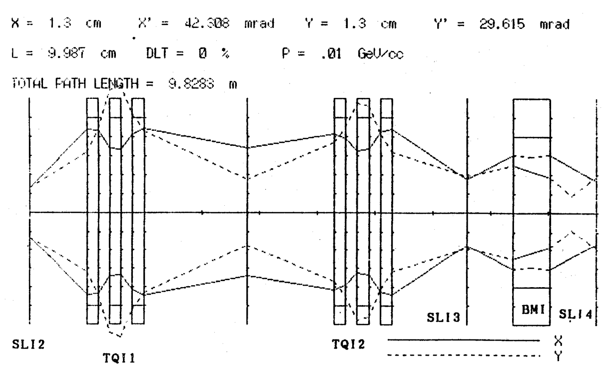

Fig. 6 Beam Envelopes for the Holizontal Transport Section Using two Triplet Quadrupole Magnet Lenses.

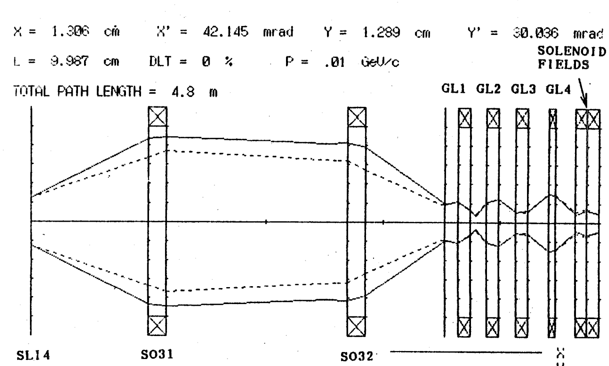

Fig. 7 Beam Envelopes for the Axial Injection Section in the Case of Using four Solenoid Lenses in the Horizontal Transport Section.

Duoplasmatron Ion Source Transport Section

The light ion injection system with the duoplasmatron ion source is connected to the horizontal transport line at the inflection magnet, which works as an analyzing magnet for this ion source. The beam envelopes are shown in Fig. 9. The section was assumed to have an Einzel lens to focus extracted ion beams with a magnification factor of 5 in a thin lens approximation.

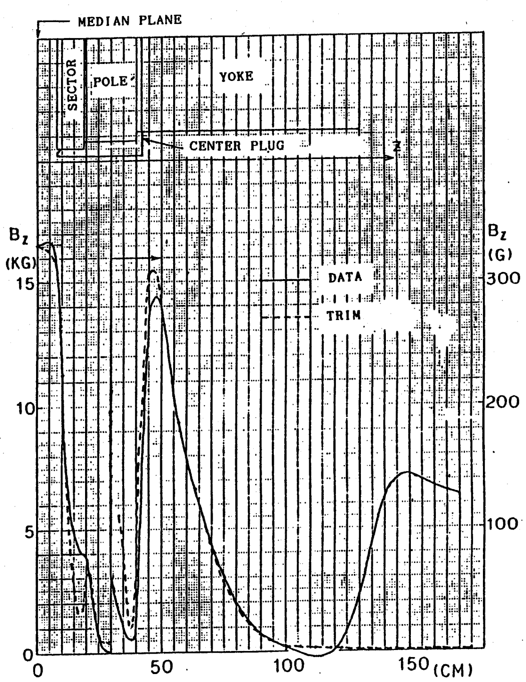

Fig. 8 Field Distribution of the Axial Injection Section in the Yoke of 930 Cyclotron at Louvain (Current in the Main Coil is 1150 A). Lines Indicate the Fields Measured, and Calculated with TRIM were Shown. There was an Approximation of Bz(0<z<10)=16.6kG and Bz(10<z<20)=4 in the Calculation.

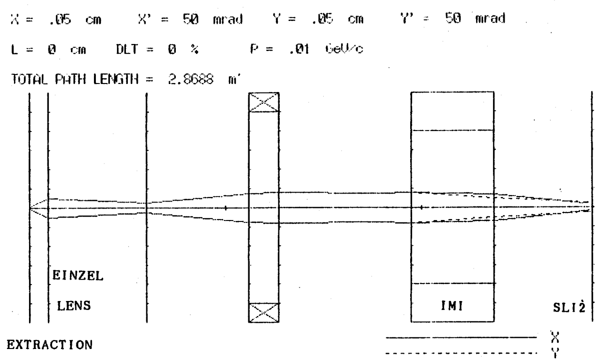

Fig. 9 Beam Envelopes for the Duoplasmatron Ion Source Injection System.

Summary

The ECR ion source injection system with high transmission for ion beams with large emittance was designed in the framework of the first order calculation including the second order correction of dipole magnets. An acceptance of about 400 π mm mrad was obtained by use of the analyzing magnet with inner clearance of 3.5 inches. Solenoid lenses were adopted to transport ion beams of large profiles.

We are planning in near future to do higher order calculation in consideration of space charge effect to investigate beam dynamics in the extraction region and the analyzing magnet region of ECR ion source, and the center region of the cyclotron.

Acknowledgement

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