A PRELIMINARY DESIGN OF THE BEAM TRANSPORT LINE FOR THE K900 SUPERCONDUCTING AVF CYCLOTRON

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Abstract

A new project aiming a breakthrough in biotechnology and materials science has been proposed at TIARA (Takasaki Ion Accelerators for Advanced Radiation Application) facilities of JAERI. We have started designing a K900 superconducting AVF cyclotron (K900 SCC). The beam transport line for JAERI K900 SCC has been designed preliminary for heavy ion beams with an energy of more than a hundred MeV/n. An achromatic beam transport system has been designed for high transmission efficiency of ion beams and good adjustability of magnet parameters using the computer code “TRANSPORT”.

1 INTRODUCTION

The TIARA is very unique facilities designed for utilization of ion beams for the research in biotechnology and materials science [1]. The present accelerators cover the energy range of keV through 27.5 MeV/n. An energy of carbon ions at TIARA is 18.8MeV/n, which is insufficient for ion induced mutation in the plants breeding. Heavy ion beams with energy of more than a hundred MeV/n will contribute to remarkable progress in breeding of plants and development of new materials. We have started designing a K900 SCC [2] with a bending limit of 900 and a focusing limit of 300. The cyclotron magnet is being designed to cope with acceleration of both the heavy ions and 300 MeV protons.

In order to meet various requirements for beam utilization in the research program, the beam optics of the transport for the JAERI K900 SCC is designed in consideration of the high transmission efficiency of ion beams and easily beam control.

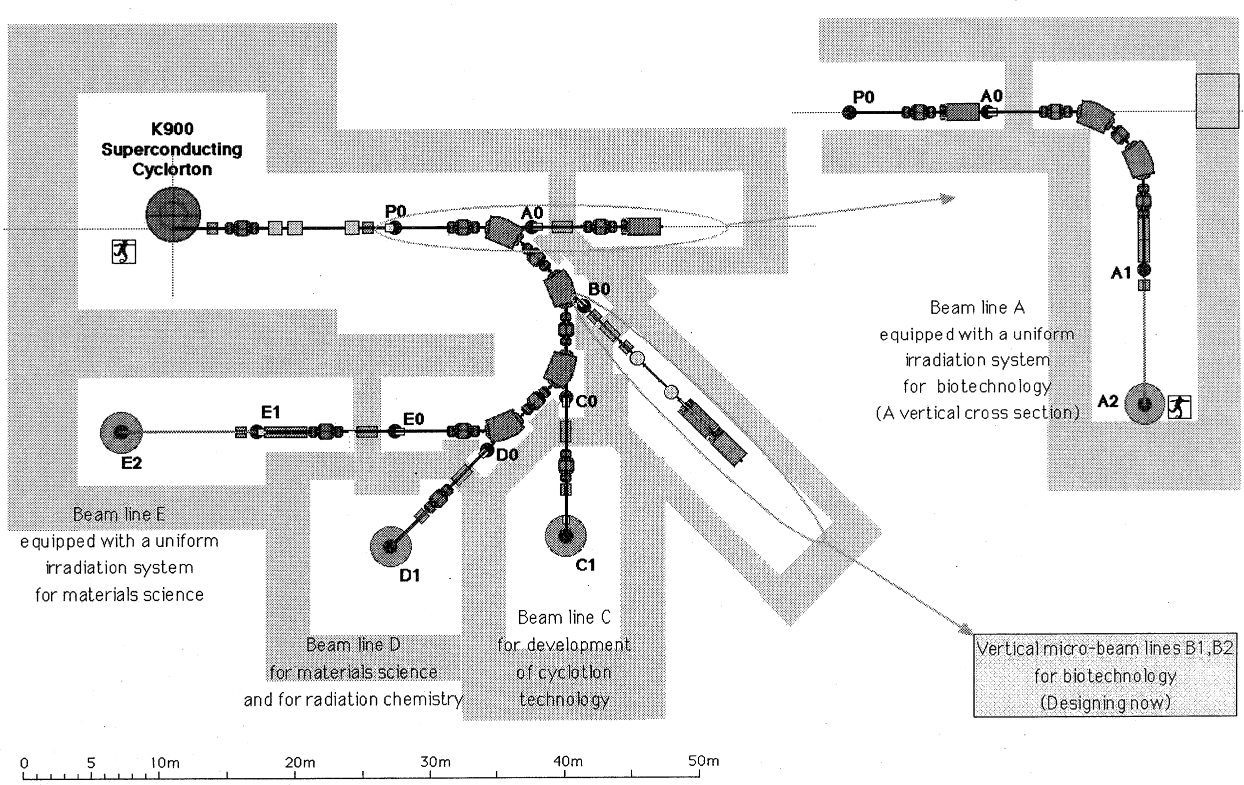

Fig. 1. The plan view of the beam transport line for the JAERI K900 superconducting AVF cyclotron. P0 is the source point of the beam optics.

Table 1 Main Characteristic requirement for ion beams of the JAERI K900 SCC

Applied research field	Biotechnology (Plant breeding)	Semiconductors for Space	Materials Science and Radiation Chemistry	Biotechnology (Elucidation of development and differentiation)
Particle - Energy (MeV/n) - Beam characteristics	C ~ Kr 50 ~ 100 Current: Several pnA	H ~ Kr H max. 300 Kr 120 Fluence rate: 0.0001 ~ 100 ppA/cm^2	H ~ Pb H 100 Heavy ions 100 Pulsed beam	H ~ Kr 50 ~ 100 Micro-beam (Momentum spread: < 0.01%)
Irradiation condition - Diameter of Beam Spot - Field size - Uniformity of fluence - Direction	in air 0.5 ~ 20 mm < 10cm x 10cm < 5% Vertical	in air 10 mm < 15cm x 15cm < 5% Horizontal	in vacuum 10 mm < 10cm x 10cm < 5% Horizontal	in air 1 μm < 1mm x 1mm Vertical
Sample	Plant cells, Callus, Culture, Seeds, etc.	Devices mounted on circuits	Water solution, Organic solution, Organic compound, Polymer	Cells and tissues of animal-organ and plant-organ

2 DESIGN OF THE TRANSPORT

2.1 Design Philosophy of the Beam Optics

The design philosophy is shown as following:

(1) Matching section for beam dispersion

The center axis of the extracted beam from K900 SCC is matched to the axis on the beam transport line by using a pair of steering elements located in the section from the cyclotron to P0 (P0: see Fig.1).

(2) Philosophy of the beam optics

P0 is the source point of the beam optics as shown in Fig.1. The waist of the beam envelope is adjusted to P0 point, and the beam is transported by an achromatic optics to the target points.

(3) Bending elements

The normal-conducting magnets will be adopted from the point of the saving of running cost and the easiness of maintenance. The 90 degree bending magnet is difficult to cool the magnet coil by water. Therefore, we will adopt the 45 degree bending magnets.

(4) Control the beam divergence

In order to suppress the electric power of the quadrupole magnets, the beam divergence is controlled to small angle.

(5) Beam diagnostics

The beam diagnostic station is installed to all waist point of the beam envelope for measuring the beam characteristics such as beam intensity, profile, size, position and so on. The beam emittance monitor and TOF counter for measurement of the beam energy are located on the main transport line.

(6) Uniform irradiation for wide area

Uniform irradiation of high-energy ion beam over a wide area, within a field size of 150 x 150 mm, will be formed in the two target ports. Two dimensional beam scanning with electromagnets is adopted for this system in consideration of high-intensity, high-energy ion beam.

2.2 Calculation of the Beam Optics

Numerical calculations of the ion optics have been carried out using the computer code "TRANSPORT"[3]. The design of the beam transport system is based on the following specifications of the beam from the JAERI K900 SCC.

1) Maximum magnetic rigidity: $B\rho$ = 45 kG · m
2) Emittance: 5 πmm · mrad in both planes
3) Momentum spread: 0.1%

The design of standardized ion-optical elements is shown as following:

1) Bending Magnet
   - Bending angle: 45 degree
   - Radius: ρ = 3 m
2) Triplet Quadrupole
   - Homogeneous field: < 15 kG,
   - Effective length: 40 cm (outer), 80 cm (inner)
   - Maximum field gradient: < 1.5 kG/cm

Typical beam envelope is shown in Fig. 2.

2.3 The Beam Lines Layout

The characteristics for various requirements of ion beam in the facilities are summarized in Table 1. The plan view of the beam transport line is shown in Fig. 1. There are three horizontal and three vertical beam courses in the six irradiation rooms. Typical size of irradiation

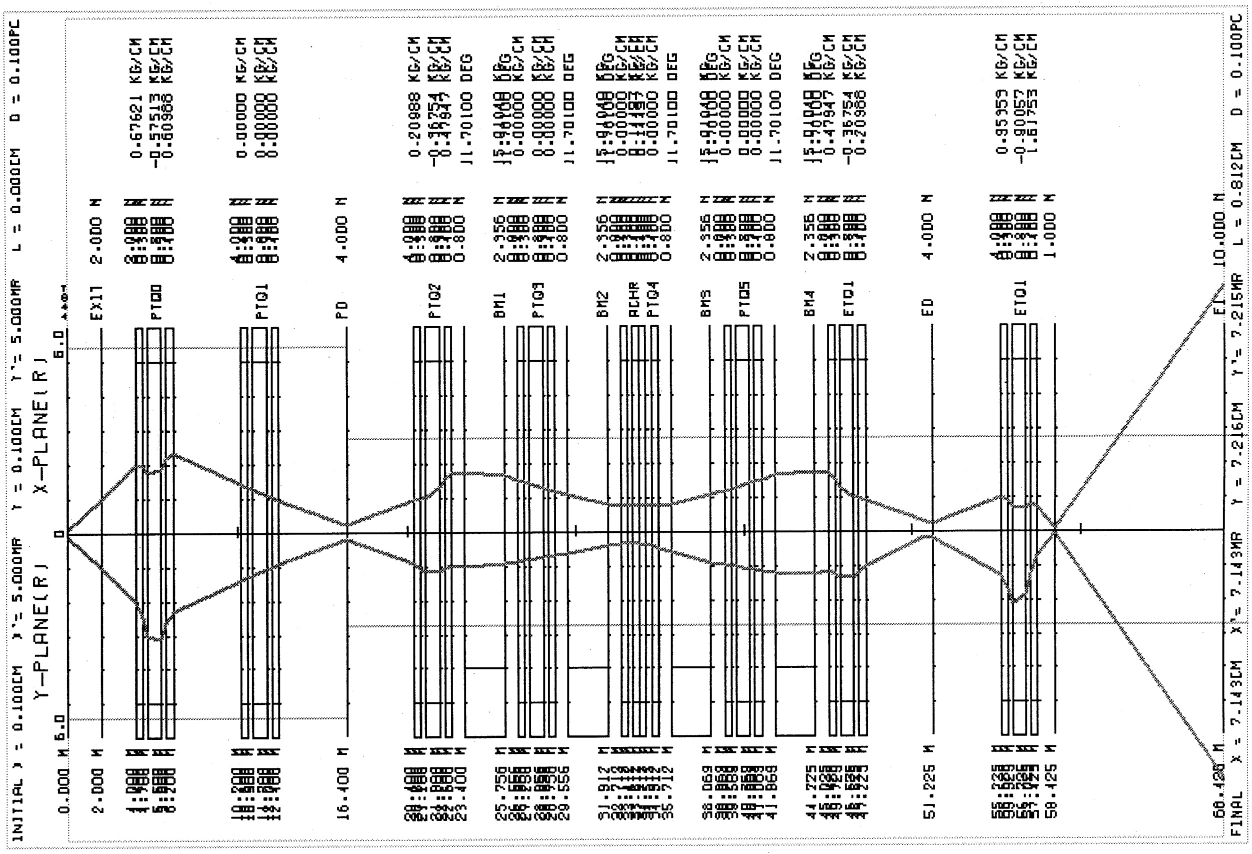

Fig. 2 Typical horizontal (X) and vertical (Y) beam envelope in the case of achromatic transport for the JAERI K900 superconducting AVF cyclotron. The irradiation of wide area will be realized by using a scattering method with defocused beam.

room is 13 x 8 m, and the each room will be isolated with shielding wall.

3 SUMARY

We designed the beam transport system for the JAERI K900 superconducting cyclotron. Now we are designing the bending magnet, the quadrupole triplets, the beam diagnostic system, the vacuum system, the micro-beam lines, the calculation of shielding and the utility of the building etc. The present design of the beam transport system will be modified to meet other design study.

REFERENCES

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