FIELD ANALYSIS FOR JAERI AVF CYCLOTRON

M. Fukuda, K. Arakawa, T. Kamiya and T. Karasawa
Japan Atomic Energy Research Institute
Takasaki, Gunma, 370-12, Japan
and
T. Tachikawa and J. Kanakura
Sumitomo Heavy Industries, Ltd.
Niihama, Ehime, 792, Japan

ABSTRACT

We have measured the magnetic field for the JAERI AVF cyclotron(K=110). Maps of the main coil fields, the trim coil fields and the harmonic coil fields have been obtained. The first harmonic amplitude in the main coil field is less than 4G within the extraction radius of 923 mm. This amplitude can be corrected by four pairs of harmonic coils in the extraction region. The isochronous field produced by the optimization calculation of the main and trim coil currents agrees with the measured field.

INTRODUCTION

An ion beam accelerated by the JAERI AVF cyclotron is utilized for fundamental research in various scientific fields, especially on materials science and bio-technology.[1] We have two external ion sources, multi-cusp type for light ions such as p, d and α and ECR type[2] mainly for heavy ions. The ion beams extracted from the ion sources are transported and axially injected to the medium plane of the cyclotron. Acceleration harmonic modes of 1, 2 and 3 are available. The ions from proton to xenon with M/Q=1 - 6.5 can be accelerated in a broad energy range: 10 - 90 MeV for p, 10 - 50 MeV for d, 20 - 100 MeV for α and ($2.5\times M$ - $110\times Z^2/M$) MeV for heavy ions. The isochronous fields depending on M/Q and energy of the accelerated ions are full of variety.

The JAERI AVF cyclotron is of the model 930 of Sumitomo Heavy Industries, Ltd. The characteristics of the cyclotron magnet are shown in Table 1. An schematic view of the cyclotron is shown in Fig. 1. The cyclotron magnet is of an H-type with a pole diameter of 2156 mm and four spiral sectors. Twelve pairs of circular trim coils are wound concentrically on the sectors. Four pairs of harmonic coils are placed in a central region for centering the off-centered beam. Another four pairs of harmonic coils are placed in an extraction region for fine adjustment of turn separation. A magnetic channel and a field gradient corrector are located downstream of a deflector. The magnetic channel brings effective adjustment of the extraction orbit. The field gradient corrector is used for horizontal focussing of the extracted beams.

The field measurement for the cyclotron magnet has been carried out for the purpose of investigating the field characteristics. We measured the main coil field, the trim coil field, the harmonic coil fields both in the central and extraction regions and the field in the axial injection hole.

A field mapping on the medium plane in the cyclotron was done in polar coordinates of (r, θ). A Hall plate, Siemens SBV 601-S1, was placed in a housing 50 mm long, 34 mm wide and 20 mm thick. The inside of the housing were kept at a constant temperature by a temperature regulator. The

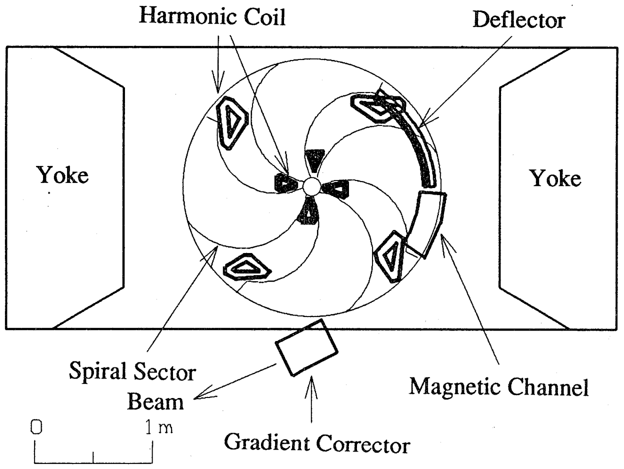

Fig. 1 Schematic view of the JAERI AVF cyclotron.

Table 1
Characteristics of the JAERI AVF cyclotron magnet.

K-number	110
Extraction Radius	923 mm
Number of Sectors	4
Maximum Main Coil Current	900 A
Maximum Main Coil Field	16.7 kG at r = 923mm
Number of Trim Coils	12
Number of Harmonic Coils	4 in central region 4 in extraction region
Total Weight of Cyclotron	229 ton
Pole Diameter	2156 mm
Pole Gap	405 mm
Sector Gap	166 mm

housing was moved by 2 cm steps in r and 1.8 degree steps in θ.

MAIN COIL FIELD

Excitation procedure of the cyclotron magnet is as follows; 1) The magnet is excited up to a maximum field level at a main coil current of 900 A, 2) It is de-excited down to a low field level at 50 A, 3) The main coil current is set up to a higher level by 1% than the required field level, 4) The current is set down to a lower level by 1% than the required field level, 5) The current is set up to the required field level. It takes 4 minutes for each process. The procedure is the same as that for the RIKEN injector AVF cyclotron[3].

The main coil fields were measured at ten different main coil currents. The excitation curve at an extraction radius of 923 mm is shown in Fig. 2. Saturation of the field strength begins at around 10 kG. The maximum field strength at the extraction radius is 16.7 kG which is high enough to produce the isochronous field for heavy ions with high energy. The radial distributions of the base fields at ten excitation levels are shown in Fig. 3. The radial distributions of the first harmonic fields for four main coil fields are shown in Fig. 4. The strength of the first harmonic fields is less than 4G within the extraction radius. The strength of 4G can be corrected by optimizing the harmonic coil field.

TRIM COIL FIELD

The trim coil field measurement was carried out at three base field levels of 120A, 585A and 850A. Trim coils were excited in addition to the field generated by exciting the inner trim coils. The strength of each trim coil field is obtained by subtracting the field of the inner coils at the same radius. The radial distributions of twelve trim coils at 585A are shown in Fig. 5. The strength of the trim coil field at the same current depends on a base field level because of field saturation. The trim coil field strength at 850A is weakened to nearly 50% of that at 120A.

HARMONIC COIL FIELD

Two pairs of the harmonic coils were excited at a maximum current with opposite polarity. The radial distribution of the first harmonic amplitude generated by the harmonic coils is shown in Fig. 6. The maximum amplitudes at r=200mm and r=860mm at a base field level of 850A are 17G and 27G, respectively. The first harmonic amplitude slightly depends on the base field level.

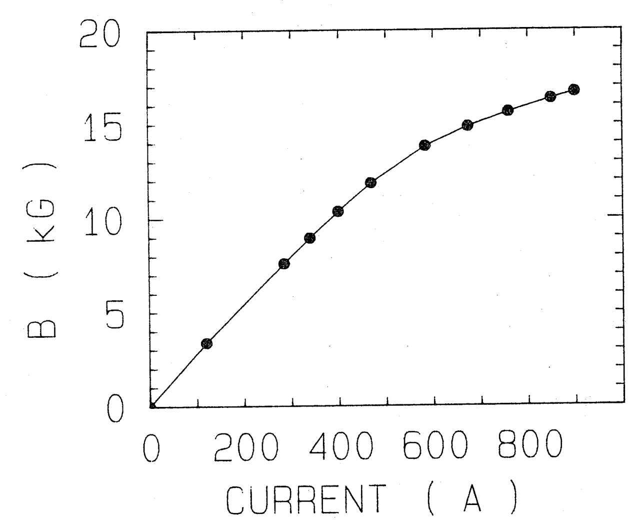

Fig. 2 Excitation curve at an extraction radius of r=923mm.

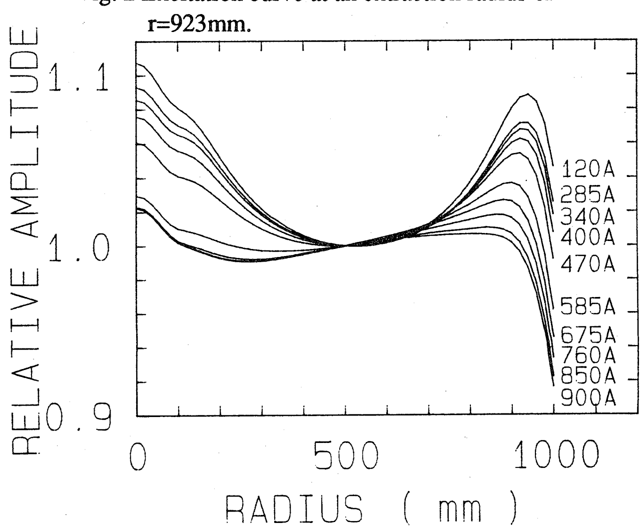

Fig. 3 Radial distributions of the main coil field at ten field levels. The field strength is expressed in relative amplitude to the strength at r=500 mm.

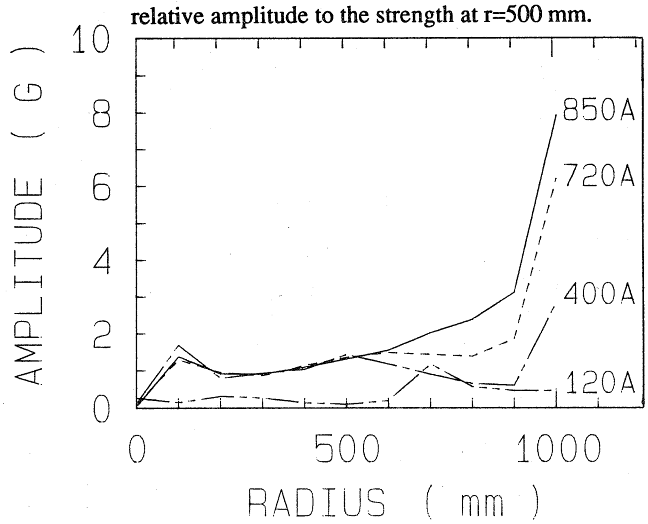

Fig. 4 First harmonic amplitude versus radius for four base field levels of 120A, 400A, 720A and 850A.

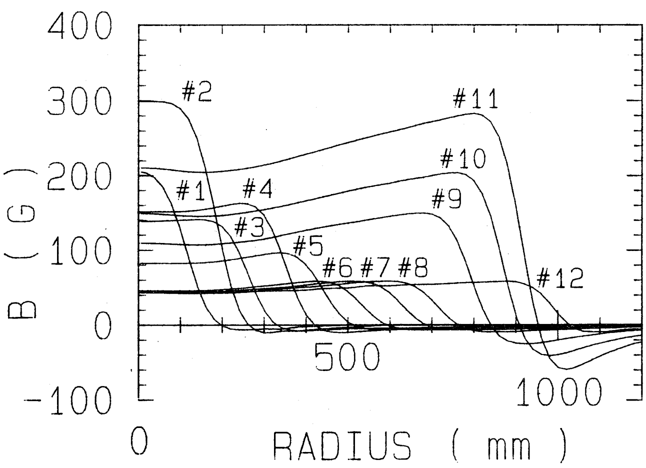

Fig. 5 Radial distributions of twelve trim coil fields at a base field level of 585A.

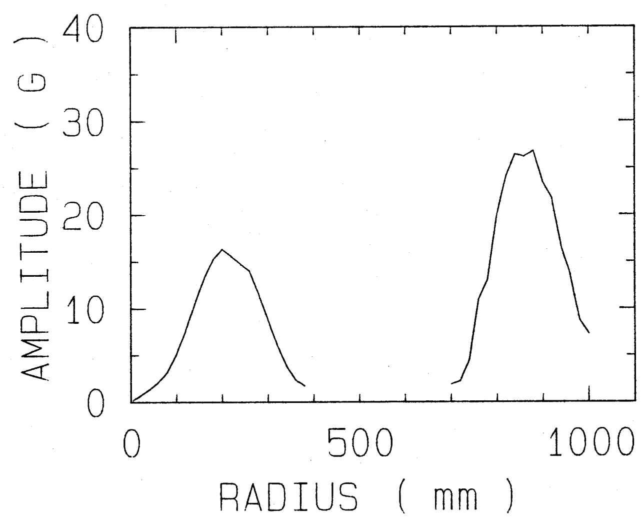

Fig. 6 First harmonic amplitude generated by two pairs of harmonic coils placed in a central and an extraction regions.

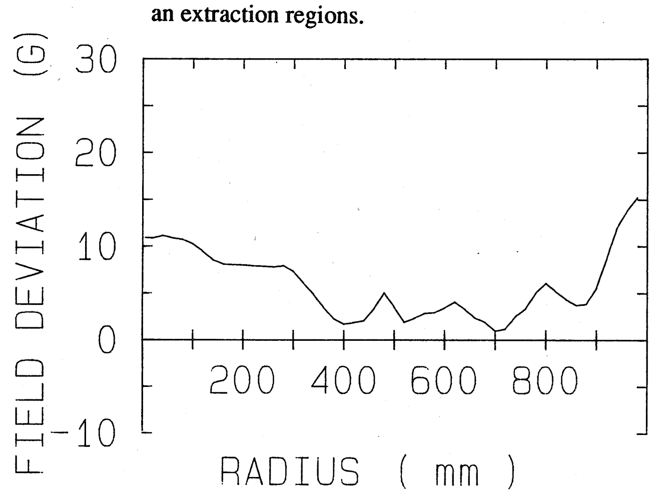

Fig. 7 Difference between the calculated isochronous field and the measured field for 75 MeV proton. The calculated field is produced by the optimization calculation based on the measured main and trim coil field maps.

ISOCHRONOUS FIELD

The isochronous field for 75 MeV proton was measured by exciting the main coil and the trim coils at the calculated optimum currents. The optimum currents for producing the isochronous field were calculated by using the optimization calculation[4] by means of a simplex method. The field maps averaged along equilibrium orbits were used in the calculation. The comparison between the calculated isochronous field and the measured field for 75 MeV proton is shown in Fig. 7. The isochronous field is reproducible within 4×10^{-4}.

CONCLUSIONS

Field measurements for the JAERI AVF cyclotron have been carried out and the basic field characteristics were analyzed. The results show that the cyclotron magnet has good assembly quality. The isochronous field for light to heavy ions can be produced accurately based on the measured main and trim coil fields. Analysis of beam dynamics based on the measured field maps is in progress.

Acknowledgement

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