DEVELOPMENT OF MAGNETIC FIELD INSTRUMENTATION FOR 10 MeV CYCLOTRON

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Abstract

To produce a radio isotope for Positron Emission Tomography (PET), 10 MeV compact Cyclotron was installed at Sungkyunkwan University. This cyclotron had been produced 10 MeV proton beam. For this cyclotron magnet, the magnetic field measurement instrumentation was being developed. The hall probe sensor was used for field measurement. This hall probe sensor moves radial direction and angular direction by mechanically. The Magnetic field measurement instrumentation measures the field in the range of 5 mm for radial direction and 1 degree for angular direction. Magnetic field was measured with and without cooling. Magnetic field was carried with 4 Gauss without cooling and 0.1 Gauss with cooling. Our developed magnetic field measurement instrumentation has 0.1 Gauss of an error and 0.01 Gauss of resolution over 9 hours.

INTRODUCTION

The SKKUCY-10 Cyclotron at the Sungkyunkwan University was been developed since 2015 for production of proton beam. 10 MeV proton beam can produce radioisotopes for positron emission tomography (PET) imaging. To produce 10 MeV proton beam, magnetic field was modified by calculated magnetic field error. The magnetic field error between isochronous field and designed field should be less than 15 Gauss to get high quality of proton beam [1, 3].

This paper presents a development of magnetic field measurement instrumentation for compact cyclotron. The Hall probe sensor can measure ~3 T range, 0.01 Gauss resolution [2]. Specification of hall probe sensor was shown as Table 1.

The coil of the electromagnet creates heat and it interrupt the magnetic field while cyclotron operating. Also the unexpected vibrations of magnetic field measurement instrumentation cause measurement errors. These kinds of errors had been fixed by taking data processing and the operation methods of the measurement system.

Magnetic field measurement instrumentation measures the field in the range of 5 mm for radial direction, and 1 degree for angular direction. Field measurement program is based on LABVIEW. It can monitor the field intensity synchronously, and it is utilized for full field mapping of 10 MeV cyclotron.

DESIGN AND SYSTEM DESCRIPTION

The specification of hall probe sensor was shown as Table 1. The magnetic field range of SKKUCY-10 cyclotron was 0.33 T to 2.17 T and operating temperature was around 50°C. This hall probe sensor was expected high accuracy of measurement.

Table 1: Specification table of hall sensor probe [2]

Parameters	Values
Field measurement range	~ 3 T
Field measurement resolution	0.001 ~ 0.01 Gauss
Temperature Range	-20 °C ~ 60°C
Temperature stability	± 10ppm of reading/°C
Accuracy at 25°C	± 0.01%

3D model of magnetic field measurement instrumentation for 10 MeV cyclotron are given in Fig. 1. The hall sensor probe was on the bracket ①. It will rotate midplane of magnet. The step motor ② was installed at valley, which is connected with rotation jig using by tension belt. The Rotation plate ③ prevent the rotation jig form tilting when magnetic field measurement instrumentation operates. The hall probe sensor had been moved by spur gear ④ and ratchet gear ⑤ along the radial direction. The Linear guide ⑥ supports hall probe sensor.

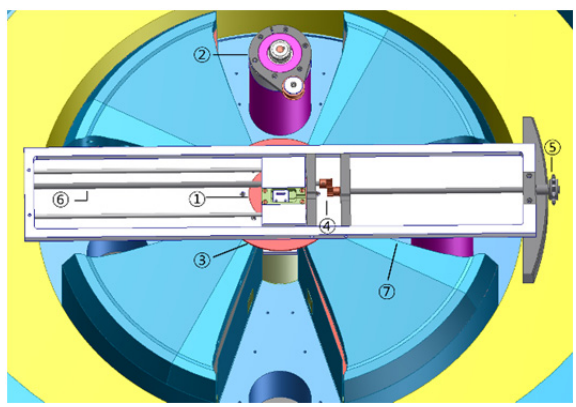

Figure 1: 3D Model of Magnetic Field Measurement Instrumentation. ① : Step motor, ② : Hall Probe Sensor bracket, ③ : Rotation Plate, ④ : Spur Gear, ⑤ : Ratchet Gear, ⑥ : Linear Guide, ⑦ : Rotation jig.

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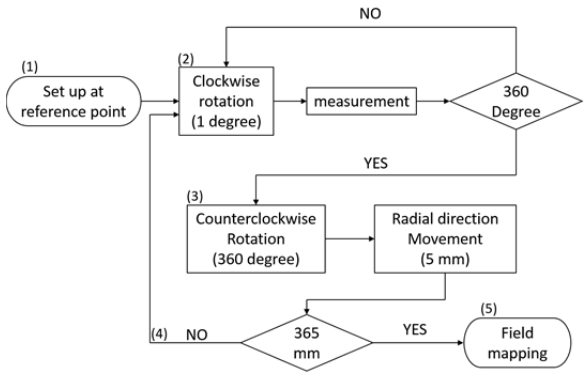

Figure 2: Flow chart of magnetic field measurement.

The flow chart of magnetic field measurement was shown as Fig. 2. This program is based on LABVIEW program [4]. Measurement process was described in the following steps.

(1) The hall probe sensor set up as reference point.
(2) Magnetic field measure with same step size of θ (1 Degree) while rotating in clockwise direction at same radius.
(3) The hall probe sensor was rotate in the counter-clockwise direction, and then it was move 5 mm along the radial direction.
(4) Measure the radial region of R=365 mm of the electromagnet repeating the procedure (2) and (3).
(5) Map the measured data in 2D field mapping.

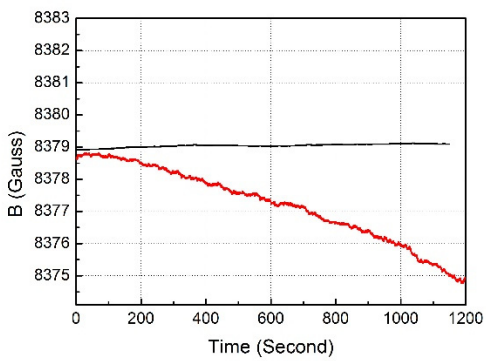

Figure 3: Magnetic field variation.

The magnetic field variation is shown in Fig. 3. Red line shows that the magnetic field had been reduced about 4 Gauss in 20 minutes and temperature had risen when the field was measured in a fixed point. Black line shows that the magnetic field is constant with the value of 8379 Gauss when the field was measured in a same position during 20 minutes. The electromagnet coil creates heat and it interrupts the magnetic field while cyclotron operating. When the temperature of the electromagnet increase, the magnetic field had been reduced. The magnetic field of the electromagnet is formed by the flowing current in the coil which causes the particles of the iron to be arranged along the constant direction that generates the polarity. When the heat is applied to the electromagnet, the kinetic energy of the uniformly polarized particles increases, to that the polarity falls away and finally the magnetic field decreases. Whenever the temperature of the electromagnet maintain constantly, the magnetic field is approximately 0.1 gauss. The range of the magnetic field tuning is -15 to +15. Magnetic field measurement result was constant at a stable condition.

RESULTS AND DISCUSSIONS

There are some errors caused by the load generated from step motor or measurement instrument while operating the magnetic field measurement instrumentation. The magnetic field had been compensated by getting rid of data with large amount of error or receiving more data in the same position with increasing the sampling number of the Hall probe sensor to 5. Figure 4 represents the result for the magnetic field in R=30 cm while operating the measurement instrument. The measurement had been conducted with 10 A for the current of the coil. and the magnetic field on the hill and valley were 2500 Gauss, 700 Gauss respectively.

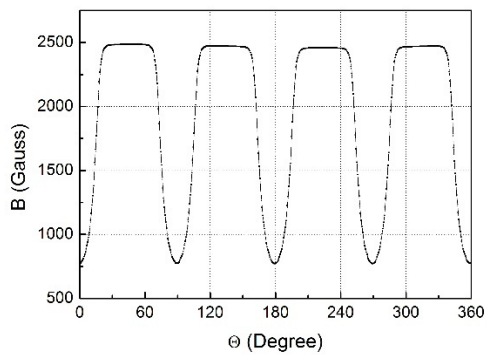

Figure 4: Magnetic field measurement.

Figure 5 shows error bar of measurement. The error of magnetic field was around 0.1 Gauss and it was guarantee high accuracy of measurement.

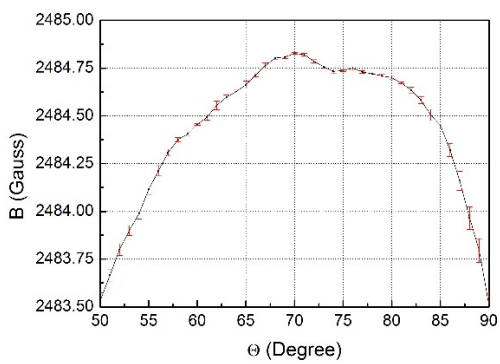

Figure 5: Error bar of magnetic field measurement.

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Table 2: Parameters of Magnetic Field Measurement

Parameters	Values
Radial step range	1 ~ 15 mm
Radial measurement resolution	5 mm
Angular step range	0.07 ~ 360 Degree
Angular measurement resolution	1 Degree
Sampling number	5
Field measurement range	0 T ~ 3 T
Field measurement Resolution	0.01 Gauss
Measurement Time	9 hour
Magnetic field error	0.1 Gauss

Magnetic field measurement instrumentation specification is shown as Table 2. This instrument designed for measuring the magnetic field of 10 MeV Cyclotron. Magnetic field measurement instrumentation measures the field in the range of 5 mm for radial direction, and 1 degree for angular direction. The range is adjustable in the program code. The hall probe sensor takes 5 data each measurement step for increase accuracy of measurement.

CONCLUSION

In this study, Magnetic field measurement instrumentation for compact cyclotron has been developed. Magnetic field measurement instrument measures the field in the range of 5 mm for radial direction and 1 degree for angular direction. The range is adjustable in the program code. Magnetic field measurement instrumentation can monitor the field intensity synchronously. It was adopted simple structure and magnetic field measurement error was less than 0.1 Gauss. It is utilized for full field mapping of electromagnet with high accuracy.

ACKNOWLEDGMENT

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