A LARGE AREA SCANNING MAGNET FOR HOMOGENOUS IRRADIATION OF TARGETS

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Abstract

The scanner is an important tool for accelerator based material science research. For high energy (~100 MeV) ion beam scanner has to be magnetic one. Major problem faced with magnetic scanner is its high inductance which causes large impedance to the a.c. power supply used to energise the magnet. We have designed a magnetic scanner keeping attention to minimise its inductance. The scanner is composed of two independent H-type dipole magnets which are fed by saw tooth pulses. It can scan over an area of 50 mm x 50 mm at a distance of 3 metre. The power supplies for this scanner have also been designed. These are bipolar, wideband, high speed amplifiers that can reproduce complex waveform without any distortion. The ratings are 60 V, 50 A operating at 50 Hz for x-scanner and 5V, 70A at 0.2 Hz for y-scanner.

INTRODUCTION

Beam Scanner is an important tool in Accelerator based research in Material Science in the scientific laboratory as well as in industry. It helps in scanning ion beam over a large area of the sample in a considerably less time, thus saving a lot of costly beam time which in turn helps in reducing price of the product in the industry. The scanner used in the low energy accelerator is electrostatic whereas it is magnetic in the high energy end. We have developed a magnetic scanner for homogenous irradiation of samples in material science beam line in beam hall – II of 15 UD pelletron [1]. The problem encountered in magnetic scanner is the high inductive impedance of the magnet which poses great problem in developing suitable power supply for energising the magnet. Keeping this in view we have made the design criteria of the magnet to have low inductance ~ 4mH. We have also developed suitable power supply for the magnet. The following sections describe the design of the magnet and power supply.

DESIGN OF THE MAGNET

The scanning magnet has been designed with the following beam and geometrical specifications:

ME/Z^2 for the beam = 400 a.m.u.MeV where M is mass in a.m.u and E, the energy in MeV and Z is charge state of the ion. L, the distance of the target from the magnet = 3 metre and scanning area = 50 mm x50 mm

To reduce the indutance we have considered two separate H-shaped magnets for scanning in horizontal (X) and vertical (Y) planes. The first dipole is for scanning in Y-plane and the second one for X-plane. The ratio of operating frequency for X and Y magnets is 100: 1. Since operating frequency for X is large compared to Y magnet, the length of X magnet has been increased compared to Y-magnet to have same scanning length in both planes at reduced current. The linear deflection of the beam by a dipole magnet of magnetic field B at a distance L is given by the formula:

$$D\ (\text{mm}) = 6950\ L \int B\ dl / (ME/z^2)^{0.5}$$

For a deflection of 25 mm at a distance of 3 metres, $\int B.dl$ = 0.02398 T.m. Taking the effective length of the x-magnet 0.2 m we get B =0.12 T. Ampere-turn is calculated using the formula NI = Bg/μ where g is the pole-gap and μ is the permeability of the air medium. Taking pole gap 53 mm, NI comes out to be 4774. If we take I= 50 A, N=96. Hence the number of turns per pole is 48. Taking the effective length for y magnet as 0.125 m, B turns out to be 0.19T. This is achieved by energising it at a current of 75 A for N = 96. The physical design specifications of the magnet is given below:

Pole gap	53 mm
Physical length (mm)	175(x magnet), 100 (y magnet)
Pole width	100 mm
Pole height	60 mm
Turns/coil	48
DC resistance	25 mili-ohm/coil
Inductance	~ 4 mH (2-coils)
Impedance	~ 1.2 ohm at 50Hz
Current	50 A (x), 75 A (y)
Voltage	60 V (x), 5 V (y)
Power	3 KW (x), 0.4 KW (y)

The schematic design of the magnet is shown below.

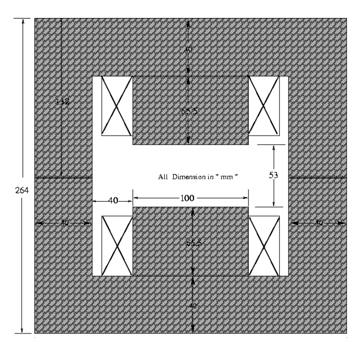

Figure 1: Schematic design of the magnet

The magnet has been fabricated by local vendor in Delhi. It has been tested with DC power supply. The excitation curve and axial field mapping are shown in figure 2 and 3 respectively.

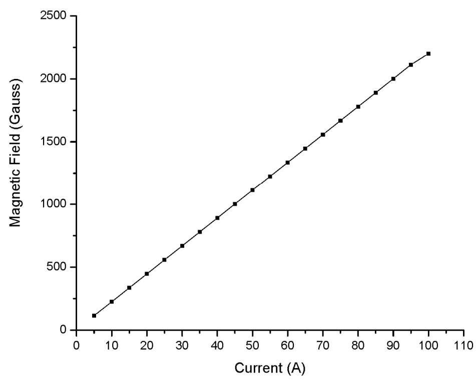

Figure 2: Excitation curve

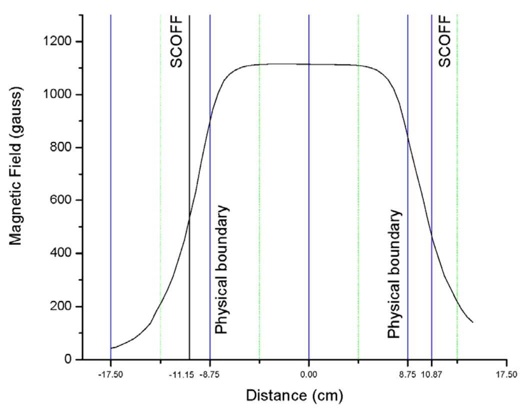

Figure 3: Axial field distribution

POWER SUPPLY

Scanner magnet power supply is basically an amplifier with considerable bandwidth which provides current regulated triangular wave output to magnet (inductive loads) corresponding to triangular wave input. The power supply works on a linear series pass technique. A group of complimentary transistors have been used in push pull configuration at output stage (series pass element) to get the bipolar output, which is driven by high gain error amplifier for achieving wide signal bandwidth and rapid output slewing. A special technique has been used in the regulation (figure 4) for achieving a cross-over distortion free output, foldback type limit for both output voltage and current. As shown in the schematic of regulation technique, the control circuit has mainly two loops viz., quiescent current loops and regulation loops. The quiescent current control circuit keeps a constant current flowing through push-pull stage, regardless of the load condition and direction of load current for getting a crossover distortion free output. While the outer feedback control loop is for output regulation, where output feedback signal is compared with reference at the input of error amplifier. The resulting error signal drives push-pull stage and regulates output. Six identical high gain error amplifiers are used in the regulation system. Four error amplifiers are for foldback limit and remaining two for output regulation. Both voltage as well as current regulation has been provided in the circuit. Whenever power supply is in voltage regulation, the current control will simultaneously work for foldback limit and vice versa. The specifications of the power supply is give below.

Specifications:

- Output current range : ±(0-50A)
- Output voltage range : ±(0-60V)
- Scanning frequency range : 0.4 - 50Hz
- Input voltage : 415V, 3 phase

Features:

- CAMAC / Local operation.
- Voltage and current regulation with foldback output limit.
- Back e.m.f protection.
- True regulated triangular wave output without crossover distortion.
- Necessary safety interlock to put-off load current if either interlock fails.
- Status indication of power supply on front panel as well as for CAMAC.

The block diagram of the power supply is shown in figure 5. The power supply has been tested with the magnet. The output waveform is shown in the figure 6.

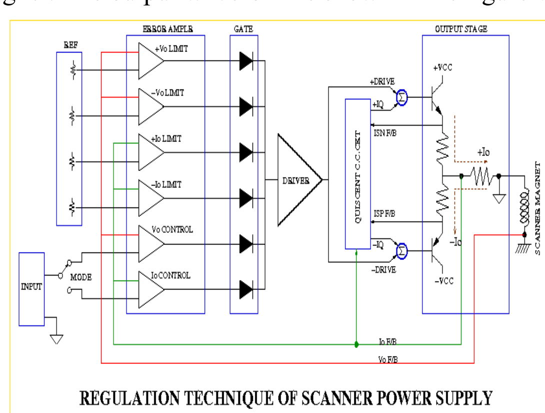

Figure 4: Schematic of regulation technique

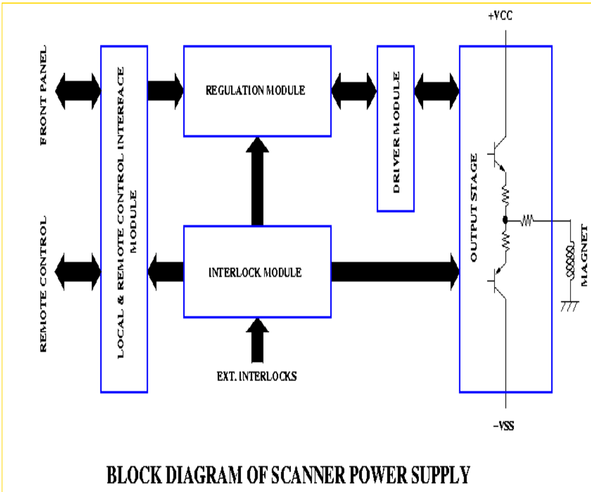

Figure 5: Block diagram of the power supply

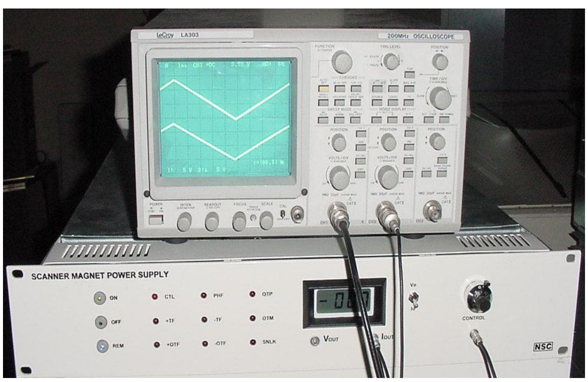

Figure 6: Output waveform with magnet as load

REFERENCES

[1] D.Kanjilal, S.Chopra, M.M. Narayanan, Indira S. Iyer, V.Jha, R.Joshi and S.K.Datta, Nucl.Instrum. Methods A 328 97 (1993)