A NOVEL METHOD OF BEAM SCANNING OVER A LARGE SAMPLE AREA AT PLF, MUMBAI

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Abstract

Many applications require uniform irradiation with heavy ion beams and special electric/magnetic devices are employed to scan the beam over the desired target area. We report a novel method of beam scanning using a magnetic steerer in the beam line. Indigenously developed magnetic steerers, comprising a pair of coils with sine-cosine winding, are installed in beam lines at PLF (Mumbai) for correcting the X-Y position of beam. This steerer is adapted to work as a scanner by employing a microcontroller and an interface unit for constant current bipolar power supply. A triangular waveform is applied to control the excitation current for scanning the beam simultaneously in both horizontal (X) and vertical (Y) planes. A programme generates a raster pattern governed by a pre-settable number of X sweeps for each Y sweep. The dwell time at each of X-Y position was adjusted considering the time constant arising due to the inductance of the steerer. Multiple raster scans were used to produce uniform irradiation over the sample. The scanner has been successfully employed for uniform irradiation of GaAs substrate for photoconductive THz applications using ^{12}C beam.

INTRODUCTION

The Pelletron LINAC Facility (PLF), Mumbai is a major centre for heavy ion accelerator based research in India. The Pelletron (14MV) was commissioned in 1989 and the superconducting LINAC booster employing Pb plated QWRs was added in 2007 [1, 2]. Several experimental facilities have been established at this centre to pursue research in nuclear, atomic, condensed matter physics, interdisciplinary areas and applications. For R&D in materials for science applications, the uniform irradiation of high-energy, intense ion beams over a large area is required. It is therefore, desirable to design and develop a relatively simple and inexpensive beam scanner. There are various methods for making uniform irradiation with a well focused pencil like narrow beam over a large area. Some of them involve simply broadening the spatial profile of the beam by defocusing, or scattering, while others employ special electric/magnetic devices for moving the beam over desired sample area. The defocusing method, although simple, can not yield a uniform irradiation over a large area and lacks good reproducibility of dose distribution. The scattering method using double scattering foils and occluding ring [3, 4] results in loss of particle energy and in beam intensity due to the scattering foils. Raster scanning with electromagnetic device is very useful for heavy ions as it does not involve scattering or energy loss. The present paper describes a novel method of beam scanning using a magnetic steerer in the beam line.

SCANNING SYSTEM

The beam scanning system is required to provide beam deflection in both horizontal (X) and vertical (Y) direction. The magnets in the scanning system must have sufficient rigidity to generate the required deflection at the target and should have fast ramping speed to ensure uniform intensity in desired area even for small doses. Moreover, the accuracy and reproducibility are highly essential for preparation of multiple samples. Indigenously developed magnetic steerers, are installed in beam lines for correcting the X-Y position of beam. This steerer is adapted to work as a scanner by employing a microcontroller and an interface unit for constant current bipolar power supply. The steerer consists of standard 36 slotted motor-stator housing with two independent pairs of sine and cosine windings, which produces a homogeneous field in the X and Y directions over a large volume. The vacuum chamber is cylindrical in shape with ~10 cm diameter and ~15 cm long. The sine-cosine winding pairs are connected in parallel to reduce the effective coil inductance. The field is found to be homogeneous (better than 1 %) in central region of 50 mm radius over an effective length of ~ 9 cm. Each doublet coil can take a maximum current of 10 A, which gives a B_{max} = 0.5 T along the axis of the steerer. The inductance of the coil is 50 µH and time constant is 15 µsec. Figure 1 shows a photograph of steerer magnet and schematic of the beam scanning system.

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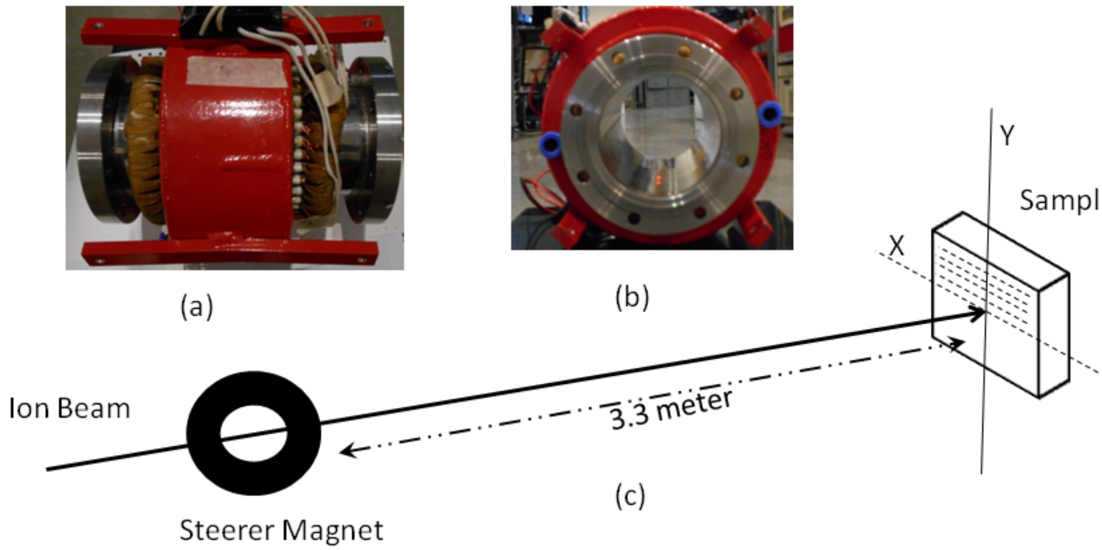

Figure 1: Steerer magnet showing (a) side view and (b) front view; and (c) schematic diagram of the beam scanner.

MAGNET CONTROL SYSTEM

The inductive load is best driven by the voltage controller with constant current drive. A pair of bipolar constant current power supplies 35V, ±15A, is used to energize the steerer. Two banks of complementary emitter follower transistors in Push-Pull configuration are used for a smooth transition from positive to negative current. For given voltage setting, the power supply provides a constant current (±0.03%) irrespective of the load resistance, within the compliance limit.

Figure 2 shows a block diagram of the scanner control system. The scanner is developed using a Silicon Lab C8051F020 microcontroller, which is a package containing a 8051 microcontroller (with 20 MHz clock), 64K bytes of flash memory, 4K RAM and a set of peripherals like 12-bit ADC, 12-bit DAC and digital I/Os. The DAC is used to control the current and the voltage of the power supply, while the ADC is used to sense the voltage and current from the power supply. In addition, the digital I/Os are used to operate the power supplies (on/off), enable the scan mode and provide the status display through a LED indicator. The control/sense signals of the power supply are not directly compatible with the microcontroller. Therefore, an interface card is developed for gain adjustment and level shifting for suitable conversion of the power supply signals. Programming of the 8051 is achieved using an open source Small Device C Compiler (SDCC). The SDCC 8051 tools are integrated into the Silicon Lab IDE (Integrated Development Environment). The IDE provides an efficient development environment with compose, edit, build, download, and debug operations integrated into the same program.

A triangular waveform is applied to control the excitation current for scanning the beam simultaneously in both X and Y planes. A programme generates a raster pattern governed by a pre-settable number of X sweeps for each Y sweep. The dwell time at each of X-Y position was adjusted considering the time constant arising due to the inductance of the steerer.

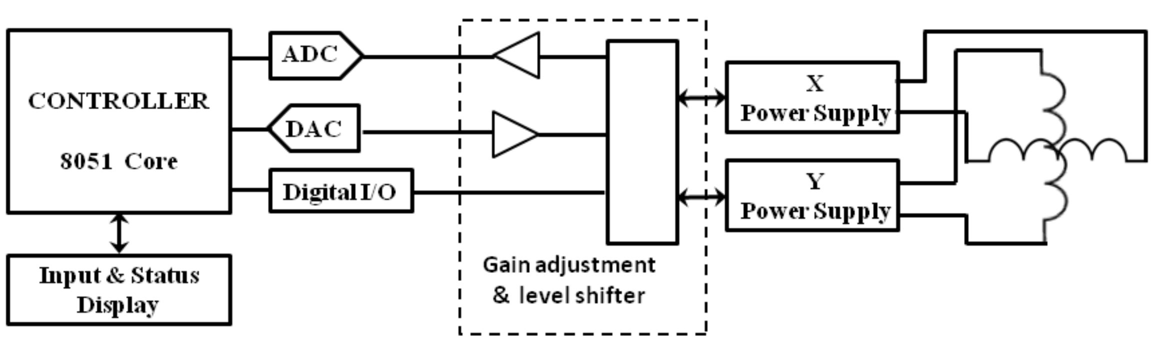

Figure 2: Block diagram of the beam scanner controller.

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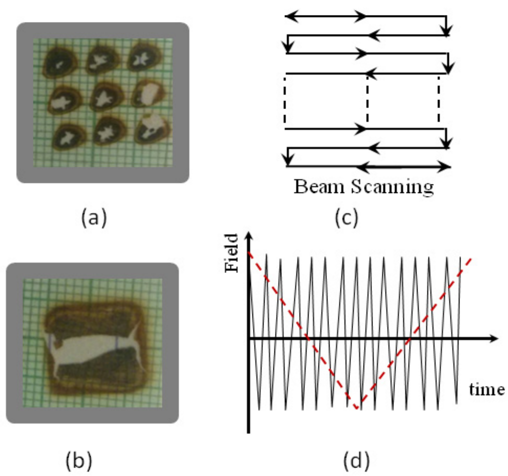

Figure 3: Picture of beam spots obtained on graph paper at target position with ^{12}C beam, corresponding to (a) different steerer current settings and (b) complete scan. (c) Scanning pattern and (d) the magnetic field amplitude as a function of time for X deflection (black solid line) and Y deflection (red dotted line).

Multiple raster scans were used to produce uniform irradiation over the sample.The scanned area on the target is controlled by adjusting the maximum current in the coil. Figure 3 shows a typical beam spot on graph paper at target position with ^{12}C beam (E = 33.5 MeV), different positions correspond to different steerer current settings. The scanning was done with horizontal frequency of 80 Hz and the vertical frequency of 0.2 Hz. In the present setup, the maximum area of 15 x 15 mm^2 can be scanned on a sample.

CONCLUSION

We have developed a simple method of beam scanning using a X-Y magnetic steerer in the beam line. A triangular waveform is applied to control the excitation current in the steerer for scanning the beam simultaneously in both horizontal (X) and vertical (Y) planes. A programme generates a raster pattern governed by a presettable number of X sweeps for each Y sweep. The scan area, step-size and scanning speed are adjustable parameters. The dwell time at each of X-Y position was adjusted considering the time constant arising due to the inductance of the steerer. Typically, a beam scan on a ~10 x 10 mm^2 is achieved in ~5 sec. The scanner has been successfully employed for uniform irradiation of GaAs substrate for photoconductive THz applications using ^{12}C beam [5, 6].

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REFERENCES

[1] V. Nanal et al., “Operational experience of superconducting Linac booster at Mumbai”, http://accelconf.web.cern.ch/AccelConf/HIAT2009/papers/th-07.pdf; HIAT09, Venice (Italy) 2009.

[2] V. Nanal et al., “Extension of superconducting linac operation to lighter beams”, http://accelconf.web.cern.ch/AccelConf//HIAT2012/papers/po06.pdf; HIAT12, Chicago, (IL USA) 2012.

[3] Y. Takada, “Dual-ring double scattering method for proton beam spreading,” Japan J. Appl. Phys., 33, 353-359 (1994).

[4] E. Grusell, A. Montelius, A. Brahme, et al., “A general solution to charged particle beam flattening using an optimized dual-scattering-foil technique, with application to proton therapy beams,” Phys. Med. Biol., 39, 2201-2216 (1994).

[5] Abhishek Singh, Sanjoy Pal, Harshad Surdi, S. S. Prabhu, Vandana Nanal and R. G. Pillay “Highly Efficient and Electrically Robust Carbon Irradiated Semi-Insulating GaAs Based Photoconductive THz Emitters” Appl. Phys. Lett. 104, 063501 (2014); doi:10.1063/1.4864623.

[6] Abhishek Singh, Sanjoy Pal, Harshad Surdi, S. S. Prabhu, S. Mathimalar, Vandana Nanal, R. G. Pillay, and G.H. Döhler “Carbon Irradiated Semi-Insulating GaAs For Photoconductive Terahertz Pulse Detection” Optics Express 23(5), 6656 (2015); doi:10.1364/OE.23.006656.

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