50MEV PROTON BEAM TEST FACILITY FOR LOW FLUX BEAM UTILIZATION STUDIES OF PEFP

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Abstract

The 50MeV proton beam test facility at the MC-50 cyclotron of KIRAMS (Korea Institute of Radiological & Medical Sciences) has been established by PEFP (Proton Beam Engineering Frontier Project) of KAERI. This facility will be used for the pilot studies of PEFP, especially, for the studies using very low flux proton beam, 1×10^6~1×10^{10}/cm^2-sec. We surveyed users' demands of proton beam utilization last year [1]. According to the demand survey result, scientists who are interested in biological application and space technology development hope to use low flux proton beam. The beam line is composed of SBD (Stray Beam Detector), Faraday cup, beam drift vacuum tube, bellows, BPM (Beam Profile Monitor), exit window with phosphor screen, scattering foil, energy degrader, target stage, irradiation uniformity measurement system, dose measurement system, etc. The length and width of the beam line supporter are 4m and 80cm. The exit window consists of aluminium plate with 2mm thickness, 180mm diameter, and 116mm active area. Twelve Al foils of different thickness are used as energy degraders to control proton beam energy and LET value to the biological samples. The scanning method similar to the wobbler scanning method using rotative stage is adopted for the uniform irradiation of large area more than 8cm diameter in the first place. In the next place, we will develop spiral scanning system and wobbler scanning system. The scatterer is made of gold foil of a few tens micrometer thickness. This low flux proton beam line will be used for the biological application and development of space technologies until the PEFP's accelerator and user facilities are established.

INTRODUCTION

Several research projects concerned with biological technology, nano-technology, space technology, semi-conductor technology, etc are on progress. On the needs from these projects PEFP has a plan to establish two kinds of test facilities, low flux and high flux ones, using some existing domestic accelerators. As low flux test facility, 50MeV proton beam test facility has been developed and established at MC-50 cyclotron of KIRAMS. This facility will be used for biological and space technology developments with low flux proton beam of 10^6~10^{10}/cm^2-sec. High flux test facility of 10^{13}~10^{15}/sec for nano- and semiconductor technology developments will be developed and established at 1MV Tandem accelerator of KAERI in near future.

DEMANDS ON LOW FLUX PROTON BEAM TEST FACILITY

On the basis of the demand survey result which was carried out last year, 50MeV test facility has been designed. Most of respondents want to use domestic facilities because of good accessibility and low cost. The PEFP decided to establish test facilities to the existing accelerators in Korea and 50MeV test facility has been developed and attached to the MC-50 cyclotron of KIRAMS. This facility will be very useful in the fields of biological and space technology.

Biological Application

The uses of high LET (Linear Energy Transfer) proton beam have attracted an increasing interest over the last years. In the PEFP, development of new genetic resources using few tens MeV proton beam was the main concern in the field of biological radiation technology. In this research, it is highly important to investigate impacts on biological species through LET of varying proton beam properties [2]. A low flux external beam irradiation facility is essential for the study. The requested energy range is 1~50MeV, with flux density of 10^9~10^{10} /cm^2-sec. During irradiation, the temperature of samples has to be maintained below 50 degree centigrade.

Space Application

The need of electronic devices for space applications has been increasing with the growth of space industry. To evaluate radiation-tolerant characteristics of space devices is very important in view of operational safety. Proton beam specifications for space applications are similar to those of biological ones. The energy range is 10~50MeV and the flux density is in the range of 10^6~10^{10}/cm^2-sec.

50MEV PROTON BEAM TEST FACILITY

For the pilot studies of low flux proton beam utilization of PEFP, 50MeV test facility has been developed and attached to the MC-50 cyclotron of KIRAMS. The beam line is composed of collimator, Faraday cup, vacuum tube for beam drift, bellows for easy alignment, BPM (Beam Profile Monitor), exit window for external beam, phosphor screen, scattering foil, energy degrader, target stage, irradiation uniformity measurement system, dose measurement system, energy measurement system, etc. The schematic drawing of the beam line is shown in Fig. 1. The length of the vacuum side is 3.15m and the controllable distance from exit window to the target is 3m maximum.

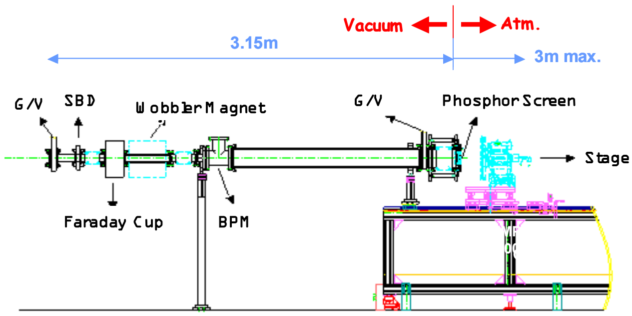

Figure 1: Layout of 50MeV beamline.

Beamline Supporter

To increase usefulness of the beam line, supporter was designed to move components easily using LM (linear motion) blocks. Its length and width are 4m and 80cm, and alignment accuracy is less than 0.1mm. The distance from exit window to the target can be controlled from 10cm to 3m.

Beam Profile Monitor

Beam profile monitor was installed to monitor profiles in the middle of the beam line in the front of the beam drift tube entrance. The beam profile monitor, BPM-NEC83, has an effective scanning area of 7cm diameter with 1.5mm diameter Mo-wire.

Exit Window

Exit window is made of 99% pure aluminium plate of 2mm thickness and 180mm diameter and coated with 50um thick phosphor material P43 (Gd_2O_2S : Tb). The photograph of exit window and installed exit window assembly with bellows type alignment system in the beam line is shown in Fig. 2.

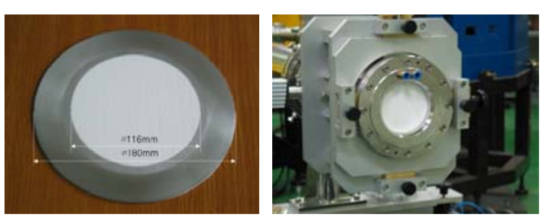

Figure 2: Photograph of exit window coated with P43 phosphor material and its assembly.

Energy Degrader

Energy degrader was designed to supply proton beam of wide energy range from 5MeV to 40MeV. Degrader assembly is composed of 12 pure Al foils of different thickness from 0.01mm to 2mm. To use this assembly we can change degrader thickness from 0.01mm to 3.5mm. The transmitted energy with degraders was calculated by SRIM code simulation. As a results, 28~40MeV external beam can be supplied to the users with 45MeV incident proton beam, and 5~27MeV will be possible with 35MeV proton beam as shown in Fig. 3.

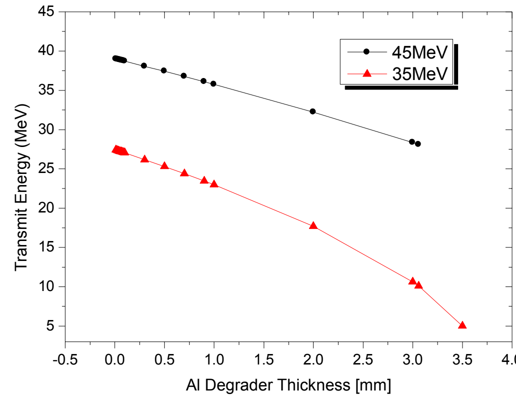

Figure 3: Transmitted proton beam energy vs. Al degrader thickness.

Target Stage

For uniform irradiation of proton beam, two scanning systems, wobbler scanning system and spiral scanning system, were considered. For the spiral scanning, the target stage was designed to be able to rotate and move linearly along to x-axis by the control systems and artificial function generator. The maximum rotation speed is 1000rpm, is a little low than that of general wobbler scanning system with magnet. We have to check the effect to the samples by the rotation motion. The sample like plant in the petri-dish has no change before and after irradiation. Another candidate, wobbler magnets now under development and will be attached to the beam line near future.

Irradiation Uniformity Measurement System

Two kinds of irradiation measurement tool were prepared for this beam line test. First of all, we used Gaf film (GafChromic MD-55) to measure the beam size and irradiation uniformity roughly. Gaf film has 4 layer of different material as shown in Fig. 4. The colour of film is changed to blue by proton beam irradiation.

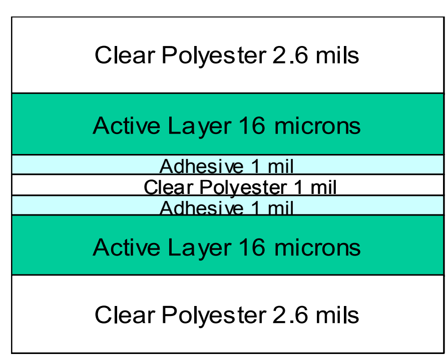

Figure 4: Cross section of Gaf film.

BEAM EXTRACTION AND MEASUREMENT EXPERIMENT

Beam measurement experiment was carried out at this beam line with 45MeV and 5nA proton beam extracted from the MC-50 cyclotron. At the middle of the beam line, SBD and Faraday cup were installed. The current was measured by Faraday cup. First beam was checked at the phosphor screen of exit window as shown in Fig. 5.

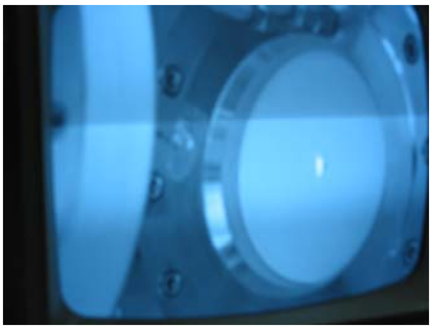

Figure 5: Beam appeared by phosphor screen.

At the distance 20cm from exit windows, target stage was installed and Gaf film was attached on the surface of it. Measured beam size was 45mm diameter as shown in Fig. 6.

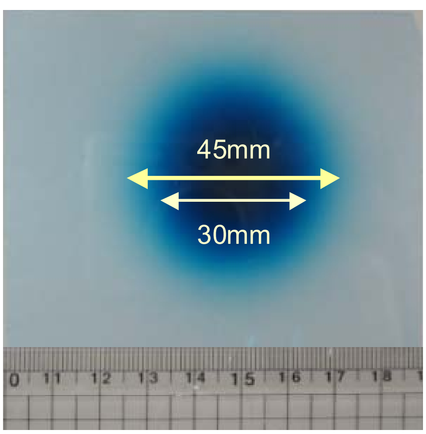

Figure 6: Beam size measured by Gaf film.

To acquire wide irradiation area, new experimental scanning system similar to wobbler scanning with rotative target stage was tested. As a result, wider irradiation was possible to more than 70mm diameter as shown in Fig. 6. The average flux density calculated on the basis of the measure current by Faraday cup was about 5×10^{8} /cm^{2}-sec.

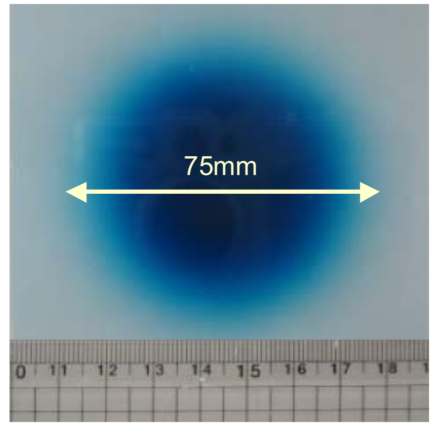

Figure 7: Irradiation uniformity measured using Gaf film.

CONCLUSIONS

50MeV proton beam test facility for low flux beam utilization technology development has been established and basic beam measurement experiment was performed with 45MeV proton beam of 2nA current using phosphor screen and Gaf films. At the target distant 20cm from exit window measured beam size was 45mm diameter.

Prior to using main scanning systems, wobbler and spiral scanning systems, experimental irradiation system using rotative target stage has been tested. As a result, the irradiated area with 20mm offset from the beam center and 300 rpm stage rotation speed was 70mm diameter.

Energy degraders made of Al plate with purity above 99% also have been designed and will be installed in near future.

Scanning system with wobbler magnets and spiral scanning system will be established and tested.

Additional beam line components such as a collimator will be installed to this beam line for the space technology development application.

ACKNOWLEDGEMENTS

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REFERENCES

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