CONSTRUCTION OF USER FACILITIES FOR THE PROTON BEAM UTILIZATION OF PEFP*

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Abstract

The PEFP(Proton Engineering Frontier Project) was approved by the Korean government under its 21C Frontier R&D Program last year. Final goals of this project are construction of 100MeV proton linear accelerator, development of beam utilization technologies, and promotion of related industrial technologies [1]. Its major beam utilization areas are new genetic resource development, simulating space radiation environment, SOI(Silicon On Insulator) wafer development using ion-cut technology, and fast switching power semiconductor development. In addition, there are several small research projects concerned with basic science and nuclear physics. In the PEFP, 20MeV proton beam will be supplied to the users for their experiments from the middle of 2007. This paper contains the conceptual design of user facilities and the construction results of 6MeV proton beam test facility for pilot studies of the proton beam utilization experiments in the PEFP.

INTRODUCTION

In the PEFP, there are several research projects concerned with biological technology, nano-technology, space technology, information technology, etc. For basic experiments and pilot studies of the proton beam application projects, some test facilities will be developed and attached to some existing accelerators. In order to understand users' demand, a demand survey was carried out. And on the basis of its result, a development plan of the test facilities has been established and a conceptual design of the 20MeV proton beam utilization facilities of the PEFP has been performed. First of all, a test facility on the 3MV tandem accelerator of SNU(Seoul National University) has been designed and will be installed in a few months.

DEMAND SURVEY

The demand survey for user facilities has been carried out during the period from February 24th to March 15th. 17 researchers who participate in the PEFP replied to the survey suggesting beam specifications and irradiation conditions which they want to apply for their pilot studies of proton beam utilization. They preferred using domestic facilities to foreign ones because of good accessibility and low expenses. The facilities under consideration are 3MV tandem accelerator of SNU, MC-50 Cyclotron of the KIRAMS (Korea Institute of Radiological & Medical Science), and 1MV tandem accelerator of KAERI which is now under development. Some users proposed the irradiation condition of 0.3~50MeV proton energy, 10^7~10^{16} /cm^2 of total dose, and 2cm~15cm diameter of irradiation. On the basis of the survey results, a 6MeV test facility on SNU tandem accelerator has been designed and a design of 20MeV user facilities of the PEFP will follow.

In Korea, several low current proton beam accelerators including industrial ion implanters, tandem accelerators, and cyclotrons have been operated during last 10 years. Two tandem accelerators in KIGAM (Korea Institute of Geo-science and Mineral resources) and KAERI and one cyclotron of KIRAMS are the candidates of PEFP's test facilities. Especially, 1MV tandem accelerator, which is under development in KAERI, has a merit of large current of 10mA. For this reason, it will be utilized as a main test facility for researches with high dose rates.

Proton beam utilization technologies are being developed in the fields of NT, BT, IT, and ST. And several small projects are progressing under a user program development project.

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 10^7~10^9 /cm^2-sec. During irradiation, the temperature of samples has to be maintained below 50 degree centigrade.

Nano Application

A representative theme of nano-technology is SOI wafer development using ion-cut technology. Ion-cut technology was developed by SOITECH and named as Smart-Cut in France in 1994. SOI wafers of several hundreds nanometer thickness are now commercially produced by SOITECH with this technology. Key technologies in manufacturing SOI wafers by ion-cut are uniform ion beam irradiation over whole wafer surfaces of 2~5" size and CMP(Chemical-Mechanical Polishing) technology. The uniformity of dose distribution has to be greater than 95% and the energy difference ΔE has to be less than 3keV regardless of incident energy in the range of 300~600keV. The maximum dose is .5310^{16}/cm^2.

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.

6MEV PRPTON BEAM TEST FACILITY

For pilot studies of proton beam utilization of PEFP, a 6MeV test facility has been designed and will be installed at tandem accelerator in SNU. The beamline is composed of scanning magnets for raster scanning, a beam profile monitor, and an irradiation chamber with a pumping port, a movable target stage and detectors. The schematic drawing of the beamline is shown in Fig. 1. Some manufactured components has been tested.

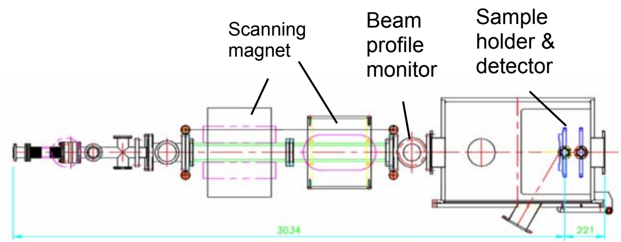

Figure 1: Layout of 6MeV beamline at SNU tandem.

Scanning Magnet

Scanning magnet was designed to irradiate 6MeV proton beam over the area of 6cm36cm with raster scanning method. The pole gap and depth are 110mm and 300mm respectively. As a result of its installation test, the required magnetic field of 1000G has been achieved with 84.2A coil current from 60Hz sine wave power supply as shown in Fig. 2. The magnetic field is linearly proportional to the coil current and the uniformity over the pole area was above 95%. A new power supply of 2~10Hz operation frequency will be installed to improve irradiation uniformity.

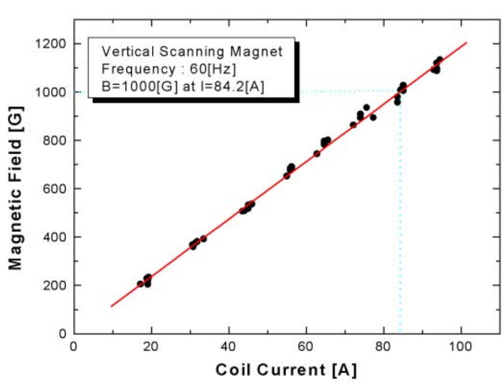

Figure 2: Characteristics of scanning magnet.

Faraday Cup

Small Faraday cup was designed to measure proton beam current. Its material is 99.9% pure Aluminium of 5mm thick and its aperture and depth are 10mm and 60mm respectively. To suppress secondary electrons from cup surface arising through proton beam bombardment, an electrostatic ring with maximum voltage of 1kV and a 830G SmCo permanent magnet are installed, respectively inside and outside of the Faraday cup.

Beam Profile Monitor

Beam profile monitor will be installed to monitor profiles in the middle of the beamline, in the front and back of the scanning magnets to compare beam profile and position changes across the magnets. The beam profile monitor, BPM-NEC83, has an effective scanning area of 7diameter with 1mm diameter Mo-wire.

Irradiation Chamber

Irradiation chamber has a pumping port, movable target stage, detector, etc. To maintain vacuum pressure in the beamline below 2310^{-7} torr, TMP of 800L/sec pumping speed will be installed at the bottom of the chamber. To acquire uniform irradiation performance, the target stage has been designed to allow applications of both raster scanning and spiral scanning methods. For spiral scanning method, the target stage has been designed to have a rotational movement system. For more accurate measurement of dose rates to samples, target and detector will have the same axis of beam. Behind target stage, a kind of 2D detector with high spatial resolution will be installed to measure absorbed dose rates to samples in the radiobiological experiments.

20MEV USER FACILITY

As 20MeV user facilities of the PEFP, 3~4 beamlines will be attached to the main proton linac. The facility for radio biological and space experiments will comprise scanning magnets (wobbler magnets or raster scanning magnets), a scattering foil, a beam monitor, an energy degrader, a modulator, a collimator and a sample changer. The window material of the vacuum chamber for the external beam will be 50μm Kapton or aluminium film of 50mm diameter. In order to obtain a uniform irradiation field, the scanning magnets and a scattering foil of Au with high Z-number will be used. An energy degrader will be used to change LET at irradiation site through reducing proton beam energy. A modulator will be used to make a spread-out Bragg peak. Conceptual design of 20MeV beamline is shown in Fig. 3

A petri dish has been designed for radio biological experiments. Stopping power and lateral straggling of proton beam upon thickness of window material was calculated with TRIM code. The calculation results were illustrated in Table 1. The window material was decided 20μm thick Kapton film. Inner volume of the dish is 80mmϕ335mm and the wall thickness is 4mm. It will be

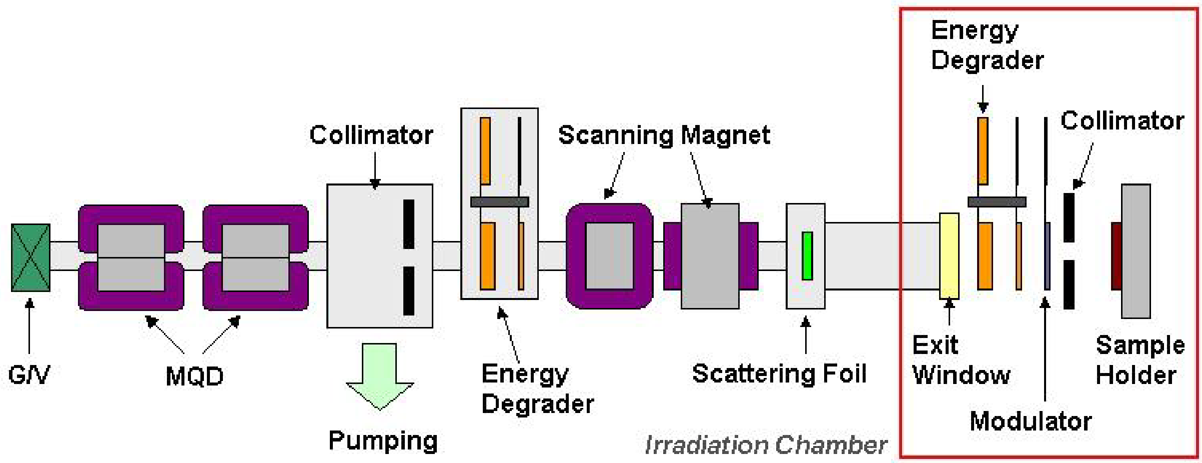

Figure 3: Conceptual design of 20MeV beamline for radio biological experiments.

applied to the experiments for developing new genetic resources using proton beam irradiation.

Table 1: TRIM code calculation results

Material	Stoppimg Power [keV/μm]	Ion Range [mm]	Lateral Straggling [A]
Kapton	3.485	3.17	84.58
Mylar	3.463	3.19	85.04
Polystylene	2.779	3.96	96.42

CONCLUSIONS

Demand survey for user facilities has been carried out and 17 researchers who participate in the PEFP replied to it. On the basis of the survey results, 6MeV test facility for the pilot studies of proton beam utilization technology development at the PEFP has been designed and will be installed at 3MV tandem accelerator in SNU. The magnetic characteristics of scanning magnets of 6MeV beamline have been performed with 60Hz sine wave power supply. To improve irradiation uniformity, a new AC power supply of 2~10Hz will be added. Conceptual design of 20MeV beamline especially for radio biological and space radiation experiments has been performed.

ACKNOWLEDGEMENTS

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