Instrumentation for Measurement of the Energy Distribution of the RF Implanter

Tu Anh Trinh[a,*], Ji Ho Jang, Hyeok Jung Kwon and Yong Sub Cho
Proton Engineering Frontier Project, Korea Atomic Energy Research Institute, Daejeon, Korea
[a] *University of Science and Technology, Daejeon, Korea*
[*] *Corresponding author: tuanh@kaeri.re.kr*

1. Introduction

A microbeam production using the RF implanter at PEFP is in progress for research in material science. For this purpose, the energy spread of the beam less than 1% is required. A beam focusing system with a triplet quardrupole has been adopted. In order to measure the energy spread, we have developed a simple analyzing system using the disperse power of a deflecting magnet in the transport line. The instruments have been designed and installed to the beam diagnostic station which is located image position of the deflecting magnet system. Detailed work will be presented in this paper.

2. Methods and Results

2.1 Measurement principle

When an ensemble of charged particles traverses in a homogeneous magnetic field, particles are deviated in the field region due to the Lorentz force depending on their momentum. As particles with the same momentum are equally deviated, a spectrometer magnet sorts them along a spatial axis in the bending plane of the magnet. This spatial distribution is registered by a detector. If the optical design of the spectrometer line and the value of the B-field of the spectrometer magnet are known, then the central value of the distribution is equivalent to the mean energy value of the beam. In addition, from the geometrical extent of the distribution, the momentum spread can be calculated by the following formula:

$$r = \sqrt{\left(D.\frac{dp}{p}\right)^2 + \beta.\varepsilon}$$
$$r = D.\frac{dp}{p}\sqrt{1+\Delta^2} \qquad (1)$$

with $\Delta = \frac{\sqrt{\beta\varepsilon}}{n.\frac{dp}{p}}$ is the perturbation coefficient

β and ε are the beta-function and emittance value at the detector in the bending plane, while D is the dispersion and dp/p is the relative momentum spread of the beam.

From this equation, the relative momentum spread can be calculated when the dispersion value is known at the point where the beam size is measured. Then, from the relativistic relation between total energy E and momentum p the kinetic energy spread dT can be calculated by:

$$\frac{dE}{E} = \beta^2\frac{dp}{p} \qquad (2)$$

TRACE 3D [1] was used to simulate the transportation of He^{1+} ion beam. Beam emittance and dispersion are given by this simulation. 31keV ions are generated from a Duoplasmatron ion source, focused by a quardrupole triplet, accelerated by a 13.56MHz RF cavity and then bended by a defecting magnet to a diagnostic chamber. The energy gain is 120keV. Simulation result is shown in Fig. 1.

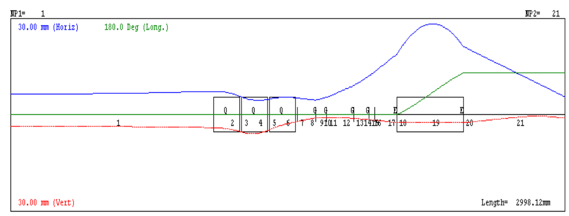


Fig. 1 TRACE -3D simulation of He^{1+} beam

2.2 Analyzing system

This system consists of a 90 degree deflecting magnet, a slit with a minimum width of 0.01mm and a beam intensity monitor. The slit is installed at the image of the deflecting magnet system calculated by TRACE-3D.

The bending magnet with bending radius and angle are 800mm and 90 degrees, respectively is used. Edge angle focusing is applied with the entrance and exit edge angle are 13 and 15 degrees, respectively. The magnetic field profile of this magnet is given in Fig. 2.

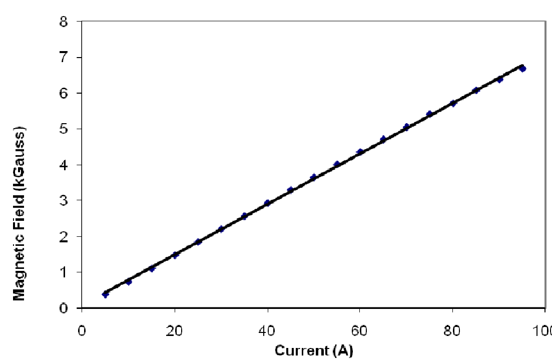
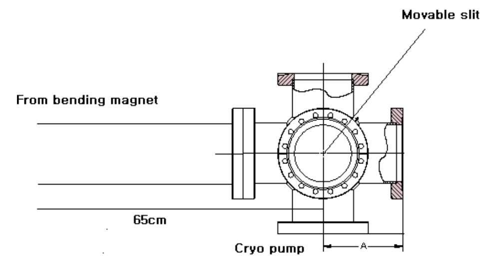
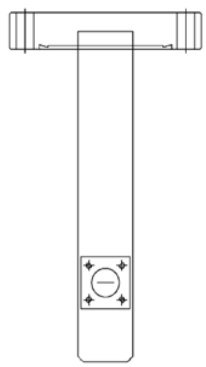


Figure 2: Magnetic field of the bending magnet

Beam instruments, such as a Faraday cup, movable slit are mounted on the station with the standardized ports (outer diameter: 172mm) equipped with a cryo pump. Distance from the exit of bending magnet to the diagnostic chamber is 650mm (Fig. 3)



(a)



(b)

Figure 3: (a) Energy spread measurement chamber; (b) The slit plate and its holder. The slit width is 0.01mm.

The slit assembly in the slit chamber is vertically mounted with a stepping motor to be changeable at the specific experiment position. The sizes of the slit are determined by considering the signal to noise ratio of the beamlet and the acceptance angle when the beam goes through the slit plate [2-3]. The slit size is set to be 0.01mm with a precision of 0.001mm. The slit plate is aligned by a high accuracy stepping motors on the slit chamber. Scanning the single slit is used usually with y directional linear motion which requires a precision moving control for the full measurement of small beam size.

2.3 Uncertainty analysis

The error on the energy spread measurement can be divided into the errors in the beam size measurement, the determination of the dispersion value D, and the error on the perturbation coefficient Δ

$$\frac{\sigma_{dT}}{dT} = \sqrt{\left(\frac{\sigma_r}{r}\right)^2 + \left(\frac{\sigma_D}{D}\right)^2 + \left(\frac{\Delta^2}{1+\Delta^2}\right)^2 \cdot \left(\frac{\sigma_\Delta}{\Delta}\right)^2} \quad (3)$$

Besides a statistical error due to the reconstruction method of the beam width, all uncertainties are estimated by imposing alignment and manufacturing errors on the optimal line design. Therefore:

- The alignment error for slit, spectrometer magnet is assumed to be 1 mm.
- The manufacturing accuracy of the spectrometer entrance and exit edge angles is simulated to be $\pm 0.5^{o}$
- The value of the B-field are allowed to vary by ±0.1%
- The slit width is varied by ±5.0%

3. Conclusions

Beam instrumentation for energy spread measurement of the 13.56MHz RF implanter at PEFP with the energy resolution is of 1% was designed and presented in this paper. The installation and experiment will be carried out in the near future.

Acknowledgment

This work was supported by Ministry of Education, Science and Technology of Korea.

REFERENCES

[1] K. R Crandall and D. P. Rusthoi, "TRACE 3D Documentation", LA-UR-97 886.
[2] S.G Anderson, J. B. Rosenzweig, G.P. LeSage and J.K Crance: Phys. Rev. ST Accel. Beams **5** (2002) 014201.
[3] K. Flottmann: TESLA-FEL 96-09, May 1996.