PA08

ACCELERATION OF DEUTERON AND ALPHA BEAMS IN THE KEK-PS INJECTOR

Akira TAKAGI, Kiyoshi IKEGAMI, Chikashi KUBOTA, Zenei IGARASHI, Michikazu KINSHO, Katsuhiro SHINTO*, Shinji MACHIDA, Masahito YOSHII, Eiichi TAKASAKI, Yoshiharu MORI**

National Laboratory for High Energy Physics(KEK), Oho, Tsukuba, Ibaraki, Japan
*The Graduate University for Advanced Studies(GUAS), Oho, Tsukuba, Ibaraki, Japan
**Institute for Nuclear Study, University of Tokyo(INS), Midori-cho, Tanashi, Tokyo, JAPAN

Abstract

Many experiments have been carried out for helium ion beam acceleration in the KEK 12GeV Proton Synchrotron throughout in 1994. A helium beam has been successfully accelerated. the 750 keV Preinjector has a He^+ ion source of multicusp type and a gass stripper cell installed in the low energy beam transport(LEBT). Maxmum value of $^4He^{2+}$ ion current at the exit of the Proton Linac was 1.6 mA. A deuteron beam was also produced by carbon stripping foil installed in the LEBT just after high current D^- ion source for machine tuning.

In addition helium-3 beam acceleration has been tried in the 40 MeV Proton Linac in 4π-mode acceleration. $^3He^{2+}$ ion beam current of 1.8 mA was observed.

1. Introduction

Acceleration of heavy ion beams in the KEK PS was discussed about more than 10 years ago. However, the project was stopped by several reasons and heavy ion acceleration in the KEK PS has not ben realized so far. Very recently, as one of the possible candidates among the future plans of the KEK PS, the PS-Collider, which aims to accelerate and collide heavy ion beams with the beam energy of up to 7GeV/u for a gold beam, has been proposed.[1]
The PS-Collider is designed to use the present KEK PS as its injector, therefore a much more simple scheme compared with the previous one for accelerating heavy ions in the PS has been examined carefully for ease of operation. Simultaneously, possibility of a polarized deuteron beam acceleration in the PS has been also studied.[2]

In the KEK 12 GeV proton synchrotron, the experimental study of helium beam acceleration have been carried out and helium beam was supplied for the physics experiment.[4] There were several modifications: A helium ion source of multi-cusp type was installed in the second preinjector for the production and preacceleration of positive ions.[3]

2. Acceleration of He^+ ion beam in the preinjector

The injector comprises a 750 keV Cockroft-Walton preinjector and a 40 MeV Alvaretz linac. There are two sets of Cockroft-Walton preinjectors, the first preinjector is used to accelerate a high intensity beam of H^- and D^-, whereas the second preinjector is for a

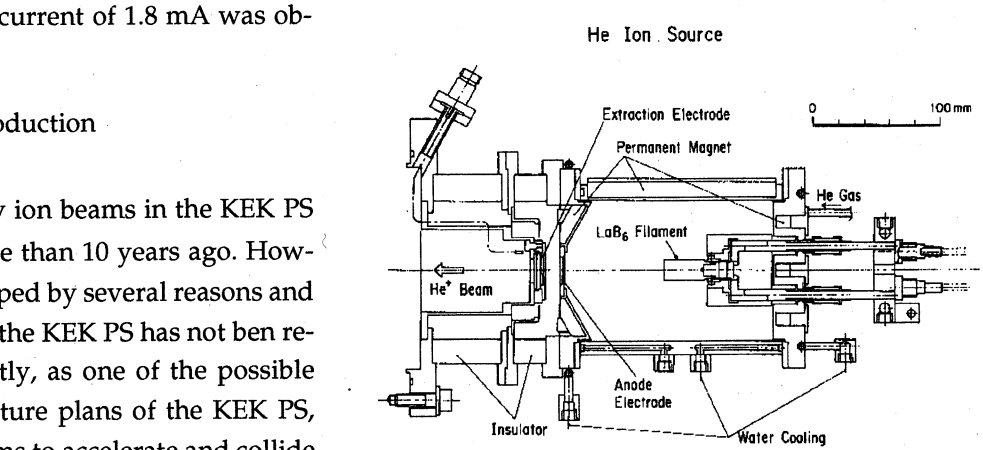

Fig. 1 Shematic drawing of a helium ion source.

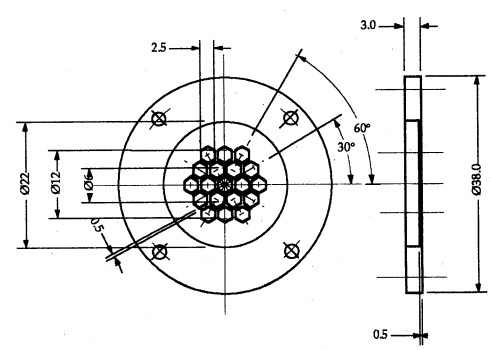

Fig. 2 Multi-hole anode electrode for the helium ion source.

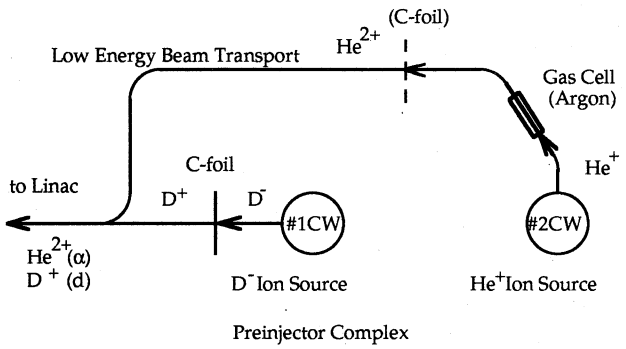

Fig. 3 KEK preinjector complex for the acceleration of positive ions (deuteron and alpha).

polarized beam.

Some modifications of the second preinjector have been made in order to accelerate positive ions. The electric polarity of the Cockcroft-Walton high voltage generator and the power supply for bending magnets of low energy beam transport (LEBT) have been inverted. A multi-cusp ion source is utilized to produce singly charged helium ions.[6] Fig. 1 shows a shematic drawing of a helium ion source. This ionsource has special anode hole electrode as shown in Fig. 2. An extraction voltage of 50 kV is suppied to the ion source, and a 50 keV-He^{+} beam is injected into the 700 kV accelerating column of the oreinjector. In order to convert a He^{+} beam to a He^{2+} beam, a gas stripper cell has been installed in the LEBT as shown is Fig. 3 .

The 750 keV He^{2+} ion beam is injected into the linac. During linac acceleration, the helium beam is accelereted under the 4π mode operation scheme. Its velocity is half that in the case of proton acceleration. As a result, at the end of the linac it has 3% less momentum than that of proton beam. The beam transport parameters and booster injection parameters must be optimized according to the beam momentum.

3. Production of He^{2+} ion beam by a charge stripper

Production of He^{2+} ions by the charge stripper.
Two methods of charge stripping: an argon gas cell and a carbon foil were tested to convert fro He+ ions to He^{2+} ions. A gas charge striper device was installed in just after first bending magnet in 750 keV beam

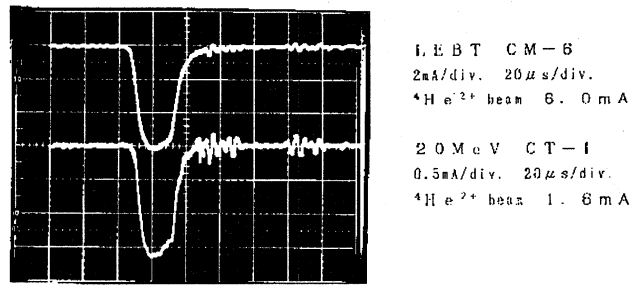

Fig. 4 Waveform of He^{2+} ion beam at the entrance of the Linac and Linac output.

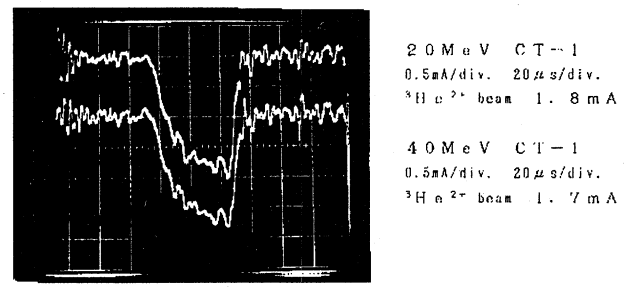

Fig. 5 Waveform of the accelerated $^3He^{2+}$ ion beam at the Linac.

transport line. The canal size of a stripper gas cell areinner dia. of 30 mm and full length of 600 mm and the maximum efficiency of charge transfer from 1+ to 2+ was 46 % in partcle number.
Whereas a carbon foil stripper device which was installed in a straitght section of beam line, a carbon foil stripper device showed the efficiency of charge transfer was about 50 %. It was obtained the maximum capture efficiency at the accelerated voltage of 759 kV with a gas cell stripper. Whereas, in the case of a carbon stripper foil, aditional higher acceleration voltage was required: 16 kV for 10 μg/cm², 24 kV for 20 μg/cm².

4. Acceleration of $^4He^{2+}$ ion beam

Most of the problems in accelerating heavy ions of Q/A=0.5 at the KEK-PS had been solved at the time when deuteron acceleration succeeded in 1992. However, in the acceleration of helium ions, there remains difficulties with respect to multi-turn injection of the positive ions.

In 4π mode acceleration of deuteron in the linac, the possible injection energy is not only 375 keV, which is a just half of that for proton. A relatively high energy of 540 keV is also possible. It is found

Table 1.
Typical Operating Parameters during Helium Acceleration

Ion source	
Type of ion source:	multi-cusp ion source with 19 multi-anode hole
Beam width:	20 msec
Beam repetition rate:	20 Hz
Extraction gap/voltage:	14 mm / 50 kV
After pre-acceleration	
He^+ beam current:	7.6 mA(750 keV)
After gas stripper	
He^{2+} beam current:	6.6 mA
Linac beam	
Beam current:	1.5 mA(20 MeV)
	0.8 mA(40 MeV)
Emittance*: $\varepsilon_V/\varepsilon_H$	0.94 / 0.75 mm.mrad

that not only the beam energy of 375 keV but the higher energy such as 540 keV can be acceptable for the linac. [7][8] In normal operation, 540keV injection was chosen and the optimized beam capture efficiency in the linac was reached to about 30 %.

Figure 4 shows a typical waveform of heliumion beam. Typical operating parameters during $^4He^{2+}$ acceleration is shown table 1.

5. Acceleration of $^3He^{2+}$ ion beam

$^3He^{2+}$ ions was also accelerated by 4π-mode in the Linac A wave form of the $^3He^{2+}$ ion beam is shown in Fig. 5. In this operation, the voltage of Cockcroft is 567 kV, a beam intensity of 10 mA was obtained jast after the accelerating column. It was obtained that he capture efficiency of the Linac was 26%, 7.0 mA at the Linac entrance and 1.8 mA at the exit of the Linac as shown in Fig. 5.

6. Conclusion

Helium beam acceleration is one of the setp to next step. It is proposed to deveplope the KEK Proton Synchrotorn for acceleration of light ion beams. Figure 6 shows the proposed scheme of the

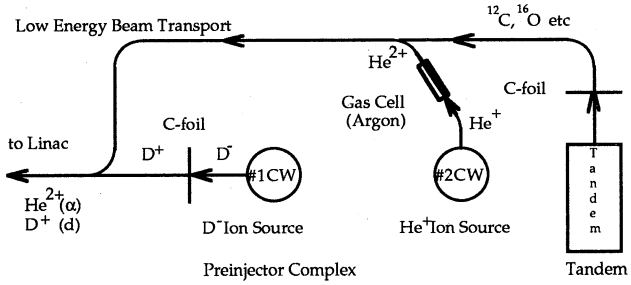

Fig. 6 Proposed scheme of the preinjector complex for the light ion beams with a Tandem accelerator.

preinjector complex for the light ion beams with a Tandem accelerator.[1]

At present, a heavy ion beam acceleration program has been scheduled for one month every April. Polarized deuteron acceleration is also planned.

The auther thanks all members of the PS group for useful discussions and their encouragement.

References

[1]PS-Colleder design group; KEK Report 89-20, 1990(in Japanese), KEK Report 90-13, 1990(in English).
[2] Proc. of the Workshop on Deuteron Beam Acceleration in the KEK 12GeV PS, edited by Y. Mori, KEK-Proc. 91-12, 1991(in Japanese).
[3] Y. Mori, "Acceleration of deuteron beam in the KEK proton synchrotron", Proc. 1993 Particle Accelerator Conf. Vol. 5,3754-3756 (Washington, 1993).
[4] I. Sakai et al, "Helium Beam Acceleration in the KEK Proton Synchrotron with A newly Developed Injection System for Positive/Negative Ions", Proc. 1995 Particle Accelerator Conf.
[5] S. Fukumoto, Z. Igarashi, S. Inagaki, K. Ito, T. Kato, C.n Kubota, Y. Mori, A. Takagi, E. Tkasaki and T. Takenaka, "Polarized proton preaccelerator program", IEEE Trans. Nucl. Sci., NS-28, 2693-2695 (1981).
[6] Y. Mori, T. Okumura A. Takagi and D. Yuan, "Development of the KEK volume H^- ion source", Nucl. Instrum. Meth. , A301, 1-8 (1991).
[7]S. Ohnuma, Th. Sluyters; Proc. 1972 Linear Conf., Los Alamos, 1972, page 191.
[8]T.Kato;KEK Report 86-5(1986).