ACCELERATION TEST STAND OF THE KEK 750 keV RFQ

Eiichi TAKASAKI, Takao KATO, Sadayoshi FUKUMOTO, Yoshiharu MORI, Zen-ei IGARASHI
Kiyoshi IKEGAMI, Chikashi KUBOTA, Akira TAKAGI and Tateru TAKENAKA
National Laboratory for High Energy Physics
Oho-machi, Tsukuba-gun, Ibaraki-ken, 305, Japan

Shinji MACHIDA
Department of Physics, The University of Tokyo
Hongo, Bunkyo-ku, Tokyo, 113, Japan

ABSTRACT

The KEK 750 keV RFQ was designed and made. To study the emittance growth, the capture efficiency and current limits of this RFQ structure, some equipments are prepared. This paper discusses the design and requirements of components arranged on the acceleration test stand.

INTRODUCTION

The radio frequency quadrupole (RFQ) linac for proton acceleration has a lot of attractive features as a low injection energy as large as 50 keV, very high capture efficiency of 90 % and its small size compared with a Cockcroft-Walton accelerator. However, an important problem is how to keep good electric contact between the vane and the cavity wall as well as the accurate mechanical alignment.

At KEK, the cavity with a rectangular cross section was chosen. After accurately machining four vane poles and four flat cavity plates, the vane pole is welded to the flat plate within good mechanical tolerance. The contact between vane and the cavity wall can be completely solved by electron beam welding (EBW).

In order to study rf characteristics and unknown geometrical dimensions, an RFQ model linac of 62 cm long at a frequency of 200 MHz was constructed. The accelerating and focussing fields were measured on the axis by the bead perturbation method. The excellent agreement between the results measured and the values calculated was obtained[1].

As the desirable field distribution was achieved in the model RFQ, the electron acceleration experiment was performed with good success[2].

On the basis of the experiences of the model RFQ, the KEK 750 keV RFQ was calculated by the computer program "QKEK" developed at KEK and mechanically designed[2,3]. The surface treatment of the vanes were researched and electrolytic polishing was adopted as final surface treatment[3]. On the basis of the experiences of electrolytic polishing, polishing thickness for vanes was determined.

To study the beam current limits, the capture efficiency and the emittance growth in the KEK 750 keV RFQ, the acceleration test stand has been designed and some equipments are on hand.

This paper presents the equipments used for measurements of the beam characteristics and the main parameters of the KEK 750 keV RFQ.

PREINJECTOR

The preinjector consists of the duoplasmatron ion source improved at KEK, the solenoid lens, the 10°-bending magnet and the vacuum chamber where some beam monitors are installed. The schematic diagram of the preinjector is shown in Fig. 1.

From this duoplasmatron ion source, the proton beam with intensity of 100 mA and 200 μsec in pulse width is easily extracted with 50 keV energy. The proton ratio of about 90 %, which depends on the pressure in the extractor part, is obtained[4].

The whole preinjector is pumped by a 500 ℓ/s turbomolecular pump just after the ion source.

Solenoid has been chosen as an element focussing the low energy proton beam because the beam extracted from the duoplasmatron ion source and injected into the RFQ is rotationally symmetric. It has a 4.5 cm bore diameter and 20 cm in length. The magnetic field strength is about 0.21 T, with which the proton beam is focussed at the entrance of the RFQ. As seen in Fig. 1, the solenoid is installed on the preinjector line between the ion source and the 10°-bending magnet.

The 10°-bending magnet has a 4.5 cm gap and 100 cm bending radius. The average magnetic field strength is about 460 Gauß. This magnet is required for the complete separation of the atomic and molecular fraction (H_2^+, H_3^+) beams and would be used as a momentum analyzer.

There is the multi purpose vacuum chamber down the 10°-bending magnet. In this chamber, a Faraday cup,

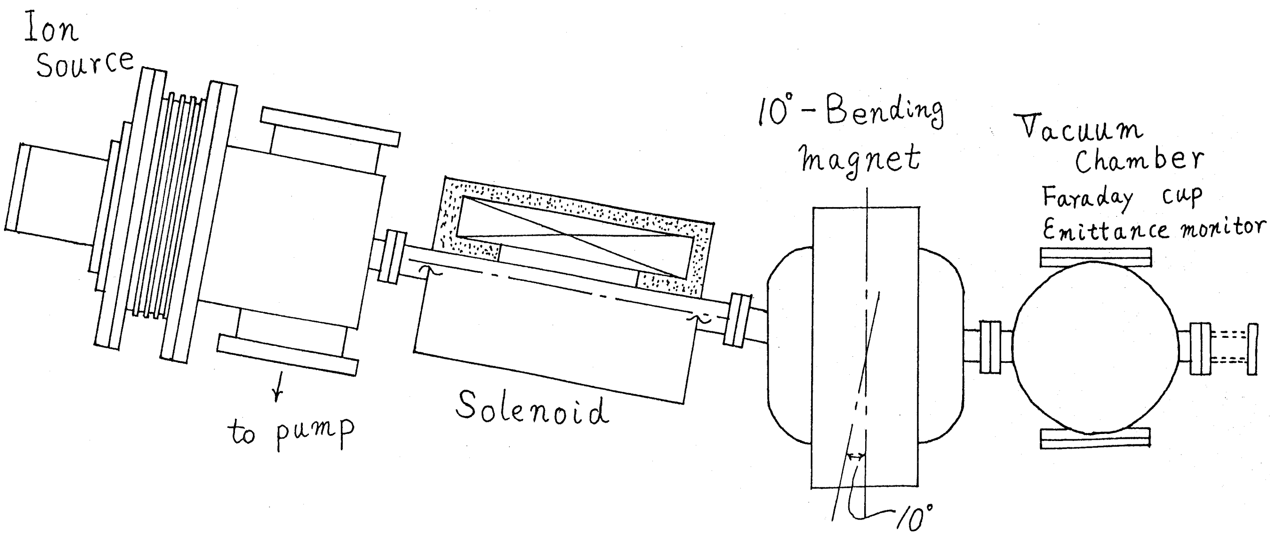

Fig. 1 Schematic diagram of the preinjector.

the emittance monitor, the profile monitor and the small equipments for beam diagnostic would be installed. The equipment of emittance reconstruction would be prepared for measurements of emittance growth.

RFQ[1,2,3]

The parameters of the KEK 750 keV RFQ are summarized in Table I. Figure 2 shows this RFQ fastened temporarily by screws.

The features of the mechanical structure of the RFQ are copper-made (OFHC), rectangular cross-sectional view, electron beam welding (EBW) between the vanes and the flat cavity plates and no rf joints except for rf coupling ports. The machining of the vanes was done three times, rough, semi-finish, final cut. The overall mechanical tolerance of the vane pole was less than 50 μm. After machining, a lot of small notches were observed in the parallel and perpendicular directions to the cutter path. In order to smooth out these notches, electrolytic polishing was adopted. From the experiences of the surface treatment and DC voltage breakdown test, electrolytic polishing thickness of 35 μm for the vanes, 25 μm for the flat cavity plate and 5 μm for the cavity were chosen[3].

Design output current is 98 mA, which is limited by the space charge. The normalized acceptance is 0.41 π cm·mrad. The emittance calculated at the exit of the KEK 750 keV RFQ is shown in Fig. 3. The maximum divergence of the beam is about 0.15 rad..

The rf tuning and examination at low power level are performed with keeping the temperature of the RFQ constant after the four sets and two flat end plates are fastened temporarily with screws within mechanical tolerance. Now, one set is an assembly of the vane pole fastened to the flat cavity plate with screws. After the desirable field is achieved, all welding of the cavity will be done to form the RFQ. The rf power of 100 kW will be fed through a coaxial waveguide to the RFQ using a coupling loop.

750 keV LINE

The doublet quadrupole magnets, the vacuum chamber I, the spectrometer magnet and the vacuum chamber II are installed on the 750 keV line. The layout of the 750 keV line and the RFQ are shown in Fig. 4.

The beam at the exit of the RFQ has a large divergence as seen in Fig. 3. Therefore, the doublet quadrupole magnets[5] are used to focuss the beam on a Faraday cup (bunch monitor) or the narrow slit, which is an entrance slit for the spectrometer magnet.

The spectrometer magnet, which is a sector type magnet, has the bending angle of 80 degree, the bending radius of 30 cm and a 7.0 cm gap. The average magnetic field strength is about 4200 Gauß. According to Barber's law, the profile monitor is installed on the focal plane and the 0.1 mm slit is set on the entrance line of the magnet. Considering the energy spread at the exit of the RFQ is ± 3 %, the sufficient momentum resolution is obtained even with the bending radius of 30 cm.

THE MONITORS

Emittance monitor[6]; this monitor consists of the narrow slit, the drift space and the ceramic plate with thirty two gold segments. The detector head is linearly moved with pulse motor and its position is read. At each of positions the beam intensity collected by each segment is integrated, digitized and averaged. Normalized emittance is calculated with the microcomputer.

Bunch monitor[7]; the 50 Ω matching bunch monitor is set in the vacuum chamber I on the 750 keV line. This bunch monitor consists of the 50 Ω reducer and the beam catcher. In particular, the coupling of the longitudinal to transversal motion is inevitable and depends on the rf level. Therefore, it is interest to directly observe the bunch and to investigate the relation between the bunch shape and the rf level at RFQ.

The current monitor is also installed on the pre-injector line[8]. It is a toroidal transformer and consists of Senpermax core wound with a few hundred turn coil and a low carbon steel shield for noise rejection.

The profile monitor with a good sensitivity, which is set on the focal plane, is prepared.

Table I

Parameters of the KEK 750 keV RFQ

Frequency	201.08 MHz
Injection energy	50 keV
Final energy	750 keV
Vane voltage	89 kV
Number of cells	118
Vane length	136.4 cm
Initial radius	2.4 cm
Minimum radius	0.4 cm
Initial modulation	1.0
Maximum modulation	2.0
Initial phase	-90.0
Final phase	-30.0
Normalized acceptance	0.41 π cm·mrad

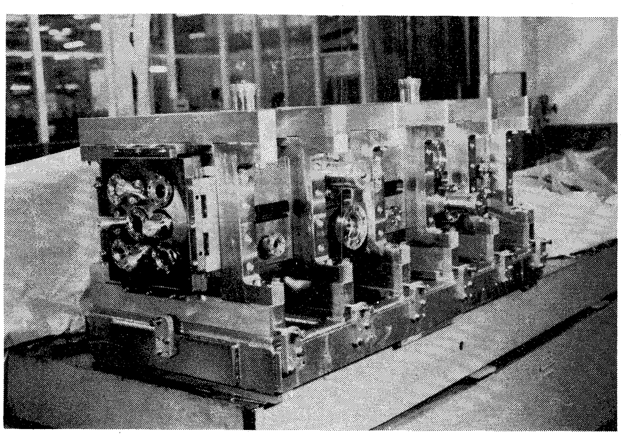

Fig. 2 The KEK 750 keV RFQ fastened with screws for rf tuning.

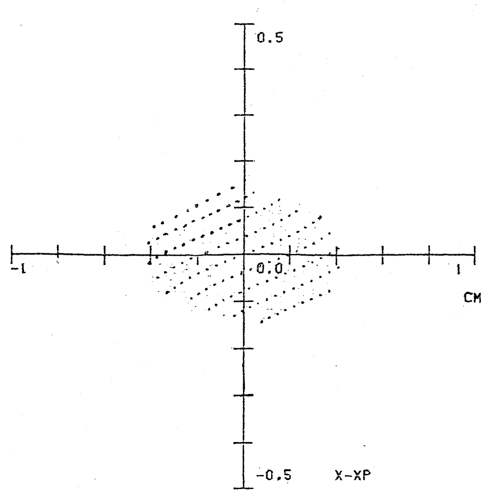

Fig. 3 Emittance calculated at the exit of the RFQ.

SCHEDULE

Now, the acceleration test stand is under construction. The KEK 750 keV RFQ is tested for rf tuning. The vacuum chamber, the spectrometer magnet, the bunch monitor, the emittance monitor and the circuit used are on hand. The first beam test of the preinjector is scheduled to start in October 1984 and then the total beam test is planned from November.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to Dr. T. Nishikawa, the Director General of KEK and Prof. T. Kamei, the head of the Accelerator Depertment. They are deeply indebted to Mr. Iino and his group of Mitsubishi Heavy Industries for the RFQ fabrication.

REFERENCES

1) T. Kato et al., IEEE Trans. NS-30, p.3569 (1983).
2) T. Kato et al., Proc. 7-th Symp. on Ion Source and Ion Assisted Technology (ISIAT'83), p.629 (1983).
3) T. Kato et al., "RFQ Development at KEK", 1984 Linear Accelerator Conf., 1984, Darmstdt, Germany.
4) A. Takagi et al., ISIAT-'79 (Tokyo) p.67 (1979).
5) S. Fukumoto et al., IEEE Trans. NS-28, p.2693 (1981).
6) K. Ikegami et al., Proc. 4th Symposium on Accelerator Science and Technology, p.229 (1982).
7) Z. Igarashi et al., KEK 82-14, p.89.
8) Z. Igarashi et al., Proc. 4th Symposium on Accelerator and Technology, p.143 (1982).

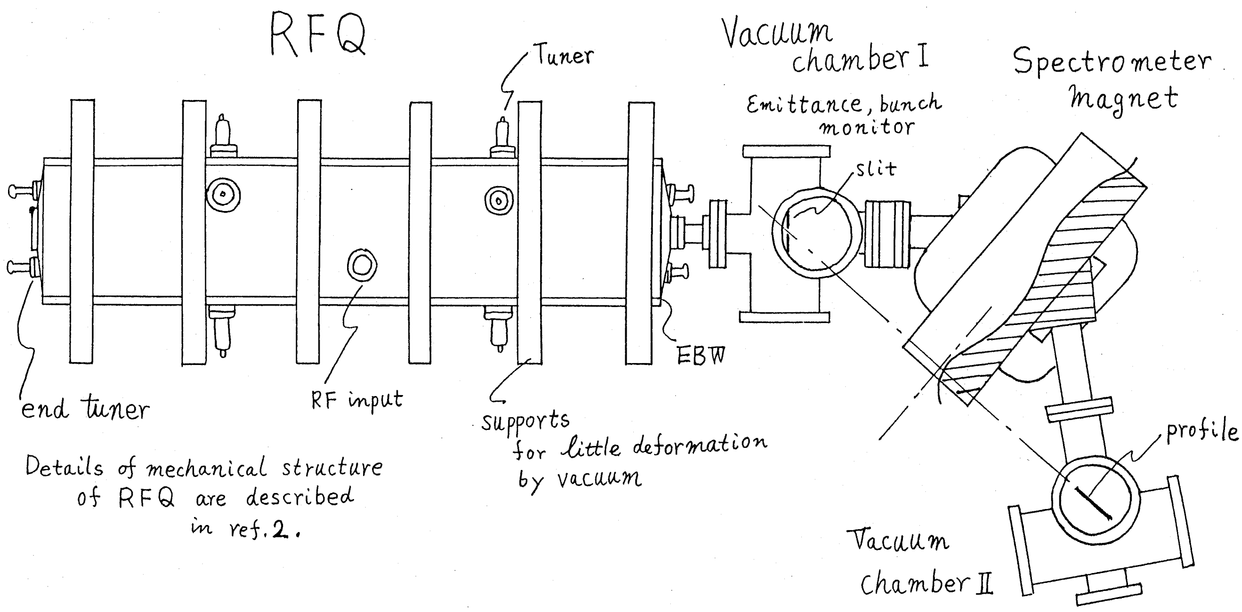

Fig. 4 Layout of the 750 keV line and the RFQ.