Present Status of 7 MeV Proton Linac at Kyoto University

Y. Iwashita, H. Egou, H. Fujita, K. Fukunaga*, M. Inoue, S. Kakigi,
A. Noda, H. Okamoto and T. Shirai,

Institute for Chemical Research, Kyoto University
Gokanosho, Uji-city, Kyoto 611, Japan

Abstract

After the vacuum pressure of the RFQ cavity is improved better than 1 x 10^{-6}Torr, a high RF power up to 680 kW (2.0 Kilpatrick) has been applied with the designed duty of 1 %. H^+ beam, which has a fraction of ~10% of the extracted beam from the ion source, is observed by profile monitors made of aluminum oxide including chromium oxide (Desmarquest AF995R) both before and after the RFQ.

1. Introduction

At Institute for Chemical Research, Kyoto University, a proton linear accelerator up to 7 MeV consisting of an RFQ and a DTL with the operating frequency of 433 MHz has been constructed. Recently main efforts for the accelerator system are focused on attainment of stable operation of the RFQ. For this purpose, the evacuation system for the linac cavity is improved and a circulator is installed between the klystron(L5773) and the RFQ. Owing to these improvements, we have succeeded to feed such a high power as large as 680 kW corresponding to the gap voltage of 90 kV (2.0 Kilpatrick) while the design value is 530 kW corresponding to the gap voltage of 80 kV (1.8 Kilpatrick).[1] Following this success, beam tests have been also performed and proton beam is transmitted through the RFQ by feeding the designed RF power. In the present paper, the procedure of the above improvements and the beam test is described.

2. Improvement of the Evacuation System

In order to reduce the probability of sparking, it is needed to pump out quickly the materials produced by the first discharge, which might become the core of succeeding spark.[2] From this point of view, the evacuation system of the linac cavity is improved. In Fig. 1, the total evacuation system is shown schematically. An ion pump with the pumping speed of 160 l/s attached to the coupler of the RFQ[3] is replaced by a turbo-molecular pump with pumping speed of 500 l/s. Another ion pump with the same specification attached

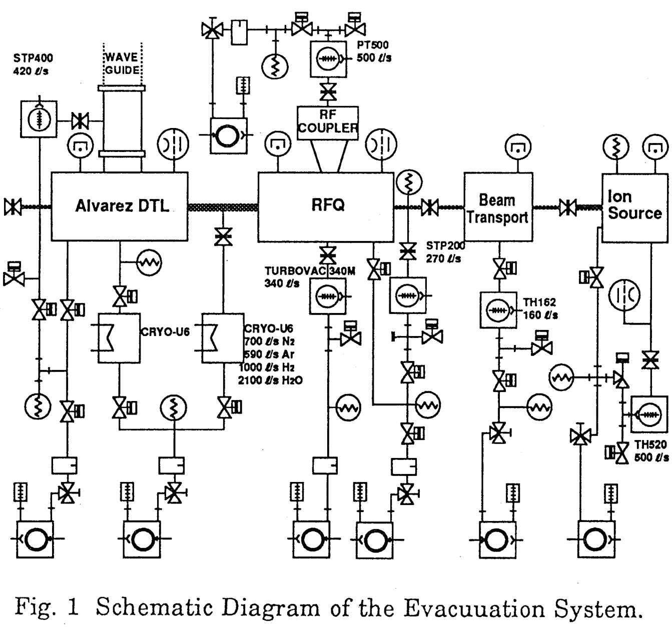
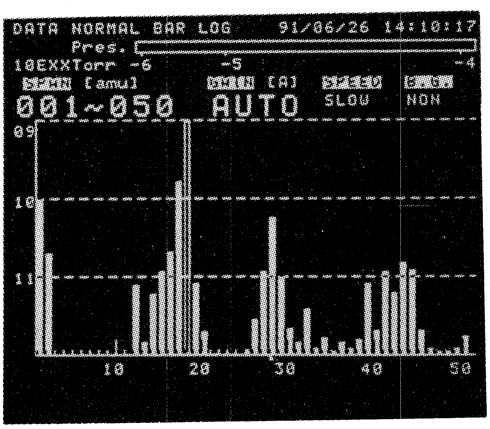
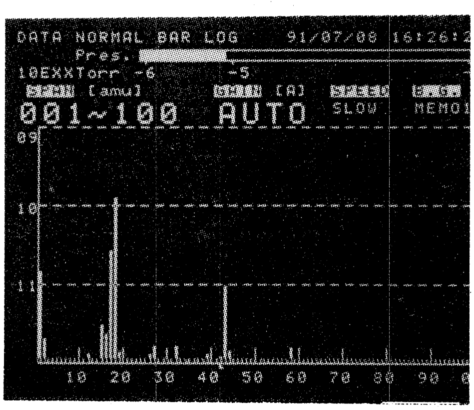


Fig. 1 Schematic Diagram of the Evacuuation System.



(a) before baking



(b) after baking during a week

Fig. 2 Residual Gas Spectra.

* Present Address: Yamagata University

to the RF coupler of the DTL is replaced by a turbo-molecular pump with pumping speed of 420 l/s. A cryogenic pump with large pumping speed as indicated in Fig. 1 is also attached to the DTL cavity. After such modification, the average pressure of 1~2 x 10^{-6} Torr is attained with the residual gas mass spectrum shown in Fig. 2(a). So as to reduce the large peak of H_2O, we have applied baking process through a whole week at the relatively low temperature of ~60 °C. The temperature of the baking is limited at the above value in order to avoid damage of pipings of cooling water made of synflex tubes. After the treatment, the vacuum pressure reached into the order of 10^{-7} Torr with the mass spectrum shown in Fig. 2(b).

3. High Power RF System

The klystron (L5773) had been directly linked to the loop coupler of the RFQ through a wave guide of the size WR-2100. However, from the point of view of stable operation and protecting the klystron from a damage by a large reflected power in case of sparking, it is highly desirable to insert a circulator between the klystron and the coupler and thus guide the reflected power to the dummy load. Recently we have installed the circulator with the specifications given in table 1.[4] In Fig. 3, the circulator installed in the place is shown. The cooling of the output horn of the klystron is also modified for 1% duty operation.

By these improvements, the high RF power up to 680 kW is safely fed to the RFQ cavity as shown in Fig. 4. Before the process of aging shown in the figure, we have already applied aging up to 600 kW[1] and put the air into the cavity during half a day in order to install equipments for the measurement of the beam profile. It should be noted that RF power up to 350 kW can be applied without serious sparking even after such break of the vacuum.

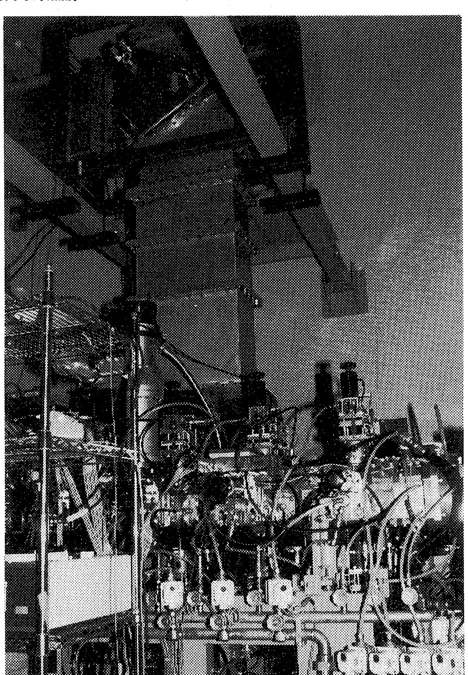


Fig.3 Photograph of the circulator and the RFQ.

Frequency	433.3 MHz
Band Width	±1 MHz
Maximum Peak Power	1 MW
Maximum Duty	1 %
VSWR	<1.4
Insertion Loss	<0.5 dB
Isolation	>20 dB

Table 1 Parameter of the Circulator

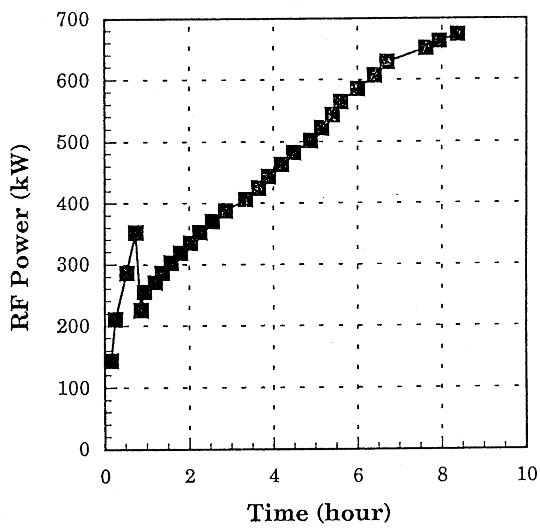


Fig. 4 Relation between aging time and applicable power.

4. Beam Test

The proton beam extracted from an ion source with multi-cusp field by the high voltage of 50 kV is focused by an einzel lens with 30 kV and a triplet of electrostatic quadrupole lens. It is deflected by 45 degree with a dipole magnet (Mixing Magnet) and is guided to the linac room as shown in Fig. 5. Three peaks are observed at the magnetic field levels of 1.40, 1.99 and 2.44 kG corresponding to the beams of H^+, H_2^+ and H_3^+, the fractions of which are 10, 70 and 20 %, respectively.

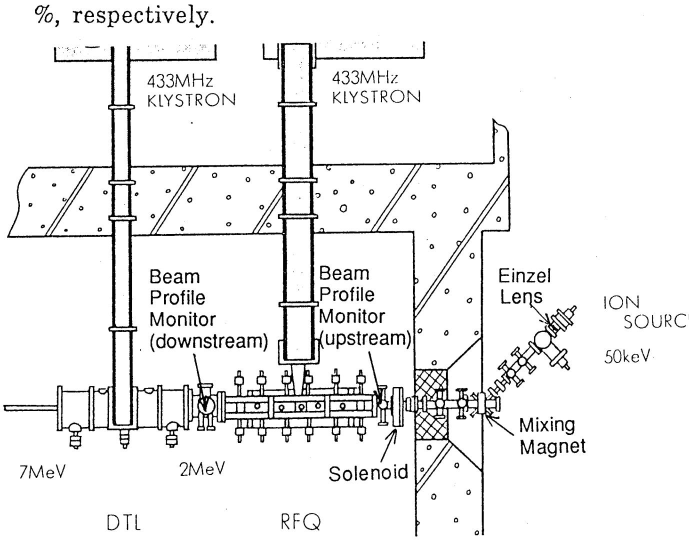


Fig. 5 Layout of the linear accelerator system.

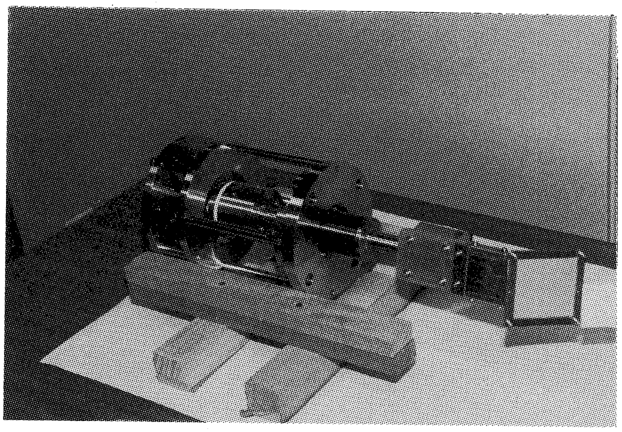
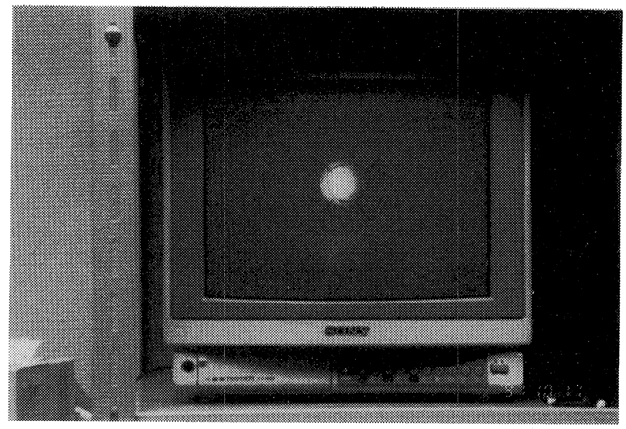


Fig. 6 Beam profile monitor used downstream of the RFQ.

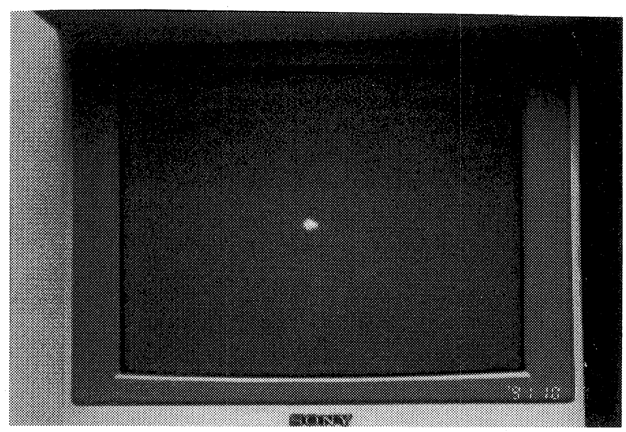
A beam profile monitors utilizing plates of aluminum oxiside containing chromium oxide (Desmarquest AF995R) are fabricated. They are installed before and after the RFQ as shown in Fig. 5. The monitor installed after the RFQ is shown in Fig.6. Utilizing these monitors, beam profiles are measured at the entrance and exit of the RFQ as shown in Fig. 7(a) and (b). It should be noted that proton beam with low energy of 50 keV is also visible by scintillation light on the aluminum oxide (Desmarquest AF995R). The profile shown in Fig.7(b) is taken without applying RF power and excitation current in the solenoid located just upstream of the RFQ as shown in Fig. 5. In this condition by exciting the solenoid coil, the beam signal disappears because of the over focusing by the solenoid. Then we applied RF power and the beam image reappeared. The brightness of the beam image has dependence on the applied RF power and at the power lower than 400 kW (corresponding to the vane voltage of 70 kV which is 0.86 times of the designed value), the beam signal on the plate of aluminum oxide disappeared.

5. Summary

The high power as high as 680 kW can been safely applied which corresponds to 90 kV (2.0 times Kilpatrick limit) and 12 % over than the designed value. The vacuum pressure has come into the order of 10 $^{-7}$ Torr under the condition without a high power. The proton beam is analyzed by the Mixing Magnet and only H^+ beam which has the fraction of 10 % is guided to the RFQ. The beam is transmitted through the RFQ with RF power higher than 400 kW.



(a) upstream of the RFQ



(b) downstream of the RFQ

Fig. 7 Beam profile observed by destructive monitors made of aluminum oxide containing chromium oxide (Desmarquest AF995R).

References

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(2) N. Wilson, Private communication.
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