OPERATING CHARACTERISTICS OF THE ICR PROTON LINAC

Yoshihisa Iwashita, Toshiyuki Shirai, Hideki Dewa, Hiromi Okamoto,
Akira Noda, Hirokazu Fujita, Shigeru Kakigi, and Makoto Inoue
Accelerator Laboratory, Institute for Chemical Research
Kyoto University, Gokanosho, Uji, Kyoto, JAPAN 611

Abstract

After the vacuum improvement, the cooling modification and the insertion of the circulator, the high power RF (530kW to RFQ, and 330kW to DTL) have been fed into the accelerating tanks and the ICR 7MeV proton linac system accelerates the proton beam to the energy of 7 MeV successfully.

Introduction

The ICR 7 MeV proton linac have been developed at Kyoto University [1]. Hydrogen ion beam from the multi-cusp ion source at 50kV is accelerated to 2 MeV by the RFQ linac and to 7MeV by the Alvarez DTL. The operating frequency is 433MHz, and the klystron L5773 is used as the RF power source for each tank. To attain the stable operation of the accelerator system, many efforts have been made [2,3].

Adding cryo and turbo pumps, the vacuum is improved better than 1×10^{-6}Torr. The klystron cooling is modified to feed the sufficient air to the inner conductor of the output horn. A circulator is installed into the waveguide between the klystron and the RFQ cavity to obtain a stable high power RF feeding [4]. After these improvements, up to 630kW (2.0 Kilpatrick) has been fed into the RFQ cavity, and 330kW into the DTL cavity. At designed RF power level (530kW for RFQ, and 330kW for DTL), the linac system accelerates the proton beam to the energy of 7 MeV successfully. The output beam energy of the linac is confirmed to be 7.0±0.2 MeV by the absorber foils.

Along with these efforts, the power supply system for the injector including the high voltage power supply was modified for better stability and durability against discharges. The low energy transport system is also improved to transport the beam efficiently, by installing electrostatic Q lenses.

Recently many efforts have been made especially on the RFQ system, and the description is concentrated to the RFQ experiments in this paper except for the next section.

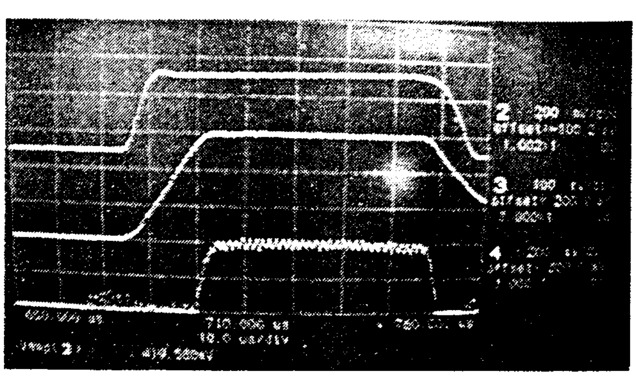

Photo 1 The detected RF signals picked up from the RFQ and DTL cavities together with the accelerated beam current

7MeV Acceleration

Photo 1 shows the detected RF signals picked up from the RFQ and the DTL cavities together with the accelerated beam current passing through the absorber foils [5]. The output beam of about 50μS length is obtained. Because the Q value of the DTL is higher than that of the RFQ, the filling time of the DTL is longer than that. The filling time of the DTL will be reduced by an over drive technique in near future, and the pulse length of the output beam is supposed to increase 10% longer.

The correlation between the transmission of the linac system and the relative phase between the RFQ and the DTL is given in Fig. 1. The origin of the RF phase is defined so that the peak of the measured data coincides with that of the PARMILA calculation.

High power RF Characteristics

The feedable power to the RFQ cavity is shown in Fig.2 as a function of the conditioning time. Only the first three and the last experiments are shown. The power level is calibrated by the measured Q value and the SUPERFISH calculation. Between each experiment, the cavity was opened to the air for several hours except for the last one in which case the cavity had been exposed to the air for about 20 hours. The temperature of the linac tanks are controlled at around 37°C. The vacuum pressure in the tank was 2.0×10^{-6} Torr at on-power, and 1.6×10^{-6} Torr at off-power state.

To ensure the calibration of the vane voltage, we measured the spectrum of the X-ray emission from a glass view port of the RFQ tank by a pure Ge counter. Photo 2 shows a typical spectrum. An absorber is placed in front of the detector to reduce the pileups of the output pulses by the low energy X-rays. Almost of the X-rays from the RFQ is

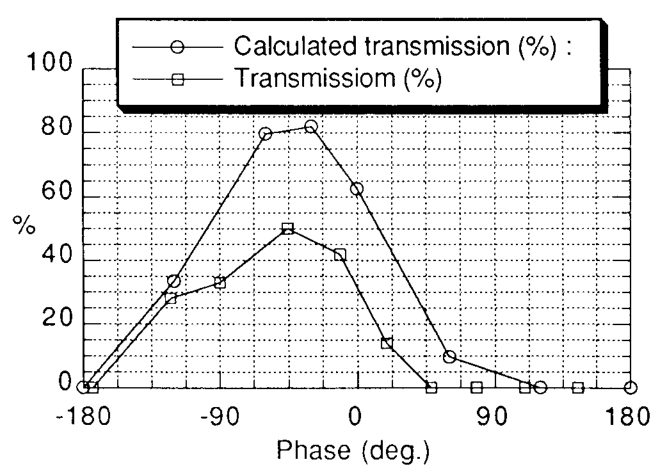

Fig. 1 Dependence of the transmission of the DTL on the phase relative to the RFQ.

supposed to be the bremsstralung of electrons emitted by the RF electric field on the vane surface, and the maximum energy of the X-rays should correspond to the vane voltage. Figure 3 shows the leading edge energy of the spectrum as a function of input RF power. According to the result, the designed vane voltage of 80 kV is reached at 530kW. The SUPERFISH calculation predicts it as 540kW, which is consistent with this result.

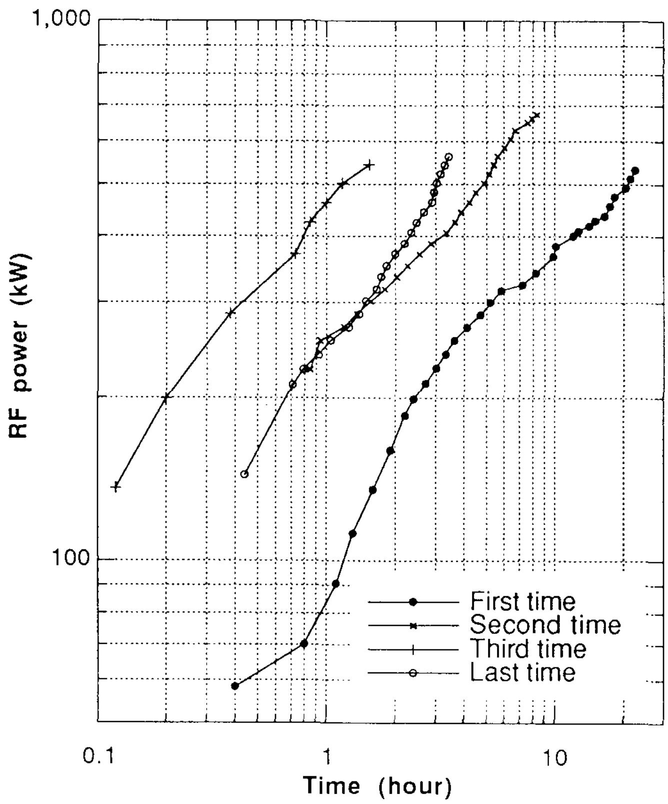

Fig. 2 High power RF conditioning time of RFQ

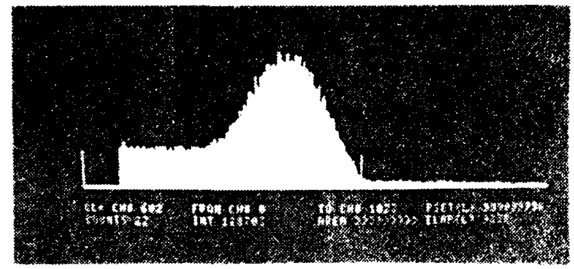

Photo 2 Energy spectrum of the X-ray

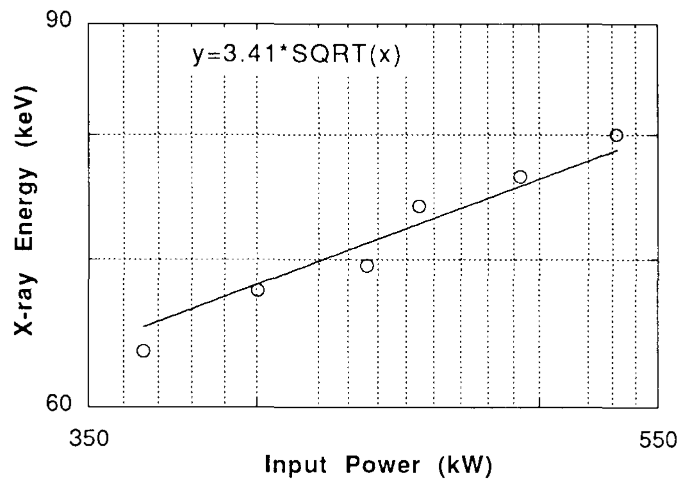

Fig.3 Leading edge energy of the spectrum as a function of the input RF power.

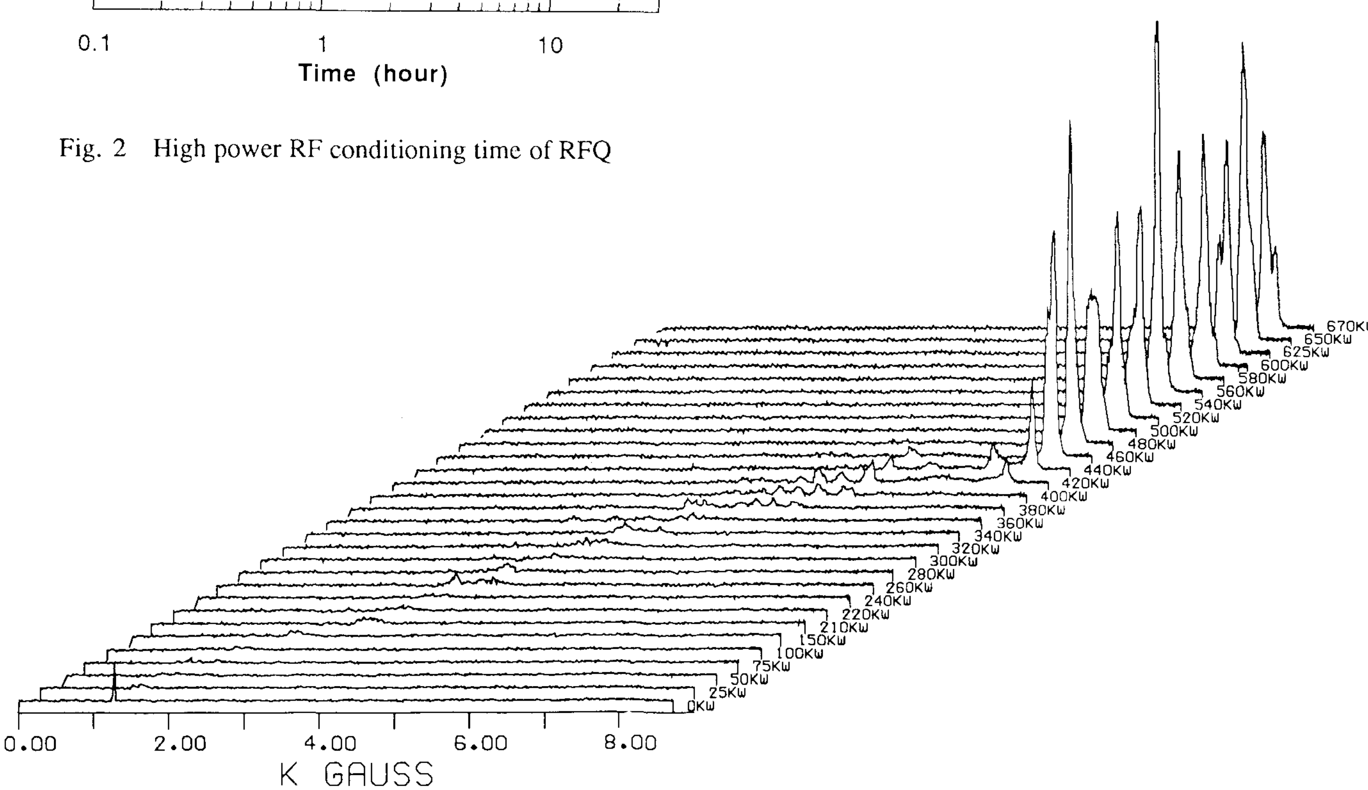

Fig.4 Momentum spectrum of the RFQ output beam at various input power.

Output Beam Characteristics of RFQ

Momentum spectrum

The momentum spectrum of the RFQ output beam is measured by a magnet installed in the MEBT section (between RFQ and DTL). Because the vacuum system of the RFQ and the DTL is not separated, the magnet had to be installed into the limited space without moving the DTL tank. The momentum analyzing magnet is shown in Photo 3. The magnet poles are inside of the vacuum, and the iron yoke pass through a stainless steel flange. The gap is 8mm wide. The coil is outside of the vacuum, and cooled by air. The deflection angle is 30°, and the distance between the poles and a Faraday cup is about 210mm. The Faraday cup is installed also in the MEBT section. The measured momentum spectrum of the RFQ is shown in Fig. 4. Because a collimator of 0.5 mm square is located before the magnet in order to increase the resolution, the vertical scale of the current is in an arbitrary unit. The rising point of the transmission is at 440 kW, which has 90% of the designed vane voltage. It is consistent to the PARMTEQ calculation [6]. Below 420kW, the small peak goes down to the injection energy of 50 keV as shown in Fig.4. The energy spread is roughly 2% of the output energy of the RFQ.

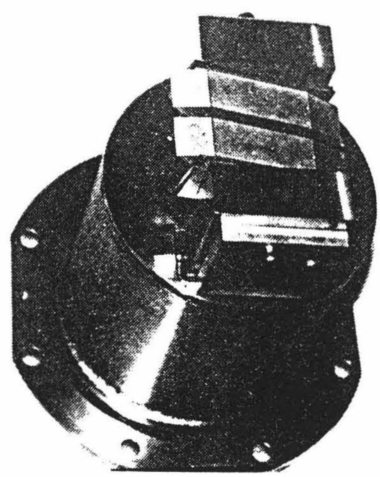

Photo.3 Momentum analyzing magnet installed in the MEBT section between RFQ and DTL. (Bottom view)

Transmission

Figure 5 shows the measured transmission as a function of vane voltage. According to the result of the momentum analysis, the output beam does not have sharp cut off below the designed operating voltage. As shown in Fig.5, the total current after the RFQ does not have an obvious cut off. Sheets of Al foil with 15μm thickness are inserted between the RFQ and the Faraday cup. The stopping power of the 15μm and 30μm Al foil are about 1MeV.and 1.6MeV respectively. Three sheets of foils are also inserted and no current is detected.

Although highly converging beam is required at the RFQ entrance, the vacuum port at the entrance side makes the installation of the focusing element difficult. It will be improved in near future. The final focus is achieved by a solenoid lens located before the vacuum port for the time being, and the strength of the lens is too small to match the beam in RFQ completely. The transmission is supposed to be improved by the precise beam matching.

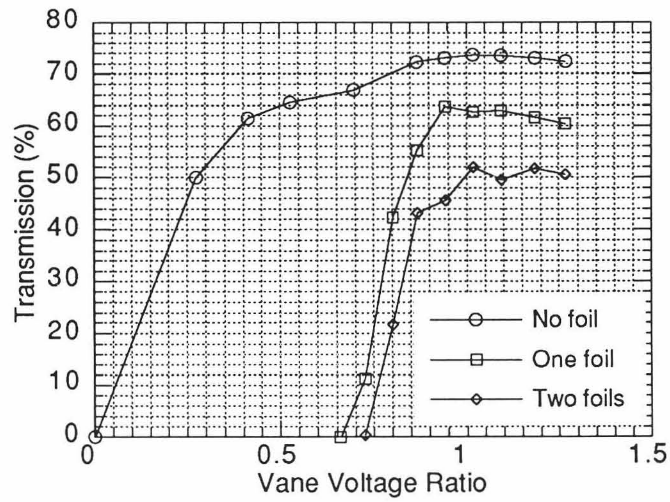

Fig. 5 Transmission of the RFQ

Summary

The high power RF feed has been succeeded to attain the designed vane voltage of 80kV which corresponds to 1.8 Kilpatrick criteria. The maximum power fed to the RFQ is 680kW or vane voltage of 90kV. The vacuum pressure has come into the order of 10^{-7} Torr without a high power RF feeding.

A further beam transmission improvements and beam matching improvements are scheduled [7].

Acknowledgement

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