One Year Operation of the 7 MeV Proton Linac

T.Shirai, H.Dewa, H.Fujita, M.Ikegami, Y.Iwashita, S.Kakigi, H.Okamoto, A.Noda and M.Inoue
Institute for Chemical Research, Kyoto University
Gokanosho, Uji-city, Kyoto 611, Japan

Abstract

On the 7 MeV proton linac at ICR, the improvement of the beam transmission has been made. The measurement of the RFQ output beam was performed and the beam matching elements were designed and constructed to match the RFQ output beam to the acceptance of the Alvarez linac. The emittance is 42 π·m·mrad and 30 π·m·mrad in the x-x' plane and y-y' plane, respectively. The energy spread is 80 keV at 2 MeV. The matching elements consist of four permanent magnetic quadrupoles and a quarter wave-length resonator buncher. The RF power up to 5.0 kW has been safely fed into the buncher, which is well enough to provide a designed bunching voltage of 180 kV.

I. INTRODUCTION

At Institute for Chemical Research (ICR), 7 MeV proton linac consisting of an RFQ and an Alvarez cavities, has been constructed. The layout of the accelerator is shown in Figure 1. It is operated at 55μsec pulse width, 180 Hz repetition rate. The operating frequency of 433 MHz is chosen to be more than twice higher than that of conventional proton linacs, so that the cavity size becomes compact and klystrons are available as RF power sources in this frequency range.

The first 7 MeV beam was accelerated about one year ago. The input RF power were 540 kW for RFQ and 320 kW for Alvarez cavity. The total transmission through two cavities is measured to be 50 % [1]. This low transmission comes from the mismatching of the beam in the injection into the RFQ and Alvarez cavity. For the former, the final focus element in the injection line is prepared just before the RFQ [2]. For the latter, the beam matching elements between two cavities were designed and constructed, based on the beam measurements of the RFQ, such as a transverse emittance and an energy spectrum.

II. BEAM MEASUREMENTS OF THE RFQ

The transverse emittance and the energy spectrum were measured at the place for the beam matching section between the RFQ and the Alvarez linac. The measurement devices were developed to be compact for the limited space. The beam current is low for these measurements, usually about 200 μA.

A. Transverse emittance

The emittance monitor consists of a fluorescent screen (Desmarquest, AF995R) and movable slits. A schematic diagram of the monitor is shown in Figure 2 [3]. The x-slit and y-slit define the transverse position. The transverse spread of the beam is measured by the screen that is located downstream of the slits. Because of the high position sensitivity of the screen, we can get the high resolution of the transverse momentum. The distance between the slits and the screen is 315 mm. The resolution is 0.5 mm for the position and 1 mrad for the angle.

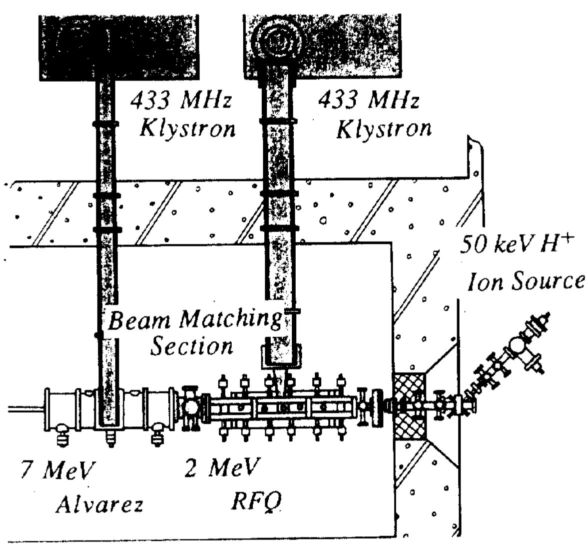

Figure 1. Layout of the accelerator system.

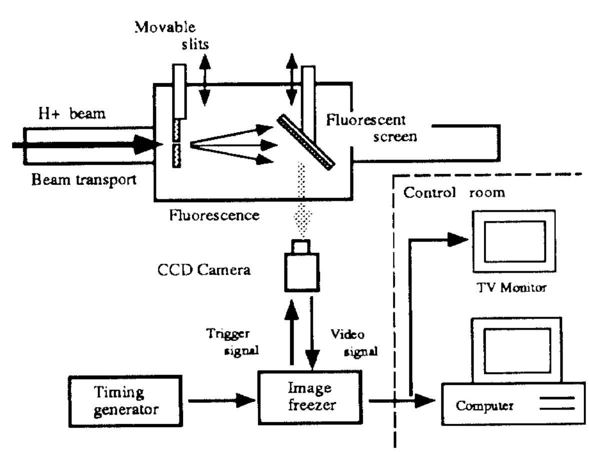

Figure 2. Schematic diagram of the beam emittance monitor system.

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The screen can be also used for the profile monitor when the slits are extracted.

The fluorescent material is an alumina ceramic (99.5 % - Al_2O_3) in which a little chromium oxide is homogeneously doped. The fluorescence is observed by a CCD camera (PULNIX model TM720) which is placed 80 cm away from the screen. The camera is adjusted so that the output signal may be in proportion to the input light intensity. The shutter timing is synchronized to the pulse operation of the linac. The output signals from the CCD are digitized and stored by an image freezer. The digitized image is displayed on a TV monitor and transferred to a personal computer. It calculates the beam profile and the emittance.

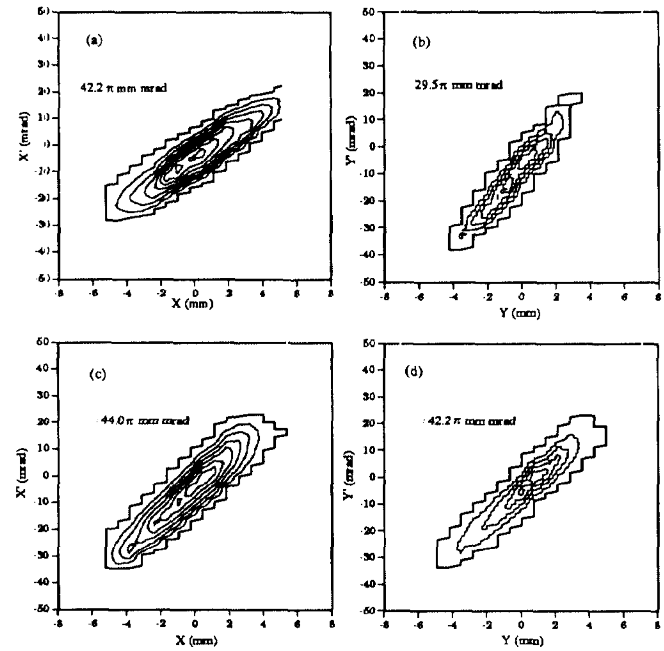

Figure 3. Measured 90 % emittance of the RFQ output beam.
(a), (b) : the input RF power of 540 kW,
(c), (d) : the input RF power of 370 kW.

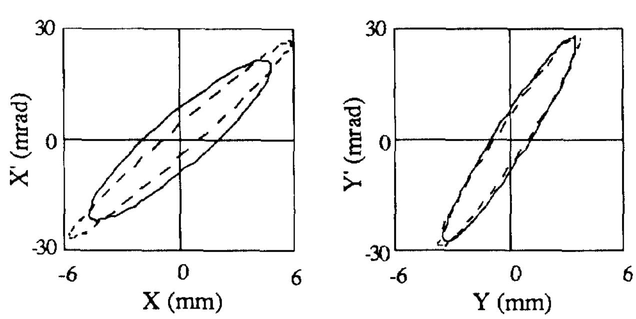

Figure 4. Comparison between the measured (solid line) and calculated (dotted line) emittance.

The measured results are shown in Figure 3. The emittance is for 90 % of the beam intensity and measured at 180 mm behind the vane end of the RFQ. The input RF power is 540 kW at (a), (b), which is the designed input power and 370 kW at (c), (d). Figure 4 shows the comparison between the measured emittance and the calculated one. The fluctuation of the emittance by the RF power level is within 2 % for the power level around the designed one.

B. Energy spectrum

A compact analyzing magnet was devised to measure the energy spread of the RFQ beam [4]. The cross section of the magnet is shown in Figure.5. It has C-shape and only the poles is in vacuum side, because the magnet had to be installed in the small space and in the vacuum. The yokes go through the vacuum flange made of stainless steel and the coil is located in the air side. It can generate the magnetic field of 1 Tesla at 8 mm gap through out 100 mm length. The deflection angle is 30 degree. The beam is detected by a Faraday cup with a collimator which is 210 mm away from the poles. The energy resolution is 1 % at 2 MeV.

The energy spectrum is shown in Figure 6. The input RF power is 540 kW. The FWHM of the energy spread is 80 keV. The result is consistent with the simulation.

III. BEAM MATCHING SECTION

The schematic view of the beam matching elements between RFQ and Alvarez linac are shown in Figure 7 [5]. The transverse beam matching is attained by four permanent magnetic quadrupole lenses (PMQs). They are compact compared with an electromagnet and the multiple elements can be installed in the limited space. The magnet material of the PMQ is Nd-Fe-B. The bore radius is 5.5 mm and the magnetic field

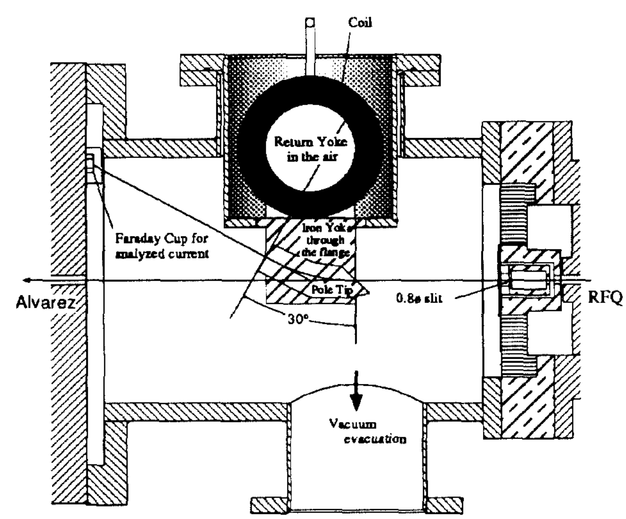

Figure 5. The cross section of the analyzing magnet.

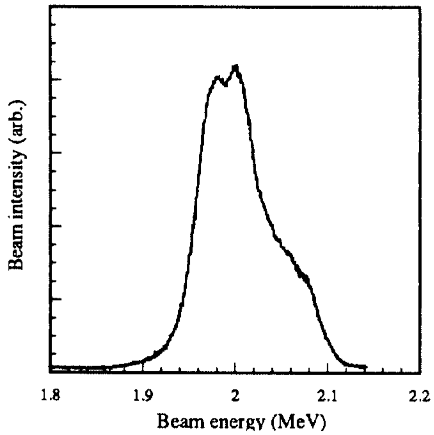

Figure 6. The energy spectrum of the RFQ output beam.

gradient is around 18.6 kGauss/cm.

The buncher matches the longitudinal beam distribution. It is a quarter wave-length resonator (QWR) and the resonance frequency is 433 MHz, which is the same as that of the linac system. It has merits of a high shunt impedance and a simple structure. The unloaded Q-value is 7400 and the shunt impedance is 8.8 MΩ. In the high power test, the RF power of 5.0 kW has been successfully fed after the 5 hours conditioning. The designed bunching voltage is 180 kV. The voltage was estimated from the maximum energy of the emitted X-ray and it was confirmed that the designed voltage can be obtained when the input RF power is 3.6 kW.

IV. SUMMARY

We have developed the compact analyzing magnet and the emittance monitor using the fluorescent screen. The transverse emittance and the energy spectrum of the RFQ beam were measure by the devices. Based on the results and the simulation, the matching elements were designed and constructed to match the Twiss parameters of the beam between RFQ and Alvarez. They consists of the four PMQs and the QWR buncher. The designed RF power can be fed into the buncher.

The beam test of the linac system with the matching elements is in progress and the improvements of the injection line to the RFQ is also scheduled.

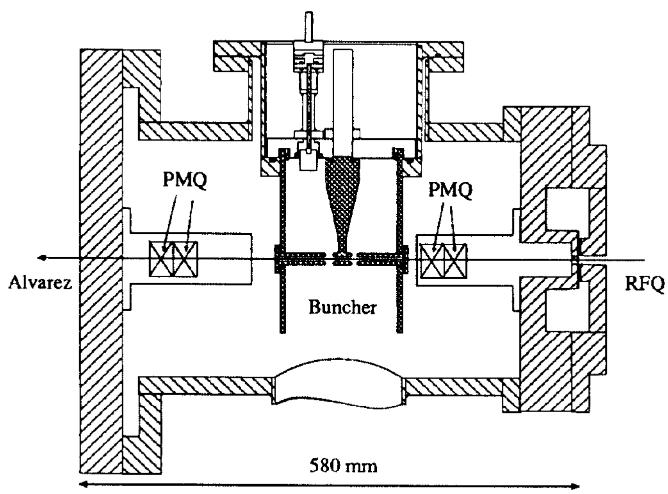

Figure 7. The cross section of the beam matching section.

V. REFERENCES

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