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Commissioning of the 7 MeV Proton Linac at ICR Kyoto University

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The ICR 433 MHz linac which consists of an RFQ and an Alvarez cavities has successfully accelerated protons up to the goal energy of 7 MeV. The present intensity is about 200 μA without a buncher which is now under construction. Emittance and momentum of the beam has been measured at the end of the RFQ section. Low energy beams are observed when the RF power is fed at low power levels in the RFQ cavity.

KEY WORDS: Pulsed ion source/ Space charge/ RFQ linac/ Momentum analyzer/ RF phase buncher

1. INTRODUCTION

A compact proton liner accelerator has been designed and constructed at the nuclear science research facility of the Institute for Chemical Research, Kyoto Univerisity. Aims of this project are to develop a new principle of a compact machine for a future meson factory and to deliver new ion beams for material science at the ICR. In spite of a small amount of budget, we have decided to construct two cavities. One of them is an RFQ cavity and the other is an Alvarez type DTL cavity. Both are operated at 433.3 MHz which is two times higher frequency than usual low energy proton linacs. This makes the cavities very compact. On the other hand the compact linac needs precise machining, vacuum system for a low conductance cavity, compact beam focussing system and so on. After fabrication and assembling of the main part of the linac, we have had to improve step by step our linac.

Improvents of the vaccum system including additional vaccum pumps and replacement of dirty gaskets by new ones have been made. Another essential improvment has been made in RF system. We have put a circulator and a dummy load in the wave guide of the RF feeding line. These devices have mede it easy to feed high power in the RFQ cavity.[1)]

After a full power operation at the RFQ cavity, the Alvarez cavity has been operated at a full power without a circulator system. Thus the proton beam was successfully accelerated up to 7 MeV in the evening of 22nd January 1992.

The intensity of the first beam was order of μA at peak. Since then our effort has been mainly concentrated into increasing of beam intensity and reliable operation of the total system.

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During one year operation after the first beam we have made many tests and improvements.

2. ION SOURCE

A multi-cusp type ion source was so far opereated by a DC power supply system. On the other hand the linac is operated by the pulsed power supply with a duty of 1% at most. Therefore we constructed a new pulsed power supply for the ion source. High peak-power arc operation of the ion source has been obtained with this pulsed power supply. Many shapes of extraction electrodes from the ion source have been examined. Focussing property for the extraced beam depends on a shape of the electrode and plasma surface at the exit of the ion source which varies with plasma density and aperture of the exit. At a low power operation the beam was over focussed. After replacement of the ion source power supply we can extract high intensity beam with a moderate focussing at the extraction region. Therefore the shape of the extraction elecctrode was modified depending on the operating condition. Details of the ion source is decribed in this bulletin.[2)]

3. LOW ENERGY BEAM TRANSPORT (LEBT)

Our low energy beam transport system which transports a beam from ion source to the RFQ linac consists of mainly electrostatic quadupoles. The exceptions are a bending magnet which analyzes the beam and a magnetic solenoid which is located near entrance of the RFQ cavity. These elements have small aperture because of economical reason. This small aperture system is able to transport the 50 keV proton beam with intensity up to 1 mA, but it is difficult to transport higher intensity beams to the entrance of the RFQ linac because the space charge effect becomes too large at higher than 1 mA to make the beam size small. At the moment the beam intensity before the bending magnet is 10 mA and the analyzed proton (H^+) beam intensity just after the bending mangnet is about 3 mA.[2)]

4. RFQ LINC BEAM

Properties of the accelerated beam of the RFQ linac has been measured by a compact analyzing magnet and a profile monitor. The analyzing magnet should be designed to be very small because the transport section between the RFQ cavity and the Alvarez cavity is very short. Thus the pole tips are only situated in the vacuum region, but the magnet yokes and a coil are located outside of the vacuum chamber as shown in Figs. 1 and 2. Because of small space for the coil it is difficult to use water cooling. Therefore a saw tooth shape pulsed current is applied to excite the magnet to avoid the heating up the coil. Fig. 3. shows momentum spactra of output beams from the RFQ linac in which the RF power varies from zero to full power. The measured beam energy at the full power operation was 2.00 ± 0.02 MeV. As shown in Fig. 3 low energy beams are accelerated at below full RF power level. This is not surprising because such beams are usually neglected by a limitted energy window in case of the computer simulation.

The beam profile has been measured by a kind of fluorescent ceramic, Desmarquest, which is chromium-doped aluminium oxide and a CCD camera. Details of this system is reported in this bulletin.[3)] Emittance of the beam out from the RFQ has been observed to be 35π mm mrad which is consistent with a computer simulation.[3)]

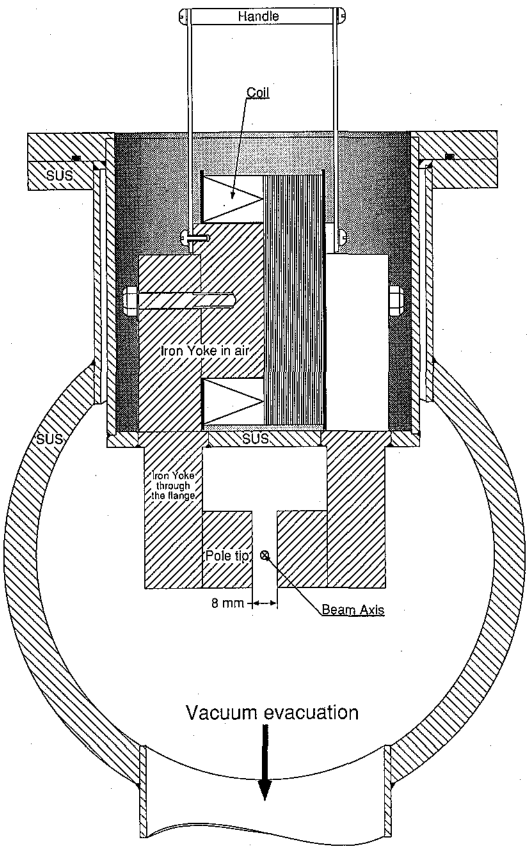

Fig. 1. The compact momentum analyzing magnet (cross section).

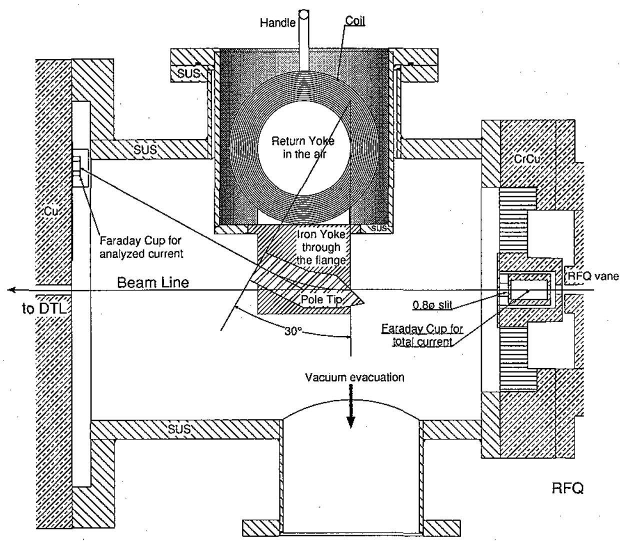

Fig. 2. Side view of the compact momentum analyzer.

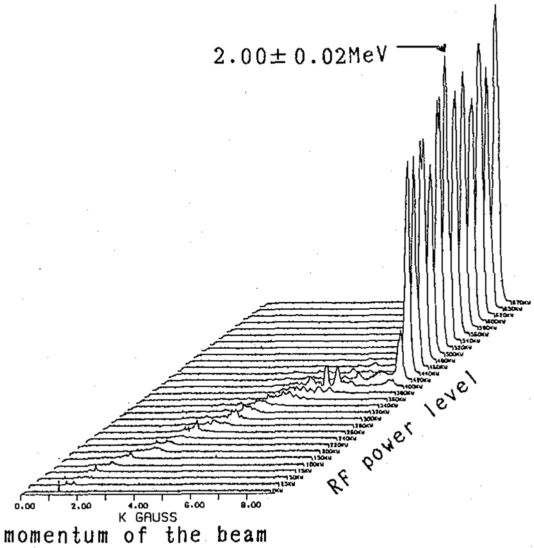

Fig. 3. Obtained momentum spectra of the RFQ linac beam depending on the RF power level.

5. MEDIUM ENERGY BEAM TRANSPORT (MEBT)

Beam transport system between the RFQ and the Alvarez cavities should contain permanent quadrupole magnets and an RF phase buncher to match the output beam from the RFQ linac with the Alvarez linac. But the buncher is not so far installed. At the present the beam transmission from the exit of the RFQ cavity to the exit of the Alverez cavity is about 30% without the buncher. Design and construction of a double gap buncher are now in progress.

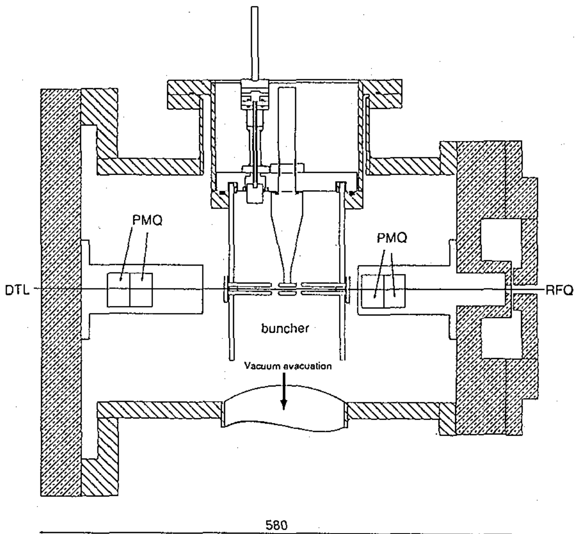

Fig. 4. The RF phase buncher.

Conceptual drawing of the buncher is shown in Fig. 4. The RF power test has been successfully done at a required power level of 5 kW.[4)]

6. ALVAREZ LINAC

Feeding the RF power into the Alvarez cavity is rather easy comparing with the RFQ cavity, but it is also desirable to insert a circulator and a dummy load in the wave guide system for a reliable operation of the linac. Thus a new circulator and a dummy load same as those of the RFQ system are now under construction.

The output current of the 7 MeV beam from the Alvarez linac is at present 200 μA without the RF buncher in the MEBT section.

The orbit planes (x *and* y) *in the calculation in our case are rotated by* 45° *to the real* horizontal and vertical planes for the sake of easy setting of the RFQ cavity. But this is inconvenient to transport the beam to the target stations in the real laboratory. Therefore two sets of skew magnetic quadrupole doublets have been designed to get nearly parallel beams in the both planes. The skew quadrupole magnets are now under construction based on a calculated beam optics.

7. CONCLUSION AND DISCUSSION

After one year operation of the ICR proton linac since the first beam the intensity of the 7 MeV beam is now 200 μA without the RF buncher in the midium energy beam transport section. Beam energy and emittance of the RFQ linac have been measured by newly developed devices.

Some improvements such as the RF buncher, the circulator in the Alvarez system, skew quadrupole magnets at the high energy beam transport section and so on are now in progress.

The space charge effect is proved to be very important at the low energy beam transport (LEBT) section. Small modifications of the LEBT including edge focussing of the bending magnet and a strong axial field magnetic lens just before the RFQ are now studied. But a large modification may be necessary to increase the beam intensity up to the order of 50 mA which is the design value of the linac cavities.

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