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TRANSVERSE CHARACTERIZATION OF 1 MeV/n RFQ OUTPUT BEAM AT KOMAC

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Abstract

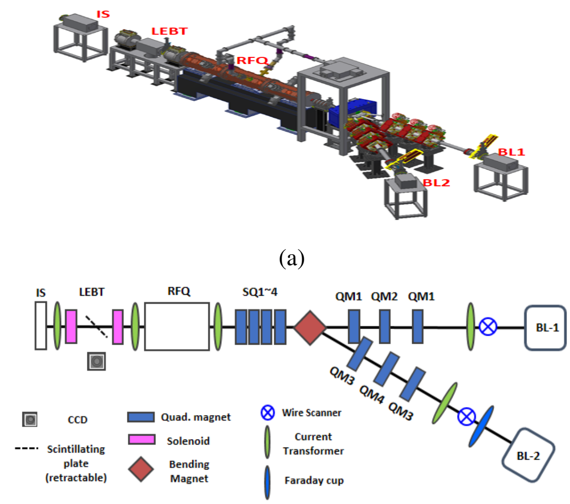
A 1 MeV/n Radio-Frequency Quadrupole (RFQ) has been developed and commissioned at Korea Multipurpose Accelerator Complex (KOMAC). The RFQ is designed to accelerate ions with mass to charge ratio up to 2.5. The designed peak current is 10 mA with 10 % duty factor. Currently we are utilizing the RFQ as a test bench for the reliable operation of the 100 MeV proton linac operational at KOMAC since 2013. The test bench has two beamlines installed with beam transport optics, diagnostics and irradiation chambers. We performed a quad scan experiment using a wire scanner installed in the beam line to obtain beam emittance and Twiss parameters at the entrance of the scanning quadrupole magnet. From these value, we calculated the beam emittance and Twiss parameters at the exit of the RFQ. In this paper, we report the current status of the RFQ test bench, the quad scan result and the characterization results of the 1 MeV/n RFQ output beam at KOMAC.

INTRODUCTION

A Radio-frequency Quadrupole (RFQ) has been developed [1] and commissioned recently at Korea Multi-purpose Accelerator Complex (KOMAC). It was initially designed to accelerate various species of ion beams (such as $^4He^{2+}$) to 1 MeV/n with maximum A/q=2.5. Currently we are utilizing the RFQ and following beam transport system (BTS) as a test bench for RF control and beam diagnostics studies. Results of these studies will be applied to the 100 MeV proton linac which has been operational at KOMAC since 2013. The BTS layout is shown in Fig. 1 (a) and (b). The RFQ BTS consists of a microwave ion source, a low energy beam transport (LEBT), a RFQ, two beam lines, a RF system and other ancillary system such as vacuum system, beam diagnostic system, cooling system, control system and radiation safety system. In each beam lines, we have a triplet quadrupole magnets and a wire scanner. Using them, quad scan experiments are performed to study the transverse beam dynamics. In this paper, we describe the RFQ BTS status, our preliminary experimental results of the transverse beam characteristics and some of our upgrade plans in detail.

RFQ BTS STATUS

The RFQ BTS has been commissioned for proton and $^4He^{2+}$ ion generated from the microwave ion source of a 2.45 GHz magnetron. LEBT has two solenoid to match the beam to the entrance of the RFQ. From LEBT to the RFQ exit, we have more than 90% beam transmission through the RFQ. We think that the beam transmission will improve further more once the steering magnets are installed in the LEBT. RFQ BTS main parameters are tabulated in Table 1.



(b)

Figure 1: (a) Layout of the RFQ BTS and (b) Layout of the magnets and diagnostics in the RFQ BTS are shown (IS = ion source, LEBT = low energy beam transport, RFQ = radio-frequency quadrupole, SQ = small quadrupole magnet, QM = quadrupole magnet).

Table 1: RFQ BTS Main Parameters

Parameter	Values
Particle	proton, H^+
Input Beam Energy	25 keV
Output Beam Energy	1 MeV
Peak Current	10 mA
RF frequency	200 MHz
RF power	130 kW
Max. Electric field	1.63 Kilpatrix

For the beam transport in the beam lines, we obtained the quadrupole magnet gradient values from the simulation results using TraceWin Code [2]. The trajectory simulation results of the BL1 and BL2 are shown in Fig. 2.

TRANSVERSE BEAM CHARACTERISTICS

Transverse beam characteristics is studied using a quad scan method in the two beam lines (BL1 and BL2). In the beam lines, there are quadrupole triplets installed to provide better beam transportation to the target chambers. In the

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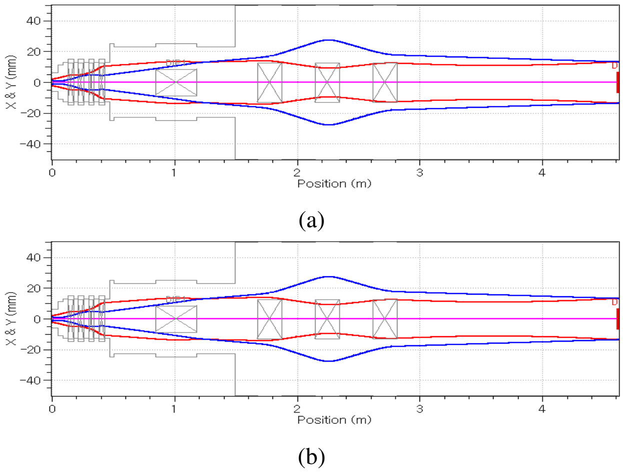

Figure 2: Beam envelop calculation of the BL1 (a) and BL2 (b) are plotted as x (blue) and y (red).

triplet, the two outer quadrupole magnets are connected to the same power supply and the inner one is connected independently. Quad scan experiments in the both beam lines are performed while the inner quadrupole magnets are scanned and the outer magnets are operating at a certain current value. Figures 3 and 4 show the quad scan experimental results from the beam lines BL1 and BL2 respectively. In Fig. 3 and Fig. 4, (a) and (b) are rms beam radius square as a function of magnet field gradient, fitted with a thick lens equation. (c) and (d) show the beam centers in horizontal (x) and vertical (y) axes plotted against the magnet field gradient. In the RFQ BTS, there is no steering magnet installed yet. Due to mal-alignment between the beam and the optics, there is a shift in x and y. In BL2 case, we used the bending magnet to correct the horizontal shift in some extend. Due to this, Fig. 4 (c) shows that the beam center x is less affected by the magnet field gradient, compared to the result in Fig. 3 (c) showing a rather large slope of beam center x w.r.t the magnet field gradient applied.

From the BL1 quad scan experiment, we obtained the preliminary transverse beam characteristics of the beam emittance and the twiss parameters to be norm. rms ϵ_x=0.544 pi mm mrad, α_x = -18.984 and β_x=20.127 pi mm/mrad for x axis, and norm. rms ϵ_y=0.480 pi mm mrad, α_y = 17.211 and β_y=15.548 pi mm/mrad for y axis. Similarly, from the BL2 quad scan experiment, we obtained the beam emittance and the twiss parameters to be norm. rms ϵ_x = 1.039 pi mm mrad, α_x = -8.380 and β_x = 19.756 pi mm/mrad for x axis, and norm. rms ϵ_y = 0.193 pi mm mrad, α_y = 17.678 and β_y = 44.831 pi mm/mrad for y axis.

UPGRADE PLANS

We have done the commissioning of the RFQ BTS and the preliminary quad scan experiments in the BL1 and BL2 successfully. However, there is no steering magnet installed in the RFQ BTS shown in Fig. 1. We plan to install six sets

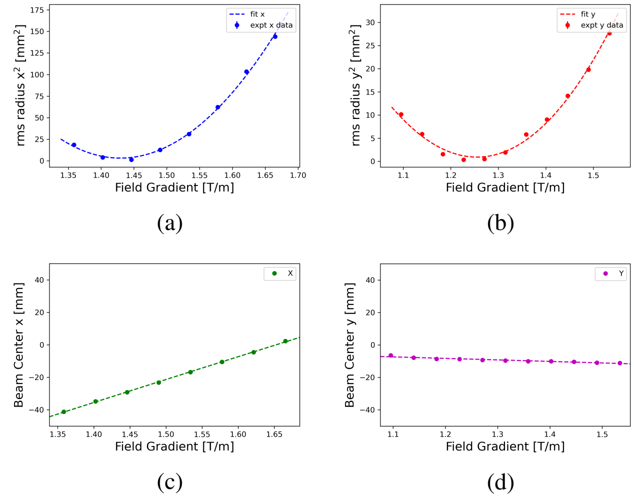

Figure 3: Quad scan results from the beamline 1 (BL1) are plotted

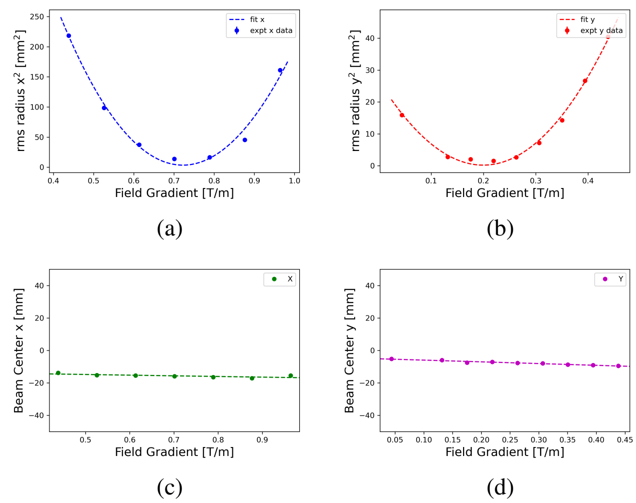

Figure 4: Quad scan results from the beamline 2 (BL2) are plotted

of x-y steering magnets. Two sets will be installed in the LEBT to improve the beam transmission from IS to the RFQ entrance. In each beam line, two other sets will be installed with beam position monitors. To study the orbit correction scheme, we will employ pairs of steering magnets and a beam position monitor. We expect that in a small system like RFQ BTS, it is ideal to compare experimental results and simulation results and give a good insight of the beam physics.

CONCLUSION

A 1 MeV/n RFQ has been developed and commissioned. It is now used as a test bench with beam transport optics, diagnostics and irradiation chambers. We performed and obtained a quad scan experiment using a wire scanner installed in the beam line for the preliminary characterization

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of the transverse beam properties. From these results, we observed that the absence of the steering magnets is affecting the beam quality in a large extent. In near future, we will install steering magnets and beam position monitors for the orbit correction.

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