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Design Study on the Helium Beam Irradiation System Based on the RFQ

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1. Introduction

A radio frequency quadrupole (RFQ) was studied to accelerate helium beams for power semiconductor irradiation purpose [1]. The studies extended to overall system including ion source, RF system, control system, beam transport system and utility system. The purpose of this study is to develop a helium beam irradiation system based on the RFQ and install it in the beam utilization building in the KOMAC site which is now being constructed and will be finished at the end of 2014. In this paper, we will focus on the ion source, RFQ, RF system and ancillary system. Also brief schedule will be discussed.

2. System Design

The specification of the system is shown in Table 1. The system consists of ion source, low energy beam transport (LEBT), RFQ, medium energy beam transport (MEBT), target, RF system, vacuum system, beam diagnostics, control system and utilities including cooling water system and electricity. The block diagram of the system is shown in Fig. 1. The red dots include the main hardware system and the blue dots include the ancillary system. The number in the block corresponds to the WBS.

Table 1: Specification of the helium irradiation system

Particle	$^4He^{2+}$
Beam energy	4 MeV
Peak beam current	10 mA
Beam duty	1 %

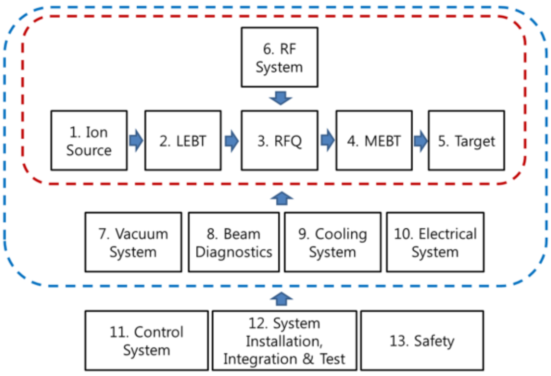

Fig. 1. Block diagram of the helium irradiation system.

2.1 Ion Source and LEBT

The 2.45GHz microwave ion source, which is being used for KOMAC 100MeV proton linear accelerator, is a candidate. Only one solenoid was used in the KOMAC ion source for system compactness, but the magnetic field geometry should be modified for increasing plasma density including two solenoid magnets to produce mirror field. Also the extraction geometry should be optimized for the $^4He^{2+}$ beam extraction including the magnetic field leakage profile at the plasma electrode. The extraction energy from the ion source is 100keV (25keV/u) and the peak beam current is 10mA. The electrostatic lenses are considered at low energy beam transport system for system compactness and we are going to reduce the length of the LEBT as short as possible.

2.2 RFQ

The basic design parameters of the RFQ are the RF frequency of the cavity and the RF duty of the RF system. We chose the RF frequency of 200MHz in order to avoid klystron as a RF amplifier which requires complicated high power RF system. For the RF duty, we chose 10% in order to limit the thermal load on the RFQ structure up to several kW which corresponds about 20% of the KOMAC 3MeV RFQ.

We performed the basic structure design and the beam dynamics study. The design parameters are summarized Table 2. We found the energy spread is less than ±0.1%, the length is 3.2m which can be manufactured with 4 sections and the total RF power is 130kW. The beam trajectory is shown in Fig. 2. Also the output beam properties including beam distribution in phase space are shown in Fig. 3.

Table 2: RFQ design parameters

Particle	$^4He^{2+}$
Input beam energy	50keV
Output beam current	4MeV
Peak beam current	10 mA
Emittance (nor. rms)	0.2 π mm mrad
Type	Four vane
RF frequency	200MHz
RF power	130kW
Maximum electric field	1.63Kilpatrick
ρ/r_0	0.87
Length	320cm
Transmission	96.4%

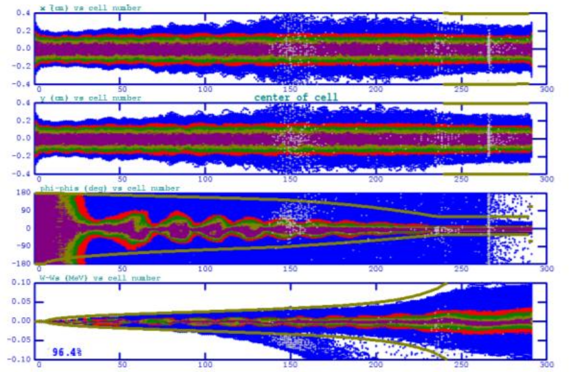

Fig. 2. Beam trajectory through RFQ
(1: x vs cell number, 2: y vs cell number,
3: Δϕ vs cell number, 4: ΔE vs cell number)

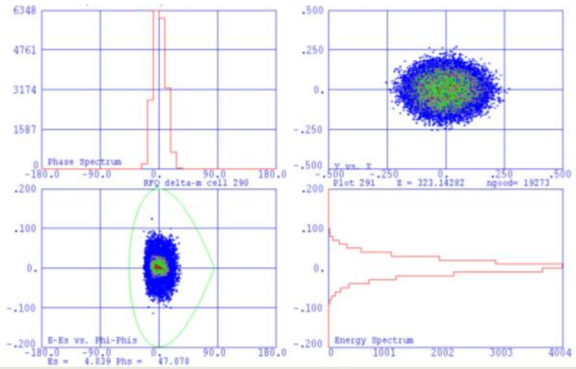

Fig. 3. Output beam properties
(upper left: phase spectrum, upper right: x vs y
lower left: Δϕ vs ΔE, lower right: energy spectrum)

2.3 RF System

The total required RF peak power is 200kW which includes 80% Q degradation in the cavity, 10% loss in the transmission line and 15% control margin. The design strategies of the RF system are 1) Full digital LLRF system 2) Frequency tracking to the RFQ cavity 3) Two couplers in order to maintain the symmetrical perturbation into the RFQ cavity. To fulfill the full digital LLRF system, we are going to directly get the 200MHz RF signal with IQ modulation and produce 200MHz RF signal directly from the NCO by using commercially available signal processing digital board. In addition, we are going to implement the frequency tracking availability in the LLRF system in order to eliminate the cavity frequency stabilization system such as a movable tuners or resonance frequency control cooling system. The coaxial disk type window will be used for the RF window because of its compactness and well proven technology. Also coaxial coupler with loop is used because of the easy adjustment of the coupling coefficient.

2.4 Other Ancillary System

The base line of the control system will be based on the EPICS which is well used for the KOMAC 100MeV proton accelerator control system. The power capacity of the electricity which is required for the system is 200kW in 220V, 3 phase. The required cooling water flow rate is 33 m3/hr to limit the temperature increase of the RFQ structure within 1°C, but the building can supply the water about 25% of the required value. Therefore, we are going to install another cooling loop which can supply enough water flow rate.

2.5 Building and Schedule

The construction of the beam utilization building was started at Oct. 2013 and will be finished at Dec. 2014. It is located beside the accelerator building in the KOMAC site. Several rooms are prepared to accommodate low energy ion implanter in addition to the helium irradiation system. The room sizes for the helium system are 15m × 9m. The mile stone of the helium system is to complete the design, develop one section model of the RFQ and develop RF system in this year. And all of the system are planned to be installed by the end of 2015.

3. Conclusions

A design study on the helium beam irradiation was carried out. Most of the technologies including the ion source, RFQ, RF system and control system were already well developed through the KOMAC 100MeV proton linear accelerator development. The system will be installed by the end of 2015.

ACKNOWLEDGEMENT

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REFERENCES

[1] Yong-Sub Cho, et al., Basic Design Study of RFQ for Helium Implantation in Power Semiconductors, Transactions of the Korean Nuclear Society Spring Meeting, Gyeongju, Korea, Jeju, Korea, 2012.