COMMISSIONING RESULTS AND PROGRESS OF A HELIUM INJECTOR FOR COUPLED RFQ & SFRFQ PROJECT AT PEKING UNIVERSITY*

Jia Chen, Shixiang Peng#, Haitao Ren, Wenlong Xia, Shuli Gao, Zhi Wang, Jie Zhao,Yuan Xu, Tao Zhang, Ziheng Wang, Yuting Luo, Zhiyu Guo, SKLNPT&IHIP, School of Physics, Peking University, Beijing 100871, P.R.China

Ailin Zhang, Jia'er Chen, SKLNPT&IHIP, School of Physics, Peking University, Beijing 100871, P.R.China, University of Chinese Academy of Sciences, Beijing 100049, P.R.China

Abstract

At Peking University (PKU) a new helium injector for coupled radio frequency quadrupole(RFQ) and separated function radio frequency quadrupole(SFRFQ) within one cavity, so called as coupled RFQ & SFRFQ, was designed recently[1]. It will provide a 30keV 10mA He^+ beam whose emittance is less than 0.15 π.mm.mrad for the accelerator. It is a combination of a 2.45GHz PKU permanent magnet electron cyclotron resonance ion source (PMECRIS) and a 1.16 m long low energy beam transport (LEBT). Within the 1.16 m LEBT, 2 solenoids, 2 steering magnets, a space charge compensation section, a collimator, two vacuum valves, a Faraday cup and an ACCT are installed. The manufacture has been completed and the commissioning is on the way. In this paper we will address the commissioning results and its progress.

INTRODUCTION

For the purpose of studying the material irradiation damage effects, an accelerator-based material irradiation facility with MeV injecting energy will be very helpful. Conventional design of this kind of relatively low energy facility is composed of a RFQ and a post-RFQ acceleration structure such as DTL, H-type cavity, etc. At PKU, a new type of post-RFQ accelerating structure called SFRFQ which separates accelerating and focusing functions in one cavity has been studied since 1990s.[2]

Based on former experiences accumulated by Peking University Neutron Imaging Facility (PKUNIFTY) [3], a He^+ injector for RFQ-SFRFQ cavity is brought up at PKU. Recently, the He^+ injector, which includes all the components before RFQ, is finished assembling, and the immediate experimental beam tests feedback very well results.

In this paper we will address the general designs of the He^+ injector in part 2. The commissioning results and beam diagnostic experiment designs would present in part 3. In part 4, the beam tests results would present. And a summary will follow at the end.

PHYSICAL & MECHANICAL DESIGN

The He^+ injector comprehends 2 parts including the ion source and LEBT. The purpose of this injector is to provide qualified beam to inject into RFQ-SFRFQ cavity, and the beam qualification requirements are as Table 1.

Table 1: Parameters of the Helium Injector

Parameter	Unit	Value
He^+ beam current	mA	10
Energy	keV	30
Duty cycle	Hz	166 or CW
Pulse length	ms	1
Emittance(norm rms)	π.mm.mrad	0.15

Ion Source Body & Extraction System

Ion source includes 3 parts in total which are microwave system, ion source body and extraction system. Due to the unique merits of ECRIS such as high ion density, stability and reproducibility, and considering PKU's research skills on 2.45 GHz PMECRIS, we choose this kind of ion sources to produce He^+ beam in our injector. To obtain high intense plasma, the ion source body we use in helium injector is with 3-layer ceramic medium waveguide against BN microwave window, 25 mm radius and 54 mm long cylindrical discharge chamber, and 3 NuFeB alloy permanent magnet rings applying to set up 900 ~ 1000 Gs magnetic fields, etc. [4].

We choose tri-electrode type of extraction system because of the virtues after the suppressing electrode added such as the possibility to decide the plasmas setup quality and stability. What's more, the shape of electrodes is using optimized 90° cone apex shape, which is proved to be able to improve beam distribution and emittance [5].

LEBT

Considering the 2-solenoid LEBT could manipulate beam more easily because of its symmetrical structure, this type of LEBT is chosen in the helium injector. The LEBT is so divided into 5 parts: drift I, solenoid I, drift II, solenoid II and drift III, with lengths 280 mm, 200 mm, 200 mm, 200 mm and 280 mm, respectively. So the total length of the LEBT is 1.16 m. The Trace3D simulation shows this design could transport and inject beam into RFQ with qualified characteristics. Based on this simulation support, the mechanical design and review for this injector is as Fig 1.

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#sxpeng@pku.edu.cn

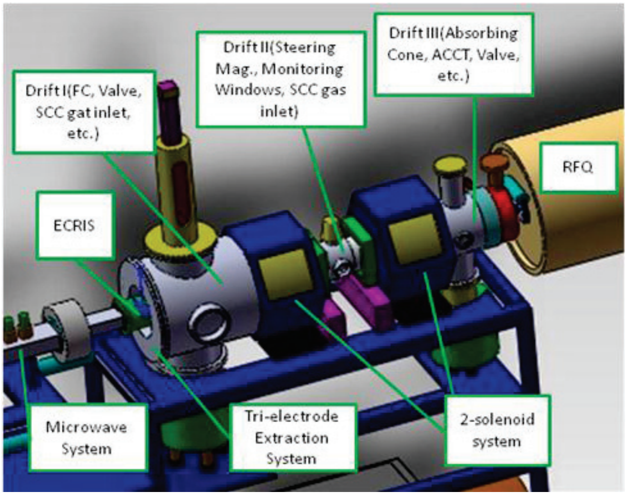

Figure 1: Mechanical review of injector.

Improvements Compared with PKUNIFTY Injector

Compared with PKUNIFTY's injector, this helium injector executes 4 main improvements in design.

- According to previous experimental results on the test bench, front space charge compensation (SCC) could induce a better compensation compared with rear compensation [1]. So a front compensated gas inlet is added in the drift I section.
- A 4-quadrant diaphragm is added in drift III to provide RFQ with beam of required current.
- A kicker installation position is included in the drift II, with the purpose of providing a chance for further beam manipulation.
- Total length of the LEBT is optimized to 1.16 m versus 1.36 m in PKUNIFTY.

BEAM DIAGNOSTIC DESIGNS&ASSEMBLING RESULTS

The assembling of this injector has been completed in April, 2013. After the due process, the injector with beam diagnostic system has been designed, assembled and

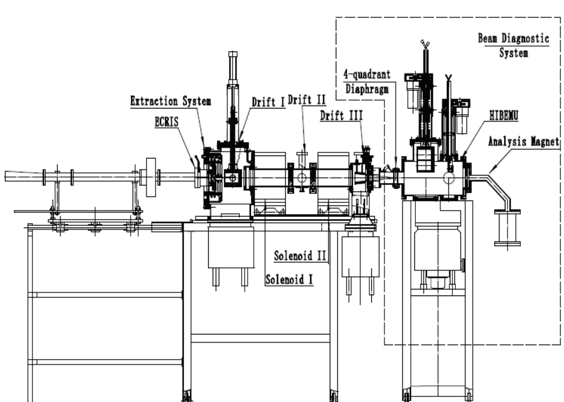

Figure 2: Injector with beam diagnostic system.

commissioned, as Fig. 2 and Fig. 3 showing.

As Fig. 2 shows, a 4-quadrant diaphragm is used to simulate the RFQ entrance and measure the beam trajectory deviation, a PKU High Intense Beam Emittance Measurement Unit (HIBEMU) is installed to get the beam emittance information [6] and at last an analysis magnet is with the purpose of getting the ion proportion parameter.

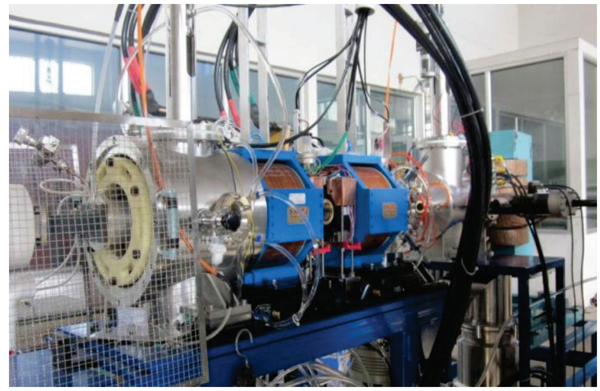

Figure 3: Injector with beam diagnostic system.

After the diagnostic system had been assembled, a series of experiments were operated to get injector performance parameters including extraction beam current and LEBT beam transport efficiency. Other parameters like beam emittance and ion proportion also need monitoring, and will be measured in near future.

EXPERIMENTAL RESULTS

Until now on, all the experiment results point positive prospects, satisfied with and surpassed to related injector designed parameters in Table 1.

Ion Source

After extraction system succeeds in performing 35 kV conditioning, He^+ beam is extracted from ion source on the condition of 1.8×10^{-5} Pa pressure with 30 keV energy. At the Faraday Cup (FC) in the drift I, an 18 mA beam current is obtained as Fig. 4 showing. Channel 1, 2, and 3 are the triggered, microwave and FC signal, respectively.

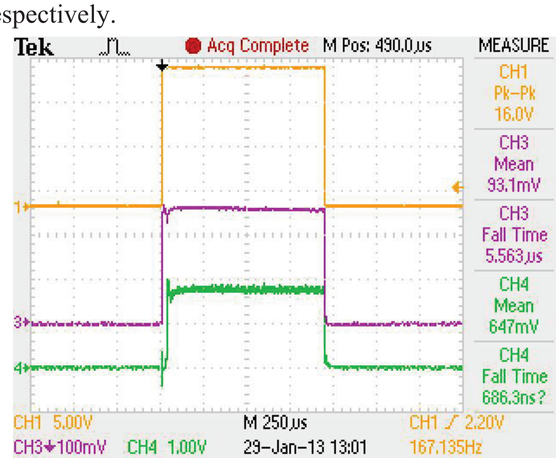

Figure 4: Faraday cup signal in drift I.

LEBT

The beam signals of ACCT and slit cup in the front of HIBEMU are also measured after the beam is transported through LEBT. By means of measuring and comparing the currents at FC, ACCT and slit cup, we could deduce the transport efficiency of LEBT and estimate whether the following test methods for beam emittance and ion proportion behind the HIBEMU are reasonable.

As Fig. 5 and 6 depicted, we get experimental results with FC, ACCT and slit cup signal being 18 mA, 15 mA and 14 mA, respectively, which indicates a 83% LEBT transport efficiency.

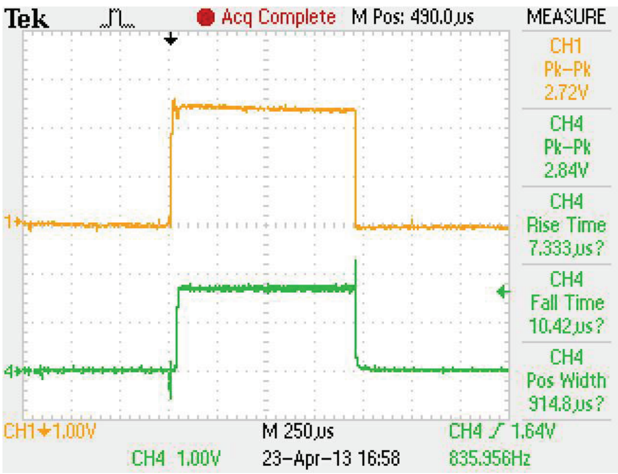

Figure 5: Microwave(CH1) and FC(CH4) signals.

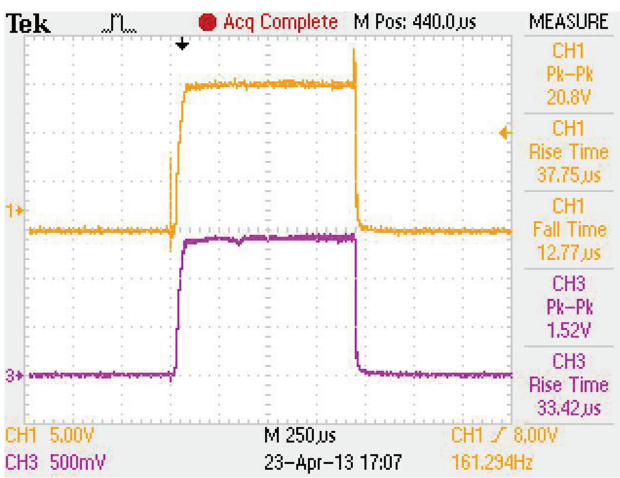

Figure 6: ACCT(CH1) and Slit Cup(CH3) signals.

Based on these results, we may assert the injector satisfies the designed requirements by now since it could provide 14 mA helium ion beam to RFQ versus required 10 mA, and the reasonability of following beam diagnostic experiment designing for parameters like beam emittance and ion proportion, etc.

SUMMARY

We design and commission an injector for RFQ-SFRFQ cavity based on previous PKUNIFTY experiences with 4 main improvements. The assembling work is completed and immediate beam testing experiments are designed and some of them are executed in April, 2013. By now all the experimental results feedback positively that the injector is satisfied with and surpassed to the design parameters. The designed and experimental parameters are compared in Table 2. The measurements of other beam parameters are on the way.

Table 2: Summary of Experimental Results

Parameter	**Designed Value**	**Experimental Results**
Drift I Vaccum	5×10^{-5} Pa	1.4×10^{-5} Pa
Drift II Vaccum	5×10^{-5} Pa	1.7×10^{-5} Pa
Drift III Vaccum	5×10^{-5} Pa	2.0×10^{-5} Pa
Extraction Conditioning	30 kV	35 kV
He^+Beam Current	10 mA	14 mA

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