Design and Installation of A Prototype Multi-pinhole Faraday Cup

Dong-Hwan Kim [a,b], Jeong-Jeung Dang [b*], Hyeok-Jung Kwon [b], Seung-Hyun Lee [b], Han-Sung Kim [b], Kyoung-Jae Chung[a] and Yong-Seok Hwang[a]
[a]*Dept. of Nucl. Engr., Seoul Nat'l Univ., 1 Kwanak-ro, Kwanak-ku, Seoul, Korea*
[b]*Korea Multi-Purpose Accelerator Complex, KAERI, 181 Mirae-ro, Geoncheon-eup, Gyeongju, Korea*
[*]*Corresponding author: jjdang@kaeri.re.kr*

1. Introduction

The proton injector consists of high-intensity microwave ion source and low-energy beam transport (LEBT) system in KOMAC. The LEBT system is composed of two solenoid magnets and two steerers which take a role of matching the proton beam from the ion source to the RFQ [1]. As a beam diagnostics tool, AC current transformer (ACCT) has measured the RFQ input current in the downstream of the LEBT. An Allison-type emittance scanner had been installed and utilized to investigate the dependence of emittance on various conditions in the proton injection system [2]. This scanner has shortcoming of taking a long time to get data, so that alternative beam diagnostics was required. A multi-pinhole faraday cup (MPFC) was developed to measure ion beam uniformity. It has two parallel plates with many apertures in the form of pepper-pot mask, and small copper cups to collect protons through the pinhole [3]. We designed the similar device and installed to measure two-dimensional beam current density profile and to estimate transverse beam emittance in phase space with thin-lens approximation and solenoid scan method. This paper presents the design and fabrication of the prototype MPFC and preliminary results.

2. Methods and Results

2.1 Design: A Prototype Multi-pinhole Faraday Cup

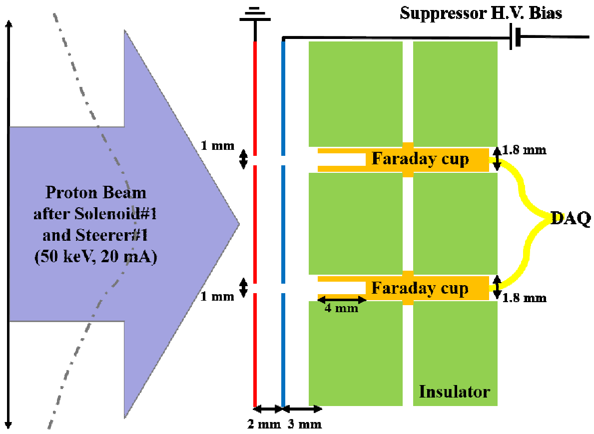

Fig. 1. An Overview of a prototype multi-pinhole faraday cup

A prototype multi-pinhole faraday cup (MPFC) was designed to assure its feasibility and optimize performance as the major beam diagnostics tool for the KOMAC LEBT. A MPFC has two parallel electrodes made up of tantalum plate with a thickness of 0.25 mm and fifty respective faraday cups. The first plate is ground electrode to absorb most of beam current except for the one through apertures. The second plate is suppressor electrode to mitigate perturbation of measured ion current by secondary electron emission. The diameter of apertures in the two plates is 1 mm each. The last electrodes are small pin-typed faraday cups made from a gold-plated copper alloy. A prototype MPFC has fifty channels which are 4 or 12 mm apart from each other to partially cover up to 56 mm * 56 mm of beam size at a time as following figure.

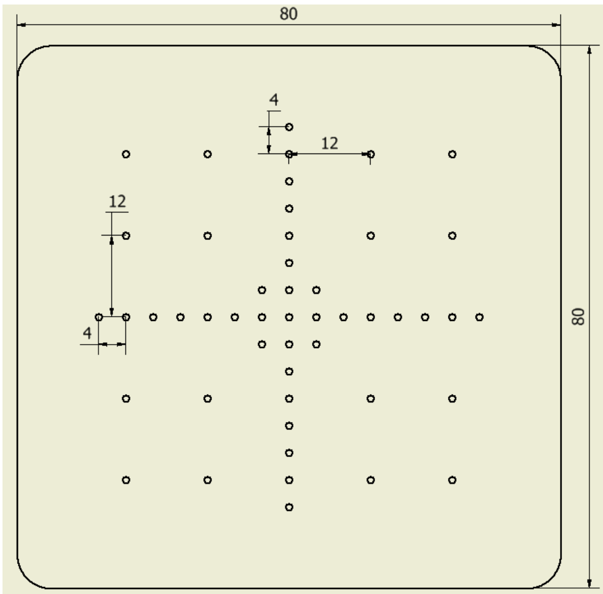

Fig. 2. An Overview of a prototype multi-pinhole faraday cup

2.2 Fabrication and Installation

Each plate and faraday cup is electrically insulated by G10 epoxy glass laminate which is favored for its high physical and chemical strength. All components above mentioned were assembled with bolts fastening, and were enclosed in grounded 5 mm-thick aluminum housing for the electromagnetic noise immunity. The assembly hung from a flexible in-vacuum bellows, so that the MPFC could be remotely armed or disarmed using bipolar stepper motor connected to a shaft with bellows. Bias voltage was fed into suppressor plate using high voltage supply module such as ORTEC 556.

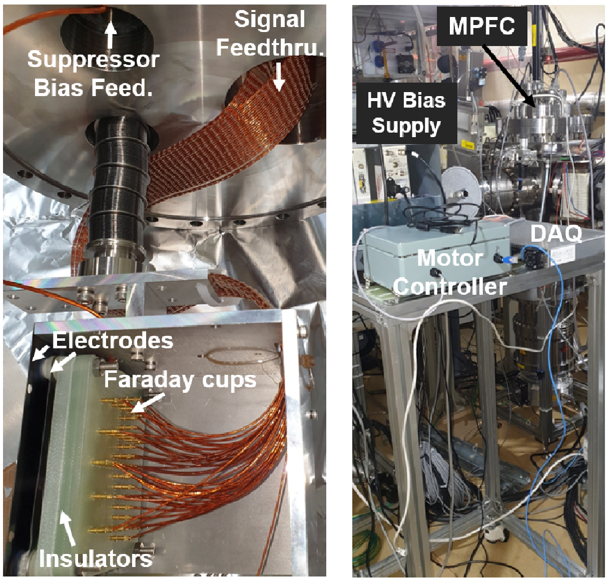

Fig. 3. Installation of multi-pinhole Faraday Cup in vacuum and relevant electronics

2.3 Data Acquisition

Data acquisition (DAQ) board is 128-channel electrometer I128 model with input current rating of +550 nA. This low current rating is limiting factor to measure high current, especially on the center channel in focused beam operation during solenoid scan. Other DAQ system have been prepared based on a general-purpose digitizer such as NI PXIe-6363 module.

2.4 Beam Dynamics Calculation for the Solenoid Scan

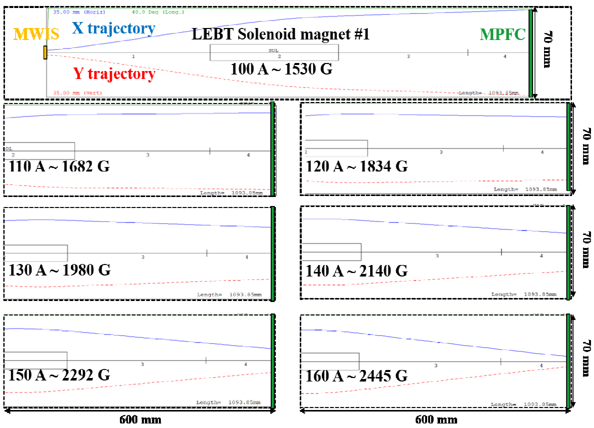

Fig. 4. Beam dynamics calculation to the LEBT solenoid magnet #1 using trace3d code

A beam dynamics calculation using trace3d code was performed to analyze and estimate the range of solenoid scan experiment. The first solenoid magnet typically plays a role of making beam go straight in the middle of LEBT. According to calculation results, 1700 G of magnetic field make beam pass in parallel to z-direction. Defocused beam is anticipated to be measured at scanning point less than this value, and vice versa.

2.5 Preliminary Results

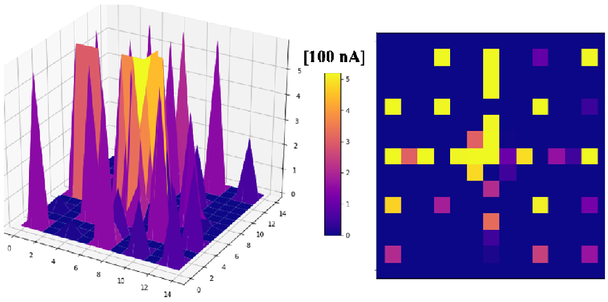

Fig. 5. Measured transverse beam current profile in a normal operation condition.

In a normal operation with 124 A of solenoid #1 current, proton beam strikes the prototype MPFC with 50 keV of energy, 20 mA of current, and 10 mm of standard deviation, assuming Gaussian beam profile. In this case, maximum measured current is estimated more than 100 uA, and it is unacceptable to the existing DAQ based on I128 electrometer. Most channels are saturated at the maximum current with little meaningful data. Current-integrated signals were extracted from I128 software and post-processed by Python for the two-dimensional imaging as shown in figure 5.

3. Conclusions

A prototype multi-pinhole faraday cup was designed, fabricated, and installed in the middle of KOMAC LEBT. This beam diagnostics device is aimed to measure transverse beam current density and estimate beam emittance. Beam dynamics simulation was performed to set solenoid scanning point and make comparison with the measurement. This remotely controllable device will be able to characterize LEBT system and help to comprehend neutralization effect for the enhancement of RFQ transmission ratio.

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