Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 19-20, 2022

Beam Commissioning Results of Proton Injector Test Stand for the KOMAC.

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1. Introduction

The proton injector produces a high-current and low-energy proton beam with minimum loss and makes the beam parameters matched to a subsequent accelerator such as radio-frequency quadrupole (RFQ) [1-2]. Proton injector test stand has been built to improve beam dynamics such as developing novel beam diagnostics system and beam tuning method, instead of the 100-MeV accelerator, which is usually occupied by users [3].

2. Methods and Results

2.1 System layout and beam dynamics of the Proton Injector Test Stand.

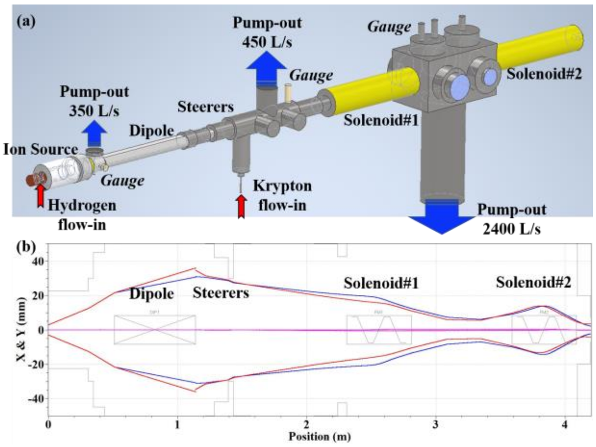

Fig. 1. (a) System layout and (b) beam dynamics calculation of the proton injector test stand for the KOMAC.

The proton injector consists of a microwave discharge ion source, low energy beam transport (LEBT) system, and beam diagnostics as shown in Figure 1. The ion source extraction system can generate 50-keV proton beam with maximum current of 30 mA. The LEBT section is composed of a dipole magnet for a 90° bending with edge focusing, two solenoid magnets for the beam focusing, and two steering magnets for the beam orbit correction. Focusing lenses are utilized to prevent a beam from striking a wall and to make matched beam parameters downstream. In addition, steerers are used to correct alignment errors that inevitably exist between the beam-line components involved in the transport process.

2.2 Beam Extraction Experiments and Beam Current Measurement

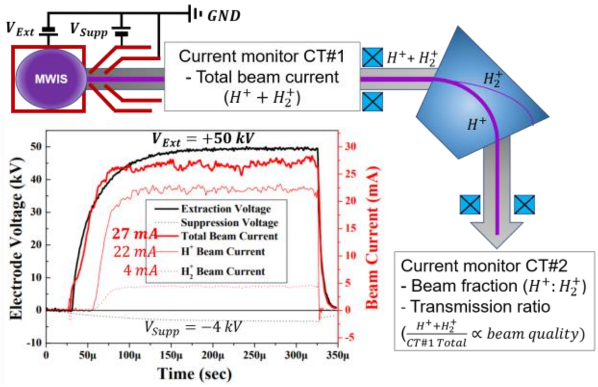

Fig. 2. The schematic of beam extraction and the beam current measurement at two positions: upstream and downstream the dipole magnet.

Microwave discharge is in a dc-operation state, and when high voltage is applied in the form of a pulse to the plasma electrode and the suppression electrode, a pulse beam is extracted. Figure 2 demonstrates the schematic diagram of beam extraction experiment and beam current measurement. An electric potential difference of 50 kV is applied between the plasma electrode and the extraction electrode, and the rise time is about 50 μs. The first beam current monitor is installed downstream of the bias-feeding flange in the ion source extraction system. Not only H+ contained in hydrogen plasma, but also H2+ and H3+ are generated together in a specific ratio, and the total current is measured.

There is a dipole magnet that bends the beam at 90 degrees, which can selectively pass the particle species according to the difference in mass and charge, or magnetic rigidity. For a 50 keV proton beam, a uniform magnetic field of about 808 G is required for a 90 degree circular motion with a radius of curvature of 400 mm. On the other hand, in the case of an H2+ beam, it can be transported with a magnetic field of 1142 G. In the case of H3+, it accounts for 0.1% of the system and is ignored. Atomic fraction and transmission ratio of the beam can be estimated by the ratio of the current values of the two current monitors located upstream and downstream the dipole bending magnet.

Table 1. The operation conditions of ion source and measured beam current data.

Ion source control parameters	Input values	Measurable beam parameters	Output values
Hydrogen	2.0	H+ beam	21.8 mA

flow rate	sccm	current	
Microwave power	410 W	H2+ beam current	4.3 mA
Solenoid current	75.8 A	Atomic beam fraction	83.5% (21.8 / 26.1)
Extraction voltage	+50 kV, -3 kV	Transmission ratio	97.4% (26.1 / 26.8)

2.3 Beam Profile Measurement

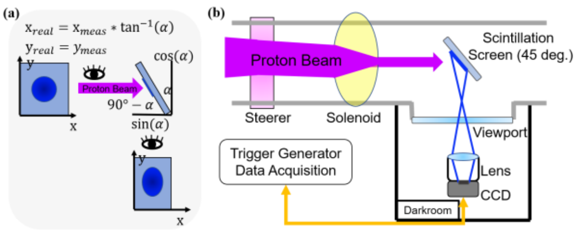

Fig. 3. Fraction of counts lost with voltage and charge sensitive preamplifiers as a function of the true count rate.

Beam current monitors measure the intensity of the beam, but not the density distribution in the transverse direction. A beam profile monitor is used to measure the change in size and center position of a low energy beam transported from an ion source through the dipole bending magnet, the steerer magnets, and the solenoid magnet. The beam profile monitor in Figure 3 can obtain beam size and position by capturing the light emitted when the proton beam hits the scintillating screen directly. Installing it at an angle of 45 degrees in the horizontal direction with respect to the transverse plane of the beamline, the difference in the aspect ratio between the actual image and the measured image is not distorted.

Quartz glass and chrome-doped aluminum oxide, chromox-7 (Al_2O_3:Cr), are used for the scintillating screen. The two materials have different sensitivity, generate light in different wavelength ranges, and have different decay times. Chromox-7 belongs to a scintillator with very good sensitivity, but it has the characteristic of saturation when the beam current is high. The proton injector generates a proton beam of 10 mA or more, and if this beam is focused at the screen position through a solenoid magnet, it is saturated and unable to measure the beam distribution. Therefore, it is suitable for use in a beam with relatively weak intensity like H2+ beam. Quartz glass has lower sensitivity than chromox-7, so it does not saturate even when the beam current density is high. Instead, in a solenoid magnet setting that is far from the focal length, the light intensity is not sufficient and repeated measurements are required. Since the scintillating screen method measures accumulated beam profile during the exposure time, it is difficult to observe the change of the beam over time such as dynamic process of space charge neutralization, compared to an electrical signal-based beam profile monitor.

Table 2. Specification and setting conditions of vision camera used in beam profile monitor.

Model name	*Basler* acA640-120gc
Resolution	658 * 492 VGA GigE color
Pixel	5.6 μm * 5.6 μm
Sensor	1/4 CCD (3.68 mm * 2.75 mm)
Frame rate	120 fps (max.)
Exposure time	1 ms (variable)
Lens	*Computar* M2514-MP2 megapixel

A vision camera is used and its specifications and setting conditions are summarized in Table 2. The frame rate is up to 120 fps, but since the repetition rate of operation is typically set as 1-10 Hz, a pulse delay generator is used to synchronize a camera trigger with a beam trigger. The image is focused with the center of the screen by manually adjusting the lens, and the exposure time and gain are adjusted to obtain an image under the condition of obtaining enough signal-to-noise ratio. From this measurement setup, transverse beam profile is measured with varying the strength of solenoid magnet as shown in Figure 4.

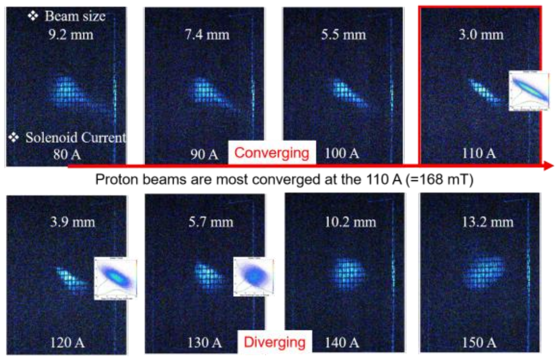

Fig. 4. Transverse beam profile with varying the strength of solenoid magnet in the LEBT.

3. Conclusion

Beam commissioning of proton injector test stand is successfully performed in terms of beam extraction experiments and beam measurement. Total hydrogen beam current up to 30 mA is obtained with maximum 10 Hz and 1 millisecond pulse. Transverse beam profiles are measured by scintillating screen and CCD camera with varying the strength of solenoid magnet in the LEBT section.

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