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Time Evolution of the PEFP LEBT Beam in Phase Space

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1. Introduction

As a front end part of the 100-MeV proton linac of Proton Engineering Frontier Project (PEFP), a 20-MeV proton accelerator has been installed and tested at Korea Atomic Energy Research Institute (KAERI) site. The 20-MeV accelerator consists of a 50-keV proton injector, a 3-MeV Radio frequency quadrupole (RFQ) and a 20-MeV Drift Tube Linac (DTL) [1]. A beam profile in phase space was measured at Low Energy Beam Transport (LEBT) to investigate the matching characteristics of the beam from the ion source into the RFQ. The emittance scanner was used to measure the beam density in phase space. The beam from the ion source was pulsed structure, the entire beam pulse was measured and analyzed depending on the time. In this paper, the measurement result is presented and the time evolution of the beam in phase space is discussed.

2. Measurement Method

2.1 Emittance Scanner

An Allison type emittance scanner was designed and fabricated to measure the beam density in phase space [2]. The design parameters of the emittance scanner are summarized in Table 1. It was designed to accommodate the beam size at 130A of the solenoid magnet current. The fabricated emittance scanner was installed at the vacuum box in the PEFP proton injector as shown in Fig. 1 [3]. The 3ea. vacuum feedthrus were installed for the measurement: One was for the plate voltage, another was for the bias voltage, the third was for the collector signal. A BOP (Bipolar Operational Amplifier) and current amplifier were used as a plate voltage sweep source and an output signal conditioner respectively. The data acquisition system was implemented with LabView [4].

Table 1: Design Parameters

Chamber length	65mm
Electrode length	57mm
Plate margin	4mm
Slit width	0.1mm
Beam voltage	50keV
Gap distance	2.5mm
Maximum voltage	600V
Maximum analyzable angle	68.5mrad
Mechanical angular resolution	1.5mrad
Maximum beam radius	60mm

Fig. 1: PEFP 50-keV proton injector. The ion source is located at right side and the RFQ is located at left side.

2.2 Signal Processing

The measured signals at fixed position and fixed angle (or voltage) are shown in Fig. 2 for several measurement conditions. In the Fig. 2, the designation of -8_40_001 means that the position was -8mm and the applied voltage was 40V. The applied voltage can be converted into the angle of the incident proton beam at the measurement position. The pulse width is 2ms long during the measurement. Two signals captured at the same conditions were averaged to reduce the local fluctuation effect in the data processing. As shown in the Fig. 2, the measured beam signal has a time dependent shape. Therefore, four points (0.2ms, 0.7ms, 1.2ms, 1.7ms after the beam pulse beginning) were selected and the beam densities at those times were plotted in the phase space.

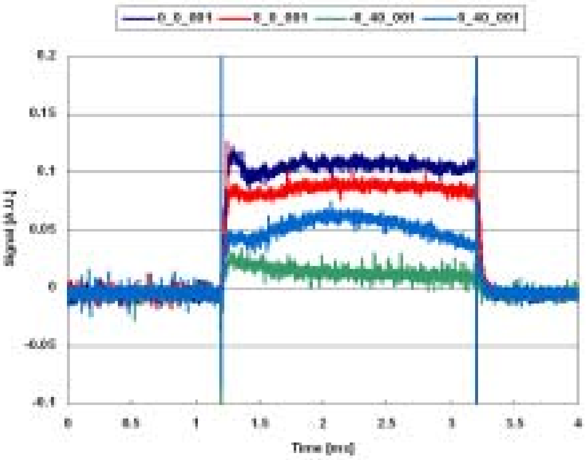

Fig. 2: Measured signal profile
(0_0_001: 0mm, 0V, 8_0_001: 8mm, 0V,
-8_0_001: -8mm, 0V, 0_40_001: 0mm, 40V)

3. Measurement Results

3.1 Phase Space Distribution

The phase space plots of the beam distribution were shown in Fig. 3. The operating conditions of the proton injector were such that the arc current of the ion source was 10A, extraction voltage was 50kV, the solenoid 1 current was 130A and the LEBT vacuum pressure was 8.5×10^{-6} torr. The distributions of the proton and H2+ were clearly visible in the Fig. 3. The unnormalized rms emittance was 47.4 π mm mrad at 1.2ms when the RF pulse of the RFQ started.

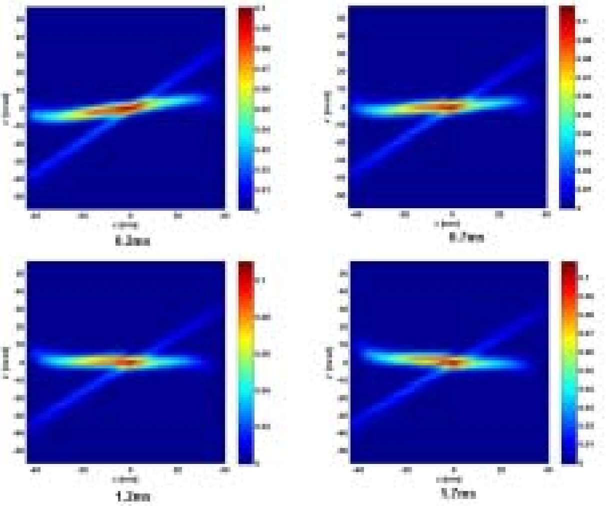

Fig. 3: Phase space distribution of the beam from the proton injector at selected time

3.2 Time Evolution of the Phase Space Distribution

As shown in the Fig. 3, the phase space distribution changed depending on the time. The twiss parameters depending on the time are shown in Fig. 4. The alpha among the twiss parameters is the parameter that defines the tilt angle of the ellipse. The tilt angle changed from negative to positive value along the time, which means that the beam was divergent at first and became convergent as time passed. The main reason for this is supposed to be the neutralization process in the LEBT. It is well known that there is a charge neutralization occurring due to ionizing collisions of the proton in the background gas. Moreover the charge neutralization has an important role on the focusing of the low energy proton beam transport. The charge neutralization time is 56μs for the 50keV protons in the background pressure of 8.5×10^{-6} torr without any perturbing magnetic field. If there were magnetic field along the beam transport line, it is difficult to estimate the neutralization time in analytical form. There are two solenoid magnets in the PEFP proton injector for the beam focusing. Therefore it is supposed that it take more time than estimated to stabilize the charge neutralization in the LEBT due to the magnetic field of the solenoid.

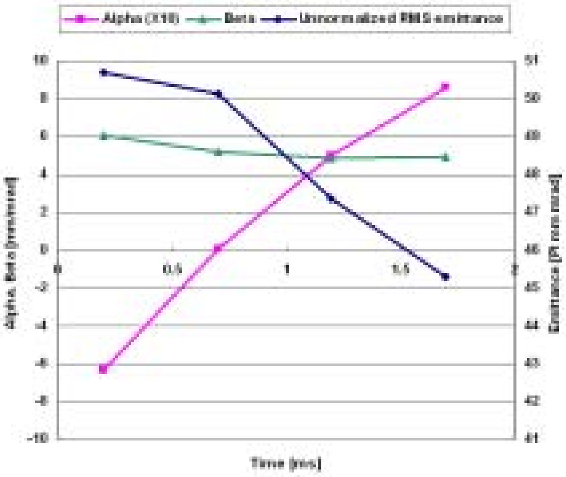

Fig. 4: Time evolution of the twiss parameters and unnormalized rms emittance of the proton beam

3. Conclusions

The phase space distribution of the proton beam was measured at the PEFP proton injector. An Allison type emittance scanner was used. The entire pulse shape was obtained in order to analyze the tendency depending on the time. The results were such that the beam was divergent at first and became convergent as time passed. The main reason for this is supposed to the finite charge neutralization time. In future, the time evolution of the phase space distribution will be measured depending on the LEBT pressure to confirm the charge neutralization effect.

Acknowledgement

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