

## A PEPPER-POT BASED DEVICE FOR DIAGNOSTICS OF THE SINGLE-SHOT BEAM\*

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### Abstract

In order to measure the peak current and the beam transversal distribution of an ampere-scale microsecond single-pulse ion beam, a novel single shot beam diagnostic device based on pepper-pot technique, which is a combination of Faraday cup and pepper-pot measurement facility, was developed at Peking University (PKU) [1]. It consists of a main Faraday cup with a pepper-pot mask at its bottom, and a Faraday cup array locating 3 mm away from the pepper-pot mask. This device has been tested at the PKU LEBT test bench and the measurement results are consistent with the results acquired by the Allison scanner. By replacing the Faraday cup array with a fluorescent screen and a CCD camera, this device becomes a facility that not only has the ability to measure the total beam current and the beam profile, but also has the capability to measure the beam emittance for CW or pulsed ion beams. Details will be presented in this paper.

### INTRODUCTION

A project to measure the beam distribution and its peak beam current of an ampere-scale microsecond single-pulse ion beam has been launched at PKU. The single-pulse beam is of 0.1~10 A at 20~150 keV with the pulse length of 4  $\mu$ s.

The beam current, beam transversal distribution and the beam emittance are important parameters to demonstrate the beam quality of an ion source and to evaluate beam transportation behaviour after a long distances. Generally, the total beam current can be measured with a Faraday cup or a beam transformer, and the beam distribution information and its emittance can be achieved by Emittance Measurement Units (EMUs), such as slit-wire type facility [2,3], Allison-type scanner [4,5] and the pepper-pot device [6,7]. However, the traditional slit-wire facility and Allison-type scanners are not suitable for measuring a microsecond single-shot ion beam because they need a time period of minute-scale to finish the mechanical scan during a measurement [6]. In contrast, the pepper-pot principle device is able to measure the beam distribution and beam emittance of a very short single-shot ion beam because of its cut-off single-shot technique without any time-consuming step. However, there is no way to give out the total beam current with a conventional pepper-pot device. The Argonne National Laboratory of USA developed a pepper-pot emittance

meter which consists of a movable Faraday cup and a pepper-pot device, but it cannot measure the total beam current and emittance simultaneously [7].

At PKU, we developed a pepper-pot device recently [1]. It is a multi-purpose measurement device with the ability of measuring total beam current and beam distribution of a single-shot beam simultaneously. A Faraday cup array is adopted to replace the imaging system of the traditional pepper-pot device to measure the beam distribution, which can avoid the high cost and the complexity of the imaging facilities. The test of this pepper-pot device has been performed at the PKU test bench with the measurement results verified by an Allison-type scanner.

In this paper, a description of the pepper-pot beam profile measurement device is given in section II. The experimental conditions and results analysis are described in section III and the paper ends with our improvement plan for next step in section IV.

### PEPPER-POT DEVICE

The schematic diagram of this pepper-pot beam profile measuring device is shown in Fig. 1. It consists of a main Faraday cup with a pepper-pot mask on its bottom, a Faraday cup array disk, two pairs of permanent magnets and an outer casing.

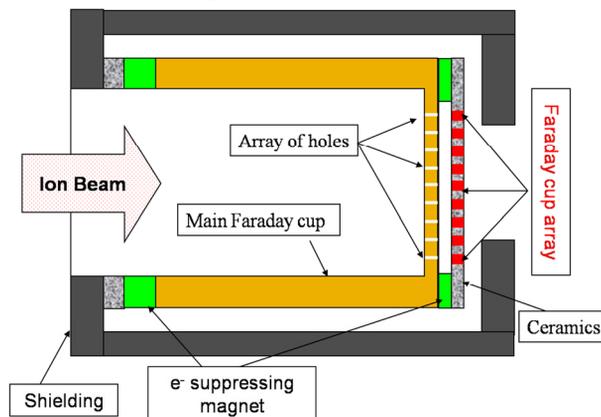


Figure 1: Schematic diagram of the pepper-pot beam profile measuring device.

An overall view of the pepper-pot device is shown in Fig. 2. The outer diameter is 45 mm and its total length is

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only 70 mm. The signals of the main Faraday cup and Faraday cup array are delivered outside the vacuum chamber by multi-core shielded wires.

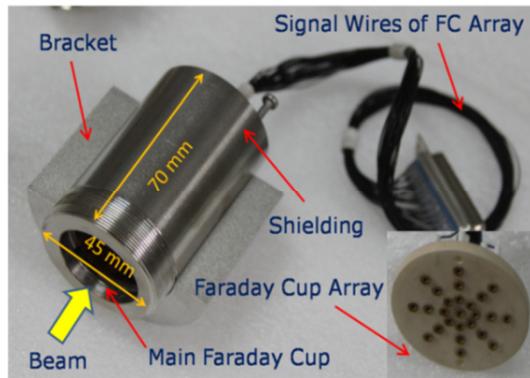


Figure 2: Photo of the pepper-pot beam distribution measuring device.

The total beam current will be measured by the main Faraday cup integrated inside the pepper-pot device. The pepper-pot mask contains 25 identical holes (diameter of 0.5 mm) and its thickness is 2 mm, but the actual thickness of the holes wall is only 0.5 mm to prevent any smearing effects due to beam scattering [8]. According to the theoretical calculation, Errors of the total current caused by the 25 holes is less than 0.1% and can be ignore during the measurement.

The measurement of the beam profile will be performed with the pepper-pot mask and the Faraday cup array which locates 3 mm downstream from the pepper-pot mask. The diameter of each small Faraday cup is 2 mm which is designed to detect the ion beams with 0~180 mrad divergent angles.

In order to ensure the accuracy of the measurement, the secondary electrons are suppressed by the permanent magnets locating at the entrance of the main Faraday cup and in front of the Faraday cup array. The grounded outer casing is a shielding to reduce the measurement background introduced by secondary electrons and other stray ions in the vacuum chamber.

## EXPERIMENTAL PROCEDURE AND RESULT ANALYSIS

The pepper-pot beam profile measuring device was tested on the PKU Low Energy Beam Transport (LEBT) test bench (shown in Fig. 3). It was installed at the end of this test bench, supported by two semicircular brackets. As shown in Fig.3, Faraday cup 2 (FC2) and an Allison-type scanner on this test bench were used to verify the results acquired by the pepper-pot device.

We used a pulsed  $H^+$  ion beam with pulse repetition rate of 100 Hz and pulse length of 1 ms to test the pepper-pot measuring device. The data acquisition system consists of sampled resistances and a computer with a multi-channel acquisition card. A comparison experiment on the signals of the main Faraday cup and the Faraday cup array was performed using an oscilloscope. The waveforms of the total ion beam and the centre beamlet (shown in Fig. 4) demonstrate a good synchronicity between signals of the main Faraday cup and the Faraday cup array.

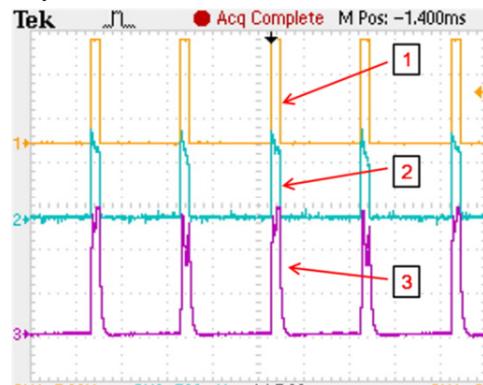


Figure 4: Currents of total ion beam and one of the beamlets: 1. trigger signal, 2. main Faraday cup signal (~100 mA), 3. signal of the central small Faraday cup (~15 uA).

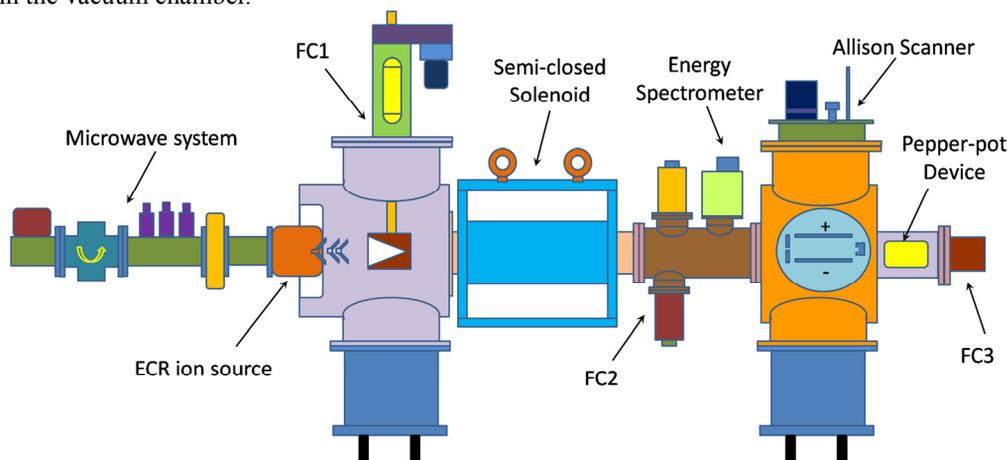


Figure 3: Schematic diagram of LEPT Test Bench at PKU.

A LabVIEW program has been written to perform the data acquisition, set relevant measurement parameters and reconstruct the transverse distribution of the ion beam. The scattered data of the Faraday cup array cannot give all detailed information of ion beam distribution before the data processing. Therefore, an approximation method called grid data function in Matlab is used to reconstruct the beam transverse profile. In the grid data function, some different interpolation methods can be chosen and by comparison we found that the method of nearest neighbour interpolation can lead to a result more consistent with the output of the Allison-type scanner. Fig. 5 shows the three-dimensional projections of the transverse distribution after calculation by the Labview program.

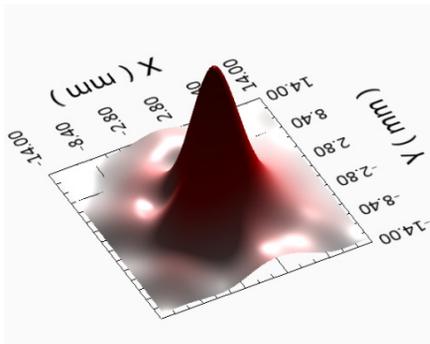


Figure 5: Three-dimensional projections of the transverse distribution.

The measuring error of this kind of pepper-pot beam distribution measuring device is mainly caused by the error of sampled resistances and the number limitation of small holes in the pepper-pot mask. The sampled resistances we used in this test experiment are metal film resistors with the value error about  $\pm 1\%$  and it will be corrected with a series adjustable resistance in the future. Using a pepper-pot mask with more holes can make the measurement result closer to the real beam distribution, but accompanying with an increase in cost.

### LIMITATION AND IMPROVEMENT

Although this pepper-pot device has the ability to measure the total beam current and beam distribution of a single pulse microsecond beam simultaneously, it cannot provide the beam emittance information so far. In order to solve this problem the upgrade plan was proposed with replacing the Faraday cup array disk with a fluorescent screen and a CCD camera. The pepper-pot device with improvements becomes a beam emittance meter for CW or pulsed ion beams, and has the ability to measure beam current, beam divergence and beam distribution simultaneously.

The schematic diagram of the pepper-pot device with improvement plan is shown in Fig. 6. The position-sensitive detector of fluorescent screen locates at a fixed distance downstream of the pepper-pot mask. The entire images on the fluorescent screen are collected by a CCD camera with the help of a flat mirror. The PC program finally presents the measurement results of the total beam

current, beam profile and 4-D beam emittance. The screen thickness and the fluorescent material should be carefully treated to weaken the interference caused by light diffusion, inhomogeneity, and nonlinear response of the fluorescent screen.

The details of the improvement and the emittance measurement results will be reported in the future.

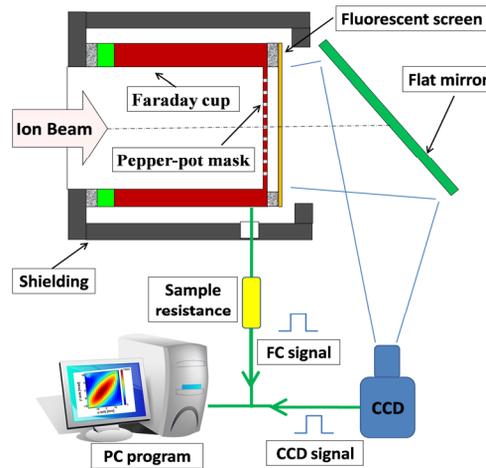


Figure 6: Schematic diagram of the pepper-pot emittance meter.

### SUMMARY

A novel beam current and distribution measuring device based on Faraday cup and pepper-pot technique was developed at PKU. The commissioning test has been performed on the PKU LEBT test bench and the results were verified by the Allison-type scanner. The improvement plan aiming to measure the beam emittance is carried out right now.

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