METHODS TO REDUCE THE SYSTEM ERROR FOR HIGH POWER MSSW EMITTANCE METER

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Abstract

Recently a new Multi-Slit Single-Wire (MSSW) type high power beam emittance meter named as HIBEMU-5 has developed in Peking University (PKU). Compared to previous MSSW devices, HIBEMU-5 greatly reduced the system error from 16.4% to 3.7% by specific designs to solve the incomplete short-slit sampling and fixed slit-wire distance. The problems of previous PKU devices are analyzed in part one. In part two, we describe the specific updating methods to solve its short-slit disadvantage by re-designing a longer-slit board with sufficient cooling, detail the mechanical scheme of changing the slit-wire distance for different beam divergence. The commissioning results given at part three prove that this new long slits design is successful to complete the beam sampling without being distorted by high power H^+ beam. And the movable wire cup is able to locate the best measurement position for different beam focusing.

INTRODUCTION

Multi-Slit Single-Wire (MSSW) method is popular in emittance measurement for high power beams[1]. The slits are used to sample the beam and the wire that locates some distance downstream the beam is used to obtain the beam divergence angle. To ensure the measurement accuracy, the length of slits should be longer than the beam diameter so that the sampling is complete and the thickness of slits board should be as thin as possible to avoid its collimation effect. As a measurement device, it should have the universal ability to deal with different kinds of beam no matter it's divergence is larger (low energy heavy ion beam) or smaller(high energy light ion beam).

At Peking University (PKU) we have developed 4 MSSW emittance meters[2][3][4]. Their processing technic and electronic equipments have been upgraded one by one. But they have two common demerits. First, a 0.3 mm thick molybdenum board with 25 or 35 slits is attached at the bottom of the water cooled Faraday cup to sample the beam and the slit board exposes to the whole beam all the time during the measurement period. Very thin slit board prevents cooling directly and the heat absorbed from the beam hit can only be taken away through Faraday cup. To avoid heat distortion, the length of slits is shortened to 5 mm. But 5 mm is much shorter than the size of the beam diameter in most cases. And this leads to incomplete sampling. As shown in Fig. 1, the incomplete sampling brings a system error of about 8.7% for a ϕ 50mm typical Gaussian distributed beam[5].

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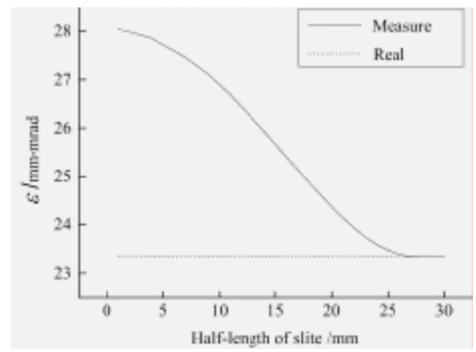

Figure 1: Emittance simulation with different slit length[5].

The second demerit is the fixed length L between slit and wire. This limits the universality of MSSW emittance meters. For an emmitance device whose slits interval is d , the beamlet will start to overlap at a distance of D.

$$D \approx d/2\sqrt{\varepsilon/\beta}$$

Here ε is beam emittance and β is Twiss parameter. For different beam focusing D is different. $L=D$ is the best condition, or L is slightly less than D is also tolerable for this emmitance measurement unit. If $L<<D$, too less data can be collected in the whole scanning; If $L>D$, data overlaps between adjunct slits, as shown in Fig.2. Both improper conditions can generate an error up to 5%.

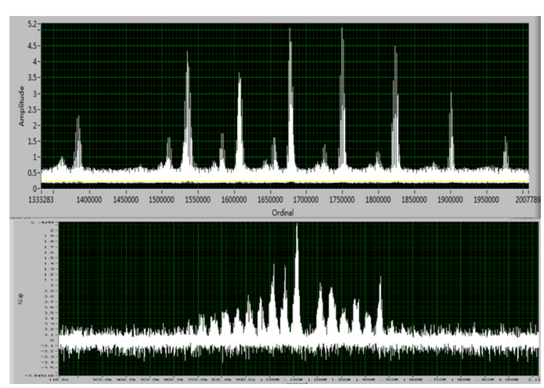

Figure 2: (up)situations of $L<<D$ with too less data collected, (down) conditions of $L>D$ with data overlap.

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To overcome the short-slit error and the fixed L error, a new device named HINEMU-5 has been developed at PKU recently.

PHYSICAL DESIGN

Noticing that at one moment only one slit is in charge of measurement, covering all other slits is a possible way to reduce the beam bombarding on the slits board for better cooling condition. This way makes long slits sampling feasible. A protecting Faraday cup with a small window that faces the measuring slit can fulfill this requirement. Unlike the previous ones, the slits board is separated from the main faraday cup and the faraday cup and slits board are moving independently. During a measurement, the sampling window is in relative rest to the wire cup, and both of them are moved by one driven motor. In this case each point of the slit board will be bombarded for much less time. The sampling window width w determines the exposing time t and also the acceptance angle θ. On the one hand $t=w/v$ requires the window width the smaller the better, where v is the scanning velocity. On the other hand $\theta=w/2L$ has the opposite requirement that the window should be wide enough to accept the whole beam. In our case the sampling window is designed to be 20 mm width, which makes the heating time for each point reduced to 25%, meanwhile the maximum acceptance angle is 133 mrad.

Fixed slit-wire distance design is replaced by a movable wire cup, which is able to locate the best measurement position of F2 in Fig.3. Based on the experiences of previous measurement, the slit-wire distance L changes between 50 mm and 100 mm to avoid both data overlap(F3) and insufficient data.

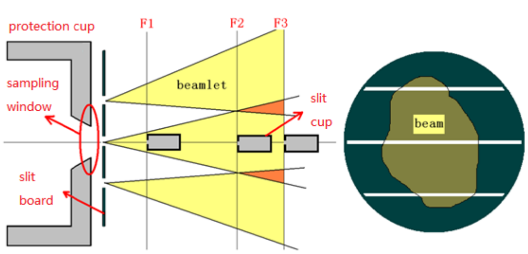

Figure 3: Two improvements of HIBEMU-5[4]. On F1 too less data is collected, on F3 data get overlapped, F2 is the best place.

Two bellows are needed to realize the physical design. One is for the slits board and the other is for the protection cup. Two guide bars are fixed to the protection cup, though which the wire can move along the beam transport direction. The movement is controlled by a gear of 180 mm in height covering the vertical scanning, so that the gear and the wire cup will occlude all the time (Fig. 4). And L can be read outside the vacuum from a mechanical dial. To keep the movement accuracy of scanning, the protection cup has a slide rail for slit board holder to move along. Close fit is used in this part and a shell of brass is inlayed between the two rubbing surfaces to smooth the movement.

The protection of the slits board is designed to be a cup rather than a shielding board for two purposes. One purpose is to measure the total current of the beam. At both ends of scanning, the protection cup bottom covers the whole beam. The other purpose is to collect all beam halo and to cut off secondary electrons by magnetic field, so that the particle noise in downstream areas around the wire cup gets to its minimum.

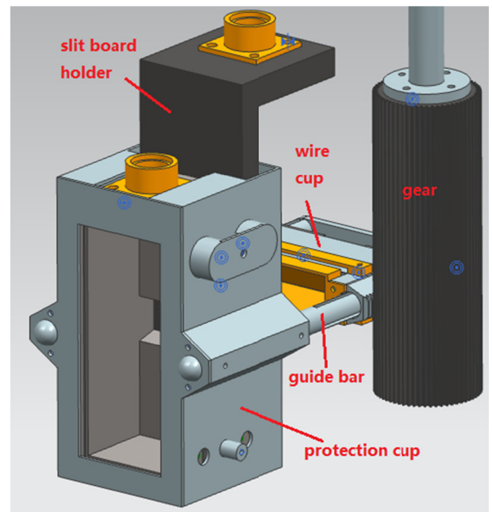

Figure 4: Mechanical design for HIBEMU-5.

To protect the slit board, protecting grids are designed to clamp the thin slit board (Fig.5). Grids and slits have the same special period of 2 mm. Slits have a width of 0.2 mm and Grids have a width of 1 mm. These dimensions make sure a 133 mrad beamlet will pass though the slit board and grids with little collimation.

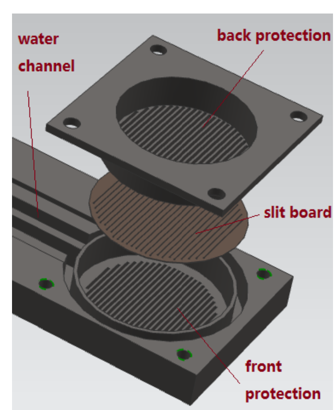

Figure 5: Protection grids design.

Besides these treatments, the protection cup and the slit board are covered together in a shielding shell to reduce noise signals. The material of PEEK is used as the insulation. All the screws are shielded, too. Both the protection cup and the wire cup have magnet suppression.

COMMISSIONING RESULTS

The fabrication of HIBEMU-5 has just been finished and it has been installed into the ion source test bench of

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Peking University. H^+ beam with the parameter of 40 keV, 4.8 mA, 100 Hz and 1 ms is used to test the new emittance meter. The wire cup is able to move in vacuum just as designed, and the long slits kept their shape and having direct water-cooling

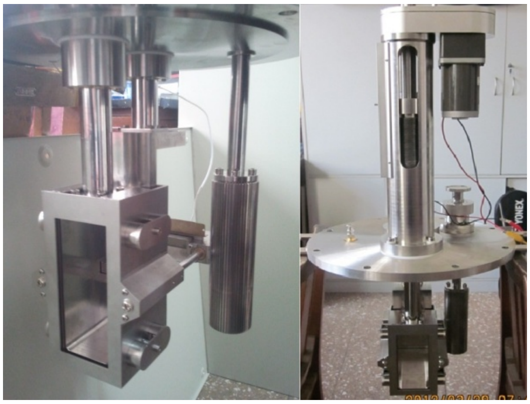

Figure 6: A photograph of HIBEMU-5.

As the first result, Fig. 7 shows the measurement result and the phase ellipse of measured H^+ beam. Emittance is measured as 0.17 π mm·mrad. Comparison with previous facilities and further tests are still needed to evaluate the performance of HIBEMU-5.

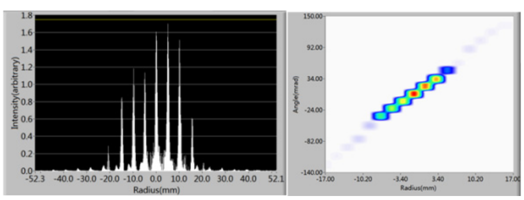

Figure 7: Mesurement results and the phase ellipse of H^+ beam by HIBEMU-5.

CONCLUSION

The two improvements of MSSW emittance meter make HIBEMU-5 more advanced than previous facilities, specifically in complete sampling and avoiding data overlap. Long term application will start on PKU ion source test bench.

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