Revaluation of beam orbit calculation method for the injection line of AVF cyclotron after tuning pepper-pot emittance monitor

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We developed a calculation method for the beam orbit from the Hyper ECR ion source to the AVF cyclotron using the 4D emittance measured by a pepper-pot emittance monitor[1] named PEM_IH10[2,3] and evaluated it with the degree of fit, which is χ^2 divided by the degree of freedom (DOF) between two projections to an arbitrary coordinate axis made from both the measurement of other diagnostics and the beam orbit calculation. However, the dispersion of χ^2 is assumed to be the square of 10% of the highest value of the measurement. Subsequently, the method of processing the beam image on the fluorescent plate of PEM_IH10 recorded by a digital camera was improved.[4] This report is a summary of Ref. 4).

This year, as it was found that the degree of fit varied at different thicknesses of the fluorescent agent, the variation of the degree of fit was examined while varying the combination of the exposure time and gain and the thickness. The results of beam orbit calculations are compared with the beam profile monitor (BPM), which measures 3 axes of profiles set 867 mm behind PEM_IH10 using the 23.6-keV $^4He^{2+}$ ion beam of 100 eμA. In this test, the degree of fit is defined by dividing the sum of 3 axes of χ^2 by the sum of 3 axes of DOF. The thickness is defined by dividing the weight by the area and density. The upper and lower tables of Fig. 1 show the degree of fit obtained from thickness of 1.9 and 34.6 μm, respectively. From these results, irrespective of the thickness, the measurement of PEM_IH10 can be homogenized if the gain and exposure time are optimized.

In order to revalue the beam orbit calculation method after the optimization with respect to the thickness of the he fluorescent agent, the degree of fit is examined using 4 beam intensities (124, 187, 196, and 308 eμA) of 15.4 keV

thickness 1.9 μm — High ⟵ Gain (dB) ⟶ Low

Exposure time (sec) long ↑ short ↓	15	13	11	9	7	5
1/10	1.33	0.97	0.77	0.68	0.63	0.68
1/20	0.91	0.8	0.69	0.65	0.79	1.1
1/38	0.81	0.63	0.64	0.81	1.43	1.73

thickness 34.6 μm — High ⟵ Gain (dB) ⟶ Low

Exposure time (sec) long ↑ short ↓	15	13	11	9	7	5
1/10	1.68	1.38	1.1	0.93	0.51	0.51
1/20	1.19	0.94	0.67	0.49	0.64	1.04
1/38	0.72	0.56	0.5	0.79	1.52	1.86

Fig. 1. Degree of fit compared with BPM when the thickness of the fluorescence agent and the exposure time and gain of the digital camera are varied. (top) thickness = 1.9 μm; (bottom) thickness = 34.6 μm.

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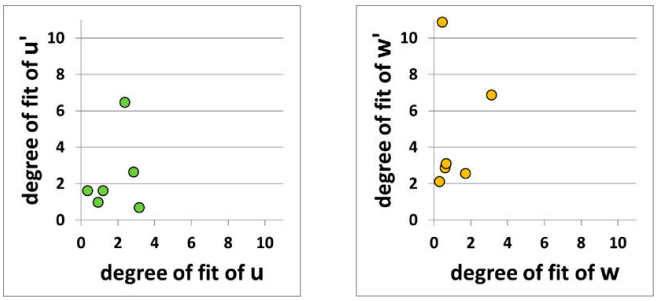

Fig. 2. Scatter plots showing the degree of fit of (left) (u, u') and (right) (w, w') compared with EM_I36.

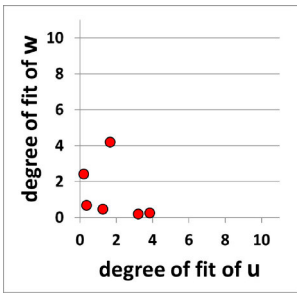

Fig. 3. Scatter plot showing the degree of fit of (u, w) compared with a BPM set 107.5 mm behind EM_I36.

$^4He^{2+}$, 100 eμA of 12.6 keV $^2H^+$, and 214 eμA of 12.8 keV $^2H^+$ by comparing the measurement of a 2D emittance monitor[5] (EM_I36) set 6.2 m behind PEM_IH10 with u and w coordinate axes perpendicular to the beam direction. The angles of u and w are indicated by u' and w', respectively. The left and right of Fig. 2 show the scatter plot of the degree of fit of (u, u') and (w, w') of EM_I36, respectively. The u or w values of all samples are less than 4. However, 3 samples showed u' or w' values are greater than 6, and their widths of angular distributions from the beam orbit calculations were all smaller than those from the measurements for both u and w.

On the contrary, Fig. 3 shows the scatter plot of degree of fit of (u, w) of BPM set 107.5 mm behind EM_I36. It is found that all the degrees of fit are less than 4.2. This reason is not clear yet. We will check the tendency with more data. On the whole, the results of beam orbit calculation using 4D emittance measured by PEM_IH10 agree with real beam orbit so that they are useful for analysing real beam orbits.

References

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