Emittance measurements for RIKEN 28 GHZ SC-ECRIS†

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During the last several years, we have been working on increasing the intensity of highly charged uranium (U) ion beams and we have produced intense beams (≈180 eμA for U^{35+} and ≈230 eμA for U^{33+}) using the sputtering method [1]. It is obvious that the emittance of highly charged U ion beams should be sufficiently smaller than the acceptance of the accelerators of the RIKEN RIBF for safe acceleration. Therefore, to minimize the extent of emittance for intense beams of U ions, we intensively studied the effect of the ion source parameters on the emittance. If the magnetic field distribution affects the ion dynamics and the trajectory of the extracted beams, [2] it may also affect the emittance of highly charged heavy ions.

Emittance was measured using an emittance monitor, which consists of a movable thin slit and wires (beam profile monitor).

The root mean square (rms) emittance is defined as

$$\varepsilon_{x-rms} = \sqrt{\langle x^2\rangle\langle x'^2\rangle - \langle xx'\rangle^2}$$
$$\varepsilon_{y-rms} = \sqrt{\langle y^2\rangle\langle y'^2\rangle - \langle yy'\rangle^2} \qquad (1)$$

In these equations, the averages of the phase-space coordinates of position (x, y) and divergence (x', y') are weighted by the beam intensity [3].

To investigate the magnetic field distribution effect, we measured the emittance for various magnetic field distributions with 18- and 28-GHz microwaves.

The magnitude of maximum mirror magnetic field strength at the beam extraction side (B_{ext}) was changed from ≈1.8 T to ≈1.4 T, while keeping the other magnetic field strengths constant (B_{injti}≈3.1 T, B_{min}≈0.65 T and B_r≈1.8 T) for investigating the B_{ext} effect with 28-GHz microwaves. The RF power and the extraction voltage were ≈1.5 kW and 22 kV, respectively. Figure 1 shows the normalized rms y-emittance as a function of B_{ext}. The emittance drastically changed from ≈0.07 to ≈0.17 π mm mrad as B_{ext} decreased from ≈1.4 T to ≈1.8 T. The beam intensity also depended on B_{ext}. It changed from ≈60 eμA to 40 eμA as B_{ext} decreased from ≈1.8 T to ≈1.4 T. In this figure, open circles denote the averaged emittance for various drain currents (2.5-4.5 mA), which is proportional to the extraction current. The error bars (emittance spread ≈0.015 π mm mrad) are the standard deviations.

The magnitude of B_{inj} was changed from ≈1.5 T to 3.1 T, while keeping the other magnetic field strengths constant (B_{ext} ≈1.45 T, and B_{min} ≈0.65 T, B_r ≈1.8 T) for investigating the B_{inj} effect. Figure 2 shows the results for rms y-emittance. The emittance increased from ≈0.09 to ≈0.17 π mm mrad as B_{inj} increased.

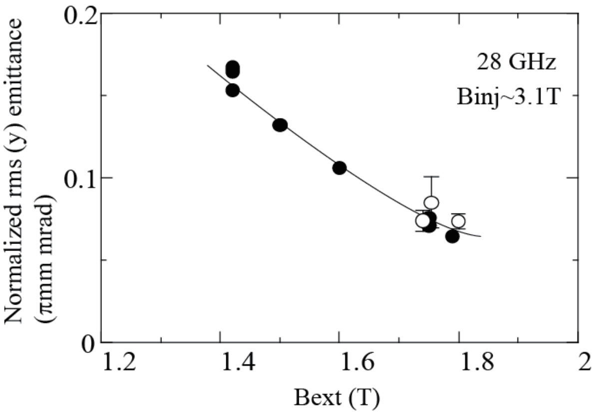

Fig. 1. Normalized rms y-emittance as a function of B_{ext}.

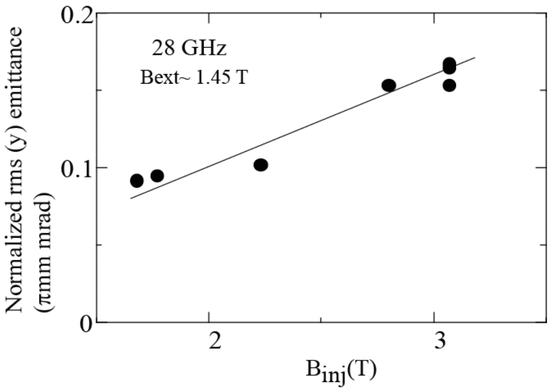

Fig. 2. Normalized rms y-emittance as a function of B_{inj} with 28-GHz microwaves, for B_{ext} ≈1.45 T.

We measured the emittance of U^{35+} ions for various ion source conditions. The extent of emittance was independent of the drain current and extraction electrode position. On the other hand, it strongly depended on the magnetic field distributions. The study of the B_{inj} effect may yield some novel information, implying that the emittance of U^{35+} ions is not influenced by the extraction conditions, but rather by the ion dynamics in the plasma modified by B_{inj}. On the other hand, for less heavy ions such as Xe, Kr, and O ions, preliminary experimental results did not show any strong effects of the magnetic field distributions as for U^{35+} ion beams. The magnetic field distribution may affect only highly charged very heavy ions. Additional research is required to understand these phenomena.

References

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†Condensed from the proceedingw of ECRIS 2014, 21st International Workshop on ECR Ion Sources August, 24-28,Nizhny Novgorod, Russia

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