Space-charge effects on transverse emittance in the extraction region of the RIKEN 28-GHz ECRIS†

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The space-charge effects (SCEs) on the emittance growth in the low-energy beam transport between the puller electrode of a ion source and a magnetic analyzer, which we called "extraction region," is expected to become more pronounced as the highly charged ion beam intensity increases. We measured the four dimensional rms emittances ϵ_{4D}[1)] of argon (^{40}Ar) beams traveling through high-intensity nitrogen (^{14}N) beams through the "extraction region" of the RIKEN 28-GHz electron-cyclotron-resonance ion source (ECRIS)[2–4)] as shown in Fig. 1.

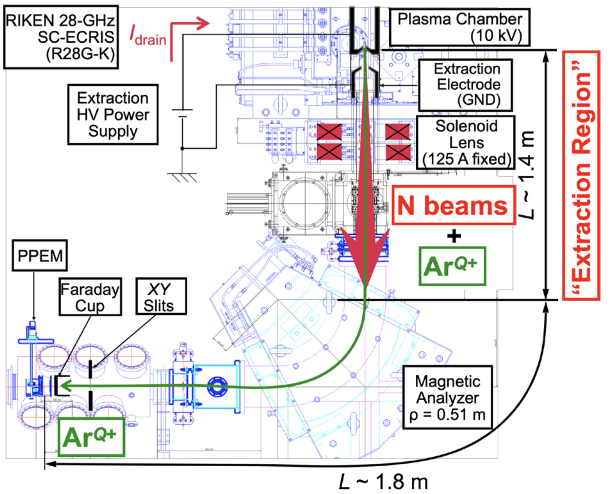

Fig. 1. Schematic of the experimental setup. The transverse PSD of an analyzed Ar beam was measured by a PPEM at the diagnostics chamber.

The N- and Ar-ion beams were extracted from the ECR plasma generated with a large amount of N_2 gas and a small amount of Ar gas at the extraction voltage of 10 kV. The intense N beams were primary source of the SCE at the "extraction region." The drain current of the extraction high voltage power supply I_{drain}, as shown in Fig. 1, was proportional to the total current of N beams. The I_{drain} was controlled from 1.5 mA to 6.0 mA by changing the amount of N_2 gas and the power of 28 GHz microwave. The ϵ_{4D} of Ar beams, which were exposed to the SCEs due to the high-intensity N beams, was measured after magnetic analysis using the pepper-pot emittance meter (PPEM)[5)] in Fig. 1. Because we suppressed each Ar beam current below 50 μA, the expansion in the transverse phase-space distribution (PSD) due to the SCEs after the "extraction region" could be sufficiently reduced. The emittance growth owing to the aberration of the magnetic analyzer was eliminated by the 3D backtracking with a realistic magnetic field distribution computed in OPERA 3D, thereby successfully reconstructing the PSD at the end of "extraction region."

The ϵ_{4D} of ^{40}Ar beams with charge states of 10, 11, 13, and 16+ at the end of "extraction region" were obtained as shown in Fig. 2, where the emittances were normalized by multiplication of relativistic $\beta^2\gamma^2$. The figure shows that the emittance increases as the drain current increases. Surprisingly, the emittance growth is more pronounced for ^{40}Ar ions with smaller charge Q. Further experimental measurements and analysis, including detailed beam trajectory simulations, are underway to elucidate the charge-state dependent mechanism of emittance growth.

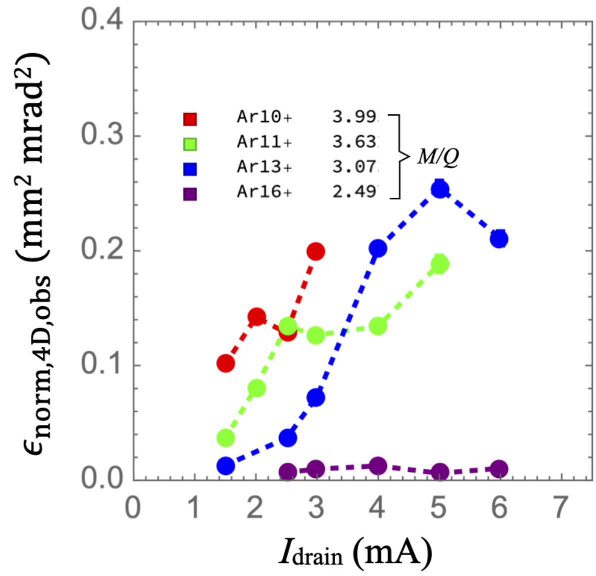

Fig. 2. Normalized 4D rms emittances of Ar beams with charge states of 10, 11, 13, and 16+.

References
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