4 - 3 Explanation for the Observed Wide Deceleration Range on a Coasting Ion Beam by a CW Laser at the CSRe*

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A significant deceleration effect on a stored coasting ion beam by a continuous-wave (CW) laser light was observed during the laser cooling experiments with lithium-like oxygen ion beams stored at a relativistic energy of 275.7 MeV/u at the CSRe. The observed deceleration range of the laser ($\delta p/p \approx 5.7\times10^{-6}$) is much broader than the calculated capture range ($\delta p/p \approx 3.6\times10^{-8}$). A phase space tracking code has been developed to explain this huge deviation. Simulations reveal that the deceleration range of the typically narrow CW laser force is highly enlarged by taking into account the transverse betatron oscillation of the ions with larger emittance and the angular misalignment of the laser light direction. Figure 1 shows the simulated ion distributions, Schottky-noise spectra, and transverse envelopes of coasting ion beams with different emittance after interaction with a counter-propagating laser light. As the emittance increase, the maximum ion angle and the transverse envelope grows significantly. Consequently, it enables more ions to be resonant with the purple solid resonance line, which leads to an increasingly broader deceleration range by the laser in the associated Schottky-noise spectrum. The experimental observation is well described by the systematic simulations. For detailed simulations and discussions, please refer to the published paper[1]. The present work is crucial for forthcoming laser cooling and precision laser spectroscopy experiments and simulations on heavy highly charged ions at the CSRe and the future facility HIAF.

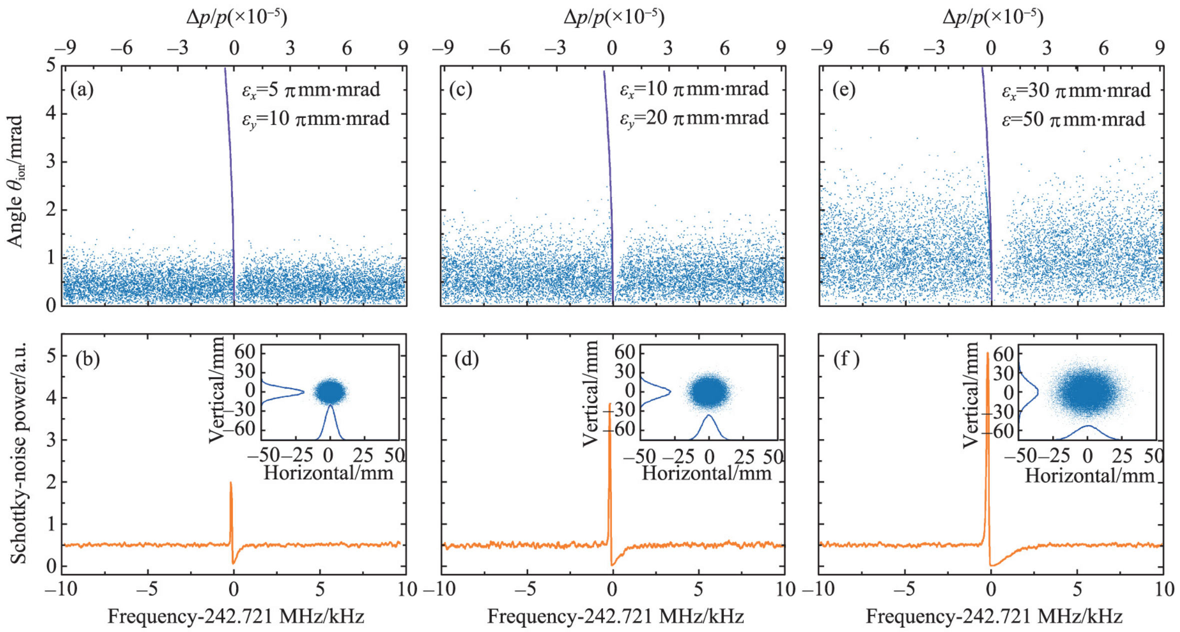

Fig. 1 (color online) (a) Ions distribution and (b) Schottky-noise spectrum of coasting ion beam with an emittance of $\varepsilon_x = 5$ πmm·mrad and $\varepsilon_y = 10$ πmm·mrad after interaction with a counter-propagating laser without angular misalignment, and the inset shows the transverse envelope of the ion beam, (c) and (d) for an emittance of $\varepsilon_x = 10$ πmm·mrad and $\varepsilon_y = 20$ πmm·mrad, (e) and (f) for an emittance of $\varepsilon_x = 30$ πmm·mrad and $\varepsilon_y = 50$ πmm·mrad.

Reference

[1] D. Y. Chen, H. B. Wang, W. Q. Wen, et al, Nucl. Instrum. Meth. A, 1047(2023)167852.

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