Anomalous Longitudinal Schottky Signals of Coasting Ion Beams with Interaction of a CW Laser at Storage Ring CSRe

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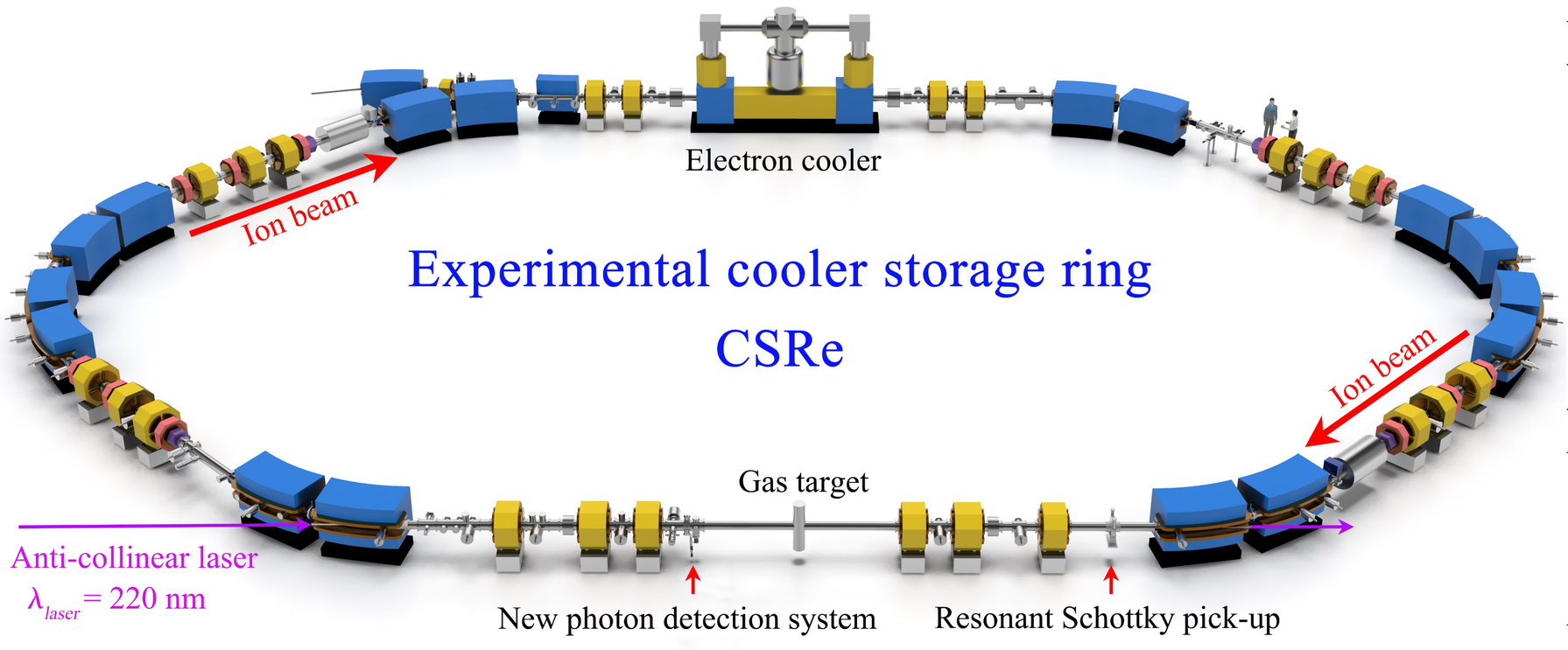
Laser Cooling of heavy ion beams at Storage Rings

The cooling of stored heavy ion beams to high phase space densities is of general importance when low momentum spread is required for precision spectroscopy or high luminosity for collision experiments. Laser cooling is the most promising cooling scheme to achieve phase transition and obtain ordering beam or even crystalline beam of relativistic ion beam at storage rings.

Recently, laser cooling of lithium-like $^{16}O^{5+}$ ion beams with a relativistic energy of 275.7 MeV/u has been realized at the storage ring CSRe at the Institute of Modern Physics (IMP) in China, and the mechanism of the coasting ion beam-laser interaction was investigated.

Laser Cooling at Storage Ring CSRe



CSRe parameters	
Circumference	128.80 m
Ion species	$^{16}O^{5+}$
Beam energy E	275.7 MeV/u
Relativistic β, γ	0.636, 1.296
Revolution frequency	1.48 MHz
Beam lifetime	~35 s
Transition $2s_{1/2} - 2p_{1/2}$	103.76 nm
Transition lifetime τ	2.44 ns
CW laser system	
Laser wavelength	220 nm
Laser power	40 mW
Linewidth	10 MHz
Scanning range	20 GHz

Fig.1. Schematic view of the cooler storage ring CSRe and the main parameter settings for laser cooling experiment of $^{16}O^{5+}$ ion beams.

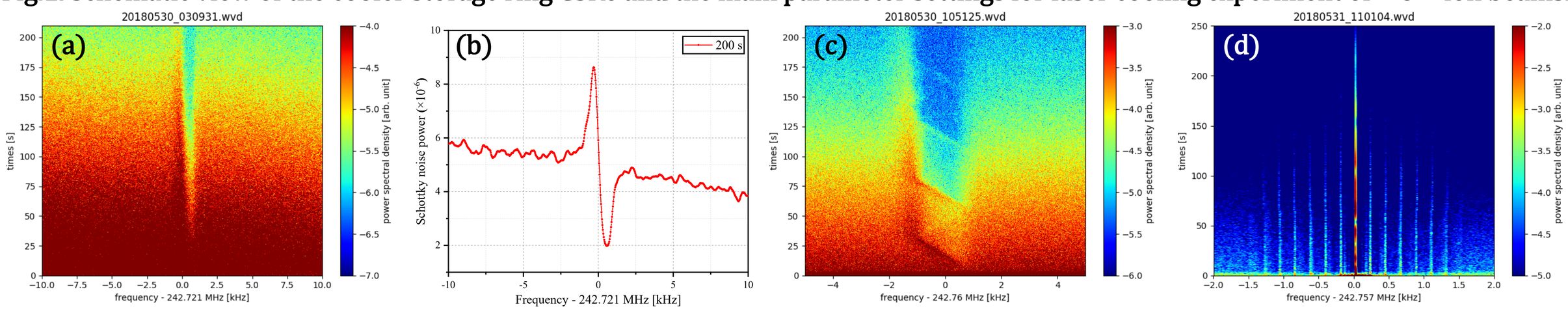


Fig.2. Experimental results: (a) coasting ion beam interaction with fixed laser; (b) 200s of (a); (c) coasting ion beam interaction with scanned laser; (d) laser cooling of bunched ion beams.

The experimental laser-force capture range (~ 762.9 Hz, $\delta p/p \sim 7 \times 10^{-6}$) in Fig.2(b) is much wider than the calculated width based on the linewidth of the cw laser and ion transition (~ 9.5 Hz) !!!

Coasting ion beam interaction with laser under transverse oscillation (preliminary results)

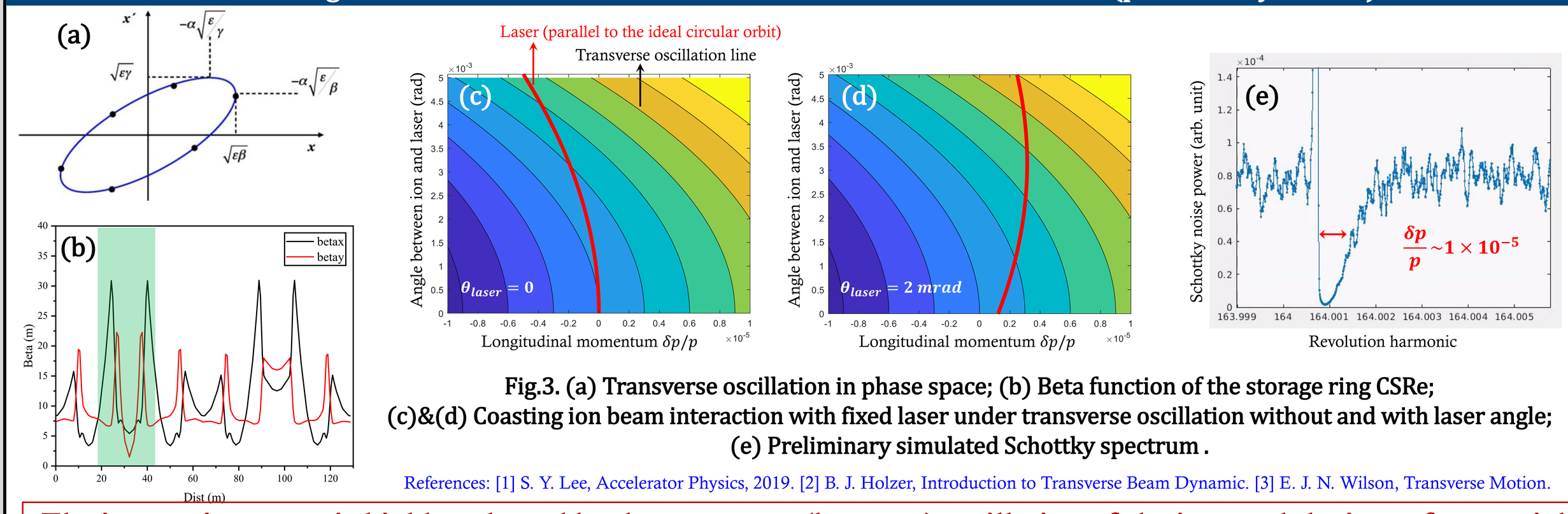


Fig.3. (a) Transverse oscillation in phase space; (b) Beta function of the storage ring CSRe; (c)&(d) Coasting ion beam interaction with fixed laser under transverse oscillation without and with laser angle; (e) Preliminary simulated Schottky spectrum .

References: [1] S. Y. Lee, Accelerator Physics, 2019. [2] B. J. Holzer, Introduction to Transverse Beam Dynamic. [3] E. J. N. Wilson, Transverse Motion.

The interaction range is highly enlarged by the transverse (betatron) oscillation of the ions and the imperfect spatial overlap of the laser light and the ion beam!!! And more detailed simulations are in progress…