COUNTERDIABATIC VORTEX PUMP IN SPINOR BOSE–EINSTEIN CONDENSATES

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Topological phase imprinting is a well-established technique for deterministic vortex creation in spinor Bose–Einstein condensates of alkali-metal atoms. It was recently shown that counterdiabatic quantum control may accelerate vortex creation in comparison to the standard adiabatic protocol and suppress the atom loss due to nonadiabatic transitions [1]. Here we apply this technique, assisted by an optical plug, for vortex pumping to theoretically show that sequential phase imprinting generates a vortex with a very large winding number [2].

Our method significantly increases the fidelity of the pump for rapid pumping compared to the case without the counterdiabatic control, leading to the highest angular momentum per particle reported to date for the vortex pump. Our studies are based on numerical integration of the three-dimensional multicomponent Gross–Pitaevskii equation, which conveniently yields the density profiles, phase profiles, angular momentum, and other physically important quantities of the spin-1 system.

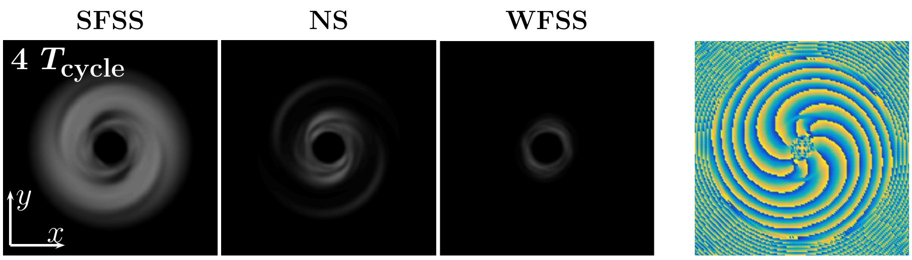

Figure 1: Particle densities of the strong-field-seeking state, neutral state, and weak-field-seeking state integrated along the z-axis after the fourth vortex pumping cycle. The field of view in each panel is 30×30 μm^2 and the maximum particle density is $\tilde{n}_\text{p} = 1.52 \times 10^{11}$ cm^{-2}. The rightmost column shows the phase of strong-field-seeking state in the $z = 0$ plane.

[1] S. Masuda, U. Güngördü, X. Chen, T. Ohmi, and M. Nakahara, Phys. Rev. A **93**, 013626 (2016).

[2] T. Ollikainen, S. Masuda, M. Möttönen, and M. Nakahara, Phys. Rev. A **95**, 013615 (2017).