Atom chip based generation of entanglement for quantum metrology

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Abstract

Entanglement-based technologies, such as quantum information processing, quantum simulations, and quantum metrology, have the potential to revolutionize our way of computing and measuring, and help clarify the puzzling concept of entanglement itself. Ultracold atoms on atom chips are attractive for their implementation, as they provide control over quantum systems in compact, robust, and scalable setups.

In this talk we report experiments where we generate multi-particle entanglement on an atom chip by controlling elastic collisional interactions with a state-dependent potential [1, 2]. We employ this technique to generate spin-squeezed states of a two-component Bose-Einstein condensate that are a useful resource for interferometry beyond the standard quantum limit. The observed -3.7 ± 0.4 dB reduction in spin noise combined with the spin coherence imply four-partite entanglement between the condensate atoms and could be used to improve an interferometric measurement by -2.5 ± 0.6 dB over the standard quantum limit. Our data show good agreement with a dynamical multi-mode simulation [3] and allow us to reconstruct the Wigner function of the spin-squeezed condensate. The techniques demonstrated here could be directly applied in chip-based atomic clocks which are currently being set up.

Keywords: ultracold atoms, atom chips, entanglement, spin squeezing, quantum metrology

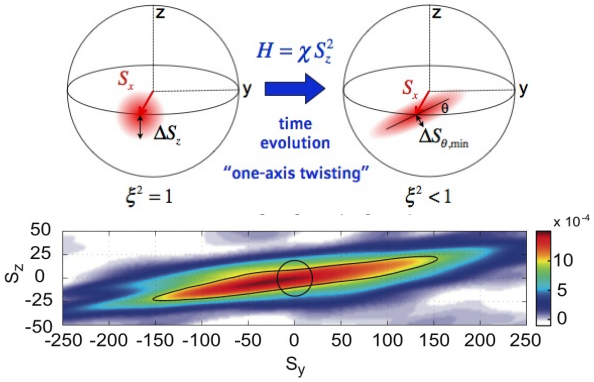

Figure 1: Spin-squeezing in a Bose-Einstein condensate on an atom chip. Upper graph: spin-squeezing through time evolution with the nonlinear one-axis twisting Hamiltonian. Lower panel: Wigner function of the spin-squeezed state reconstructed from our experimental data. The squeezed and anti-squeezed quadratures are clearly visible by comparing with the uncertainty circle of a coherent spin state.

References

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