Spin-squeezed states with ultracold fermions

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Generation, storage, and utilisation of correlated many-body quantum states are crucial objectives of future quantum technologies and metrology. Such states can be generated by the spin-squeezing protocols. In this work [1], we consider the dynamical generation of spin squeezing in a lattice system composed of ultra-cold fermionic atoms in the Mott phase at half-filling. To induce the generation of squeezing, we add the position-dependent laser coupling between the internal degrees of freedom of atoms (Fig. 1). We study the Ramsey-type spectroscopy scheme in which the atom-light coupling is turned on during the interrogation time, as illustrated in Fig. 2. By choosing an appropriate propagation direction of the laser beam inducing the SOC and acting on a fermionic lattice with a sequence of such laser pulses we expect to realise efficient spin-squeezing. We show analytically, using the perturbation theory, how the Fermi-Hubbard model with the atom-light coupling effectively simulates the one-axis twisting model with the tunable axis of squeezing. This paves the way for the simulation of the famous two-axis counter-twisting model when two laser couplings are used during interrogation time. The presented method might deliver gains in real applications like optical clocks.

References

[1] T. Hernandez Yanes *et al.*, Phys. Rev. Lett. 129, 090403 (2022).

Figures

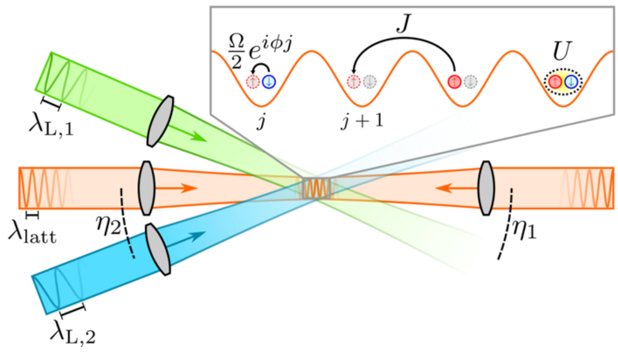

Figure 1: Fermi-Hubbard model for atoms in optical lattices with nearest-neighbour tunnelling rate *J*, on-site interaction *U* and additional coupling between atomic internal degrees of freedom with position-dependent strength $\Omega e^{i\varphi j}$ realised with one or two off-resonant laser beams.

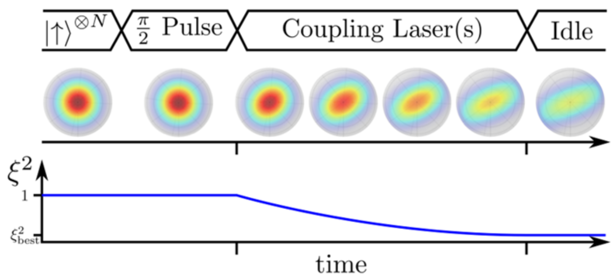

Figure 2: The Ramsey-type spectroscopy for the generation of Mott-squeezed states: (i) preparation of the initial spin coherent state with ultra-cold fermions in the Mott phase, (ii) unitary evolution using the Fermi-Hubbard Hamiltonian with the atom-light coupling reduces the value of the spin squeezing parameter, (iii) freezing the spin squeezed state in the Mott phase when the atom-light coupling is turned off.