Engineering Persistent and Entangled Current States in Dipolar Atomtronic Circuits

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The field of atomtronics has emerged as a promising platform for developing quantum devices by utilizing the coherent flow of neutral atoms in ring-shaped condensates [1]. A central challenge in these technologies is the efficient and robust preparation of persistent currents. This presentation details two complementary approaches for controlling ultracold dipolar bosons within atomtronic circuits, leveraging the anisotropic and tunable nature of the dipole-dipole interaction.
First, we propose a magnetostirring protocol designed for a three-well ring circuit [2]. We dynamically modulate the orientation of an external magnetic field in a spherical spiral motion to induce high average circulation. We demonstrate that this protocol is robust against variations in on-site interaction strengths and remains effective as the number of bosons increases, offering a scalable method for creating persistent currents.
Second, we extend this control framework using Quantum Optimal Control theory [3], to engineer selected states with entangled circulation in larger lattice rings [4]. We identify the fundamental symmetry constraints that limit the reachability of certain states and define the theoretical upper bounds for fidelity. Furthermore, we analyze the impact of experimental regimes, such as the hard-core boson limit [5], on the preparation of NOON and W states.
Together, these results establish dipolar orientation manipulation as a powerful tool for high-fidelity state engineering in quantum technologies.

References

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Figures

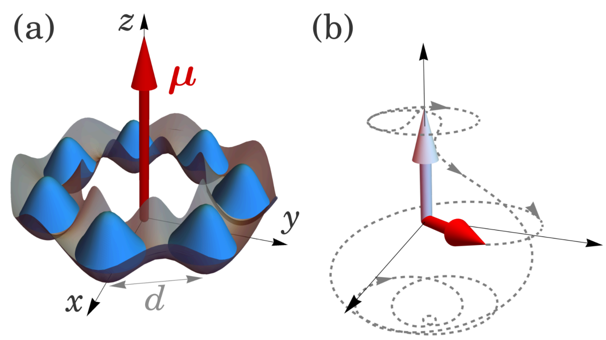

Figure 1: (a) Schematic representation of a lattice ring with dipole polarization along the z-axis. (b)Example trajectory during a protocol.