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(G*) (POS-9) Demonstrating Novel Quantum Control With Ultracold Atoms

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Ultracold neutral atoms are an excellent test-bed for novel quantum control techniques due to their stability, and efficient coupling to fields in the radio, microwave, and optical regimes. Various control protocols which could be used in quantum information processing (QIP) may first be investigated in ultracold atoms to prove their efficacy before being generalized to other more established systems. In this spirit we present two different novel control protocols. First we demonstrate holonomic single-qubit gates, which are conventionally performed via the adiabatic evolution of a degenerate manifold of states through a path in parameter space; this yields a non-Abelian geometric phase which couples the states in a way that depends only on the path taken. In this study, we eliminate the explicit need for degeneracy through Floquet engineering, where the atomic spin Hamiltonian is periodically modulated in time. We characterize the non-Abelian character of the geometric phase through a gauge-invariant parameter, the Wilson loop. Next, we demonstrate a decomposition of SU(3) including a resonant dual-tone operator which synthesizes coupling between two disconnected qutrit levels. For many conventional systems where the third coupling is not possible this technique provides a potential workaround. A decomposition of SU(3) using this operator is tested against conventional methods by performing a Walsh-Hadamard gate and performing maximum likelihood tomography on the resulting states. In both protocols we demonstrate novel methods for precision quantum control essential in advancing QIP techniques which can be readily adapted to trapped ions, superconducting qubits, and other quantum computing platforms.

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