Pythagorean Coupling in a Four-Level Josephson Phase Circuit

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Multi-level qudits are advantageous for a number of applications of quantum information science, but introduce complex dynamics which must be understood and controlled. The recently proposed theory of Pythagorean coupling uses the well-known isomorphism between the SO(4) group and the SU(2)xSU(2) product group to map the dynamics of a four-level system onto a pair of uncoupled two-level qubits, uncovering a method of transferring population between non-adjacent qudit states with a single continuous excitation. We demonstrate the first experimental implementation of this coupling scheme with a Josephson phase circuit. Deviations from theory are shown to be a result of the finite anharmonicity of a physical qudit, which causes the dynamics to "leak" from SO(4) to SU(4). This appears in the SU(2)xSU(2) picture as oscillations in the bipartite entanglement entropy of the qubit pair.