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Mach-Zehnder Interferometry and Microwave-Induced Cooling in Persistent-Current Qubits

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Superconducting persistent-current qubits are quantum-coherent artificial atoms with multiple energy levels. In the presence of large-amplitude harmonic excitation, the qubit state can be driven through one or more of the energy-level avoided crossings. The resulting Landau-Zener transitions mediate a rich array of quantum-coherent phenomena as a function of the driving amplitude and frequency. In this talk, we present three such demonstrations of quantum coherence in a strongly-driven niobium persistent-current qubit. The first is Mach-Zehnder-type interferometry [1], for which we observe quantum interference fringes for 1-50 photon transitions. The second is a new operating regime exhibiting coherent quasi-classical dynamics [2], for which the MZ quantum interference persists even for driving frequencies smaller than the resonance linewidth. The third is microwave-induced cooling [3], for which we achieve effective qubit temperatures ¡ 3 mK, a factor 10x-100x lower than the dilution refrigerator ambient temperature. These experiments exhibit a remarkable agreement with theory, and are extensible to other solid-state qubit modalities. In addition to our interest in these techniques for fundamental studies of quantum coherence in strongly-driven solid-state systems, we anticipate they will find application to nonadiabatic qubit control and state-preparation methods for quantum information science and technology. [1] W.D. Oliver, Y. Yu, J.C. Lee, et al., Science 310, 1653 (2005). [2] D.M. Berns, W.D. Oliver, S.O. Valenzuela et al., PRL 97, 150502 (2006). [3] S.O. Valenzuela, W.D. Oliver, D.M. Berns, et al., Science (2006).