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Quantum Control of Two-Qubit Gates via Dynamical Decoupling Filtering of 1/f Noise

E. PALADINO, A. D'Arrigo, G. Falci

Dipartimento di Fisica e Astronomia
Università degli Studi di Catania, Catania, Italy

Abstract:

Achieving high-fidelity universal two-qubit gates is a central requisite of any implementation of quantum information processing. In solid-state nanocircuits, noise with 1/f power spectrum represents a severe obstacle towards this goal [1]. For single-qubit gates considerable improvement has been achieved by operating at optimal points and further enhancement has been obtained by open-loop dynamical decoupling. However, protection of qubit coherence during a multi-qubit gate poses non-trivial additional problems. In fact decoupling may disrupt the inter-qubit dynamics thus conflicting with gate operation. Here we present the integration of dynamical decoupling into a universal two-qubit gate in the presence of 1/f noise acting locally on each of the qubits forming the entangling gate. We address both the case of pure dephasing and of depolarizing noise and investigate the gate efficiency under periodic, Carr-Purcell, and Uhrig dynamical decoupling sequences.

Our analysis is based on the exact numerical evaluation of gate operation for 1/f noise measured in superconducting qubits and on perturbative (Magnus) expansion for quasi-static noise. For transverse noise we find that a threshold value of the number of pulses exists above which the gate error is reduced as n^{α} with α depending on the

dynamical decoupling sequence. For smaller pulse numbers, dynamical decoupling may even increase the error with respect to the unconditioned evolution, a behavior reminiscent of the anti-Zeno effect. For pure dephasing noise we find an analytic expression of entanglement fidelity in terms of noise filter functions allowing to single out the sequence-specific capability to bypass cumulants of the underlying non Gaussian processes. The possibility to reach the accuracy threshold for fault- tolerant quantum information processing with solid-state devices by quantum gates with integrated decoupling is critically discussed.

[1] E. Paladino, Y. Galperin, G. Falci, and B. Altshuler, Rev. Mod. Phys. 86, 361 (2014).