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Qubit Dynamics in Noisy Environments: T1 Relaxation, T2 Dephasing, and Coherence Refocusing

The preservation of quantum information in real devices is strongly limited by the interaction of qubits with their environment, leading to energy relaxation and loss of phase coherence. This work aims to investigate how relaxation, characterized by T1, and dephasing induced by low-frequency noise affect qubit coherence, and to evaluate the extent to which refocusing pulses can mitigate these effects. Computational simulations were performed in Python using Qiskit, implementing noise models for energy loss (amplitude damping), phase decoherence (phase damping), and thermal relaxation, with parameters fixed at T1 = 50 μs and T2 = 30 μs. The analysis shows that low-frequency noise accelerates the loss of contrast during free evolution; however, techniques such as Spin Echo and CPMG dynamical decoupling partially suppress quasi-static phase errors and generate coherence echoes associated with reversible dephasing. From the simulated data, T1 = 49.69 μs and an effective transverse coherence time of T2 = 29.77 μs were extracted, in close agreement with the configured values of 50 μs and 30 μs, respectively. After applying the Hahn Spin Echo sequence, the effective coherence time increased to 30.18 ± 1.12 μs.

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