Probing Decoherence with Electromagnetically Induced Transparency in Superconductive Quantum Circuits

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Superconductive quantum circuits (SQCs), comprising mesoscopic Josephson junctions, quantized flux, and/or charge states, are analogous to the quantized internal levels of an atom [1]. This SQC-atom analogy can be extended to the quantum optical effects associated with atoms, such as electromagnetically induced transparency (EIT) [2].

The three-level Λ-system for our S-EIT system (Figure 1a) is a standard energy level structure utilized in atomic EIT. It comprises two meta-stable states |1⟩ and |2⟩, each of which may be coupled to a third excited state |3⟩. In an atomic EIT scheme, a strong "control" laser couples the |2⟩→|3⟩ transition, and a weak resonant "probe" laser couples the |1⟩→|3⟩ transition. By itself, the probe laser light is readily absorbed by the atoms and thus the transmittance of the laser light through the atoms is very low. However, when the control and probe laser are applied simultaneously, destructive quantum interference between the atomic states involved in the two driven transitions causes the atom to become "transparent" to both the probe and control laser light [2,3,4]. Thus, the light passes through the atoms with virtually no absorption. In this work we propose to use EIT in SQCs to sensitively probe decoherence.

The SQC (Figure 1b) can be biased to result in an asymmetric double well potential as shown in Figure 2. The three states in the left well constitute the superconductive analog to the atomic Λ-system [5]. States |1⟩ and |2⟩ are "meta-stable" qubit states, with a tunneling and coherence time much longer than the excited "readout" state |3⟩. State |3⟩ has a strong inter-well transition when tuned on-resonance to state |4⟩. Thus, a particle reaching state |3⟩ will tend to tunnel quickly to state |4⟩, causing the circulating current to switch to the other direction, an event that is detected with a SQUID. Knowing how long the SQC remains transparent (i.e., does not reach state |3⟩) in the S-EIT experiment provides an estimate for decoherence time.

Figure 1: (a) Energy level diagram of a three-level Λ system. EIT can occur in atoms possessing two long-lived states |1⟩, |2⟩, each of which is coupled via resonant laser light fields to a radiatively decaying state |3⟩. (b) Circuit schematic of the persistent–current qubit and its readout SQUID.

Figure 2: One-dimensional double-well potential and energy-level diagram for a three-level SQC.

REFERENCES: