Modelling non-Markovian noise in driven superconducting qubits

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Abstract

In superconducting qubit quantum computers available today, interactions between qubits and two-level system (TLS) defects in the device are known to be a significant source of noise [1,2]. Coherent qubit-defect interaction can manifest itself as non-Markovian noise in the dynamics of the qubit subsystem. Existing methods to identify such effects involve low-level noise spectroscopy experiments [2,3]. We develop a method based on repeated mirrored pseudo-identity gates to characterise resonant qubit-TLS interactions and include them in a noise model to describe the effects of the TLS defects on the quantum circuits. We run experiments on superconducting quantum computers and find that our method is well suited to characterize such interactions, and that their presence is an important source of noise. Including the non-Markovian components within our noise model allows us to significantly improve the accuracy of the predictions of the noise model when compared to experiments.

References

[1] Burnett, Jonathan, et al.,Nature communications 5.1 (2014): 4119.
[2] Müller, Clemens, Jared H. Cole, and Jürgen Lisenfeld, Reports on Progress in Physics 82.12 (2019): 124501.
[3] Cole, Jared H., et al., Applied Physics Letters 97.25 (2010): 252501.

Figures

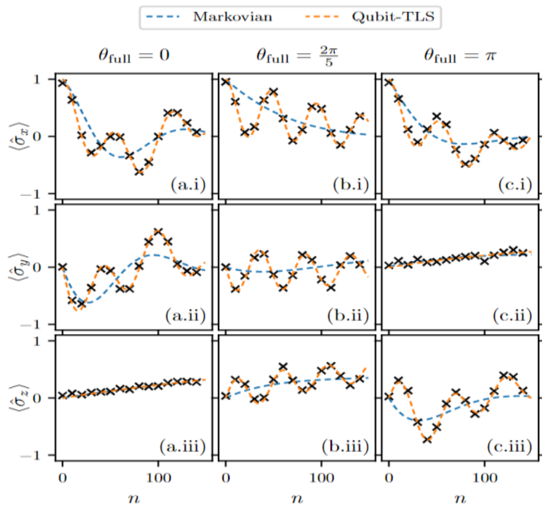

Figure 1: Expectation values of the qubit in different measurement basis plotted against the number of applied pseudo-identities n. The columns correspond to different mirrored-pseudoidentities. The model including the qubit-TLS interaction (orange line) can be seen to fit the experimental data (black crosses) much better than the Markovian model (blue line).

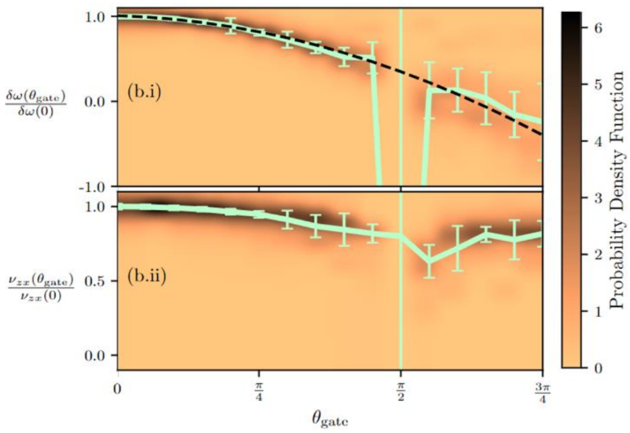

Figure 2: The ratio of the noise model parameters for the driven vs undriven qubit plotted against the amplitude of the applied pulse. The phase error $\delta\omega$ can be seen to change quadratically, while the qubit-TLS interaction strength ν_{zx} changes non-monotonically.