Parsing Spurious Transitions in Driven Superconducting Circuits

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Parametrically driven superconducting circuits often experience deleterious state transitions that degrade the speed and fidelity of quantum operations, posing a significant challenge for applications such as quantum error correction. These transitions, which lead to leakage outside the computational subspace, have been theoretically [1,2] and experimentally [3,4] linked to multi-quanta resonances in the Josephson potential. Recent work suggests that Floquet steady-state simulations of driven transmons provide an efficient means to identify these transitions[5]. A key question for the experimentalists remains: Can we predict all such transitions in advance and mitigate them in the circuit design?

In this talk, we experimentally examine the correspondence between observed spurious transitions in a fixed frequency transmon and theoretical predictions based on Floquet simulations of the lumped element circuit. By analyzing transitions across a broad drive-frequency range spanning over 9 GHz, we elucidate their underlying mechanisms. Our results reveal that these transitions can involve additional geometric modes of the system as well as degrees of freedom associated with material defects, as illustrated in Fig. 1. These findings highlight the pervasive impact of spurious modes and defects, both within and beyond the relevant frequency band. Finally, we provide practical design guidelines for mitigating these unwanted transitions in superconducting circuits.

References

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[2] Shillito et al, Phys. Rev. Applied 18, 034031 (2022)
[3] Sank et al., Phys. Rev. Lett. 117, 190503 (2016)
[4] Khezri et al, Phys. Rev. Applied 20, 054008 (3023)
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Figures

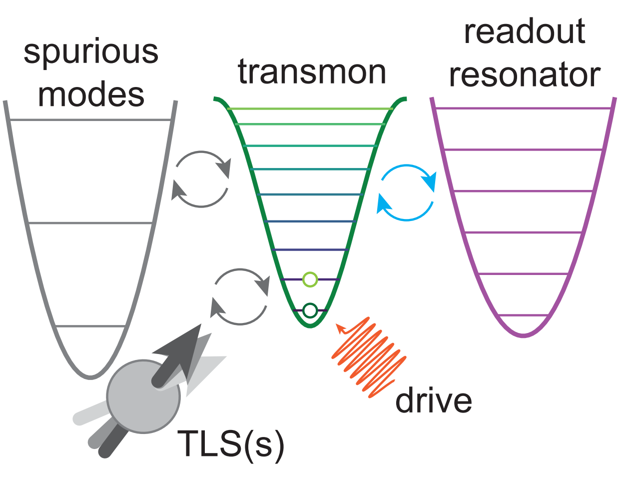

Figure 1: Driven superconducting circuits undergo undesired state transition when the drive strength exceeds certain threshold, limiting the speed and fidelity of these operations. Typically, these transitions arise due to multi-quanta resonances within the transmon potential (green). But they can also involve external degrees of freedom such as the geometric modes of the package and material defects (TLS).