

# A gate-tunable transmon in the ultrastrong coupling regime

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References

- [1] T. W. Larsen et al., *Phys. Rev. Lett.* **115**, 127001 (2015).
- [2] G. de Lange et al., *Phys. Rev. Lett.* **115**, 127002 (2015).
- [3] I. Casal Iglesias et al., *in preparation*.

We implement a gate-tunable transmon (gatemon) qubit [1,2] based on an InAs nanowire Josephson junction and identify distinct features in its microwave spectra that provide clear evidence of ultrastrong light–matter hybridization with a probing resonator. These signatures include deviations of the measured anticrossing from the predictions of the Jaynes–Cummings model, as well as unequally spaced qubit frequency shifts observed at different resonator photon occupancies. We interpret these observations using extended theoretical models that incorporate both counter-rotating interaction terms and the multilevel, non-conventionally anharmonic structure of the gatemon. Finally, we characterize the qubit coherence properties and find coherence times comparable to those of gatemon devices operating outside the ultrastrong coupling regime [3].