Observation of light-dressing effects in a superconducting artificial molecule

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Since their demonstration, superconducting artificial atoms have been extensively used for studies in quantum optics [1]. Their particular advantages compared to natural systems are strong coupling to radiation and high level of control over their state [2, 3]; these properties open the way to previously unexplored physics.

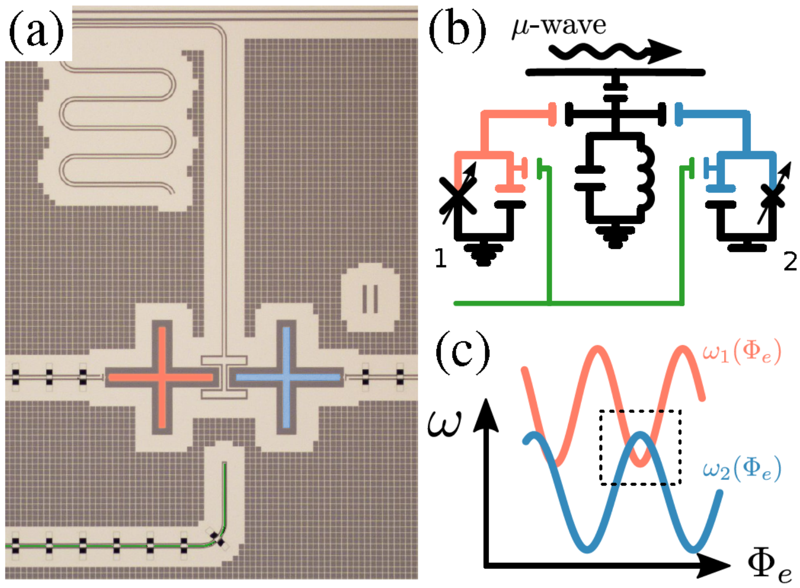

Figure 1: (a) Optical photograph of the device (false coloured). Two transmons (orange, first and blue, second) are coupled capacitively to a $\lambda/4$ coplanar resonator and a microwave excitation antenna. (b) The equivalent electrical circuit. (c) Frequencies of the ge transitions of the transmons $\omega_1(\Phi_e)$ and $\omega_2(\Phi_e)$.

In this work, we irradiate a superconducting artificial molecule composed of two flux-tunable X-mons [4] with intense light while monitoring its state via joint dispersive readout [5]. We find that at certain flux points, the molecule demonstrates spectral features deviating qualitatively from the stationary solution. Reproduced accurately by numerical simulations, these deviations turn out to be a consequence of an Autler-Townes-like effect when a single tone is simultaneously dressing the system and probing the transitions between new eigenstates. We find a good agreement with self-consistent models accounting for both these processes at the same time. We note that this study is important for understanding the behaviour of more complex artificial systems interacting with strong radiation.

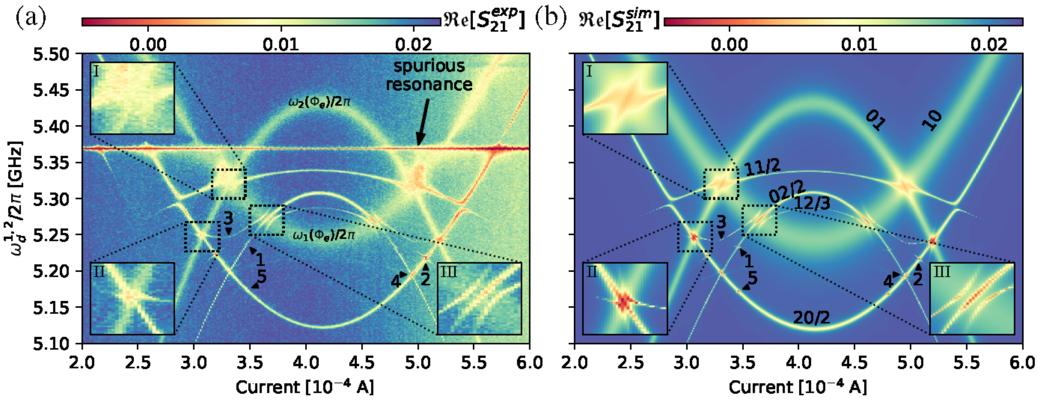

Figure 2: Two-tone spectroscopy of the molecule: experiment (a) and numerical modelling (b). Colour shows the real part of complex transmission through the sample. Two transmons are aligned as in fig. 1 (c) and form a symmetric picture. Features I, II and III are a caused by two-atom Autler-Townes-like processes.

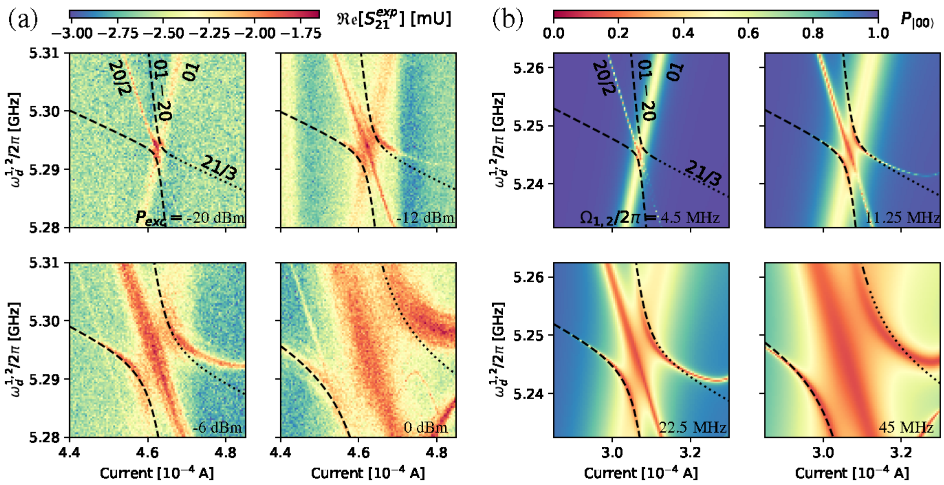

Figure 3: Power dependence of feature II: experiment (a) and simulation (b). Dashed are the model curves turning to dotted when the model is not expected to be valid; model values for 2 are the same for both (a) and (b): $\Omega_2/2\pi = 4.5, 11.25, 22.5$ and $45\,\mathrm{MHz}$.

References

[1] *You J.Q., Nori Franco.* Atomic physics and quantum optics using superconducting circuits // Nature. **474**, 7353, P. 589, (2011).

[2] *Andreas Wallraff, David I. Schuster, Alexandre Blais et al.* Strong coupling of a single photon to a superconducting qubit using circuit quantum electrodynamics // Nature, **431**, 7005, P. 162, (2004).

[3] *P. Forn-Díaz, L. Lamata, E. Rico et al.* Ultrastrong coupling regimes of light-matter interaction // Reviews of Modern Physics. **91**, 2, P. 025005, (2019).

[4] *Rami Barends, Julian Kelly, Anthony Megrant et al.* Coherent Josephson qubit suitable for scalable quantum integrated circuits // Physical review letters, **111**, 8, P. 080502, (2013).

[5] *JM Chow, L DiCarlo, JM Gambetta et al.* Detecting highly entangled states with a joint qubit readout // Physical Review A, **81**, 6, P. 062325, (2010).