Towards resonant coupling between a RF superconducting qubit and a mechanical resonator

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Nowadays, the state-of-the-art chip-scale mechanical resonators can achieve lifetimes over 100 s and coherence times in the order of seconds in a thermal environment at 10 mK. [1]. The strong coupling between these outstanding mechanical resonators and the superconducting qubits, the most promising platform for scalable quantum computers, has been a long-pursued goal since it could open the door to novel quantum technology applications, like record-beating quantum memories or microwave-optical quantum transducers [2]. The main challenge to overcome is reducing the wide frequency difference between both quantum devices, typically 10^3. Inspired by recent works [3], our group had proposed a novel coupling scheme to finally turning the dream into a reality, nevertheless, for it to work out, we need a qubit that is resonant with the mechanical mode, in the MHz range, that is sufficiently insensitive to charge noise and that has strong capacitive matrix elements at the right frequency, all three at the same time. Is it possible? The answer is the so-called heavy fluxonium [4], which is a highly non-linear circuit made of a Josephson junction shunted by a large inductance and a large capacitance in the high-impedance regime. Recently, we had managed to design it and fabricate it in our lab achieving frequencies as low as 2 MHz with state-of-the-art coherence times for this qubit architecture [5].

References

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[2] R. W. Andrews, et al. Nat. Phys. 10, 321 (2014)
[3] J. J. Viennot, X. Ma, and K. W. Lehnert, Phys. Rev. Lett. 121 (2018) 183601
[4] V. E. Manucharyan, et al., Science 326 (2009) 113
[5] Helin Zhang, et al., Phys. Rev. X 11 (2021) 011010

Figures

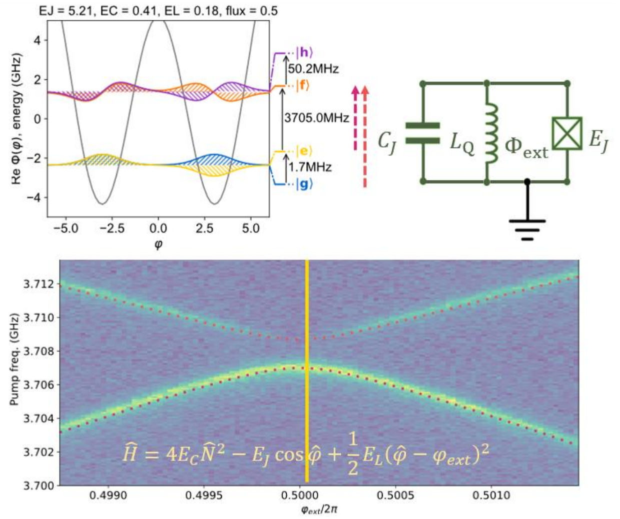

Figure 1: Grounded heavy fluxonium: potential energy and wave functions (top left), lumped-element simplified circuit (top right), and two-tone spectrum (bottom).

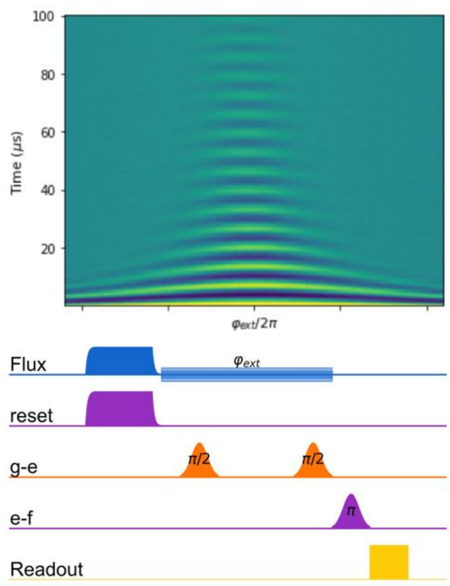

Figure 2: T2 Ramsey as function of bias flux (top) and protocol pulse sequence (bottom)