Recent Progress in Electron-on-Neon Qubits

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Electron-on-neon (eNe) qubits are emerging solid-state qubits. We previously demonstrated their strong coupling with microwave photons in a niobium (Nb) superconducting resonator and long-coherence high-fidelity single-qubit performance [1,2]. Here we report our recent progress toward two-qubit entanglement and in-depth investigation of charge decoherence. (Fig. 1.) With a superconducting resonator made of 30nm high-kinetic-inductance titanium nitride (TiN) films, we have improved the electron-photon coupling strength by 5 times into the 10-20 MHz range. The qubit coherence time has been extended to 120μs through dynamic decoupling (DD). These results pave the way toward strong-dispersive coupling between two eNe qubits for the realization of two-qubit gates. We further mapped the charge noise spectroscopy of eNe qubits via the DD technique. The measured charge noise on a single qubit biased away from its charge sweet spot shows a $1/f^{1.3}$ frequency dependence in the 10^4 – 10^6 Hz range. Its absolute charge noise spectral density is orders of magnitude smaller than some semiconductor qubits. Furthermore, temperature dependence of the qubit coherence up to 500mK indicates a decrease in the dephasing time T_ϕ dominated by thermal photons. The relaxation time T_1 shows a slower decay compared to superconducting transmon qubits that are limited by two-level-system (TLS) fluctuators in the junctions, suggesting that solid Ne provides a cleaner environment at elevated temperatures.

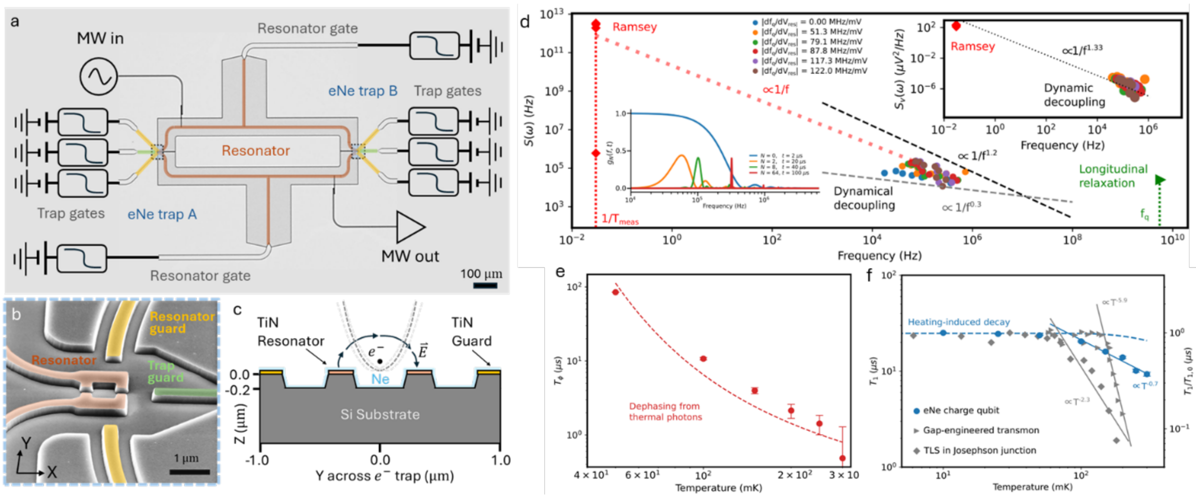

Fig 1. (a). TiN superconducting resonator for eNe qubit. (b) eNe trap. (c) Schematic of the eNe trap cross-section. (d) Noise spectroscopy of eNe qubit. (e) and (f) Temperature-dependent T_ϕ and T_1.

[1] X. Zhou, G. Koolstra, *et al.*, “Single electrons on solid neon as a solid-state qubit platform”, Nature 605, 46–50 (2022).
[2] X. Zhou, X. Li, *et al.*, “Electron charge qubits with 0.1 millisecond coherence time”, Nat. Phys. 20, 116–122 (2024).