Engineering a bosonic CZ gate between two superconducting cavities[1]

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Bosonic modes encoded in the infinite Hilbert space of microwave cavities offer a powerful route towards hardware-efficient and intrinsically error-correctable quantum information processing. Realizing this potential, however, requires the **deterministic creation of entangled states** through coherent photon-photon interactions.

Here, we present the latest experimental results towards engineering a **cross-Kerr interaction between two bosonic modes with high on-off ratio**, enabling a controlled-phase entangling operation between bosonic states encoded in rotationally symmetric codes. The interaction exploits the nonlinearity of an auxiliary two-level system via virtual processes, without populating its excited states. The resulting photon–photon coupling **preserves the bosonic code space and is protected against auxiliary qubit decoherence**, which typically limits gate performance.

By realizing a purely bosonic entangling gate that can also be exploited for **fault-tolerant detection of photon loss**, we advance error-correctable quantum information processing directly within the large Hilbert space of bosonic modes.

Figures

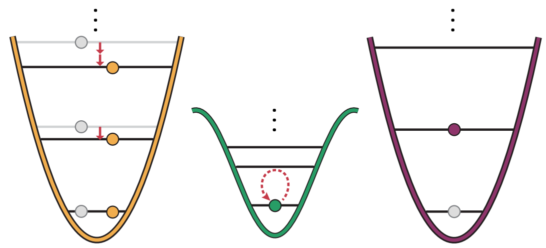

Figure 1: The engineered cross-Kerr interaction between control (purple) and target cavity (yellow) is mediated through virtual processes in the auxiliary transmon qubit (green).

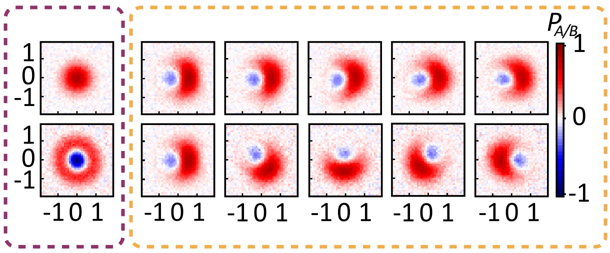

Figure 2: Wigner functions of the target cavity as a function of gate time with the control in vacuum (upper row) and Fock state 1 (lower row). We achieve a CZ gate in ~5us.

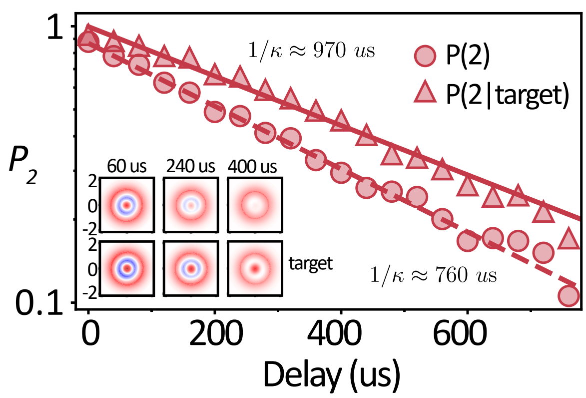

Figure 3: We can detect photon loss in the control cavity by reading out the state of the target cavity after the engineered interaction. This enhances the lifetime of the control cavity.

References

[1] Manuscript in preparation