Remote readout and arbitrary-phase gate between spatially separated superconducting nodes

Anatoly Kulikov[1,2]
Josua Schär[1,2], Aleksandr Grigorev[1,2], Guillermo F. Peñas[3], Juan José García-Ripoll[3], Andreas Wallraff[1,2]

[1]*ETH Zurich, Switzerland;* [2]*QC-ETHZ, Switzerland;* [3]*Instituto de Física Fundamental, IFF-CSIC, Spain*

akulikov@phys.ethz.ch

Establishing a complete set of primitive gates and operations is fundamental for distributed quantum computation and communication networks. One of the approaches to do so consists of employing superconducting circuits as a universal quantum node that is capable of storing and processing quantum information, and traveling microwave photons as means of communication.
In this work, we use a primitive two-node superconducting circuit QED network consisting of two dilution cryostats connected into a 30m-long cryogenic quantum link [1]. We perform a bidirectional photon transfer protocol, where a microwave photon emitted by Alice's communication qubit acquires a conditional phase based on the state of Bob's qubit [2]. We vary the communication photon frequency, hence tuning the conditional phase acquired during the reflection off the remote node, effectively implementing an arbitrary-phase CZ gate. Finally, we perform remote single-shot readout of a quantum bit in a network node located 30~m away, achieving single-shot readout fidelity exceeding 85%. An interesting feature of our scheme is that it does not require precise synchronization of the active node with the remote node; in particular, remote readout can be performed without any active participation by the remote node. These protocols add to the quantum communication toolbox with superconducting circuits [3] and provide a reliable way of realizing basic distributed quantum computing operations.

References

[1] S. Storz *et al*, Nature 617:265–270, 2023
[2] G. F. Peñas *et al*, Phys. Rev. Appl. 17, 054038 (2022)
[3] J. Grebel *et al*, Phys. Rev. Lett. 132, 047001 (2024)

Figures

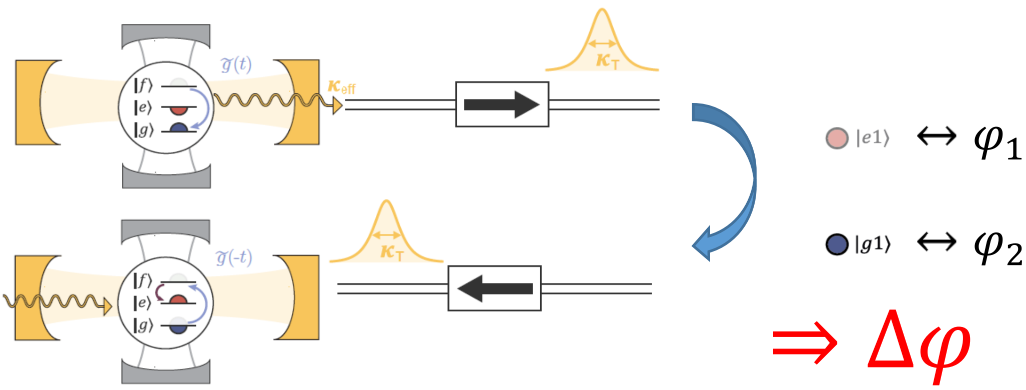

Figure 1: A schematic illustration of the bidirectional photon transfer implementing an entangling gate. A transmon qubit in node A (left) emits a symmetrically-shaped microwave photon (yellow) into the communication line using a parametrically-driven |f0>-|g1> transition. The photon gets reflected off the remote node and acquires a phase depending on the state of the remote qubit. When the photon travels back to the node A, we deterministically absorb it. Varying the photon frequency allows controlling the conditional phase Δφ acquired by the photon, and hence by the qubit in node A.