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Deterministic Quantum Teleportation with Feed-Forward in a Solid State System

ANDREAS WALLRAFF[1], ETH Zurich

Using modern micro and nano-fabrication techniques combined with superconducting materials we realize electronic circuits the dynamics of which are governed by the laws of quantum mechanics. Making use of the strong interaction of photons with superconducting quantum two-level systems realized in these circuits we investigate both fundamental quantum effects of light and applications in quantum information processing. In this talk I will discuss the deterministic teleportation of a quantum state in a macroscopic quantum system with near unit success probability at a rate of 10 kHz [1]. Teleportation is useful for distributing entanglement between distant qubits in a quantum network and for realizing universal and fault-tolerant quantum computation. Previously, we have demonstrated the implementation of a teleportation protocol up to the single-shot measurement step [2]. Now we have realized a new device in which four qubits are coupled pair-wise to three resonators. Making use of parametric amplifiers [3] coupled to the output of two of the resonators we are able to perform high-fidelity single-shot read-out. Based on a close to ideal Bell-measurement identifying all four Bell-states in a single joint two-qubit measurement we have implemented fast feed-forward to complete the teleportation process. In this setup we have demonstrated teleportation by individually post-selecting on any Bell-state, by deterministically and simultaneously distinguishing between all four Bell states, and by implementing the feed-forward step to have the protocol succeed with near unit probability [1]. In all instances, we demonstrate that the fidelity of the teleported states and the fidelity of the teleportation process are above the thresholds imposed by classical physics. The presented experiments are expected to contribute to the realization of quantum communication over small and medium scale distances with microwave photons in the foreseeable future.

[1] L. Steffen et al., Nature 500, 319 (2013).
[2] M. Baur et al., Phys. Rev. Lett. 108, 040502 (2012).
[3] C. Eichler et al., Phys. Rev. Lett. 107, 113601 (2011).

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