Photonic Quantum Networks

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1. Introduction

Hybrid light-matter networks offer the promise for delivering robust quantum information processing technologies, from sensor arrays to quantum simulators. New sources, detectors and memories illustrate progress towards build a resilient, scalable photonic quantum network.

2. General Instructions

Building complex quantum systems has the potential to reveal new phenomena that cannot be studied using classical simulation. Photonics has proven to be an effective means to engineer quantum systems of this kind, and for the investigation of such effects. The challenge is to build a quantum state of sufficient complexity, both in the number of photons and the number of modes. Hybrid light-matter quantum networks,[1] in which the channels use light as a communication medium and the nodes use matter for processing operations, have emerged as a particularly important class of architectures for constructing and utilizing such states. A quantum network, consisting of simple nodes with some quantum dynamics, interconnected by coherent channels, inherits the features of robustness and scalability from its classical network counterparts, but it also exhibits functionality that goes beyond what is possible with conventional technologies.[2]

In this paper, we describe experiments exploiting the quantum interference of three single photons on a reconfigurable integrated photonic chip. We develop multiple on-chip, low-loss sources of single photons and introduce a low-loss silica-on-silicon waveguide architecture that enables us to show the first genuine quantum interference of three single photons on an integrated platform.[3] We make use of this three-photon interference for the first proof-of-principle demonstration of a new intermediate model of quantum computation called boson sampling, and we perform an on-chip demonstration of the quantum teleportation protocol where all key parts — entanglement preparation, Bell-state analysis and quantum state tomography — are performed on a reconfigurable photonic chip.[4-6]

Further we demonstrate a new class of on-chip superconducting transition edge sensors detectors, fabricated on the surface of a guided mode, which achieve high efficiency and energy resolution. A new approach to the characterization and operation of such detectors to enable quantum experiments using more photons is also described.[7] The final element of photonic networks is a quantum memory for light. We have demonstrated a broadband, efficient, low-noise atomic ensemble memory that is capable of operation at ambient conditions, and which can store and retrieve single photons in arbitrary temporal modes. [8]

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