Stabilized Dissipative Single-photon Switch for Fiberized Quantum Networks

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Abstract We report on the first demonstration of a fully fiberized quantum network by using a fiber-integrated metamaterial as a dissipative switching element. Utilizing the coherent absorption phenomenon in plasmonic metamaterials we achieve high-contrast control of the single-photon absorption probability. We also demonstrate switching application by deploying a feedback mechanism to actively control the phase fluctuations of the network.

While the absorption of photons from a travelling wave is probabilistic, standing wave absorption can be observed deterministically, with nearly unitary probability of coupling a photon into a mode of the material (e.g. a localized plasmon) as a metamaterial is excited at the plasmon resonance. This process has been used in various forms of switching applications ranging from logical functions XOR, NOT and AND with CW [1] and short-pulse lasers [2].

Here we demonstrate manipulation of light at a single-photon level in an all-fiber-optic quantum network (Sagnac-like interferometer, Fig. 1a) with a fiber-integrated plasmonic absorber (Fig. 1b) which is impinged by the heralded down-converted single photons.

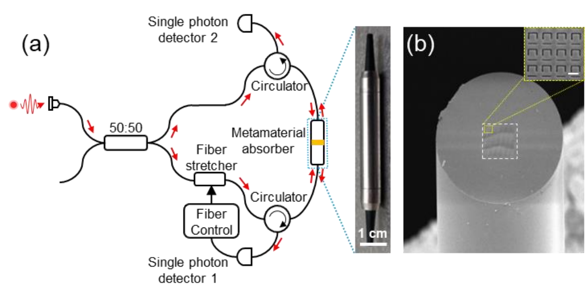

Fig. 1. (a) Schematic of the fiber-optic quantum network for active single-photon switching using a fiberized plasmonic metamaterial absorber (inset shows a photograph of the packaged metadevice), (b) SEM of an ultrathin (50 nm) metasurface deposited on the end-facet of a polarization-maintaining single-mode silica fiber (inset shows the SEM of individual asymmetric split ring resonators, scale bar is 500 nm.).

We actively stabilized the phase fluctuations of the fiberized network (Fig. 2a) and deterministically control the single-photon absorption probability with visibility up to 90% (Fig. 2b) by altering phase retardation in one arm of the interferometer. We also demonstrate single-photon switching (Fig. 2c) with active phase modulation, showing the ability of driving the quantum network in time-domain between coherent single-photon transmission and absorption regimes.

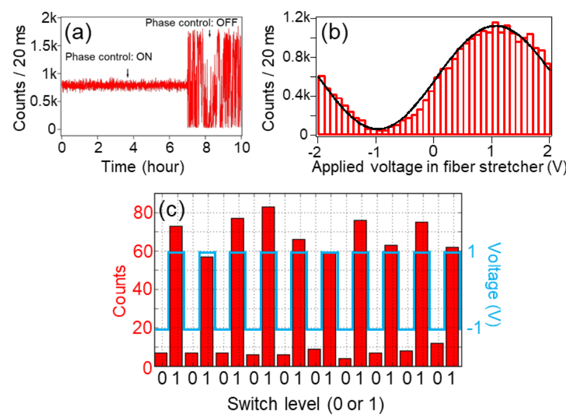

Fig. 2. Demonstration of (a) active phase stabilization, (b) interference fringe with 90% visibility, (c) single-photon switching with active phase modulation, where each bar shows the cumulative photon counts from 10 experiments. (Each experiment consists of a train of switch levels (i.e. 0,1), each of which lasts 20 ms.).

Our results show that stabilized fiber networks can be robustly used in dissipative single-photon switching, thus paving the way for novel coherent optical data processing architectures.

Reference

[1] A. Xomalis et al., “Fibre-optic metadevice for all-optical signal modulation based on coherent absorption,” Nat. Commun. 9, 182 (2018).

[2] A. Xomalis et al., "A fiberized metadevice for ultrafast all-optical signal processing and picosecond dark pulse generation," SPIE Phot. Europe (2018).