All-Optical Switch and Transistor Gated by One Stored Photon

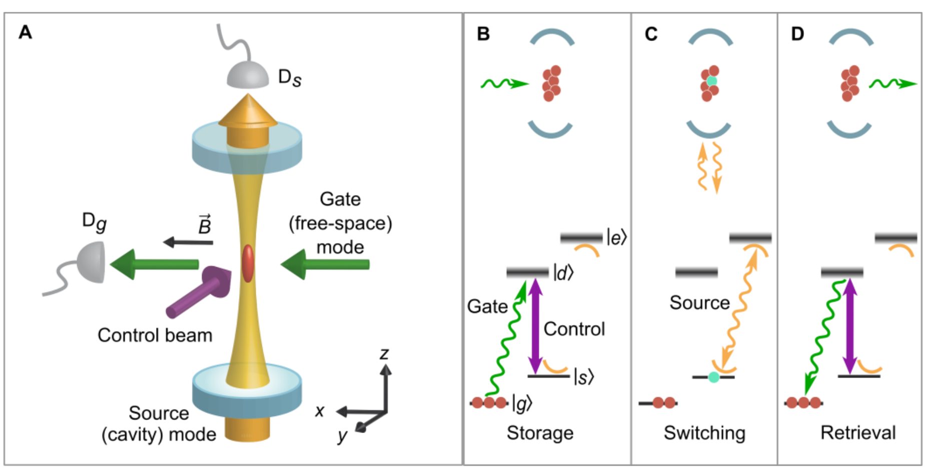
Wenlan Chen, Kristin M. Beck, Robert Bücker, Michael Gullans,
Mikhail D. Lukin, Haruka Tanji-Suzuki, Vladan Vuletić

*Department of Physics and Research Laboratory of Electronics,
Massachusetts Institute of Technology, Cambridge, MA 02139*

The realization of an all-optical transistor, in which one "gate" photon controls a "source" light beam, is a long-standing goal in optics. By slowing and stopping a light pulse in an atomic ensemble contained inside an optical resonator, we realized a device in which one stored gate photon controls the resonator transmission and reflection of subsequently applied source photons [1].

We test this device by sending a weak coherent gate pulse and measuring the induced bimodal transmission distribution of source photons. This showed that one stored gate photon produces fivefold attenuation of the source photons. More than 500 source photons can be switched by just one stored gate photon in this transistor. If only a few source photons are used, the stored gate photon can be retrieved for further processing.

With improved storage and retrieval efficiency, this scheme may enable various new applications, including photonic quantum gates and quantum non-demolition (QND) measurement of traveling photons. I will also report our recent progress toward QND measurement.



In the setup (Fig. A), we first stored a gate photon in the atomic ensemble, which corresponds to a collective atomic excitation to state |s⟩ (Fig. B). This collective excitation blocks the transmission of source photons through the cavity (Fig. C) and can be retrieved into its original mode (Fig. D). Retrieved gate and transmitted source photons are measured with photon counters D_g and D_s, respectively in Fig. A.

[1] W. Chen et al., Science **341**, 768 (2013), doi: 10.1126/science.1238169