Controlling photons with a photon

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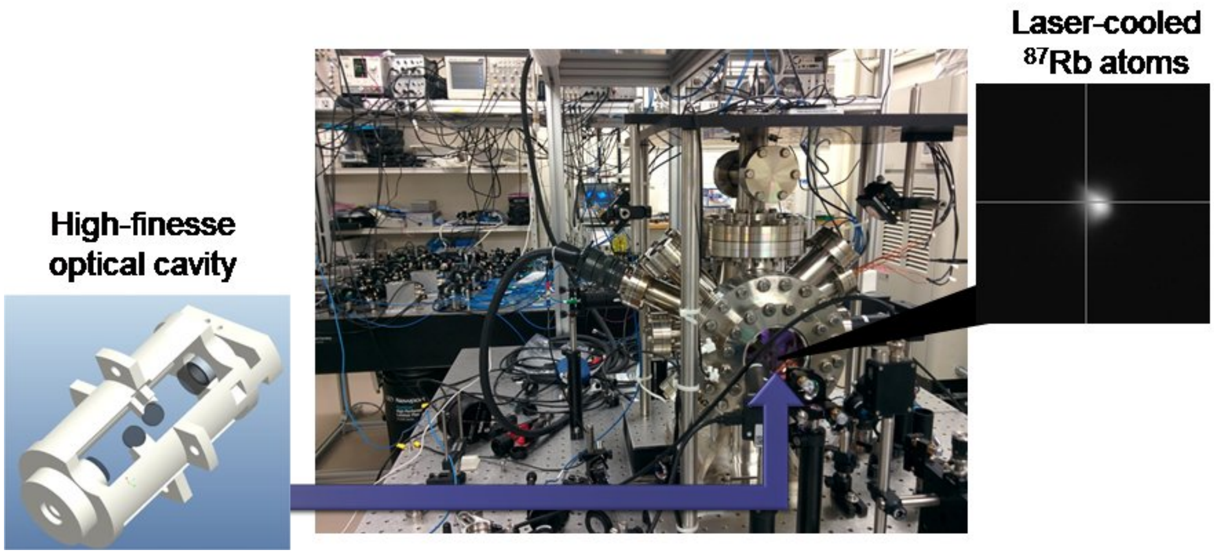

Vacuum chamber with high-finesse optical resonator and cold atoms. Credit: University of Electro Communications

Photons are considered to be ideal information carriers and expected to play important roles in quantum communication and information processing, where quantum mechanics allows for absolutely secure cryptographic key distribution as well as computation much faster than conventional computers. In order to take full advantage of quantum information carried by photons, it is important to make them directly interact with each other for information processing.

However, photons generally do not interact with one another. So it is necessary to mediate such interactions with matter to realize effective photon-photon interaction, but light-matter interaction is usually extremely weak in normal media.

Haruka Tanji-Suzuki and colleagues at the Institute for Laser Science, the University of Electro-Communications, Tokyo, are currently working to develop all-optical quantum devices that are sensitive to a single photon input, such as a single photon switch in which an incoming photon switches the state of another photon.

In order to realize the strong light-matter interaction that is necessary for such devices, Tanji-Suzuki uses a laser-cooled ensemble of 87Rb atoms (~10 uK) trapped within a high-finesse optical resonator (finesse ~50000) in an ultrahigh-vacuum chamber. Notably, in order to switch a photon with a photon in such a system, the researchers use an effect known as 'vacuum-induced transparency' observed recently by Tanji-Suzuki et al., in which an electromagnetic field as weak as a vacuum field (light with no photons) is shown to alter the optical properties of atoms.

"The realization of such all-optical single-photon devices will be a large step towards deterministic multi-mode entanglement generation as well as high-fidelity photonic quantum gates that are crucial for all-optical quantum information processing," says Tanji-Suzuki.

More information: H. Tanji-Suzuki et al. Vacuum-Induced Transparency, *Science* (2011). DOI: 10.1126/science.1208066

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