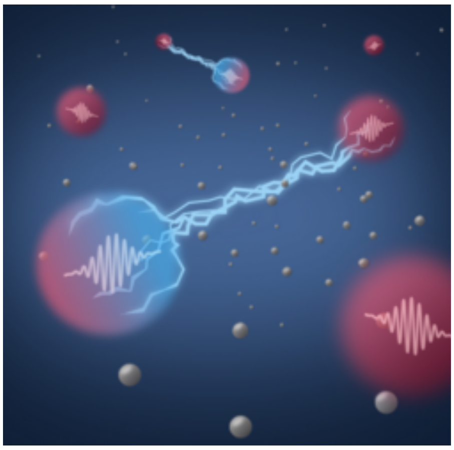
Research highlight

Research in the Niels Bohr Professorship for Many-Body Quantum Optics at Aarhus University discovers new strategies for manipulating light at the quantum level.

Photons, the fundamental constituents of light, are well known to freely pass through one another unimpeded. This defining property of light is pivotal to the success of optical-communication technologies, allowing for long-distance transmission of information. Yet, there are many other emerging technologies that would instead benefit from the ability to make two photons interact, whereby one photon can strongly influence the propagation or state of another. This is nonlinear optics at its most extreme, at the level of individual light quanta.

One promising approach to make photons interact is to shine light through a special form of atomic quantum matter featuring strong interactions between the constituent atoms. Under these circumstances, photons can be converted into so-called polariton excitations of the material and thereby acquire some of the properties of the medium. Exploring this strategy, the Aarhus group has devised and demonstrated novel methods for engineering controlled photon-photon interactions. The team discovered an effect where the presence of one polariton can cause another to be converted between two different kinds that have vastly different propagation characteristics. It turned out that such a process can cause photons to effectively behave like mirrors, and bounce off one another like billiard balls.



Artistic illustration of emerging photon interactions via their coupling to atoms in a quantum gas.

This exotic type of photon interaction has no counterpart in our more familiar world of classical particles. Quantum mechanically, however, such an effect can be exploited for a number of useful functionalities, such as quantum routing. In the same way that a standard internet router is used to control and distribute the data traffic it receives, a photonic quantum router is a device that can control the destination of optically encoded information via the quantum state of only a single photon. Such a capability would find wide ranging applications in future quantum technologies, from secure communication to quantum computing with light.

Already, it is now possible to use these concepts for performing elementary operations, such as the subtraction of a photon. In collaboration with researchers at the Joint Quantum Institute (USA) and experiments at the University of Southern Denmark, the team devised and realised an optical quantum memory that can extract precisely one photon from a light beam. Photons are temporarily held in the memory and manipulated with a second optical beam in such a way that exactly one stored photon can be tagged and removed. Being robbed of a single photon, the light beam is left in a peculiar quantum state that in itself has numerous scientific and technological applications. Much remains to be achieved and understood before quantum technologies based on interacting photons become fully operational. Yet, the demonstrated prototype provides an important milestone on the way.

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