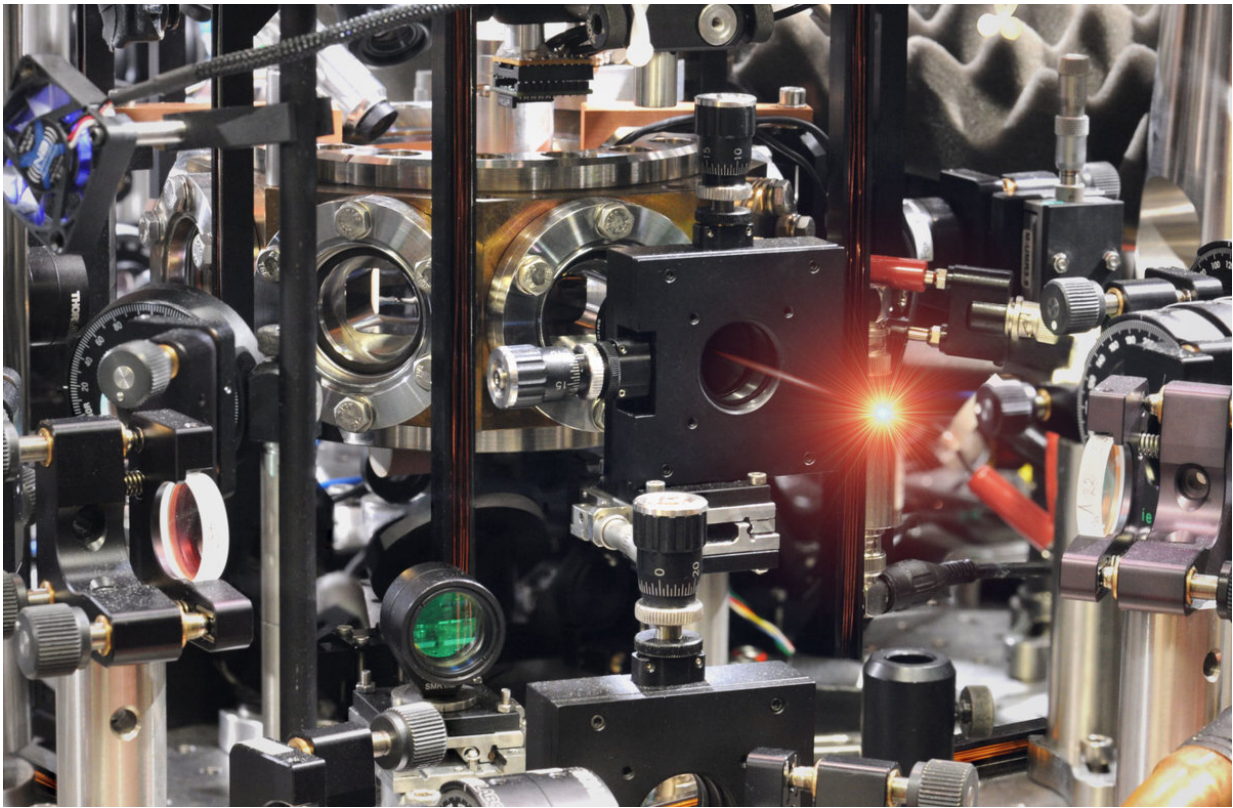


An atom in a cavity extracts highly pure single photons from weak laser light

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Doesn't quite look like a Schnapps distillery - the photon still in Garching.
Credit: Severin Daiß /Quantum Dynamics Group

Quantum physicists can now distil a kind of photon schnapps. When spirits are distilled, the alcohol content increases relative to the water content. A similar method developed by a team from the Max Planck

Institute of Quantum Optics in Garching works on light quanta – photons. It extracts individual photons from a light source, pushes back the unwanted vacuum component, and reports this event. Such single photons are important quantum bits for the currently emerging quantum information technology.

It is indeed reminiscent of the principle behind the distillation of alcohol – even though the device housed in a laboratory at the Max Planck Institute of Quantum Optics looks completely different from something used for distilling schnapps. The Garching experiment increases the proportion of individual photons in relation to the vacuum. This motivation may sound strange to the general public. However, it leads directly to the strange world of [quantum](#) physics. Ultimately weak light sources that can deliver exactly one [photon](#) play a central role in [quantum information technology](#). As a quantum bit, a photon can transport the elementary quantum information required for quantum networks, quantum encryption, and quantum computers – just as current digital technology processes individual bits as information carriers.

The construction of single photon sources is a challenge that has been researched worldwide for many years. This sounds astonishing because it takes only a single touch of a light switch to illuminate a room. However, the light from a lamp corresponds to a current of enormous numbers of photons. If you dim down a [light source](#) to such an extent that only single photons can escape from it, you are confronted with the roll-of-the-dice nature of the quantum world; sometimes nothing comes, and then two or three photons come and so on. It's a bit like the dripping from a still. You can't precisely predict when the drop will come or how big it will be.

No vacuum may be added to a cleanly prepared photon

The physicists from Gerhard Rempe's Department at the Max Planck Institute of Quantum Optics had no intention of developing another single-photon light source. Instead, their experiment can extract individual photons from the light of any very weak light source – like a still – and reliably report this event. Strictly speaking, it reduces the fraction of pure vacuum compared to the event of obtaining a photon. This is what you learn from Severin Daiß, doctoral student at the Institute and first author of the publication. One of the peculiarities of the quantum world is that the vacuum itself represents a [quantum state](#). If you want to cleanly prepare a photon, no vacuum must be added.

Two challenges come together in the new research work of Rempe's team. The first challenge is to obtain exactly one photon. The second is to reliably detect it. A single rubidium atom solves both tasks in one step. This atom is in a kind of mirror cabinet. More precisely, it is trapped between two almost perfect mirrors facing each other. The distance of the mirrors in this "resonator" corresponds precisely to a multiple of half a wavelength of light in which the atom could radiate or absorb its own photon. In this system, the atom can be folded back and forth between two display positions like a pointer; this plays an important role here.

Several photon stills in succession increase the purity of the light

"We can use this system of the atom in the resonator as a still for the photon", says Severin Daiß. The Garching-based group directs extremely weak laser light – from which they want to obtain a single photon – onto the cavity. There it does something that only works in the quantum world: It entangles with the atom-resonator arrangement, thereby forming a common quantum state. This entangled state makes the system a still: With a measurement on the atom, physicists can extract an even

or an odd number of photons from the incident light.

However, this does not work like a switch; the roll-of-the-dice nature of the quantum world prevents a photon from coming through at the push of a button. "What is decisive here is that we can now use the atom as a pointer to report a successful single-photon distillation", explains Daiss. The physicists let the arrangement roll photons but get the dice count reliably displayed.

In conjunction with ultra-weak light, the "odd photon number" mode can now produce events with one photon because more photons are rarely available. The distillation succeeded with a "purity" of 66 percent, which means that the vacuum content was reduced to one third. Compared with single photon light sources, this is a good result for a first attempt. This purity can be considerably increased with better optical cavities. The photon distilling elements can be connected in series in order to further increase the purity of the photon that passes through. The quality of the [light](#) from other single photon sources can also be improved. It's like making 60 percent (or higher) vodka from 40 percent vodka.

More information: Severin Daiss et al. Single-Photon Distillation via a Photonic Parity Measurement Using Cavity QED, *Physical Review Letters* (2019). [DOI: 10.1103/PhysRevLett.122.133603](https://doi.org/10.1103/PhysRevLett.122.133603)

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