Building a bridge to the quantum world

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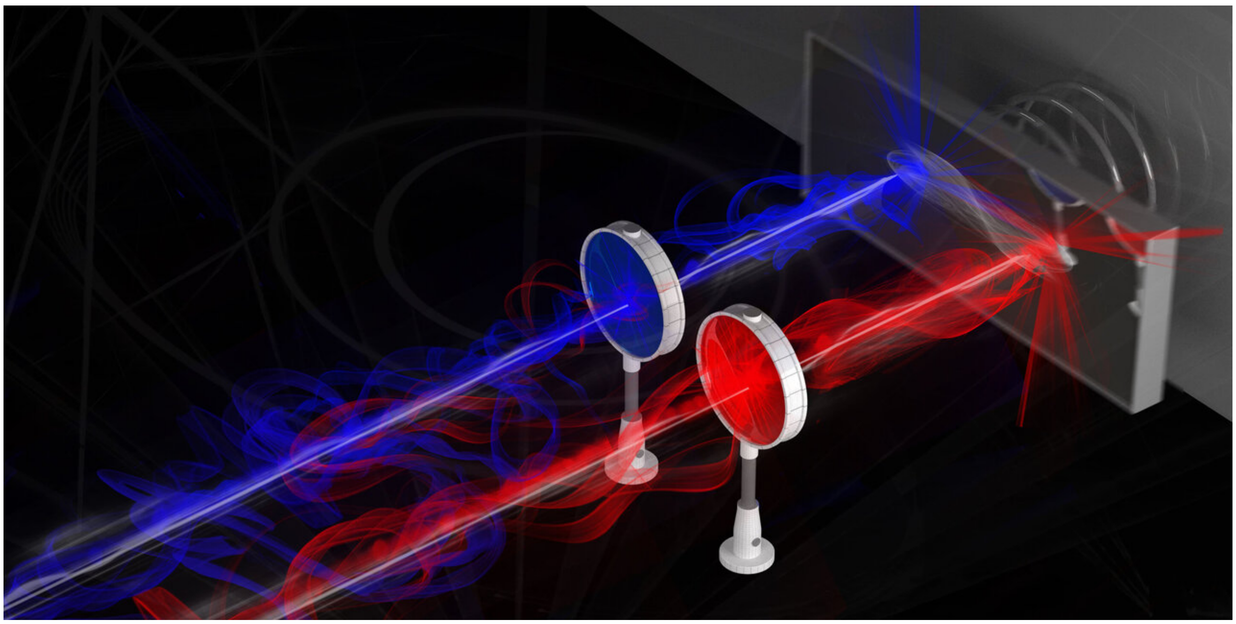

Illustration of a prototype of what may, in the future, serve as a link to connect quantum computers. Credit: IST Austria/Philip Krantz, Krantz NanoArt

Entanglement is one of the main principles of quantum mechanics. Physicists from Professor Johannes Fink's research group at the Institute of Science and Technology Austria (IST Austria) have found a way to use a mechanical oscillator to produce entangled radiation. This method, which the authors published in the current edition of *Nature*, might prove extremely useful when it comes to connecting quantum computers.

Entanglement is a phenomenon typical of the quantum world, which is not present in the so-called classical world—the world and laws of physics that govern our everyday lives. When two particles are entangled, the characteristics of one particle can be determined by looking at the other. This was discovered by Einstein, and the phenomenon is now actively used in quantum cryptography, where it is said to lead to unbreakable codes. Radiation can also be entangled: This is the phenomenon that Shabir Barzanjeh, a postdoc in the group of Professor Fink at IST Austria and first author of the study, is currently researching.

"Imagine a box with two exits. If the exits are entangled, one can characterize the radiation coming out of one exit by looking at the other," he explains. Entangled radiation has been created before, but in this study, a mechanical object was used for the first time. With a length of 30 micrometers and composed of about a trillion (10^{12}) atoms, the silicon beam created by the group is large on a quantum scale. "For me, this experiment was interesting on a fundamental level," says Barzanjeh. "The question was: Can one use such a large system to produce non-classical radiation? Now, we know that the answer is yes."

But the device also has practical value. Mechanical oscillators could serve as a link between the extremely sensitive quantum computers and optical fibers connecting them inside data centers and beyond. "What we have built is a prototype for a quantum link," says Barzanjeh.

In superconducting quantum computers, the electronics only work at extremely low temperatures, a few thousandths of a degree above absolute zero (-273.15 °C). This is because such quantum computers operate on the basis of microwave photons, which are extremely sensitive to noise and losses. If the temperature in a quantum computer rises, all the information is destroyed. As a consequence, transferring information from one quantum computer to another is at the moment almost impossible, as the information would have to cross an environment that is too hot for it to survive.

Classical computers in networks, on the other hand, are usually connected via optical fibers, because optical radiation is very robust against disturbances that could corrupt or destroy data. Using this successful technology for quantum computers requires building a link that can convert the quantum computer's microwave photons to optical information carriers, or a device that generates entangled microwave-optical fields as a resource for quantum teleportation. Such a link would serve as a bridge between the room temperature optical and the cryogenic quantum world, and the device developed by the physicists is one step in that direction. "The oscillator that we have built has brought us one step closer to a quantum internet," says first author Barzanjeh.

But this is not the only potential application of the device. "Our system could also be used to improve the performance of gravitational wave detectors," explains Shabir Barzanjeh and Johannes Fink adds: "It turns out that observing such steady-state entangled fields implies that the mechanical oscillator producing it has to be a quantum object. This holds for any type of mediator, and without the need to measuring it directly, so in the future our measurement principle could help to verify or falsify the potentially quantum nature of other hard to interrogate systems like living organisms or the gravitational field."

More information: Barzanjeh, S. et al. Stationary entangled radiation from micromechanical motion, *Nature* (2019). DOI: 10.1038/s41586-019-1320-2 , www.nature.com/articles/s41586-019-1320-2

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