Mechanical quanta see the light

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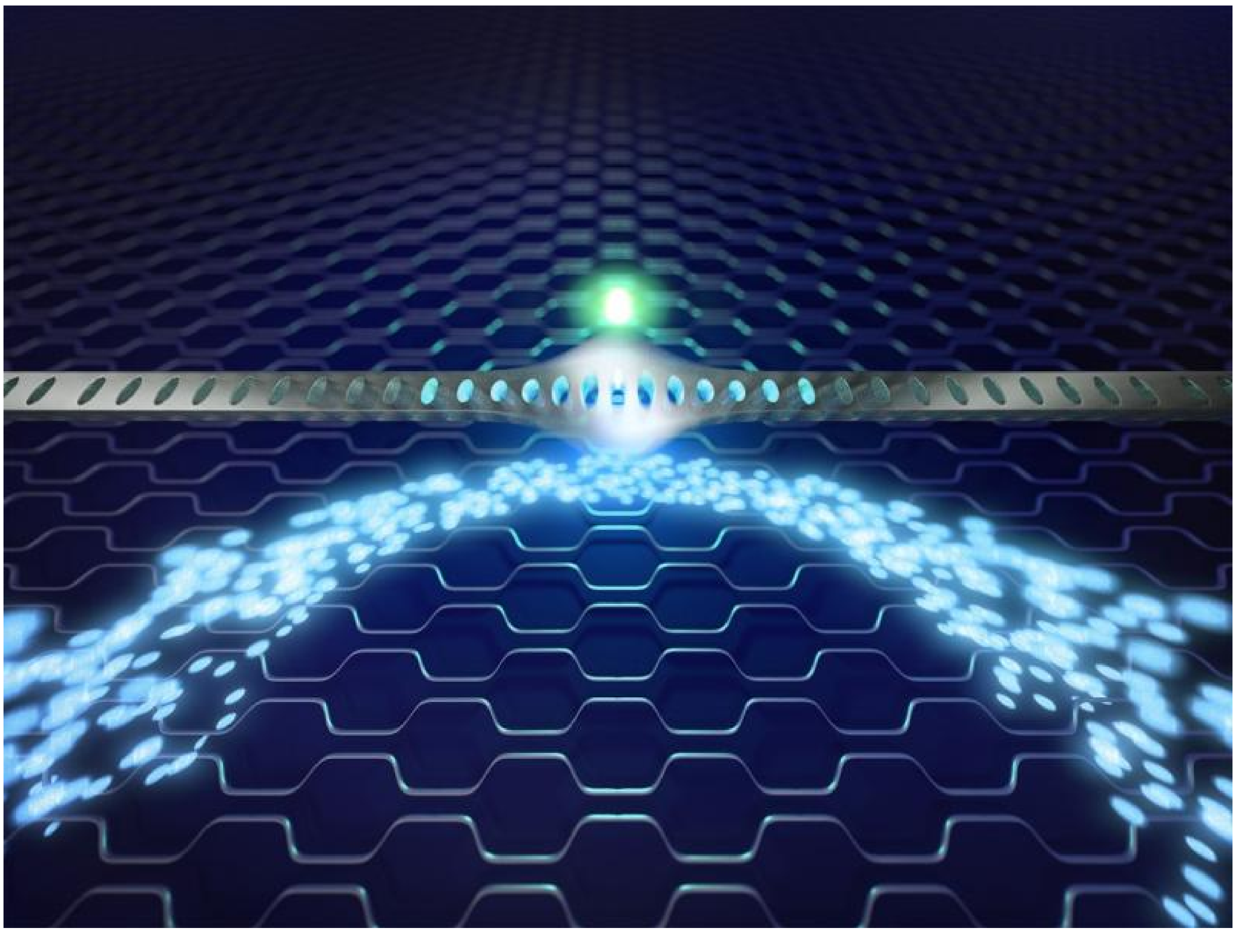

A stylization of the researcher's nanomechanical device. By way of vibrating back-and-forth, the hole-filled silicon beam converts quantum particles of light into quantum vibrations, and later back into light. Credit: Copyright: Jonas Schmöle, The Aspelmeyer Research group, Faculty of Physics, Vienna Center for Quantum Science and Technology (VCQ), University of Vienna

Interconnecting different quantum systems is important for future quantum computing architectures, but has proven difficult to achieve. Researchers from the TU Delft and the University of Vienna have now realized a first step towards a universal quantum link based on quantum-mechanical vibrations of a nanomechanical device.

Quantum physics is increasingly becoming the scientific basis for a plethora of new "quantum technologies". These new technologies promise to fundamentally change the way we communicate, as well as radically enhance the performance of sensors and of our most powerful computers. One of the open challenges for practical applications is how to make different quantum technologies talk to each other. Presently, in most cases, different quantum devices are incompatible with one another, preventing these emerging technologies from linking, or connecting, to one another. One solution proposed by scientists is to build nanometer-sized mechanical objects that vibrate back-and-forth, just like a tiny vibrating tuning fork. These "nanomechanical devices" could be engineered such that their vibrations are the mediator between otherwise different quantum systems. For example, mechanical devices that convert their mechanical vibrations to light could connect themselves (and other devices) to the world's optical fibre networks, which form the Internet. An outstanding challenge in quantum physics has been building a nanomechanical device that convert quantum-mechanical vibrations to quantum-level light, thus allowing one to connect quantum devices to a future quantum Internet.

Researchers led by Simon Gröblacher at TU Delft and Markus Aspelmeyer at the University of Vienna have now realized just such a nanomechanical device. It converts individual particles of light, known as photons, into quantum-mechanical vibrations, known as phonons, and then back again, as reported today in the journal *Nature*. Traditionally, the probability to first convert a photon into a phonon has been far too small to be useful. But this joint-team applied a trick: Whenever their nanomechanical device first converted a photon to a phonon, their device created a "signalling" photon. By first looking for this signalling photon, the researchers knew exactly when their nanomechanical device had succeeded in the conversion - it had converted light into quantum-mechanical vibrations of their device. Afterwards, using lasers, the researchers then had their device convert its phonon back into light, and emit a photon. Finally, by carefully counting the signalling photons and the emitted photons, the researchers demonstrated that the entire conversion process happened at the quantum level - a single particle at a time. "Not only is this exactly what is necessary to convert and store quantum bits; what I also find amazing," explains Ralf Riedinger, lead author on the study, "is the implications for fundamental physics. We normally think of mechanical vibrations in terms of waves, like waves travelling across a lake, as water vibrates up and down. But our measurements are clear evidence that mechanical vibrations also behave like particles. They are genuine quantum particles of motion. It's wave-particle duality, but with a nano-sized tuning fork."

The nanomechanical device itself is a tiny silicon beam, only half a micrometer wide, and contains a regular pattern of holes, which traps light and mechanical vibrations in the same spot. This nano-sized beam vibrates back-and-forth billions of times each second. It was fabricated at TU Delft by Prof. Gröblacher's team on a silicon chip and uses infrared wavelengths of light, exactly as industry-standard fibre optic networks, integrated electronic, and emerging photonic circuits.

"We clearly also see the long-term technological potential", says Gröblacher. "Such quantum mechanical vibrations could eventually be used as a 'memory' to temporarily store quantum information inside quantum networks or computers." One grand future vision is to establish a quantum Internet in which quantum bits, instead of classical bits, are distributed and processed all around the world. Just like in today's Internet, light will be used for global exchange of quantum information.

How it can be converted to a large variety of different quantum devices that will be available for storage and computation remains a major open question. "Our research indicates that nanomechanical devices are a promising candidate to form this link", reflects Gröblacher.

Provided by University of Vienna

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