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Hybrid quantum system on the horizon

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Researchers in Germany and France have found an experimentally viable way to physically couple a Bose-Einstein condensate (BEC) to a nanomechanical resonator for the first time. Such a hybrid quantum system is not only of fundamental interest, but could also find applications in quantum information processing and precision measurement.

The coupled system is composed of a microscopic atomic system, the BEC, and a mesoscopic solid-state nanodevice, the nanomechanical resonator. A BEC is an ultracold cloud of gas atoms that are all in the same quantum state.

"Such an interface between the microscopic world of single atoms and BECs, which obey the laws of quantum mechanics, and the mesoscopic world of nanomechanical systems is interesting from a fundamental point of view," says team member Philipp Treutlein of the Max Planck Institute of Quantum Optics in Munich. "It could allow the quantum state of the nanomechanical resonator to be engineered."

The interaction could be used to transfer the quantum state of a BEC, composed of a few thousand atoms, to the nanomechanical resonator, which contains several billion atoms. Such a feat could then be used to study quantum mechanics on a truly mechanical system, at the boundary between the microscopic and macroscopic worlds.

The key to interfacing the world of ultracold atoms and solid-state nanodevices is an "atom chip", on which BECs are trapped with the help of magnetic fields generated by micro- and nanofabricated current-carrying wires. In previous work, Treutlein and colleagues showed that the atoms could be trapped at distances of a few microns from the chip surface without destroying their excellent coherence properties.

Now, the same team has proposed using the atom chip to couple the atoms to solid-state systems on the chip surface. In the experiment, the BEC would hover in a magnetic trap, directly above the tip of the nanomechanical resonator on the chip, and the coupling would rely on a small ferromagnet placed on the

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resonator tip. And, like in a nanoscale version of a magnetic force microscope, the vibrating tip would generate an oscillating magnet field, which would couple to the spin of the atoms in the BEC.

Such hybrid quantum systems may find applications in quantum information processing by combining the advantages of the two constituents. Quantum information stored in one constituent – for example, an atomic system with a very long coherence lifetime – could be transferred to a solid-state system for processing. "This is advantageous because the dynamics in solid-state nanodevices are typically much faster than atomic dynamics," says Treutlein.

And since the atoms are very sensitive to electromagnetic fields, they could be used for precision measurements of the properties of the chip surface or of devices on the chip.

The team is now working on making the proposed hybrid system.

The work was published on *arXiv*.

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