Evading the uncertainty principle in quantum physics

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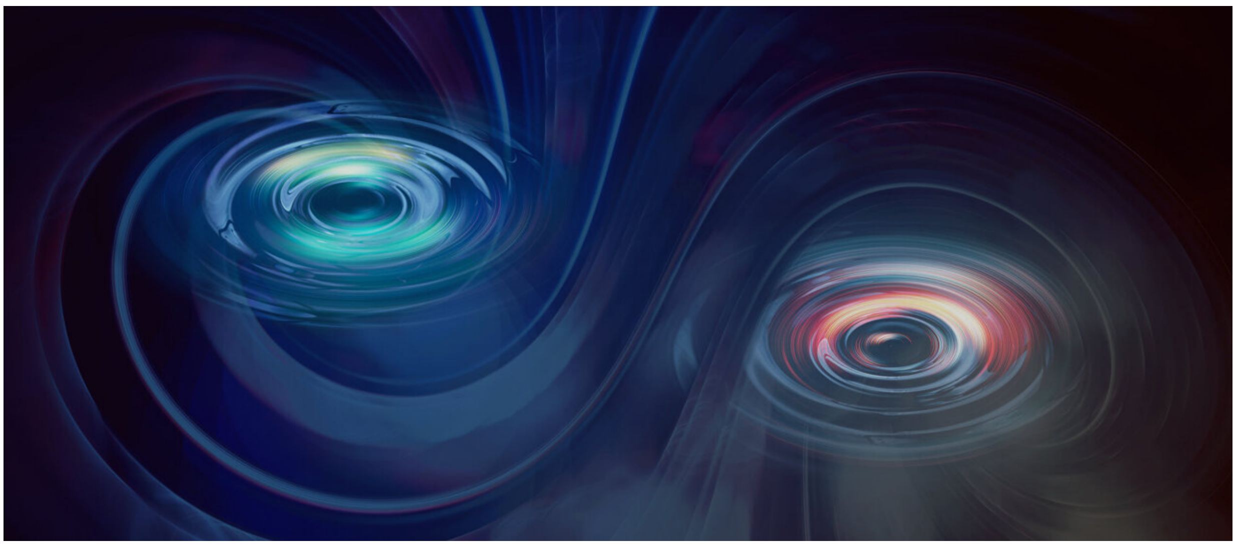

Schematic of the entangled drumheads. Credit: Aalto Universi

The uncertainty principle, first introduced by Werner Heisenberg in the late 1920's, is a fundamental concept of quantum mechanics. In the quantum world, particles like the electrons that power all electrical product can also behave like waves. As a result, particles cannot have a well-defined position and momentum simultaneously. For instance, measuring the momentum of a particle leads to a disturbance of position, and therefore the position cannot be precisely defined.

In recent research, published in *Science*, a team led by Prof. Mika

Sillanpää at Aalto University in Finland has shown that there is a way to get around the uncertainty principle. The team included Dr. Matt Woolley from the University of New South Wales in Australia, who developed the theoretical model for the experiment.

Instead of elementary particles, the team carried out the experiments using much larger objects: two vibrating drumheads one-fifth of the width of a human hair. The drumheads were carefully coerced into behaving quantum mechanically.

"In our work, the drumheads exhibit a collective quantum motion. The drums vibrate in an opposite phase to each other, such that when one of them is in an end position of the vibration cycle, the other is in the opposite position at the same time. In this situation, the quantum uncertainty of the drums' motion is canceled if the two drums are treated as one quantum-mechanical entity," explains the lead author of the study, Dr. Laure Mercier de Lepinay.

This means that the researchers were able to simultaneously measure the position and the momentum of the two drumheads—which should not be possible according to the Heisenberg uncertainty principle. Breaking the rule allows them to be able to characterize extremely weak forces driving the drumheads.

"One of the drums responds to all the forces of the other drum in the opposing way, kind of with a negative mass," Sillanpää says.

Furthermore, the researchers also exploited this result to provide the most solid evidence to date that such large objects can exhibit what is known as quantum entanglement. Entangled objects cannot be described independently of each other, even though they may have an arbitrarily large spatial separation. Entanglement allows pairs of objects to behave in ways that contradict classical physics, and is the key resource behind emerging quantum technologies. A quantum computer can, for example, carry out the types of calculations needed to invent new medicines much faster than any supercomputer ever could.

In macroscopic objects, quantum effects like entanglement are very fragile, and are destroyed easily by any disturbances from their surrounding environment. Therefore, the experiments were carried out at a very low temperature, only a hundredth a degree above absolute zero at -273 degrees.

In the future, the research group will use these ideas in laboratory tests aiming at probing the interplay of quantum mechanics and gravity. The vibrating drumheads may also serve as interfaces for connecting nodes of large-scale, distributed quantum networks.

The article, "Quantum mechanics-free subsystem with mechanical oscillators," by Laure Mercier de Lépinay, Caspar F. Ockeloen-Korppi, Matthew J. Woolley, and Mika A. Sillanpää is published in *Science* 7 May.

More information: L. Mercier de Lépinay el al., "Quantum mechanics–free subsystem with mechanical oscillators," *Science* (2021). science.sciencemag.org/cgi/doi … 1126/science.abf5389

Provided by Aalto University

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