Physicists propose the first scheme to teleport the memory of an organism

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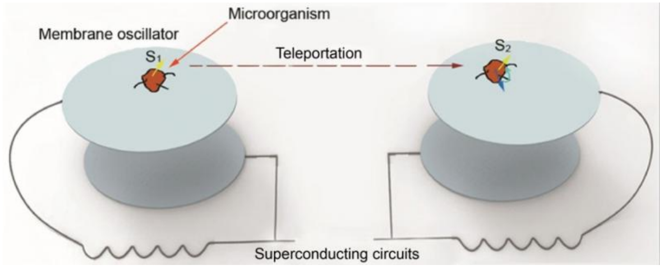

Quantum teleportation between two microorganisms is shown. The internal state (an electron spin) or the center-of-mass motion state of a microorganism on an electromechanical oscillator can be teleported to a remote microorganism on another electromechanical oscillator assisted with superconducting circuits. Credit: ©Science China Press

In "Star Trek," a transporter can teleport a person from one location to a remote location without actually making the journey along the way. Such a transporter has fascinated many people. Quantum teleportation shares several features of the transporter and is one of the most important protocols in quantum information. In a recent study, Prof. Tongcang Li at Purdue University and Dr. Zhang-qi Yin at Tsinghua University proposed the first scheme to use electromechanical oscillators and superconducting circuits to teleport the internal quantum state (memory) and center-of-mass motion state of a microorganism. They also proposed a scheme to create a Schrödinger's cat state in which a microorganism can be in two places at the same time. This is an important step toward potentially teleporting an organism in future.

In 1935, Erwin Schrödinger proposed a famous thought experiment to prepare a cat in a superposition of both alive and dead states. The possibility of an organism to be in a superposition state dramatically reveals the profound consequences of quantum mechanics, and has attracted broad interests. Physicists have made great efforts over many decades to investigate macroscopic quantum phenomena. To date, matter-wave interference of electrons, atoms, and molecules (such as C_{60}) have been observed. Recently, quantum ground state cooling and the creation of superposition states of mechanical oscillators have been realized. For example, a group in Colorado, U.S. has cooled the vibration of a 15-micrometer-diameter aluminum membrane to quantum ground state, and entangled its motion with microwave photons. However, the quantum superposition of an entire organism has not been realized. Meanwhile, there have been many breakthroughs in quantum teleportation since its first experimental realization in 1997 with a single photon. Besides photons, quantum teleportation with atoms, ions, and superconducting circuits have been demonstrated. In 2015, a group at University of Science and Technology of China demonstrated the quantum teleportation of multiple degrees of freedom of a single photon. However, existing experiments are still far away from teleporting an organism or the state of an organism.

In a recent study, Tongcang Li and Zhang-qi Yin propose to put a bacterium on top of an electromechanical membrane oscillator integrated with a superconducting circuit to prepare the quantum superposition state of a microorganism and teleport its quantum state. A microorganism with a mass much smaller than the mass of the electromechanical membrane will not significantly affect the quality factor of the membrane and can be cooled to the quantum ground state together with the membrane. Quantum superposition and teleportation of its center-of-mass motion state can be realized with the help of superconducting microwave circuits. With a strong magnetic field gradient, the internal states of a microorganism, such as the electron spin of a glycine radical, can be entangled with its center-of-mass motion and be teleported to a remote microorganism. Since internal states of an organism contain information, this proposal provides a scheme for teleporting information or memories between two remote organisms.

The proposed setup is also a quantum-limited magnetic resonance force microscope. It can not only detect the existence of single electron spins (associated with protein defects or DNA defects) like conventional MRFM, but can also coherently manipulate and detect the quantum states of electron spins. It enables some isolated electron spins that could not be read out with optical or electrical methods to be used as quantum memory for quantum information.

Li says, "We propose a straightforward method to put a microorganism in two places at the same time, and provide a scheme to teleport the quantum state of a microorganism. I hope our unconventional work will inspire more people to think seriously about quantum teleportation of a microorganism and its potential applications in the future." Yin says "Our work also provides insights for future studies about the effects of biochemical reactions in the wave function collapses of quantum superposition states of an organism."

More information: Tongcang Li et al. Quantum superposition, entanglement, and state teleportation of a microorganism on an electromechanical oscillator, *Science Bulletin* (2016). DOI: 10.1007/s11434-015-0990-x

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