Quantum physicist tame a so-called 'dark state' created in a superconducting qubit

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A team of quantum physicists at Aalto University led by Dr. Sorin Paraoanu managed to tame a so-called "dark state" created in a superconducting qubit. A superconducting qubit is an artificial atom fabricated on a silicon chip as an electrical circuit made of capacitors and tunnel junctions.

This technology is one of the most promising for the realization of quantum computers.

In the experiment, the circuit was operated in a regime where it no longer absorbs or emits electromagnetic waves of certain frequency, as if it would be hiding under an invisibility cloak - hence the term "dark state". Then, by using a sequence of carefully-crafted microwave pulses, the team employed the dark state to realize a transfer of population from the ground energy level to the second energy level, without populating the first energy level. The amount of energy transferred in this process corresponds to a single microwave photon with about the same frequency as those in mobile phones or microwave ovens. This is verified by quantum tomography - a technique of reconstructing the wave function (in general the density matrix) by applying rotations in an abstract qubit space followed by measurements.

"The matching between the experimental data and the theoretical model is quite remarkable, and this gives us confidence that we understand what is happening and we can control this quantum system. This demonstrates that three-level systems (also called qutrits) can be used in

quantum processors instead of the standard two-level qubits," says Antti Vepsäläinen, who implemented this technique and perfomed numerical simulations.

And there is another dazzling fact about the experiment: To perform the transfer, the researchers used a so-called non-intuitive sequence, applying in the beginning a pulse that couples the first level with the second level and only after some time the pulse that couples the ground level to the first level.

"Suppose you want to travel from Helsinki to New York and you have to change your flight in London", explains Sorin Paraoanu. "Normally you would first fly on a plane from Helsinki to London, then wait for some time in the airport in London, then board the flight London-New York. But in the quatum world, you would be better off boarding a plane from Helsinki to London sometime after the flight London-New York took off. You will not spend any time in London and you will arrive in New York right at the time when the plane from Hesinki lands in London." This is mind-boggling but the experiment shows that it is indeed happening.

Besides the relevance for quantum computing, the result also has deep conceptual implications. Much of our understanding of the reality is based on the so-called continuity principle: the idea that influences propagate from here to there by going through all the places in-between. Real objects don't just appear somewhere from nothing. But the experiment seems to defy this. Like in a great show of magic, quantum physics allows things to materialize here and there, apparently out of nowhere.

More information: K. S. Kumar et al. Stimulated Raman adiabatic passage in a three-level superconducting circuit, *Nature Communications* (2016). DOI: 10.1038/NCOMMS10628

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