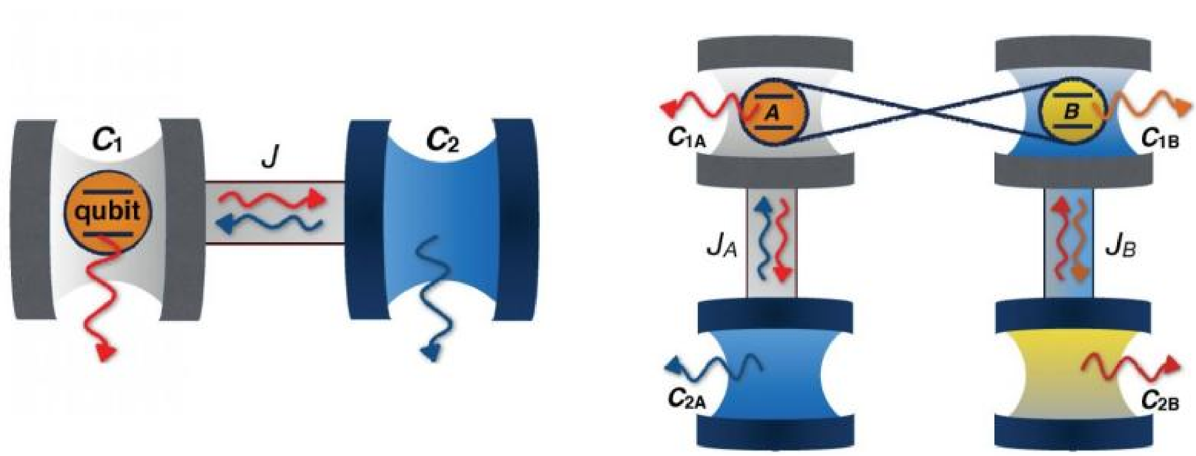
Entanglement lifetime extended orders of magnitude using coupled cavities

September 10 2015, by Lisa Zyga



(Left) In the single-qubit system, a qubit is embedded in a cavity, which in turn is coupled to a second cavity by a coupling strength J. (Right) In the two-qubit system, two entangled qubits are each embedded in their own cavity, and each cavity is coupled to a second cavity. Credit: Man, et al. ©2015 Nature *Scientific Reports*

(Phys.org)—Entangled qubits form the basic building blocks of quantum computers and other quantum technologies, but when qubits lose their entanglement, they lose their quantum advantage over classical bits. Unfortunately, entanglement decays very quickly due to unavoidable interactions with the surrounding environment, so preserving entanglement for long enough to use it has been a key challenge for realizing quantum technologies.

In a new study, physicists have developed a way to extend the quantum entanglement lifetime to nearly 10 milliseconds, which is about three orders of magnitude longer than the spontaneous lifetime of a few microseconds. The millisecond lifetime is long enough to implement some quantum algorithms and protocols, and is expected to be extended further in the future.

The researchers, Zhong-Xiao Man and Yun-Jie Xia at Qufu Normal University in China, along with Rosario Lo Franco at the University of Palermo in Italy, the University of São Paulo in Brazil, and The University of Nottingham in the UK, have published their paper in a recent issue of Nature's *Scientific Reports*.

The new set-up is relatively simple, consisting of a qubit embedded in a cavity—something that traps the qubit and holds it in place—which in turn is coupled to a second, empty cavity. Since this system contains just one qubit, it exhibits quantum coherence, which is the simultaneous coexistence of multiple states within a single qubit, rather than entanglement, which involves correlations between two or more qubits. The scientists showed that they could preserve the quantum coherence of the single-qubit system simply by adjusting the coupling strength between the two cavities.

The physicists then extended the single-qubit system to a double-qubit system by adding a second qubit embedded in its own cavity, which was coupled to its own second cavity. Again, by adjusting the coupling strengths between both pairs of cavities, the scientists could preserve the quantum resource—in this case, entanglement.

What's happening here, the scientists explain, is that adjusting the cavity coupling strength inhibits the qubits' spontaneous emission, which would otherwise dissipate into the environment and lead to entanglement decay. As the coupling strength between cavities is gradually increased, the entanglement dynamics undergo multiple transitions between two regimes (the so-called Markovian, or memoryless, and non-Markovian, or memory-keeping, regimes). Every time the dynamics enter the non-Markovian regime, the entanglement experiences a partial revival after decaying, although it eventually decays completely.

In theory, entanglement could be preserved indefinitely if the cavities without qubits were "perfect," meaning they do not leak any photons and therefore have an infinite quality factor. Due to steady progress in the field of circuit quantum electrodynamics (cQED), achieving higher quality factors may further improve the entanglement lifetime. The method is also promising in that it can be extended to more than two qubits, while keeping the qubits separated, which are requirements for realizing complex quantum information and computation protocols.

"We stress that the condition of noninteracting separated qubits is desirable in order to individually address them for quantum information and computation tasks," Lo Franco said.

More information: Zhong-Xiao Man, et al. "Cavity-based architecture to preserve quantum coherence and entanglement." *Nature Scientific Reports* **5**, 13843 (2015). DOI: 10.1038/srep13843. Also at: arXiv:1508.01675 **[quant-ph]**