Entanglement between macroscopic objects generated by dissipation

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(PhysOrg.com) -- When generating entanglement between two objects, physicists typically try to minimize the objects' interactions with the environment, since this interaction causes decoherence. But contrary to this thinking, scientists in a new study have experimentally demonstrated that dissipation caused by interaction with the environment can continuously generate entanglement between two macroscopic objects (two ensembles of cesium atoms containing about 1 trillion atoms all together). By combining the dissipative mechanism with continuous measurements, the researchers could achieve steady state entanglement between the two atomic ensembles for up to an hour.

The scientists, Professor Eugene Polzik from the Niels Bohr Institute at Copenhagen University and his coauthors, have published their study on the new approach to generating entanglement in a recent issue of Physical Review Letters. As the scientists explain, it is the first demonstration of purely dissipative entanglement generation, and could have applications in quantum information processing and other areas.

“We have generated entanglement which is ready-to-use at any unspecified instant in time,” Polzik told *PhysOrg.com*. “This should be a useful feature for applications where complex entangled networks are required. But perhaps even more important is that we have made the first step in showing how entanglement can be generated by dissipation. With this demonstration, other proposals which use dissipation for quantum computing and communication will hopefully attract the attention of experimentalists.”

The study builds on previous research over the past few years that has predicted that dissipation that is common to two systems can drive the systems into an entangled state. The idea of using dissipation rather than coherence to generate entanglement represents a paradigm shift in the field, although demonstrating it has proven too difficult until now.

To generate entanglement, the scientists placed the two cesium gas samples in 2.2-cm cubic containers in a magnetic field half a meter apart from each other. Through the combination of controlling the magnetic field and using a laser to perform optical pumping of the atoms, the scientists could engineer dissipation between the atomic ensembles and polarized vacuum modes of the electromagnetic field, which provide a common environment.

“In the past, dissipation was always a process occurring independently in each of the atoms,” Polzik explained. “In our experiment the dissipation was engineered to be a collective process for both atomic ensembles.

“A general feature which leads to generation of quantum superpositions and entanglement is indistinguishability of two or more paths towards the final state,” he said. “In other words, the absence of the so-called ‘which-way information.’ We engineered dissipation for the two atomic ensembles in such a way that it was impossible to tell whether photons which led to dissipation were emitted by the first or the second ensemble. The quantum interference of these two dissipation paths is the key reason for the generation of entanglement.”

In the first series of experiments, the scientists generated entanglement in a quasisteady state that lasted for 0.015 seconds, which is several times longer than the best previous results for measurement-induced entanglement. The scientists also experimented with keeping the optical pumping field on throughout the entanglement generation period. Since this process is incoherent, the researchers were surprised to find that the pumping did not suppress entanglement, but rather increased the entanglement duration to 0.04 seconds. Finally, by using the results from continuous measurements on the system, and combining these results with dissipative processes, the researchers could generate steady state entanglement for up to an hour.

By demonstrating that dissipation can be used to generate entanglement, the results of the study present a new entanglement method that could have several potential advantages compared with coherence-based methods. For instance, dissipation-generated entanglement can exist, in principle, for an arbitrarily long time and does not require the system to be prepared in a particular input state. These advantages make dissipative methods attractive for use in quantum information protocols by allowing for long-range, high-quality steady state entanglement.

More information: Hanna Krauter, et al. "Entanglement Generated by Dissipation and Steady State Entanglement of Two Macroscopic Objects." *Physical Review Letters* 107, 080503 (2011) DOI: 10.1103/PhysRevLett.107.080503