Researchers discover a way to avoid decoherence in a quantum system

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(Phys.org) —A team of physicists in Israel has used the scattering of a photon when it strikes an atom to better understand the process of decoherence. In a paper the team has published in the journal *Science*, the group describe how, as part of their research, they found that the spin of an atom prior to being shot with a single photon determined whether decoherence took place or not.

Decoherence is the process that comes about when a quantum state transitions to a classical world state. Scientists are studying the way it comes about (and ways to prevent it from happening) to help in designing atomic clocks and hopefully one day, a quantum computer.

In this new effort, the researchers fired single photons at atoms and then studied the results using a detector. When the photons struck the atoms, they were deflected, a process called scattering. In so doing, they discovered that if the photon struck an atom whose spin was not aligned in the same direction as its path, than the photon and atom became entangled—where two particles behave as if one, even at a distance. If the photon and atom's spin were aligned, however, entanglement did not occur.

This experiment suggests a way to prevent decoherence—if the photon and atom became entangled, they experienced decoherence the moment the photon struck the detector and was measured—one of the basic rules of quantum mechanics. If the two didn't become entangled though, then decoherence never occurred because there never was a superposition state (a scenario defined by quantum mechanics whereby systems can exist simultaneously in more than one state) in the first place. It also shows that decoherence can perhaps be controlled in a quantum system by taking advantage of an atom's spin state.

These findings could help researchers develop better atomic clocks or lead to new ideas on ways to build a real true functional quantum computer, which would of course revolutionize the field by allowing for systems that operate at orders of magnitude faster processing speeds. One of the major hold-ups at this point is preventing decoherence as data is manipulated and measured. This new research might just be one step towards solving that problem.

More information: Emergence of a Measurement Basis in Atom-Photon Scattering, *Science* 8 March 2013: Vol. 339 no. 6124 pp. 1187-1191 DOI: 10.1126/science.1229650 (on ArXiv)

ABSTRACT

After measurement, a wave-function is postulated to collapse on a predetermined set of states—the measurement basis. Using quantum process tomography, we show how a measurement basis emerges in the evolution of the electronic spin of a single trapped atomic ion after spontaneous photon scattering and detection. This basis is determined by the excitation laser polarization and the direction along which the photon was detected. Quantum tomography of the combined spin-photon state reveals that although photon scattering entangles all superpositions of the measurement-basis states with the scattered photon polarization, the measurement-basis states themselves remain classically correlated with it. Our findings shed light on the process of quantum measurement in atom-photon interactions.