JQI researchers create entangled photons from quantum dots

November 18 2009

To exploit the quantum world to the fullest, a key commodity is entanglement—the spooky, distance-defying link that can form between objects such as atoms even when they are completely shielded from one another. Now, physicists at the Joint Quantum Institute (JQI), a collaborative organization of the National Institute of Standards and Technology and the University of Maryland, have developed a promising new source of entangled photons using quantum dots tweaked with a laser. The JQI technique may someday enable more compact and convenient sources of entangled photon pairs than presently available for quantum information applications such as the distribution of "quantum keys" for encrypting sensitive messages.

Quantum dots are nanometer-scale bits of semiconductor—so small that electrical charges in the dots are confined in all directions. They can be made to emit photons—fluoresce—by pumping in energy to create so-called "excitons," a pairing of an electron and the electron-less "hole." When the electron falls back into the hole, the excess energy is released as a photon. Quantum dots can also host the even more exotic "biexciton," composed of two electrons and two holes.

When a short-lived biexciton decomposes, it undergoes two drops in energy, analogous to descending two rungs of a ladder, and a photon is released at each stage. Physicists have long been trying to use this process to get pairs of entangled photons from quantum dots. What makes entanglement possible is that the biexciton could decay along one of two possible pathways, analogous to two different ladders that both get it to the ground. During its descent it releases a pair of photons with a different kind of polarization (electric field direction) depending on the ladder it descends. If the energy drop at each stage is exactly the same in both pathways, so that the ladders look identical, the pathways become indistinguishable—and as a result the biexciton releases photons with undetermined polarization values. Measuring a photon would both determine its polarization and instantly define its partners—a hallmark of entanglement.

But imperfections within the structure of the quantum dot create differences in the energy levels (rung heights) between the two pathways, making them distinguishable and creating photons with predetermined, clearly defined polarizations. Except in rare instances, this holds true even for the reliable, widely fabricated indium gallium arsenide (InGaAs) dots that JQI researcher Andreas Muller and his colleagues created at NIST. Muller and his coworkers solved this problem by beaming a laser at the quantum dot. The laser's electric field shifts the energy levels in one of the pathways so that the two pathways match up, resulting in the emission of entangled photons.

Entangled photons have come from individual quantum dots before, but they have been spotted by hunting for dots in large samples whose imperfections accidentally gave the two pathways identical energy structure. JQI group leader Glenn Solomon says that this entanglement technique could work for a wide variety of quantum dots. Though the dots must be cooled to cryogenic temperatures, he adds that quantum dots could offer advantages as entanglement sources over their conventional crystal counterparts as they are less bulky and can conveniently produce one pair of entangled photons at a time, instead of in bunches.

More information: A. Muller, W.F.Fang, J. Lawall and G.S. Solomon. Creating polarization-entangled photons from a quantum dot. Upcoming in *Physical Review Letters*.

Source: National Institute of Standards and Technology (news : web)