Quantum technologies move a step closer with the demonstration of an 'entanglement' filter

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(PhysOrg.com) -- A team of physicists and engineers has demonstrated an optical device that filters two particles of light (or photons) based on the correlations between their polarisation that are only allowed in the seemingly bizarre quantum world. This so called "entanglement filter" passes the pair of photons only if they inhabit the same quantum state, without the user (or anything else) ever knowing what that state is.

This device will have many important applications to quantum technologies, including computers, communication and advanced measurement.

Jeremy O'Brien, Professor of Physics and Electrical Engineering at Bristol University, together with his collaborators in Japan, has realised an entanglement filter made by combining two state-of-the-art developments in optical technologies with single photons: a special type of mirror that is sensitive to the polarisation of light; and an optical device that enables stability at the billionth's of a meter level.

The team reports its results in the latest issue of *Science* [23 January 2009].

Professor O'Brien speaking about the research, said: "This is a very exciting development in quantum information science. Because our entanglement filter acts on photonic qubits, it is promising for quantum technologies because photons are the logical choice for communication, metrology and lithography and are a leading approach to information processing.

"The filter can be used for the creation as well as the purification of entanglement, which will be important in realising quantum relays and repeaters for long-distance quantum communication."

An Entanglement Filter

Filters are one of the most powerful tools available in science and technology, while entanglement is the defining characteristic of quantum information science. An entanglement filter is of fundamental interest and will likely find wide application in quantum information science and technology.

Filters that act on the quantum correlations associated with entanglement must operate nonlocally on multiple quantum systems, typically two-level "qubits". Such a device has been proposed for photonic qubits, but the technical requirements to build such a device, an optical circuit with two extra photons and multiple quantum gates, requiring both quantum interference and classical interference in several nested interferomters, have been lacking.

The entanglement filter will be a key element in the control of multiphoton quantum states, with a wide range of applications in entanglement-based quantum communication and quantum information processing.

Quantum technologies with photons

Quantum technologies aim to exploit the unique properties of quantum mechanics, the physics theory that explains how the world works at very small scales.

For example a quantum computer relies on the fact that quantum particles, such as photons, can exist in a "superposition" of two states at the same time - in stark contrast to the transistors in a PC which can only be in the state "0" or "1".

Photons are an excellent choice for quantum technologies because they are relatively noise-free; information can be moved around quickly - at the speed of light; and manipulating single photons is easy.

Making two photons "talk" to each other to realise the all-important controlled-NOT gate is much harder, but Professor O'Brien and his colleagues at the University of Queensland demonstrated this back in 2003 [*Nature* 426, 264]. (www.nature.com/nature/journal/ … 426/n6964/index.html)

Last year, Professor O'Brien's Centre for Quantum Photonics at Bristol showed how such interactions between photons could be realised on a silicon chip, pointing the way to advanced quantum technologies based on photons [*Science* 320, 646]. (www.sciencemag.org/content/vol … /issue5876/index.dtl)

Photons are also required to "talk" to each other to realise the ultra-precise measurements that harness the laws of quantum mechanics - quantum metrology. In 2007 Professor O'Brien and the same Japanese collaborators reported such a quantum metrology measurement with four photons [*Science* 316, 726]. (www.sciencemag.org/content/vol … /issue5825/index.dtl)

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