Creating a six-qubit cluster state

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(PhysOrg.com) -- Many scientists believe that quantum entanglement is required in order for effective quantum computing. Entanglement takes place when there is a connection that exists between two objects - even when they are spatially separated - that allows what happens to one to happen to the other. The link is such that each entangled object cannot be adequately described without its counterpart. So far, entangling qubits for practical use has been difficult, since scientists want to be able to entangle several qubits at once.

The idea of entangling more qubits appears to be gaining traction with a recent experiment conducted the University of Rome in Italy. Giuseppe Vallone is a member of group that was able to entangle a two-photon, six-qubit cluster state. "The degree of entanglement increases with more qubits," Vallone tells *PhysOrg.com*. "If you want a bigger entanglement, you need to be able to work with more qubits. This is moving us in that direction." The results of the experiment can be found in *Physical Review Letters*: "Experimental Entanglement and Nonlocality of a Two-Photon Six-Qubit Cluster State."

Vallone and his peers believe that this represents the first time a six-qubit linear cluster state built using a two-photon triple entangled state has been experimentally demonstrated. The demonstration aims at creating a hybrid method of increasing entanglement by adding more qubits, but also limiting the decoherence that comes when a greater number of particles is involved with the system. "If we can increase the number of particles and degrees of freedom," Vallone explains, "you can get a more highly entangled state, which would have a number of possible uses in a possible future quantum technology."

In order to set up the experiment, Vallone and his colleagues prepared a six-qubit state that was hyper-entangled using two photons with triple entanglement. Longitudinal momentum and polarization were used to encode three qubits in each particle, and then a series of unitary transformations were performed in order to entangle some of the qubits. The process was an extension of work that has been done to create four-qubit states.

To make sure entanglement had taken place, measurements had to be taken. "We measured each particle with the encoded qubits, and measured their states," Vallone says. "Entanglement is a correlation between different systems, and we were able to compare the measurements on the two photons and see that there was entanglement."

Going forward, Vallone hopes that the number of qubits used can be increased to eight. "When you increase the qubits, the computational power grows exponentially," Vallone says. "So it is important to see if we can get this effect with a higher number of qubits. Now that we have shown that it can be done with six, the next step is go on to eight, and then add even more qubits." This way, he continues, it should be possible to eventually use the method for practical quantum computation. "We are trying to use the two-photon state to perform a quantum algorithm that can be seen as a proof-of-principle demonstration of a quantum computer, and I think that we will be able to get there at some point."

More information: Ceccarelli, et. al. "Experimental Entanglement and Nonlocality of a Two-Photon Six-Qubit Cluster State," Physical Review Letters (2009). Available online: http://link.aps.org/doi/10.1103/PhysRevLett.103.160401.