New one-way quantum computer design offers possibility of efficient optical information processing

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One of the most exciting and diverse fields of science today involves quantum information processing. There are many designs for quantum computers suggested, and a few that have been demonstrated. Among the demonstrated suggestions for a quantum computer is a one-way quantum computation process that makes use of a two-photon four-qubit cluster state.

Kai Chen, a scientist at the Physikalisches Institut in Heidelberg, Germany and the University of Science and Technology of China (USTC) in Hefei, China, tells *PhysOrg.com*, "One-way quantum computing model was proposed years ago, but our experiment is a brand new demonstration of the computing model." Chen and his team, lead by Prof. Jian-Wei Pan, which consists of colleagues from the Physikalisches Institut as well as from USTC and the National Chiao Tung University in Hsinchu, Taiwan, present their results in a *Physical Review Letters* piece titled, "Experimental Realization of One-Way Quantum Computing with Two-Photon Four-Qubit Cluster States."

"Our new model of quantum computing is different from the quantum circuit model, which has an input and an output." Chen says. "We use two-photon cluster states, and information is written onto the cluster, processed, and read out from the cluster by one-particle measurements only." He does point out that work is needed to produce this method of obtaining output: "We have designed a specific order and choices of measurements to get desired output."

Cluster states in quantum computing are highly entangled states deemed necessary in one-way quantum computing. In the quantum world, entanglement among quantum objects, such as qubits, is described with reference to the others, even though they may be spatially separated. Indeed, Chen and his colleagues performed their experiment showing a two-photon four-qubit cluster state entangling photons in both spatial and polarization modes.

Chen says that this demonstration of quantum computing is more efficient than other photonic schemes. "Developing and using two-photon cluster states allows us to be four magnitudes more efficient than the previous sources. We are increasing the efficiency of quantum computing."

He also points out that the new design for photonic quantum computing developed by Pan's team allows for high fidelity. "With the previous source, there is a lot of intrinsic noise due to multi-photon generation," Chen says. "Using two-photon, our system offers much lower noise with a very high fidelity quantum gate." This means that more of the information is passed on, and less of it is lost in background noise.

Chen explains that this type of quantum computing is an optical quantum computer, using light. "We have designed a new scheme for producing the four-qubit cluster states, which are based on techniques that we have developed before for generating hyper-entangled states. With our new designs, the scheme is expected to motivate further progress in quantum computing." He continues: "We think this quantum computing technique with optics has a very bright future."

What kind of a future? Chen and his colleagues are already working on ideas for the future of quantum information processing. "We are working on extending qubit numbers to perform more complicated tasks," he says. In their experiment Chen and his peers implemented a Grover's search algorithm. They hope that being able to increase their cluster states to eight qubits or more will "exponentially increase the ability to do quantum computing."

Chen continues: "If we combine our technique of optics with quantum memory using atoms, we can extend our abilities of performing quantum computation and quantum communication. One can think that in the future, we can get a true quantum computer, and have a global quantum network."

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