Graph States and Entanglement

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One of the bigger problems with current experiments on linear optics quantum information is that as the system is scaled up, it leads to inefficient scaling, and this in turn limits implementation to small systems. Luming Duan, a professor at the University of Michigan, and his undergraduate student Tim Bodiya, might have found a way to solve this problem.

"Here we want to find something to improve the scaling," he tells *PhysOrg.com*. "If we start with realistic optical elements, one can realize a many-body state called a graph state." It is this preparation of a graph state that Duan and Bodiya address in their Letter, titled "Scalable Generation of Graph-State Entanglement Through Realistic Linear Optics," published October 3.

Graph states make up an important class of entangled states in physics. They are described in terms of a variety of graph structures that grow with system size. "For graph states that look like a tree," explains Duan, "we can generate them efficiently with realistic linear optics. We have a method that can help find efficient scaling with these states." There are several applications for graph states. Indeed, entangled states are the basis of the current push toward realizing quantum information processing. "Quantum computation or other information protocols," says Duan, are among the most popular applications for graph states. Other applications using graph states include quantum error correction, quantum entanglement, and multi-partite quantum communication. Graph states can also aid in the study of issues of a more foundational nature in quantum mechanics — issues such as decoherence and quantum non-locality.

Because photons are a precious resource in current experimental study, it can be inefficient to waste them. Duan and Bodiya suggest a way to use a polarization beam splitter in order to create a gate for generating graph states. In this model, photons are not wasted in gate operation, and so the model is more efficient. Further efficiency is achieved by the fact that Duan and Bodiya propose a method for scalable generation of many-qubit entanglement.

Their theory posits that the overall scaling is efficient, even when photon source and detectors have moderate efficiencies as in current experiments. This is a departure from other known theories, in which to have an overall efficient scaling, photon sources and detectors must have very high efficiencies, presenting difficulties for experiments. And, the larger the system is, the greater effect for this improvement in scaling. “This overcomes the problems with getting more and more photons entangled,” claims Duan.

Another benefit of the system proposed by Duan and Bodiya is the fact that it makes use of linear optical technologies that are realistic. “This is based on the current technology,” says Duan. “Some things might be needed to put the technology together in a couple of years, but it is something that is realistic.”

Duan admits that this idea is theoretical at this stage. But he insists that working on getting his and Bodiya’s version of scalable graph state generation would overcome problems. “This is a new idea, and hopefully some experimentalists will go in this direction. Many groups want to see more photons entangled, and this is a way to that goal.”

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