Sending quantum information over long distances

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Ever since the idea of quantum communication was proposed, scientists have considered quantum communication systems as completely separate from classical communication systems. However, an international group of scientists is challenging this idea with a quantum communications scheme that incorporates existing classical telecommunications structures.

"This resulting system is more powerful," explains Peter van Loock, one of the authors of the June 19th letter in *Physical Review Letters*, "in addition to classical communication, we'd be able to communicate quantum information."

In their letter, titled "Hybrid Quantum Repeater Using Bright Coherent Light," van Loock and his colleagues from the National Institute of Informatics in Tokyo, the Nanoelectronics Collaborative Research Center in Tokyo, Stanford University, and the Hewlett-Packard Laboratories in Bristol, England explain how it could be possible to use quantum repeaters in tandem with existing fiber optics to send quantum information over long distances using a series of repeaters.

"The idea of quantum repeaters is not new," van Loock explains to *PhysOrg.com*. Scientists have recognized for seven or eight years that repeaters would be necessary in order to prevent the break down of quantum information over long distances. Sending the information over a distance of more than 10 or 20 kilometers could result in the accumulation of so much noise that the original information is gone by the time it reaches the end. A repeater distills the information and then passes it to the next station in a process that would allow information to travel more than 1,000 kilometers.

Van Loock says that other quantum communication schemes concentrate only on using discrete degrees of freedom; entangled matter qubits are distributed by detecting discrete photons or polarization of light. For this, rather than using strong laser pulses, weak pulses are used. While this results in high quality entanglement, it also takes quite a bit of time. Efficiency is low, as there is a great deal of waiting for a successful result.

The theory expressed in the *PRL* letter written by van Loock and his peers works differently. “We have a hybrid system in that we use both discrete and continuous degrees of freedom. The discrete variable describes the spin in the qubits, and the continuous variables describe the light.” A continuous variable, says van Loock, deals more with light amplitudes and phases than with photon numbers. “It is a more natural way to work with light, similar to what people do in classical optics” he says.

Rather than using a weak laser pulse to carry the entangled qubits from repeater station to repeater station, van Loock and his colleagues propose a bright light pulse carrying 10^4 photons. To detect the phase of the light and thus produce the entangled spins, this scheme would use homodyne detection, which is generally used in quantum optics, but not incorporated into current schemes of long-distance quantum information transport.

“The main advantages of our system,” explains van Loock, “are that we have high efficiency of detection and high efficiency of entanglement generation. Even though the entanglement is initially slightly worse [than other methods], it is sufficiently good that we can bring it up to nearperfect entanglement." This is done by a process of distillation.

Van Loock points out that even though the initial fidelity of the system is modest, it works at a much higher speed. Additionally, calculations show that the success rate is at about 40 percent—higher than the success rates offered by other systems.

Right now, such a scheme is theory. However, van Loock says that his Stanford co-authors are already working on ways to experimentally realize the idea. Quantum information transport work is already underway at Stanford, and van Loock believes that once experiments that can establish conditional phase shifts with lasers are realized, it should be possible to experiment with different distribution schemes. The use of bright light, as proposed in the letter, could be tested.

Quantum information transport in this manner would be useful for a variety of future applications, says van Loock: "You could connect quantum computers over long distances, allowing them to exchange information." He also points out that quantum communication is the only unconditionally secure way to send sensitive information. Such a set-up would allow for transmission of secret information without fear of interception.

However, he does point out that there are some applications for which quantum information is unnecessary. "It's more practical to keep with classical communications for many things. Much like in quantum computing, it is only for the more complex things that such a scheme is practical."

And that's the beauty of a hybrid system. It would allow for classical fiber optic communication systems to remain in place, but also be compatible for quantum information transport when needed. "We believe our scheme is more practical than other schemes," says van

Loock. “It takes the best of both the classical and the quantum worlds.”

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