HP researchers propose new path to optical quantum computing

July 4 2005

Researchers from HP Laboratories in Bristol, UK, have proposed an approach to distributed optical quantum computing with a technique that is highly efficient, flexible and scalable.

Quantum computing is expected to be much more powerful than conventional information processing. It should be able to search faster and simulate better, factor large numbers efficiently and virtually guarantee secure communications.

Optical quantum computing – using photons instead of electrons for computation – is one possible approach to quantum computing. The technology might still be several decades away from practical implementation.

The researchers – Dr Bill Munro and Dr Tim Spiller, of HP Labs Bristol, with Professor Kae Nemoto, of the National Institute of Informatics (NII), Tokyo – have proposed an approach that generates interactions between photons by using so-called weak optical nonlinearities and intense laser fields. The result is the creation of two-photon gates, the basic building blocks of a quantum computer. They have published their results in the *New Journal of Physic**.

Normally, photons, the basic components of light, do not easily interact or 'talk' to each other. That is why multiple light signals carrying different information can be sent along a thin optical fibre without interfering with each other. But for quantum information processing and communication, it is vital that photons do interact when called upon to do so. The photons are the qubits – the basic information bits – in this model of a quantum computer.

Why use an optical quantum system rather than solid state? Dr Spiller points out that light can be used for both quantum computing and quantum communication at the same time, which would not be the case with a solid-state system, where "static" quantum information would have to be mapped onto light to communicate it. This means that the approach is suitable for distributed quantum computing, so that small but useful clusters of qubits can be physically separated – even at different sites – but linked together for computation.

The new approach uses weak nonlinearities and strong laser pulses to generate the interaction between the two individual photons. The laser pulse acts as an intermediary between the photons, first 'talking' to one, then the other, so that the two photons become entangled. In quantum processing, generally attempting to check on the state of entangled qubits leads to the collapse of the information they carry. But with the HP-NII team's approach, only the information in the laser pulse collapses; the qubit photons become entangled through this collapse.

Dr Spiller describes single photons – in fact any kind of qubit – as "precious" and points out that optical quantum computing systems that have previously been proposed would need hundreds of them to operate at all. And most of those photons would be wasted. The HP-NII system operates with single photons and wastes none. This makes it much more practical and efficient for quantum information and communication because today, single photons are hard to generate.

At the heart of the system is a single-photon detector – an innovation proposed by the HP Labs team – that is also used as a single-photon source. This is used to generate photons on demand.

The scheme is reliable because the communication between separated quantum processing sites can be mediated by robust laser pulses rather than fragile single photon qubits.

Dr Munro said: “Our approach provides the fundamental building blocks for quantum computation, including highly efficient non-absorbing single-photon detectors, two-qubit parity detectors, near deterministic CNOT gates and more. All these elements are essential quantum information processing devices.” The approach is open for experimentalists to test.

HP Labs is one of the leading corporate research institutions with activities in the field of quantum science. As a global IT company, it is important for HP to be involved in such far-reaching research in quantum information processing, which could have a significant impact on information and communication technology in the future.

*__Publication:__ W J Munro et al 2005 *New J. Phys.* 7 137, [Weak nonlinearities: a new route to optical quantum computation]