Quantum meld brings photons together

Merging the information of two photons could boost quantum-optical technologies.

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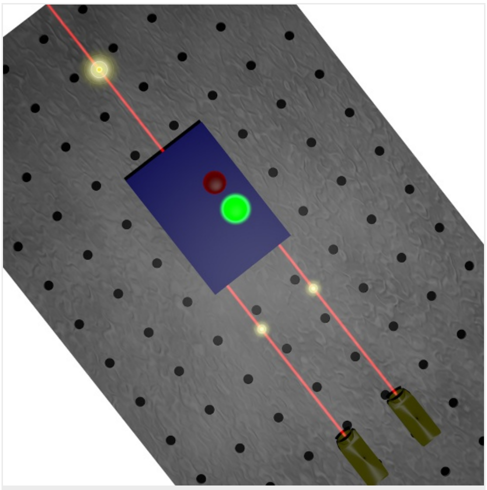
09 May 2013

Encoding information in quantum particles such as photons, the quanta of light, could lead to powerful new technologies, such as ultrafast quantum computers and unbreakable quantum cryptography. A method for loading the information carried by two photons into a single photon, described in *Nature Photonics*[1], suggest a way to boost the efficiency of data transmission in such systems.



Ref. 1

A new device combines the quantum information encoded in two photons into the state of a single photon.

Data streams in conventional fibre-optic networks are routinely combined, or 'multiplexed', to increase network capacity. For example, digital data can be encoded into light pulses of different wavelengths, which are sent simultaneously along a single fibre and separated again ('de-multiplexed') at the other end.

This sort of capability would be handy in quantum information technology too. It would entail feeding the data carried by two or more 'quantum bits', or qubits, into one. Two qubits each carrying a binary digit (1 or 0) — encoded, for example, in the polarization of photons — could be replaced by a single photon with four possible states, capable of specifying both digits.

But because photons do not really interact with one another, it is challenging to transfer the 'contents' of two photons into one. If the photons won't talk, how can the message get across?

Physicists Lorenzo Marrucci of the University of Naples Federico II and Fabio Sciarrino of Sapienza University of Rome and their collaborators have worked out a way to achieve such information transfer. It involves feeding the two initial photons into logic gates — devices that produce binary output signals whose values depend on the inputs.

The researchers used a logic gate called a controlled NOT (CNOT) gate, which takes two input bits and ejects two output bits. One bit, called the control input, is unchanged in the output, but the other, called the target input, is switched (from 0 to 1, say) if the control input is 1.

The researchers combined two CNOT gates constructed from systems of mirrors that split light beams by reflecting some of the beam while transmitting the rest. By using polarized photons as control and target inputs, they were able to extract an output photon that carried all the information of the inputs. They call the process quantum joining.

By running the process backwards, the researchers achieved the reverse process of 'quantum splitting' — extraction of two photons in the same states as those that were originally joined into one. This corresponds to de-multiplexing the signal.

In quantum-mechanical processes, outcomes cannot be predicted perfectly but only with a certain probability. But the researchers have demonstrated experimentally that their setup — which includes lasers to feed beams of polarized light into a network of optical fibres, beam-splitters and other optical devices — gives results that agree closely with their predictions.

"It is a very nice piece of work that comes up with a clever solution to this problem," says Ian Walmsley, a specialist in quantum optics at the University of Oxford, UK.

Walmsley says he does not think that the work will bring quantum computers much closer at present, however. "I don't think one of the bottlenecks to next-generation quantum computers is in this direction," he says. But he feels that the approach could have valuable applications in fundamental investigations of quantum behaviour.

The work “will certainly generate further developments in quantum photonics”, adds Brian Smith, who also works on quantum optical technologies at Oxford. “This transfer of quantum information should have a significant impact on approaches to quantum multiplexing.”

Nature | doi:10.1038/nature.2013.12942

References

1. Vitelli, C. *et al*. *Nature Photonics* advance online publication http://dx.doi.org/10.1038/nphoton.2013.107 (2013).