QUANTUM PHYSICS

Tangled memories

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The latest quantum trick — mapping two entangled photon states onto two separate regions of an atomic cloud, and then retrieving them — could be a fillip for applications, among them quantum cryptography.

On page 67 of this issue, Choi *et al.*[1] recount how they store two 'entangled' photon states in a memory consisting of a cloud of cold atoms, and then, after a certain delay, retrieve those self-same states from the cloud. The optical modes are stored in spatially separated regions of a single atom cloud, but there is no reason why the technique should not be used to imprint the same quantum states on two distinct atom clouds separated by a macroscopic distance. That would allow the controlled entanglement of two distant atomic samples — a step that might be of great importance for the practical implementation of quantum protocols to generate secure keys for the transfer of information over public networks.

Choi and colleagues' experiments start off with a light pulse containing a single photon. Like most of us, this photon soon comes to a point in life — in its case, a beam splitter — at which it is faced with a choice between two paths. In such a situation, the quantum world is kinder than the classical: it allows the photon to take both paths at the same time. If we set up a light detector to monitor one of the two paths, we will register a click (a photon hit) or no click, each with a 50% chance. But say some other (possibly distant) observer sets up a detector to monitor the other path. In this case, if this second observer detects a click, that instantaneously affects our own measurement: we will detect 'no click' with 100% probability (or vice versa, an absolutely certain click if the remote observer has detected no click).

This is entanglement: the strange correlation of two spatially separated quantum states. Entangled states are hard to maintain, because interactions with the environment destroy the entanglement. As a result, they are rare in our macroscopic world. But that doesn't stop them being essential to quantum information processing, for computing, teleportation and encryption applications.

In a classical computer, information is stored in strings of bits of value 0 or 1. The quantum bits of a quantum computer, on the other hand, can be in 'superposition states': they can be 0 and 1 at the same time. Here, entanglement comes into its own. Let's say the quantum computer is set up to calculate the output value of a function that varies periodically with its input value (a sine wave, for example); we wish to find that period. The quantum computation leaves the system in a superposition of matched pairs, in which the output register holds the function value for the corresponding input.

The two registers are in fact entangled: a measurement of the output register will immediately affect the input register. For a periodic function, in which many input values correspond to a particular output value, the input register ends up in a superposition of precisely these inputs. After just one run-through of the calculation, therefore, global information

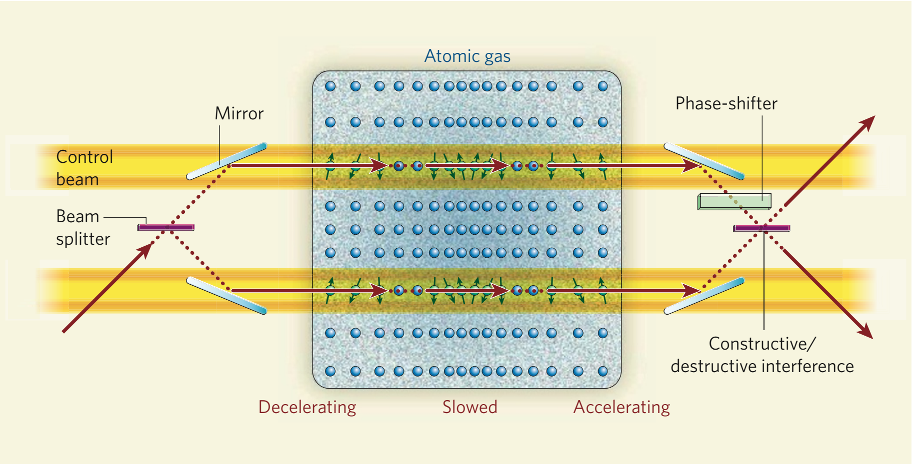

Figure 1 | Light split and slowed. In Choi and colleagues' experimental apparatus[1], a light pulse (red arrow) is split into two entangled states and fed into an atomic gas. There, under the influence of controlling laser beams, the split pulse is slowed, and the two entangled quantum states are imprinted onto two separate regions of the gas — effectively creating entanglement between the atoms of these regions. The light is then extinguished, and after a delay the photonic quantum states are regenerated from the information stored in the atoms. The amount of remaining entanglement is measured through the degree of constructive or destructive interference when the regenerated optical fields are recombined.

50 & 100 YEARS AGO

50 YEARS AGO

"A three-dimensional model of the myoglobin molecule obtained by X-ray analysis." By Drs J. C. Kendrew *et al.* — Until five years ago, no one knew how, in practice, the complete structure of a crystalline protein might be found by X-rays, and it was realized that the methods then in vogue among protein crystallographers could at best give the most sketchy indications about the structure of the molecule. This situation was transformed by the discovery, made by Perutz and his colleagues, that heavy atoms could be attached to protein molecules in specific sites and that the resulting complexes gave diffraction patterns sufficiently different from normal to enable a classical method of structure analysis, the so-called 'method of isomorphous replacement', to be used to determine the relative phases of the reflexions ... The present article describes the application, at low resolution, of the isomorphous replacement method in three dimensions to type *A* crystals of sperm whale myoglobin. The result is a three-dimensional Fourier, or electron-density, map of the unit cell, which for the first time reveals the general nature of the tertiary structure of a protein molecule ... Perhaps the most remarkable features of the molecule are its complexity and its lack of symmetry. The arrangement ... is more complicated than has been predicated by any theory of protein structure.

From *Nature* 8 March 1958

100 YEARS AGO

It is reported by The Hague correspondent of the *Globe* (March 3) that Prof. Kamerlingh Onnes, professor of physics in the University of Leyden, has succeeded in liquefying helium.

ALSO:

In the report of the Maidstone Museum, Library, and Art Gallery for 1907, attention is directed to the unprecedentedly large number of visitors during the year.

From *Nature* 5 March 1908.