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Quantum quirk heralds new generation of supercomputer

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Like something out of Harry Potter, scientists have made light vanish and reappear again, reports Roger Highfield

Scientists have carried out an extraordinary magic trick – converting light into matter and back again - that could be exploited in the next generation of supercomputer.

They have turned a light beam into matter and then converted the matter back into light at another location. Because matter can be manipulated much more easily than light, the experiments provide a powerful new tool to control optical information and exploit the extraordinary possibilities of quantum computers that, in theory, will be able solve problems millions of times faster than current machines.

The findings, published by Harvard University researchers in the journal Nature, could in the short term present an entirely new way for scientists and engineers to manipulate the light pulses used in fibre-optic communications, the technology at the heart of our highly networked society

"We demonstrate that we can stop a light pulse in a supercooled sodium cloud, store the data contained within it, and totally extinguish it, only to reincarnate the pulse in another cloud two-tenths of a millimetre away," says Prof Lene Vestergaard Hau, the head of the team.

The feat exploits quantum theory, a highly mathematical theory of how atoms and molecules behave which has been shown to work again and again, even though it is baffling, counterintuitive and impossible to understand with simple metaphors and analogies.

The new work rests on an implication of quantum theory worked out in the 1920s by Albert Einstein and the Indian physicist Satyendra Bose who found that if a gas of atoms were cooled sufficiently, atoms would "spread" out - so they shed their identities and condense into one "superatom", called a Bose-Einstein condensate.

Prof Hau created two condensates - clouds of around two million sodium atoms cooled to just billionths of a degree above absolute zero. When one cloud was bathed in laser light, it extinguished an injected light pulse and, in effect, stored it as a small holographic imprint in the atoms.

The atomic imprint carrying this stored copy of the laser pulse moved out of the first cloud at 200 metres per hour. This is a snail's pace when compared with the speed of light which is around one million million metres per hour.

The matter imprint of the pulse was then readily converted back into light when it entered the second supercooled cloud around 160 millionths of a metre away (or two tenths of a millmetre), a vast distance in the atomic world. The fidelity with which it can spit out the laser pulse is a consequence of the strange properties of the Bose-Einstein condensate. By the standard of light, an eternity passes between the moment the pulse of light is stored in the first cloud and then revived in the second, offering vast opportunities to manipulate optical information.

"While the matter is travelling between the two Bose-Einstein condensates, we can trap it, potentially for minutes, and reshape it -- change it -- in whatever way we want," she said. "This novel form of quantum control could also have applications in the developing fields of quantum information processing." This form of information processing lies at the heart of quantum computers, the extraordinary properties of which were outlined by theorists such as the late Richard Feynman at Caltech and David Deutsch of Oxford University. While a conventional PC shuffles information in the form of binary numbers, those containing only the digits 1 and 0, which it remembers as the "on" and "off" positions of tiny switches, or "bits."

By contrast, the switches in a quantum computer can be both "on" and "off" at the same time. A "qubit" could do two calculations at once, two qubits would do four and so on. Thus, it was theoretically possible to use quantum computers to explore vast numbers of potential solutions to a problem simultaneously, but many scientists doubted that they could ever be made practical.

But the new work adds to a range of advances in manipulating the quantum world that make scientists confident that quantum machines will be feasible within a few years. Prof Hau said: "This work should allow for classical and quantum information to be carried as light signals in optical fibres and then - at the processor - converted into matter form, processed, and converted back to light and send on its way down another optical fibre".

To store light in a cloud of atoms this way "is standard quantum sorcery," commented Michael Fleischhauer of the Technische Universitat Kaiserslautern, Germany. But he added that to then restore the light is astonishing. "Retrieving the same light pulse from a second, distant set of atoms looks rather like black magic. But it, too, is just quantum mechanics."