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The quantum snapshot

The elusive world of quantum computing has come one step closer, says S.Ananthanarayanan.

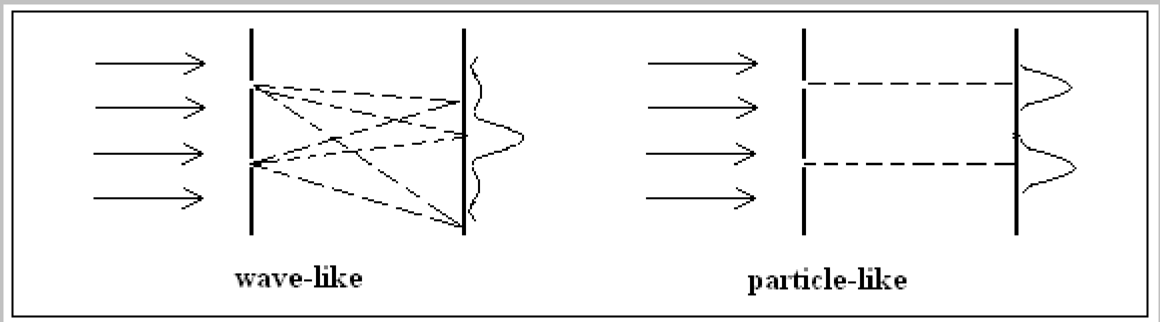
Nature, at the atomic scale, begins to move in ‘steps’, or quanta, rather than continuously, and things exist not in one of possible states but in ‘all states at once’, with some chance of being found in any of them. The physics at this scale then allows that searches, which normally must be serially, one path at a time, to be carried out as ‘all paths at the same time’, or, for particles, which must normally be at one place at a time, to be at ‘all places at the same time’. This counterintuitive nature of reality at the microscopic scale has potential for high speed computing and in secure communications – but the conditions for ‘all searches’ or ‘all places’ to actually exist, or are ‘entangled’, as it is called, are difficult to maintain for practical use.

Choi, Deng, Laurat and Kimble, at the California Institute of Technology, Pasadena, report an that they are able to ‘record’ an entangled state, which may exist very fleetingly, for later retrieval.

Quantum effects

We know that light moves in waves and also that light of any colour consists of ‘particles’ or wave packets, called ***photons***, all of the same size, frequency and energy. This two-fold nature of light leads to some strange results in experiments.

Take a beam of light shone on a barrier with 2 small holes that can let light through. If the holes are close together, light that passes through the barrier and strikes a screen on the other side shows an interference pattern, because of the wave nature of light. This is because the light striking points on the screen where the distance from both the holes is the same, or where the difference in the distance is a round number of ‘steps’, or wavelengths, will be brightly lit. But where the waves come ‘out of step’, they will cancel and we find dark spots or bands. Most of us may have seen this in action at the seaside, where incoming waves sometimes ‘add’ with the backflow, and sometimes cancel out.



But in the case of light, we can also say that what is passing through one hole or the other are really whole photons, with no question of interference with ‘light from the other hole’. This is also found to be the case – if we set up detectors to detect a photon when it passes through either hole, then the detector for the other path always shows ‘no photon’, or vice versa. In fact, if we did check on which hole the photon passed through, the interference pattern, which comes from the ‘both holes’ condition, also disappears.

The resolution of the paradox is that so long as we do not interfere with the system, the photon follows ‘both paths at once’ and shows interference effects. But if we check, or detect the path, then a ‘1’ for one path immediately sets the value for the other path to be ‘0’. The 2 paths, when left alone, are said to be ‘entangled’, but a measurement on either one permanently fixes the value of both paths.

Quantum computing

This property suggests the possibility of a computer which can work ‘in parallel’ where otherwise, it must work ‘in sequence’. For instance, the computer that needs to check a million names in a database to identify a taxpayer may take many seconds. But if the computer could check all the names at the same time, then the search would be over in the time taken for a single comparison!

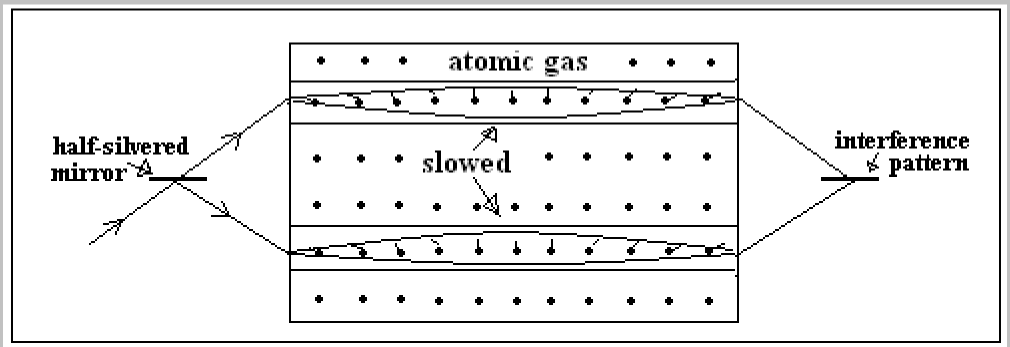
The way computers actually work is with electronic devices, which are in one of 2 states, ‘on’ or ‘off’, to represent ‘1’ or ‘0’, placed in arrays, to represent numbers, letters and so on. The devices could be replaced by photons or atomic particles, which could be in ‘path 1’ or ‘path 2’ or even ‘spin up’ or spin down’. At the atomic scale, with the possibility of ‘entanglement’ of these 2 states, many numbers, letters, etc could be represented at the same time, for computation, but only if we could hold on to this ‘entangled’ state long enough!

Nature seems to make use of such effects in computing paths, for instance in photosynthesis. Photosynthesis, where light is converted into chemical energy, is incredibly efficient, compared to man-made methods of energy conversion. The reason is the optimum choice of the path taken by light, within chlorophyll-rich, green leaves, to move to the centres of energy conversion. It has been found that the photons compute by ‘all paths at once’ to instantly determine the best path for highest efficiency of energy conversion!

Holding ‘entanglement’

The scientists at Caltech split a beam of light into two parts, using a splitter, like a half-silvered mirror. The two parts of the beam were then passed through a gas of atoms, which would be affected by the light passing through. In this case of a split beam, so long as the two portions are not worked upon, the two parts of the beam would be ‘entangled’, and the effect on the atoms affected by the beams would be in the same, delicate condition.

The Caltech scientists used a form of ‘slow light’, where the speed of a light pulse injected into a gas of atoms at low temperatures, bathed in laser light can be slowed down. When the light particle slows down, it shrinks in size and the wave packet is entirely within the gas. If the laser is switched off, the light could get extinguished, but the imprint of the light pulse is recorded in the state of the many atoms, in an entangled state.



Now, if the laser is switched back on, the light particle is revived, its precise state safe in the atom gas and the split beam can be recombined, etc. This kind of storage of optical information in atom clouds has been demonstrated for single photons and also for many photons at once.

The Caltech scientists have also shown that the entanglement of the two beams also survives the ‘storage’ in the atom gas. When the beam is revived and measurements are made, the same effect of measurement of one split part fixing the state of the other is seen. It has even been possible to slow down one part of the beam more than the other and control the kind of entanglement!

The results represent a way of recording optical quantum state information on to quantum states of a material. It is in such material components that the future of quantum computing is most promising. But fast communication of such short-lived conditions is vital for the capability to be of use. That ‘entanglement’ can be transferred between atom gas – light beam offers the possibility of transferring ‘entanglement’ over distances.