Atomic nuclei intimately entangled by a quantum measurement

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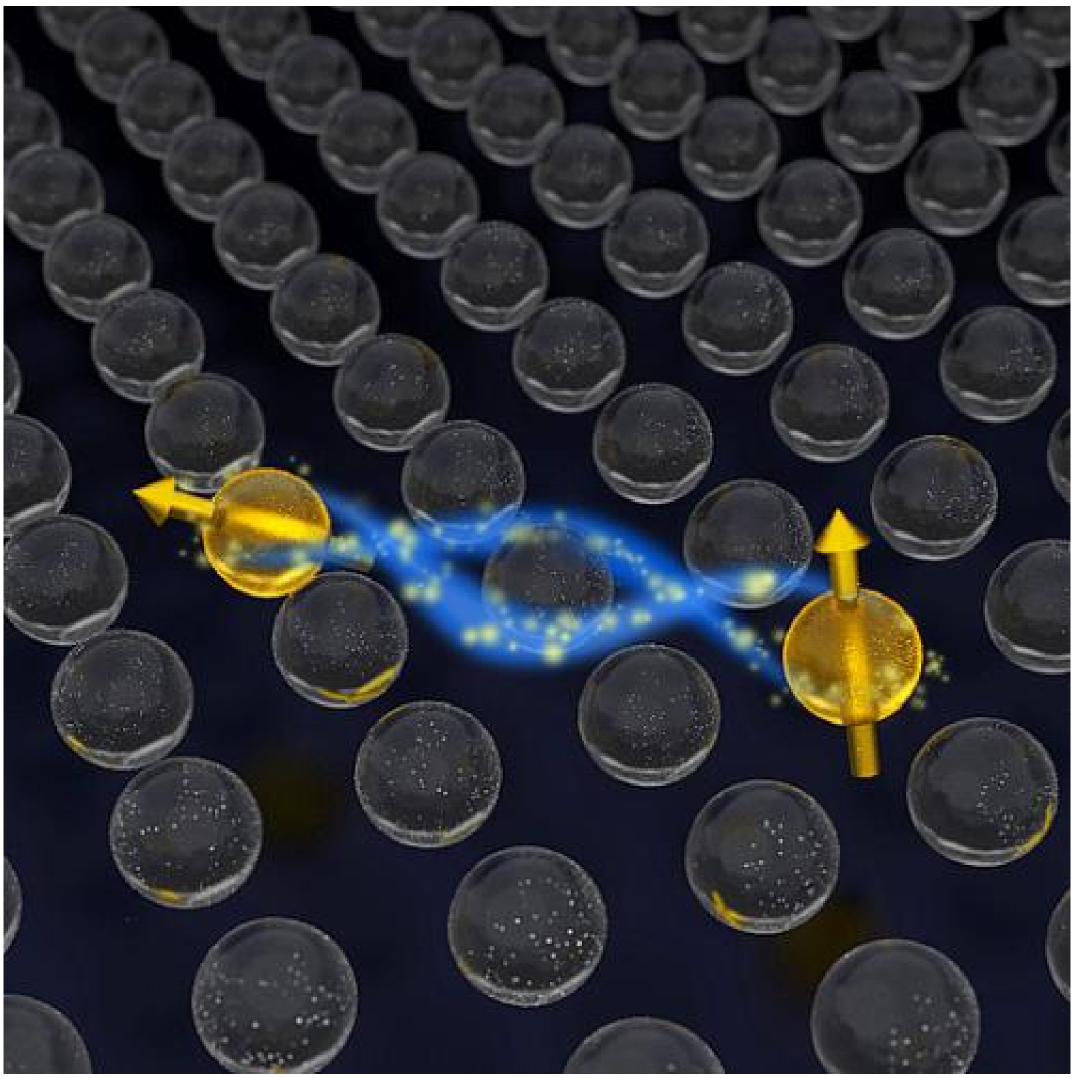

Scientists from the Netherlands (Delft University of Technology and the FOM Foundation) and the UK (Element Six) have brought two atomic nuclei in a diamond into a quantum entangled state. This exotic relation was created by subjecting the nuclei to a new type of quantum measurement. These experiments mark an important step towards the realization of a quantum computer. The results were published on 14 October 2012 online in *Nature Physics*.

Quantum entanglement is one of the most intriguing phenomena in physics. When two particles are entangled their properties are so strongly connected that they lose their own identity. Measuring both particles yields fully correlated outcomes, even when the particles are very far apart. Einstein famously called this feature 'spooky action at a distance'. It was only after John Bell found an inequality that could prove these weird properties that entanglement was accepted as a fundamental part of nature. Today, quantum entanglement is recognized as a resource for revolutionary new technologies that could provide secure communication and ultra-fast computation.

Atomic nuclei in synthetic diamond are promising building blocks for a quantum computer. These nuclei behave like a tiny magnet (spin). The two possible orientations of the spin (up or down) can be used to encode quantum information. Scientists from Delft University of Technology (Netherlands) reported last year in Nature that they could control and read out individual nuclear spins. Furthermore, using chemical vapour deposition techniques, the Element Six team (UK) produced synthetic diamond, where due to its exceptional purity the quantum states of the nuclear spins were well protected from their environment. However, interactions between nuclear spins in synthetic diamond are weak, making it challenging to create the entanglement required for quantum computing. The scientists from Delft, working in partnership with Element Six, have now overcome this challenge by exploiting a special property of quantum measurements.

Quantum measurements not only provide information about a system but also force the system to choose between its possible states. This projective nature of quantum measurements makes them a powerful tool for manipulating quantum systems. The team used an elegant variation on the conventional quantum measurement to generate the desired entanglement. Instead of probing the spin state of each nucleus separately, they measured a joint property of the two nuclei without gaining any knowledge on the individual states. In particular, the measurement forced the nuclei to either assume the same spin orientation or opposite ones, thus imprinting the desired correlations.

The scientists proved that the nuclei were entangled by violating the famous Bell inequality; the first demonstration with spins in a solid. The team now plans to use the entanglement to demonstrate basic quantum algorithms that have no classical counterpart, such as the teleportation of spin states.

More information: Pfaff, W., et al. Demonstration of entanglement-by-measurement of solid-state qubits. *Nature Physics.* DOI: 10.1038/NPHYS2444

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