Electrically controlling magnetic polarization of nuclei offers new way to store quantum information

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Storing information in long-lasting quantum states is a prerequisite for building quantum computers. Intrinsic properties of nuclei known as magnetic spins are good storage candidates because they interact weakly with their environment; however, controlling them is difficult. Now, researchers in Japan have demonstrated an all-electrical method for preparing the magnetic states of nuclei that would be useful in storing quantum information. Keiji Ono at the RIKEN Advanced Science Institute, Wako, led the work.

In an [atomic nucleus](), protons and neutrons pair up such that their magnetic spins align in opposite directions. However, in [nuclei]() with an odd number of protons and neutrons, this pairing is incomplete; thus, they have a so-called 'magnetic moment' that points in no particular direction, hindering control.

Nuclear spins are difficult to align except at low temperatures and with large magnetic fields. But in devices called quantum dots, Ono and other researchers have shown they can manipulate the nuclear spins electrically. A quantum dot is made from a semiconductor material of just a few tens of nanometers in size. Using an external voltage (Fig. 1), the researchers could add electrons to a quantum dot one at time.

Similar to protons and neutrons, a single electron on a quantum dot possesses a spin that acts like an effective magnetic field on the surrounding nuclear spins. Physicists have used this interaction to control nuclear magnetic moments; but, they had only succeeded in significantly polarizing the nuclear moments in one direction. Ono's team, however, showed that it is possible to polarize the nuclear moments either up or down—a quantum version of the '1' and '0' on a digital bit.

Ono and his team demonstrated this behavior in a double quantum dot—two quantum dots in series—made from the semiconductor gallium-arsenide. They showed they can 'pump' the nuclear spins into a particular direction by using voltages to place one electron on each dot and then polarize their spins such that they are either both up, or both down. As the spins on the dot relaxed, they 'dragged' the nuclear spins, polarizing them in the process. The nuclei remained polarized for several milliseconds—significantly longer than the polarized states of electron spins in similar devices.

The work offers a new way of controlling nuclear spins, says Ono, who now plans to study the polarization reversal process of the nuclear spins in more detail. Nuclear spins could "become a ubiquitous resource for storing information in a semiconductor," he adds.

More information: Takahashi, R., Kono, K., Tarucha, S. & Ono, K. Voltage-selective bidirectional polarization and coherent rotation of nuclear spins in quantum dots. *Physical Review Letters* 107, 026602 (2011). prl.aps.org/abstract/PRL/v107/i2/e026602

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