Can Neutrons be Used in Quantum Computers?

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“In quantum mechanics, you typically have arguments about locality and non-locality,” Yuji Hasegawa tells *PhysOrg.com*. “But in our experiment we are testing correlation between degrees of freedom.”

Hasegawa, a scientist affiliated with the Atominstitut der Österreichischen Universitäten and PRESTO at the Japan Science and Technology Agency, feels that the most recent experiment undertaken by him and his colleagues will offer a new way to look at questions involving quantum information processing. The results of the experiment appear in *Physical Review Letters* with the title “Quantum Contextuality in a Single-Neutron Optical Experiment.”

Hasegawa explains that photons are most often used in quantum information technology, but that he hopes that this recent experiment, which is fundamental in nature, will contribute to the consideration of different quantum systems, including neutrons, for quantum information processing.

Hasegawa and his colleagues, Rudolf Loidl and Matthias Baron from the Atominstitut and from the Institut Laue Langevin in France, and Gerald Badurek and Helmut Rauch at the Atominstitut, suggest that noncontextual theories involving neutrons are clearly violated with the results of this experiment. This most recent experiment is related to a paper published in 2003 in the journal *Nature*. In the previous paper, Hasegawa and his colleagues address Bell-like inequalities found in neutrons. However, with this new experiment the Kochen-Specker theorem is tackled, looking at quantum contextuality:

"We use a neutron interferometer, and the Schrödinger equation represents our phenomena. We wanted to show a contradiction in noncontextual theories. We wanted to show a prediction in quantum mechanics. There's a contradiction in Kochen-Specker with photons, and we wanted to show it with neutrons."

Hasegawa explains that the experiment took place at Institut Laue Langevin (ILL) in France, with the largest reactor in the world, and made use of polarized neutron beams split inside the interferometer. With some manipulation, observations of three separate products were measured. After the analysis was performed, the values were found to be outside the limits predicted by noncontextual hidden variable theory. The contradiction was found.

There is no way to obtain a completely ideal experimental situation, Hasegawa admits, but the interferometer was key to the experiment. "Our neutron interferometer experiment is one of the best suited for such a fundamental experiment." He also points out that single neutrons were used. "Instead of two particles as usually used in two-photon entanglement experiments," Hasegawa says, "we used two degrees of freedom in single particles."

Even though entanglement between different particles is considered essential for their use in quantum information processing, this does not appear to be the case with single-neutrons. With the use of entanglement between degrees of freedoms in this experiment, Hasegawa believes that single particles are good candidates for quantum information processing: "This neutron case is completely different from the photon case," he says. "They have mass and spins and obey Schrödinger equation. This experiment shows that they can probably be used for information processing as well as for fundamental research in quantum mechanics just like photons.”

Hasegawa continues: “I hope that this fundamental experiment can help with further technical development in quantum information processing.”

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