Fundamental quantum mechanical experiments in perfect crystal neutron interferometry

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Since the introduction of neutron interferometry in 1974, it has been proven to be a powerful tool for the investigation of fundamental quantum phenomena. The neutron can simultaneously pass two spatially separated points and therefore be manipulated differently before being recombined and detected, enabling quantum entanglement and weak measurements of spin and path.

Pushing the limit of neutron interferometry, a newly developed perfect crystal neutron interferometry setup with active temperature stabilization and innovative 3D-printed spin-manipulation devices, can provide valuable information on many fundamental quantum effects. The novel device has been used at the ILL Grenoble to investigate quantum phenomena with neutrons and therefore a pure quantum mechanical system for the first time. The results presented include measurements of Bell's inequalities, the Cheshire Cat, and a which way experiment.

The Bell's inequality measurement is the answer to Einstein's question asked in the EPR paradox, on whether or not a deterministic hidden variable theory can replace probabilistic quantum theory, proving that god does roll dice after all.

The quantum Cheshire Cat describes (analogous to the cat from ‘Alice in Wonderland’) the separation of the cat and its grin, i.e. the neutron and its spin in the physics case. The first measurement of this effect is realized using a weak measurement scheme.

The well-known double-slit experiment raised the question which way a particle takes in an interferometric experiment and how to trace it. Using a newly constructed double loop interferometer and a time resolved detector signal, a which way experiment asks the neutrons where they have been and surprisingly gets an answer as well.