Direct extraction of path weak values from interferograms without auxiliary qubits

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Since the first definition by Y. Aharonov, D. Albert, and L. Vaidman [1], weak values have gained an important role in the field of quantum physics. In particular, they have been shown to be strictly related to many fundamental concepts of quantum mechanics, such as: uncertainty relations [6], negative quasi-probability distributions [5], quantum paradoxes [2], and more [4]. Neutron interferometry has historically been a pillar in studying the foundations of quantum phenomena, and once more revealed itself to be a valuable tool for the study of weak values. The 2 paths of an interferometer constitute a two-level quantum system: it is in all regards a qubit. Moreover, the established quantum nature of neutrons, which enter the interferometer one particle at a time, doesn't leave space to any other classical interpretation of the phenomena. Weak values of the path operators have been extracted by using an ancilla qubit, such as the spin of the neutron [3]. In our experiment we show that the full path weak value information (real and imaginary part) can be encoded in simple interferograms, without the need of auxiliary qubits. The experiment is realized using unpolarized neutrons traversing a triple Laue neutron interferometer with two phase shifters; one is used for the preparation and the other is for the manipulation of the state. The absence of polarization and spin analysis is a great advantage as it preserves a high neutron flux, significantly reducing the measurement time. The results clearly confirmed that it is possible to extract the real and imaginary part of the path weak values using interferograms.

References

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