Twin Paradox in Light-Pulse Atom Interferometry

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Light-pulse atom interferometry has matured into a standard tool for the realization of high precision experiments, quantum sensing applications as well as tests of relativity. The latter relies on the fact that the phase of a matter wave is partially determined by proper time [1] and thus atom interferometers are in principle susceptible to special- and general-relativistic time dilation. On the other hand the proper time of a classical observer is defined operationally [2, 3] as the quantity an ideal clock [4] placed at the observer's position measures while the observer moves along a worldline. This relative definition of time directly leads to the twin paradox when two classical clocks are compared after moving along two different worldlines where they experience different amounts of time dilation. However, contrary to the classical clocks used in the formulation of general relativity, today's most accurate clocks are atomic clocks and thus quantum objects which obey the superposition principle. Consequently, an atomic clock can be brought into a superposition of moving along different worldlines which is impossible for classical clocks. This is naturally achieved by combining atomic clocks with atom interferometry in the form of quantum clock interferometers [4, 5]. This combination directly suggests that a *single* quantum clock traveling in *superposition* along two *different* worldlines experiences a twin paradox with itself. In our contribution we demonstrate which type of atom interferometers implement such a quantum twin paradox and how it manifests in an interferometer. Furthermore, we show how to generally describe quantum clock interference and reveal its sensitivity to different types of time dilation.

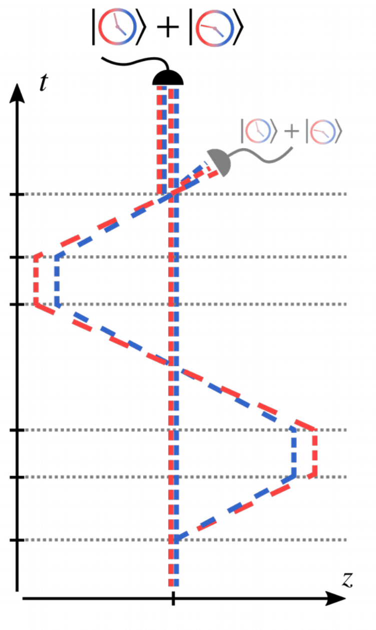

Fig. Twin-paradox in quantum clock interferometry.

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