

Interference of clocks: A quantum twin paradox

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Atom interferometry has become an excellent tool for high-precision quantum metrology as well as a testbed for the interface of relativity and quantum mechanics. On the other hand, quantum systems in the form of atomic clocks are routinely employed in tests of special and general relativity. The combination of atom interferometry and atomic clocks in terms of quantum-clock interferometry [1,2] is a promising candidate for the investigation of special and general relativistic effects with and on quantum objects.

Proper time determines the phase of matter waves, such that atom interferometers are in principle susceptible to time dilation. However, the kinetic symmetry of the interferometer determines whether proper time differences have an impact on the measured interference pattern. We show which type of light-pulse atom interferometers, performed with a single internal atomic state, are sensitive to time dilation. Only geometries that entail the special-relativistic twin paradox display time dilation, whereas gravitational effects do not contribute in lowest order. In such a configuration, recoil measurements that can be used for the determination of the fine structure constant are sensitive to proper time differences [3,4].

When each of the two quantum twins in such a setup carries a superposition of two internal states which constitute a clock, the visibility of the signal is modulated, which can be interpreted as a beating of the interferometers associated with each state. We propose a specific geometry for a quantum clock experiment that displays a genuine implementation of the twin paradox in light-pulse atom interferometry.

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