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Photon exchange and Decoherence in Neutron Interferometry

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ABSTRACT

The general subject of the present work concerns the action of time-dependent, spatially restricted magnetic fields on the wave function of a neutron. Special focus lies on their application in neutron interferometry. For arbitrary time-periodic fields, the corresponding Schrödinger equation is solved analytically. It is then shown, how the occurring exchange of energy quanta between the neutron and the modes of the magnetic field appears in the temporal modulation of the interference pattern between the original wave function and the wave function altered by the magnetic field. By Fourier analysis of the time-resolved interference pattern, the transition probabilities for all possible energy transfers are deducible. Experimental results for fields consisting of up to five modes are presented. Extending the theoretical approach by quantizing the magnetic field allows deeper insights on the underlying physical processes. For a coherent field state with a high mean photon number, the results of the calculation with classical fields are reproduced. By increasing the number of field modes whose relative phases are randomly distributed, one approaches the noise regime which offers the possibility of modeling decoherence in the neutron interferometer. Options and limitations of this modeling procedure are investigated in detail both theoretically and experimentally. Noise sources are applied in one or both interferometer path, and their strength, frequency bandwidth and position to each other is varied. In addition, the influence of increasing spatial separation of the neutron wave packet is examined, since the resulting Schrödinger cat-like states play an important role in decoherence theory.