Weak values in solid state systems: Charge sensing amplification and decoherence effects

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In a classical measurement it is possible to acquire information about the state of the measured system without affecting it. In a quantum measurement, instead, the detector's back-action cannot be avoided, as described, in the simplest version, by the the wave-function collapse [1]. In a more refined description, a quantum measurement is a continuous process of data acquisition by a detector, alongside gradual modification of the system's state. In this framework, weak (non-invasive) measurements are possible, wehere the limited information acquired by the detector corresponds to a weak back-action. A remarkable consequence is the emergence of a new quantum mechanical average, termed weak value (WV) [2] as a result of a weak measurement followed by a second strong one. The outcome of the first is conditional on the result of the second (post-selection). Weak values are complex numbers and their real part may take peculiar values, out of the range of eigenvalues of the measured observable. They are insightful quantities to address fundamental aspects of quantum mechanics, including the simultaneous detection of different observables. Recently weak values protocols have been employed for ultra-sensitive detection of small quantities in quantum optics [3].

Here, after introducing the concept of weak values, we briefly discuss recently proposed protocols for the observation of weak values in solid state systems. We address the detrimental effects of decoherence due to fluctuations of the system's parameters, and identify in what conditions peculiar weak values are still observable. We then focus on a recently proposed protocol [4] employing weak values to obtain ultra sensitive amplification of weak signals in the context of a solid state setup. We consider an Aharonov-Bohm interferometer where both the orbital and the spin degrees of freedom are weakly affected by the presence of an external charge to be detected. The interplay between the spin and the orbital WVs leads to a significant amplification even in the presence of finite temperature and voltage.

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