Dephasing by a Zero Temperature Detector and the Friedel Sum Rule

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Detecting the passage of an interfering particle through one of the interferometer's arms, known as "which path" measurement, gives rise to interference visibility degradation (dephasing). Here we consider a detector at *equilibrium.* At finite temperature dephasing is caused by thermal fluctuations of the detector. More interestingly, in the zero temperature limit, equilibrium quantum fluctuations of the detector give rise to dephasing of the out-of-equilibrium interferometer. This dephasing is a manifestation of an orthogonality catastrophe which differs qualitatively from Anderson's. Its magnitude is directly related to the Friedel sum rule.

We condsider an electronic Mach-Zehnder interferometer, one arm of which is coupled electrostatically to a detector. The interferometer is defined by the outer edge channel of a $\nu = 2$ quantum Hall setup while the detector consists of localized electronic state, which is tunnel coupled to the inner edge. We consider two limiting cases, i) where the outer edge channel can freely pass through the detecter, and ii) where the detector is a closed quantum dot embedded in the upper arm of a Mach-Zehnder interferometer. In the first case, we find that thermal fluctuations of the occupancy of the localized state lead to dephasing through statistical averaging over shifted interference patterns [1]. In the limit of zero temperature, the passage of an electron through the upper arm of the MZI modifies the many-body state of the detector. The degree of dephasing depends on both the magnitude of the system-detector coupling, and the strength of quantum fluctuations in the detector. The former can be expressed through the Friedel sum rule. In the second case of a closed dot, transmission resonances and phase lapses can be studied, in analogy to, but in clear distinction from, studies of quantum dots in zero magnetic field. We find that there are two possible mechanisms for the occurrence of phase lapses and dephasing: Changes in the occupancy of the inner edge state, and population switching due to the Coulomb interaction inside the dot.

We stress that our dephasing protocol [2] involves energy transfer from the system (MZI) to the detector. Our results provide a conceptual and technically workable framework for dealing with tunable zero temperature dephasing.

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[1] E. Weisz, H.K. Choi, M. Heiblum, Y. Gefen, V. Umansky, and D. Mahalu, Phys. Rev. Lett. **109**, 250401 (2012).
[2] B. Rosenow and Y. Gefen, Phys. Rev. Lett. **108**, 256805 (2012).