Adiabatic Passage and Noise in Quantum Dots

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I. INTRODUCTION

The dynamics at avoided level crossing is an intriguing topic since the early days of quantum mechanics. As early as in 1932, Landau, Zener, Stückelberg, and Majorana independently of each other derived the well-known formula for the corresponding transition probability. Today in the realm of quantum dots, adiabatic transitions motivated both theoretical and experimental investigations on the control of solid state qubits. Here we discuss two applications for which noise plays a crucial role: In the first one, shot noise of an electric current is used as signal; in the second one, we analyze how quantum noise stemming from substrate phonons influences of repeated adiabatic passages.

II. COHERENT TRANSFER BY ADIABATIC PASSAGE

Adiabatic passage of an electron in a triple quantum dot from the first to the last dot without ever occupying the middle dot recently attracted much attention. This coherent transfer by adiabatic passage (CTAP) represents an all-electronic version of stimulated Raman adiabatic passage. A major experimental obstacle for the implementation of this protocol is the impossibility of directly measuring the non-occupation of the middle dot, because the unavoidable backaction would influence the effect that it should substantiate. It will be shown that an indirect verification is possible by attaching electron source and drain to the triple dot. Then the protocol can be repeated such that a steady state current flows. The noise properties of this current hint on the proper course of the protocol.

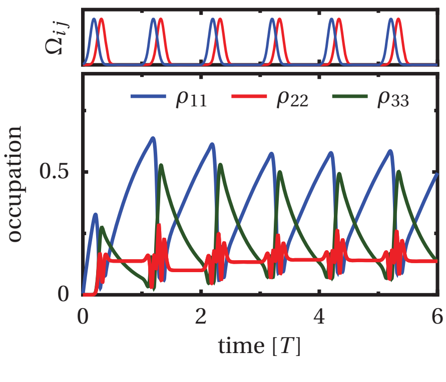

FIG. 1. Upper panel: Sequence of Gauss pulsed tunnel matrix elements that induce adiabatic electron transfer from the first to the third quantum dot[1]. Lower panel: Resulting occupation of each quantum dot. The middle dot (dot no. 2) exhibits only a small occupation which changes considerably less than the occupation of dots 1 and 3.

III. LANDAU-ZENER INTERFEROMETRY

Quantum dots with long coherence times also allow the implementation of tunnel phenomena under the influence of AC driving. In a comprehensive picture, one may study the average current as function of the static level detuning and the driving amplitude. This yields a so-called Landau-Zener-Majorana-Stückelberg (LZSM) interference pattern similar to one found with superconducting qubits. The experimentally observed fading of this interference pattern with increasing temperature is explained in terms of a transport calculation for which a Caldeira-Leggett-like coupling to bulk phonons is considered. The comparison with experimental data allows one to determine the parameters of the system-bath model and to draw conclusions on the coherence time of charge qubits.

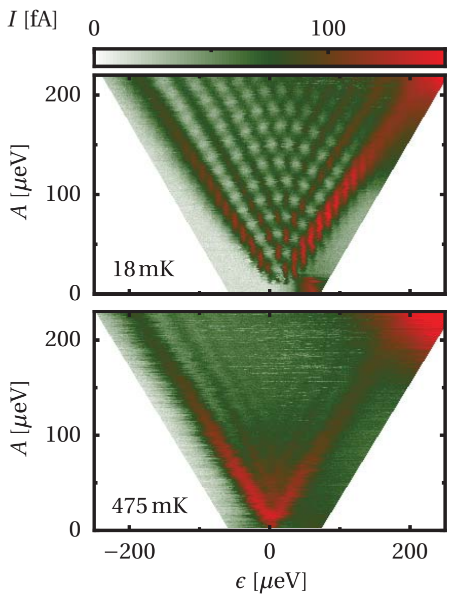

FIG. 2. Measured LZSM pattern as a function of the DQD detuning and the driving amplitude for two different temperatures[2]. A comparison with corresponding theoretical data allows one to determine the coherence times T_2 and T_2^*.

IV. ADIABATIC PASSAGE IN THE PRESENCE OF A CHARGE MONITOR

Many recent realizations of quantum dots include a charge monitor, i.e., a quantum point contact whose conductivity is affected by the capacitive interaction with the dot electrons. Measuring the current through the point contact implies monitoring the dot occupation. In the case of coherently coupled quantum dots, such measurement entails backaction on delocalized quantum dot states. It can be shown[3] that if the measurement is sufficiently strong to provide useful information, the inter-dot tunneling becomes essentially classical. Since adiabatic passages rely on quantum coherence, one must assume that it is strongly affected by such detector backaction. So far, only the basic measurement effects have been investigated, while the impact of the charge monitor on a more complex quantum dynamics such as CTAP or LZSM interference requires the development of a proper formalism for the full setup including the monitor. This is particularly challenging for a point contact with transmission close to unity, because it must combine a formalism suited for quantum dots (weak dot-lead coupling, strong interaction) with a scattering formalism which addresses the opposite limit. This would also allow testing fluctuation theorems along the lines of Ref. 4, but beyond the regime of intermediately strong wire-lead coupling.

ACKNOWLEDGMENTS

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