# Open Quantum Dots under a Strictly Parallel Magnetic Field: Influence of Orbital Effect on Universal Conductance Fluctuations

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Open quantum dots built from two-dimensional electron gas (2DEG) are an ideal system to investigate the electronic transport properties at the mesoscopic scale. During the last decade, magnetotransport measurement on these systems were mainly performed with the magnetic field applied perpendicular to the 2DEG.. Recent experiments [1-3] have generated a growing interest for the in-plane magnetic field effect on the transport characteristics of quantum billiards. We present magnetotransport measurements performed on ballistic cavities under a *purely* parallel magnetic field. Such a configuration allows one to study the effect of finite thickness and electrostatic profile of the 2DEG confinement potential on the quantum dots conductance fluctuations.

Two identical cavities of 3 µm² were patterned on two different AlGaAs/GaAs quantum wells with widths of 15 nm and 40 nm and densities of $2\ 10^{11}\ cm^{-2}$ and $3\ 10^{11}\ cm^{-2}$ respectively. In the wide quantum well (WQW) the two lowest subbands are occupied while in the case of the narrow quantum well only the ground state is populated. By means of an electrostatic top gate, we are able to tune the electronic density and to control the number of modes in the quantum point contacts. Measurements were performed down to 300 mK and the experimental setup allows us to precisely control the angle between the 2DEG and the magnetic field[1].

The conductance of the quantum dots as a function of a parallel magnetic field is shown on Fig.1. With both samples, we observe unexpected conductance fluctuations associated with coherent transport in the cavities. In the WQW, the fluctuations are superposed upon a slowly varying background generated by the magnetic depopulation of the second subband. Due to finite thickness, the parallel magnetic field induces an orbital effect, which lifts the degeneracy in k-space and increases the density of state. Since the voltage applied on the top gate determines the electronic density, the magnetic field depopulates the upper subband, moving the Fermi level toward the bottom of the conduction band [4]. This displacement of the Fermi level probes the discrete density of state of the dot, generating universal conductance fluctuations (UCFs) just like a perpendicular magnetic field would do. In the case of the NQW, we observe fluctuations that vary much slower than in the WQW billiard. This behavior is attributed to the stronger confinement of the 2DEG that reduces the transverse magnetic flux encircled by the electrons and to the absence of inter-subband mixing [5,6].

By applying a high-pass filter to the conductance of the WQW, we isolate the UCFs from the slowly varying background. The variance of the conductance fluctuations as a function of the parallel magnetic field is shown on Fig.2. The variance decreases by a factor of 4 to 6 when the magnetic field depopulates the second subband. If the upper subband is emptied by applying a high voltage on a back-gate, the variance of the fluctuations remains constant when the magnetic field is swept up to 7 T and is comparable to the variance of high parallel magnetic field in the two subbands case. These observations indicate that the presence of a second subband plays an important role in the transport properties of ballistic cavities in such a magnetic field geometry.

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[1] Accuracy of 0.01° : The angle is determined by transverse magnetoresistance measurements on a Hall bar adjacent to the cavity.

In summary, we have studied the transport properties of open quantum dots under a *strictly* parallel magnetic field. We show the existence of UCFs in this measurement configuration and observe a decrease of the UCFs variance when two subbands are occupied. We discuss these observations in terms of finite thickness, confinement geometry, Zeeman energy splitting and orbital effects [7].

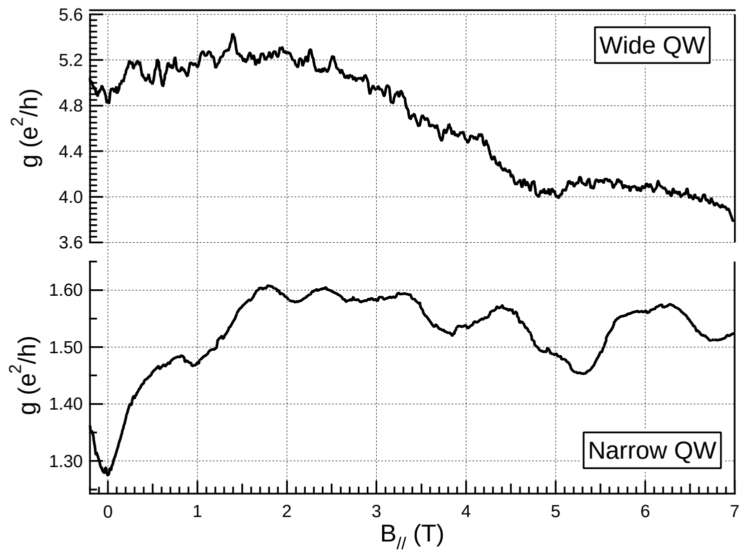


**Figure 1 : Magnetoconductance of the two cavities subject to strictly parallel magnetic field.**

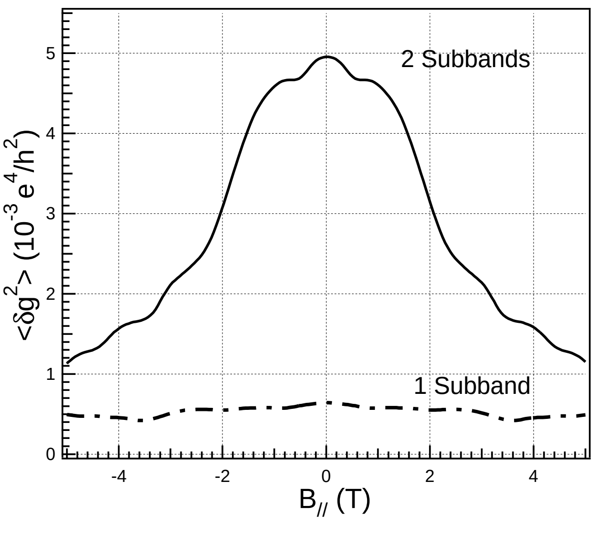


**Figure 2 : Variance of conductance fluctuations in the case of the WQW with 1 and 2 populated subbands.**

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