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Conductance Fluctuations in Ballistic Microcavities

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We have measured the magnetoresistance of two stadium-shaped cavities for which chaotic scattering is expected. The resistance fluctuates on a field scale which depends on the cavity size. We fit the power spectra of the fluctuations to semiclassical chaotic scattering theory. In the smaller stadium we observed a ballistic weak localization effect, but not under all conditions.

1. INTRODUCTION

In a 2D cavity with the shape of a stadium, classical particles will scatter with chaotic dynamics. Phase coherent electron scattering in such a cavity is predicted to reflect these dynamics [1]. The 2D electron gas of a GaAs/AlGaAs heterostructure can be confined to a cavity small enough that large angle scattering is dominated by the walls rather than random impurities, but still large enough that transport through it may be described semiclassically. Such a system may be used to test the predictions of semiclassical theory for magnetoresistance fluctuations in the presence of chaotic scattering. The observation of a difference between these fluctuations in chaotic and non-chaotic cavities has been reported recently [2]. In this paper we report measurements of magnetoresistance fluctuations for two stadia of different sizes.

2. FABRICATION AND MEASUREMENT

Our samples are fabricated from GaAs/AlGaAs heterostructures having bulk mobility of 60 m^2/V-s and density of 2.6×10^{15} m^{-2}. After fabrication the mobility of a small cavity is difficult to assess, but the density is found to be similar to the bulk. Confinement of the electron gas is achieved by patterning a Ti/Au metal mask with electron-beam lithography and exposing it to low energy ($\approx$ 200 eV) Xe ions [3], which makes the unprotected areas insulating. The metal mask is a self-aligned gate which allows the density to be varied over a small range without significantly changing the shape of the cavity. The data we present here are from a sample with two cavities whose shape and dimensions are given in Figure 2. The sample is mounted on a dilution refrigerator and all data presented here are measured with the mixing chamber at 50 mK. The actual electron temperature is estimated to be 100 mK or higher [4]. The voltage drop across the cavity is always less than 10 μV.

3. RESULTS

Figure 1 shows the magnetoresistance of the two stadia measured with the gate shorted to the 2DEG. Both stadia show random, reproducible fluctuations but on different magnetic field scales. The theory of quantum chaotic scattering predicts the following

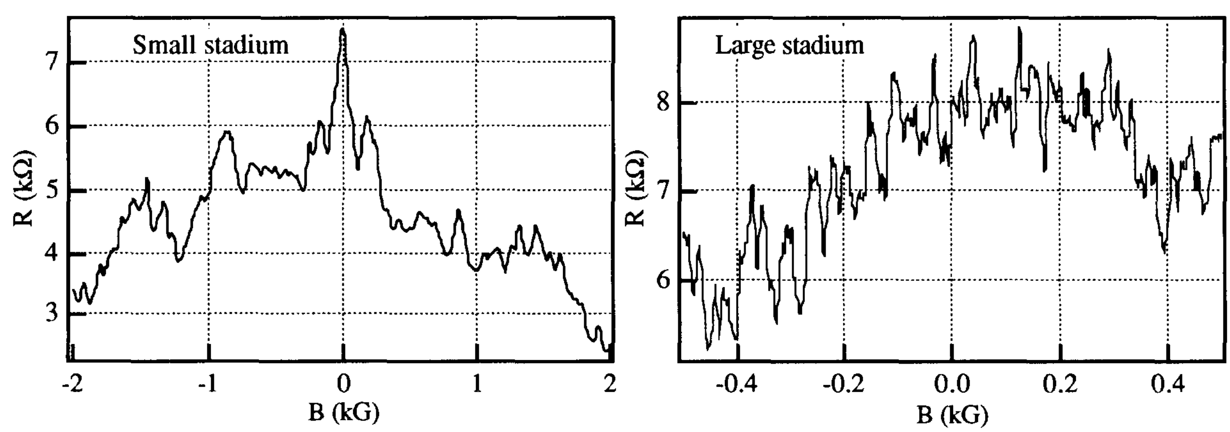

Fig. 1: Magnetoresistance of small and large stadium with $V_g = 0$. T ~ 100 mK.

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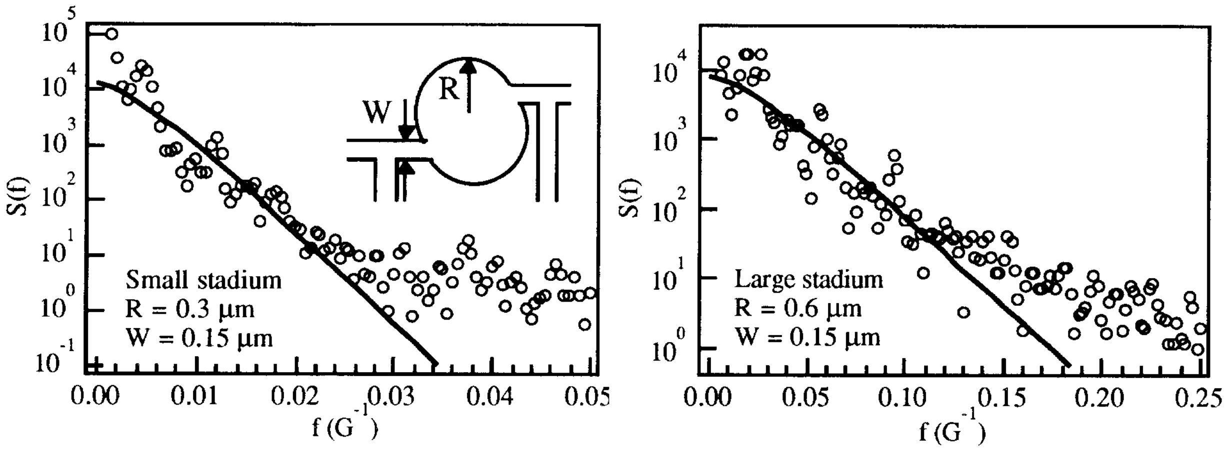

Fig. 2: Power spectra of the data in Figure 1 (circles) and fits to Eqn. (1) (lines). Inset: Stadium and leads.

form for the power spectrum of the fluctuations [1]:

$$S(f) = (1 + 2\pi\varphi_o\alpha f)\, e^{-2\pi\varphi_o\alpha f}, \qquad (1)$$

where f is inverse magnetic field, $\varphi_o = h/e$ is the flux quantum, and α is a parameter that characterizes the chaotic dynamics of classical particles scattering in a cavity of the same shape. The power spectra of the data in Figure 1 are shown in Figure 2. The smooth lines are fits to (1) for $0.002 \leq f \leq 0.021\ G^{-1}$ (small) and $0.014 \leq f \leq 0.13\ G^{-1}$ (large). The lower bound corresponds to an area of $(2\pi\alpha)^{-1}$, which is approximately the lowest f where (1) is expected to hold [1]. The upper bound is the largest f for which (1) remains a good fit to the data (found iteratively). The fits give $\varphi_o\alpha$ = 66.4 G (small) and 10.5 G (large) with about ±10% uncertainty. The agreement of these values with theory is discussed below.

We have measured this sample for several thermal cycles and for V_g = 0, – 20, – 30, and – 60 mV. The values of $\varphi_o\alpha$ for the two stadia fluctuate by about ±20%, but do not show any trend for the four values of V_g. This is evidence that the cavity shapes are approximately independent of density. We have swept V_g at fixed magnetic field and found similar fluctuations, but these data are preliminary.

The data for the small stadium in Figure 1 show a pronounced maximum at B = 0. This feature is often seen, but is not present after every thermal cycle to T ≥ 77 K, and it is not seen at all values of V_g for a given thermal cycle. It was never seen for the large stadium. A prediction has recently been made for a ballistic weak localization effect in the energy-averaged resistance of small cavities [5]. The appearance of the effect only at particular energies is not inconsistent with the existence of an average effect. Further studies of this effect are in progress.

4. DISCUSSION

The expected values of $\varphi_o\alpha$ can be found by classical simulation [1]. Our stadium shape with offset leads has not been simulated, but simulations of symmetric stadia with directly opposite leads give $\varphi_o\alpha$ = 24 G and 3.5 G, using the dimensions of our small and large stadia [7]. We observe values about three times larger than these, indicating the typical areas in our stadia are about three times smaller than expected. Jensen [1] argues that there is a strong tendency for trajectories to circulate in the symmetric stadium, which increases the typical areas enclosed. Perhaps this effect is weaker in a stadium with offset leads and/or imperfect edges. Finally, we note that the ratio of the field scales agrees well with the simulations, and is not simply the inverse ratio of the total stadium areas.

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REFERENCES

1. R.A. Jalabert, H.U. Baranger, and A.D. Stone, Phys.Rev. Lett. 65, 2442 (1990); E. Doron, U. Smilansky, and A. Frenkel, Physica D50, 367 (1991); R.V. Jensen, Chaos 1, 101 (1991).
2. C.M. Marcus et al., Phys. Rev. Lett. 69, 506 (1992).
3. A. Scherer and M.L. Roukes, Appl. Phys. Lett. 55, 377 (1989).
4. A. Mittal et al., these proceedings.
5. H.U. Baranger, R.A. Jalabert, and A.D. Stone, unpublished.
6. W.A. Lin, private communication.