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Study on Disorder and Branched Electron Flow 8

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Abstract - The effects of a magnetic afield are somewhat intuitive, but are nonetheless interesting to note. First, let us consider the effect of a magnetic field on the electron ux itself. In a system with a bat potential, the effect of the field would be to bend all electron trajectories to curves with some known cyclotron radius. With disorder present, however, the dynamics will favor some paths over others (hence the branched nature of the own). The competition between these dynamics for electrons in the magnetic field results in a \ratcheting" of the branches as the field strength is increased, rather than a continuous sweeping. Though this is difficult to convey without a continuous set of ux images. The shifting of branches has greater implications for the experimental situation, since the accessible conductance measurement depends on scattering. We can understand the correlation between the measured conductance and electron ux by considering classical trajectories. To decrease the conductance of the system, a trajectory needs to be scattered by the AFM tip and return to the QPC. In the absence Here we see two sets of electron ux density data, taken with the same disordered potential but at two differentmagnetic field values. For the top image B = 0, and for the bottom image B = 25 mT. Both data sets cover an area two microns long by one micron high. We see that, when the field is increased, the branches do not bend continuously. Rather, the branches are the same out to some distance, at which point the electrons take clearly distinct paths. We understand this as the effect of the magnetic field accumulating until it is suffcient to cause trajectories to jump from one dynamically favored branch to another. This ratcheting effect continues as the ux increases, resulting in a cumulative net bending of trajectories.

We also note that ux density has shifted within the branches present, another effect that accomplishes the net bending caused by the magnetic field.this means that the trajectory should impinge on the AFM tip Potential at a right angle to the classical turning point and be scattered back along itself.

Key Words; Images, Ratcheting, Cumulative, Trajectories.

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INTRODUCTION

Time reversal invariance guarantees that the trajectory will follow the same branch back to the QPC that it used to get to the AFM. Placing the AFM over a branch ensures both a high density of impinging electrons and a high density of possible return paths into which to scatter. In the presence of a magnetic field, we lose the time-reversal invariance that we used to describe our scattering process. The existence of a classical trajectory from the QPC to the AFM no longer guarantees the existence of a return path.

Thinking in terms of time reversal, however, points us in the direction of what we should instead expect to see. The set of trajectories that can be used to return to the QPC from the AFM are just those that are seen going to the AFM from the QPC for the opposite magnetic field. The conditions for a strong signal, the presence of both outgoing and return paths, are satisffed by those regions of space where these two branching patterns overlap. We would then predict that the signal measured with a tip scan would correlate to the product of the ux densities calculated at both signs of the magnetic field. This prediction is born out by simulations, This intuition implies a relationship that we already know to be true: the signal that we measure must be symmetric in magnetic field [16]. Changing the sign of the field merely exchanges the roles of outgoing and return paths. We show the results of a simulated AFM tip scan in the presence of magnetic field.

REVIEW OF LITERATURE

We can now, as earlier suggested, look at the effectthat a disordered potential has on the resonant cavity considered in x3.2. In a cavity, we expect noticeable effects for levels of disorder that might not be seen in an open system at our length scales. The reason is that electrons confined to a cavity will \see" the same disorder many times as they bounce around. There are three things that we consider when we introduce disorder. First is that the resonant energies of the cavity will shift, and so the peaks in the transmission curve will move. Second, we note that the closed status of the cavity, especially as we approach marginality, is a delicate balance. Small levels of disorder in the cavity can easily destroy it for the reasons noted above. As a result, we would expect that the transmission of the cavity will be increased throughout the spectrum. Finally, the symmetry of the cavity is broken by any disorder. With the symmetry broken, waves can couple to a new class of cavity modes and we should see new peaks appear in the transmission spectrum. We take the same cavity setup used before, and introduce disorder gradually. An example of the resulting potential happens to the spectrum in a narrow band as the disorder is introduced. There are five steps as the disorder strength is increased, ending at: 05EF . Even at this level of disorder, we see that the extant conductance peaks are shifted and new ones appear.

In addition, the whole conductance curve is raised, as the geometric closure of the cavity is lost.we can see what is happening to the wave functions at the same time; for comparison, we have the wave functions at the conductance peaks for zero disorder and for disorder at :05EF . Most interestingly, we see that the disorder the potential in our resonant cavity with a disordered background introduced. Because the heights of the peaks in the disorder are small (around 5%) compared to the energy of the electrons that we will send through the system, the grey scale color map is cut off and we don't see the softness of the mirror and QPC. The radius of curvature of the mirror is ffve correlation lengths of the disorder.

MATERIAL AND METHOD

The data are over a limited range, measuring one micron long by :6 microns high. In row (A), we see the ux and the results of a tip scan at zero magnetic fields. The correspondence between the two is as seen before. In (B), we have the ux at a magnetic field of ff:1 T. (The interference in the upper-right corner of the first image in (B) is simply the result of a branch hitting the corner of the grid.) In (C), we show the square root of the product of the two sets of data in (B), and the result of a simulated AFM tip scan at B = :1 T. (We have chosen the square root of the product so that, as we take B ! 0, we reduce to the image used in (A).) This tip scan correlates to the product, rather than to the actual ux at either field value. We ffnd the same tip scan data if we take B = □:1 T. The most interesting feature of the tip scan in (C) is isolated island of signal near the center of the scan where two branches cross one another. Has allowed our previously symmetric system to couple to modes with a central node. We see the evolution of the cavity transmission spectrum as the strength of the disorder is increased. In (A), we show six curves, the lowest (black) is for no disordered background and the highest (purple) is for a background at :37 meV (:05EF for the center of the spectrum), with even steps between. In (B), we show only the two extremes, and we have labeled the peaks. We see the shifting of peaks (e.g., A4 to B6), the disappearance of peaks (e.g., A3), and the appearance of new ones (e.g., B5) as the disorder is introduced. We also note the overall effect of the disorder to increase the transmission of the system.

CONCLUSION

We see the wave functions at the peaks in the transmission curves of (B). Comparing the two data sets, we note two things. First of all, looking at peaks that are present for both curves, the amount that a wave function changes is related to the height and width of the original transmission peak (compare A1 changing to B2 with A2 splitting to B3 and B4). This makes sense, as narrow, high peaks correspond to stronger resonances of the original cavity, and we might expect that these will be harder to destroy. Second, for the wave functions that changes significantly and for the one that isn't present at all without disorder (B5 is the only completely new peak since B1 has simply been shifted into this energy range), the difference is primarily the introduction of a component with a central node. In the original, symmetric system, such states weren't allowed.

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