Report of my activities at the NCTS May 20 to June 30, 2005

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Together with Prof. Chi-Shung Tang at the NCTS and Dr. Andrei Manolescu I have been investigating transport properties of semiconductor systems on the nanometer scale. In the last few months and in the beginning of my stay here we were calculating the conductance of a quantum wire with an embedded repulsive potential.

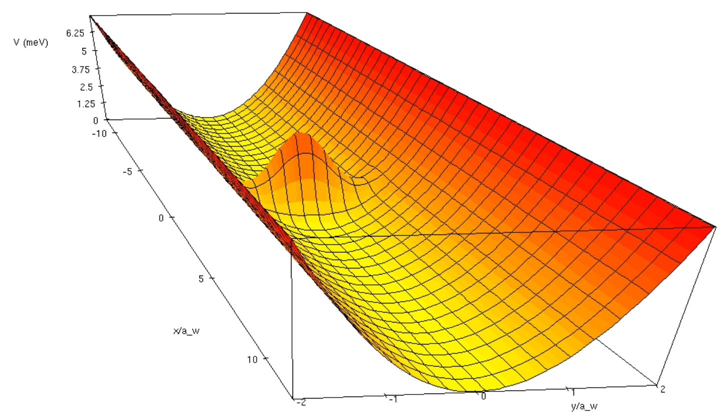

Figure 1, Quantum wire with a repulsive smooth scatterer.

We specially focused our attention on the question whether it is possible to see quasi-bound states with negative binding energy in the conductance when the wire system is in a homogeneous external magnetic field. The model is constructed using a scattering approach, where the Lippmann-Schwinger equation is transformed into a coupled set of integral equations for the multi-subband T-matrix [1], from which the conductance is derived using a Landauer-Büttiker formalism.

Several years ago research groups have looked into the effects of attractive or repulsive scatterers to understand the break down of the IQHE (Integer Quantum Hall Effect) in narrow constrictions, in the extreme quantum limit with only one subband [2], or using strong delta-scatterers [3]. A quantum wire with a large hard-wall antidot embedded has been investigated using a tight-binding formalism in order to find Aharanov-Bohm oscillations in the conductance [4].

We consider a relatively small smooth scattering center that can lead to several bound states with simple structure within each subband of the quantum wire. In Figure 2 we show two
resonances caused by the quasi-bound states with negative binding energy.

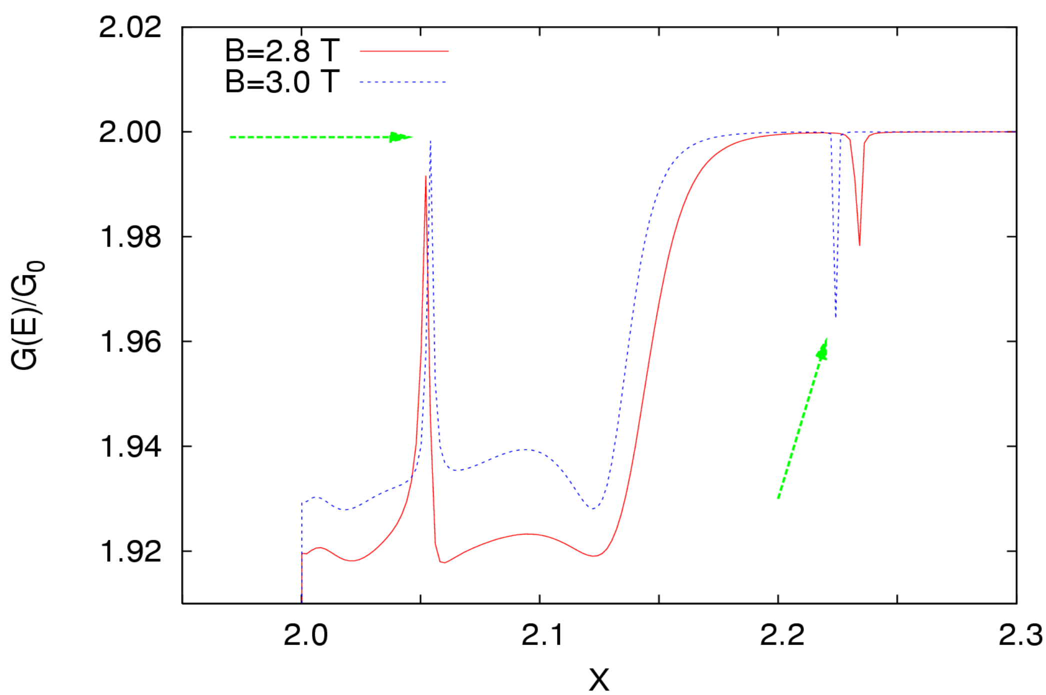

Figure 2; The conductance of the wire with respect to the scaled energy X, which assumes an integer value each time a new subband opens for transport in the wire.

The peak represents a resonant transmission and the dip is caused by a backscattering resonance. The corresponding probability densities for the electrons are shown in Figure 3 and 4. The probability density for the transmission peak shows a quasi-bound state around the repulsive scattering center with a fairly strong coupling to the edge states on the forward propagating side of the quantum wire. The probability density for the dip shows a quasi-bound state with weak coupling to the edge states. The symmetry of the state reflects the circular symmetry of the scatterer with only minor perturbation caused by the edge. The state has one radial node indicating that there is a higher lying state with simpler structure that we miss due to the narrowness of the its resonance and a small coupling to the edge. The fact that we do not see the incoming and the reflected wave in Figure 4 on the color scale we use indicates how long lived this quasi-bound state is and is in accordance with the tiny linewidth of the conduction resonance.

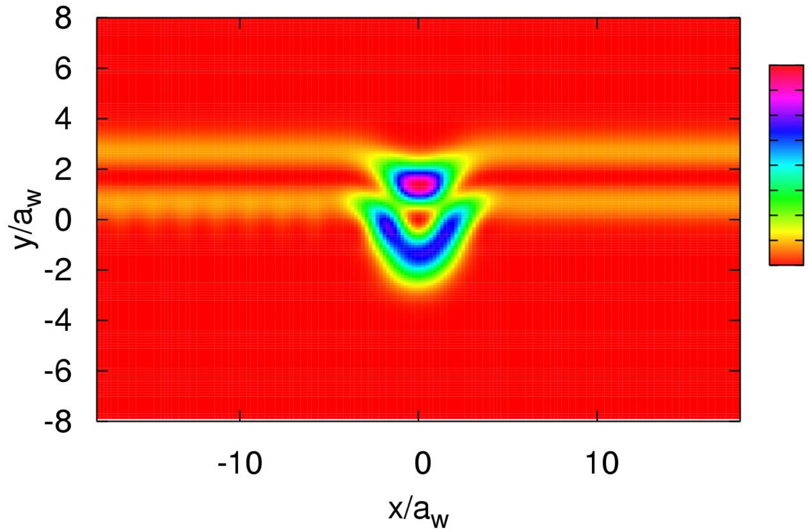

Figure 3; The electron probability density corresponding to the conduction peak in Figure 2.

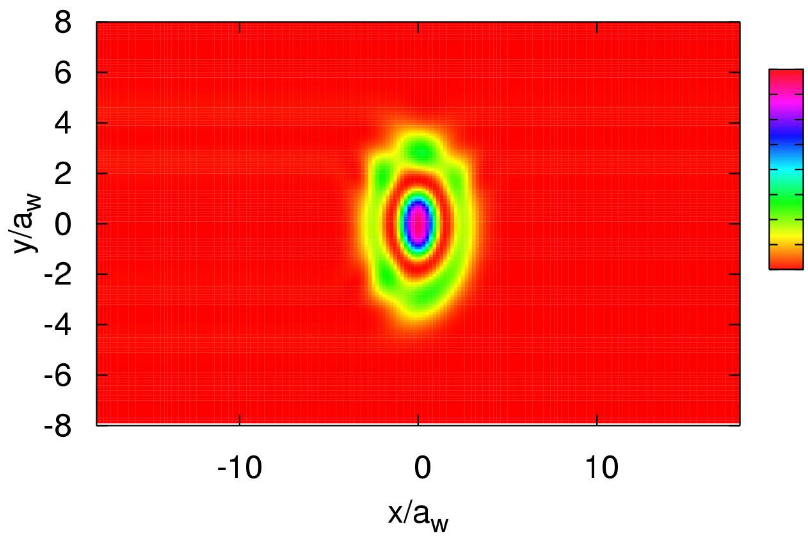

Figure 4; The electron probability density corresponding to the dip in Figure 2.

These results have now been submitted for publication and placed on an international preprint server [6]. We consider the results a small step in our quest for understanding transport properties of semiconductor systems on the nanometer scale. We are currently working on the transport properties of more complex systems, but it is too early to reveal our plans regarding them at the moment.

During my stay at the NCTS I did participate as an invited speaker in the mini-conference

"Nano-Science, Single Quanta Detection and Imaging" held in the conference center of the Department of Engineering at the Chiao-Tung University, and sponsored by the "Focus Group on Mesoscopic and Spin Physics" at the Physics Division of the NCTS: http://phys.cts.nthu.edu.tw/workshop/focus/20050621/index.htm, I talked there about the effects the quasi-bound states with negative binding energy can have on the transport of electrons through a quantum wire. The lecture is at my homepage in Iceland: http://hartree.raunvis.hi.is/~vidar/Rann/Fyrirlestrar/Qpeg_2005.pdf.

Once again, we have experienced the highly professional work of the office staff, the organizers, and the directors of the NCTS. We are amazed by the hospitality of the Taiwanese people we have met everywhere and we are very thankful for another opportunity to renew and deepen the relation with our friends in Taiwan.

References

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