

## 11.0 Ultralow-Temperature Measurements of Submicron Devices Nanometer-Scale Semiconductor Devices

### Academic and Research Staff

Prof. M.A. Kastner, S.B Field

### Graduate Students

U. Meirav, S.L. Park, J. Scott-Thomas

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Marc A. Kastner, Stuart B. Field, John Scott-Thomas, Udi Meirav Sam L. Park

### Project Goals:

1) To study the behavior of electrons in semiconductor devices so small that the behavior is quantum-mechanical.

2) To understand how the conductivity and other properties of electronic wavefunctions such as many body effects, are altered by confinement in nanometer-scale devices.

In studies of Si MOSFET's about 100 nm wide we discovered a magnetic-field induced transition to a different state of the electron gas, with conductance  $G$  about 10 times higher than that in zero field. Above the threshold field  $G$  rises in a series of steps as a function of gate voltage. Each of the risers moves to higher gate voltage approximately linearly in magnetic field, suggesting that they occur at fixed filling factor, the ratio of carrier density to flux quantum density. Each plateau disappears at a different temperature revealing a family of phase transitions, one for each plateau. There is no model that predicts in detail the phenomena we have observed. However, it has been suggested that confinement of the two-dimensional electron gas in one additional dimension might lead to a charge or spin density wave instability when the width is comparable to but somewhat larger than the magnetic length, the radius of the Landau orbit. Such instabilities would lead to dissipationless current flow and plateaus in the conductance analogous to those in the two-probe quantum Hall effect. The absence of the usual spin and valley splittings is evidence that the many-body effects are different in the quasi-one-dimensional electron gas than in the usual two-dimensional electron gas.

We are learning that the behavior of electrons in devices smaller than 100 nm is altered in fundamental ways from that in conventional devices. However, at the same time, it raises the possibility that completely new kinds of devices may emerge.



*Professor Patrick A. Lee*