Wigner Solid Transport through a Point Constriction

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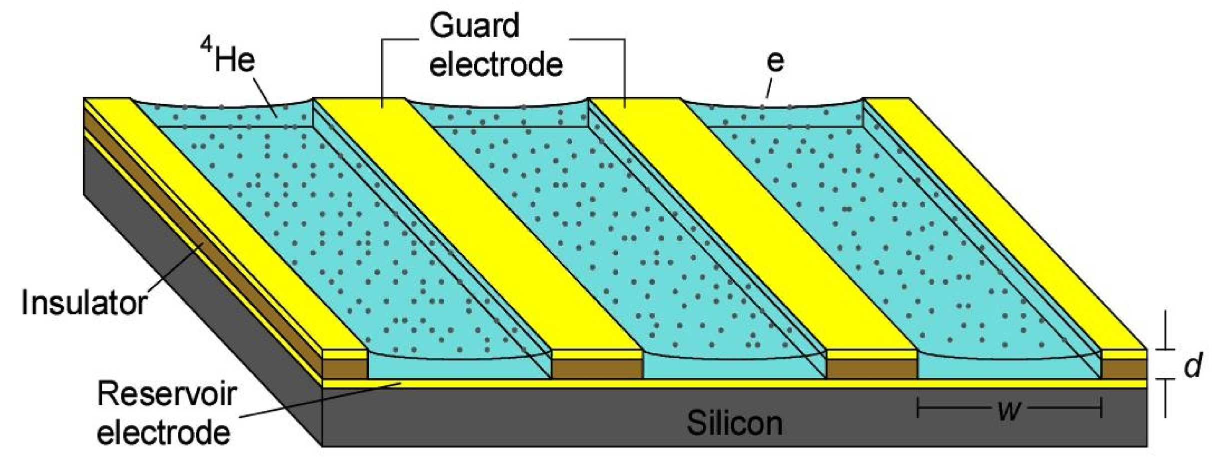
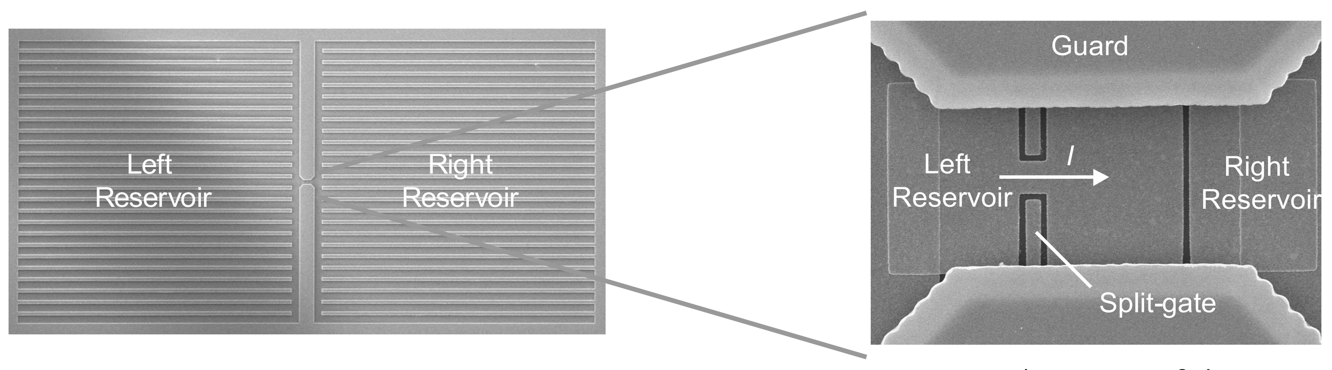
Introduction – Microchannel Split-gate Device

Microchannels allow the manipulation of small numbers of surface electrons: $n_s \sim 1 \times 10^9$ cm^{-2}

Bulk properties (high mobility, Wigner solid) maintained

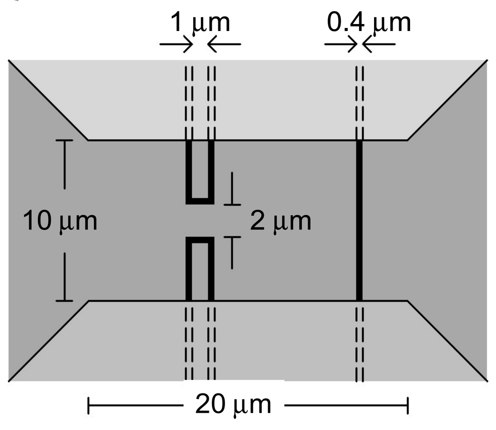


Typical dimensions: d = 1.5 μm, w = 20 μm
Radius of curvature: $R = \alpha/\rho g h + n_s^2 e^2 / 2\varepsilon\varepsilon_0$
Change in depth at channel centre: Δd ~ 0.1 μm

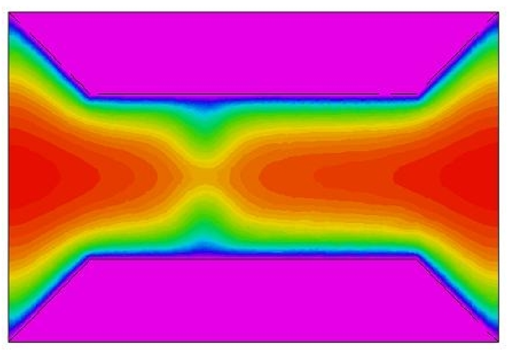


Our new device: 2 sets of micro-channels act as electron reservoirs.

A split-gate is fabricated underneath the helium between the reservoirs.

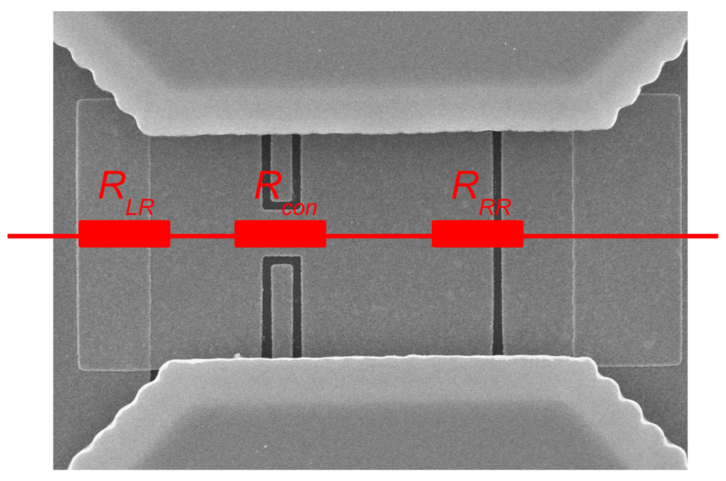


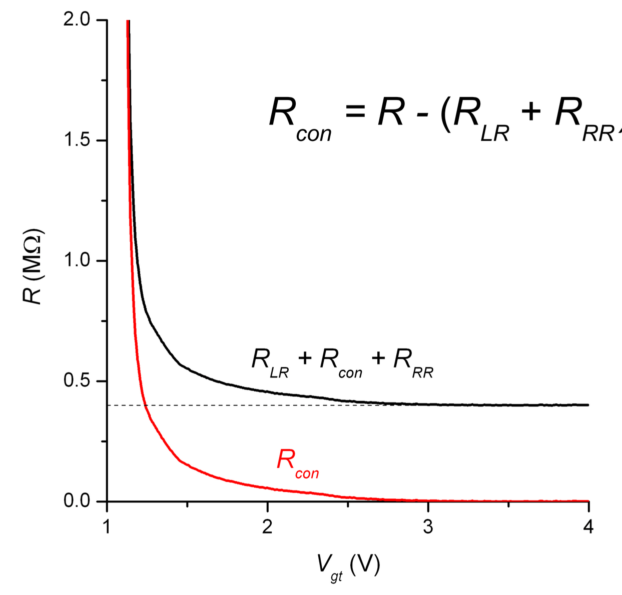
Finite element modelling shows that a saddle-point potential is formed as the split-gate is swept negative.



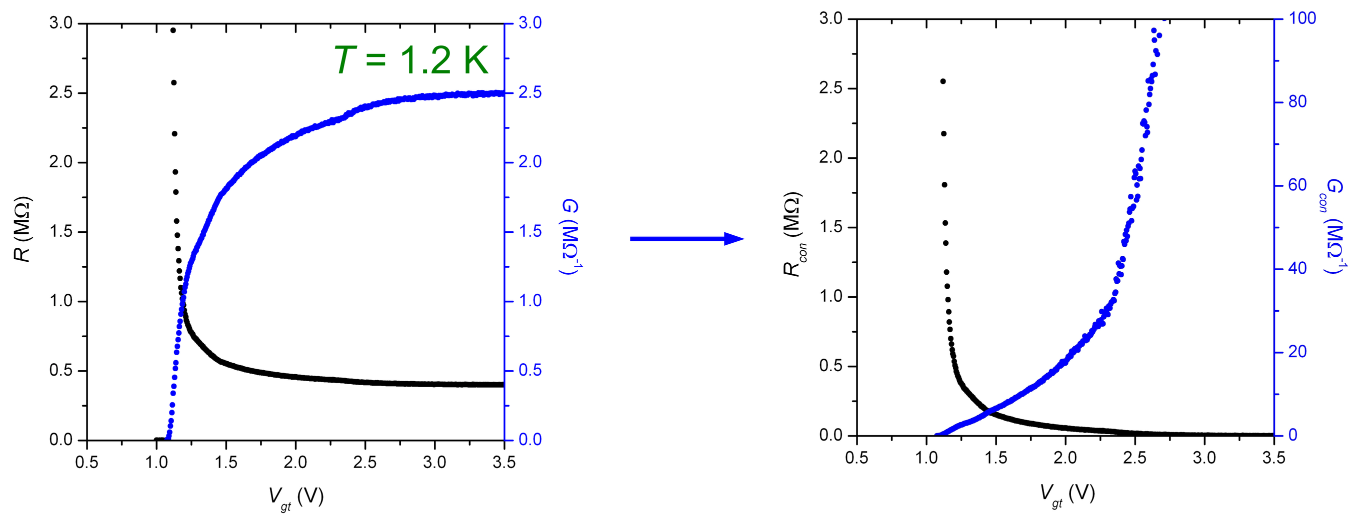
Constriction Conductance

Assume: The measured resistance R is the sum of the resistances of the two reservoirs and of the constriction:



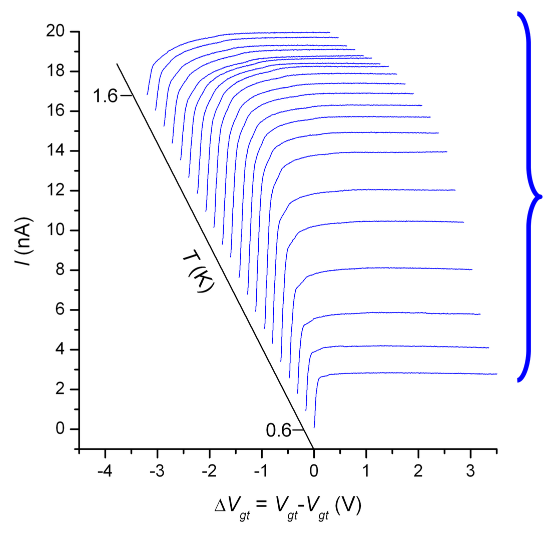


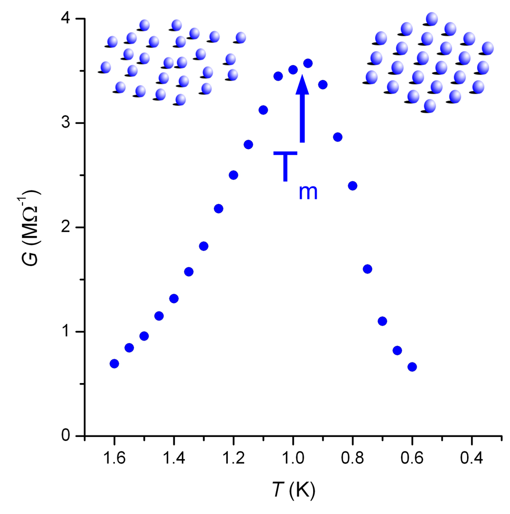
$G_{con} = 1 / R_{con}$:



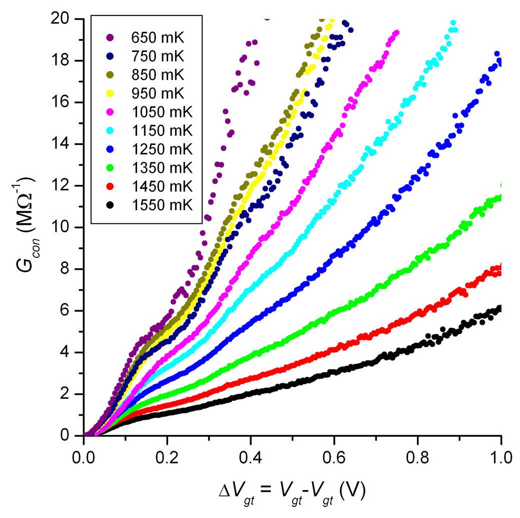
Temperature Dependence

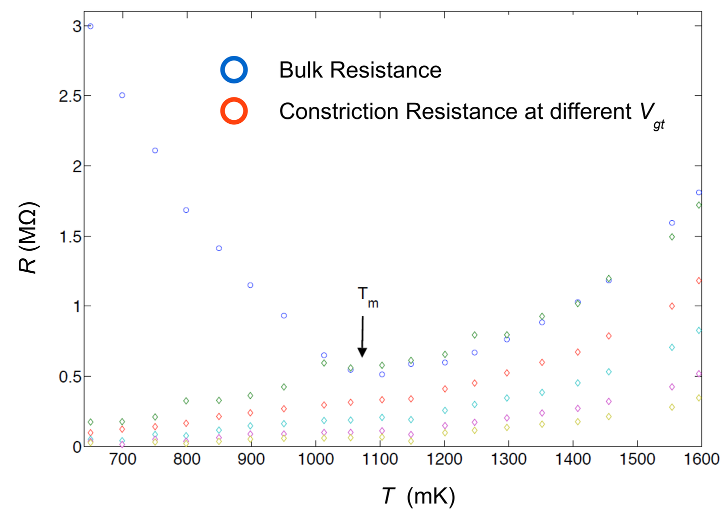
Measure I vs V_{gt} at different T: See Wigner solid transition occur at ~ 1 K:





The conductance of the constriction continues to increase with decreasing temperature.

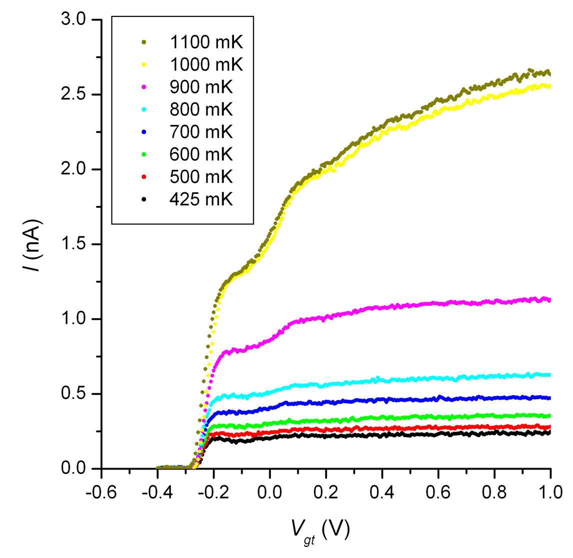




Development of 'Step' Structure

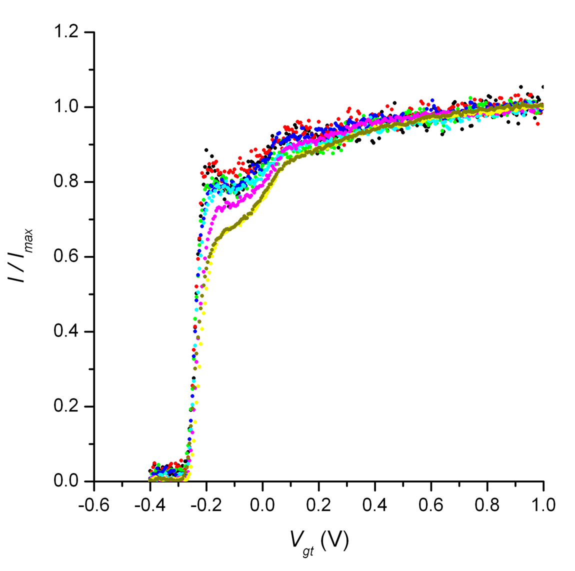
At low driving voltage, high densities...

We again see the conductance decrease with temperature due to the formation of the Wigner solid.



The 'step'-like structure observed as the gate voltage is swept negative becomes more pronounced and peak-like at low temperatures.

May be related to the melting or sliding of the Wigner solid at the constriction..?



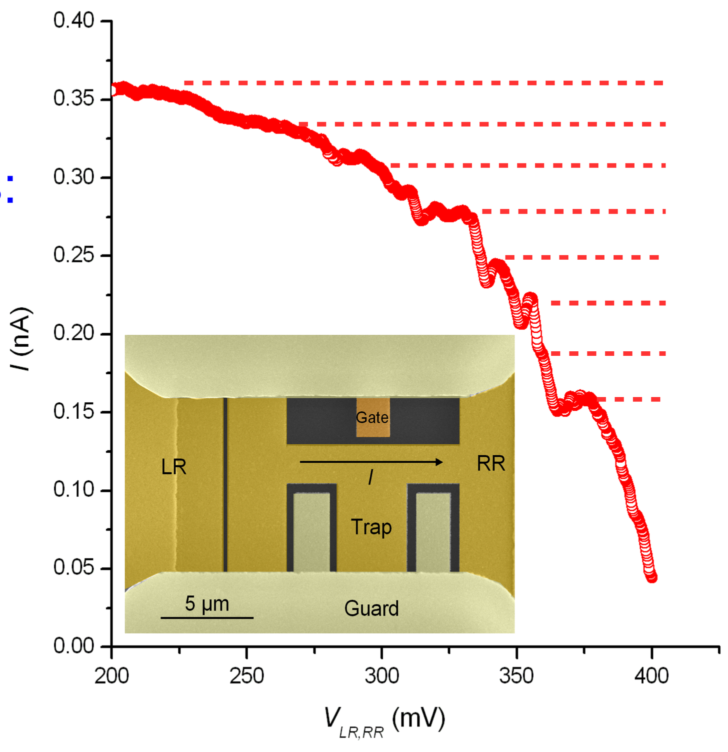
Future Work

For two potential barriers in series:

$V_B \sim f(N_e)$ (N_e electrons in trap)

→ I ~ f(N_e)

A single-electron device!



Summary

• The transport properties of electrons at a point constriction are highly temperature dependent in the liquid and Wigner solid phase.

• We may separate the conductance of the constriction from the total conductance of the electron system.

• We measure no increase in the constriction conductance due to Bragg-Cherenkov scattering of the Wigner solid although at high electron densities there is some evidence for crystal melting/sliding.

• By creating two potential barriers in series it may be possible to create single-electron devices.