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1D Coulomb Drag in the Ultra-Low Temperature Limit

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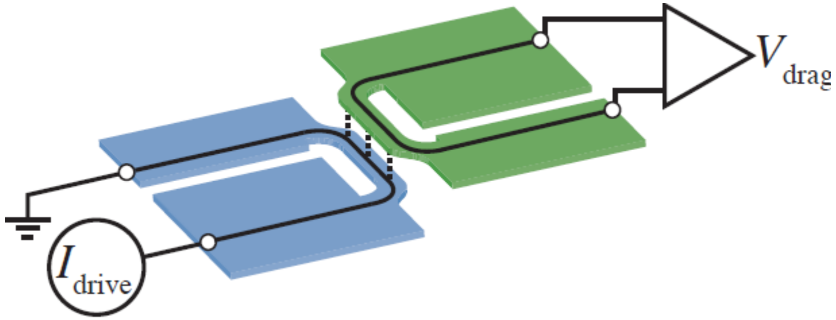
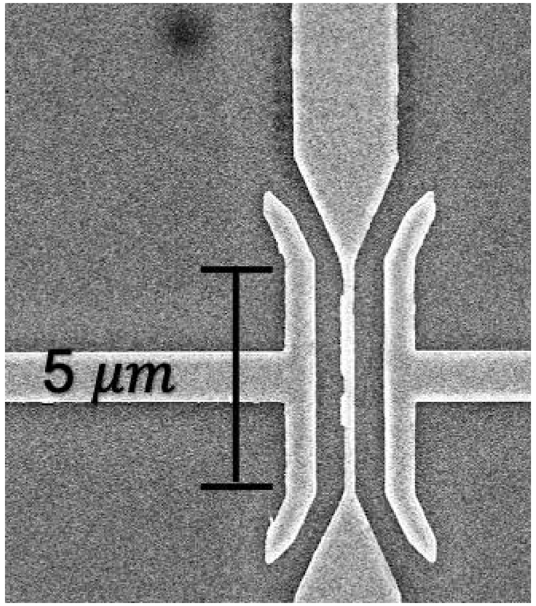
Introduction

- Strong electron-electron interactions In 1 Dimensional Electron Gasses (1DEG) give rise to exotic phenomena within the Luttinger Liquid model

- Utilizing Coulomb Drag, we will experimentally explore some key theoretical predictions that occur within the ultra-low temperature and high magnetic field (spin polarized) regimes.

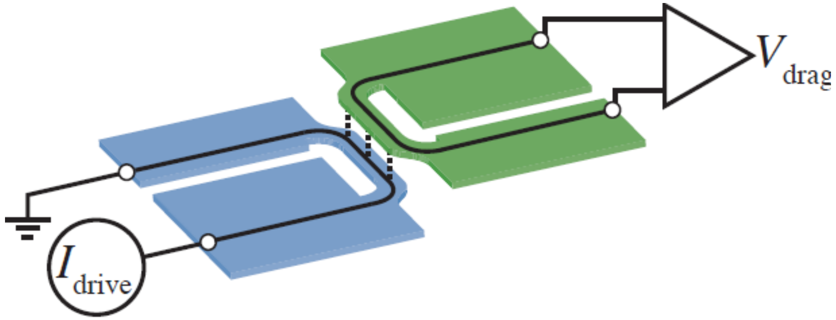


[1] D. Laroche *et al.,* Nature Nanotech. **6**, 793 (2011).



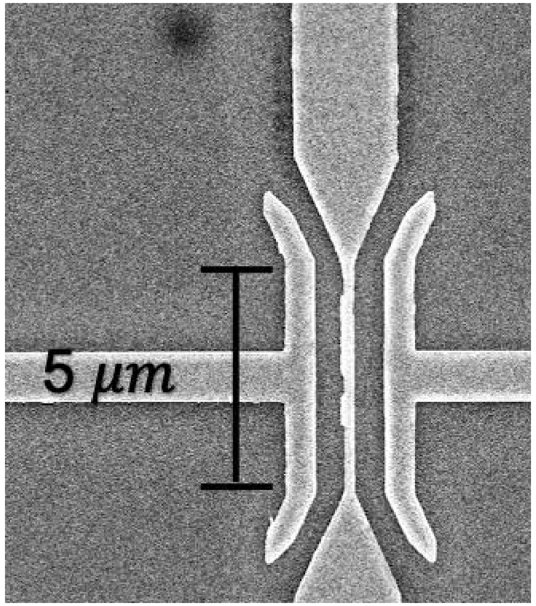
Introduction

- The strength of 1D electron-electron interactions can be extracted from the shape and functional dependance of 1D Coulomb Drag



[1]

- The dominant drag-inducing mechanism in 1D is not confirmed experimentally



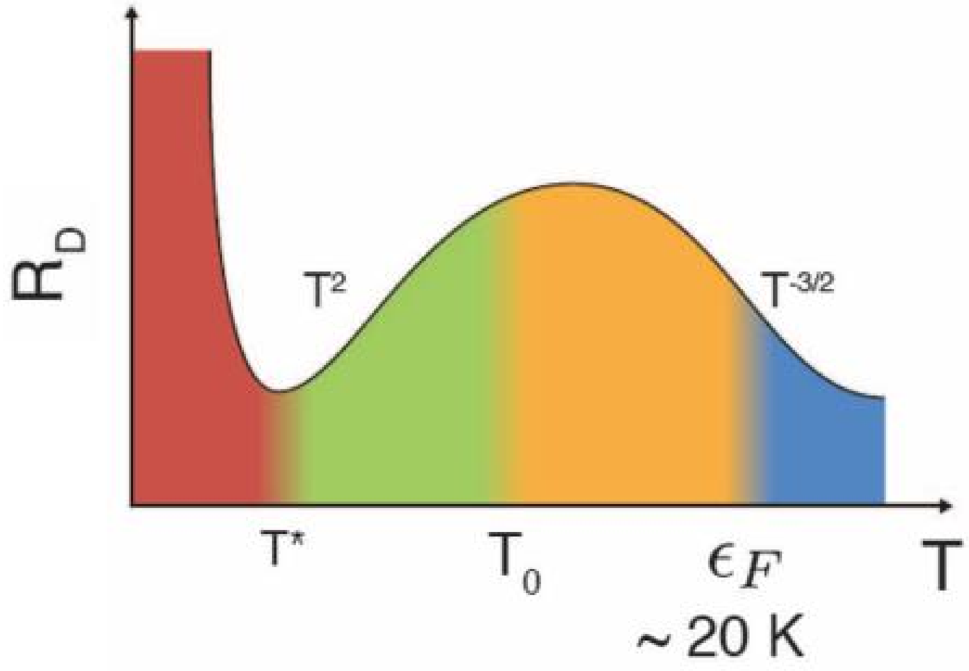
- Our new experiments will focus on extreme magnetic fields and low temperature

Theoretical justification

- One proposed mechanism for Coulomb Drag is Momentum Transfer

- This model predicts that in the regime T<T* that we should see $R_D \sim \exp(T^*/T)$

- For T>T* we expect to see a power law behavior



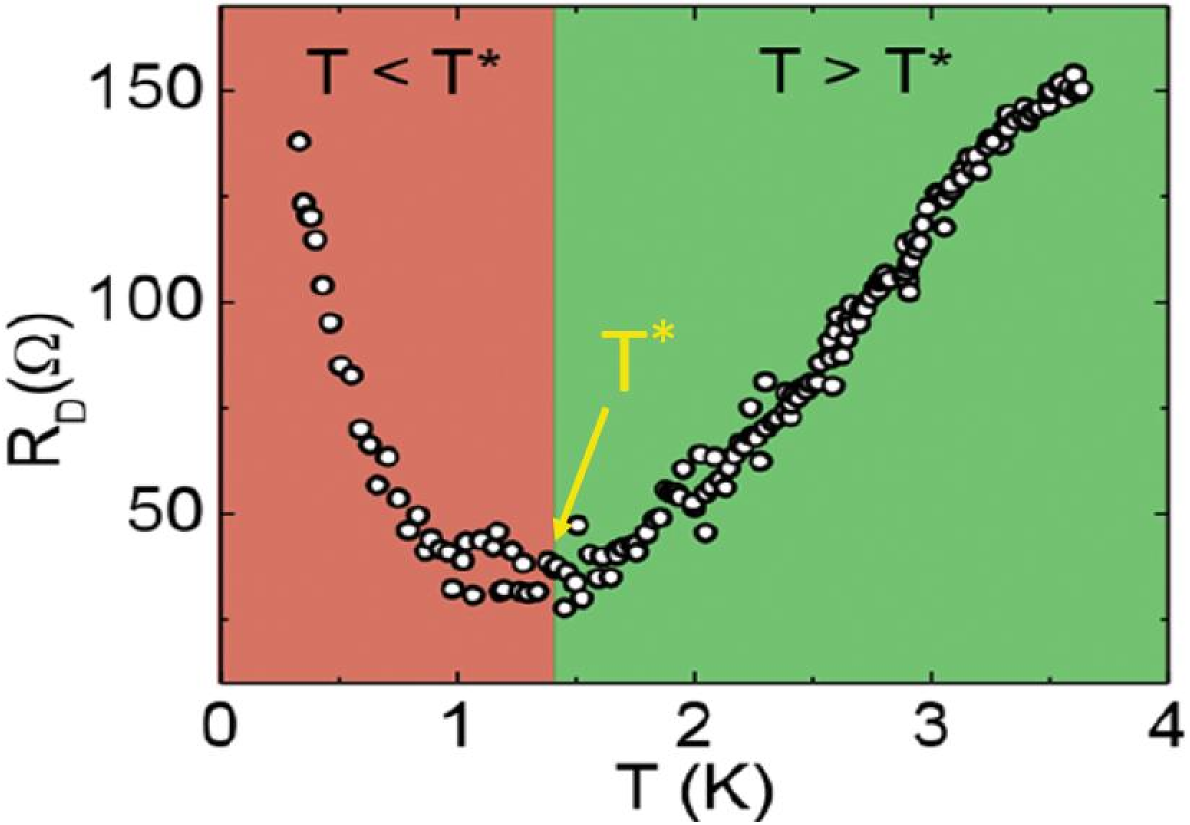
[2]D. Laroche *et al.*, Science **343**, 631 (2014).
[3] M. Pustlnik *et al.*, Physical review letters 91.12 (2003): 126805

$$T^* = \epsilon_f e^{-\frac{bk_f d}{1-K_\rho}}$$

Previous results

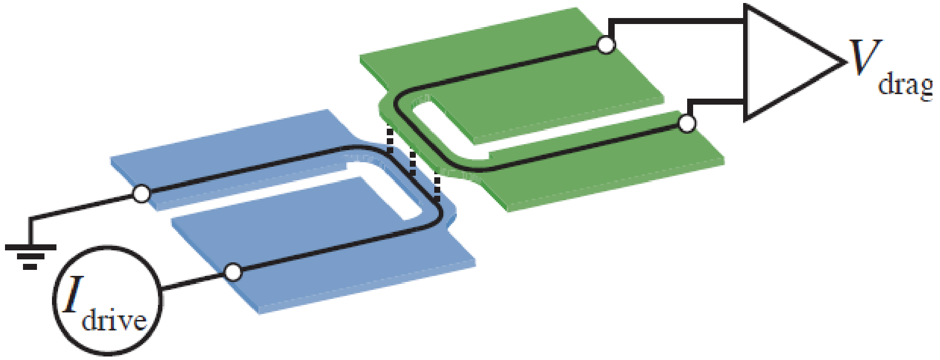
- Previous work done has shown what appears to be the transition between power law and exponential

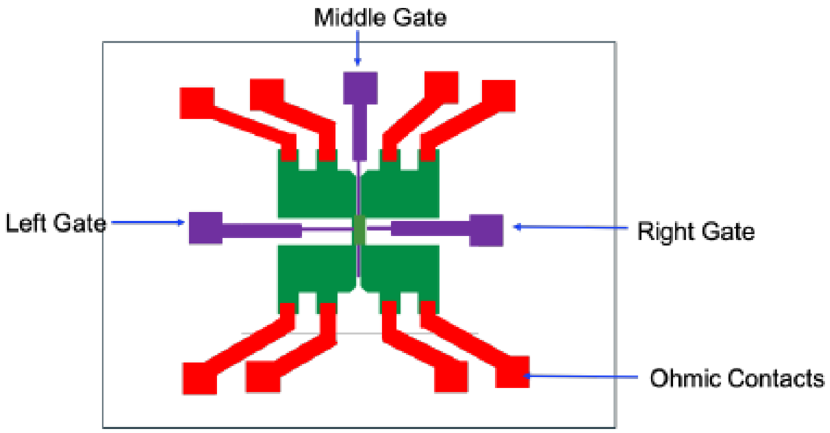
- However, due too experimental constraints, exponential behavior could not be verified

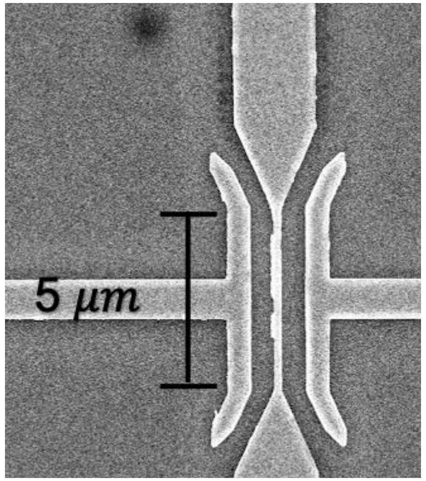


[2]

Fabrication







- Devices are created in-house at University of Florida's Nanoscale research facility
- Photo- and electron-beam lithography are used
- Two device types are made, laterally coupled and vertically coupled devices

High B/T

- We utilize the facilities at the High B/T MagLab Facility at UF

- We use a combination Dilution refrigerator and Demagnetizing cooling system, along with a 16T experimental Magnet

Measurement methods

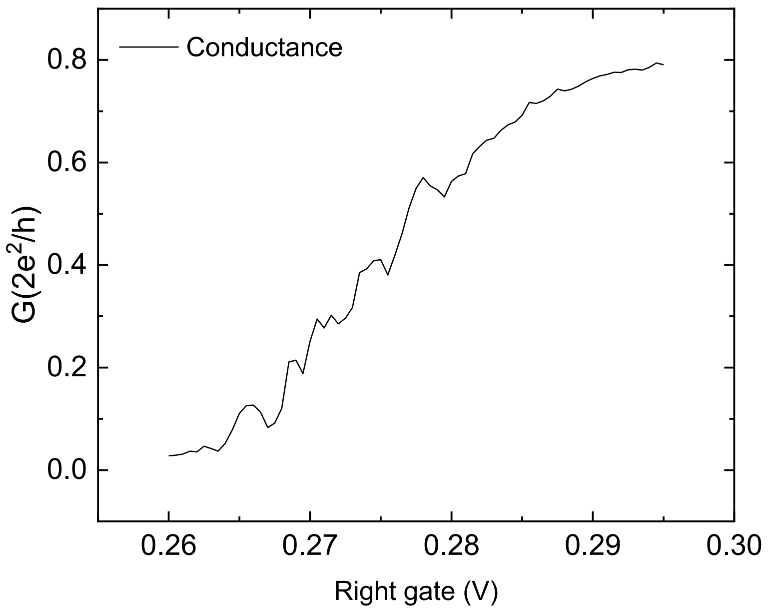
- Several steps have been taken in order to achieve ultra-low electron temperatures.
  - Liquid ^{3}He immersion.
  - Sintered silver leads.
  - RC Filtration.

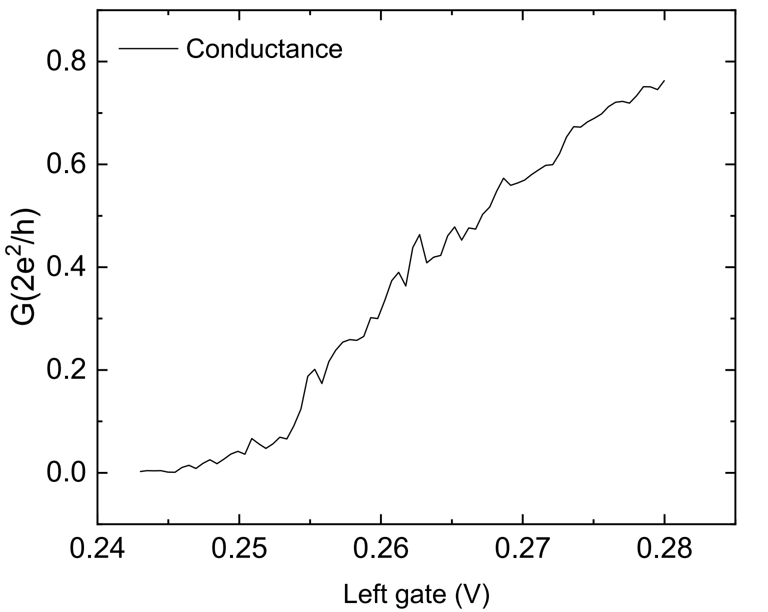
[4] M. Sarsby, *et al. Nat Commun* **11,** 1492 (2020).

- Our measurements will be conducted in the ultra low T high B field regimes

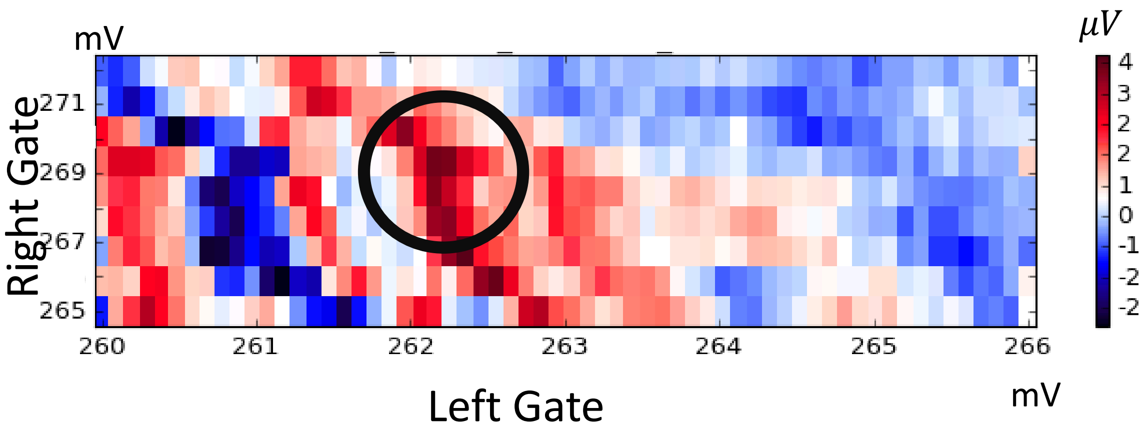
Preliminary results

- Measurements begin by characterizing wire
- Due to issues during experimental setup, wire quality damaged significantly

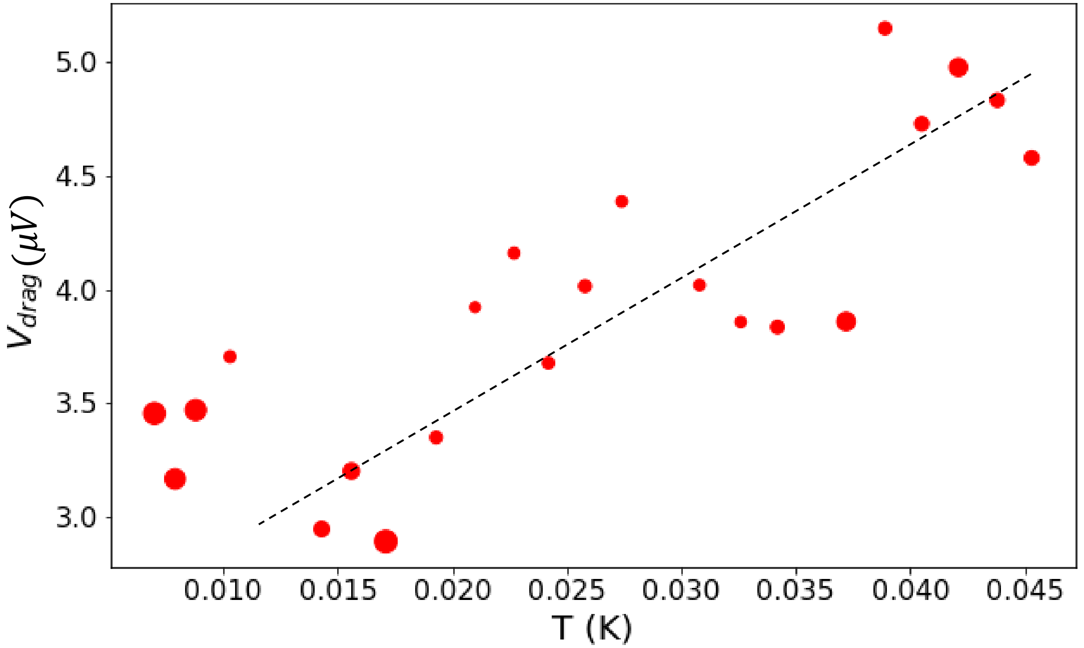




Preliminary results



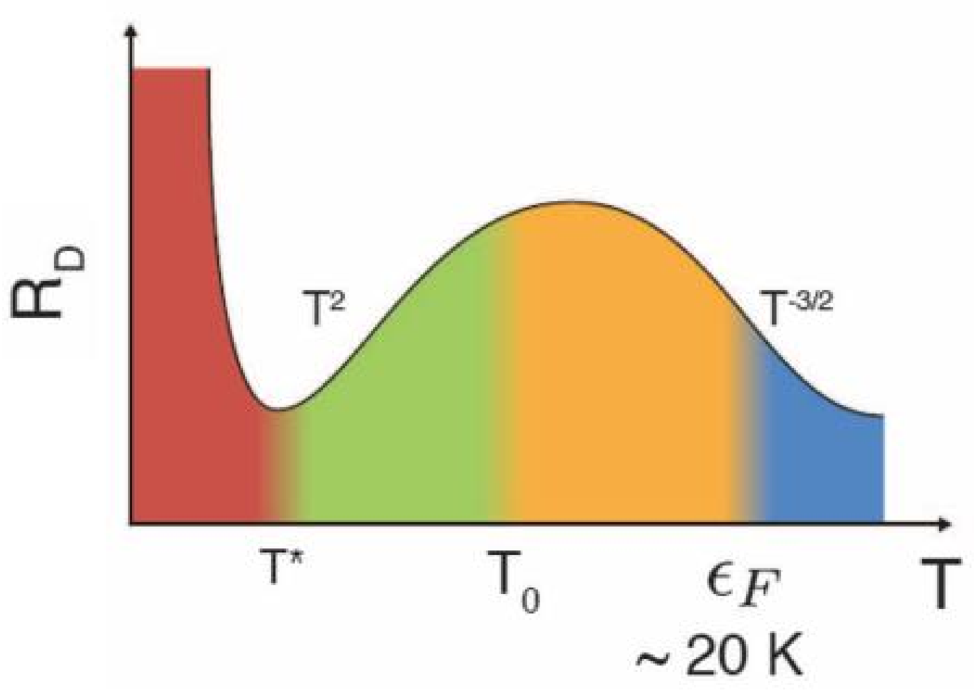
Coulomb drag scan, voltage in drag wire is measured as wires are varied. Circle indicates peak tracked for T dependance



Tracking the strongest peak as a function of temperature. Thermal trend seems to confirm that we have achieved cooling down to at least 15 mK

Future experiments

Experimental Goals
Measure 1D Coulomb drag in ultra-low temperature regime
Expect the function to be of the form $e^{T^*/T}$
Measure the effect of spin polarization on T*



Conclusion

- Understanding electron-electron interactions can be extremely important for a variety of different applications
- In order to understand and properly probe these interactions, a detailed understanding of the mechanism inducing Coulomb drag is required
- By performing these studies at ultra-low temperature and high magnetic field, we aim to gain a better understanding of these mechanisms

Thank you for your attention!

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Center for Integrated Nanotechnologies

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