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Competing Drag inducing mechanisms in quasi-1D Quantum Wires

Session Y12: Thermodynamic and Transport Properties

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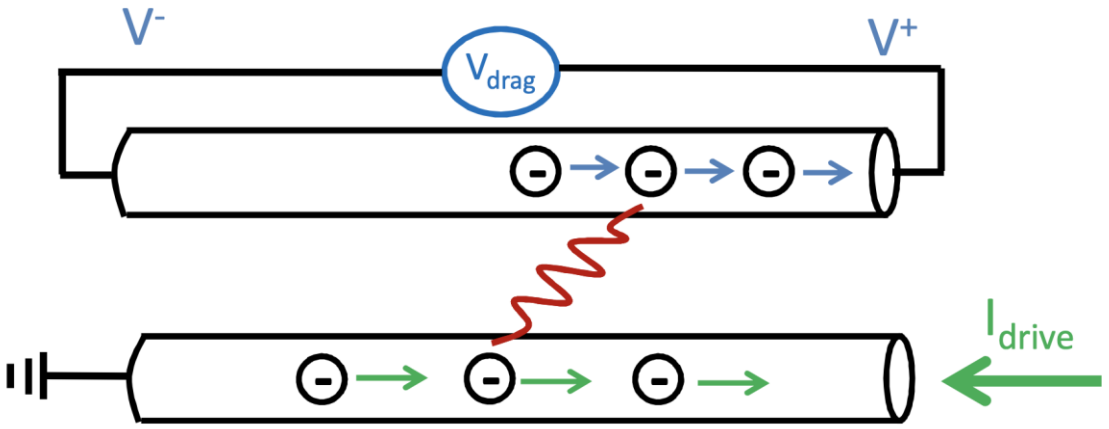
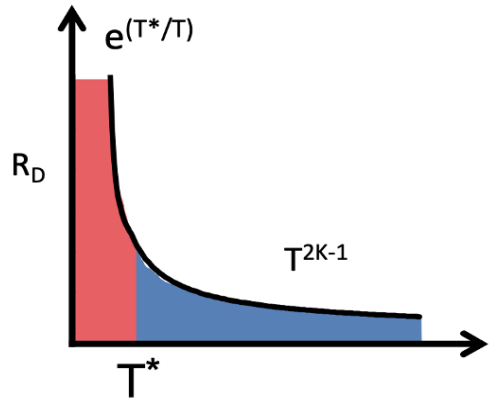
Motivation

- Understanding and quantifying the strength of the e-e interactions in coupled 1D system
- Fermi Liquid (FL) Theory breaks down for interacting 1D systems and is replaced by Luttinger Liquid (LL) theory
- e-e interactions become stronger in 1D
- Potential applications:
  - Magnetic field free topological superconductors

Coulomb Drag Mechanisms

- Momentum-Transfer Model
  - Drag current is induced through momentum transfer[1]
- Charge-Fluctuation model
  - arises from interlayer energy transfer due to interlayer electron−electron scattering[2]





[1]Klesse, R. and Stern, A. Phys. Rev. B 62, 16912 (2000).
[2]Levchenko, A. and Kamenev, A. Phys. Rev. Lett. 101, 216806 (2008).

Coulomb Drag Mechanisms

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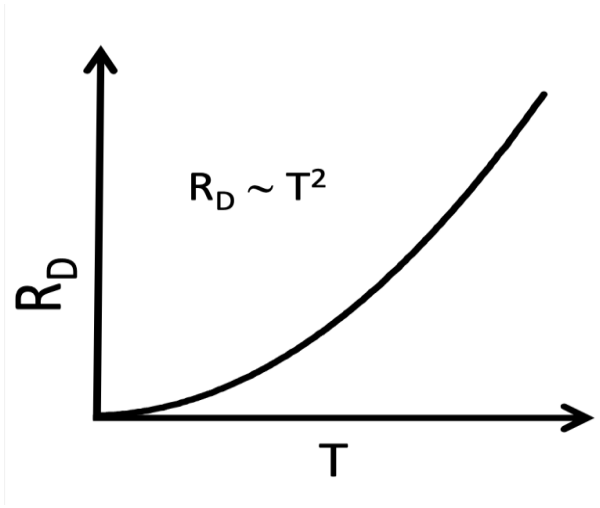

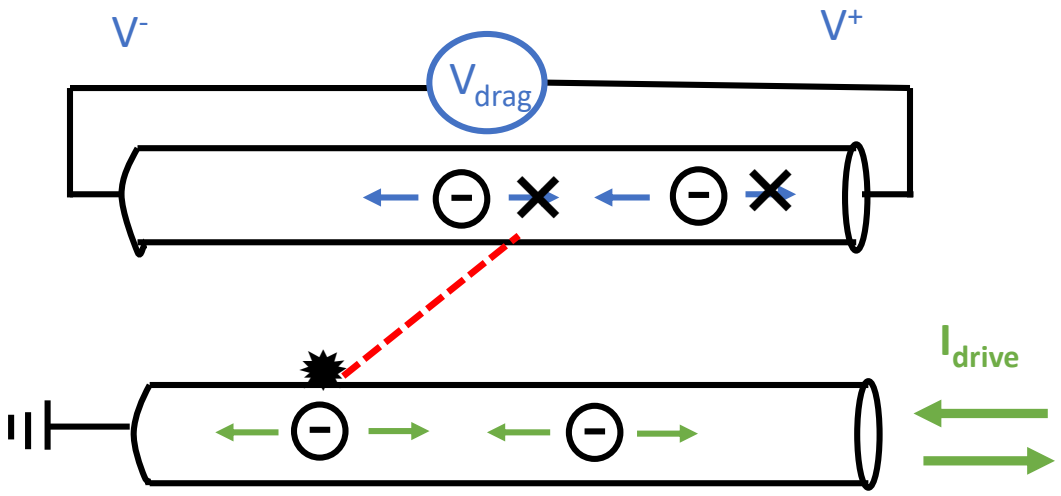

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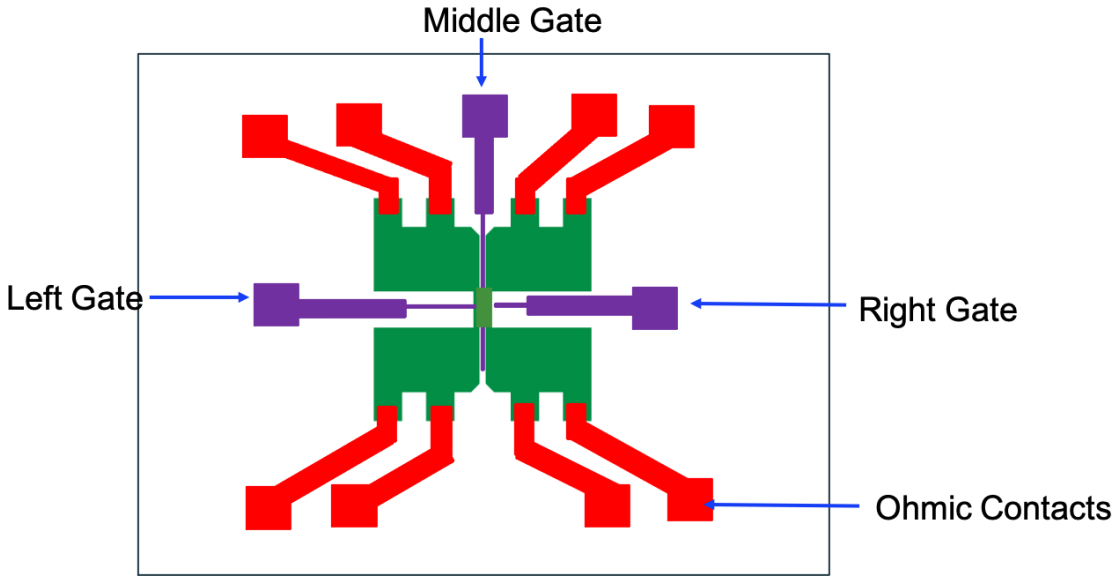
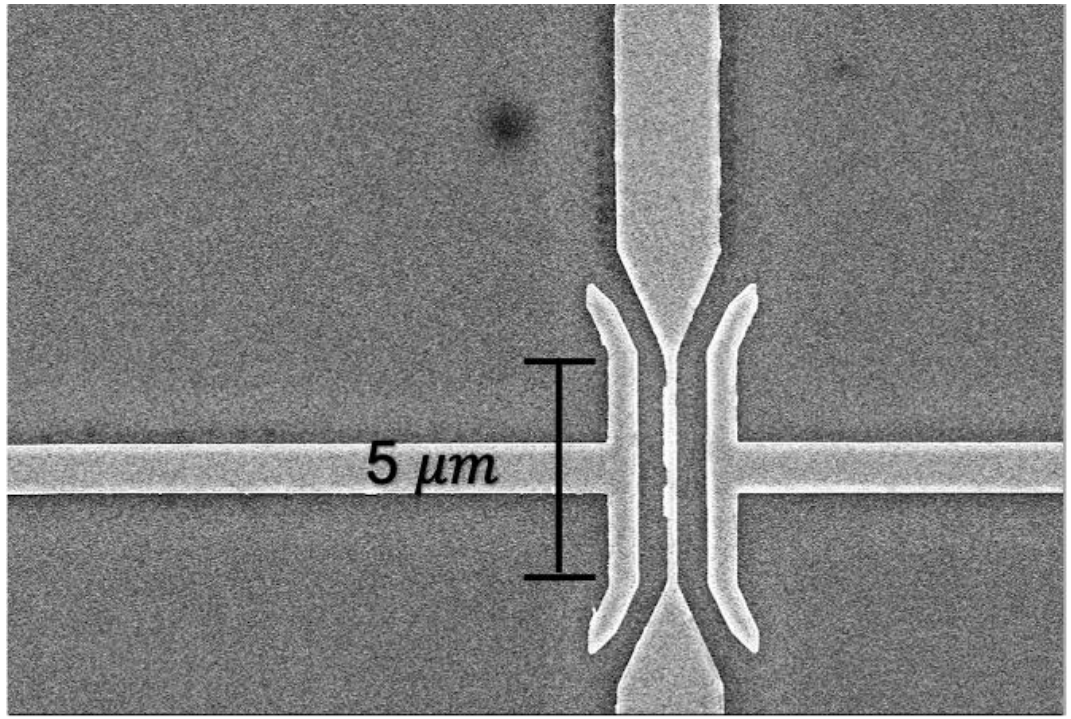
The Device

- Laterally coupled device
- 2DEG 80nm close to the surface
- Independent contacts to both wires
- Fabrication:
  - standard mesa etch with Ge-Au-Ni-Au contacts
  - single e-beam photolithography

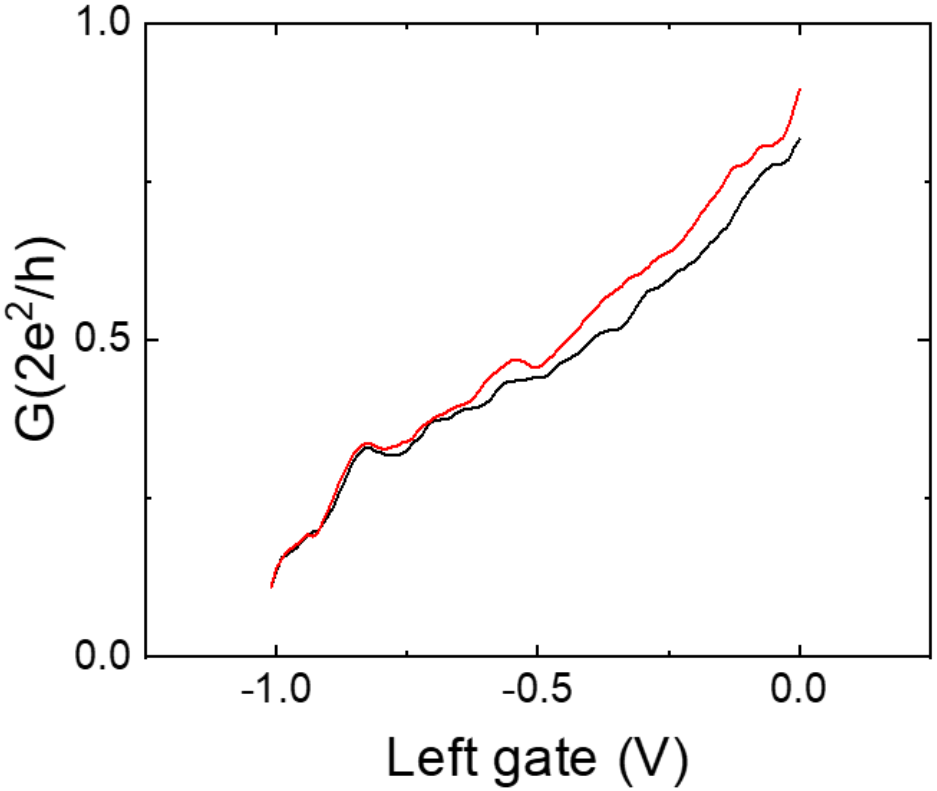




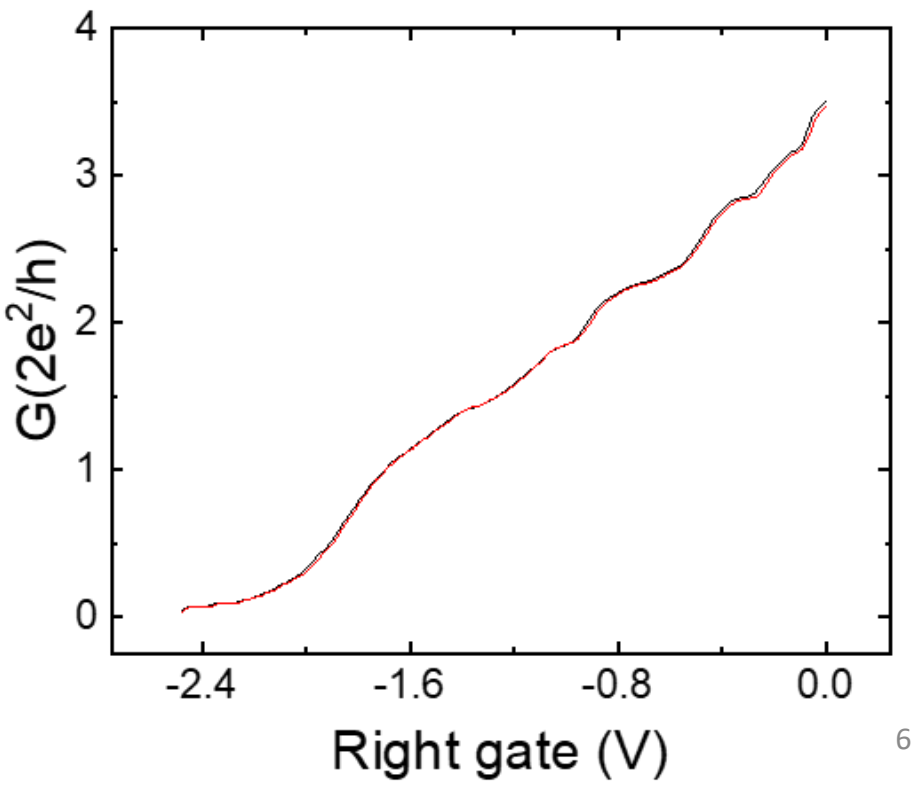
Wire Characterization

- Sweep the left and right wire separately

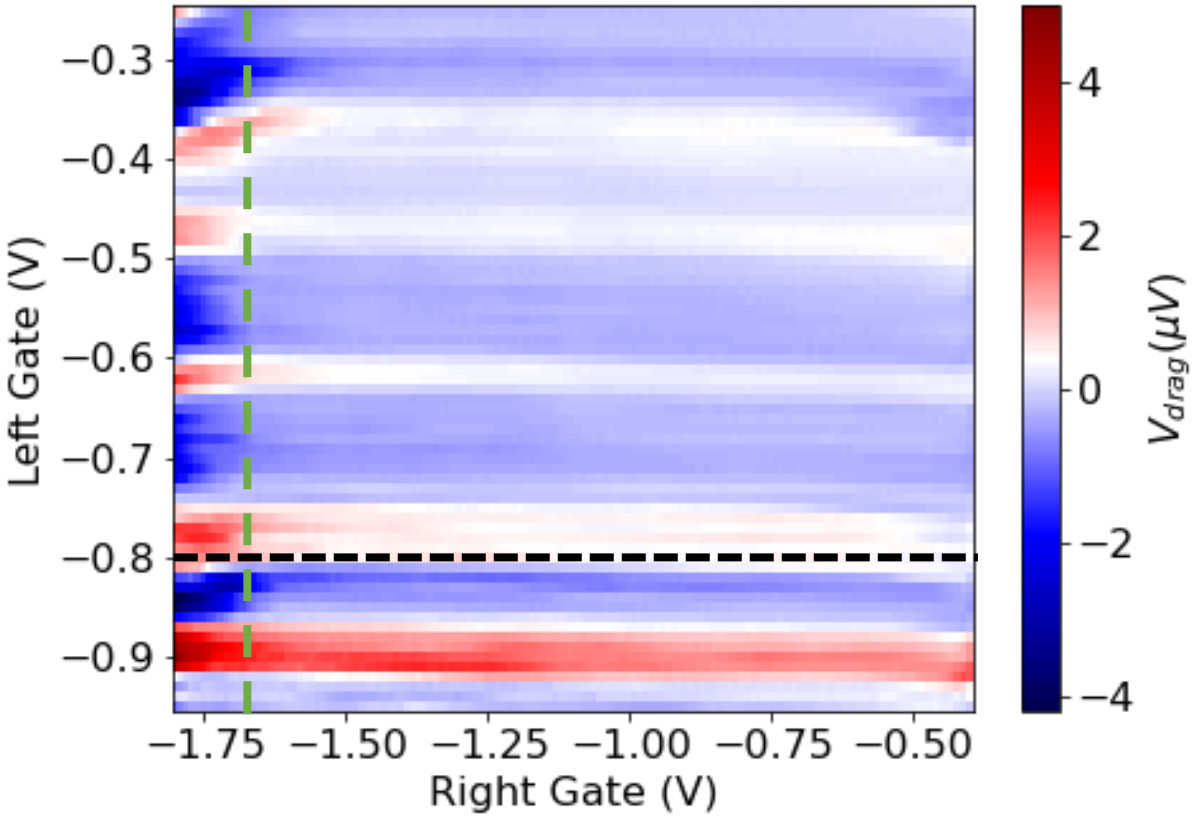
Left Wire

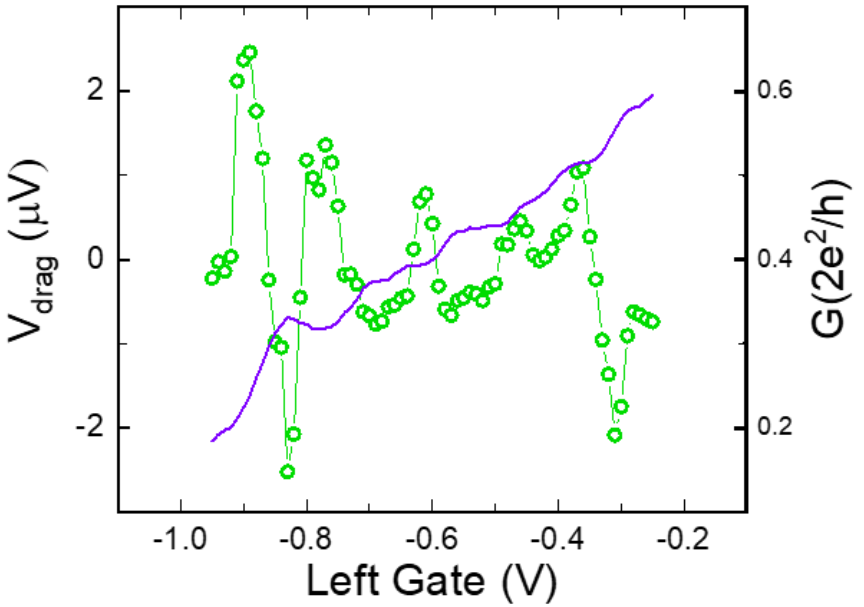


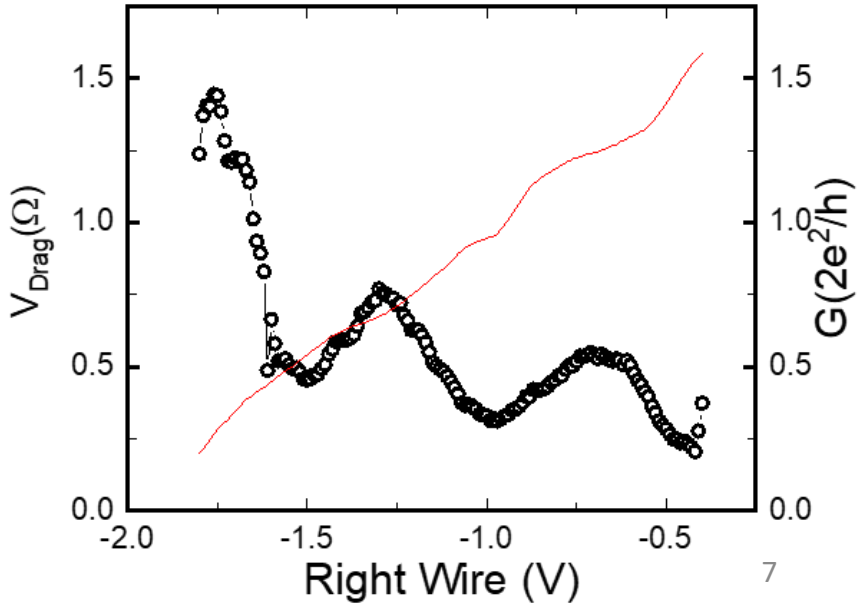
Right Wire



Initial Drag Results

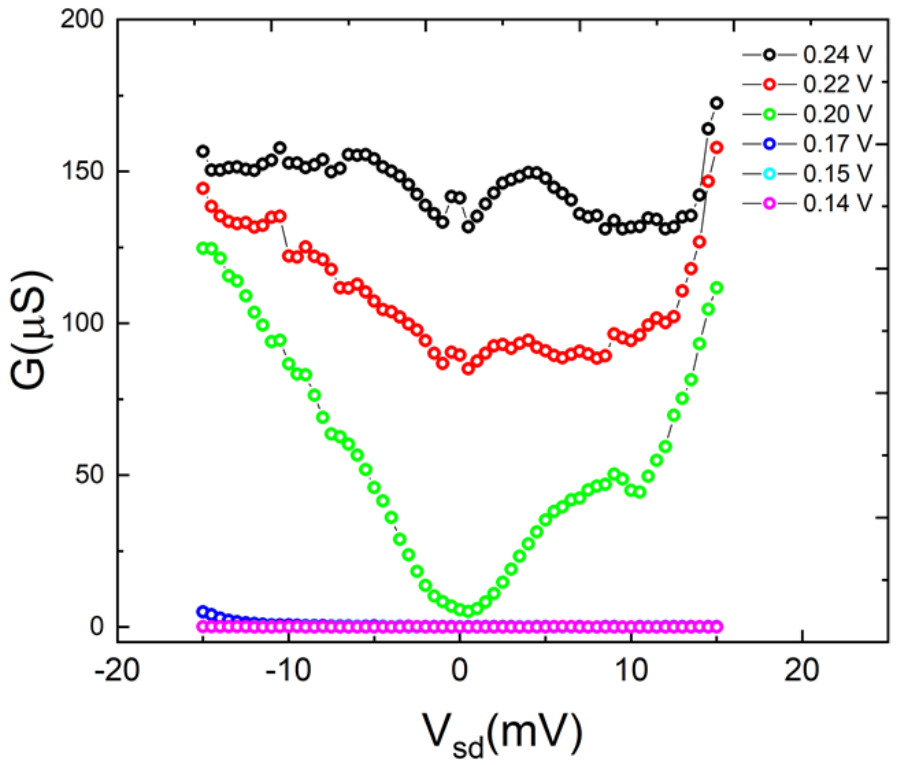




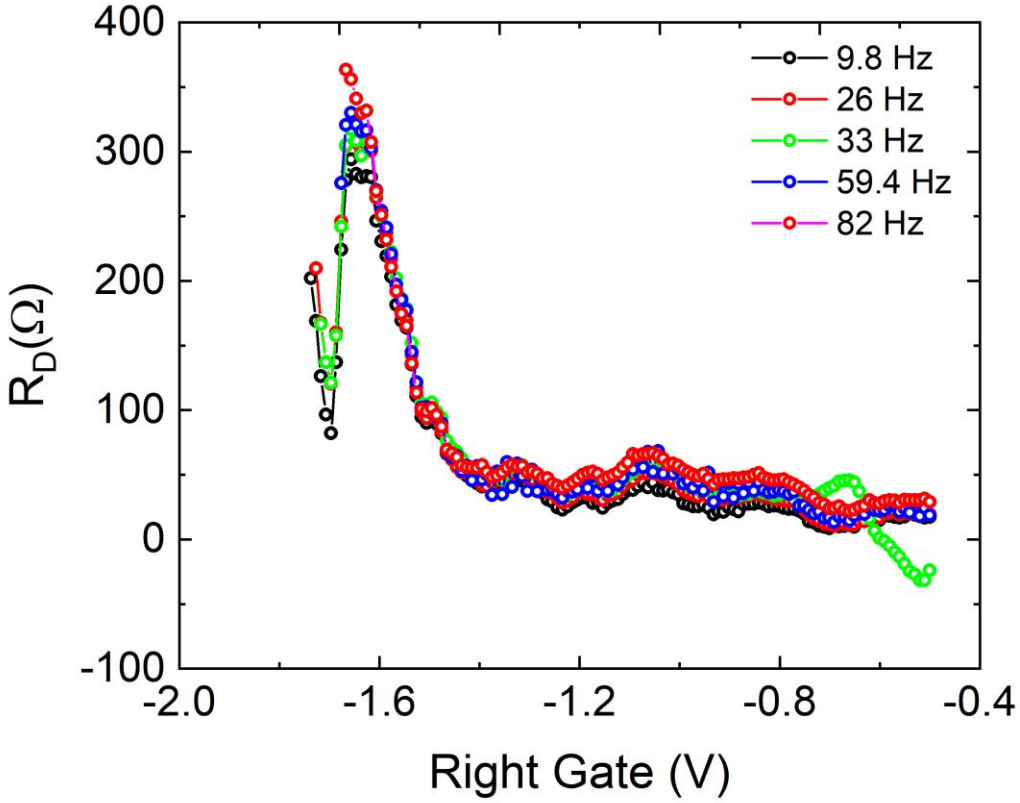


Consistency Tests

Tunneling

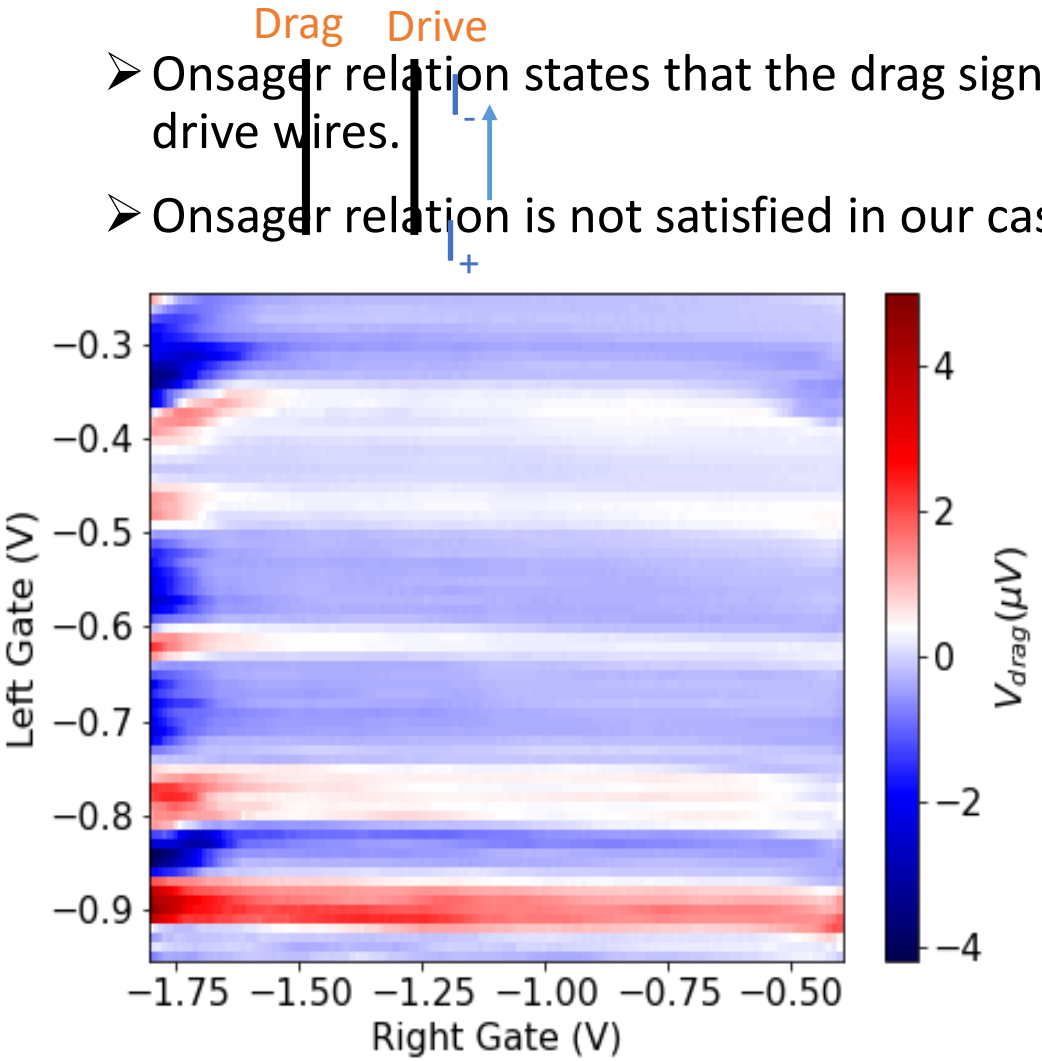


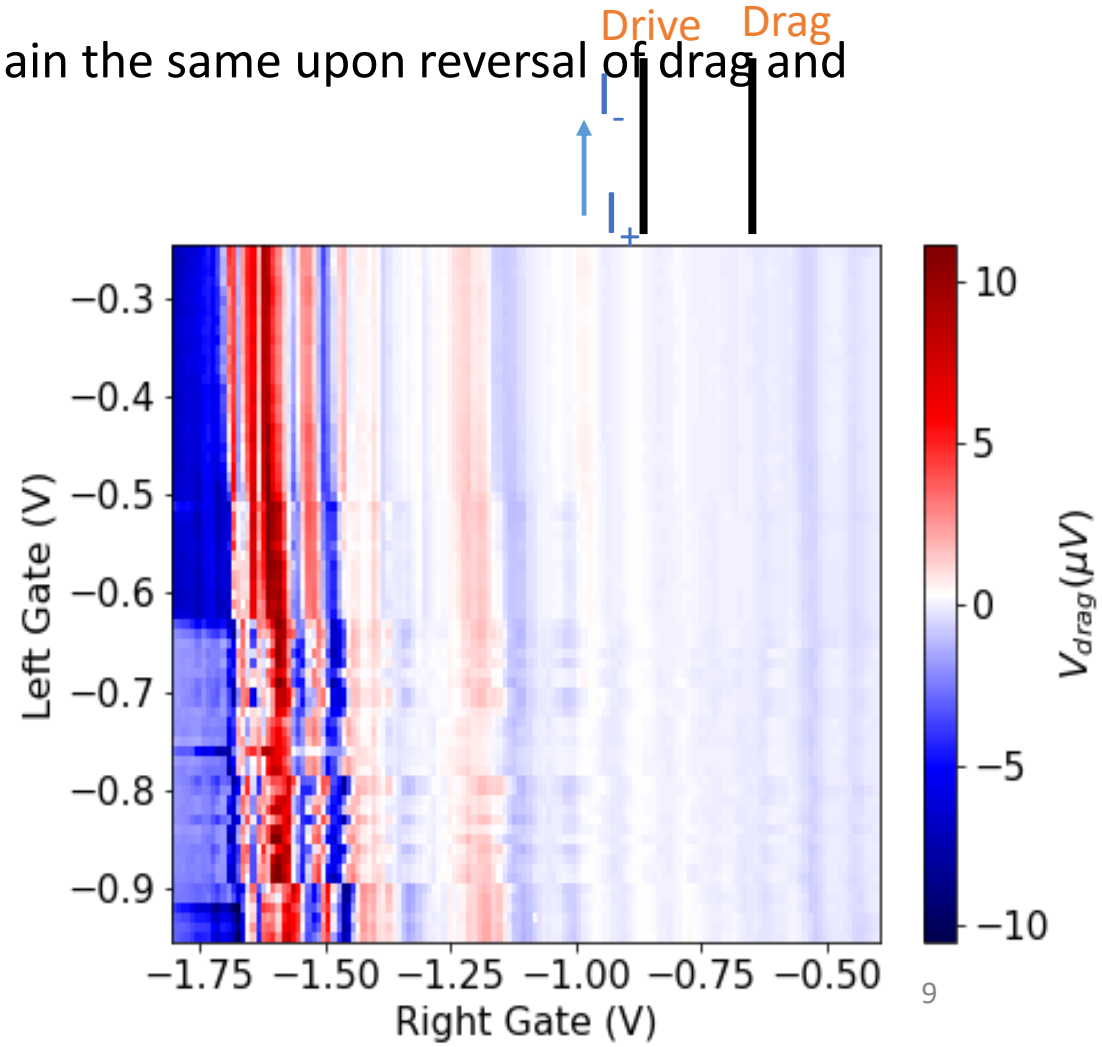
Frequency Independence



Onsager Relation

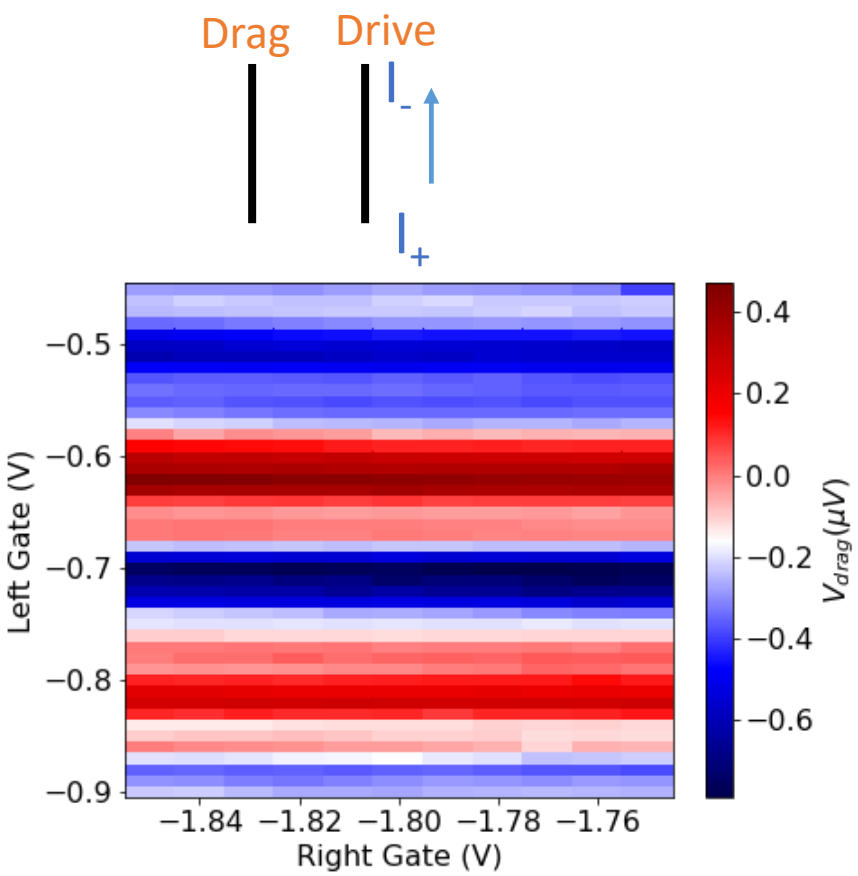
- Onsager relation states that the drag signal should remain the same upon reversal of drag and drive wires.
- Onsager relation is not satisfied in our case.

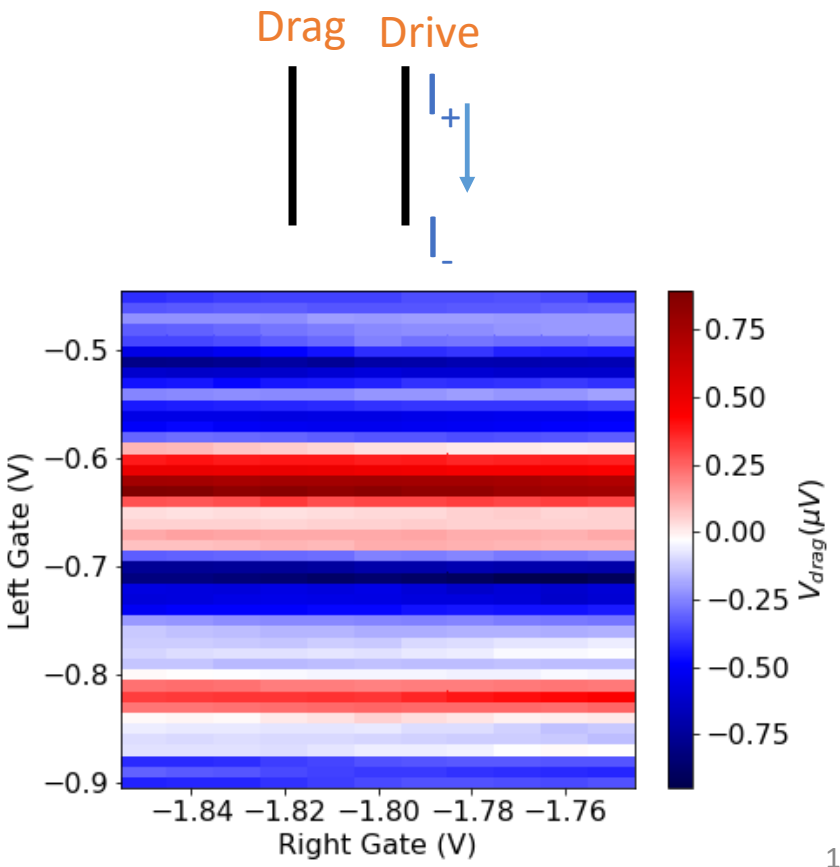




Left-Right Onsager Relation

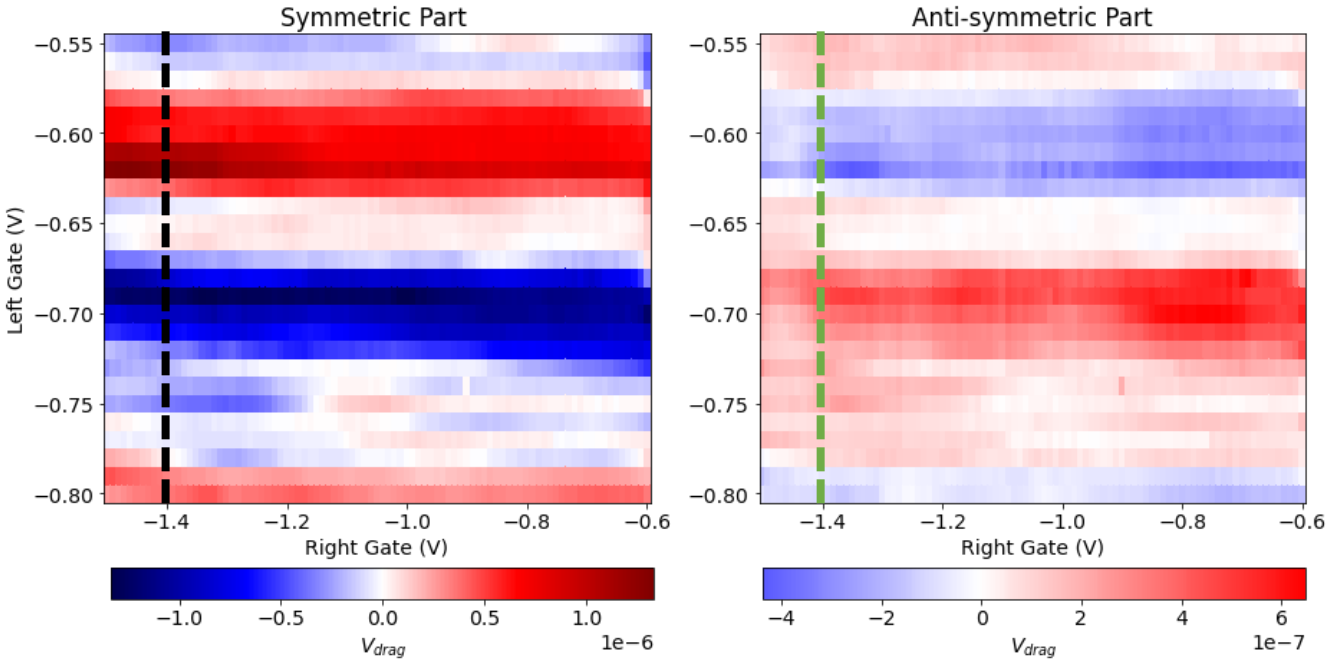
- Expected the signal to flip when changed the current direction

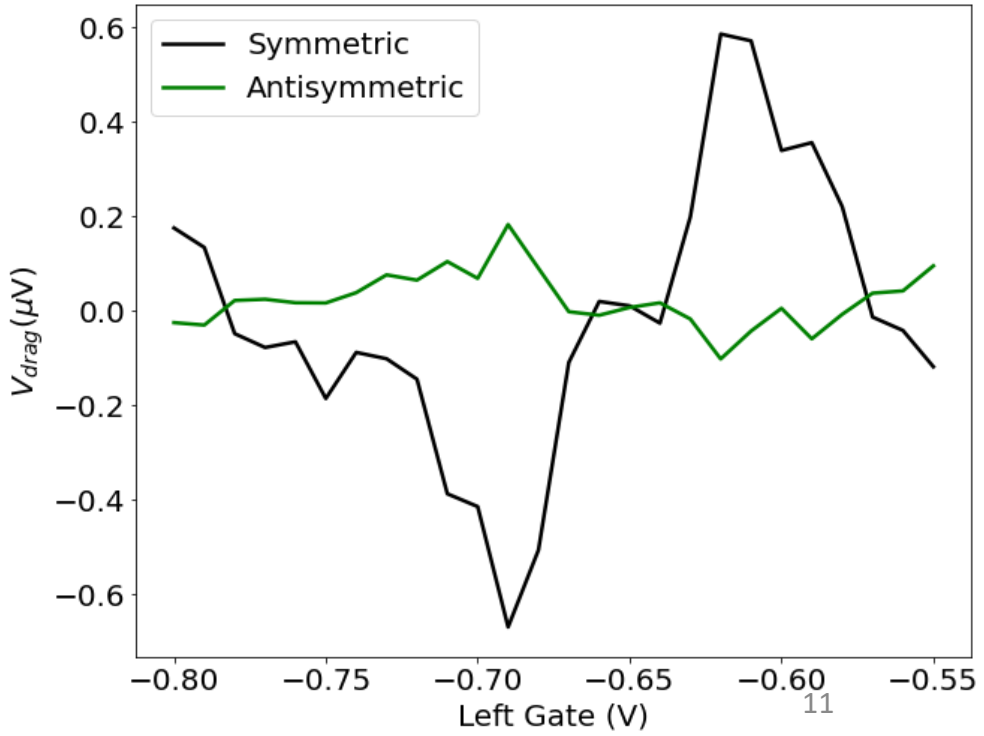




Symmetric/Antisymmetric Contribution

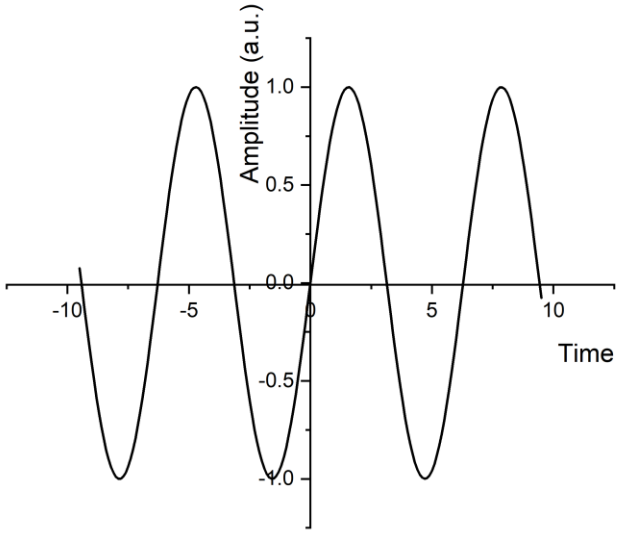
- Onsager relation is broken in both direction (I_+ and I_-)
- We have two contributions:
  - Symmetric : Rectification
  - Antisymmetric : Momentum- transfer



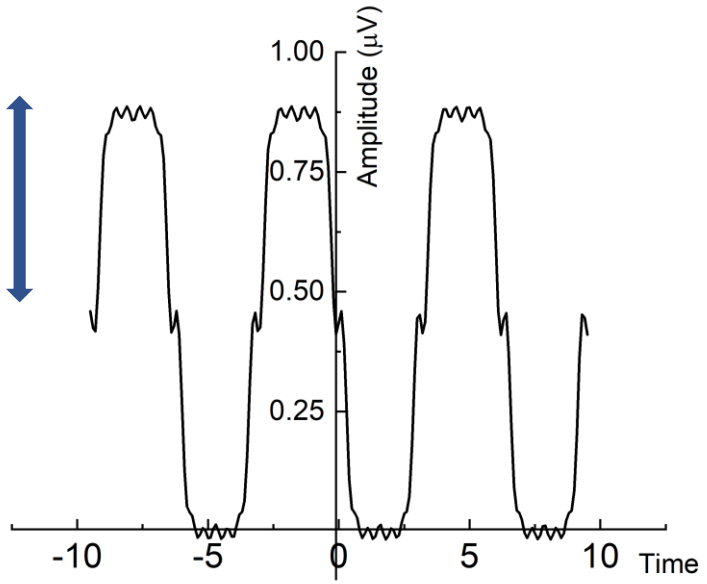


Harmonics

- Expectation: $|\sin(x)|$
- Experiment: Sum of odd sine harmonics → Square wave



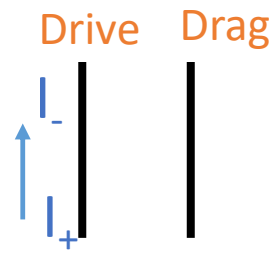
Drive signal



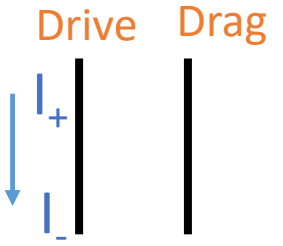
Drag signal

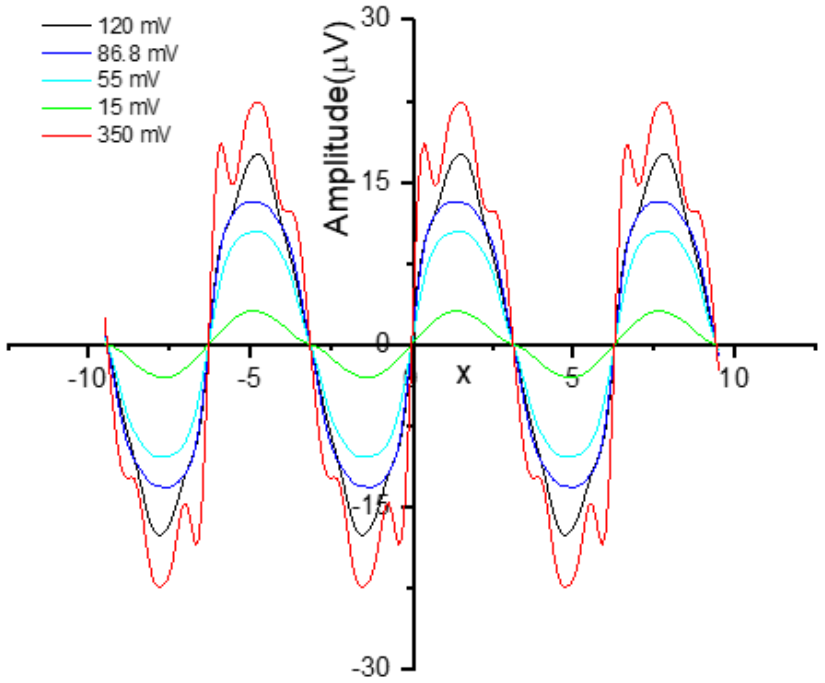
At 55mV

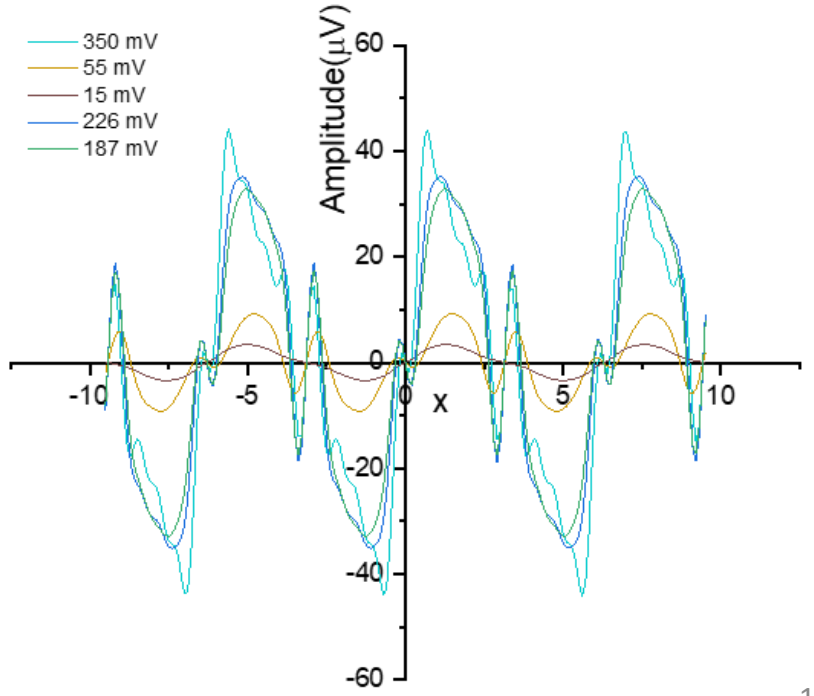
Harmonics



- At different drive voltages
- In both current direction

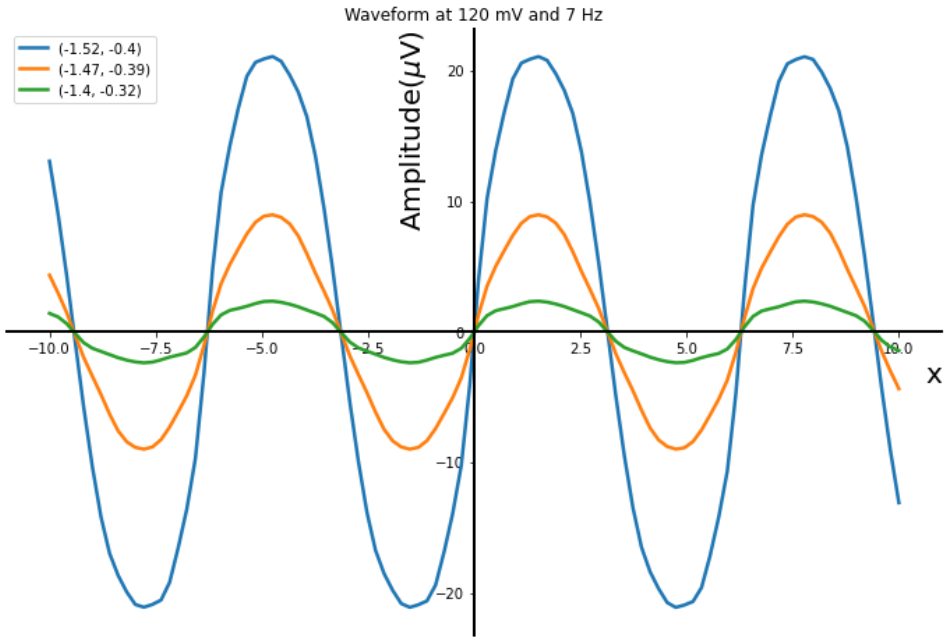




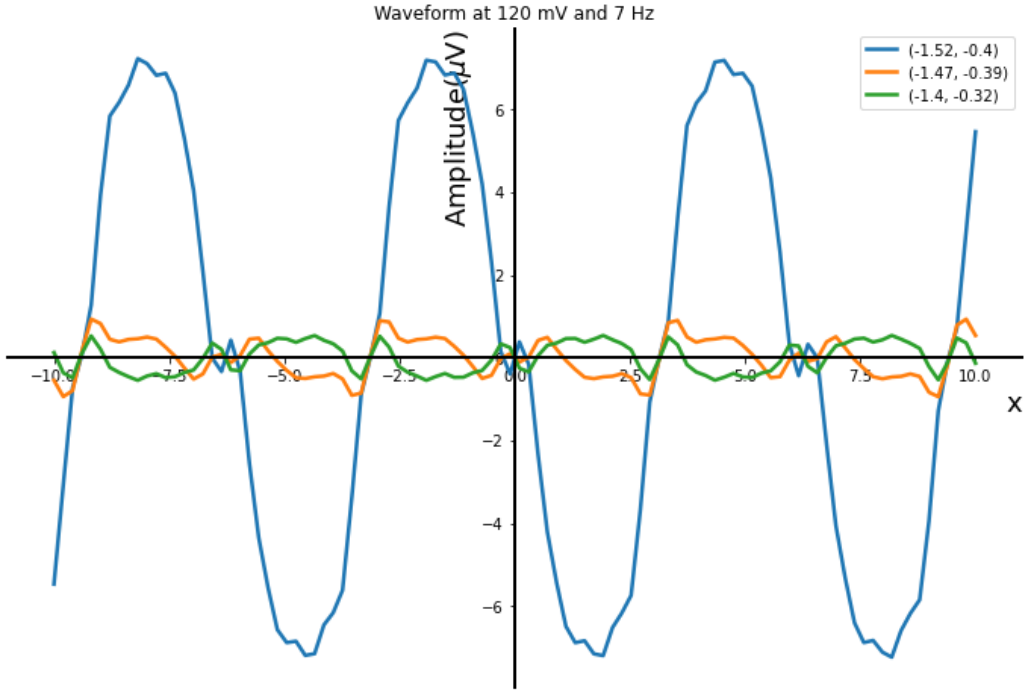


Symmetric/Antisymmetric Waveform

- Extract symmetric and antisymmetric waveform



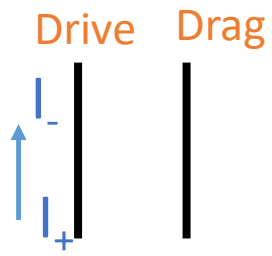
Symmetric

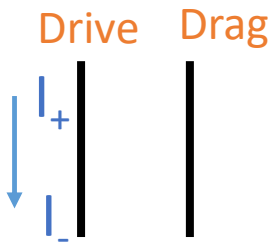


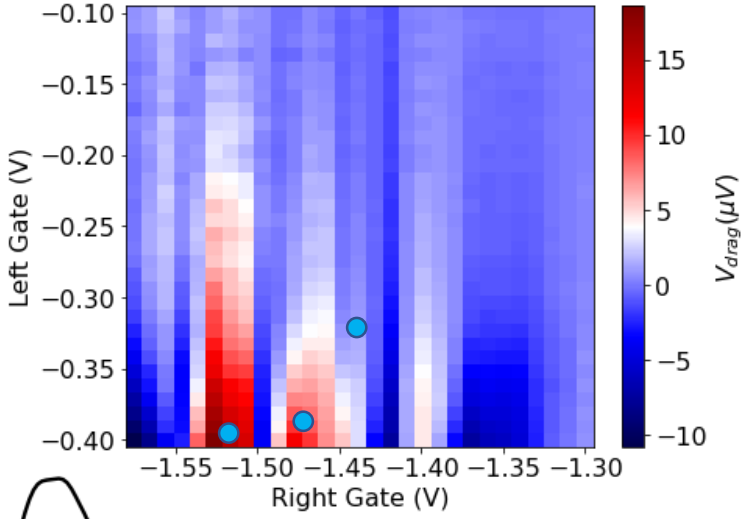
Antisymmetric

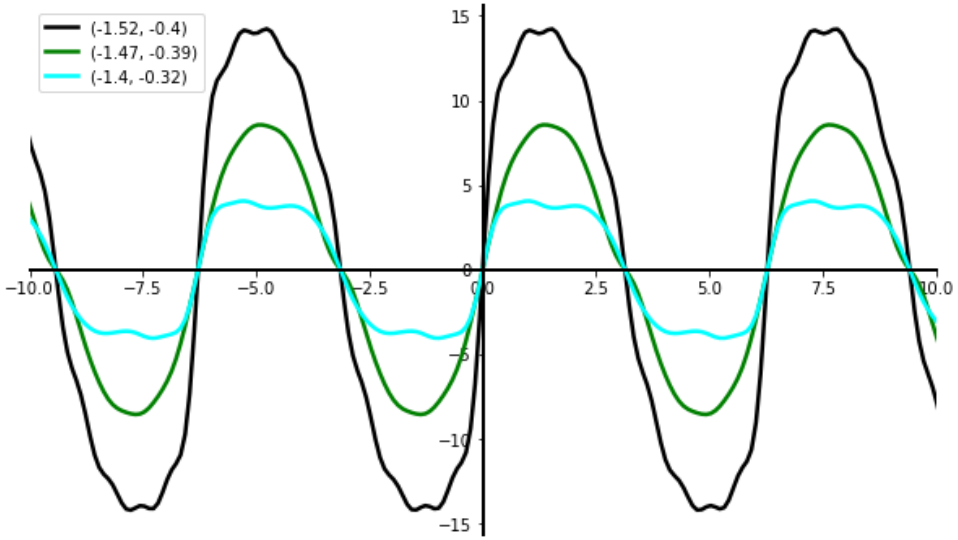
2D Harmonic Scans

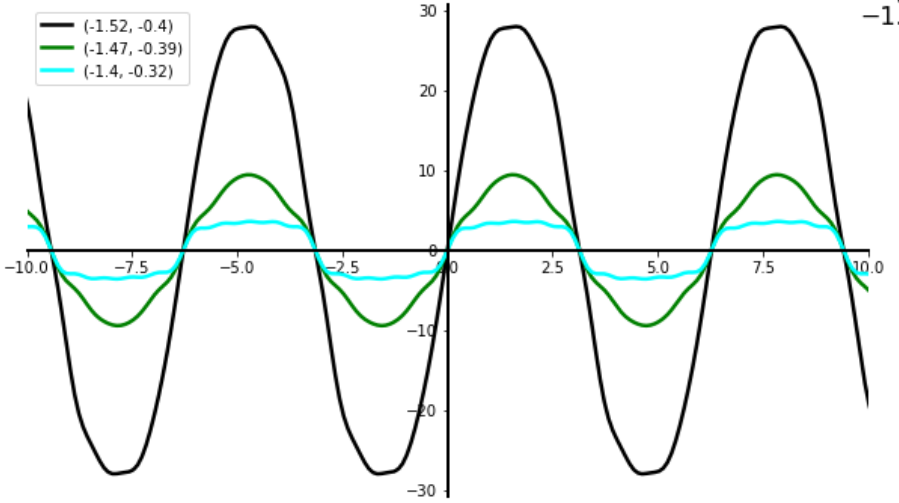
- Waveform depends on the gate voltage





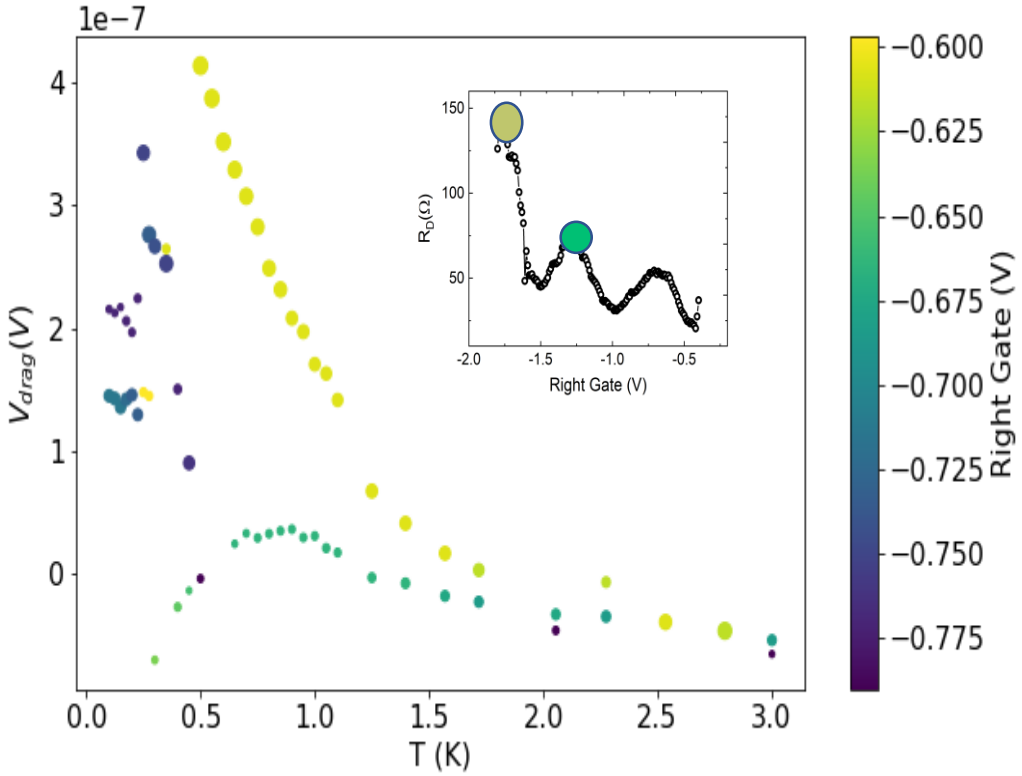


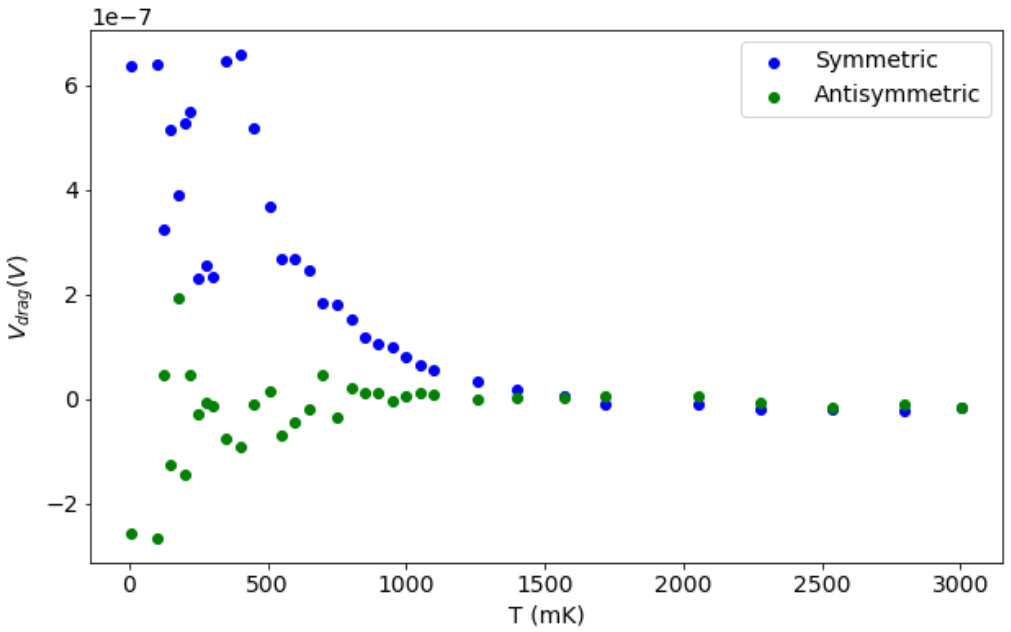




Temperature Dependence

- Track symmetric and anti-symmetric maximas

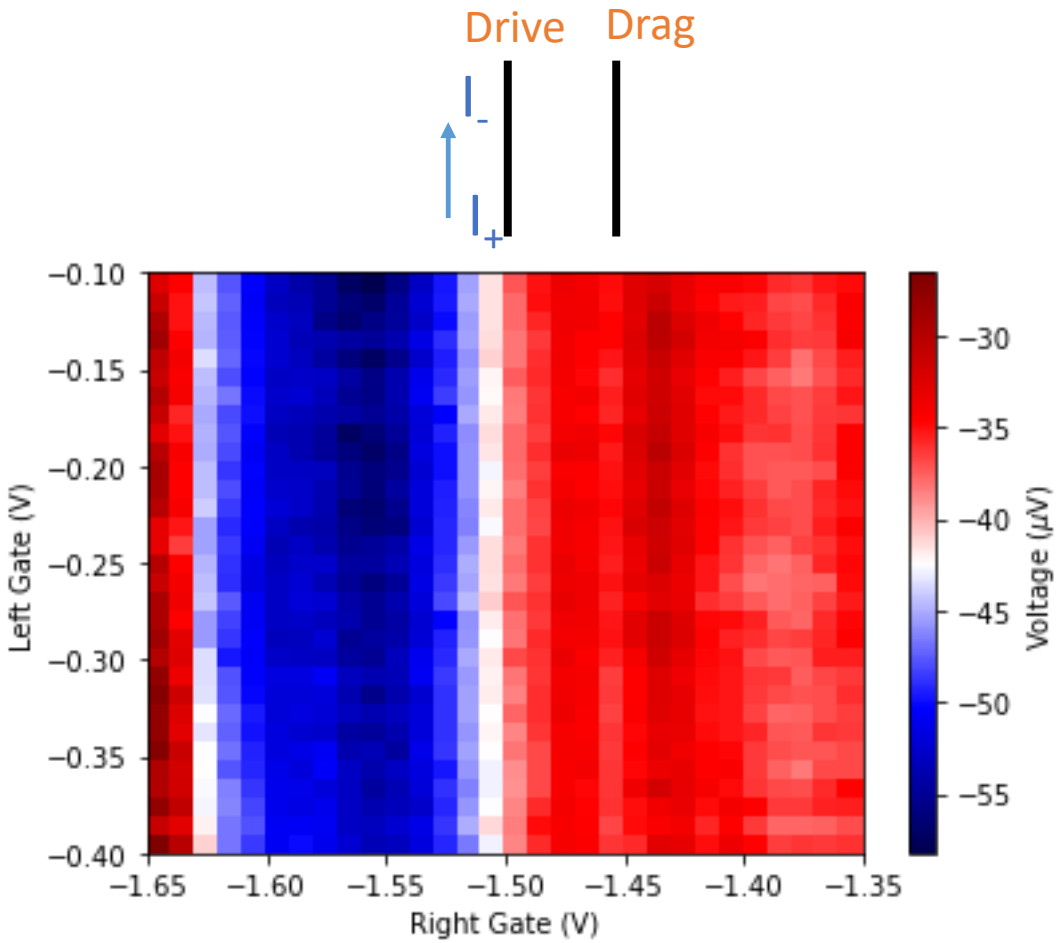


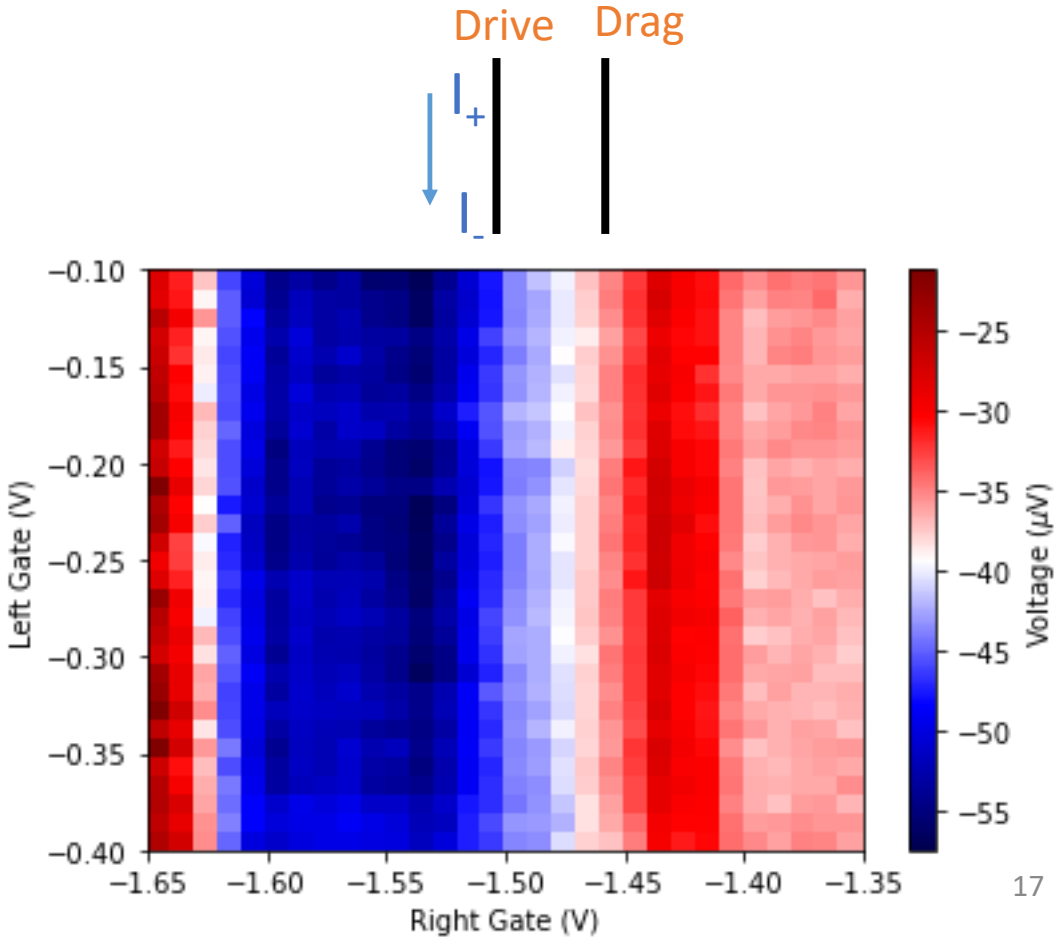


Symmetric maxima and anti-symmetric values at symmetric maxima positions

DC Onsager Relation

- Test Onsager relation with DC setup





Acknowledgements

Thank you for your attention

Harith Kassar
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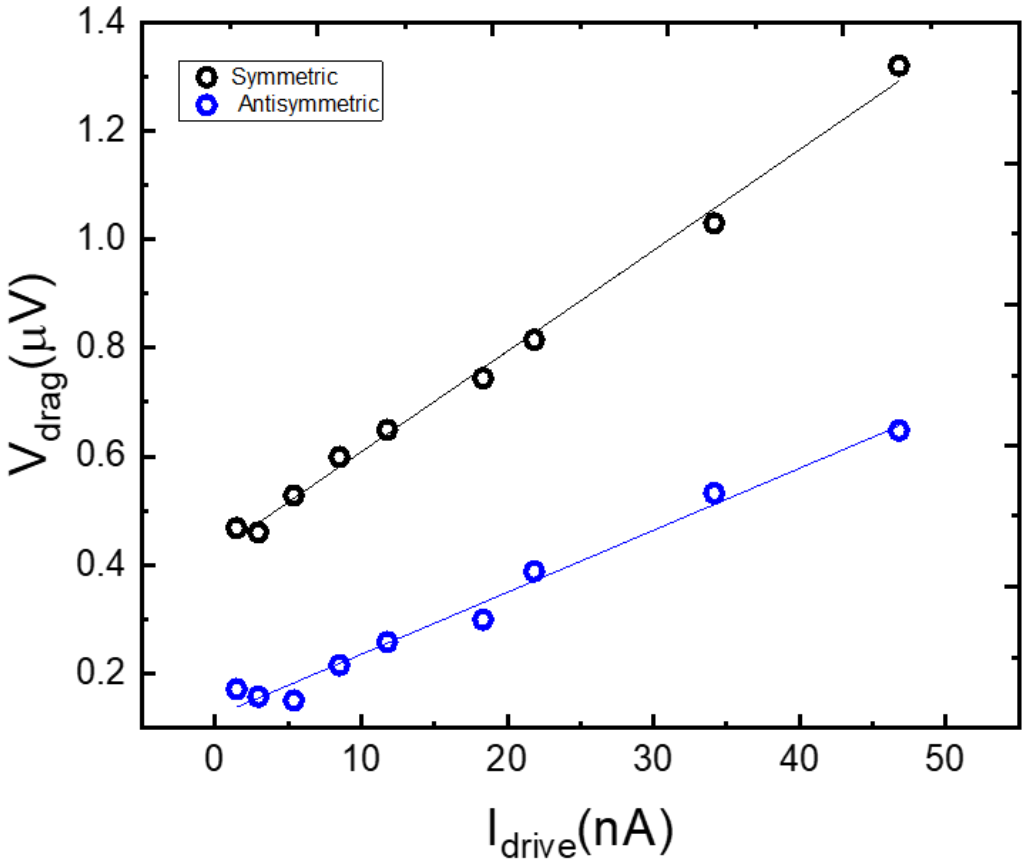
Current Dependence

- Both symmetric and antisymmetric contribution seem to be linear



DC Temperature Dependence