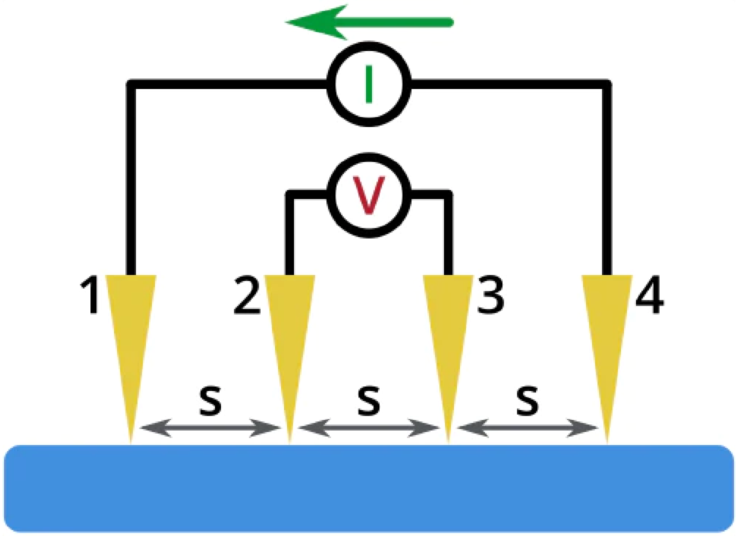
Semester Project

Mid-Sem Presentation

Transport Measurements on TMDCs using a Lock-In Amplifier

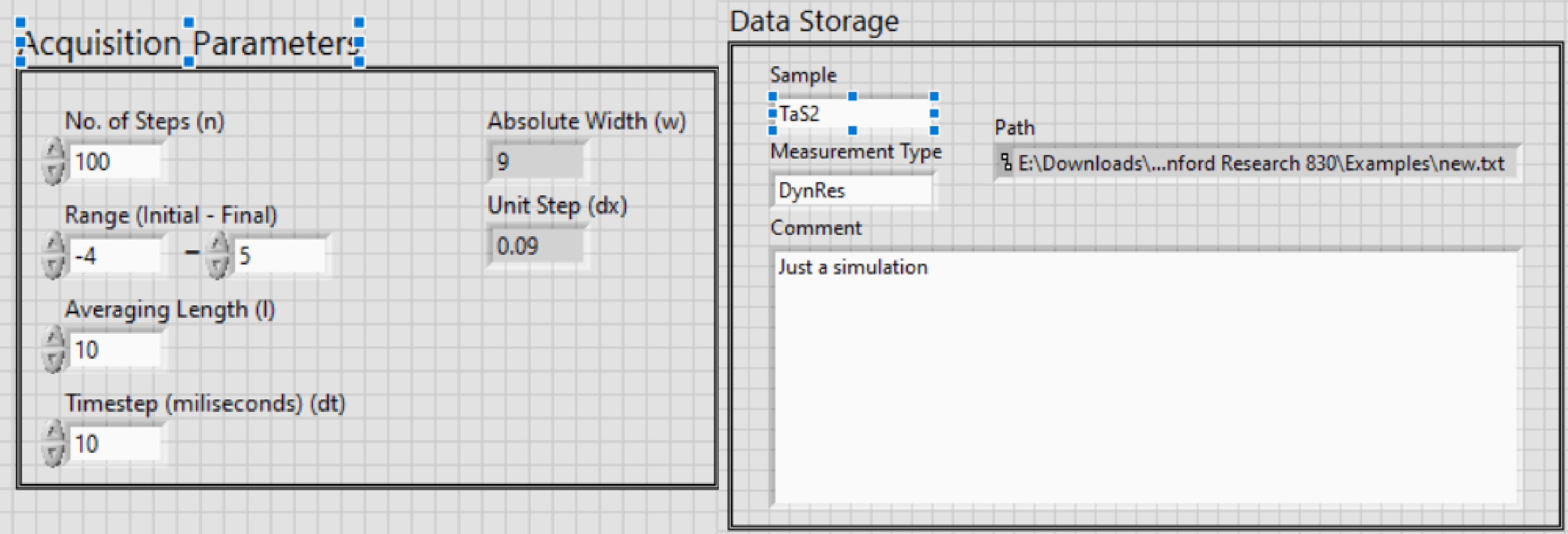
Transport Measurements

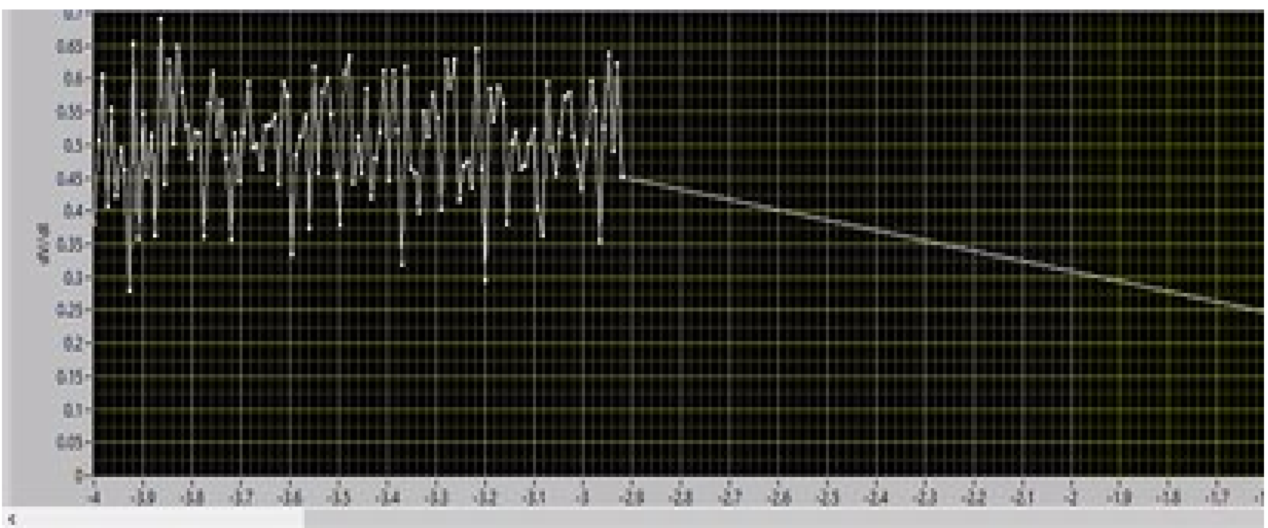
- Measurement of properties related to the transport of electron in a material.
- We are planning to measure resistivity (XX) and hall resistivity (XY) using four probe measurement.



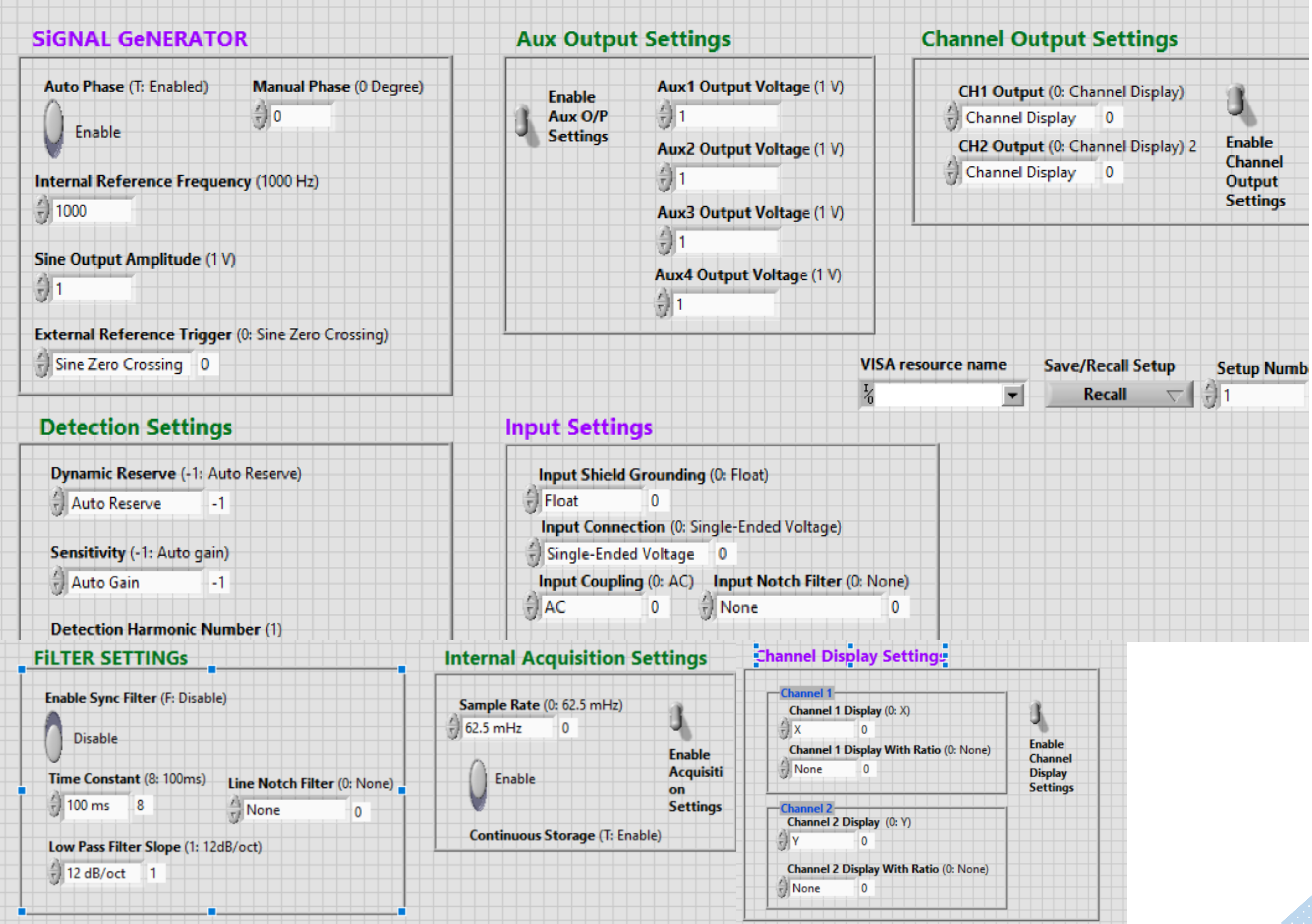
LabVIEW Virtual Instrument(VI)

- We have developed a LabVIEW project that contains several programs which can –
  1. Control every aspect of the Lock-In
  2. Change AUX output voltage in steps in provided range and store the output of Lock-In in .txt file which can then be processed and plotted in Origin.





```
#####Transport Measurement using Lock-In#####
Date: 11 October 2022
Time: 14:44
Sample: TaS2
Measurement Type: DynRes
Comment: Just a simulation
#############################################
X-Value Y-Value
-4.009000       0.566661
-4.000000       0.533176
-3.991000       0.451326
-3.982000       0.619800
-3.973000       0.662428
-3.964000       0.670490
-3.955000       0.589061
-3.946000       0.585254
-3.937000       0.470741
-3.928000       0.386272
-3.919000       0.246526
-3.910000       0.488863
-3.901000       0.451389
-3.892000       0.646488
-3.883000       0.349693
-3.874000       0.487406
-3.865000       0.585840
-3.856000       0.526132
-3.847000       0.515295
-3.838000       0.473813
-3.829000       0.603119
```

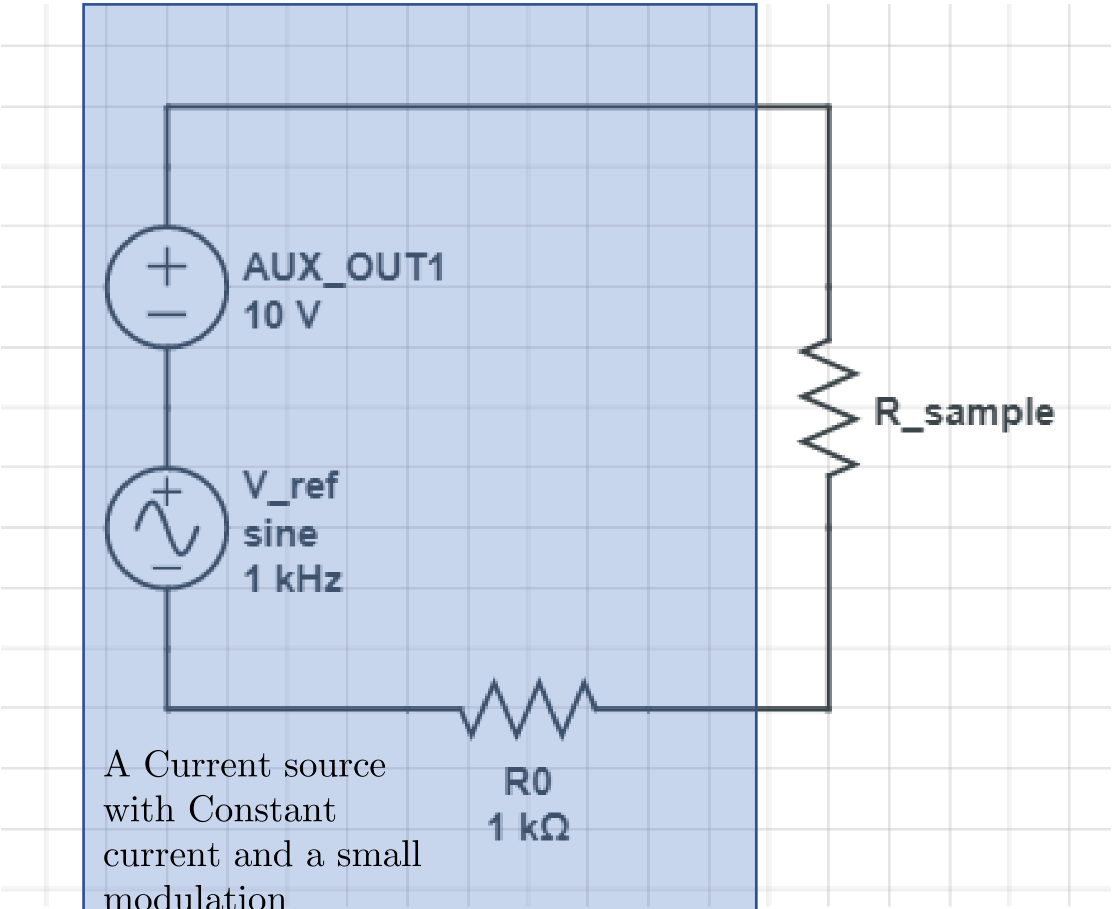


SiGNAL GeNERATOR
Auto Phase (T: Enabled)
Enable
Manual Phase (0 Degree)
0
Internal Reference Frequency (1000 Hz)
1000
Sine Output Amplitude (1 V)
1
External Reference Trigger (0: Sine Zero Crossing)
Sine Zero Crossing 0
Aux Output Settings
Enable Aux O/P Settings
Aux1 Output Voltage (1 V)
1
Aux2 Output Voltage (1 V)
1
Aux3 Output Voltage (1 V)
1
Aux4 Output Voltage (1 V)
1
Channel Output Settings
CH1 Output (0: Channel Display)
Channel Display 0
CH2 Output (0: Channel Display) 2
Channel Display 0
Enable Channel Output Settings
VISA resource name
Save/Recall Setup
Recall
Setup Numb
1
Detection Settings
Dynamic Reserve (-1: Auto Reserve)
Auto Reserve -1
Sensitivity (-1: Auto gain)
Auto Gain -1
Detection Harmonic Number (1)
Input Settings
Input Shield Grounding (0: Float)
Float 0
Input Connection (0: Single-Ended Voltage)
Single-Ended Voltage 0
Input Coupling (0: AC)
AC 0
Input Notch Filter (0: None)
None 0
FiLTER SETTINGs
Enable Sync Filter (F: Disable)
Disable
Time Constant (8: 100ms)
100 ms 8
Line Notch Filter (0: None)
None 0
Low Pass Filter Slope (1: 12dB/oct)
12 dB/oct 1
Internal Acquisition Settings
Sample Rate (0: 62.5 mHz)
62.5 mHz 0
Enable
Enable Acquisition Settings
Continuous Storage (T: Enable)
Channel Display Settings
Channel 1
Channel 1 Display (0: X)
X 0
Channel 1 Display With Ratio (0: None)
None 0
Channel 2
Channel 2 Display (0: Y)
Y 0
Channel 2 Display With Ratio (0: None)
None 0
Enable Channel Display Settings

Failed Attempt

- We tried to take a measurement of resistance of know carbon resistor using Lock-In amplifier both for the source and the measurements.
- Using a know high resistance to create current source from Lock-In voltage supply

Failed Attempt

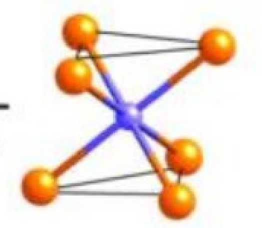


A Current source with Constant current and a small modulation

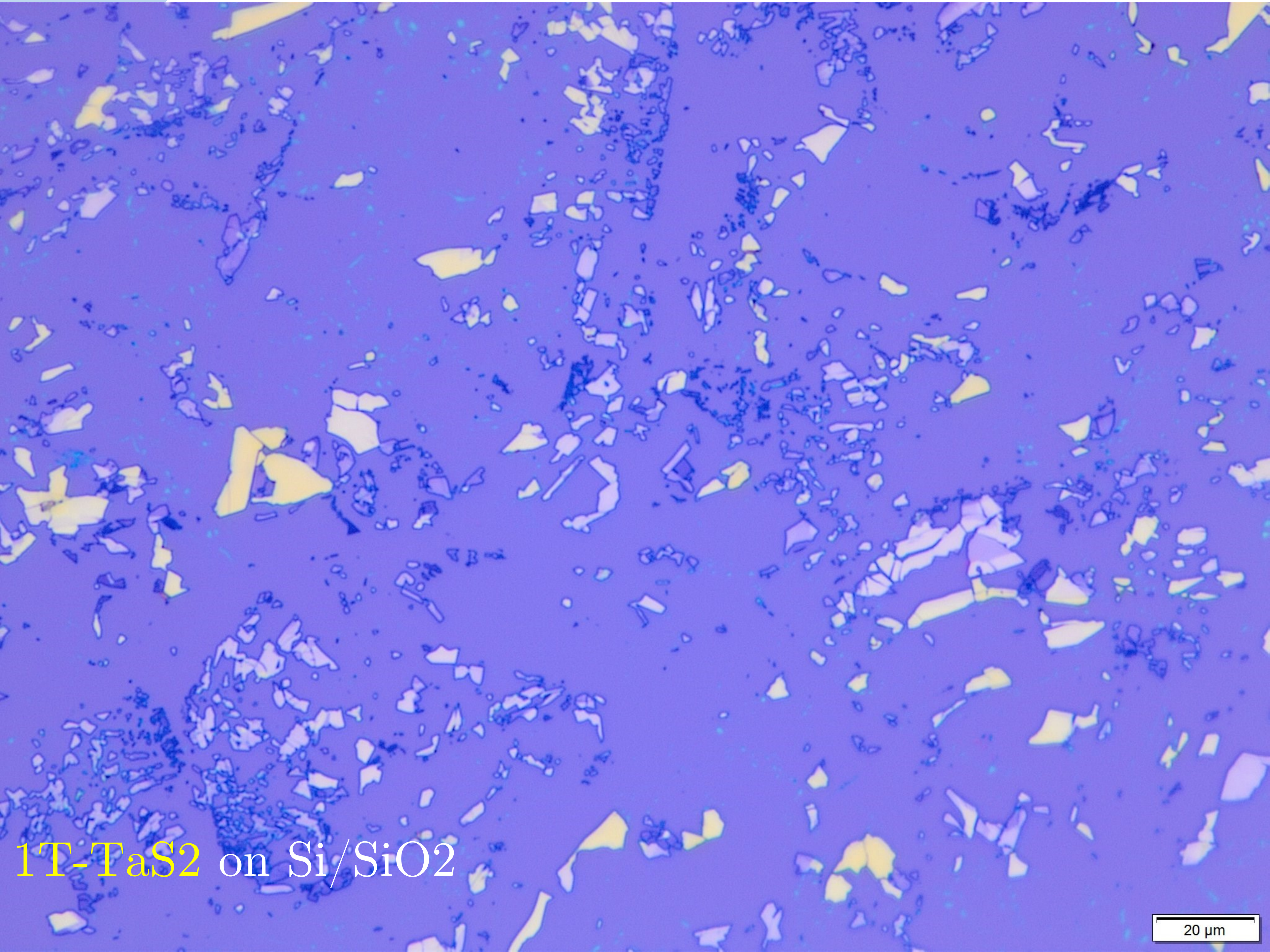
Failed Attempt

- But the result was not satisfactory and were changing with modulation frequency
- **Possible Solution:** we can first characterise the circuit, at different input voltage, frequency and load resistance to pinpoint the source problem.

Tantalum Disulfide

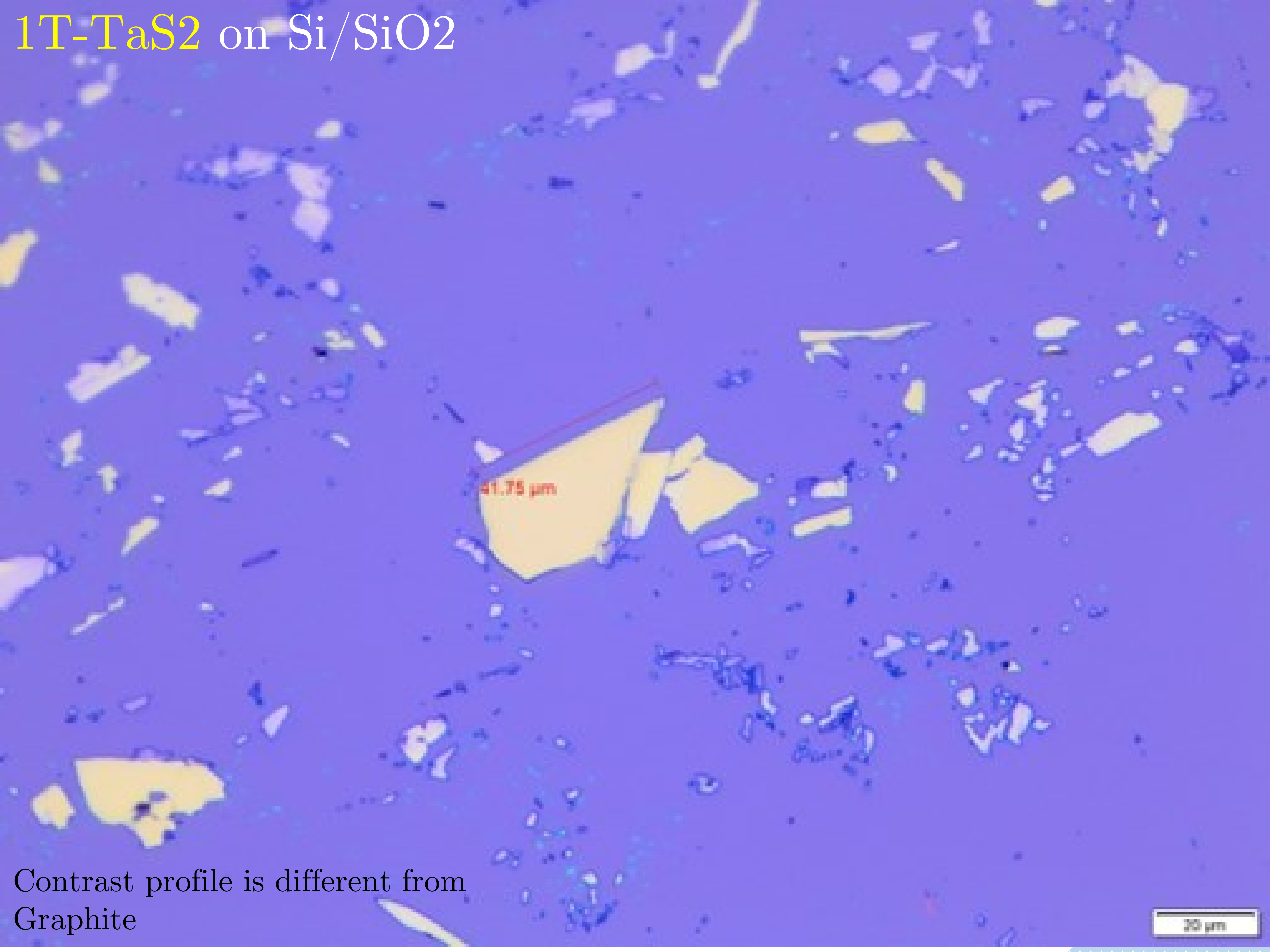


- We have 1T-TaS2 phase with each Ta atom with 6 S atoms in octahedral structure
- It shows an variety of CDW phases transitions from 550K to 50K, with an unusual insulating phase below 200K, also shows superconductivity at high pressures and low temp($\sim 2.5\, GPa\ - 1.5\, K$) [1]
- It also has a metastable **metallic** state at low temperatures ($\sim 20\, K$) which can be activated using optical and electrical pulse. [2]



1T-TaS2 on Si/SiO2
20 μm

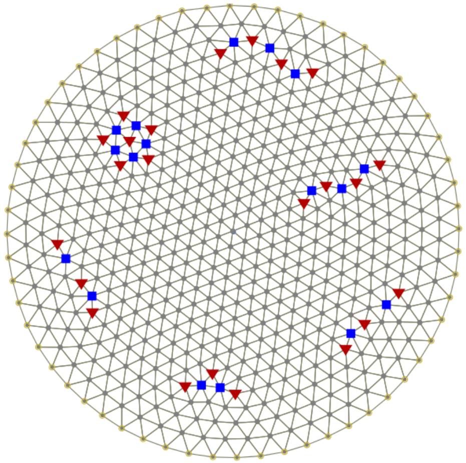
1T-TaS2 on Si/SiO2



Contrast profile is different from Graphite

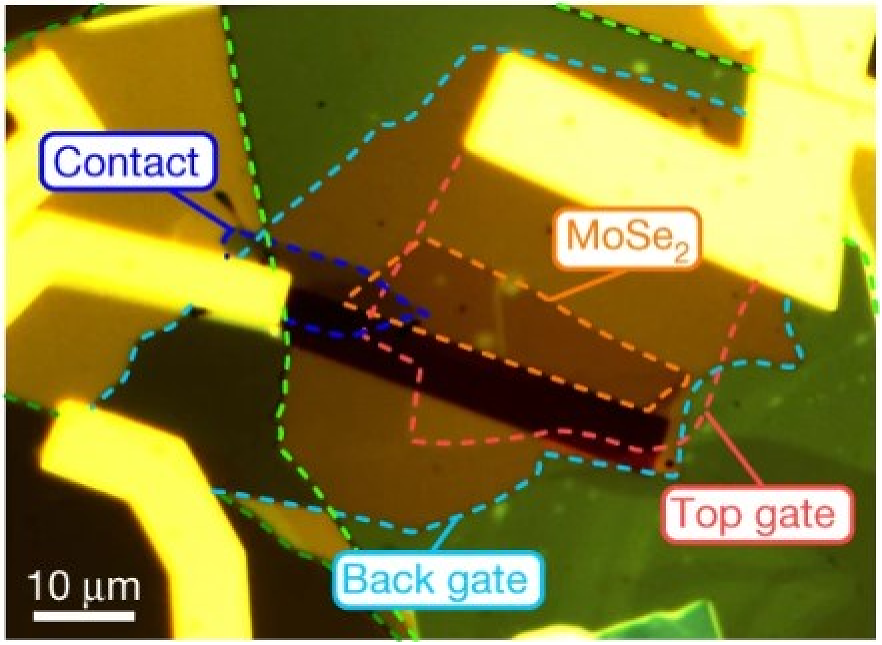
Wigner Crystals

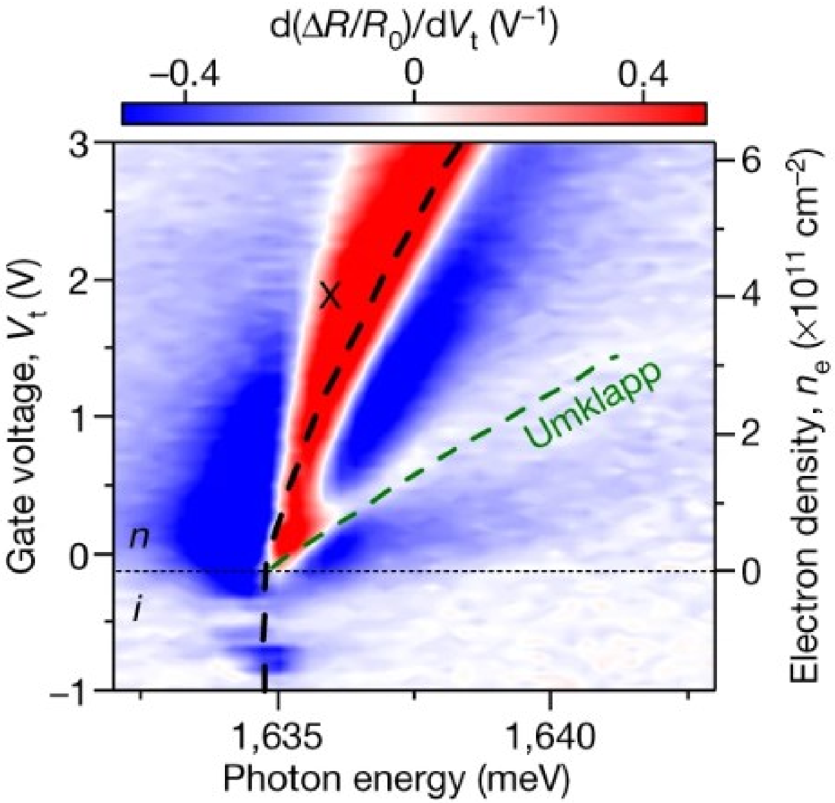
- It is an electronic crystal that was predicted by Eugene Wigner in 1934.[3]
- It is due to strong-correlation between the electrons.
- When the Coulomb interaction between the particles become more significant than the motion of particles



Signatures of Wigner crystal of electrons in a monolayer semiconductor

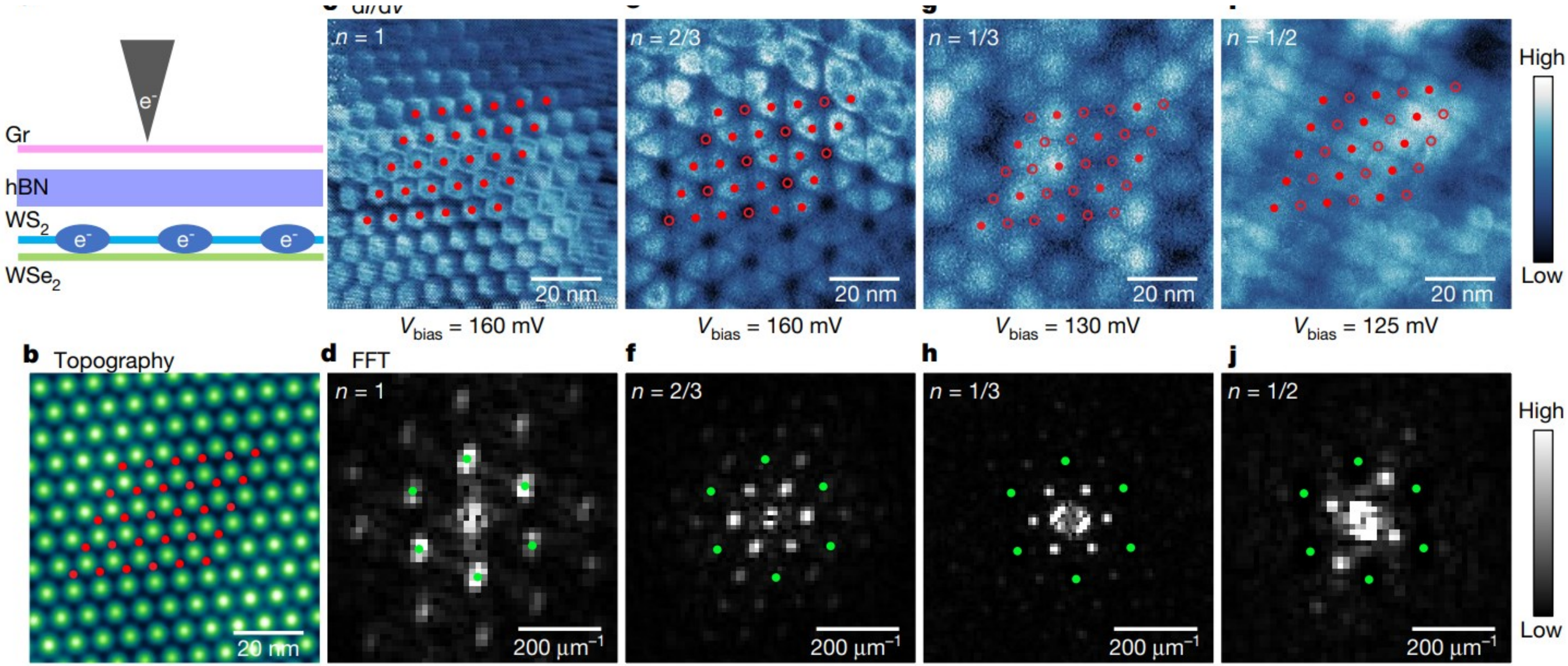
Tomasz Smoleński, Pavel E. Dolgirev, Clemens Kuhlenkamp, Alexander Popert, Yuya Shimazaki, Patrick Back, Xiaobo Lu, Martin Kroner, Kenji Watanabe, Takashi Taniguchi, Ilya Esterlis, Eugene Demler & Ataç Imamoğlu





Imaging two-dimensional generalized Wigner crystals

Hongyuan Li, Shaowei Li, Emma C. Regan, Danqing Wang, Wenyu Zhao, Salman Kahn, Kentaro Yumigeta, Mark Blei, Takashi Taniguchi, Kenji Watanabe, Sefaattin Tongay, Alex Zettl, Michael F. Crommie & Feng Wang



References

1. Sipos, B.; Kusmartseva, A. F.; et al(2008). "From Mott state to superconductivity in 1T-TaS_2". *Nature Materials*. **7** (12): doi:10.1038/nmat2318.
2. Stojchevska, L. et. al.(2014). "Ultrafast Switching to a Stable Hidden Quantum State in an Electronic Crystal". *Science*. **344** (6180): 177–180. arXiv:1401.6786. doi:10.1126/science.1241591
3. Wigner, E. (1934). "On the Interaction of Electrons in Metals". Physical Review. **46** (11): 1002–1011. doi:10.1103/PhysRev.46.1002