TATTOOS

Tunable twistronics : local tuning and probing of topological edge states and superconductivity in bilayer graphene

JTC 2019 – funded project (started Feb 2020)

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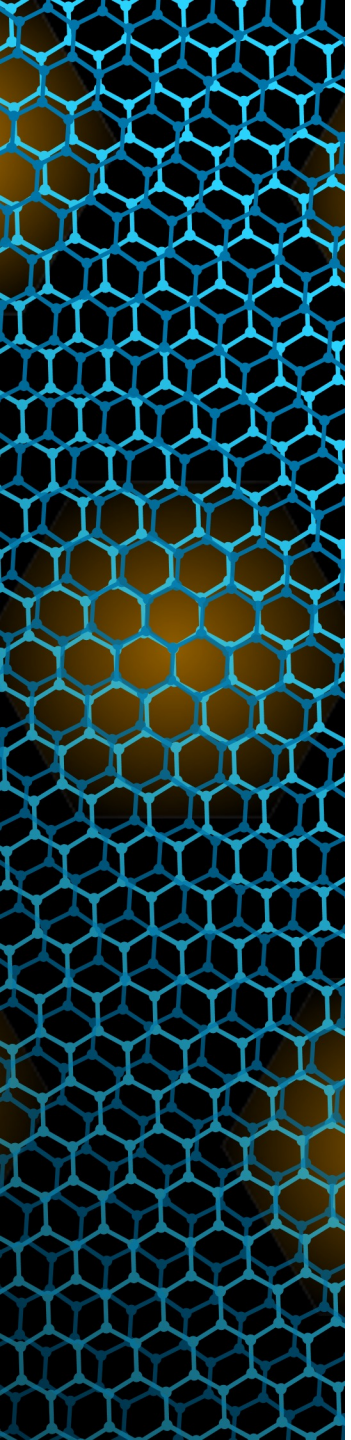
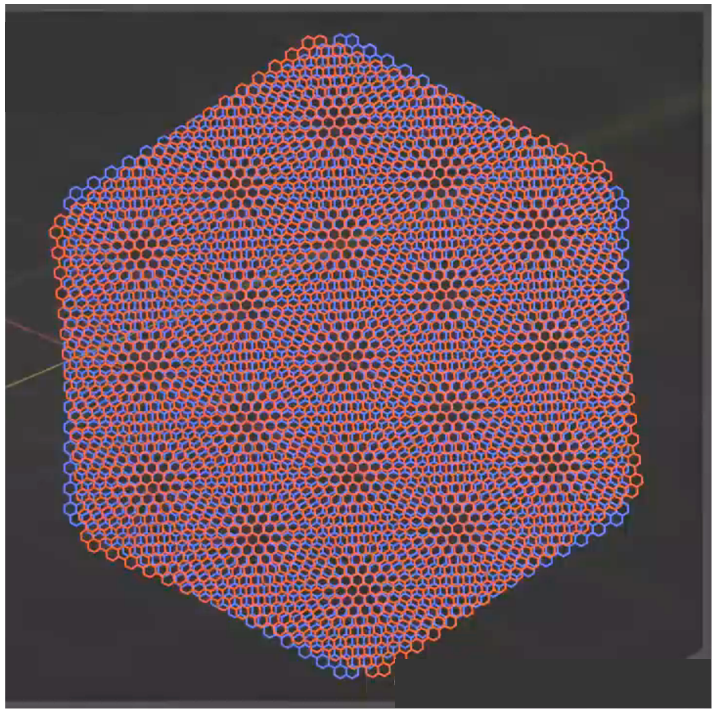
FLAG-ERA General meeting – March 21th, 2022

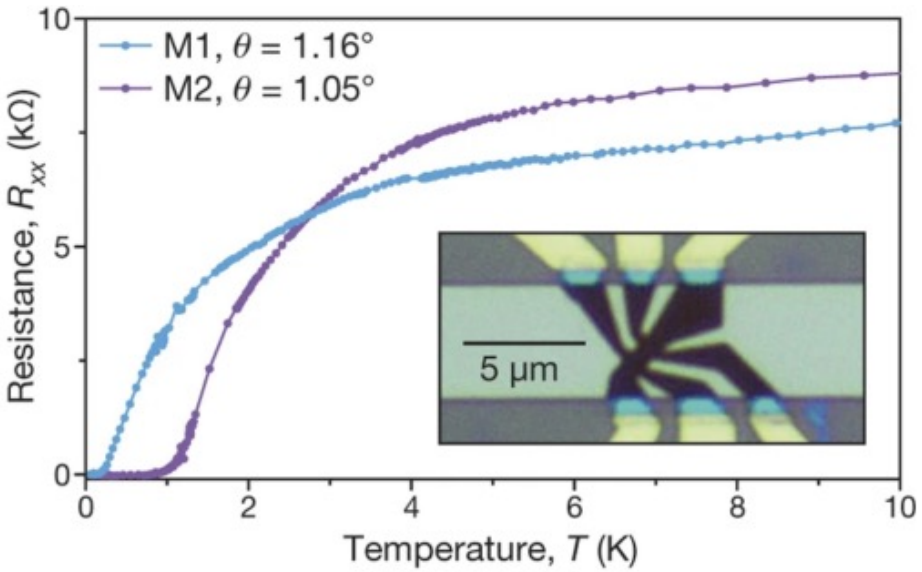


Outline

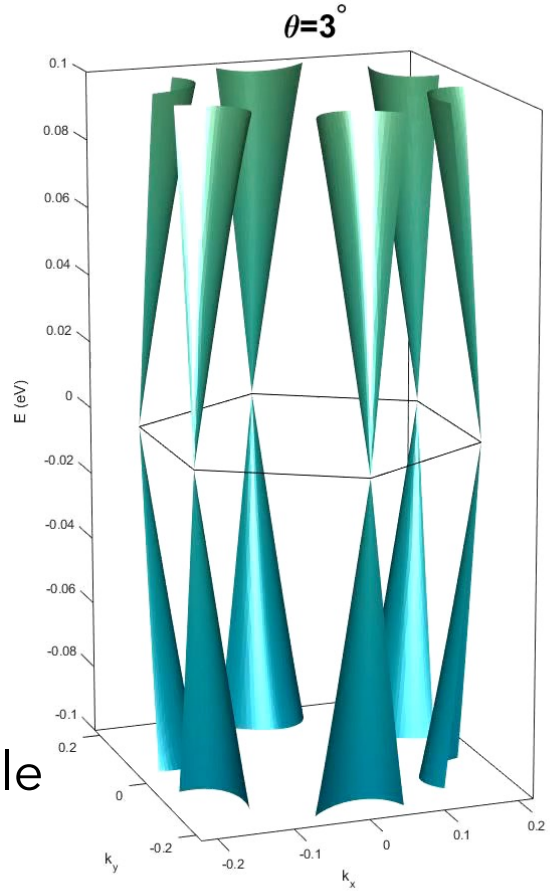
1. Context
2. Objectives
3. Main results of the second year

Context – superconducting graphene





Cao *et al. Nature* (2018)



Flat bands

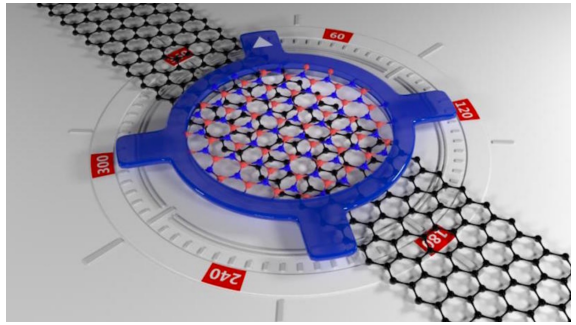
at magic angle

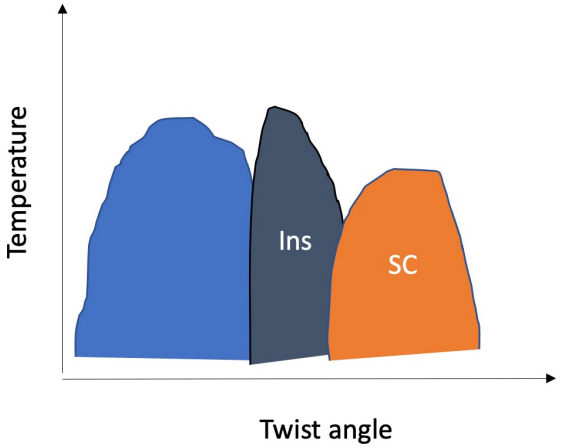
Also in trilayer : Chen et al., Nature 572, 215 (2019)
double-bilayer : Liu et al., Nature 583, 221 (2020)
(...)

Unconventional superconductivity & many other correlated electron phases

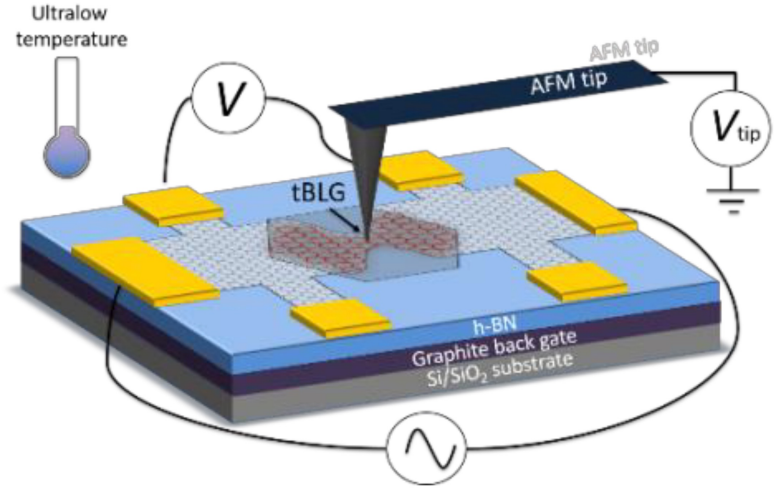
Objectives

Understanding superconducting & correlated phases in twisted graphene



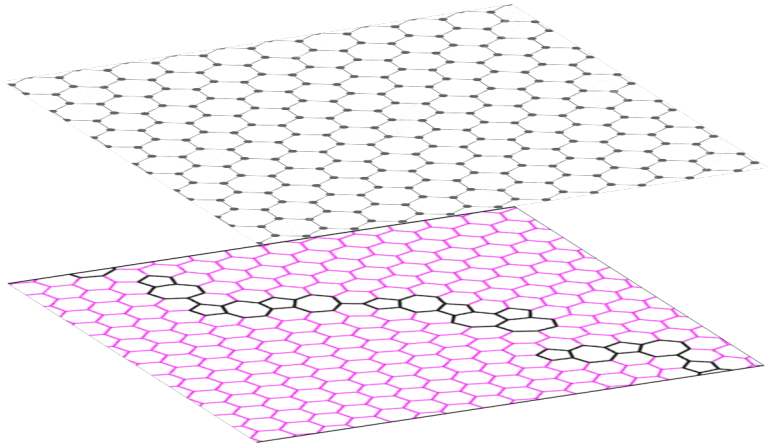


« Phase diagram » of correlated electron phases as a function of twist angle



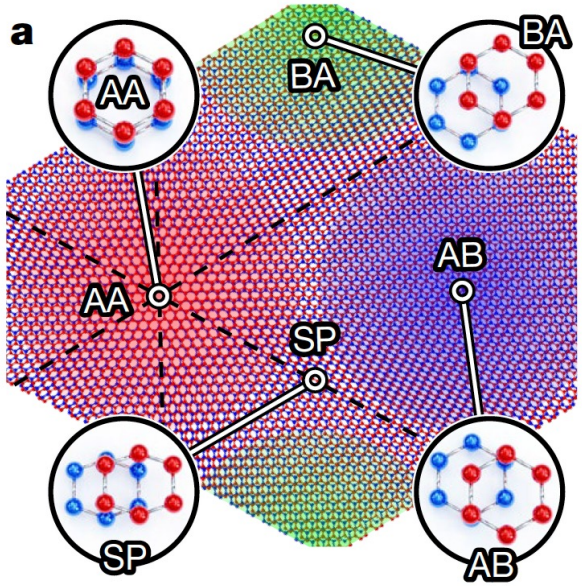
Mapping electronic transport at the local scale in moiré systems

SGM measurements

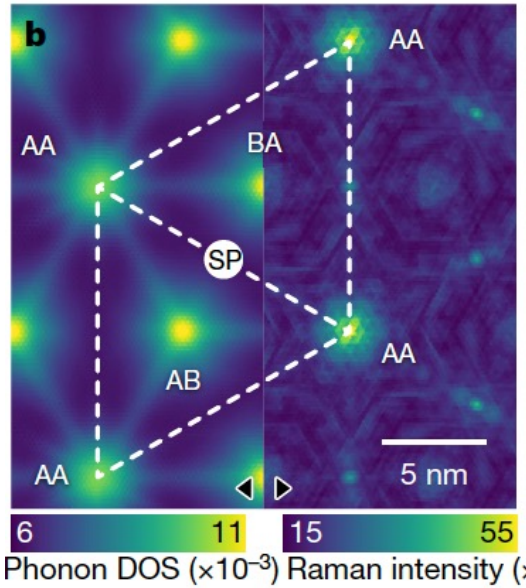


Graphene superconducting junctions

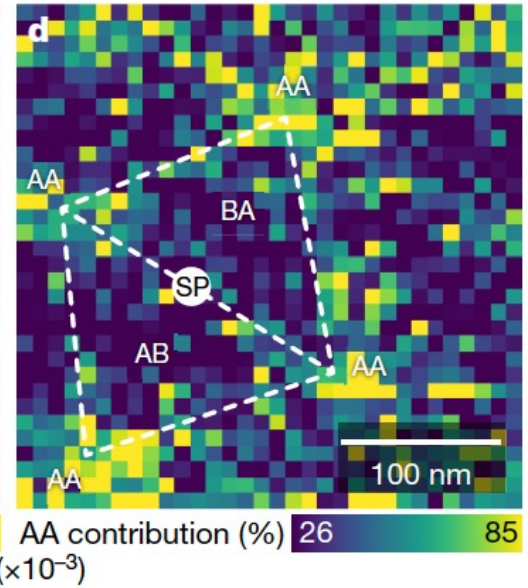
Simulating properties of twisted BLG

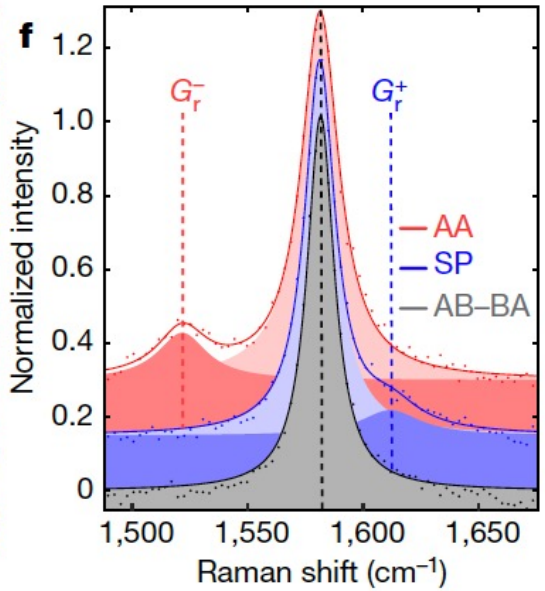


Simul. phonon DOS/Raman @ G⁻



Experimental nano-Raman @ G⁻

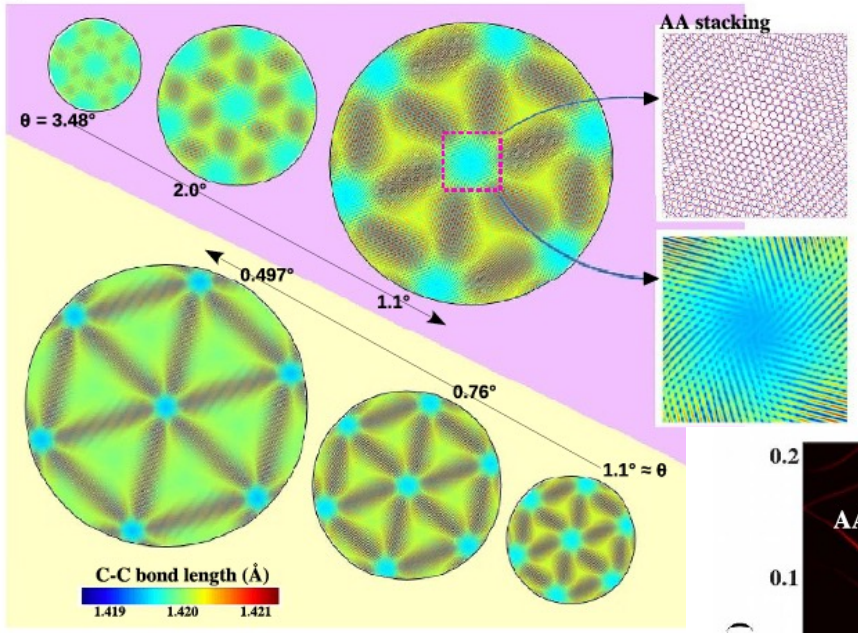




- below 1.1°, significant reconstruction of the lattice in different domains (AB-BA, AA and SP)
- local modifications of electron-phonon coupling
- observable changes in nano-Raman spectra

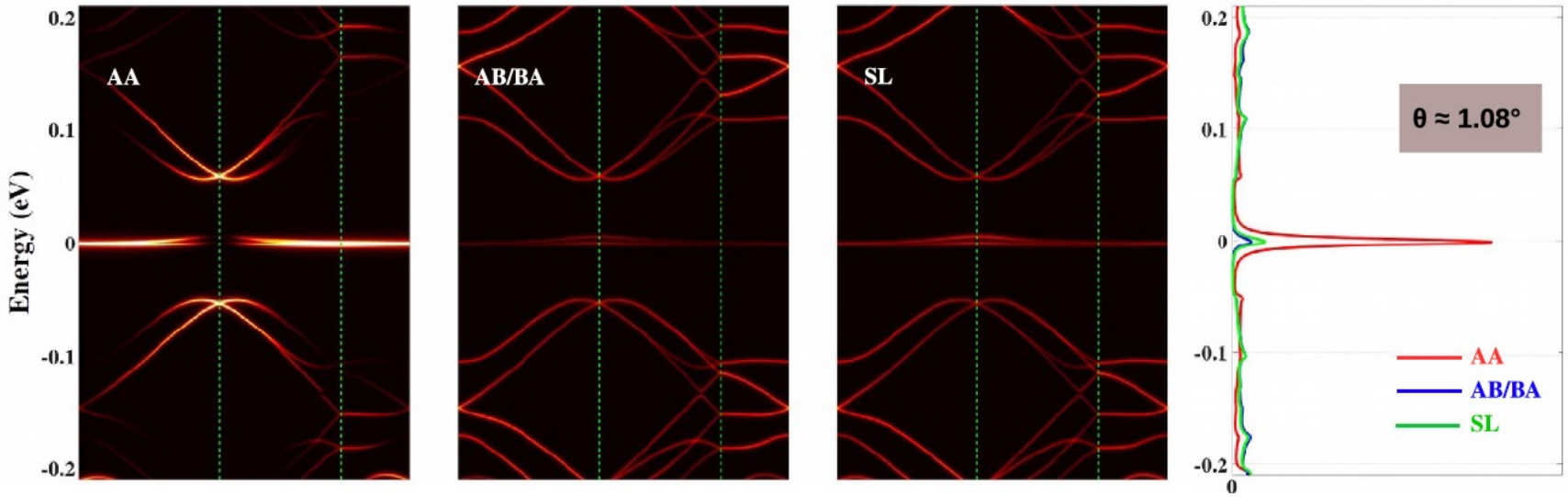
Gadelha et al., Nature 590, 405 (2021).

Moiré influence on electronic properties

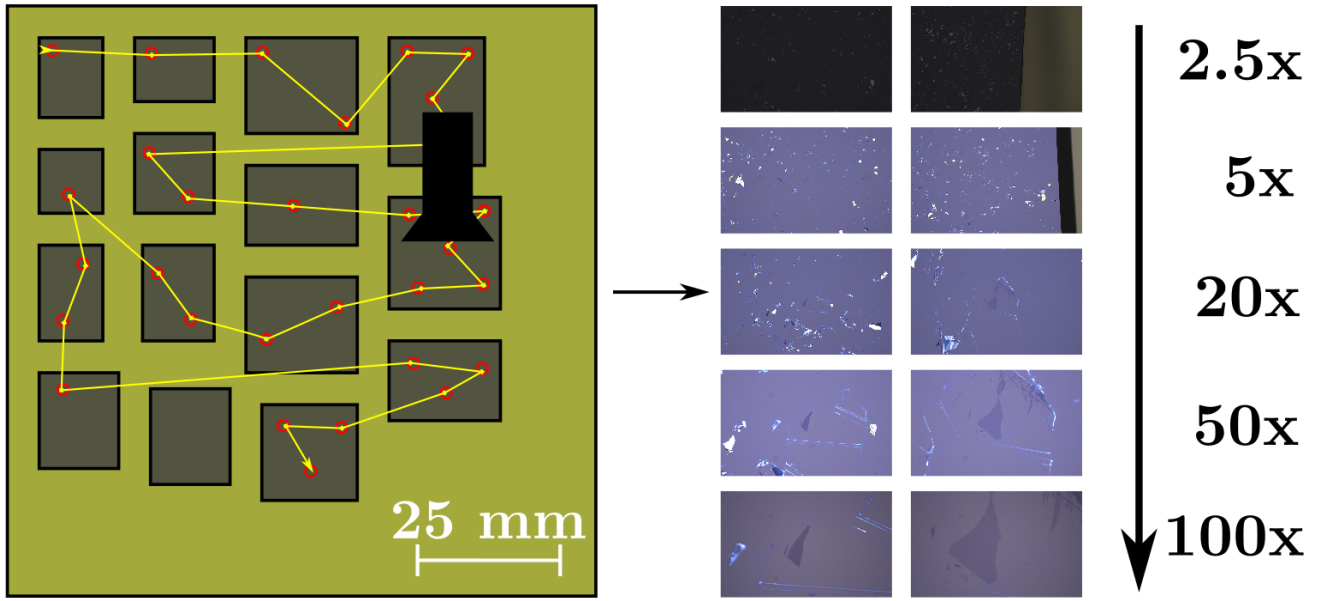


- large change in bond length in AA domains, and on soliton lines (SL)
- development of tight-binding model for reconstructed twisted BLG
- strong electronic localization in AA regions at magic angle (~1.1°)
- below 1.1°, relative importance of AA is reduced – no magic angle <1.1°

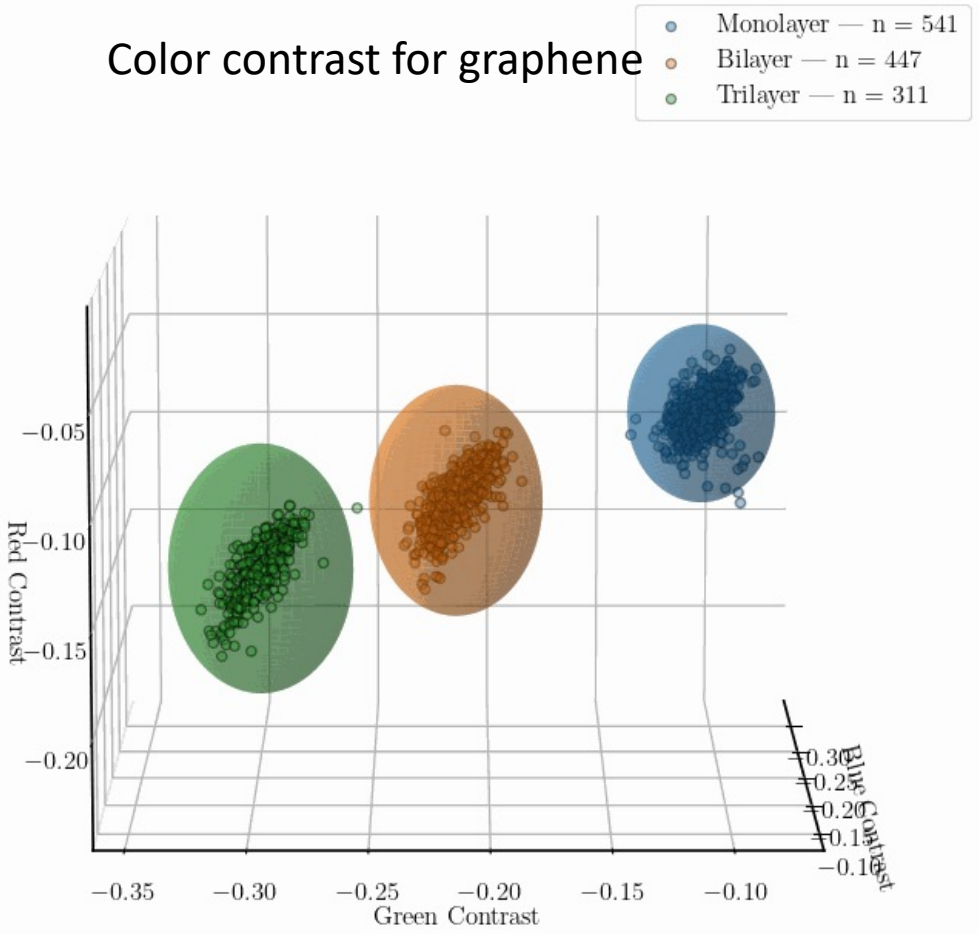
V-H. Nguyen et al., 2D Materials 8, 035046 (2021).



Automated optical detection and classification of 2D flakes



Color contrast for graphene



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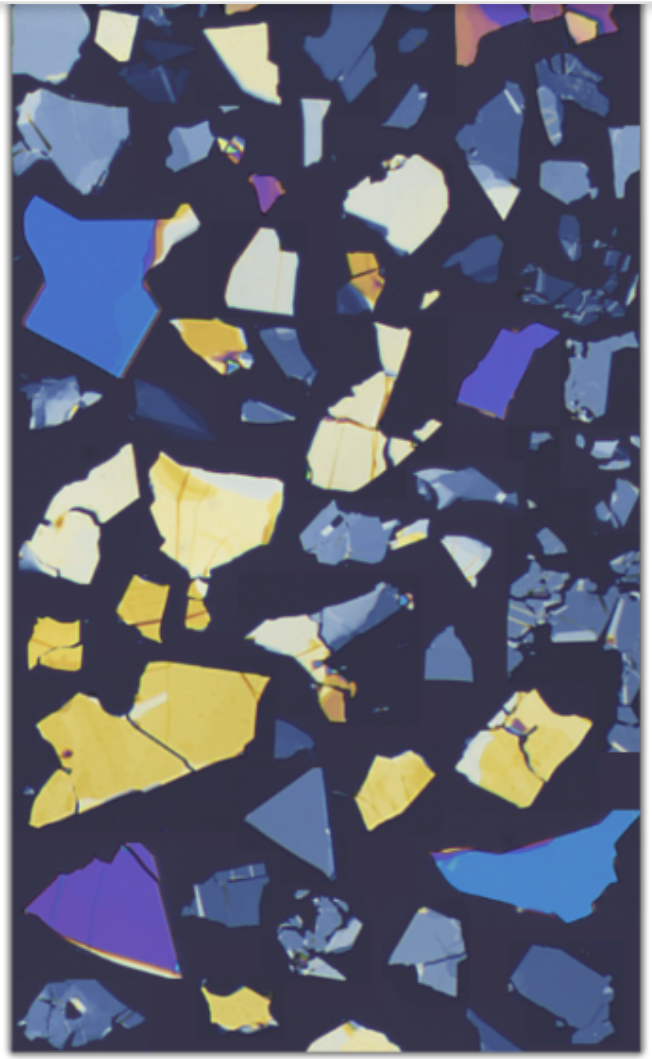
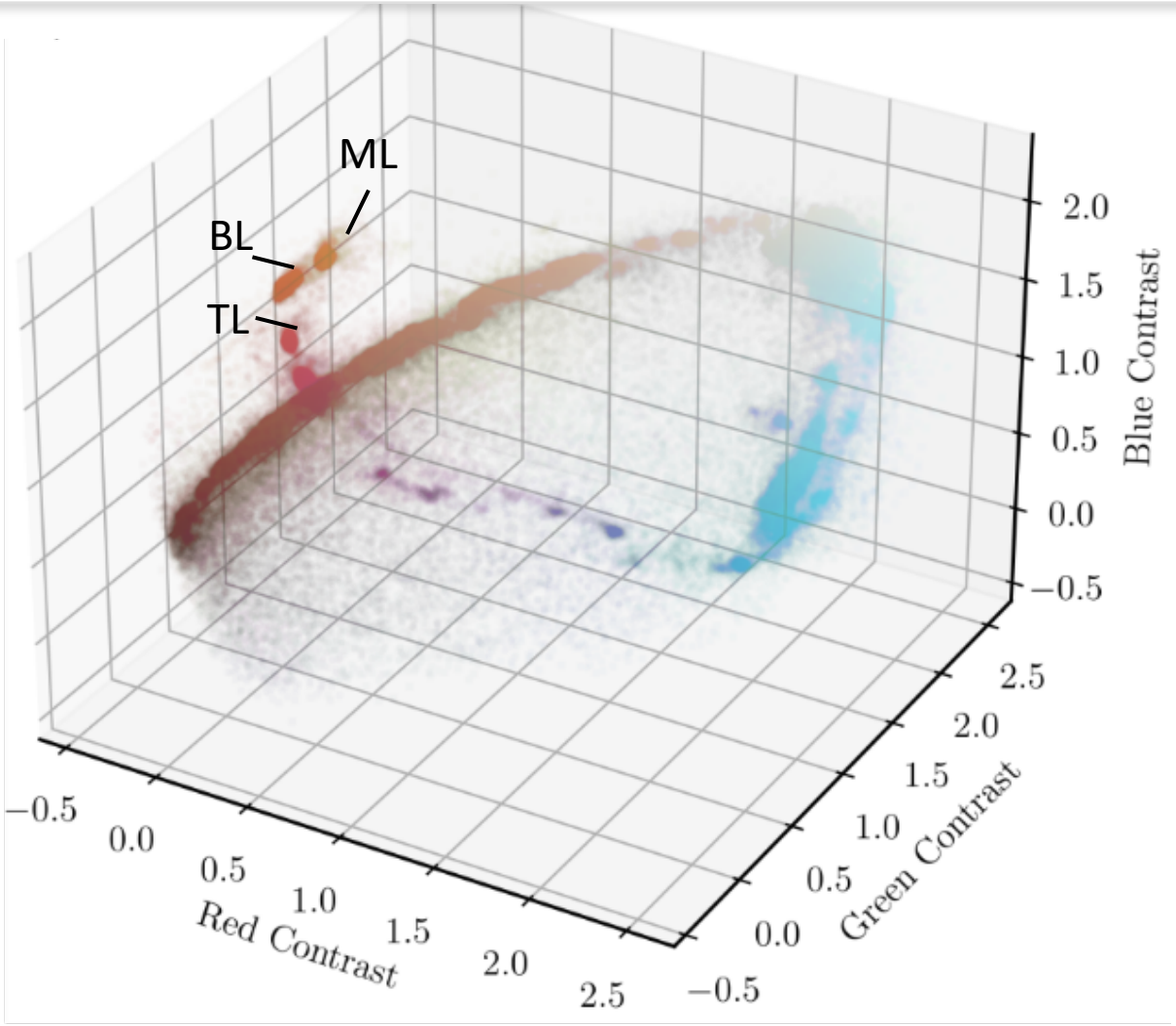
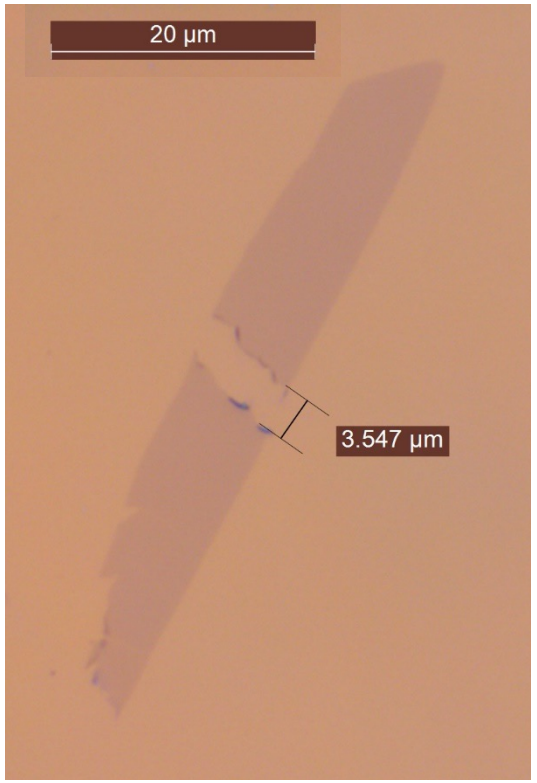
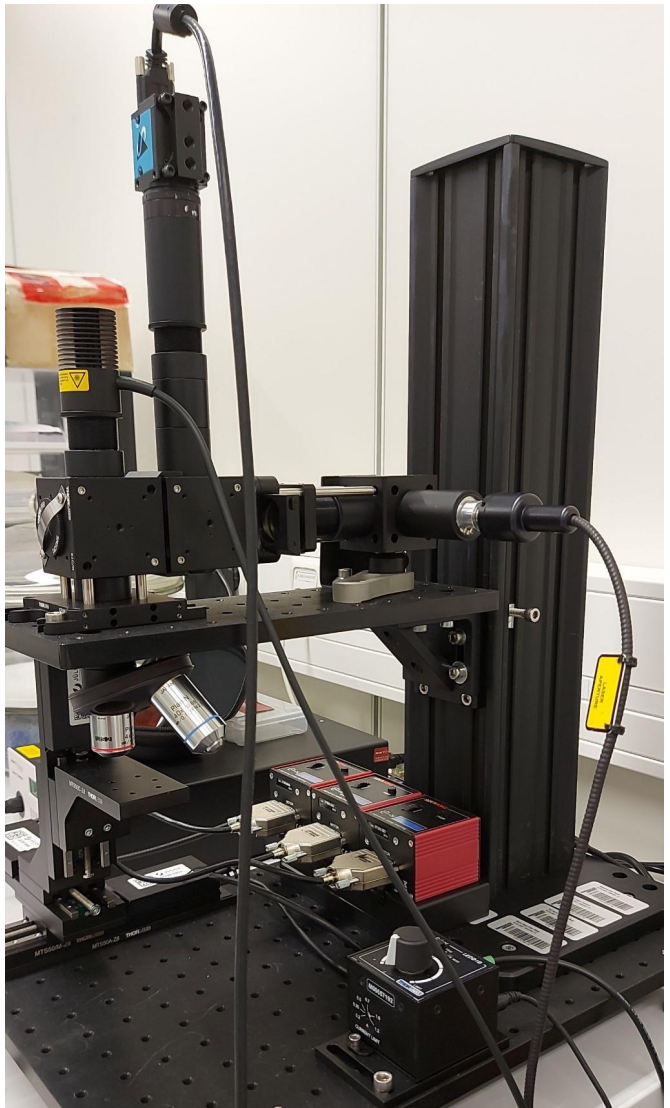




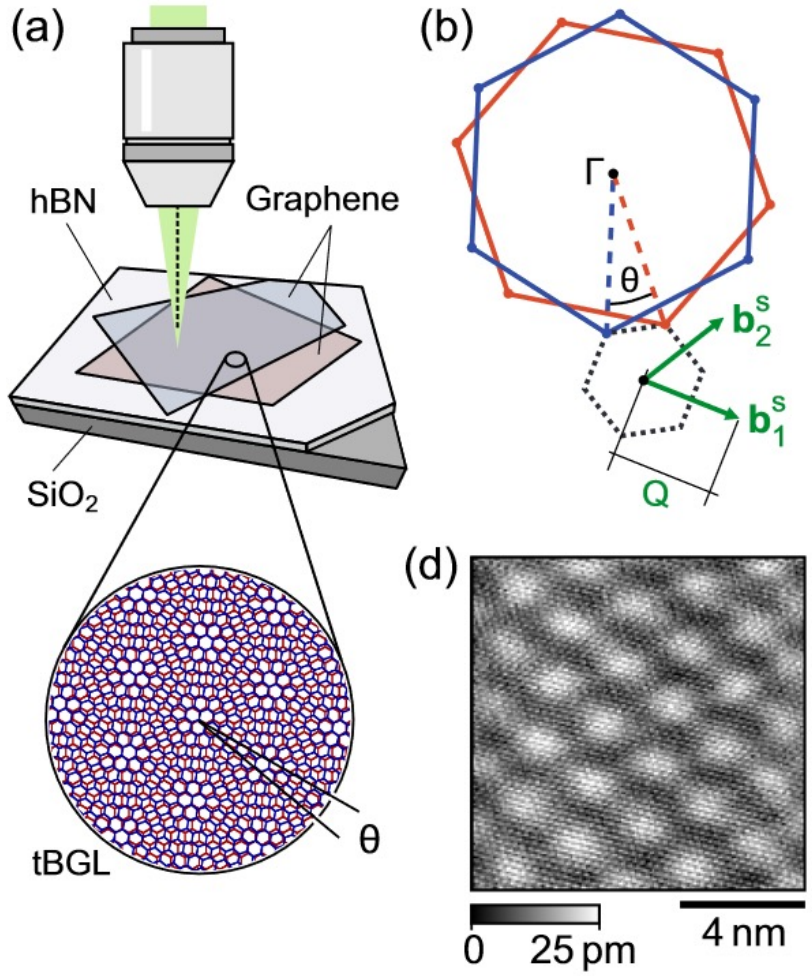
Laser cutting of SLG – critical step for TBG fabrication

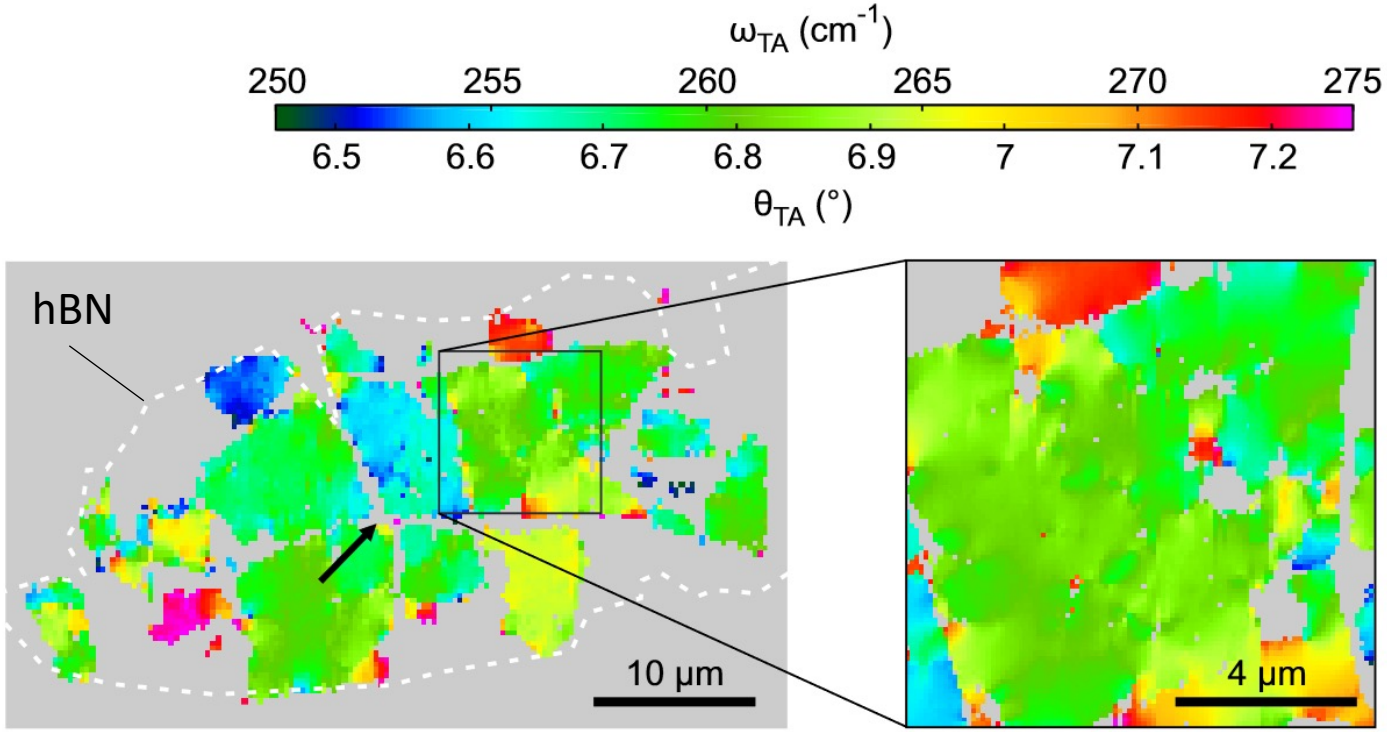


Pulsed super continuum laser



Raman imaging of twist angle variations

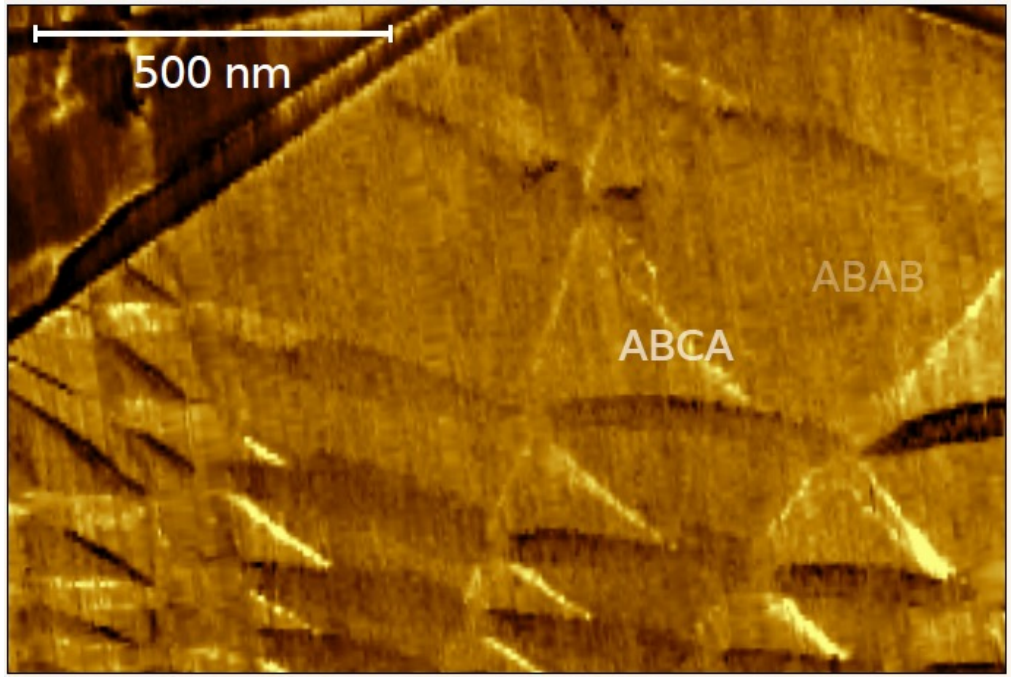


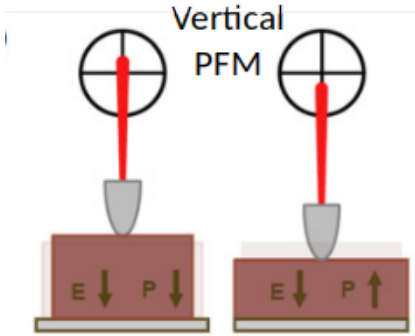


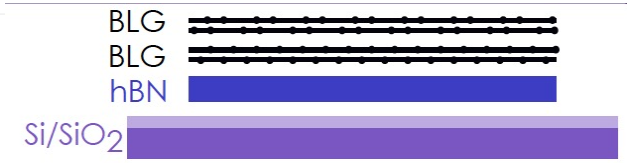
A. Schäpers et al., arXiv: 2104.06370

Imaging moirés with scanning probes

Piezoelectric-force microscopy (PFM)

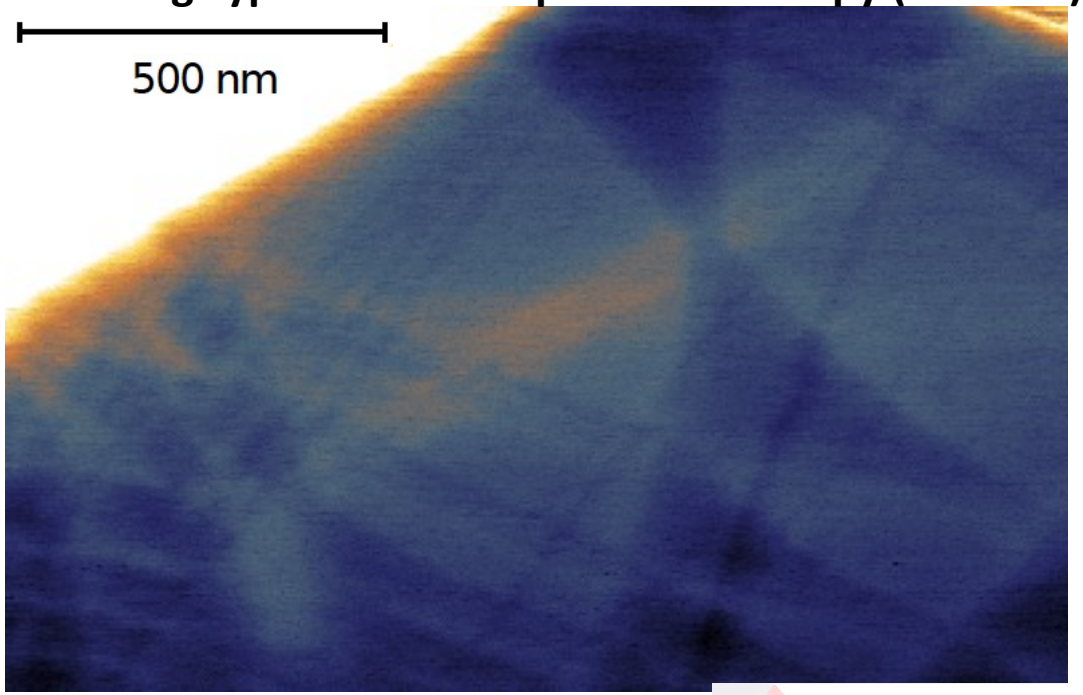






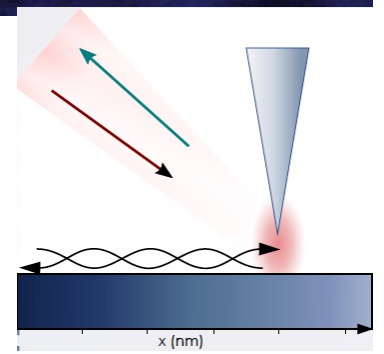
• domain boundaries are visible and can be moved

Scattering-type near field optical microscopy (s-SNOM)

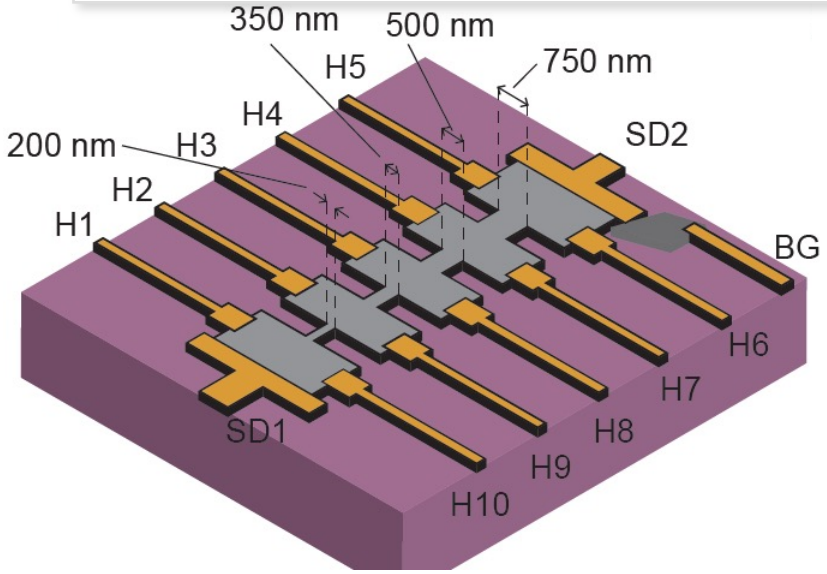


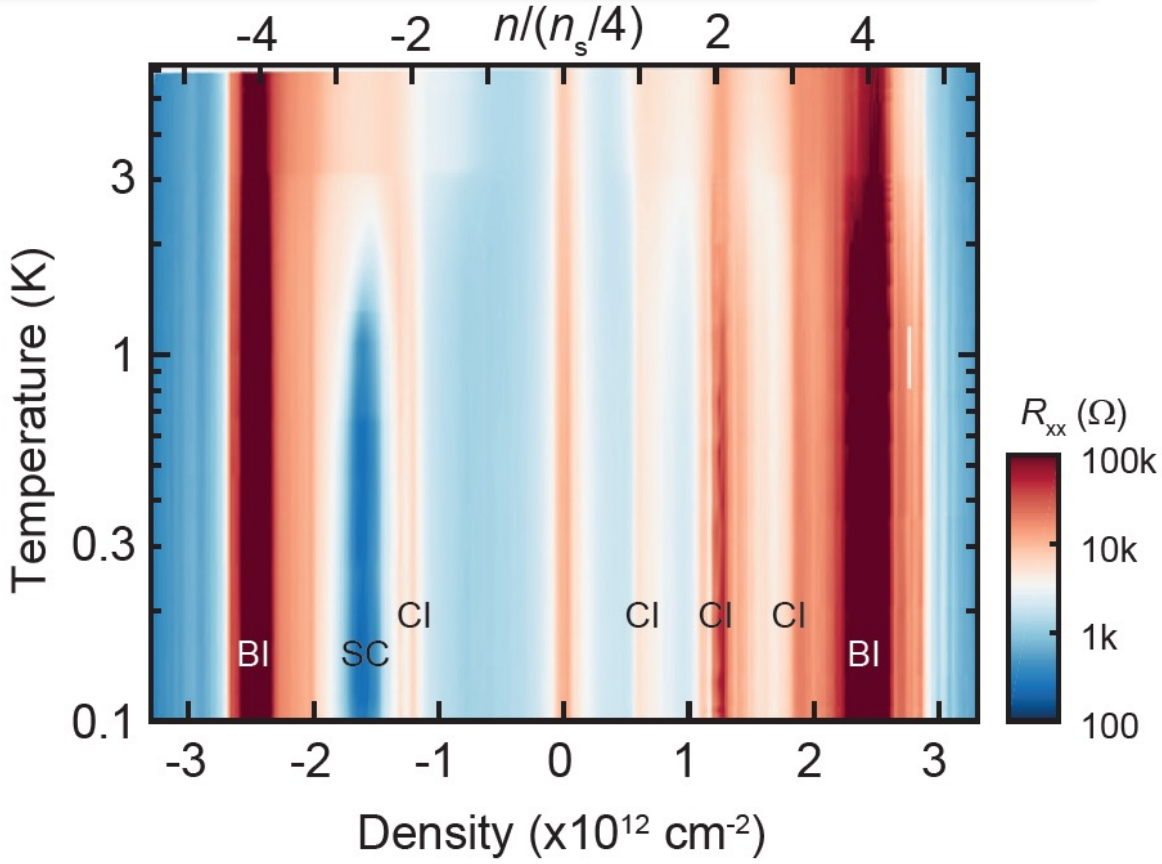
• at λ = 10.6 µm, difference of optical contrast between ABCA and ABAB

• plasmon signatures at boundaries *(not visible in PFM)*



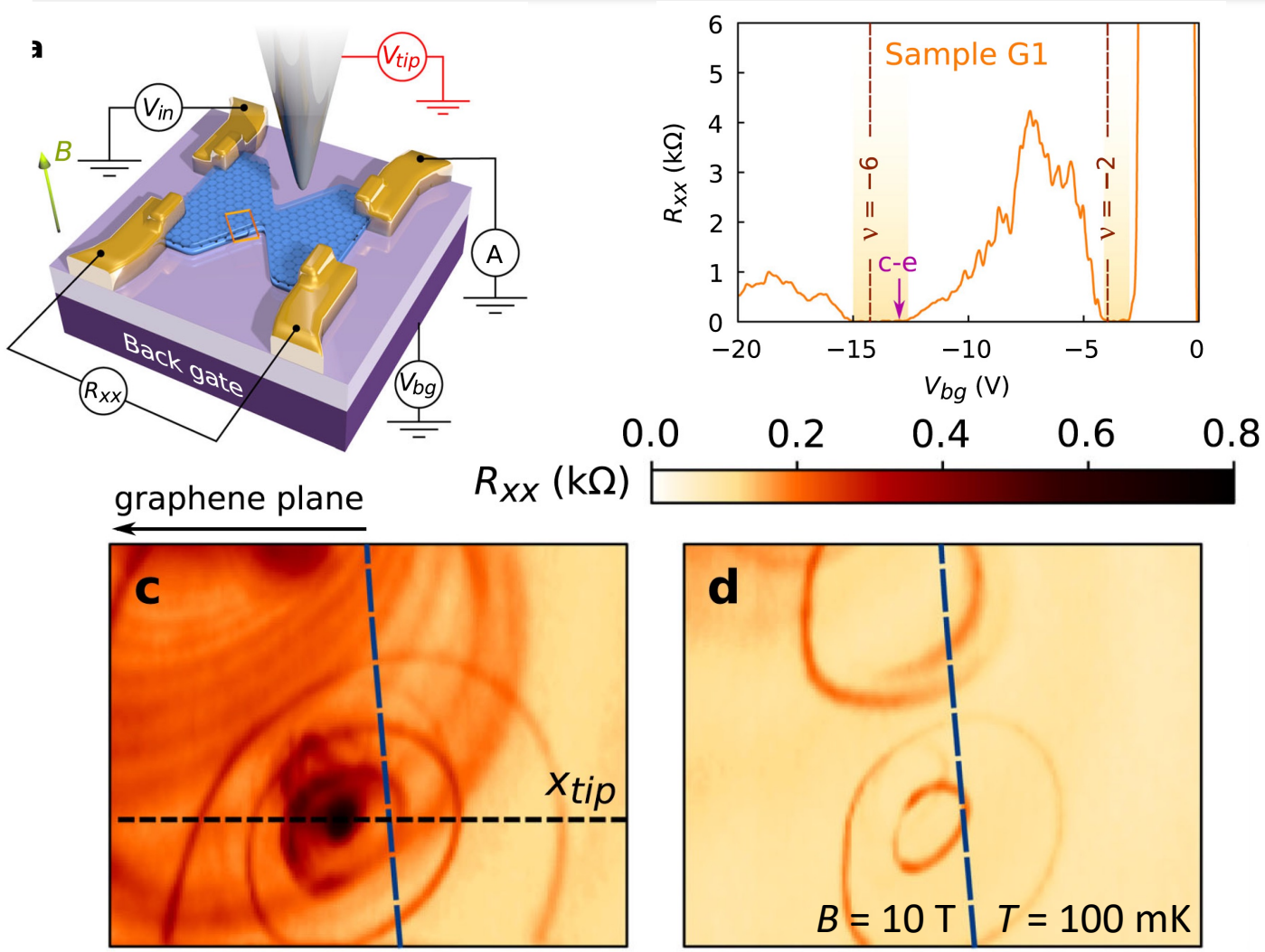
Transport in TBG near the magic angle





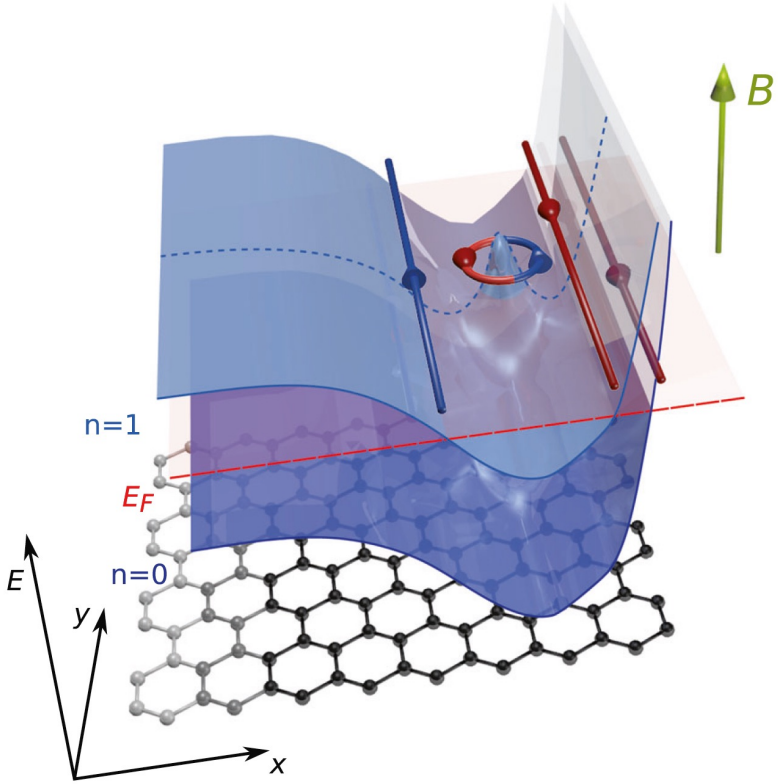
- Transport through constrictions of TBL
- Band (BI) / correlated (CI) insulating states and superconductivity (SC)

Scanning gate microscopy (SGM)

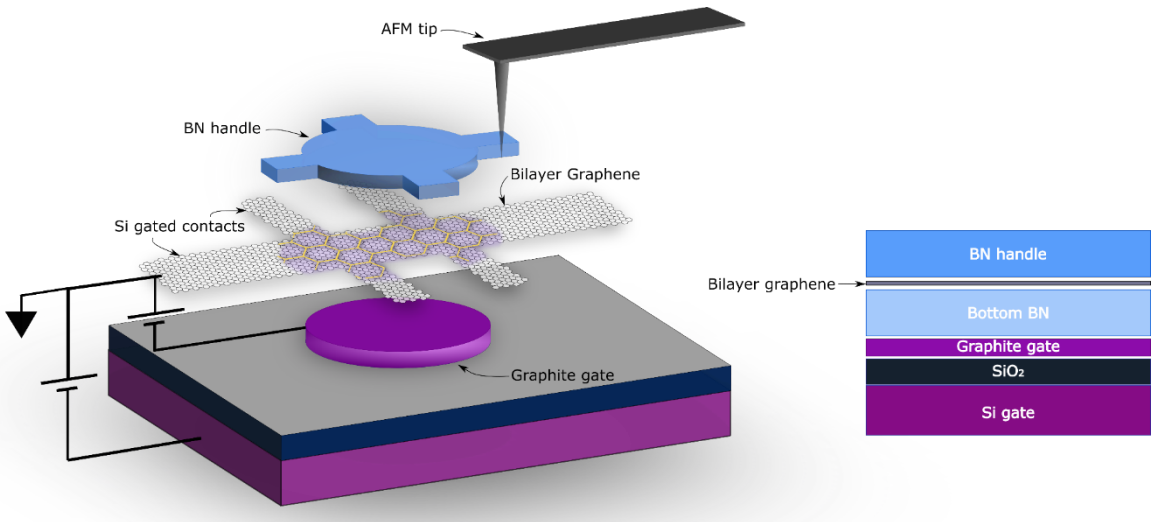


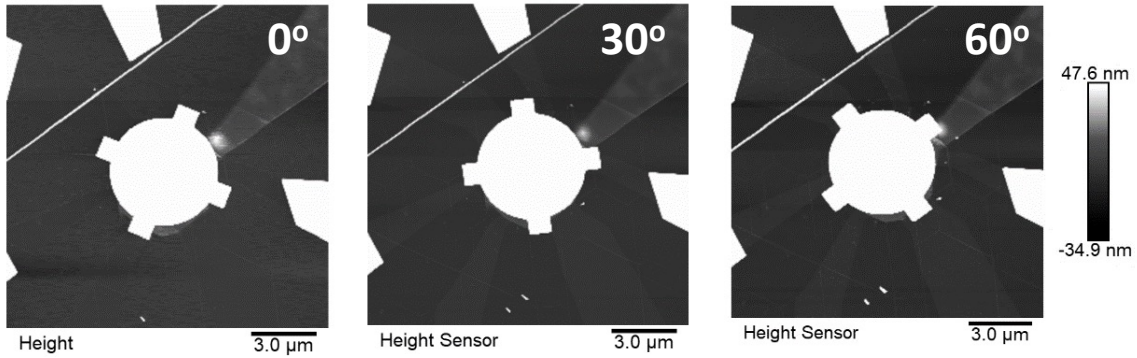
- hBN-graphene-hBN heterostructure in the quantum Hall regime : SGM reveals topological breakdown, due to antidots

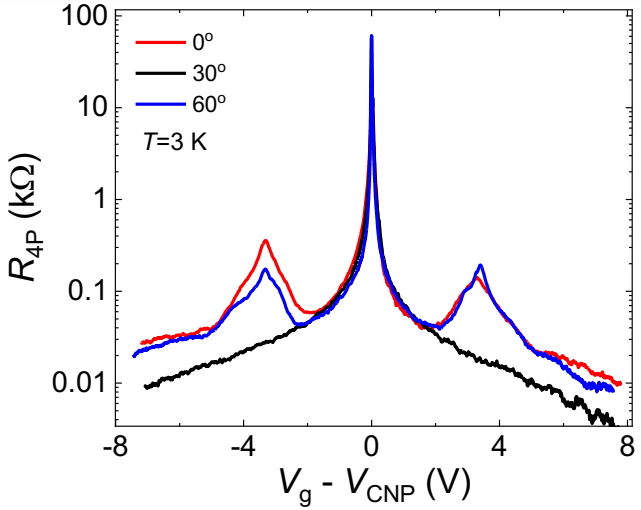
N. Moreau et al., Nature Comm. 12, 4265 (2021)

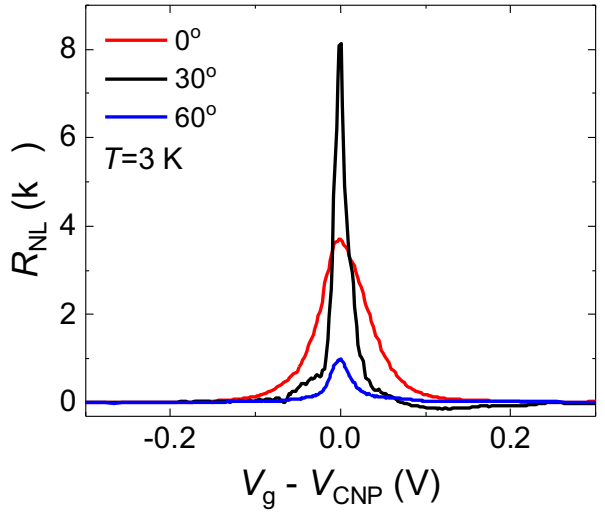


Rotating hBN on BLG – tuning transport









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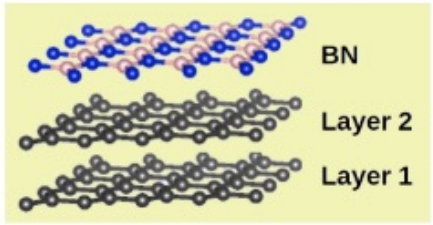
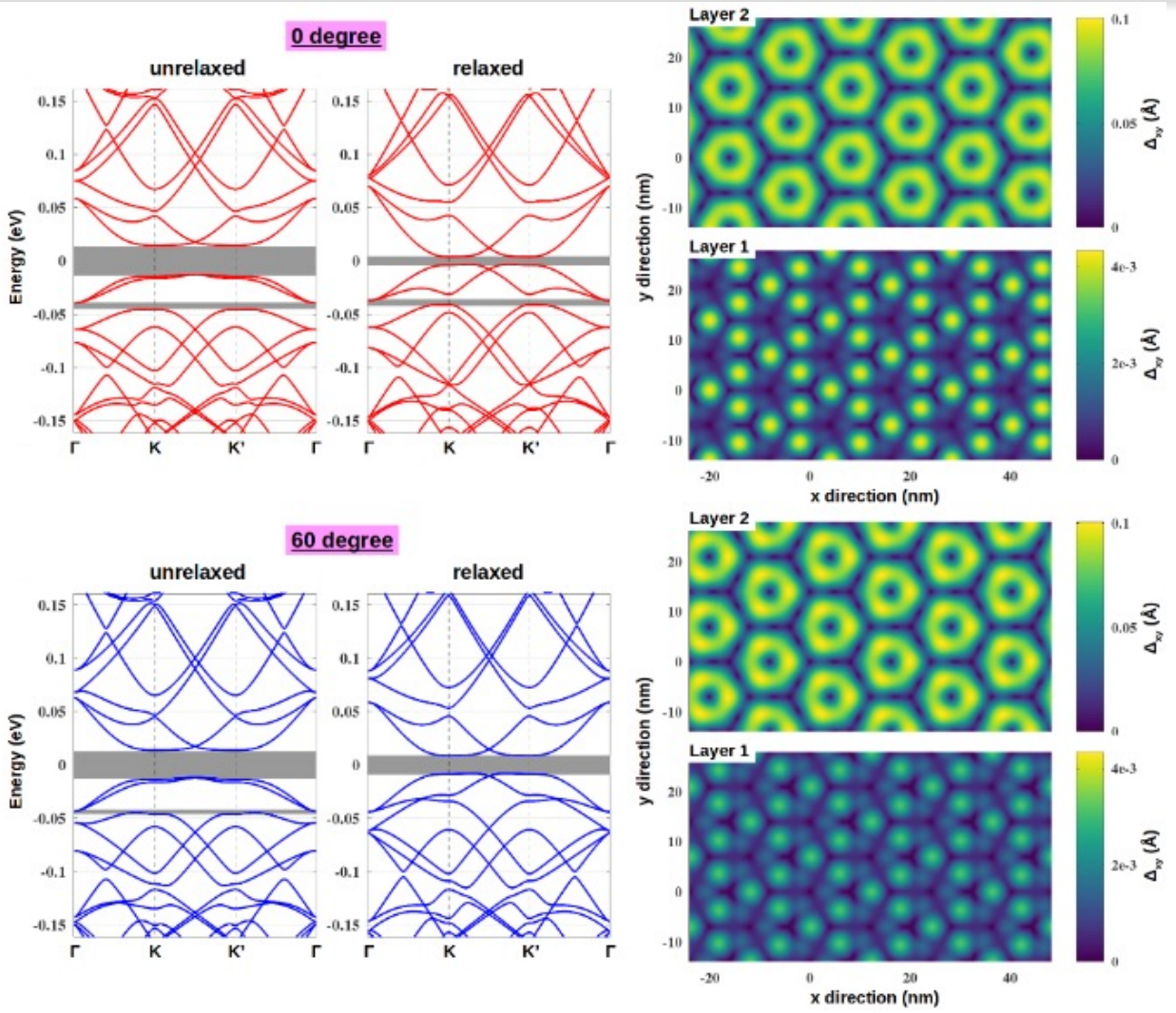
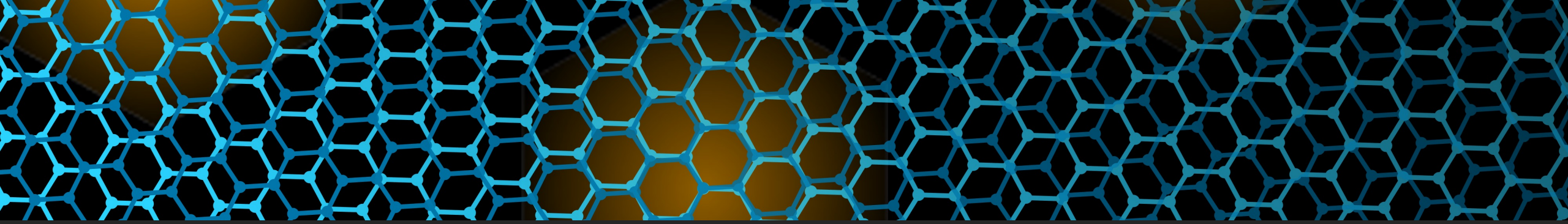




Summary/main results

- Development of **tight-binding models** of twisted multilayer systems – simulation of relaxed structures
- New tools for **assembling heterostructures** :
  - automated optical detection/classification of 2D flakes
  - laser precision cutting tools
- development of new tools for **imaging twist angle** :
  - Raman TA peak - suitable for 6.5-8°
  - direct imaging of Moiré through PFM and s-SNOM
- observation of **superconductivity and correlated electronic** phases in TBG
- **imaging topological breakdown** in encapsulated monolayer graphene using scanning gate microscopy
- rotation of hBN on double layer graphene – difference in topological valley current at 0° and 60°

=> with C atoms sitting on B or on N, one has different strains and interactions with the topmost layer
=> transition from valley Hall to ohmic behaviour.



Thank you !