

# Theoretical Physics

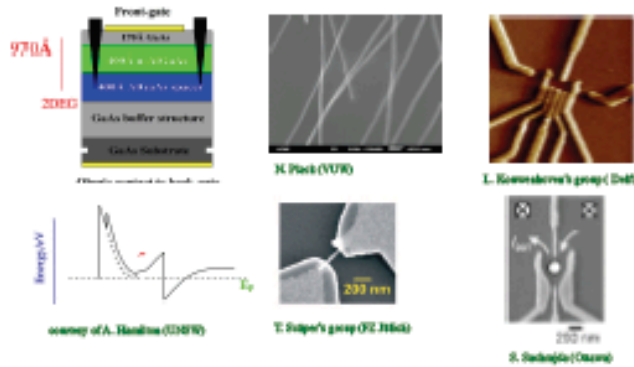
Michele Governale and Ulrich Zuelicke

## Research interests

### Functional materials

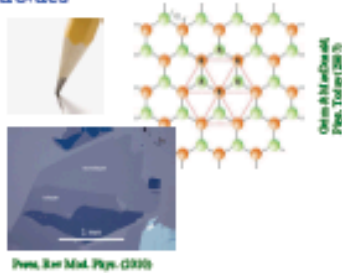
Quantum wells, wires and dots: Nano-electronic devices

- function based on quantum effects & discreteness of charge



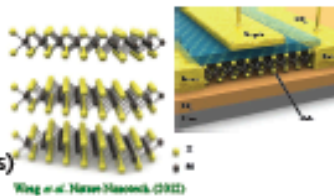
Graphene: Carbon-based electronics

- single layer of graphite (ie, sheet of pencil lead!)
- atomically thin but still conducts electric current
- transparent conductor
- robust mechanical and thermal properties



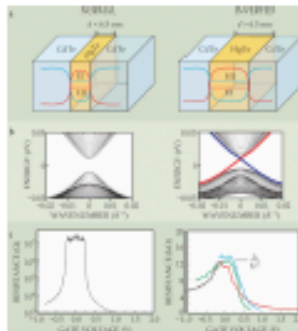
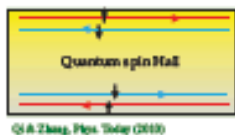
MoS<sub>2</sub> & similar layered materials: Ultra-thin semiconductors

- versatile for transistor applications and opto-electronic devices
- testbed for entirely new electronics paradigms (spintronics, valleytronics)



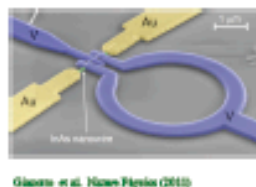
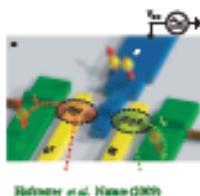
Topological insulators

- most exotic materials
- insulating in bulk but conducts current at edge
- magneto-electric coupling



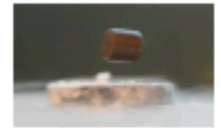
Hybrid normal-superconducting nanostructures

- macroscopic quantum effects
- entangled-electron sources



## Novel phases & complex states of matter

- magnetism & superconductivity
- phase transitions
- emergent degrees of freedom



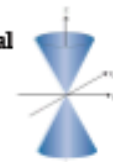
Particle Physics on a chip

- emergent physical objects (quasi-particles) realised in materials
- greater variety than elementary particles in our universe!



Massless electrons in graphene

- move at constant speed  $v \approx 10^6 \text{ m s}^{-1}$
- penetrate all internal barriers!



Emergence of Majorana quasi-particles

- hypothesised matter particles (fermions) that are their own antiparticles
- localised types can emerge in nano-wires in contact with superconductors in the presence of magnetic fields
- created from breaking up ordinary electrons



## Research capabilities

- electronic-device modeling
- theories of functional nanostructures
- study of non-equilibrium phenomena
- advanced mathematical/field-theoretical methods
- analysis and modeling of complex systems: universality & emergence

## Applications

Nano-electronics & Spintronics



Quantum information technologies