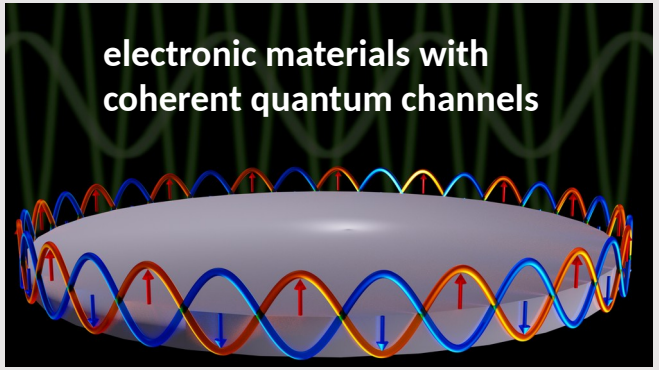
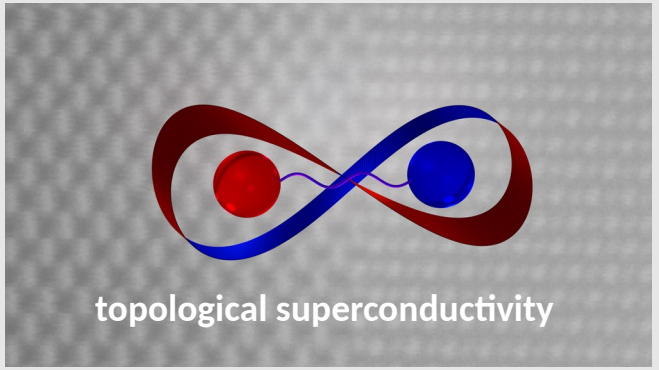
Materials for the Quantum Age

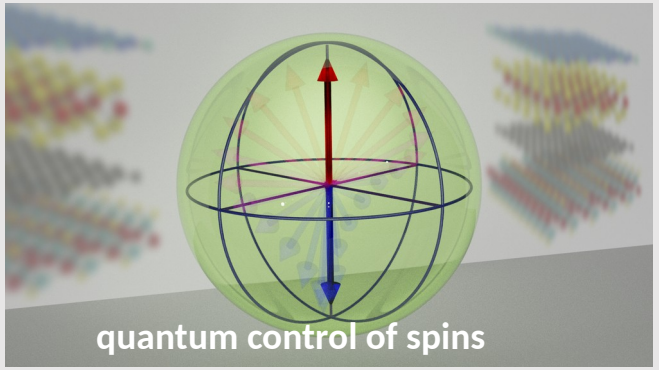
- low-dimensional materials with electronic, magnetic, superconducting, …, quantum states
- robust coherence, scalable materials, devices working under affordable conditions

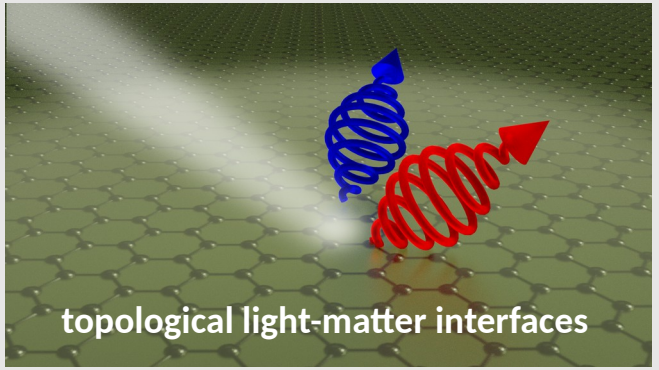
QuMat

RUG, UT, RUN, TUE, UU, TUD, UVA
Daniel Vanmaekelbergh
Mike Fremling
43 staff
27 PhD + 3 PD + 3 TT
25 PhD +5 PD + 1 TT
scientific discovery
education









Pillar 1 Electronic materials with coherent quantum channels by topological protection

Pillar Leaders: Zeila Zanolli, Daniel Vanmaekelbergh (replacement of Ageeth Bol)

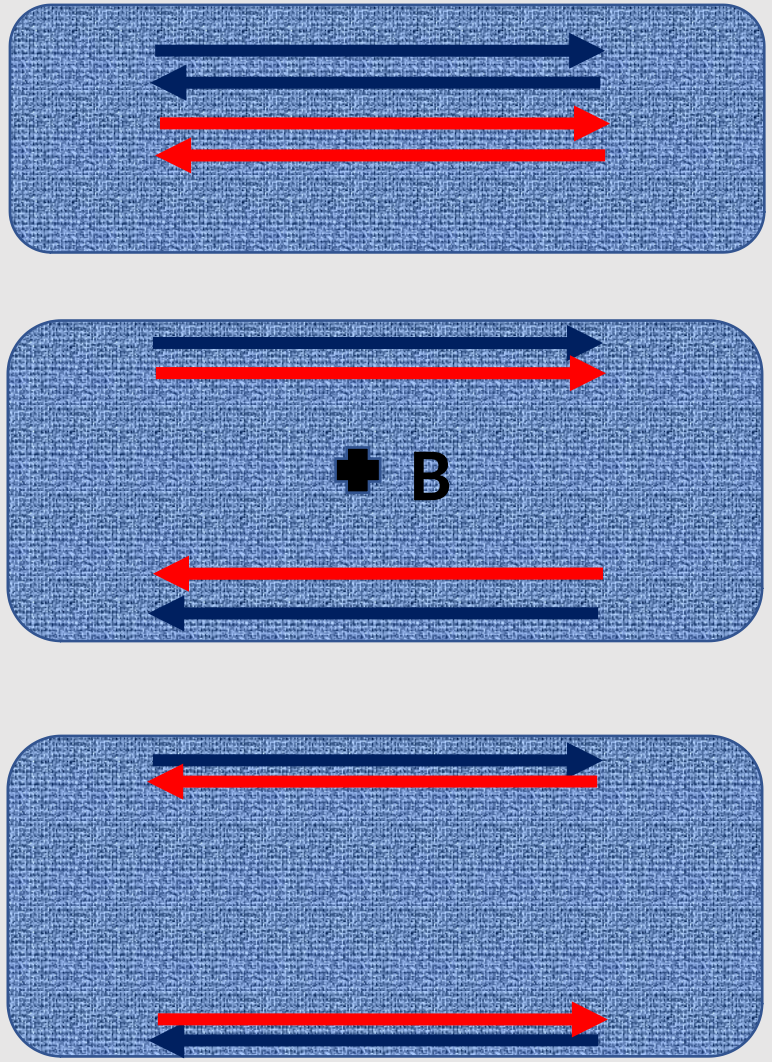
Goal: design, fabricate and characterize 2D quantum spin Hall insulators (crystalline topological insulators) with maximum topological protection

Applications: electronic information transfer without dissipation, 1D helical quantum channels as the basis for topological superconductivity

Connection to the other pillars: Pillar 3, topological Superconductivity
Pillar 4, topological light-matter interfaces

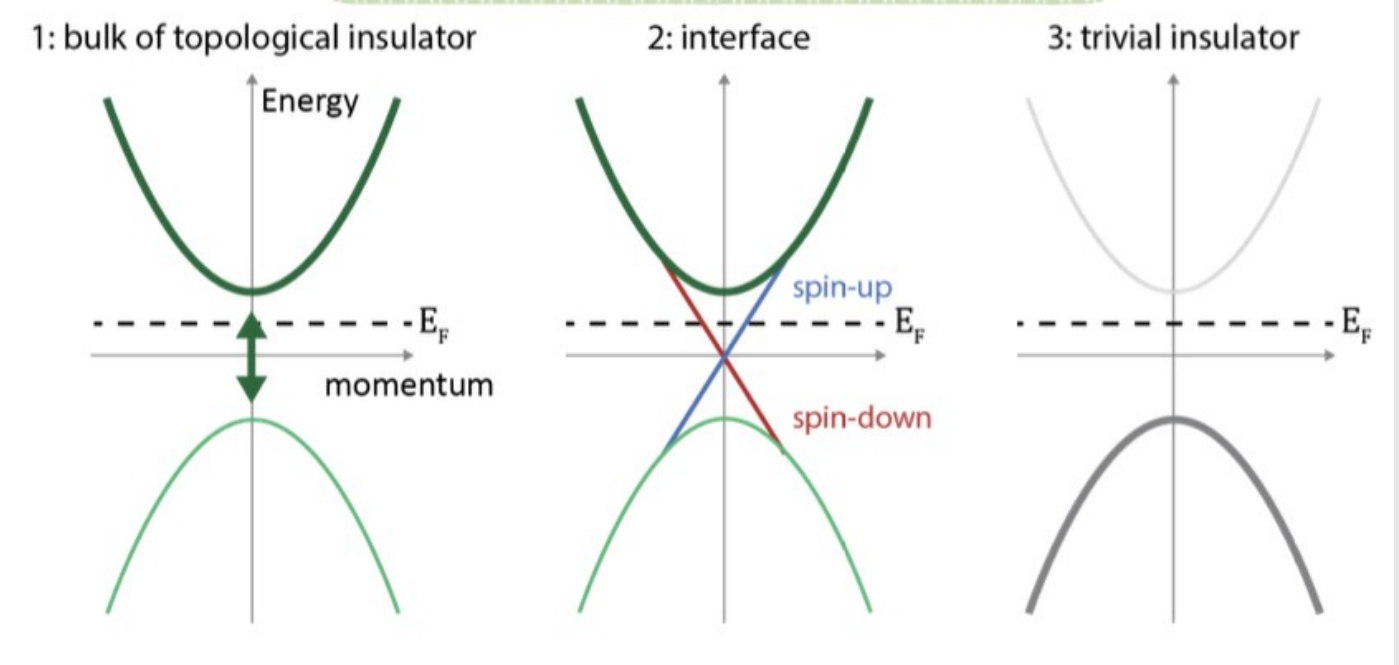
Pillar 1 Electronic materials with coherent quantum channels by topological protection:

background



Spin-orbit coupling can invert the natural order of atom energy levels and bands in a solid:

- inverted gap
- helical states with (E, k, spin) locking at boundary
- 1D quantum states without backscattering



Pillar 1 Electronic materials with coherent quantum channels by topological protection:

open questions

Maximize the topological gap

- what determines the topological gap? spin-orbit coupling, orbital type
- proximity engineering at hetero-interfaces
- spin-orbit coupling and particle interactions

Scalable synthesis of heteromaterials

- gas-phase deposition (MBE/CVD/PLD), wet-chemical
- control over thickness, hetero-epitaxi, lateral dimensions

Devices

- scalable, practical densities of quantum states
- affordable conditions

Pillar 1 Electronic materials with coherent quantum channels by topological protection:

actions and research projects

ab-initio DFT theory
design
proximity-engineering
Zanolli / Rösner / Morais Smith
Pim Keizer
PhD?

scalable synthesis
Rijnders / Bol /
Vanmaekelbergh / Guimarães /
Bakkers
PhD?
PD ?

quantum spin Hall insulators
with robust gap
Bismuthene, Bi_2Se_3, WTe_2

characterization
Zandvliet / Vanmaekelbergh /
Golden / Swart / Khajetoorians
Auke Vlasbloem
PhD?

devices
Brinkman / van Wees /
Akhmerov

PhD?

Contributions from starting PhDs

- Pim Keizer (Zanolli/Morais Smith): proximity engineering with bismuthene and plans on topological superconductivity
- Harold Zandvliet or PhD : Quantum Spin Hall States and Topological Phase Transition in Germanene
- Auke Vlasbloem (Swart/Khajetoorians): Scanning tunnelling spectroscopy to investigate helical quantum channels and topological superconductivity
- PhD Khajetoorians (can also be in Pillar 3): Superconductivity in ultra-thin AL

Pillar 1 Electronic materials with coherent quantum channels by topological protection:

actions and research projects

2. Towards robust helical quantum channels in a hybrid material based on Bi

1.1 bismuthene/X Interfaces and their effects: Ab-initio treatment of effects of charge, strain, dielectric environment
PHD: Pim Keizer / Zeila Zanolli /Cristiane Morais Smith

1.2 scalable synthesis: thickness, limited lateral dimensions, interfaces
PD / Rijnders / Bol / Vanmaekelbergh + TT at UU: Machteld Kamminga

1.3 characterization with ARPES and scanning tunnelling microscopy:
PhD / Zandvliet / Vanmaekelbergh / Golden

1.4 quantum spin Hall devices
PhD together with 2.4 / Brinkman / van Wees / Akhmerov

Pillar 1 Electronic materials with coherent quantum channels by topological protection:

actions and research projects

2. Towards robust helical quantum channels in a hybrid material based on WTe_2

2.1 Interfacial structure and its effects on the electronic band structure –
PhD / Rösner / Zanolli

2.2 scalable synthesis of WTe2 based heteromaterials
PhD / Guimarães / Bol / Bakkers

2.3 scanning probe characterization
0.5 PhD: Auke Vlasbloem combined with 0.5 PhD on TSC (pillar 3) / Swart / Khajetoorians

2.4 quantum spin Hall devices:
PhD / Together with 1.4 / Brinkman / van Wees / Akhmerov

MATERIALEN VOOR HET KWANTUMTIJDPERK...

KIJK! DEZE CHIPS ZIJN VAN NIEUW ONTWIKKELD MATERIAAL MET EEN HELE STABIELE KWANTUMTOESTAND, WAARDOOR ZE VÉÉL KRACHTIGER ZIJN IN REKENEN EN INFORMATIEVERWERKING!