UBC PHYS 449
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Ultrafast Electron Dynamics in Topological Insulators

Department of Physics & Astronomy, University of British Columbia, 6224 Agricultural Road, Vancouver, BC V6T 1Z1

Outline

- Motivation
- Theory
  - Electronic states in solids
  - Angle Resolved Photoemission Spectroscopy (ARPES)
  - Time Resolved ARPES (TR-ARPES)
- Experiment details
- Resources
- Summary

Motivation

Why study electronic states of matter?

Microscopic properties of solids

Unoccupied Electron states

Fermi Level

Occupied Electron states

How are these related?

Macroscopic properties of solids

Electric Conductivity

Motivation

Why is this important?

Microscopic properties of solids

Unoccupied Electron states

Fermi Level

Occupied Electron states

Electric Conductivity

Conductor

Semi-Conductor

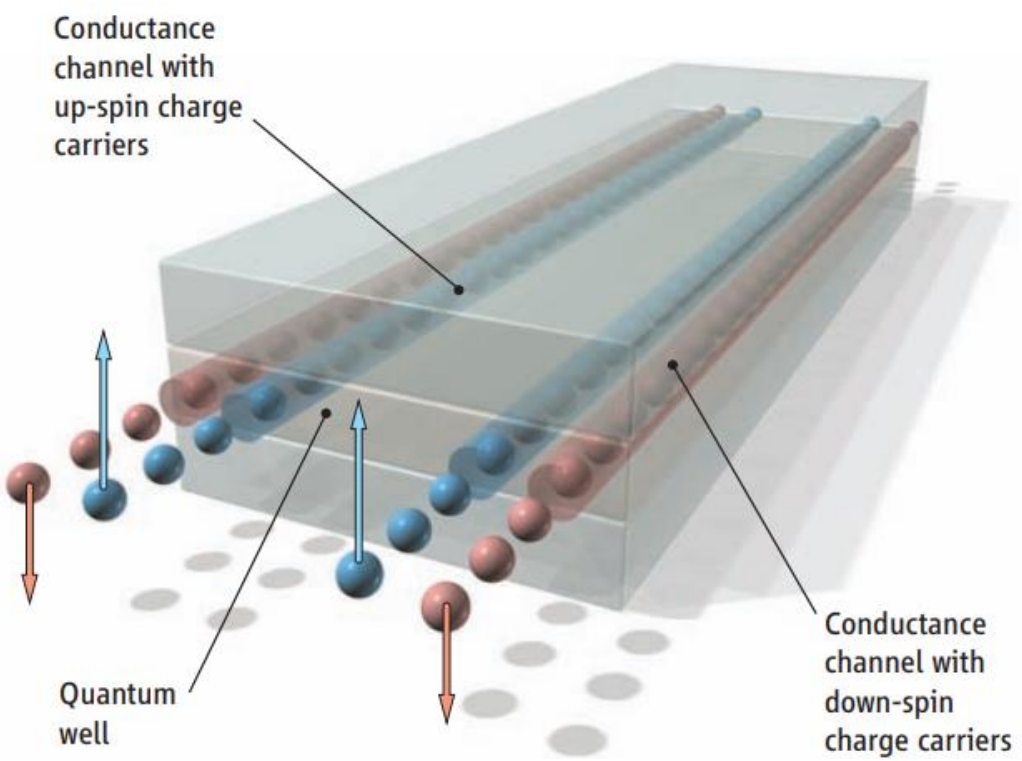
Insulator

Smaller, more powerful electronic devices

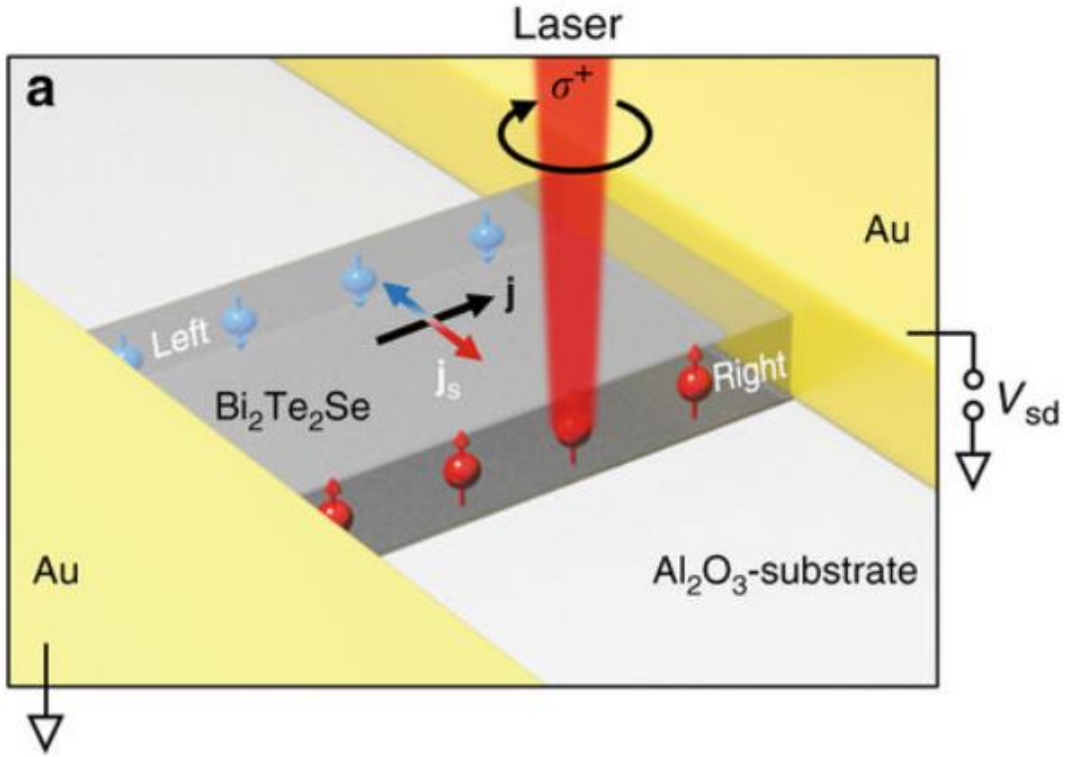
Motivation

Spintronics

Quantum spin Transport



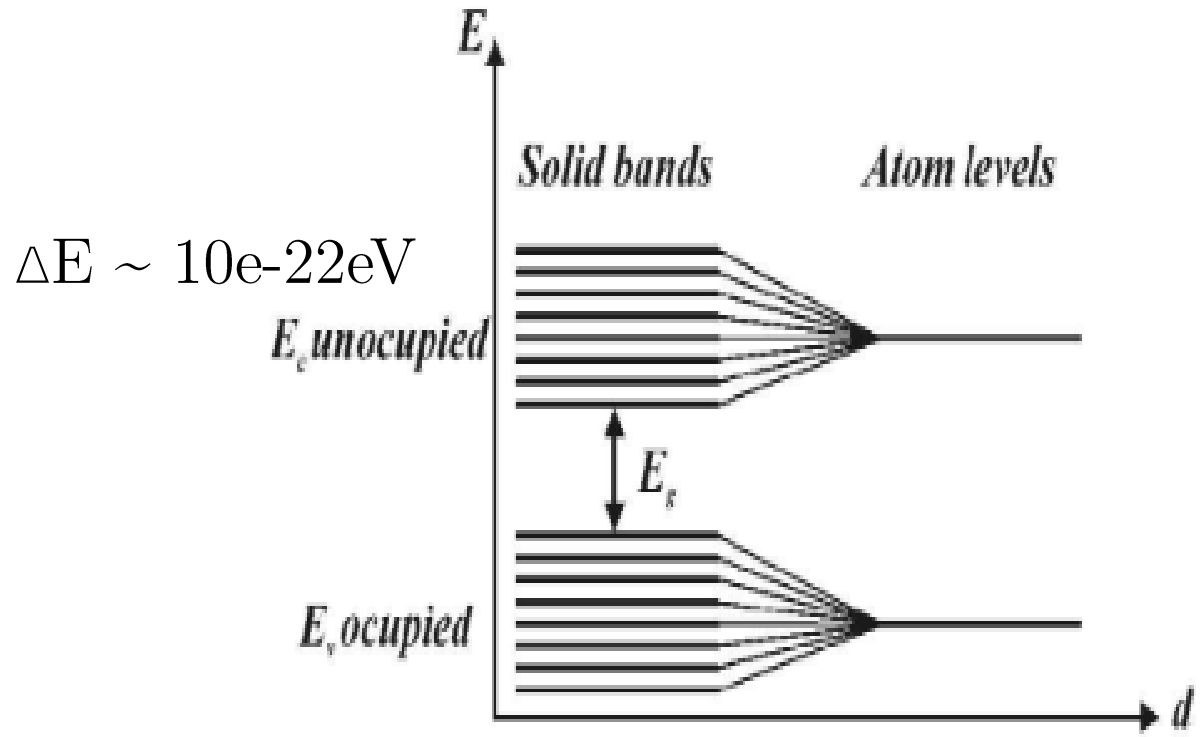
Opto-Spintronics

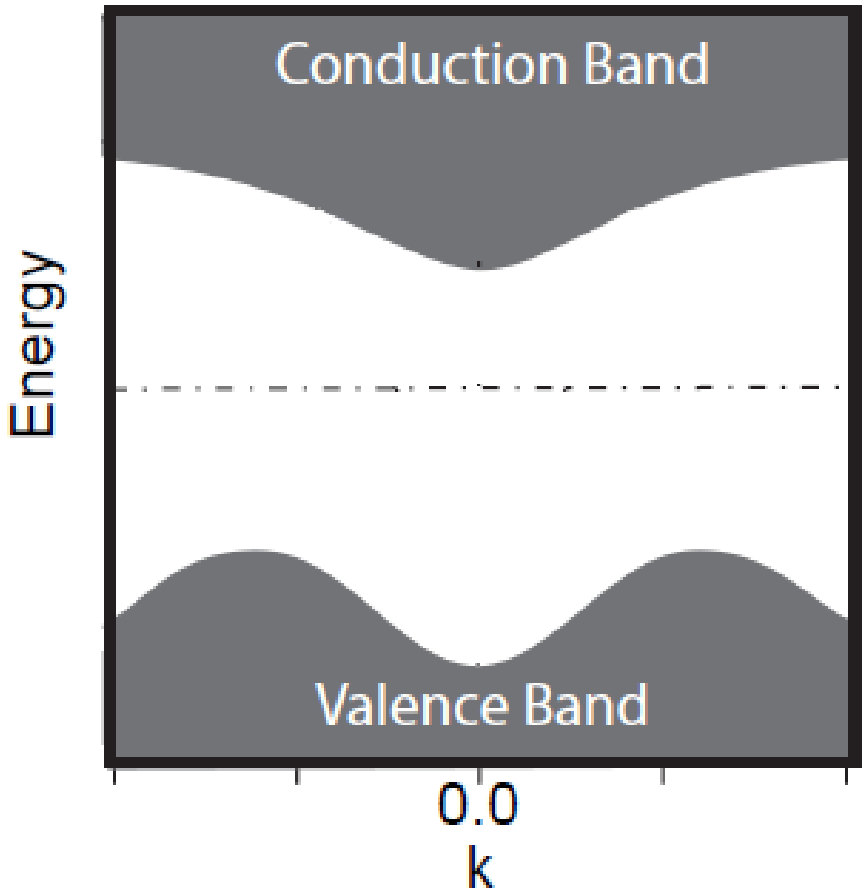


Band Theory of Solids

Allowed energy states E(**k**) are found via solving the Schrödinger equation with some assumptions.

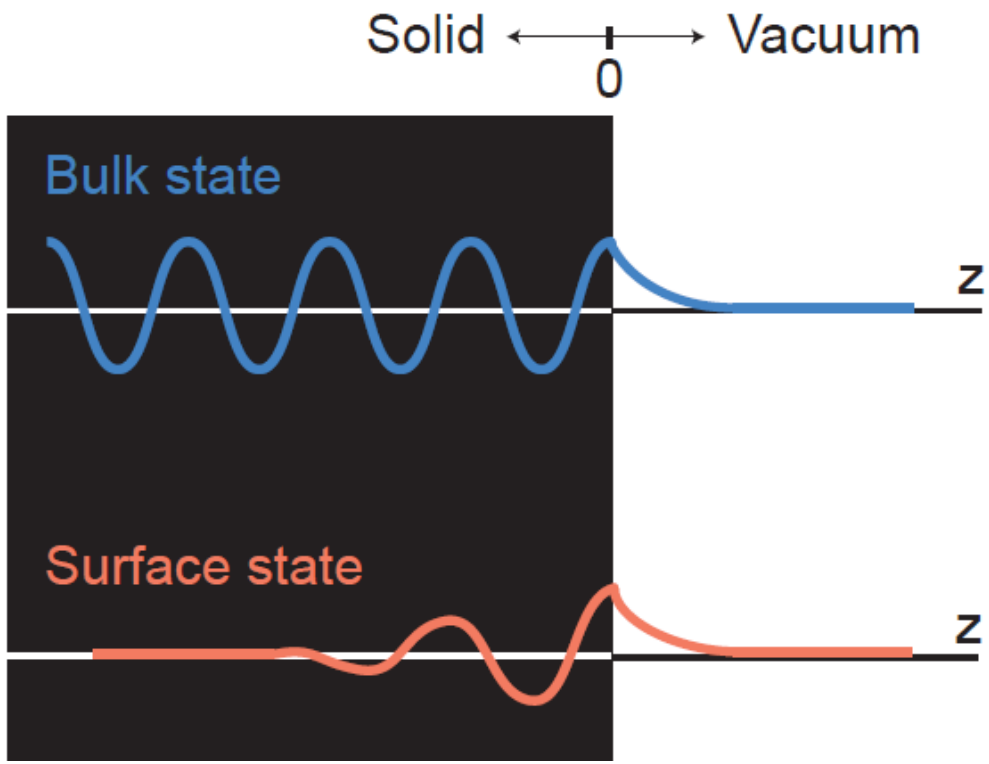
$$\psi_{n\mathbf{k}}(\mathbf{r}) = e^{i\mathbf{k}\cdot\mathbf{r}} u_{n\mathbf{k}}(\mathbf{r})$$

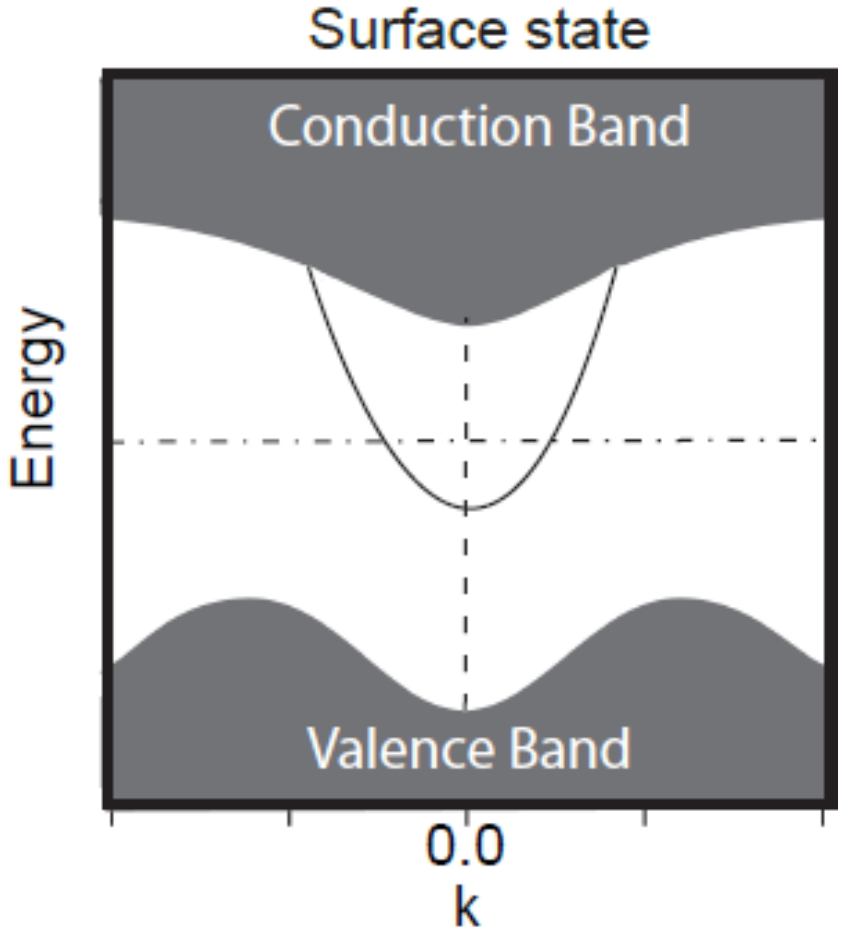




Surface States

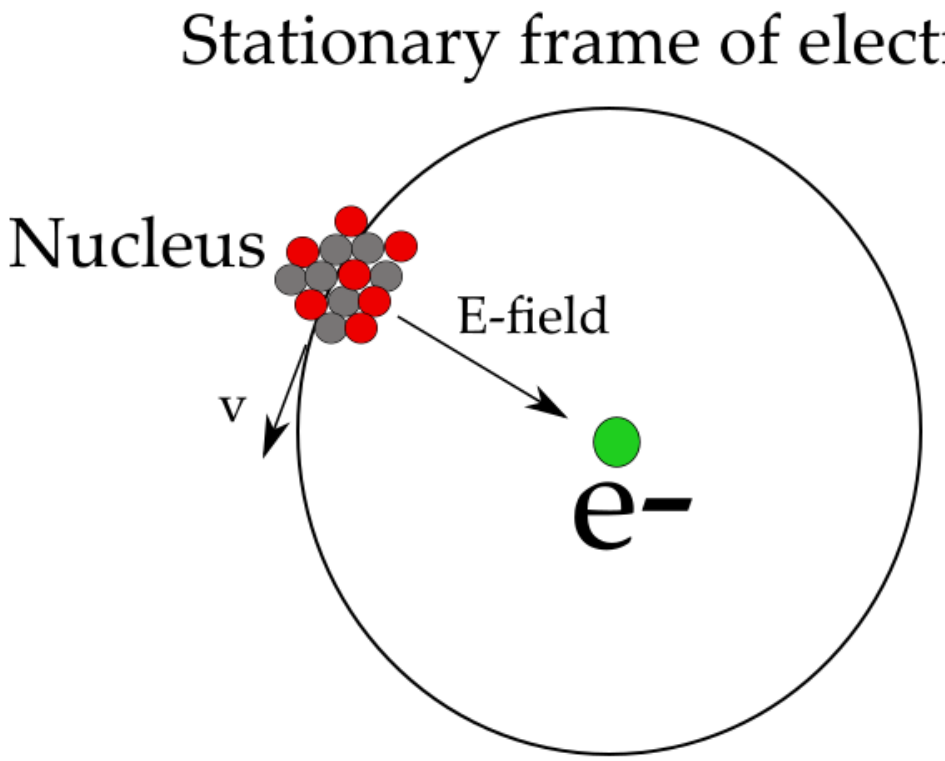
Bad assumptions from previous case hide information about electronic structure of material



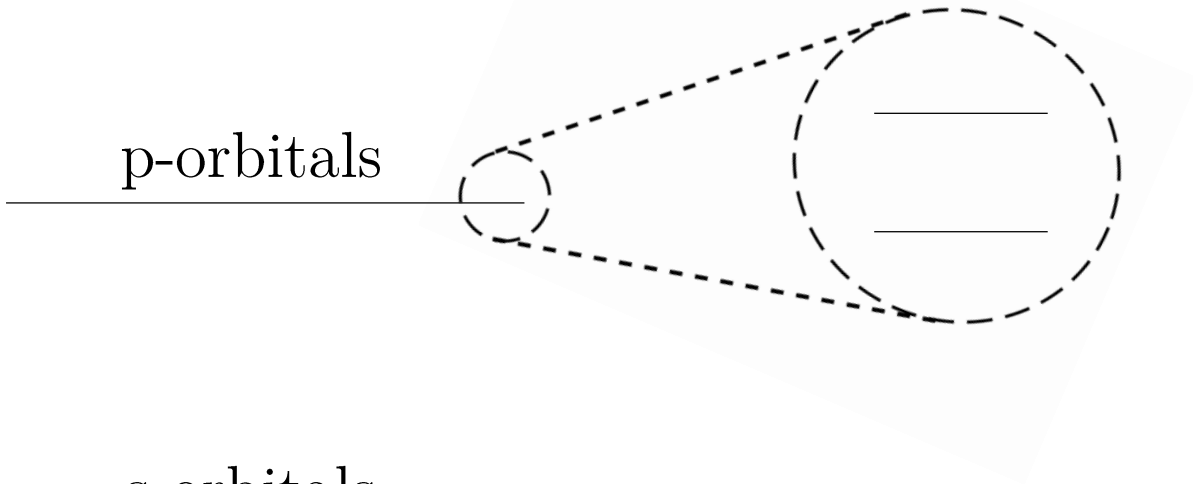


Spin-Orbit Interaction

Relativistic effect between nucleus and electron

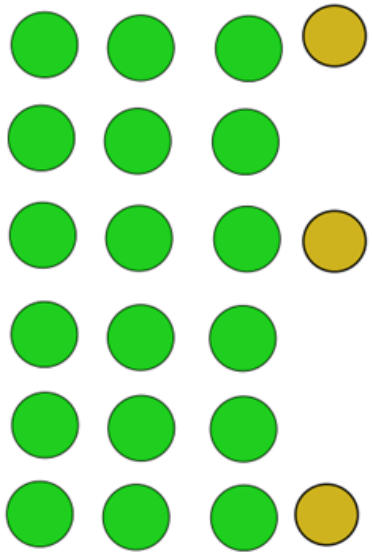


Can split spin degeneracies in atomic orbitals



Rashba Effect

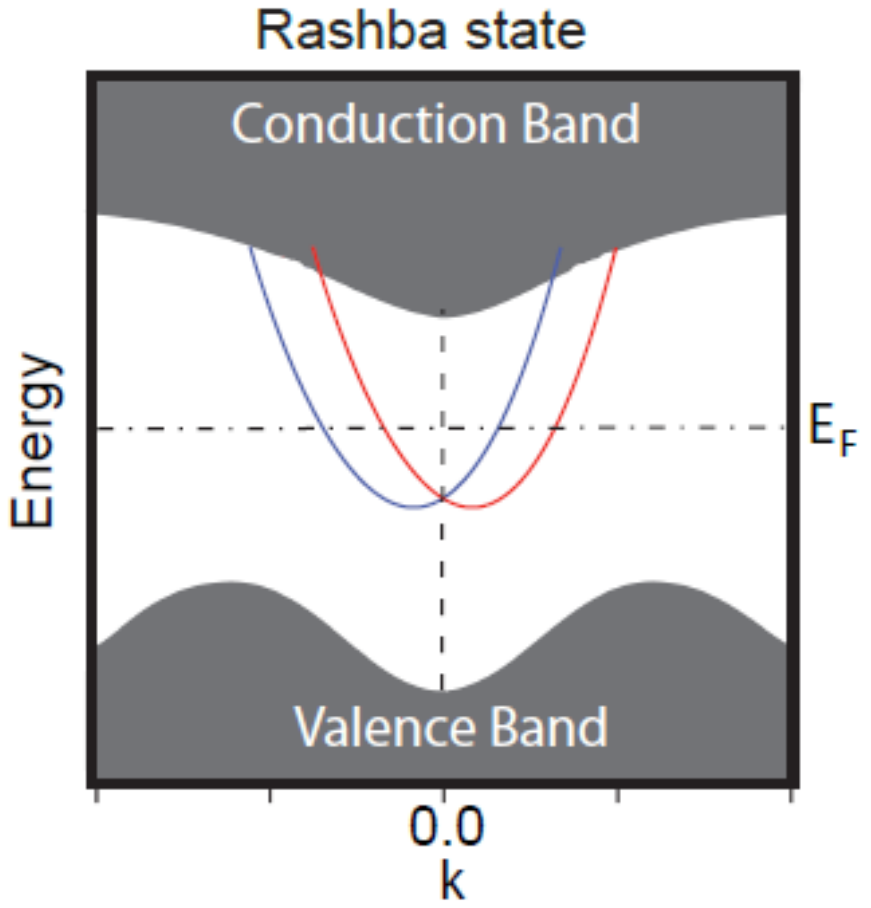
What happens to surface states when inversion symmetry is broken?



Bulk material

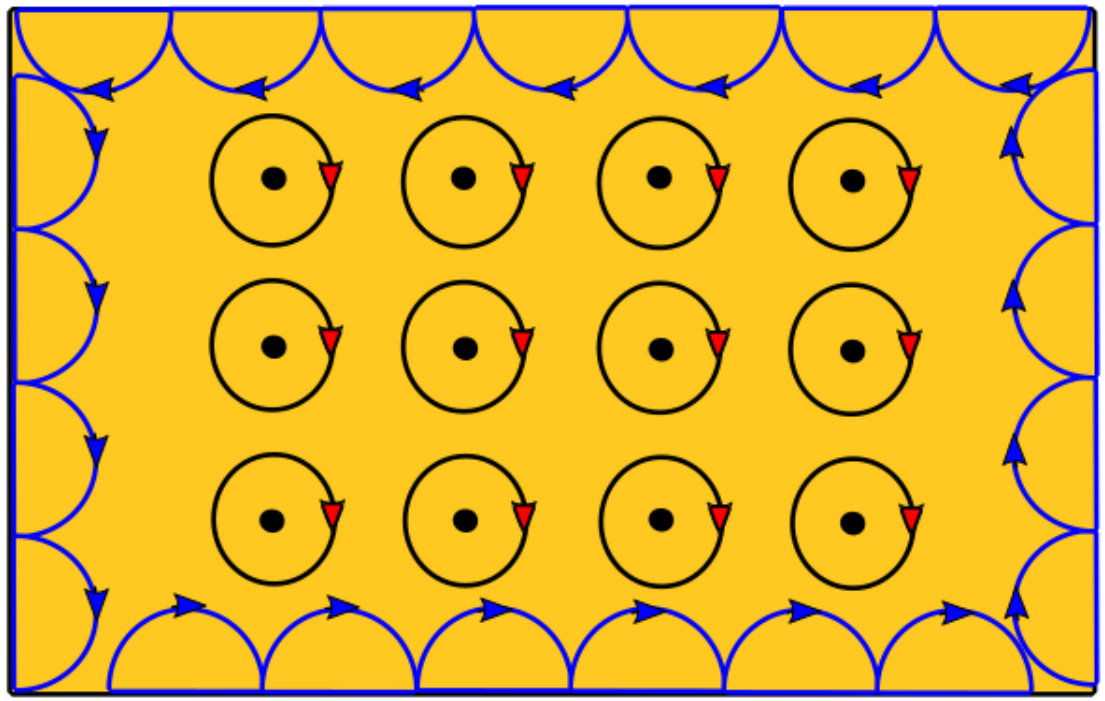
2D electron gas (2DEG)

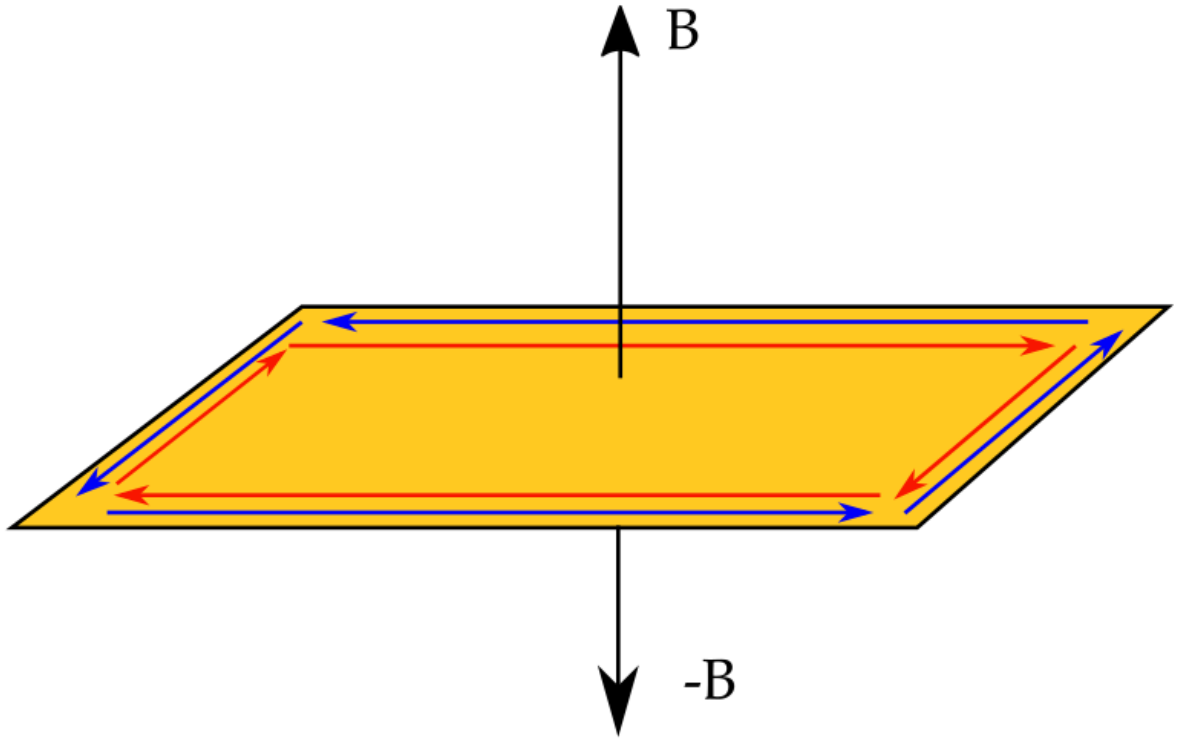
(Alkali metal donates 1 electron)



Topological Insulators

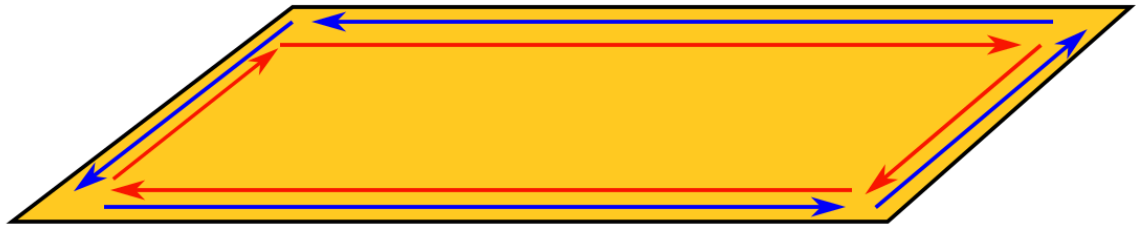
2D material containing electrons and large magnetic field into the material



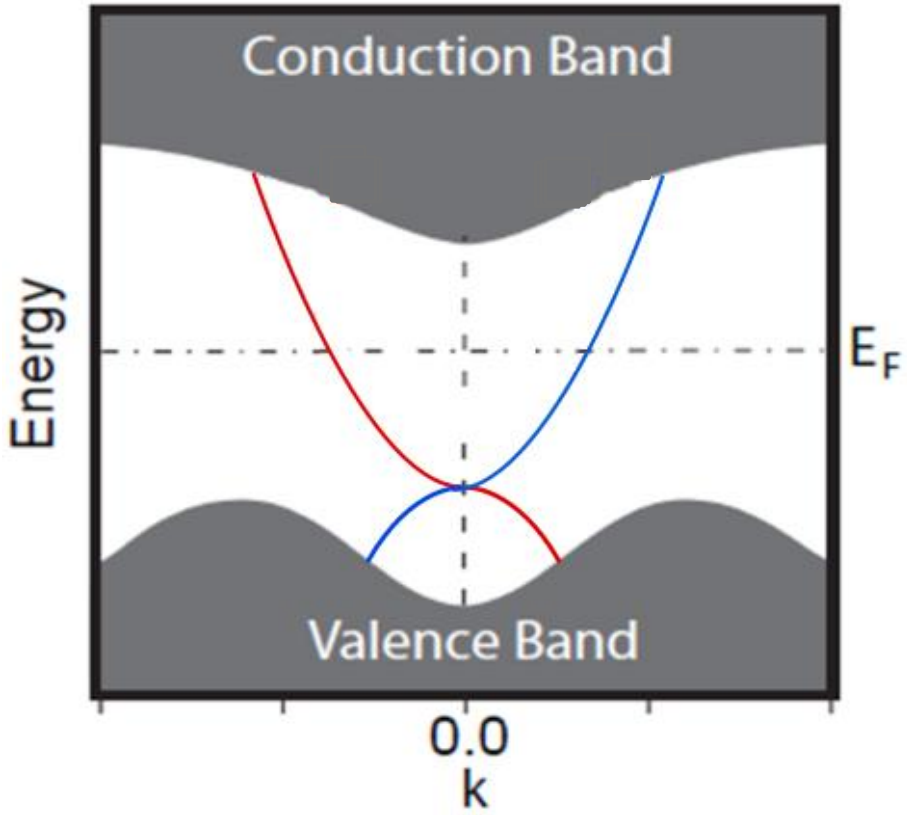


Topological Insulators

Realized without large B?



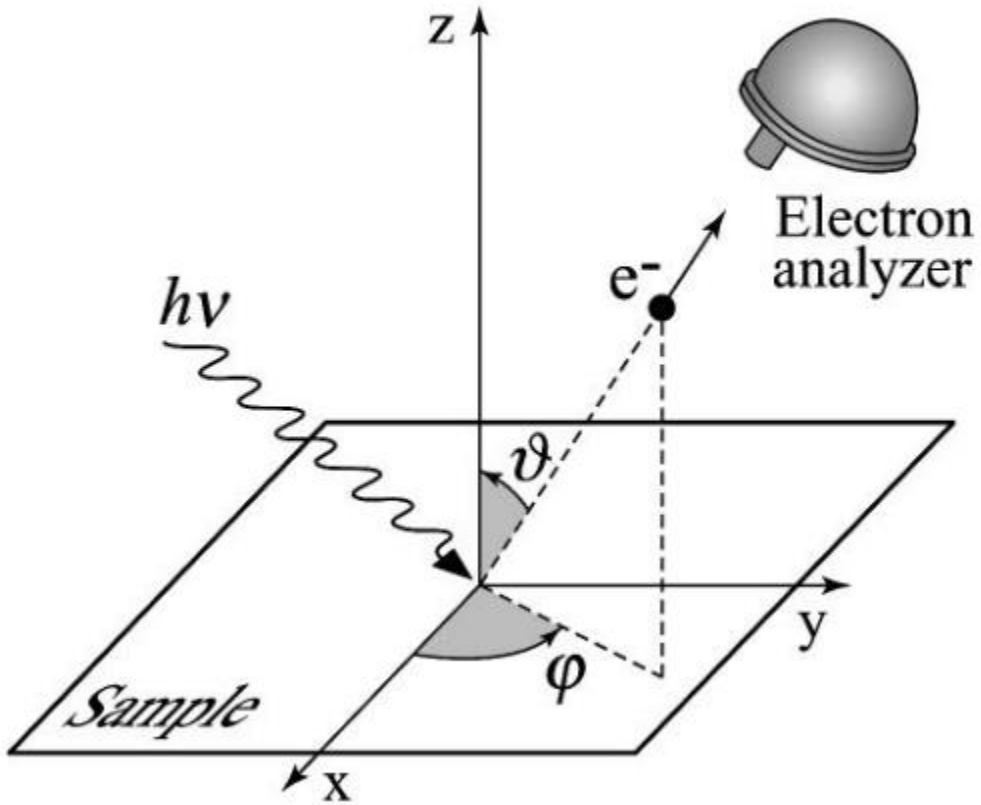
Topological states



These systems contain non degenerate spin states which are crucial for utilization in spintronics

ARPES

Direct method of determining band structure below fermi energy



2D sample → Electron momentum constrained to an x-y plane so momentum is conserved.

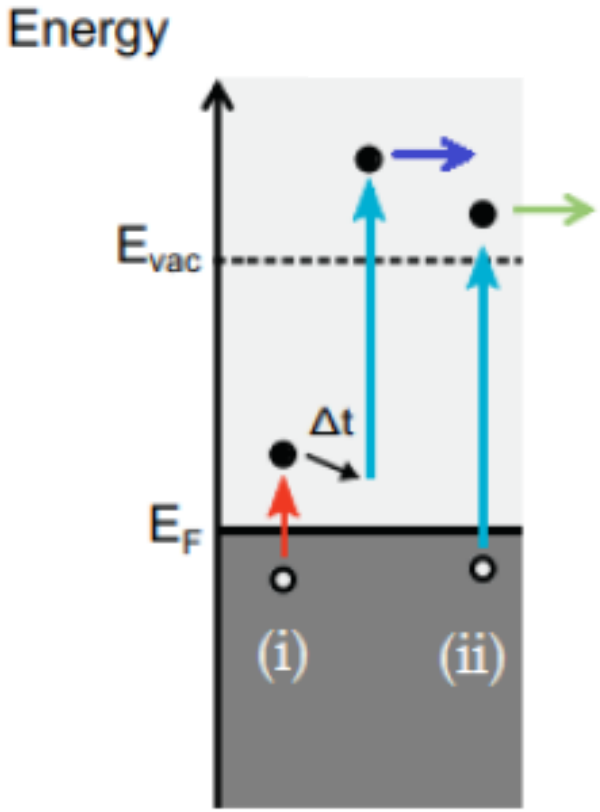
$$\vec{p} = \hbar\vec{k}_{\parallel} = \sqrt{2mE_k} \cdot \sin\vartheta$$

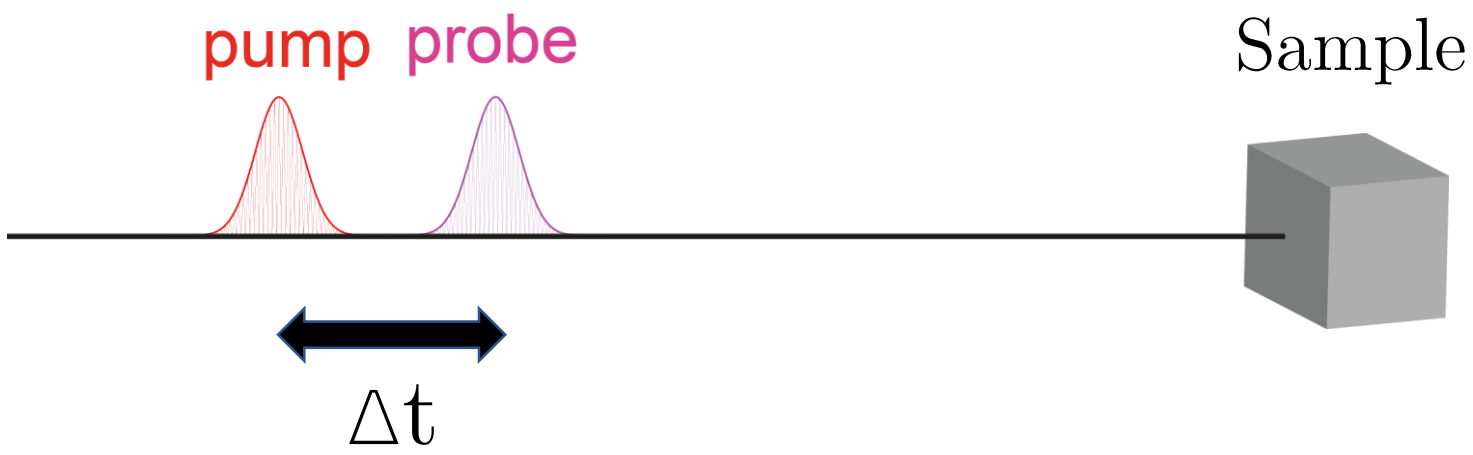
$$E_k = h\nu - \phi - E_B$$

Image from et al, 2003

TR-ARPES

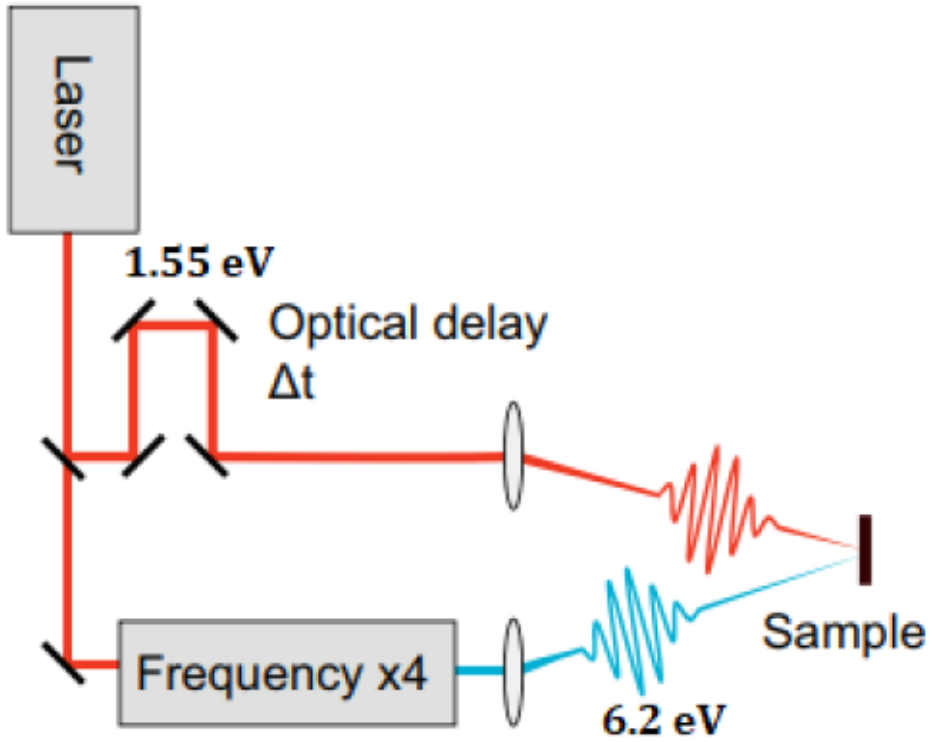
What about unoccupied states in the crystal?

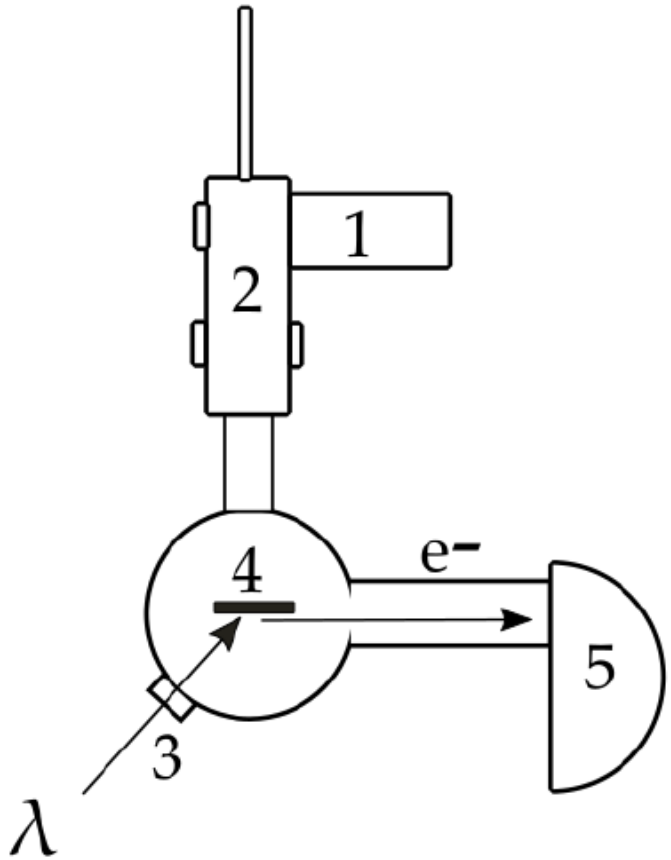




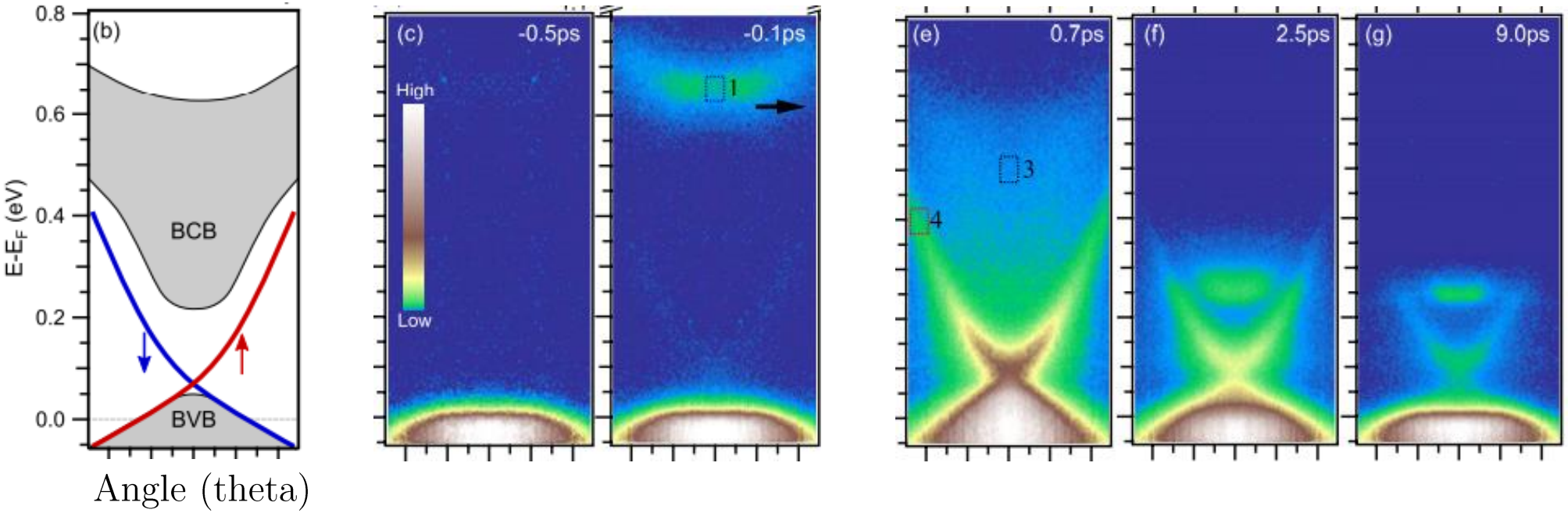
Proposed Experiment

Bi2Se3, Bi2Te3 and Bi2Te2Se





Proposed Experiment



Fewer scattering processes in non degenerate spin states

Image from J. Sabota et al, 2012

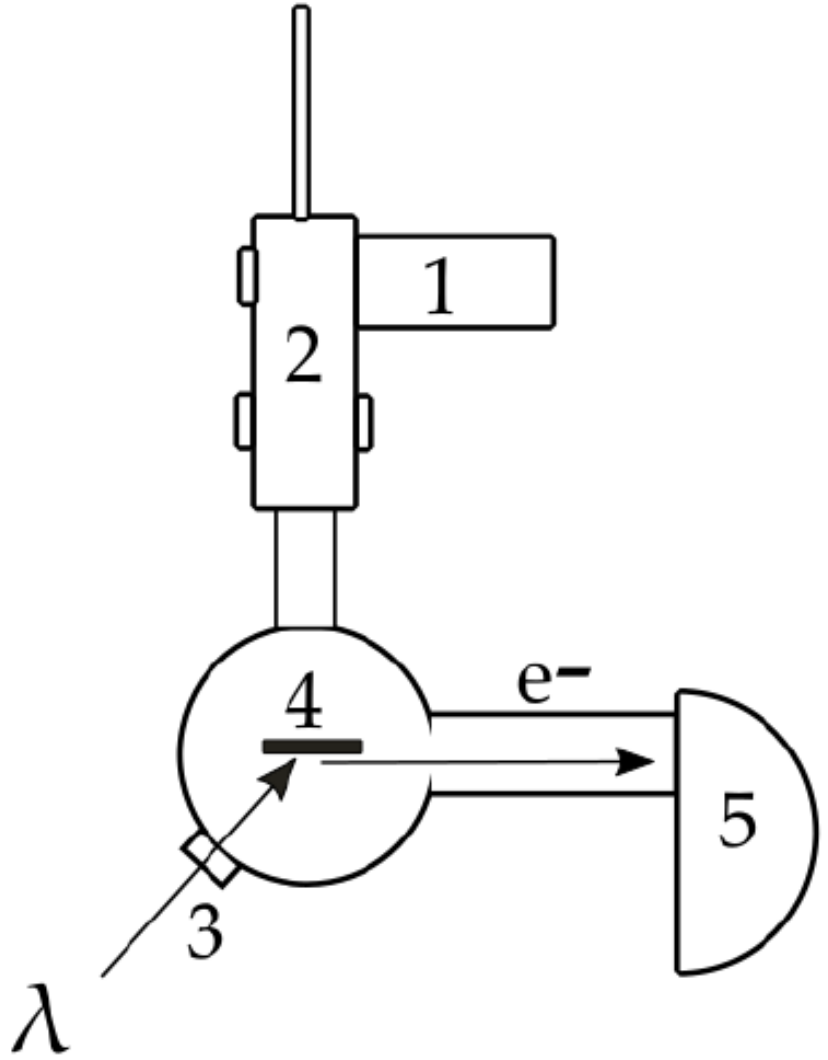
Resource List

ARPES Chamber at QMI

Igor Pro for data analysis

3: SPEC UV300

5: SPEC 2D-Phoibos150
(later: Scienta DA30)



Summary

1. We aim to study the electron dynamics of the prototypical Topological insulators Bi2Se3, Bi2Te3 and Bi2Te2Se via TR-ARPES.

2. We seek to characterize the lifetime of the topological states and Rashba states as there are fewer scattering processes in this regime.

3. Materials with topological states and Rashba states have serious consideration for spintronic devices.

Acknowledgements