Kwant project

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Week 7: april 1. - april 7.
Topological Anderson Insulator 1.

2019/04/04

1 Schedule for the semester

Table 1: Original schedule

Week	Scheduled Task
feb. 18. - feb. 24.	Installing Kwant & Running an example
feb. 25. - mar. 3.	Reading the documentation & Running more examples
mar. 4 - mar. 10	Reading theory of 2DEG & Writing a 2DEG calculation
mar. 11. - mar. 17.	2DEG constriction in a magnetic field
mar. 18. - mar. 24.	Graphene focusing
mar. 25. - mar. 31.	Mid term report
apr. 1. - apr. 7.	Topological Anderson Insulator/ Majorana fermion 1.
apr. 8. - apr. 14.	Topological Anderson Insulator/ Majorana fermion 2.
easter holiday	-
apr. 22. - apr. 28.	Topological Anderson Insulator/ Majorana fermion 3.
apr. 29. - may 5.	Topological Anderson Insulator/ Majorana fermion 4.
Eötvös/Pázmány days	-
may 13. - may 19.	Final report

Table 2: Status

Week	Scheduled Task
feb. 18. - feb. 24.	Installing Kwant & Running an example ✓
feb. 25. - mar. 3.	Reading the documentation & Running more examples ✓
mar. 4 - mar. 10	Struggling with graphene minimal conductivity - no result
mar. 11. - mar. 17.	2DEG basics & Eigenstates and LDOS calculation ✓
mar. 18. - mar. 24.	2DEG in magnetic field ✓
mar. 25. - mar. 31.	Mid term report
apr. 1. - apr. 7.	Topological Anderson Insulator/ Majorana fermion 1.
apr. 8. - apr. 14.	Topological Anderson Insulator/ Majorana fermion 2.
easter holiday	-
apr. 22. - apr. 28.	Topological Anderson Insulator/ Majorana fermion 3.
apr. 29. - may 5.	Topological Anderson Insulator/ Majorana fermion 4.
Eötvös/Pázmány days	-
may 13. - may 19.	Final report

2 Progress so far

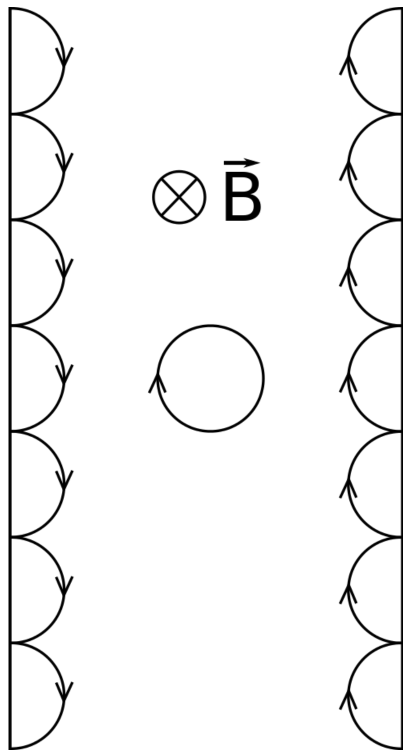
- Installing kwant 1.4.0
- Getting familiar with kwant: Sites, hoppings, builders
- Creating simple and more complex tight-binding systems
- Calculating transmission coefficients between two leads
- Calculating eigenfunctions, local densities of states
- Applying homogeneous magnetic field to a quantum point contact
- Experimenting with graphene: Minimal conductivity near Dirac-point

3 Progress in this week

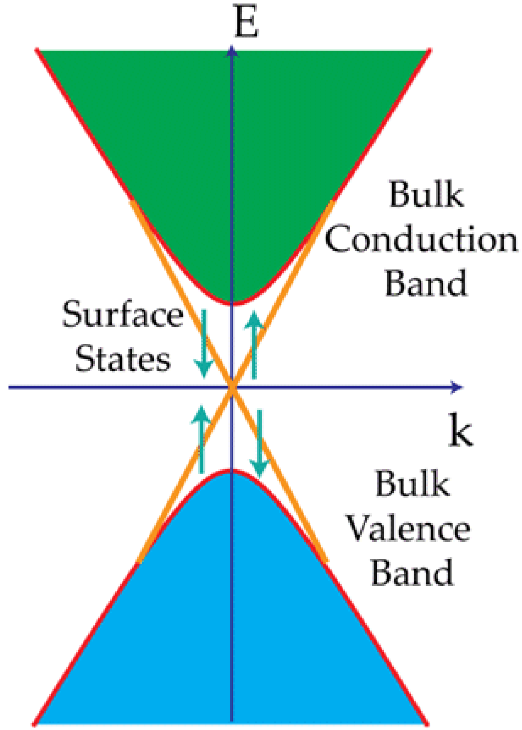
- Improved on my report
- Reading an article: Topological Anderson Insulator https://arxiv.org/abs/0811.3045
- Reading about majorana fermions:
  Introduction to topological superconductivity and Majorana fermions: http://arxiv.org/abs/1206.1736v2,
  Majorana chain in a quantum dot-superconductor linear array: https://arxiv.org/abs/1111.6600,
  Search for Majorana fermions in superconductors: https://arxiv.org/abs/1112.1950
- Trying to understand and reproduce the results described in the article about TAI (https://arxiv.org/abs/0811.3045)

4 Topological insulator theory

- Behave as an insulator in the interior, but have conducting edge states
- Quantum Hall effect creates protected edge states using a strong magnetic field
- Introducing magnetic field breaks time-reversal symmetry



- Another way to create protected edge states is to start from a system with Dirac cones, and open gaps in those
- Graphene is a two-dimensional system which has Dirac cones
- This makes graphene suitable to be used as a topological insulator



$$H_0(\mathbf{k}) = \begin{pmatrix} 0 & h(\mathbf{k}) \\ h^\dagger(\mathbf{k}) & 0 \end{pmatrix}$$

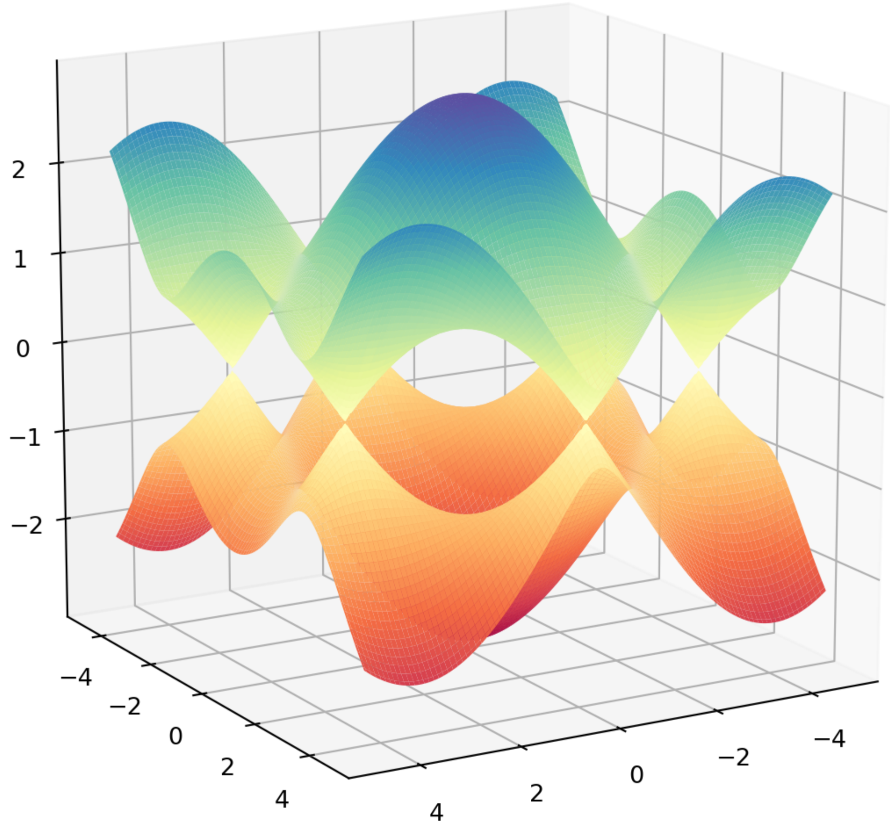
where $\mathbf{k} = (k_x, k_y)$, and

$$h(\mathbf{k}) = t_1 \sum_i \exp\left(i\mathbf{k} \cdot \mathbf{a}_i\right)$$

Rewritten:

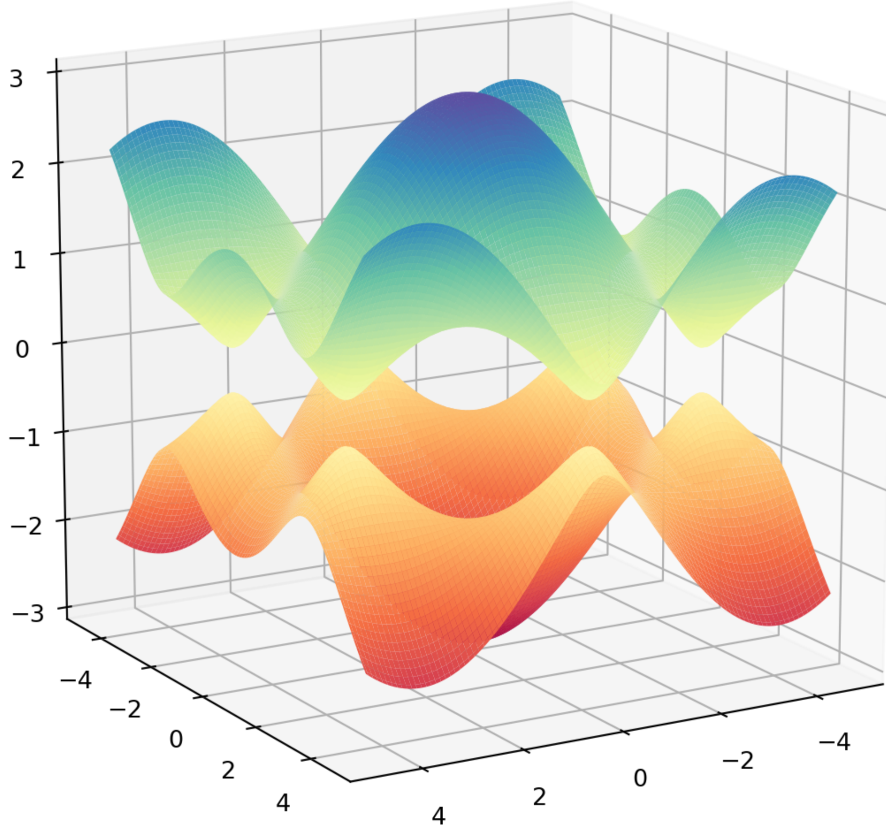
$$H_0(\mathbf{k}) = t_1 \sum_i \left[\sigma_x \cos(\mathbf{k} \cdot \mathbf{a}_i) - \sigma_y \sin(\mathbf{k} \cdot \mathbf{a}_i)\right]$$

$$E(\mathbf{k}) = \pm\left|h(\mathbf{k})\right| \leftarrow \text{Dirac cone}$$



Adding second neighbor hoppings according to Haldane (paper: https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.61.2015)

$$H = -t \sum_{\langle i,j \rangle \alpha} c_{i\alpha}^{\dagger} c_{j\alpha} + i\lambda_{SO} \sum_{\langle\langle i,j \rangle\rangle \alpha\beta} \nu_{ij} c_{i\alpha}^{\dagger} \sigma_{\alpha\beta}^{z} c_{j\beta}$$



5 Topological Anderson Insulator

What are topological Andreson insulators? https://arxiv.org/abs/0811.3045

- The physics of a topological insulator is unaffected by weak disorder, but is destroyed by large disorder
- BUT: Disorder can create a topological insulator for parameters where the system was metallic in the absence of disorder
- These states are called topological Anderson insulators
- Disorder can be modeled as random onsite energy with a uniform distribution within $[-W/2, W/2]$
- the article discusses disordered strips of HgTe/CdTe quantum wells.
- The expected result can be seen on the image