Kwant project

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Weekly presentation 9
29 april - 5 may Topological Anderson Insulator

2019/05/01

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 1. ✓
apr. 8. - apr. 14.	Topological Anderson Insulator 2. ✓
easter holiday	-
apr. 22. - apr. 28.	Topological Anderson Insulator 3. ✓
apr. 29. - may 5.	Topological Anderson Insulator 4. ✓
Eötvös/Pázmány days	-
may 13. - may 19.	Final report

2 Progress in this week

- Last time I had a question about how to implement a system with continuous Hamiltonian, like

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

- Got help from my project leader:
- He pointed out that kwant can automatically discretize a Hamiltonian using `kwant.continuum.discretize`: `https://kwant-project.org/doc/dev/tutorial/discretize`

- The paper about Topological Anders Insulator (https://arxiv.org/abs/0811.3045) defines the Hamiltonian for HgTe/CdTe heterostructure:

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

$$h(\mathbf{k}) = \epsilon(k) + \mathbf{d}(\mathbf{k})\sigma,\ \mathbf{k} = (k_x, k_y)$$

$$\mathbf{d}(\mathbf{k}) = (Ak_x, Ak_y, M - Bk^2);\ \epsilon(k) = C - Dk^2$$

- This can be rewritten as a sum of a few terms:

$$= (C-Dk^2)\begin{pmatrix} \sigma_0 & 0 \\ 0 & \sigma_0 \end{pmatrix} + (M-Bk^2)\begin{pmatrix} \sigma_z & 0 \\ 0 & \sigma_z \end{pmatrix} + Ak_x\begin{pmatrix} \sigma_x & 0 \\ 0 & -\sigma_x \end{pmatrix} + Ak_y\begin{pmatrix} \sigma_y & 0 \\ 0 & -\sigma_y \end{pmatrix} + V_{\mathrm{disorder}}\begin{pmatrix} \sigma_0 & 0 \\ 0 & \sigma_0 \end{pmatrix}$$

- A, B, C, D, M are empirical parameters. I used the values presented in an article: "Numerical study of the topological Anderson insulator in HgTe/CdTe quantum wells" (https://arxiv.org/abs/0905.4550v1)

```python
hamiltonian = """
(C-D*(k_x**2+k_y**2))*identity(4)
+ (M-B*(k_x**2+k_y**2))*kron(sigma_0, sigma_z)
+ A*k_x*kron(sigma_z, sigma_x)
+ A*k_y*kron(sigma_z, sigma_y)
+ V(x,y)*identity(4)
"""

template = kwant.continuum.discretize(hamiltonian, grid=a)

def shape(site):
  (x, y) = site.pos
  return (0 <= y < W and 0 <= x < L)

syst = kwant.Builder()
syst.fill(template, shape, (0, 0))
```

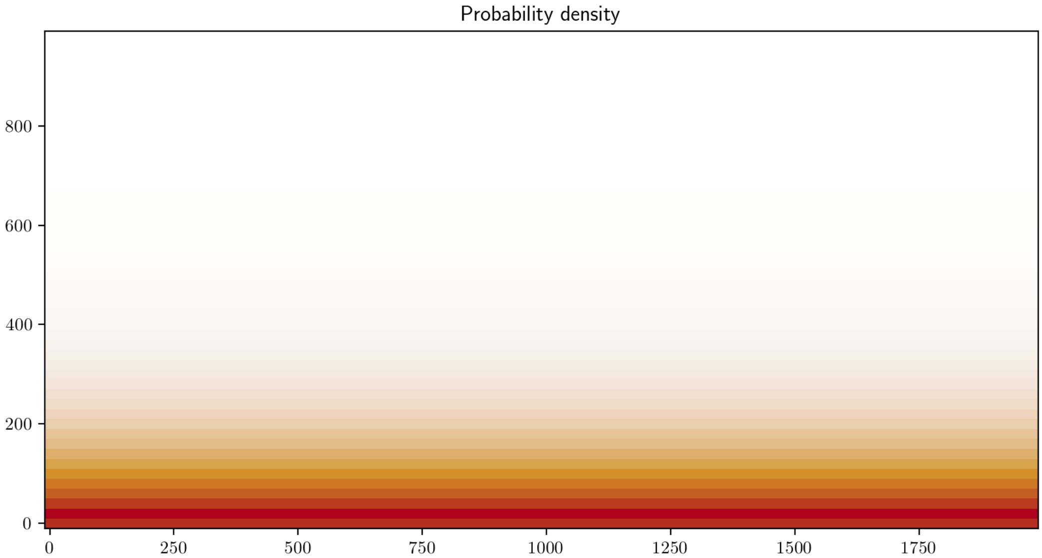

Figure 1: probability density at $W = 0$

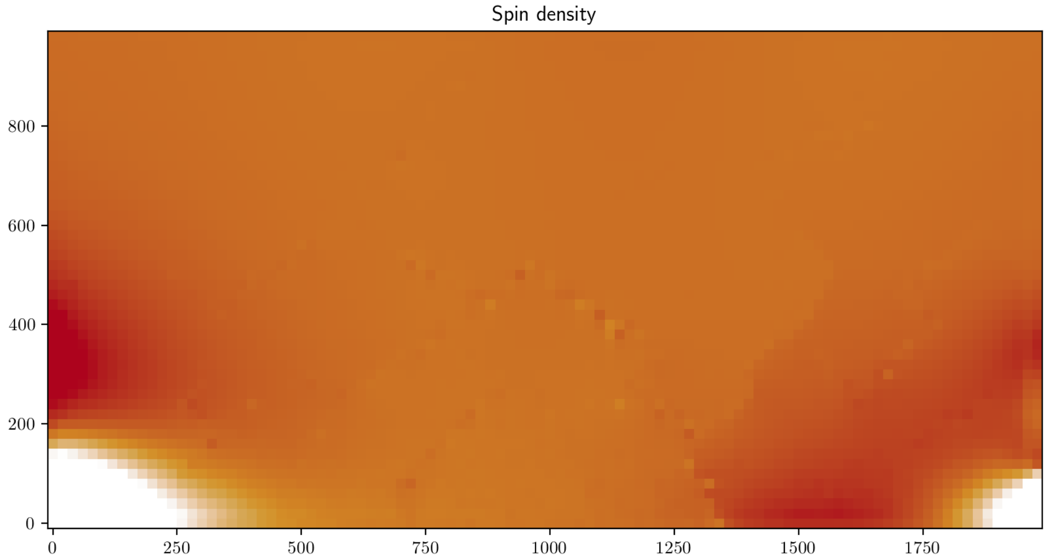

Figure 2: spin density at $W = 0$

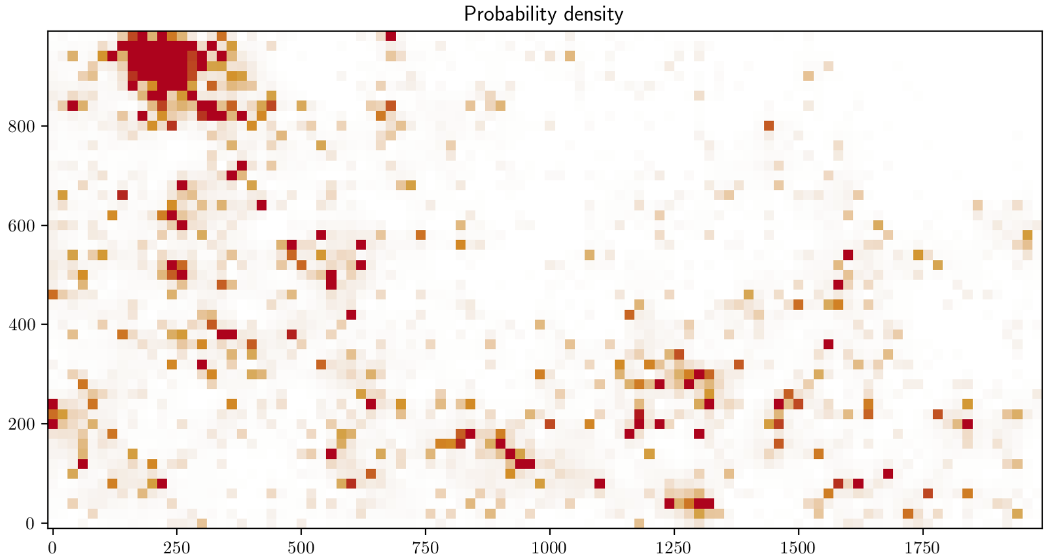

Figure 3: probability density at $W = 0.5$

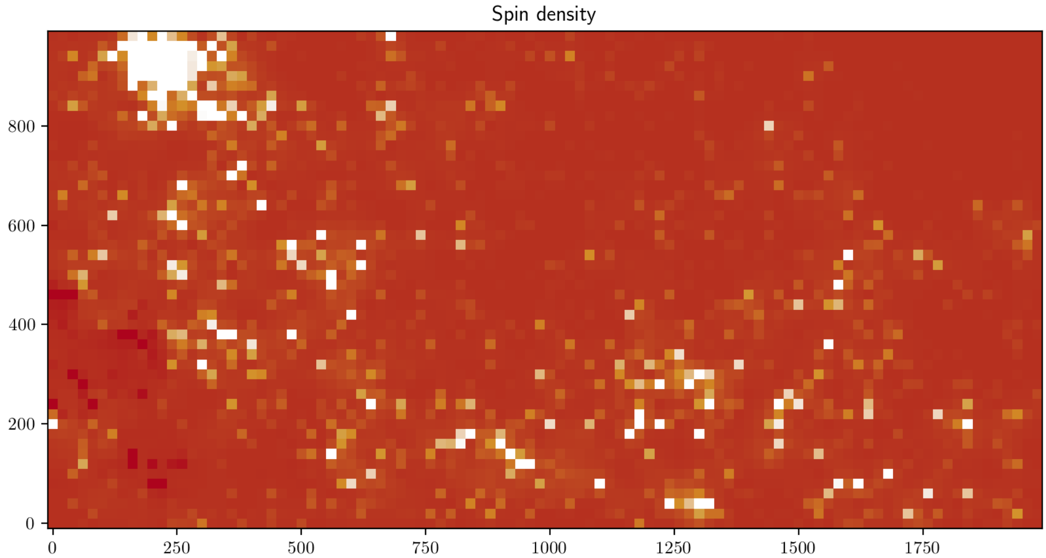

Figure 4: spin density at $W = 0.5$

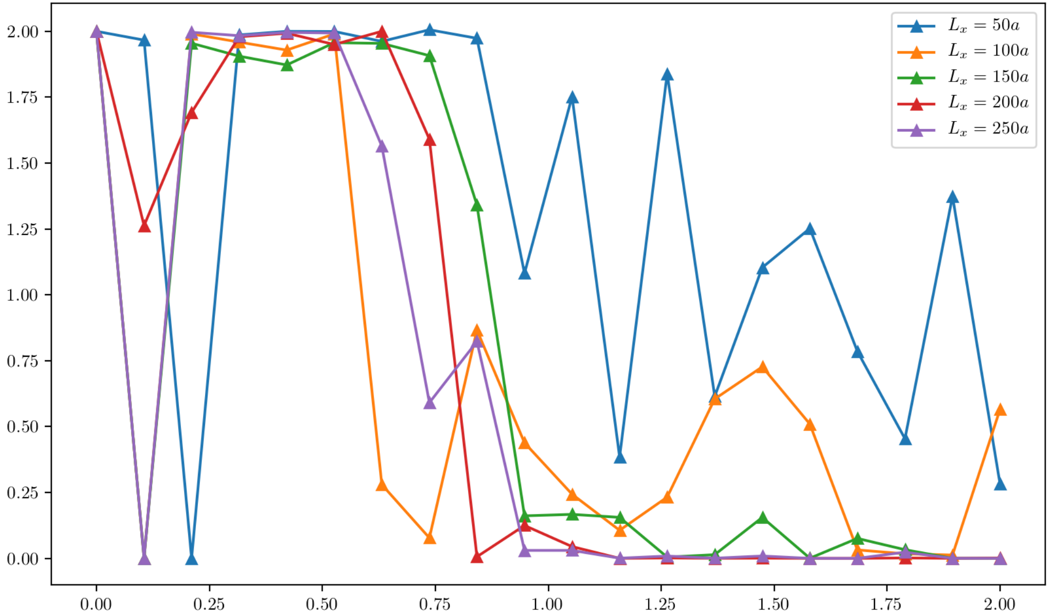

Figure 5: Transmission as a function of L at $E = 0$

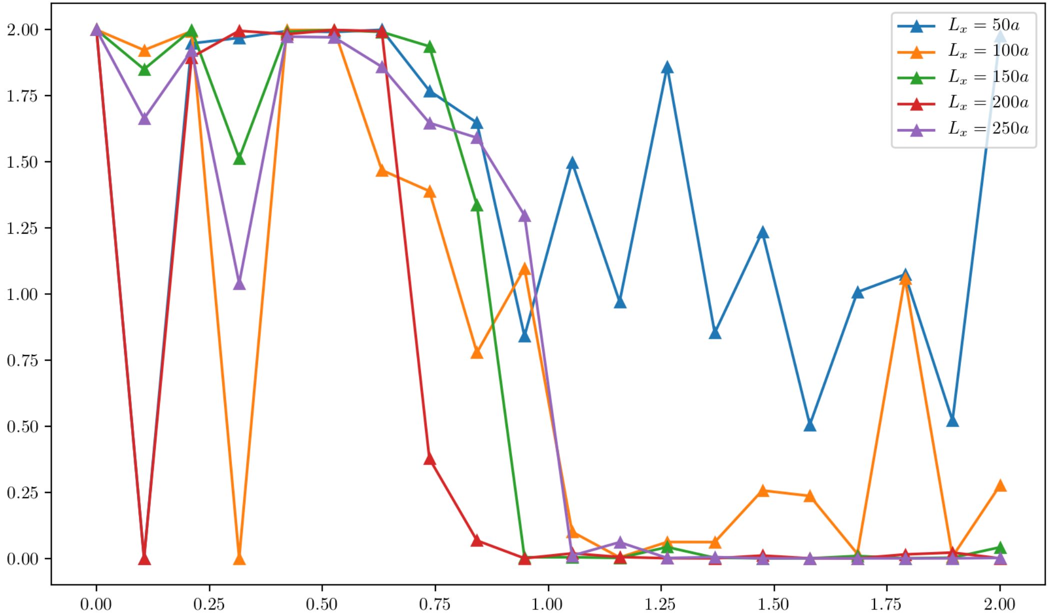

Figure 6: Transmission as a function of L at $E = 0.5$

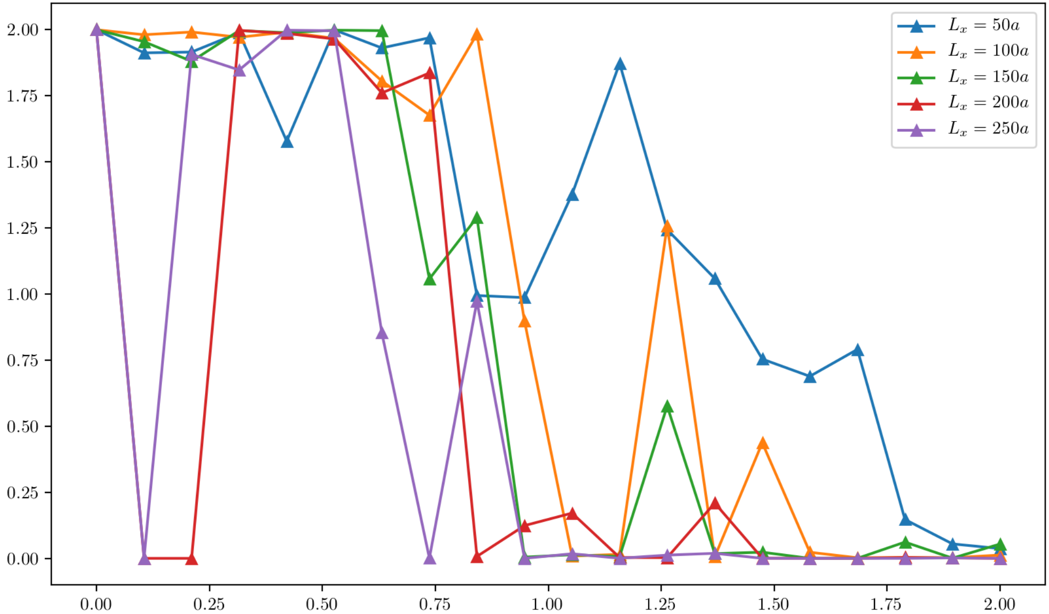

Figure 7: Transmission as a function of L at $E = 1.0$

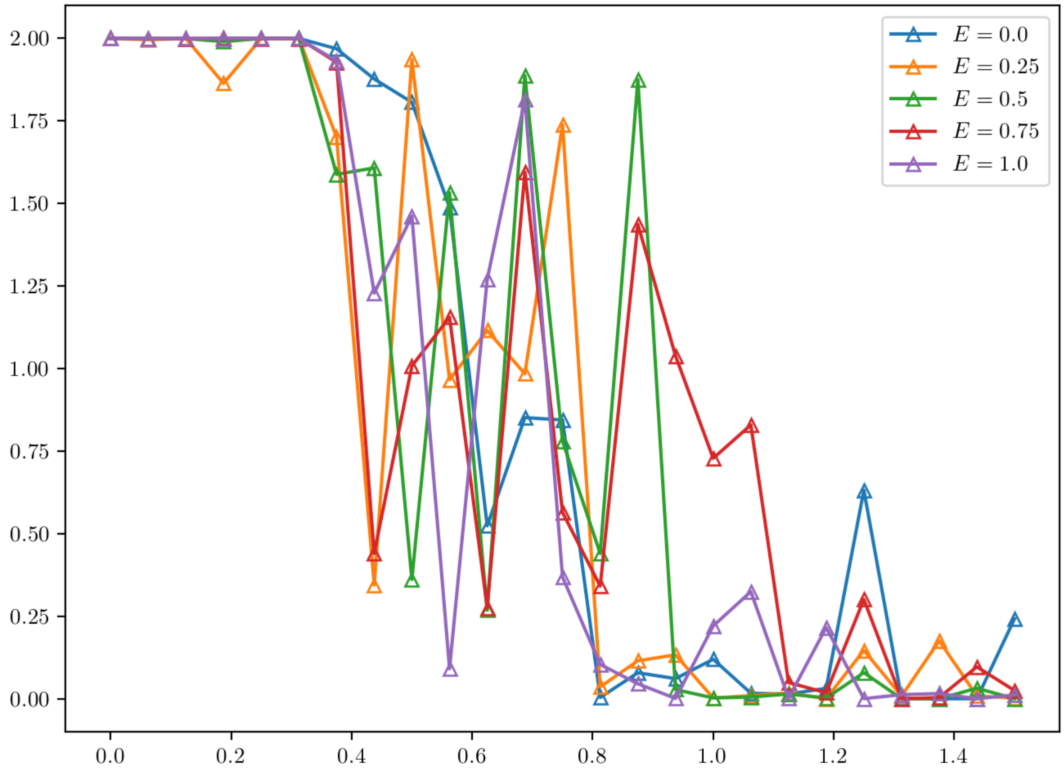

Figure 8: Transmission as a function of disorder parameter W, different energies