Introduction to Topological Insulators

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Bachelor's or Master's Project in English
(There are many models to study, the depth of the project depends of the student's motivation and time)

→ **What is this work about?**

In this project we will study the topological transition of different lattices with chiral symmetry in the tight binding approximation using theoretical and numerical methods. For instance, the Fig. 1 shows two lattices and its eigenenergies spectrum colored with respect the participation ratio (red means highly localized states and blue means extended states).

→ **The student will learn to:**

From the theoretical part: Study theoretically a model from the tight-binding approximation via Bloch waves[1]. Also, learn what is a topological invariant and how to calculate it from the Bloch eigenstates. Furthermore, what is the system's symmetry and how to calculate it from the Hamiltonian using the Dirac notation.

From the numerical part: Study numerically a tight-binding model which includes to calculate the spectrum and statistical information of the eigenstates, such as the Participation Ratio (PR). Also, how to estimate the topological invariant from statistical measures such as the averaged mean displacement[2].

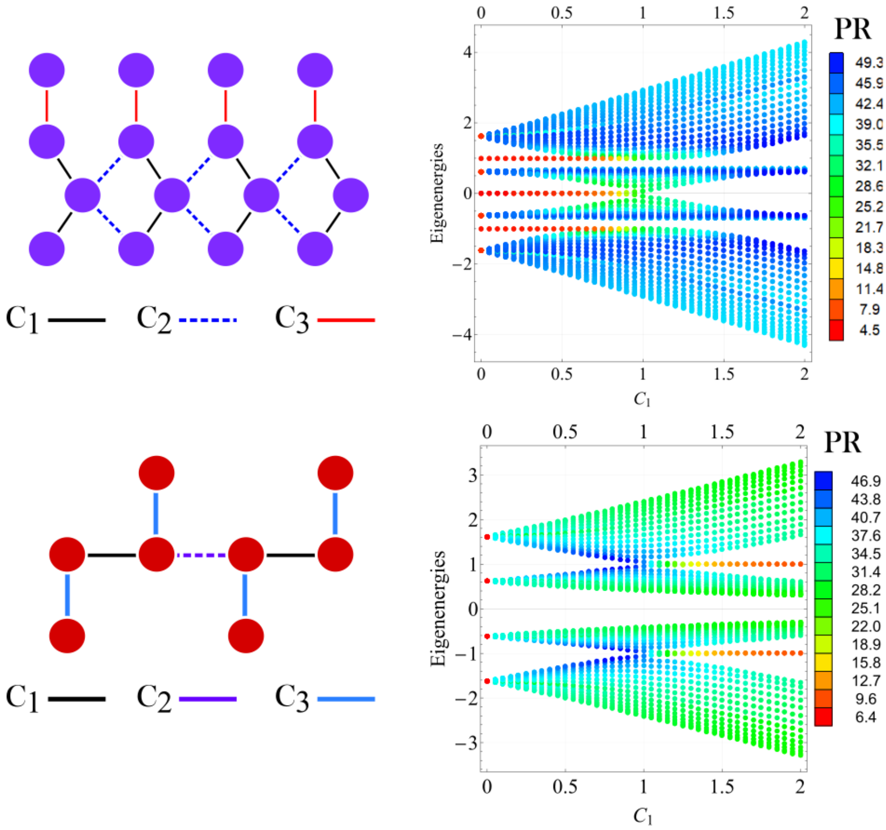

Fig. 1 (Upper) A lattice with its eigenenergies spectrum. The color of each eigenenergy is the participation ratio (PR) that indicates if the associated eigenstate is localized or extended (red for localized and blue for extended). (Lower) Other lattice with its numerical eigenenergies spectrum.

References

[1] F. Bloch. Über die Quantenmechanik der Elektronen in Kristallgittern. *Zeitschrift für physik*, 52:555–600, 1929.

[2] F. Cardano, A. D'Errico, A. Dauphin, M. Maffei, B. Piccirillo, C. De Lisio, G. De Filippis, V. Cataudella, E. Santamato, L. Marrucci, M. Lewenstein, and P. Massignan. Detection of Zak phases and topological invariants in a chiral quantum walk of twisted photons. *Nature Communications*, 8:1–7, 2017.