PHD Annual Report
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Summary of research activity

My research activity is strictly related to the field of topological insulators. These are materials in which a bulk band gap coexists with protected conducting states localized at the boundary of the system. In ordinary topological insulators, the metallic edge states propagate in one dimension less than the dimensionality of the bulk, in accordance to the principle of bulk-boundary correspondence. In a vast majority of cases, elastic backscattering within the topological modes is forbidden, for geometric or symmetry reasons. Due to these unique properties, topological insulators represent interesting platforms for quantum technological applications.

In recent years, new topological phases have been discovered, characterized by protected metallic states that live in a dimension $d - n$, with $n > 1$ (d being the dimension of the bulk). Systems that manifest such feature are called higher order topological insulators (HOTI), and n is referred to as the order of the topological phase. Up to this moment, HOTI phases have been experimentally achieved in 3D materials, while a realization on 2D materials is still missing.

Among the theoretical proposals for a two-dimensional higher order topological insulator, a noteworthy one was developed in 2020 by S. Spurrier and N. Cooper in PRR **2**, 033071. The model proposed consists of two Haldane models with opposite Chern number, coupled together in a specific geometrical configuration. The resulting lattice is cristallographically equivalent to that of the graphene quasicrystal (GQ), that is two superimposed layers of graphene with a relative rotation of thirty degrees. The GQ lattice, that has been experimentally realized in 2018, has bulk C_{12} rotational symmetry. Thanks to this feature, in presence of global rotational symmetry, the model developed in PRR **2**, 033071 realizes a second order topological insulator (SOTI) phase.

During the first year of my PHD, I have mainly focused on this model for a SOTI on the graphene quasicrystal, studying its robustness [1,3] and assessing the role of the edges on the observability of the topological phase [2].

More precisely, in [1] I have shown that this kind of topological phase is extremely fragile against global geometrical perturbations. Indeed, I have found that global deformations of the lattice break the degeneracy between the 0D corner modes that characterize the SOTI phase.

In [2], I have studied how the shape of the edges of the two honeycomb layers that compose the lattice influences the features of the higher order topological phase of the model. While dealing with this problem, I have derived general results about the edge dependence of the bands in the Haldane model, which is one of the main ingredients of the SOTI model described above. I have found that coupling Haldane edge modes that are hosted by edges with different shapes (armchair, zigzag, bearded), can result in gaps opening at different energies in the edge spectra. This fact strongly affects the SOTI phase of the model. Indeed, I have shown that, when the structure is composed of zigzag and armchair edges, the topological modes do not appear at the charge neutrality point. This result may be crucial for the observability of the SOTI phase in a future experimental realization.

Finally, in [3] I have studied the effect of local deformations of the lattice vertices on the 0D corner modes and, more generally, the role of the vertex structure. I have found that differences in the structure of the lattice around the vertices may result in the bound states appearing in different gaps, depending on the edges considered for the system. Moreover, I also showed that local deformations of the corners (i.e. the removal of a few sites located at the vertices) cause a shift of the corner mode energies. Indeed, these are found to be crucially dependent on the precise disposition of the sites near the vertices.

List of publications

[1] Traverso, S. Robustness of a quasicrystalline higher-order topological insulator. Il Nuovo Cimento C (2022).

[2] Traverso, S., Sassetti, M., Traverso Ziani, N. Role of the edges in a quasicrystalline Haldane model. arXiv preprint (2022), arXiv:2207.12996.

[3] Traverso, S., Traverso Ziani, N., Sassetti M. Effects of the Vertices on the Topological Bound States in a Quasicrystalline Topological Insulator. Symmetry (2022), 14(8):1736.

List of attended courses and exams given

- Statistical Physics (Master Degree Course) – Passed.
- Solid State Theory (PHD course) – Passed.

List of schools/conferences attended

- *Topological Quantum Matter: theory and applications*, Santa Margherita Ligure (GE), 28/03/2022 – 01/04/2022.
- *The Capri spring school on Transport in Nanostructures 2022*, Capri (NA), 08/05/2022 – 15/05/2022. I presented a poster titled "Edge dependence of the higher-order topological phase in a quasicrystalline system".