Course Syllabus: Topological band structures by Dr. Vittorio Peano

Lecture 1, (2 hours) Title: Primer on crystal symmetries and band structures.

Goal: Explain how the symmetries constrain the spectrum and normal modes of waves in a crystal. Show how these quantities can be encoded in a tight-binding model. If time permit, I will also briefly introduce Zak theory of band representations.

Lecture 2, (2 hours) Title: Topological band structures and the eightfold way.

Goal: Explain why topology is relevant for band structures. Introduce the concepts of topological invariant and bulk-boundary correspondence. Introduce important examples in 1D, 2D, and 3D and the periodic table of topological insulators and superconductors based on dimension and symmetries. If time permit, I will also introduce Topological Quantum Chemistry, a more fine grained classification method based on Zak theory of band representations.

Lecture 3, (2 hours) Title: Topology of classical waves: Photonics, phononics and optomechanics.

Goal: Focus on classical and bosonic waves. I will show how the concepts of topological physics, originally discovered for electrons and other fermionic matter waves, are also relevant for fundamentally different types of waves, in particular bosonic and classical waves. I will also review the main experimental platforms for topological photonics, phononics and optomechanics.

Lecture 4 (2 hours) Title: Topological waves in the ocean and in photonic crystals.

Goal: Show that topology is also relevant to understand the physics of ocean waves. This requires to adapt the definition of the topological invariant and the bulk-boundary correspondence to not rely on the crystal symmetry. These new concepts also provide a topological interpretation of the helical edge states in photonic and phononic crystals, which are governed by an effective Dirac Hamiltonian, derived from symmetry considerations. We show that backscattering is not entirely forbidden in these devices and how it can be understood as a tunneling process.

Lecture 5, (2 hours) Title: Topological photonic devices, travelling wave amplifiers and non-hermitian topology.

Goal: Explore the applications of topological band structures in photonics with emphasis on active devices like laser and amplifiers. I will also introduce the topology of non-hermitian Hamiltonian and show how it can help to understand transport in travelling wave amplifiers.