ICFO

PhD Thesis Defense MARIA MAFFEI 'Simulation and bulk detection of topological phases of matter'

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January 29, 2019

Tuesday, January 29. Universita degli Studi di Napoli

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Quantum Optics Theory

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Differently from the majority of the other phases of matter, which are characterized by local order parameters, the topological phases are characterized by integer or semi-integer numbers, the topological invariants, which are depending on global properties and robust against impurities or deformations. In the last decade, the study of the topological phases of matter has been developing parallel to the field of quantum simulation. Quantum simulators

are fully controllable experimental platforms simulating the dynamics of systems of interest by the use of the mapping between the two Hamiltonians. These simulators represent a key resource in the study of topological phases of matter because their observation in natural systems is usually highly problematic and sometimes impossible.
Quantum simulators are commonly realized with cold atoms in optical lattices or with photonic systems. The unitary and time-periodic protocols, known as quantum walks, are a versatile class of photonic quantum simulators. The purpose of this PhD thesis is to design feasible protocols to simulate and characterize topological non-interacting crystalline Hamiltonians in 1 and 2 dimensions. Moreover, this thesis contains the description of the experiments that have been completed using the theoretical proposals. In details: i) We demonstrate that the topological invariant associated to chiral symmetric 1D Hamiltonians becomes apparent through the long time limit of a bulk observable, the mean chiral displacement (MCD). This detection method converges rapidly and requires no additional elements (i.e. external fields) or filled bands. The MCD has been used to characterize the topology of a chiral-symmetric 1D photonic quantum walk and to detect a signature of the so-called topological Anderson insulating phase in a disordered chiral symmetric wire simulated with ultracold atoms. ii) We designed the protocol to measure the topological invariant that characterizes a 2D photonic quantum walk simulating a Chern insulator.

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