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Summary

Topological properties of wave functions in quantum mechanics, especially in the context of electrons in condensed matter systems, have recently attracted a lot of theoretical and experimental attention. One of the more recent developments in this field is the attention to systems which are subject to external fields that vary periodically in time, so-called driven systems. The external fields themselves are typically not treated quantum mechanically, but can be used to influence and change the properties (topological and otherwise) of the electrons in a wide range.

As a minimal model that captures the physics introduced by external driving, an often considered model is the so-called (discrete time) quantum walk, a quantum mechanical analogue of the classical random walk. In the "usual" formulation of topological properties in terms of invariants of bulk wave functions, the richness of topological phases in quantum walks has been realized a while ago. Another formulation of topological invariants in terms of the scattering matrix has proven very useful for non-driven systems due to its numerical efficiency and easy extension to disordered systems. We show in the second chapter of this thesis (after the introductory first chapter) how this approach could be extended to quantum walks and find that the same advantages apply. We show that the scattering matrix approach is not only useful in theoretical numerical studies, but can also directly be implemented in photonic experiments as a direct probe for the topological invariant of a quantum walk.

A model actually derived from a driven Hamiltonian, the Su-Schrieffer-Heeger (SSH) model with driven time-dependent parameters, is closely related to the quantum walk. In chapter three we explore under what conditions the symmetries of the (static) SSH model carry over to the driven version and give simple closed expressions for the topological invariants in terms of winding numbers of the time-evolution operator, and thus the driving. We show that this system can be tuned through a manifold of different phases by only changing the driving pattern.

The presence of external driving can also radically change the role of quantum noise and non-linear effects due to the environment on the system, which is inadvertently present or can even be engineered in experiments. We thus study in chapter four a non-linear modification of the quantum walk which involves terms that lead to quantum friction and thus relaxation. In the presence of topological domain boundaries, we find that for certain forms of the non-linearity, the topologically protected bound states obtain a very special role as either attractors or repellors of the global dynamics of the system.

The last two chapters of this thesis consider slightly different questions. A driven system that has been subject to recent research is the so-called single electron emitter, which consists of a quantum dot subject to a time-dependent gate voltage which emits individual electrons or holes to a coupled electron reservoir. In chapter five, we attempt to construct a superconducting version of this system where the quantum dot is replaced by a Josephson junction between topological superconductors and calculate the properties of the emitted so-called Bogoliubov quasiparticles (superpositions of electrons and holes) in the aperiodic limit of driving. We derive an analytical expression for the wave function of the emitted particles and find that both the driving speed and the nature of the coupling between junction and reservoir are crucial in determining the charge of the emitted particle.

In the sixth and final chapter, we consider the experimental challenge of extracting spin-orbit coupling strength in InSb nanowires, which are the basis for constructing (non-driven) one-dimensional topological superconductors. Spin-orbit coupling strength can be obtained by magnetoconductance measurements, which contain weak localization and weak anti-localization features. In order to extract the desired information from these features, one needs to consider the ensemble of closed paths in the given geometry and the average effect of magnetic and spin-orbit fields on these paths. For hexagonal nanowires such as the InSb nanowires under consideration, we numerically determine those influences and found striking differences, such as non-integer power laws, in comparison to previous models *e.g.* for two-dimensional nanowires. We immediately apply these results to magnetoconductance measurements performed in the QuTech laboratory at the TU Delft.