

論文 / 著書情報
Article / Book Information

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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

論文要旨

THESIS SUMMARY

系・コース： Department of Graduate major in	物理学 物理学	系 コース	申請学位 (専攻分野)： Academic Degree Requested	博士 Doctor of	(理学)
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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

In recent years, studies on non-Hermitian systems has been attracting much attention both in theories and experiments. Non-Hermitian systems described by a non-Hermitian Hamiltonian are nonequilibrium systems and open systems, which exchange energies and particles with external environment. Non-Hermitian systems emerge in various fields of classical physics, such as spring-mass systems, optical systems, and electric-circuit systems, and quantum physics, such as cold-atom systems, magnon systems, and strongly-correlated electron systems. In this thesis, we establish a non-Bloch band theory of non-Hermitian crystalline systems and study topological aspects of non-Hermitian systems in terms of this theory.

Firstly we show violation of the conventional bulk-edge correspondence in non-Hermitian systems. Then we explain that such violation results from the difference in energy spectra between a system with open boundary conditions and one with periodic boundary conditions. This phenomenon is unique to non-Hermitian systems, and it is caused by non-Hermitian skin effect. Furthermore, as another manifestation of the non-Hermitian skin effect, eigenstates of non-Hermitian systems are localized at either end of an open chain, unlike Hermitian systems. In order to explain the above phenomena, we demonstrate the non-Hermitian skin effect by using a simple model.

Next we construct the non-Bloch band theory which describes continuum energy bands in non-Hermitian systems with open boundary conditions in the thermodynamic limit. Through this theory, we can determine the generalized Brillouin zone (GBZ) for the complex wave number which reproduces continuum energy bands. Then we find some features of the GBZ. Namely the GBZ becomes not a unit circle but closed loops on a complex plane, the shape of the GBZ changes depending on the values of system parameters, and the GBZ can have cusps, which are nondifferentiable points in the direction along the GBZ.

From our non-Bloch band theory, the GBZ and the continuum energy bands can be calculated by a simple formula, which is our main result. It allows us to discuss energy levels in the limit of a large system size without going through a cumbersome calculation of energy levels in a finite open chain. This formula is independent of any boundary conditions in an open chain, which means that our result is physically reasonable. In this sense, the non-Bloch band theory is powerful for a systematic study of a non-Hermitian open chain. In fact, we can also establish bulk-edge correspondence in non-Hermitian systems between a topological invariant defined by the GBZ and existence of topological edge states. Then we demonstrate the bulk-edge correspondence in the non-Hermitian Su-Schrieffer-Heeger (SSH) model by defining a winding number.

By studying the non-Hermitian SSH model in terms of the non-Bloch band theory, we can find a new type of a topological semimetal phase in one-dimensional (1D) non-Hermitian systems. Then we show that in 1D non-Hermitian systems with sublattice symmetry and time-reversal symmetry, a topological semimetal phase with exceptional points is stabilized because of unique features of the GBZ. Furthermore we can relate the change of the values of the winding number with annihilation and creation of the exceptional points. It is also shown that each energy band is divided into three regions, depending on the symmetry of the eigenstates, and the regions are separated by the cusps and the exceptional points in the GBZ.

Finally we discuss non-Hermitian nature of 1D bosonic systems described by a Hermitian Bogoliubov-de Gennes (BdG) Hamiltonian, such as magnon systems with the dipolar interaction or the Dyaloshinskii-Moriya interaction between spins. The bosonic BdG systems are intrinsically non-Hermitian systems in general because the bosonic BdG Hamiltonian can have terms not preserving the particle number. As a result, such bosonic BdG systems can exhibit the non-Hermitian skin effect, which can be investigated by our theory. In fact, in terms of the non-Bloch band theory, we can find rich aspects of the non-Hermitian skin effect in the bosonic Kitaev-Majorana chain. In this system, we demonstrate infinitesimal instability and reentrant behavior of the non-Hermitian skin effect. Furthermore we show a way to systematically construct the Bogoliubov transformation to diagonalize a bosonic BdG Hamiltonian.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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