論文の内容の要旨

Universality of open systems: non-Hermiticity, topology, and localization
（非平衡開放系の普遍性：非エルミート性・トポロジー・局在）

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In physics, we describe and predict various phenomena on the basis of fundamental concepts such as symmetry and topology, which further leads to the universal understanding about nature. Despite the great success, the conventional physics mainly focused on closed systems at thermal equilibrium or open systems near thermal equilibrium, and a universal understanding of open systems far from equilibrium has yet to be developed. In this thesis, we develop a general theory of open systems effectively described by non-Hermitian Hamiltonians and explore new nonequilibrium phenomena that arise from the interplay between non-Hermiticity, topology, and localization. First, we show that the non-Hermitian skin effect, which is the anomalous localization due to non-Hermiticity, originates from intrinsic non-Hermitian topology. Such a topological origin not merely explains the universal feature of the known skin effect, but also leads to new types of the skin effects——symmetry-protected skin effects. As prime examples, we investigate reciprocal skin effects and higher-order skin effects that originate from symmetry-protected non-Hermitian topology. Furthermore, we develop a field-theoretical description of the intrinsic non-Hermitian topological phases. Because of the dissipative and nonequilibrium nature of non-Hermiticity, our theory is formulated solely in terms of spatial degrees of freedom, which contrasts with the conventional theory for closed systems defined in spacetime. Our theory provides a universal understanding of non-Hermitian topological phenomena, including the unidirectional transport in one dimension and the chiral magnetic skin effect in three dimensions. In addition, we show that the non-Hermitian skin effect is a signature of an anomaly from the field-theoretical perspective. The universality of our theory manifests itself as applicability even in the presence of disorder. We develop a scaling theory of localization in non-Hermitian disordered systems. We find that non-Hermiticity introduces a new scale and breaks down the one-parameter scaling, which is the central assumption of the conventional scaling theory of localization. Instead, we identify the origin of unconventional non-Hermitian delocalization as the two-parameter scaling. We also classify the universality classes of non-Hermitian disordered systems according to symmetry. Our work establishes the new universality of open systems.