Online workshop:

Mathematical approach for topological physics (III)

March 23, 2022

Titles and abstracts

WADA Kazuyuki (National Institute of Technology Hachinohe College)

Title: **The Witten index for split-step quantum walks in 1d**

Abstract: We consider a unitary operator U which corresponds to a split-step quantum walk in one-dimension. Since U has chiral symmetry, a supercharge Q can be defined. From the Fredholm index of Q, we can get some informations about eigenspaces of U. Motivated by this fact, the Fredholm index of Q was revealed by several researchers. In general, Fredholmness requires the existence of a spectral gap. In this talk, we consider the case where a spectral gap is absent. To consider the index involving the gapless case, we employ the Witten index instead of the Fredholm index. To calculate the Witten index, we apply the spectral shift function induced by the fourth order difference operator with a rank-one perturbation. This talk is based on a joint work with Y. Matsuzawa (Shinshu), A. Suzuki (Shinshu), Y. Tanaka (Shinshu) and N. Teranishi (Hokkaido).

IKEGAYA Satoshi (Department of Applied Physics, Nagoya University)

Title: **Topology in superconducting proximity effect**

Abstract: The anomalous proximity effect from a px-wave superconductor (SC) to a dirty normal-metal (DN) is one of most striking phenomena manifesting a cooperative relationship between Majorana quasi-particles and odd-frequency Cooper pairs [1,2]. As the first topic of our talk, we will explain a microscopic mechanism of the anomalous proximity effect by employing an Atiyah-Singer index theorem, which relates the topological property of the px-wave SC with the number of stable Majorana bound states penetrating into the attached DN from the surface of the px-wave SC [3,4]. As the second topic of our talk, we will present superconducting hybrid systems manifesting the anomalous proximity effect, which make up for a serious lack of candidate materials for px-wave SCs. Specifically, we propose two types of semiconductor-superconductor hybrids illustrated in Fig. 1: a hybrid device consisting of a planar topological Josephson junction [5], and a hybrid device in which a d-wave pair potential and a spin-orbit coupling potential generating a persistent spin-helix (PSH) state coexist [6].

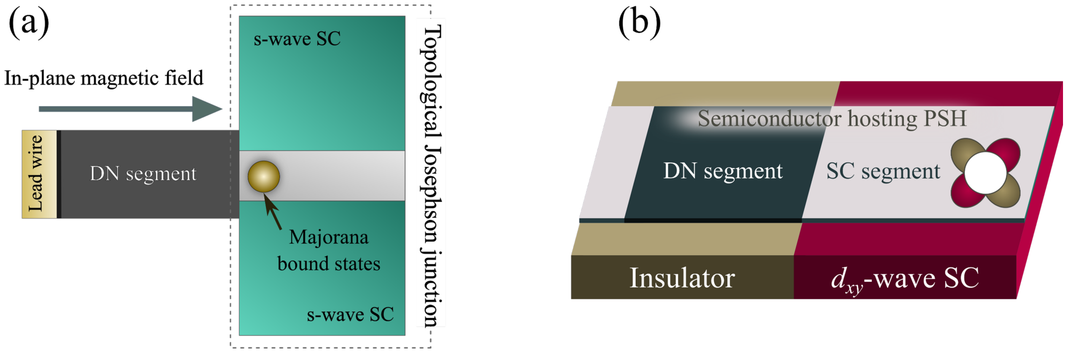

Figure 1: Schematic of the superconductor hybrid systems manifesting the anomalous proximity effect: (a) a device consisting of a planar topological Josephson junction and (b) a device in which a d-wave pair potential and a spin-orbit coupling potential generating a persistent spin-helix state coexist.

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Max LEIN (AIMR, Tohoku University)

Title: **On the bulk classification of non-selfadjoint topological insulators modeled by spectral operators**

Abstract: The topological classification of selfadjoint operators is solely determined by the presence or absence of certain discrete symmetries. Non-selfadjoint systems not only admit more types of discrete symmetries, their spectrum is a subset of the complex plane. A seminal result by Kawabata et al. classifies periodic tight-binding operators.

However, as topological phenomena are expected to be robust under random perturbations, the derivation by Kawabata et al., which rests on sophisticated mathematical tools, no longer applies. Instead, I give an alternative derivation, based on the idea of physically relevant states. Moreover, I give evidence that it is likely not all non-selfadjoint operators, but only so-called spectral operators have a topological classification. An operator on a Banach space is spectral if it admits a generalized Jordan block decomposition; periodic tight-binding operators are spectral, but random operators on the discrete or the continuum need not be.

OBUSE Hideaki (Faculty of Engineering, Hokkaido University)

Title: **Non-unitary quantum walk approach for Non-Hermitian physics**

Abstract: Recently, non-Hermitian physic which is related to open quantum systems has attracted great attention from the various fields of physics, i.e., condensed matter physics, classical and quantum optics, cold atoms, etc. While there are many experiments to imitate non-Hermitian Hamiltonians in classical systems, it is not easy to experimentally realize a true quantum system related to non-Hermitian Hamiltonians in a controlled way. At the moment, a discrete-time quantum walk (quantum walk, in short) by using entangled photons is one of the most ideal platforms to realize the non-Hermitian quantum system and study the novel phenomena in the experiment.

In this talk, we introduce a non-unitary quantum walk to realize the non-Hermitian quantum system and explain various non-Hermitian phenomena by combining theoretical and experimental results. First, we explain the novel non-Hermitian topological phases for real line gaps in the non-unitary quantum walks, i.e., the observation of topological edge states [1,2,3] and a breakdown of the bulk-edge correspondence [4]. Then, we explain the skin effect originating from the non-Hermitian topological phase for point gaps in the quantum walk [5]. Furthermore, we will also talk about the localization-delocalization transition in the non-Hermitian one-dimensional disordered system, which has been studied by a well-known Hatano-Nelson tight-binding model so far, can be realized by using the non-unitary quantum walk [6].

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EBISU Hiromi (Weizmann Institute of Science)

Title: **Fluctuations in heat current and scaling dimension**

Abstract: The flow of charge in an electric circuit is not continuous due to the discrete nature of the charge carriers. Similarly, we expect that the energy or the heat flow in the system will be comprised of "lumps" of energy associated with each carrier.

We discuss the heat flow between two 1D chiral gapless systems connected by a point contact. A canonical example of such systems are the edges of fractional quantum Hall states. We show that the ratio between heat current fluctuation and heat current itself gives a universal number – the scaling dimension, characterizing the statistics of a quasi-particle. We introduce two approaches, scattering theory and conformal field theory and see their results agree. Our proposal holds value to probe topological phases, including those which carry neutral excitations.

Organized by : S. Richard, Y. Kawaguchi, Y. Tanaka, H. Moriyoshi