Kickoff Meeting for Collaboration on Open Quantum Systems

March 20, 2015

University of Yamanashi, Kofu, Yamanashi, Japan

Program and Abstracts

Program

9:50 - 10:00
Opening address

10:00 - 10:30 **Kazuki Kanki**, Osaka Prefecture University, JAPAN
PT-symmetry and its breaking through a nonhermitian degeneracy point in the Liouvillian dynamics

10:30 - 11:00 **Ken-ichi Noba**, Osaka Prefecture University, JAPAN
Spatial distribution of asteroids at resonance point represented by solution of the eigenvalue problem of the Liouvillian

11:00 - 12:00 **Tomio Petrosky**, The University of Texas at Austin, USA
Infinity vs. semi-infinity: an unexpected non-analyticity in a universal Lorentzian line shape

12:00 - 14:00
Lunch

14:00 - 15:00 **Kazunari Hashimoto**, University of Yamanashi, JAPAN
Complex spectrum of Liouvillian and transport process in one-dimensional quantum Lorentz gas

15:00 - 15:30
Coffee break

15:30 - 16:00 **Todd Tilma**, Tokyo Institute of Technology, JAPAN
Characterization of Qubit Entanglement Through the Visualization of Spin-Coherent-State Wigner Function

16:00 - 16:30 **Satoshi Tanaka**, Osaka Prefecture University, JAPAN
Photon at a distance correlated with vacuums Rabi oscillation in cavity exciton polariton

16:30 - 17:00 **Chikako Uchiyama**, University of Yamanashi, JAPAN
Nonadiabatic effect on the quantum heat flux control

17:00 - 17:10
Closing address

Abstracts

PT-symmetry and its breaking through a nonhermitian degeneracy point in the Liouvillian dynamics

Kazuki Kanki

Department of Physical Science, Osaka Prefecture University, Japan

We found it a omnipresent phenomenon that a pair of eigenvalues of the Liouvillian changes from pure imaginary to complex with a common imaginary part. At such a transition point both the pairs of eigenvalues and eigenvectors coalesce. Consequently the spectral decomposition fails, and the effective Liouvillian has a Jordan block form. The transition can be ascribed to a spontaneous breaking of PT(parity and time reversal)-symmetry. This PT-symmetry is intrinsic in the Liouvillian dynamics, in contrast to the fact that in "PT-symmetric quantum mechanics" PT-symmetry often appears as a result of introducing ad hoc assumptions, such as a complex valued potential energy.

In the kinetic equation for a particle coupled with a bath the flow term drives the system to PT-symmetry breaking as the wave number of the spatial inhomogeneity gets larger. PT-symmetric eigenmodes with purely imaginary eigenvalues correspond to diffusive processes and eigenmodes in a PT-symmetry broken phase lead to damping wave propagation. We illustrate different behaviors with regard to presence or absence of PT-symmetry with a one-dimensional polaron model as an example.

Spatial distribution of asteroids at resonance point represented by solution of the eigenvalue problem of the Liouvillian

Ken-ichi Noba

Department of Mathematical Science, Osaka Prefecture University, Japan

The distribution of asteroids in real space at resonance point is theoretically investigated in terms of the eigenvalue problem of the Liouvillian. We consider a restricted three-body problem consisting of an asteroid, Sun and Jupiter, where Jupiter is treated as the perturbation on the two-body problem of an asteroid and Sun. Within the approximation of single resonance Hamiltonian, solutions of the eigenvalue problem of the Louvillian are analytically obtained. For the 3:2 resonance point where the ratio of the frequency of the asteroid to the frequency of Jupiter is 3/2, we demonstrate that the distribution function corresponding to the eigenstate with zero eigenvalue exhibits a steady triangle pattern in the coordinate rotating with Jupiter. This triangle pattern agrees well with observed asteroid distribution called Hilda triangle. We also examine the time evolution of distribution functions and demonstrate that distribution functions are rotating with time in the rotating coordinate.

Infinity vs. semi-infinity: an unexpected non-analyticity in a universal Lorentzian line shape

Tomio Petrosky

Center for Complex Quantum Systems, The Universtiy of Texas at Austin, USA

Photon absorption spectrum of quantum wires attached with an impurity two-level atom is investigated. We compare a semi-infinite wire with an infinite wire. By taking an infinite limit of the distance of the impurity from the edge of the semi-infinite wire, we show that a single peaked Lorentzian shape of the absorption spectrum for the infinite wire is decomposed into an infinitely many peaked line shape in the sense of distribution. Then we show that an interesting unexpected non-analyticity of the line shape on the coupling constant between the matter and field is hidden behind a universal Lorentzian absorption spectrum.

Complex spectrum of Liouvillian and transport process in one-dimensional quantum Lorentz gas

Kazunari Hashimoto

Graduate Faculty of Interdisciplinary Research ,
University of Yamanashi, Japan

Non-equilibrium transport process in a weakly-coupled one-dimensional quantum Lorentz gas is theoretically investigated based on the complex spectrum of the Liouvillian. We construct resonance states of the Liouvillian that have complex eigenvalues in terms of the Brillouin-Wigner-Feshbach type of analysis. Thanks to the simplicity of the system, we have successfully obtained an analytic solution of the eigenvalue problem within a weak-coupling approximation, and the solution can be applicable to arbitrary range of spatial inhomogeneity of the particle distribution. In our knowledge, this is the first case where the whole structure of the complex spectrum of the Liouvillian is clarified in many particle system.

In this talk, we shall especially focus of the structure of the spectrum in non-hydrodynamic situation where the spatial scale of inhomogeneity of the particle distribution is small enough compare to the mean-free-length of a particle. There we shall show that the spectrum has rich structures that explicitly reflects microscopic structures of the system such as form of interaction potential between particles. We shall also discuss transport process of the system based on the spectrum and show that the spectral structure leads to an interesting beating process in time evolution of the Wigner distribution function of the test particle.

Characterization of Qudit Entanglement Through the Visualization of Spin-Coherent-State Wigner Functions

Todd Tilma

Graduate School of Science and Engineering,
Tokyo Institute of Technology, Japan

The purpose of our research is to determine whether or not there is a general relationship between the degree of entanglement and the total amount of negativity in the Wigner function of various combinations of finite dimensional quantum states. Specifically, by using the Stratonovich-Weyl correspondence we can take the density matrix of a known, finite-dimensional quantum state (hereafter known as a "qudit") and generate its corresponding, finite-dimensional Wigner function. This Wigner function reproduces the qudit density matrix through a known volume integral. By doing the same volume integral, but with the absolute value of the Wigner function as the kernel, we get a measure of the total amount of negativity of the Wigner function instead of reproducing the density matrix. Our question is thus, is this "negative volume" equivalent to the amount of entanglement in the initial qudit state? Our results for general two-qubit states have confirmed a monotonic relationship between concurrence and this negative volume for specific cases. By analyzing the various Wigner functions of three and more qubits, as well as qubit-qutrit Wigner functions we hope to build a consensus on whether or not the negativity in the Wigner function is a measure of, or witness to, entanglement.

Photon at a distance correlated with vacuum Rabi oscillation in cavity exciton polariton

Satoshi Tanaka

Department of Physical Science, Osaka Prefecture University, Japan

Photon propagation emitted from a cavity exciton-polariton is investigated based on a complex spectral representation of total Hamiltonian. The correlation between the Rabi oscillation of a cavity exciton-polariton (intracavity dynamics) and the spatial propagation of an emitted photon (extracavity dynamics) is clarified only when correctly taking into account the correlation component between the intra- and extra-cavity states, contrary to use of phenomenological effective Hamiltonian. While a vacuum Rabi oscillation in a cavity exciton polariton is well reflected as a spatial quantum beat in a propagation of an extracavity photon, the correlation between the intracavity and extracavity dynamics disappears at a Fano resonance. This is as if there is only a single decaying state in a cavity for an outside observer. Our results raise an interesting question about a possibility to observe a quantum dynamics at a far distance.

Nonadiabatic effect on the quantum heat flux control

Chikako Uchiyama

Graduate Faculty of Interdisciplinary Research,
University of Yamanashi, Japan

The quantum transfer between two environments, especially the pumping phenomena of quantum particles, has been attracted intensive attentions to scientists as well as engineers. The issue has been mostly studied in the adiabatic regime with using the geometrical phase where the relevant quantum system can immediately follow the external driving. In this talk, I will show what happens on quantum pumping when such adiabatic condition is not satisfied by providing a general formula of quantum transfer for an anharmonic junction system. In the formulation, a newly added term appears to describe the non-adiabatic effect. It also shows that the quantum transfer depends on the initial condition of the anharmonic junction just before the modulation, as well as the characteristic environmental parameters such as interaction strength and cut-off frequency of spectral density. This means that we can obtain the optimum quantum flux corresponding to the geometrical phase by setting the initial condition of the anharmonic junction.

Reference:
C. Uchiyama, Phys. Rev. E **89**, 052108 (2014).