ABSTRACTS

WORKSHOP OF QUANTUM SIMULATION AND QUANTUM WALKS

Nov. 16th—Nov. 18th, 2015

YOKOHAMA NATIONAL UNIVERSITY

EDUCATION AND CULTURE HALL

79-1 TOKIWADAI, HODOGAYA-KU, YOKOHAMA 240-8501 JAPAN

CONTACT: KONNO-TAKEI LABORATORY, YOKOHAMA NAT. UNIV.

Program

Nov. 16 (Mon)

9:30-	Registration		
1st Session			
9:50-10:00	Opening Remark		
10:00-11:00	Carlo Di Franko	Imperial College London, UK	**[Invited talk]** Novel approach for the implementation of quantum walks in linear optics setups
11:00-11:30	Hideo Sekino	Toyohashi University of Technology, Japan	Quantum walk and Wave function
11:30-12:00	Nouredine Zettili	Alfaisal University, Riyadh,Saudi Arabia	A Computational Method for Solving the Schrodinger Equation for a System of N Interacting Fermions
12:00-13:30	Lunch		
2nd Session			
13:30-14:00	Alessandro Tosini	Universita degli Studi di Pavia, Italy	Quantum walks without coin: a link between the properties of a graph and the admissible walks over it
14:00-14:30	Akito Suzuki	Shinshu University, Japan	Asymptotic behavior of a position-dependent quantum walk
14:30-15:30	Jake Fillman	Virginia Tech University, USA	**[Invited Talk]** Spreading Estimates for Quantum Walks via Resolvent Estimates
15:30-16:00	Cofee Break		
3rd Session			
16:00-17:00	Ludwig Streit	Universitat Bielefeld, Germany Universidade da Madeira, Portugal	**[Invited Talk]** Self-Avoiding Random Walks with Long Range Memory
17:00-17:30	Hideo Mitsuhashi	Utsunomiya University, Japan	The discrete-time quaternionic quantum walk and the second weighted zeta function on a graph
17:30-18:00	Antonin Hoskovec	FNSPE CTU in Prague	Selective dynamical decoupling for quantum state transfer

Nov. 17 (Tue)

4th Session			
10:00-11:00	Takeshi Fukuhara	RIKEN Center for Emergent Matter Science (CEMS), Japan	**[Invited talk]** Entanglement generation through single-magnon quantum walks
11:00-11:30	Peng Xue	Southeast University, China	Generalized quantum measurements with photonic quantum walks
11:30-12:00	Fulvio Flamini	La Sapienza - University of Rome, Italy	Quantum suppression law in a 3-D photonic circuit implementing the Fast Fourier Transform
12:00-13:30	Lunch		
5th Session			
13:30-15:00	***Poster Session**		
15:00-15:30	Coffee break		
6th Session			
15:30-16:30	Igor Jex	Czech Technical University in Prague, Czech Republic	**[Invited Talk]** Photons walking the line
16:30-17:30	Renato Portugal	National Laboratory of Scientific Computing - LNCC, Brazil	**[Invited Talk]** Staggered Quantum Walks
18:00	Banquet at Restaurant "PORTY" on the 3rd floor of University Hall COOP		

Nov. 18 (Wed)

7th Session			
10:00-11:00	Choon-Lin Ho	Tamkang University, Taiwan	**[Invited talk]** Quantum Walk in Periodic Potential on a Line and a Model of Interacting Opinions
11:00-11:30	Martin Štefaňák	Czech Technical University In Prague, Czech Public	Percolation assisted excitation transport in discrete-time quantum walks
11:30-12:00	Tamas Kiss	Wigner Research Centre for Physics of the Hungarian Academy of Sciences , Hungary	Asymptotic dynamics of quantum walks on percolation lattices
12:00-13:30	Lunch		
8th Session			
13:30-14:00	Alessandro Bisio	University of Pavia, Italy	Quantum Walks, Quantum Fields and Relativity
14:00-14:30	Janos Asboth	Wigner Research Centre for Physics of the Hungarian Academy of Sciences , Hungary	Quantum walks vs Periodically Driven Hamiltonians: topological classification
14:30-15:00	Hideaki Obuse	Hokkaido University, Japan	Topological phases of one-dimensional Hadamard walks and non-unitary quantum walks
15:00-15:30	Christopher Cedzich	Institute for Theoretical Physics, Leibniz Universitat Hannover, German	Revivals in Quantum Walks with quasi-periodically time-dependent coin
15:30-18:00	Free discussion		

*Poster session

Keiichi Yokoyama	Japan Atomic Energy Agency	An industrial application of quantum walk: Isotope separation of radioactive wastes
Hyoung-In Lee	Seoul National University	Nanowire plasmonics: collective behaviors affected by energy exchange on flatlands
Yueh-Nan Chen	National Cheng-Kung University	Quantifying Temporal Steering Provides a Practical Measure of Strong Non-Markovianity
Jiri Maryska	Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering	Gibbs-like asymptotic states of quantum markov chains
Guang-Yin Chen	Dep. of Physics, National Chung Hsing University	Plasmonic bio-sensing for the Fenna-Matthews-Olson complex
Iwao Sato	Oyama National College of Technology	A remark on zeta functions of finite graphs via quantum walks
Leo Matsuoka	Hiroshima university	Localization in rotational excitation of diatomic molecules induced by a train of optical pulses
Chung-I Chou	Chinese Culture University, Taiwan	Simulations of the "Spreading of Rumors" by using a Simple Model based on Quantum Walk
Yusuke Fukushima	Ibaraki University	A discrete model of electrical transmission lines for quantum walks
Takako Endo	Ochanomizu University (& Paris 6)	Stationary measure of one-dimensional quantum walk with defects
		Relation between two-phase quantum walks and the topological invariant
Etsuo Segawa	Tohoku University	Szegö class and ballistic spreading of quantum walks
Kaname Matsue	The Institute of Statistical Mathematics	Quantum walks on simplicial complexes
Yusuke Ide	Kanagawa University	Entropies for discrete-time quantum walks and open quantum walks on the line
Raqueline A. M. Santos	University of Latvia	Searching with Szegedy's quantum walk by flipping marked vertices
Akihide Miyazaki	Toyohashi University of Technology	Error control of Quantum Walk
Ken Mochizuki	Hokkaido University	Topological phases and enhancement of edge states in PT symmetric quantum walks with gain and loss
Przemyslaw Sadowski	Instytut Informatyki Teoretycznej i Stosowanej Polskiej Akademii Nauk	Lively quantum walks
Masato Takei	Yokohama National University	Periodicity for the Hadamard walk on cycles
Takashi Komatsu	Mathematical Institute, Tohoku University	Limiting distributions of discrete-time quantum walks on the square lattice
Kei Saito	Yokohama National University	The probability distribution of the quaternionic quantum walk
		Quantum walks on truncated graphs
Seiya Yoshida	Yokohama National University	Stationary measures of discrete time quantum walks on cycles

Abstracts

Oral presentations

Nov. 16th

10:00-11:00

Carlo Di Franko (Imperial College London, UK)

Title: Novel approach for the implementation of quantum walks in linear optics setups

Abstract: The field of quantum computation and quantum simulation has been recently driven to a new rising edge by the experimental realization of quantum walks in various setups, highlighting that different physical systems can be adapted for the implementation of these models. In particular, optical systems have shown their full potential, allowing the experimental demonstration of two-dimensional quantum walks for the first time [1], even if several further progresses will surely be obtained also in the other physical scenarios that have been already exploited for the one-dimensional case [2]. It is expected that striking results will be experimentally found when the technology will allow proper control of two- or multi- dimensional models.

Two approaches have been mainly used so far for the optical implementation of quantum walks. The first encodes the coin degree of freedom into the polarization of a photon (in the case of higher-dimensional coin space, additional degrees of freedom are needed), and the position degree of freedom into its arrival time. The quantum walk is then realized by means of polarizing beam splitters and optical loops. Interestingly, the setup requires a fixed number of optical elements regardless of the number of time steps that one wants to obtain, the latter being limited only by the losses and the detection stage. The second approach follows the idea proposed in Ref. [3], where an array of beam splitters is exploited in order to implement a quantum walk. In this scenario, the position of the walker corresponds to the actual position of the photon on a particular axis, and the coin degree of freedom corresponds to the incoming direction of the photon at a particular beam splitter. The model can be straightforwardly mapped into an integrated waveguide circuit (see, for instance, Ref. [4]) and can therefore benefit from all the advantages of this setup. The drawback is that the number of elements grows at least quadratically (in the case of one-dimensional quantum walk) with the number of time steps that one wants to obtain.

Here, I propose a novel approach that is actually halfway between the two schemes described above. By means of this, it is possible to realize a quantum walk with optical loops in an integrated waveguide circuit, also avoiding the problem given by the fact that polarizing beam splitters are hard to be implemented in these particular setups. The number of elements, as in the first approach, is fixed regardless of the number of time steps that one wants to obtain. I will discuss the details of the new scheme, describing how the model can be modified to include the possibility of increasing the dimension of the lattice on which the walker is moving, as well as having control over the different parameters involved in the evolution. I will finally mention the

preliminary results obtained with this approach by the experimental group of Prof. Walmsley at the University of Oxford.

[1] A. Schreiber *et al.*, Science **336**, 55 (2012); Y-C. Jeong *et al.*, Nat. Commun. **4**, 2471 (2013).
[2] M. Karski *et al.*, Science **325**, 174 (2009); H. Schmitz *et al.*, Phys. Rev. Lett. **103**, 090504 (2009); F. Zahringer *et al.*, Phys. Rev. Lett. **104**, 100503 (2010); M. A. Broome *et al.*, Phys. Rev. Lett. **104**, 153602 (2010).
[3] H. Jeong, M. Paternostro, and M. S. Kim, Phys. Rev. A **69**, 012310 (2004).
[4] L. Sansoni *et al.*, Phys. Rev. Lett. **108**, 010502 (2012).

11:00-11:30

Hideo Sekino (Toyohashi University of Technology, Japan)

Title: Quantum walk and wavefunction

Abstract: Quantum Walk simulations are performed for propagation of wavefunction in several physical situations. The results are compared with an analytical and/or numerical solutions of corresponding quantum differential equations.
Schrodinger-like or Dirac-like quantum walks reproduce the solutions by the above classical methodologies for realistic physical environments. The appropriateness and efficiency of the quantum walk on such application will be discussed.

11:30-12:00

Nouredine Zettili (Alfaisal University, Riyadh,Saudi Arabia)

Title: A Computational method for solving the Schrödinger equation for a system of N Interacting Fermions

Abstract: We introduce here a computational method aimed at finding numerically the solutions of the one-dimensional Schrödinger equation for a system of N fermions. The method is based on a discretization scheme of the wave function as well as on the Numerov algorithm which offers an approximate treatment of the second derivative using the three-point difference formula. After discretizing the wave function, we derive a recursion relation which allows us to integrate forward or backward in the spatial degree of freedom. In this way, by incorporating the boundary conditions of the system, we can calculate iteratively the wave function at different values of the spatial coordinate. This process yields also the energy levels of the system. The search for the energy levels will be carried out incrementally till the wave function converges to the correct value at each boundary. The accuracy of the numerical calculations can be pushed till the energy levels and the wave function are obtained with the desired precision.

13:30-14:00

Alessandro Tosini (Universita degli Studi di Pavia, Italy)

Title: Quantum walks without coin: a link between the properties of a graph and the admissible walks over it

Abstract: Coined quantum walks describe the unitary evolution of one-particle quantum

states on a graph, with the coin a finite dimensional Hilbert space representing the particle internal degree of freedom. In the simplest case the coin is one-dimensional corresponding to a scalar quantum walk. We consider scalar walks on the Cayley graph of a finitely presented group and study the relation between the group abelianity and the walk dynamics. We prove that when the group is abelian any scalar quantum walk over its Cayley graphs is trivial, namely it is the direct sum of one-dimensional shifts each one in the direction of a single group generator. We notice that this result is independent on the dimension of the graph. On the other hand scalar walks with a non trivial dynamics are admissible if the group is non abelian. We give a systematic study of the infinite dihedral group and classify all possible scalar quantum walks over it.

14:00-14:30

Akito Suzuki (Shinshu University, Japan)

Title: Asymptotic behavior of a position-dependent quantum walk

Abstract: We consider a position-dependent coined quantum walk on the one-dimensional lattice and assume that the coin operator behaves like a position-independent coin operator at spatial infinity. We show that the random variable denoting the position of a quantum walker converges in law to a random variable, whose distribution is given by the asymptotic velocity operator.

14:30-15:30

Jake Fillman (Virginia Tech University, USA)

Title: Spreading Estimates for Quantum Walks via Resolvent Estimates

Abstract: We will discuss some mathematical techniques for studying spreading rates of quantum walks via estimates on the resolvent of the update operator. In the case of 1D coined quantum walks, the CGMV connection enables the study of the resolvent by way of transfer matrices, which allows one to prove rather strong asymptotic estimates, particularly in "quasicrystalline" models which exhibit a suitable renormalization scheme. We will discuss the CGMV connection and the application of the mathematical results to several concrete 1D models, including quantum walks with Fibonacci, Thue-Morse, and quasiperiodic coins. The contents of this presentation will contain results obtained in collaboration with David Damanik (Rice), Darren Ong (Oklahoma), and Zhenghe Zhang (Rice).

16:00-17:00

Ludwig Streit (Universitat Bielefeld, Germany Universidade da Madeira, Portugal)

Title: Self-avoiding random walks with long range memory

17:00-17:30

Hideo Mitsuhashi (Utsunomiya University, Japan)

Title: The discrete-time quaternionic quantum walk and the second weighted zeta function on a graph

Abstract: Recently, quaternionic quantum walks was formulated by N. Konno and various properties of them were studied. We define a discrete-time quaternionic quantum walk on a graph that can be viewed as an extension of the Grover walk on a graph to the case of quaternions, and study the properties of it. We give the unitary condition on the transition matrix of the quaternionic quantum walk. Under some condition, we determine all the right spectra of the transition matrix by some easily derivable parameters from the transition matrix by using of the theory of the second weighted zeta function.

17:30-18:00

Antonin Hoskovec (FNSPE CTU in Prague)

Title: Selective dynamical decoupling for quantum state transfer

Abstract: Faithful placement of a quantum state at a prescribed time to a given position on a discrete quantum network is one of the elementary tasks of quantum information processing. Vast majority of physical systems suffer from imperfections, discrete quantum networks being no exception. Some of the imperfections can severely limit the state transfer fidelity. We present a form of quantum error correction based on a procedure called selective dynamical decoupling for realistic cases of such networks – bent linear qubit chains. We were able to find several analytic solutions to the basic equation of the selective dynamical decoupling, which is obtained from a perturbation theory. Based on our numerical simulations, these schemes are able to suppress the unwanted interactions and stabilize the state transfer protocols efficiently.

Nov. 17th

10:00-11:00

Takeshi Fukuhara (RIKEN Center for Emergent Matter Science (CEMS), Japan)

Title : Entanglement generation through single-magnon quantum walks

Abstract : Ultracold atoms in optical lattices offer novel possibilities to investigate quantum many-body systems described by fundamental models such as the Hubbard model or the Heisenberg spin model. Recently, powerful tools of single-atom-resolved detection and manipulation have been developed for such systems. These new techniques enable us to access far-from-equilibrium dynamics of quantum systems. In this talk I will present quantum walks of a mobile spin impurity, or a magnon, in a one-dimensional Heisenberg spin chain comprising ultracold bosonic atoms in optical lattices. Starting from a fully magnetized chain, we locally excited a single magnon by selectively flipping a spin at the center of the chain, and tracked the subsequent dynamics with high resolution in space and time [1]. Furthermore, transverse spin correlations were observed by applying a global $\pi/2$ rotation before imaging. Combining longitudinal and transverse correlation measurements, we detected spin entanglement, which is generated and transferred through the single-magnon dynamics [2].

[1] T. Fukuhara *et al.*, Nature Phys. **9**, 235 (2013).
[2] T. Fukuhara *et al.*, PRL **115**, 035302 (2015).

11:00-11:30

Peng Xue (Southeast University, China)

Title：Generalized quantum measurements with photonic quantum walks

Abstract：We perform generalized measurements of a qubit by realizing the qubit as a coin in a photonic quantum walk and subjecting the walker to projective measurements. Our experimental technique can be used to realize photonically any rank-1 single-qubit positive operator-valued measure via constructing an appropriate interferometric quantum-walk network and then projectively measuring the walker's position at the final step. Furthermore, our results on generalized measurement pave the way for further developments.

11:30-12:00

Fulvio Flamini (La Sapienza - University of Rome, Italy)

Title： Quantum suppression law in a 3-D photonic circuit implementing the Fast Fourier Transform

Abstract：Photonic quantum simulators have recently drawn great attention, thanks to significant technological advances and to the inherent advantages of using photons for manipulating and transferring information. Moreover, quantum walks represent promising platforms for their implementation, as well as for broader investigations on the foundations of quantum mechanics. However, in view of the increasing interest towards the realization of such devices, the development of a reliable and efficient protocol for the certification of its functioning has now become indispensable in supporting this long-term goal. Indeed, distinctive quantum features have already been predicted in the case of many particles injected into multimode interferometers realizing the Fourier transformation in the Fock space. Here we develop a scalable approach for the implementation of a quantum fast Fourier transform, using 3-D photonic integrated interferometers fabricated via femtosecond laser writing technique. The experimental results demonstrate genuine quantum interference between the injected photons, thus offering a powerful tool for the diagnostic of photonic platforms.

15:30-16:30

Igor Jex (Czech Technical University in Prague, Czech Republic)

Title：Photons walking the line

Abstract : The quantum walk [1-2] is an excellent tool for modelling, simulating and testing a wide range of physical processes and effects. Quantum walks are defined as specific generalizations of classical (random) walks. The simplest model of a walk – the one dimensional discrete quantum walk (on a line) – is based on the combination of the dynamics of the internal degree of freedom defined by the coin operator and the conditioned shift in position space (step operator). In higher dimensions, depending on

the choice of the position space and the coin we observe a number of effects which are not present in its classical counterpart.
The coin as well as the step operator can suffer from imperfections and this leads to deviations from the ideal situation. The way how the ideal situation is alternated leads to additional interesting effects.
We present results of theoretical and experimental studies of ideal and perturbed quantum walks [3-7] based on the all optical implementation of quantum walks. We point out the main results, discuss the flexibility of the setup and comment on future trends.

[1] Y. Aharonov, L. Davidovich, N. Zagury, Phys. Rev. A 48, 1687 (1993)
[2] D. A. Meyer, J. Stat. Phys. 85, 551 (1996)
[3] A. Schreiber, K. N. Cassemiro, V. Potoček, A. Gabris, P.J. Mosley, E. Andersson, I. Jex, Ch. Silberhorn, Phys. Rev. Lett. 104, 050502 (2010)
[4] A. Schreiber, K. N. Cassemiro, V. Potoček, A. Gabris, E, I. Jex, Ch. Silberhorn, Phys. Rev. Lett. 104, 050502 (2011)
[5] A. Schreiber, A. Gabris, P. P. Rohde, K. Laiho, M. Stefanak, V. Potoček, C. Hamilton, I. Jex, Ch. Silberhorn,. Science 336, 55 (2012)
[6] B. Kollár, T. Kiss, J. Novotný, I. Jex, Phys. Rev. Lett. 108, 230505 (2012)
[7] F. Elster, S. Barkhofen, T. Nit Quantum Walk in Periodic Potential on a Line and a Model of Interacting Opinions sche, J. Novotny, A. Gabris, I. Jex, Ch. Silberhorn, Quantum walk coherences on a dynamical percolation graph, Sci. Rep. 5 13495 (2015)

16:30-17:30

Renato Portugal (National Laboratory of Scientific Computing - LNCC, Brazil)

Title：Staggered quantum walks

Abstract：We present a formal definition of the staggered quantum-walk model on graphs, which has the entire Szegedy quantum-walk framework as a subcase. The definition employs the notion of graph tessellation, which is a vertex partition associated with unitary operators. Using this new quantum-walk model, we describe the connection between the Szegedy and coined quantum-walk models and we show that the abstract quantum-walk search, which uses the coin minus identity on the marked vertices and the Grover coin on the non-marked ones, can be cast into Szegedy's framework.

Nov. 18th

10:00-11:00

Choon-Lin Ho (Tamkang University, Taiwan)

Title：Quantum walk in periodic potential on a line and a model of interacting opinions

Abstract: This talk consists of two parts:
1) In the first part we would like to present a numerical study of a model of quantum walk in a periodic potential on the line. We take the simple view that different potentials affect differently the way the coin state of the walker is changed. For

simplicity and definiteness, we assume the walker's coin state is unaffected at sites without potential, and is rotated in an unbiased way according to the Hadamard matrix at sites with potential. This is the simplest and most natural model of a quantum walk in a periodic potential with two coins. It is found that for certain periodic potentials the walker can be confined in the neighborhood of the origin for sufficiently long times. Associated with such localization effect is the recurrence of the probability of the walker returning to the neighborhood of the origin. This implies that it is possible, by controlling the periodicity of the periodic potential and the choice of coins, to control the motion of a quantum walker.
2) The second part of this talk concerns a model of interacting opinions inspired by quantum walk. When a person is making a decision, he/she must consider his/her personal favorites (and benefits ….) and the mainstream opinion of the community he/she is in. The competition between personal individuality and bandwagon effect give rise to many interesting phenomena such as the "Spreading of Rumors".
In the literature, the "Spreading of Rumors" in interpersonal networks is often likened to the diffusion process in physical systems. We extend this analogy, and adopt the basic ideas of discrete quantum walk to construct a simple model to simulate the rumors spread (or the competition of different opinions).

11:00-11:30

Martin Štefaňák (Czech Technical University In Prague, Czech Public)

Title : Percolation assisted excitation transport in discrete-time quantum walks

Abstract: We study the efficiency of transport on a simple graph represented by a ring. The propagation of excitation is modeled by a discrete-time (coined) quantum walk. For a two-state quantum walk, where the excitation has to jump from its present position to the neighbouring sites, the transport efficiency is unity. However, if the excitation is, in addition, allowed to stay at its present position, i.e. the propagation is modeled by a three-state quantum walk, then part of the wave-packet can be trapped in the vicinity of the origin and never reaches the sink. In such a case, the excitation transport is not efficient. Nevertheless, we show that for some three-state quantum walks the dynamical percolation of the ring eliminates the trapping effect and efficient excitation transport can be achieved.

11:30-12:00

Tamas Kiss (Wigner Research Centre for Physics of the Hungarian Academy of Sciences , Hungary)

Title: Asymptotic dynamics of quantum walks on percolation lattices

Abstract: Quantum walks take place on discrete graphs. The underlying graph structure can model various physical systems as well as some abstract space. A natural way to introduce error for a walk model is to consider broken links in the graph. This approach resembles percolation, since only certain pathways are available for transport. We consider dynamical percolation, where the graph may change after each step in the discrete time model or at certain given time instants in the continuous-time model. The broken links are modelled by a reflective boundary condition, therefore we arrive at a random unitary dynamics. We demonstrate that on a finite graph structure one can

formally solve the asymptotic evolution of the system. Moreover, it is possible to obtain explicit asymptotic solutions for one and two dimensional lattices.

[1] Bálint Kollár, Jaroslav Novotný, Tamás Kiss, Igor Jex, Eur. Phys. J. Plus 129, 103 (2014)
[2] Bálint Kollár, Jaroslav Novotný, Tamás Kiss, Igor Jex New J. Phys. 16, 023002 (2014)
[3] Zoltán Darázs, Tamás Kiss, J. Phys. A: Math. Theor. 46 (2013) 375305
[4] Bálint Kollár, Tamás Kiss, Jaroslav Novotný, Igor Jex, Phys. Rev. Lett. 108, 230505 (2012)

13:30-14:00

Alessandro Bisio (University of Pavia, Italy)

Title: Quantum Walks, Quantum Fields and Relativity

Abstract: In this talk we show how Quantum Cellular Automata and Quantum Walks can be considered as an axiomatic framework for Quantum Field Theory.
We show how the evolution of free fields, as described by the Weyl Dirac and Maxwell equations, can be recovered from the dynamics of Quantum Walks. The differences between the evolution of the Quantum Walk and the evolution described by the usual relativistic differential equations can be rigorously adressed and quantified as a channel discrimination problem.
We then prove that it is also possible introduce a definition of Lorentz transformations in the framework of Quantum Walks. The price to pay for this surprising result, is that the representation of the Lorentz group in momentum-energy space is non-linearly deformed. This fact introduces novel and counterintuitive effects that will be briefly presented.

14:00-14:30

Janos Asboth (Wigner Research Centre for Physics of the Hungarian Academy of Sciences , Hungary)

Title: Quantum walks vs Periodically Driven Hamiltonians: topological classification

Abstract: The classification of topological insulators and superconductors was one of the highlight theoretical results of the last decade. A similar classification for one-dimensional quantum walks was attempted by different authors, with sometimes conflicting results. We here attempt to reconcile these different results, using the idea of "nongentle perturbations".

14:30-15:00

Hideaki Obuse (Hokkaido University, Japan)

Title: Topological phases of one-dimensional Hadamard walks and non-unitary quantum walks

Abstract: Quantum walks, whose dynamics is prescribed by alternating coin and shift operators, possess topological phases akin to those of Floquet topological insulators, which is topological insulators driven by a time-periodic field. We study topological phases of two kinds of one-dimensional (1D) quantum walks, one is a quantum walk with the generalized Hadamard coin, say, the Hadamard walk[1] and the other one is a non-unitary quantum walk with gain and loss[2].

At first, we focus on the Hadamard walk in which the edge states originating to topological phases were experimentally observed[3]. The experiment also reports unexpected edge states in the view point of the topological phase. This motivates us to identify the hidden topological phase in the Hadamard walk. While there is ample theoretical work on topological phases of quantum walks, the spin rotation coin is employed as the coin operators. We establish a relation between the Hadamard and the spin rotation operator, which allows us to apply the recently developed theory of topological phases of quantum walks to the 1D Hadamard quantum walk. The topological invariants we derive account for the edge state observed in the experiment, we thus reveal the hidden topological phase of the 1D Hadamard walk.

Next, we study the non-unitary quantum walks with gain and loss. Recently, such a non-unitary 1D quantum walk dynamics associated with gain and loss is implemented in the coupled fiber loops experiment [4]. The fact that the absolute value of the eigenvalue of the non-unitary time-evolution operator is kept to be unity implies that the quantum walk possesses PT symmetry (combined parity and time-reversal symmetry). We directly verify PT symmetry of the time-evolution operator. We, then, study topological phases of the PT symmetric quantum walk, which is related to a Floquet topological insulator described by a PT symmetric non-Hermite Hamiltonian. We numerically confirm that the number of eigenvalues exhibiting localization is consistent with the topological number. We also find that only edge states originating to topological phases break PT symmetry in the proper setup. This provides a way to observe the highly intense probability of localized states originating to topological phases on the 1D non-unitary quantum walk in the actual experimental setup.

[1] H. Obuse, J. Asboth, Y. Nishimura, and N. Kawakami, Phy. Rev. B 92, 045424 (2015).
[2] K. Mochizuki, D. Kim, and H. Obuse (in preparation).
[3] T. Kitagawa, M.A. Broome, A. Fedrizzi, et al., Nature Comm. 3, 882 (2012).
[4] A. Regensburger, C. Bersch, M. Miri, et al., Nature **488**, 167 (2012).

15:00-15:30

Christopher Cedzich (Institute for Theoretical Physics, Leibniz Universitat Hannover)

Title: Revivals in Quantum Walks with quasi-periodically time-dependent coin

Abstract: We provide an explanation of recent experimental results of Xue et al., where full revivals in a time-dependent quantum walk model with a periodically changing coin are found. Using methods originally developed for "electric" walks with a space-dependent, rather than a time-dependent coin, we provide a full explanation of the observations of Xue et al. We extend the analysis from periodic time-dependence to quasi-periodic behaviour with periods incommensurate to the step size. Spectral analysis, one of the principal tools for the study of electric walks, fails for time-dependent systems, but we find qualitative propagation behaviour of the time-dependent system in close analogy to the electric case.

Poster presentations

Nov. 17th 13:30-

Keiichi Yokoyama (Japan Atomic Energy Agency)

Title: An industrial application of quantum walk: Isotope separation of radioactive wastes

Abstract: Treatment of nuclear waste is one of the biggest problems in the modern civilization. To extinguish the toxicity, isotope separation of radioactive wastes is mandatory. The present technology, however, cannot do that at the required level of selectivity and throughput. In 2009, we proposed a new isotope-selecting scheme using molecular rotation for a future break through. We found, in the scheme, quantum walk and localization of complex amplitude describing molecular rotation play a key role in its pronounced selectivity. Furthermore, enhancement of its advantage was found to connect directly with the discrete-time quantum walk. Detailed introduction will be presented in the poster.

Hyoung-In Lee (Seoul National University)

Title: Nanowire plasmonics: collective behaviors affected by energy exchange on flatlands

Abstract: Nanowire plasmonics in interaction with electromagnetic waves is revisited with a particular emphasis on the energy exchange with its environment. To this goal, two limits states of perfect radiation and absorption are thus considered. This idea of energy exchange is currently utilized in designing optical traps of atoms. Normal plasmonic waves are uniformly attenuated due to metallic dissipation and energy radiation, which can be overcome by energy influx from a gain medium in the radial far field. Because of rotational waves, a reversal in circular polarizations takes place depending on the sign of the radial energy transport. In addition, there seem to exist multiple pathways toward non-unique equilibrium states. An analogy is drawn to game spectators, who behave collectively to outside stimuli under varied situations.

Yueh-Nan Chen (National Cheng-Kung University)

Title: Quantifying Temporal Steering Provides a Practical Measure of Strong Non-Markovianity

Abstract: Einstein-Podolsky-Rosen (EPR) steering is a type of quantum correlation which allows one to remotely prepare, or steer, the state of a distant quantum system. While EPR steering can be thought of as a purely spatial correlation there does exist a temporal analogue, in the form of single-system temporal steering. However, a precise quantification of such temporal steering has been lacking. Here we show that it can be measured, via semidefinite programming, with a temporal steerable weight, in direct analogy to the recently proposed EPR steerable weight. We find a useful property of the temporal steerable weight that it is a monotonically-decreasing function under completely-positive trace-preserving maps and, thus, can be used to define a practical measure of strong non-Markovianity.

Jiri Maryska (Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering)

Title: Gibbs-like asymptotic states of quantum markov chains

Abstract: Quantum markov chains, i.e. iterated sequences of quantum operations, represent a convenient way of time-evolution description of a general open quantum system.

Nowadays, quantum markov chains show a great potential in many areas of quantum theory reaching from its very fundamentals to practical applications like open coined quantum walks. Recently, the asymptotic dynamics of a wide class of quantum markov chains on finite dimensional Hilbert space was studied. For this class, it was shown that the asymptotic dynamics is governed by so-called attractor space, which can be found by solving a set of algebraic equations called attractor equations. Here we give the relations between the elements of the attractor space (i.e. attractors) and the integrals of motion corresponding to such a quantum markov chain. Next, we show that the asymptotic states of such quantum markov chain can be rewritten in a form, which resembles a well known concept of a generalized Gibbs state. This so-called Gibbs-like states follow a principle, which can be regarded as a generalization of the maximum entropy principle.

Guang-Yin Chen (Dep. of Physics, National Chung Hsing University)

Title: Plasmonic bio-sensing for the Fenna-Matthews-Olson complex

Abstract: We study theoretically the bio-sensing capabilities of metal nanowire surface plasmons. As a spe- cific example, we couple the nanowire to specific sites (bacteriochlorophyll) of the Fenna-Matthews- Olson (FMO) photosynthetic pigment protein complex. In this hybrid system, we find that when certain sites of the FMO complex are subject to either the suppression of inter-site transitions or are entirely disconnected from the complex, the resulting variations in the excitation transfer rates through the complex can be monitored through the corresponding changes in the scattering spectra of the incident nanowire surface plasmons. We also find that these changes can be further enhanced changing the ratio of plasmon-site couplings. The change of the Fano lineshape in the scattering spectra further reveals that the "site 5" in the FMO complex plays a distinct role from other sites. Our results provide a feasible way, using single photons, to detect mutation-induced, or bleaching- induced, local defects or modifications of the FMO complex, and allows access to both the local and global properties of the excitation transfer in such systems.

Iwao Sato (Oyama National College of Technology)

Title: A remark on zeta functions of finite graphs via quantum walks

Abstract: From the viewpoint of quantum walks, the Ihara zeta function of a finite graph can be said to be closely related to its evolution matrix. In this note we introduce another kind of zeta function of a graph, which is closely related to, as to say, the square of the evolution matrix of a quantum walk. Then we give to such a function two types of determinant expressions and derive from it some geometric properties of a finite graph.
As an application, we illustrate the distribution of poles of this function comparing with those of the usual Ihara zeta function.

Leo Matsuoka (Hiroshima university)

Title: Localization in rotational excitation of diatomic molecules induced by a train of optical pulses

Abstract: We theoretically studied rotational excitation of diatomic molecules induced by a train of terahertz optical pulses from the viewpoint of the continuous-time quantum walk. Under an assumption of the rigid rotor, the resonant rotational excitation can be induced under the condition that the rotor is kicked in synchronization with a rational multiple of its rotational period. In the real diatomic molecules, the resonant behavior must be suppressed by the lack of spectral bandwidth, the mismatching of pulse interval, and the effect of centrifugal distortion. We classified the localization and discussed it for an application of isotope separation. We also introduced the unified parameter to deal with the combined

effect of pulse interval mismatching and centrifugal distortion.

Chung-I Chou (Chinese Culture University, Taiwan)

Title: Simulations of the "Spreading of Rumors" by using a Simple Model based on Quantum Walk

Abstract: Our work was inspired by the famous Japanese drama "Legal High". When a person is making a decision, he/she must consider his/her personal favorites (and benefits ….) and the mainstream opinion of the community he/she is in. The competition between personal individuality and bandwagon effect cause the complicated phenomenon in "Spreading of Rumors". In the literature, the "Spreading of Rumors" in interpersonal networks is often likened to the diffusion process in physical systems. We extend this analogy, and adopt the basic idea of discrete quantum walk model to construct a simple model to simulate the rumors spread (or the competition of different opinions).In this model, different opinions in each person's mind are written in a multi-state wave function. When someone tries to make a decision, the wave function will collapse into a choice (a measurement). The process of spreading is defined by a coin and a shift operator. By using these operators, the opinions can be modified and propagated. In addition, two competitive elements, namely personal individuality and bandwagon effect, are considered by using a ratio control parameter in this model.
Simulation of this model shows different types of opinion's diffusion, and the possibility of phase transition in uniformity of opinion. In this meeting, we will report the idea of our model, the simulation results in a one dimensional network.

Yusuke Fukushima (Ibaraki University)

Title: A discrete model of electrical transmission lines for quantum walks

Abstract: Based on the similarity between the telegraph equation in transmission lines and Klein-Gordon equation, we have related a discrete model of electrical transmission lines to a discrete-time quantum walk through Dirac equation. As a result, we can consider the transmission line as a discrete-time quantum walk, and understand the characteristics of quantum walks as those of the transmission line.

Takako Endo (Ochanomizu University (& Paris 6))

Title: Stationary measure of one-dimensional quantum walk with defects

Abstract: We treat one-dimensional quantum walks (QWs), whose time evolutions are described by diagonal unitary matrices with defects. We call the QW defined by diagonal unitary matrices, "the diagonal QW". We consider the stationary distributions of the diagonal QWs with defects. One of the purposes of our study is to characterize the stationary measure of the QWs, which may lead to answer the basic and natural question, "What the stationary measure is for one-dimensional QWs with defects ? ". In order to analyze the stationary distribution, we focus on the corresponding eigenvalue problems. We found some interesting properties of the stationary measure for the diagonal QWs with defects, especially, for 2-state and 3-state cases. Furthermore, we investigate the effect of the defects and diagonal unitary matrices on the stationary measure.

Takako Endo (Ochanomizu University (& Paris 6))

Title: Relation between two-phase quantum walks and the topological invariant

Abstract: We treat two kinds of position-dependent quantum walks (QWs) in one dimension, which are considered as mathematical models of topological insulator. We call the QWs, "the complete two-phase QW" and "the two-phase QW with one defect". Both of the models have

two different time-evolution operators in positive and negative parts. The difference is that the complete two-phase QW does not have defect. First, we exhibit two kinds of limit theorems concerning "localization" and "the ballistic spreading" which are the characteristic behaviors in the long-time limit for discrete-time QWs in one dimension. The analysis is based mainly on the generating function methods. Then, we calculate the topological invariants from wave function of the bulk for the two spatial regions of the complete two-phase QW, and discuss localization of the complete two-phase QW from a viewpoint of topological insulator. We note that the single defect prevents to apply the discussion of topological invariants directly, however, we show that for the two-phase QW with one defect, we can argue localization around the origin from a viewpoint of topological insulator by considering topological protection. We also give some numerical results in specific cases.

Etsuo Segawa (Tohoku University)

Title: Szegö class and ballistic spreading of quantum walks

Abstract: The spectral analysis of the CMV matrices is a useful tool to analyze discrete-time quantum walks on the half and double lines. We give examples that this method works well to show the limit theorems in which specific properties of the quantum walks. We propose also that from a specific behavior of the quantum walks, named ballistic spreading, we can estimate the class of the underlying spectral measure.

Kaname Matsue (The Institute of Statistical Mathematics)

Title: Quantum walks on simplicial complexes

Abstract: We talk about a new type of quantum walks on simplicial complexes as a natural extension of the well-known Szegedy walk on graphs. One can numerically observe that our proposing quantum walks possess linear spreading and localization as in the case of the Grover walk on lattices. Moreover, our numerical simulation suggests that localization of our quantum walks reflect not only topological but also geometric structures of simplicial complexes. On the other hand, our proposing quantum walk contains an intrinsic problem concerning exhibition of nontrivial behavior, which is not seen in typical quantum walks such as Grover walks on graphs. If time permits, we also mention this point.

Yusuke Ide (Kanagawa University)

Title: Entropies for discrete-time quantum walks and open quantum walks on the line

Abstract: The Shannon, Renyi and Tsallis entropies are important quantities in the information theory, statistics and related fields. The Renyi entropy includes several useful entropy measures such as the Shannon entropy, Min-entropy and so on, as special choices of its parameter. Also the Tsallis entropy is an one parameter generalization of the Shannon entropy. In this presentation, we will show some asymptotic behaviors of Shannon, Reniy and Tsallis entropies for the distribution of discrete-time quantum walks and open quantum walks on the line. This is a joint work with Prof. Konno (YNU, Japan) and Prof. Shikata (YNU, Japan).

Raqueline A. M. Santos (University of Latvia)

Title: Searching with Szegedy's quantum walk by flipping marked vertices

Abstract: For searching with quantum walks we need to find a way to differentiate between marked and non-marked vertices. Szegedy described in his model an evolution operator which acts differently on the marked vertices by using the transition matrix of the absorbing walk on the graph. In this way, Szegedy was able to define a quantum hitting time which is

analogous to the classical definition. Searching with the coined quantum walk model is usually done by applying a different coin operator which flips the phase of the marked vertices. Inspired by that, we analyze what happens in Szegedy's model when we add a reflection that flips the phase of the marked vertices. We show that the success probability of finding a marked vertice in the complete graph boosts to 1. The analysis is also made for multiple marked vertices.

Akihide Miyazaki (Toyohashi University of Technology)

Title: Error control of Quantum Walk

Abstract: We realize the control of Quantum Walk by introducing Bang-bang pulse (BBP) method. The phase flip error (PFE) , typical in quantum computation, is successfully suppressed by introducing a repeated refocusing pulse. We show the suppression of the error in multi-dimensional Schorodinger Walk (SW) as well as in Hadamard Walk (HW).

Ken Mochizuki (Hokkaido University)

Title: Topological phases and enhancement of edge states in PT symmetric quantum walks with gain and loss

Abstract: Recently, topological materials have attracted attentions in solid state physics. The topological material is characterized by an integer value called topological invariant. It is known that topologically protected surface states (edge states) emerge in vicinity of boundaries where the value of topological invariant varies. This feature is called "bulk-boundary correspondence". Symmetries that the material preserves or breaks are deeply related to whether topological phases are induced, that is, the topological invariant of the material takes a finite value. Discrete time quantum walks provide a versatile way to control the presence or absence of symmetries and induce the non-trivial topological phase by tunning coin and shift operators. In experiments, quantum walks using photons and coherent lasers are often employed. As demonstrated in Ref.[1], the quantum walk built by optical fibre loops enables fine controls of effects of gain and loss of the light intensity. In general, the time evolution operator with effects of gain or loss are non-unitary, and
the absolute value of the eigenvalue is not one. However, the non-unitary time evolution operator with gain or loss could have the eigenvalue whose absolute value is one if the time evolution operator has parity-time (PT) symmetry, as was demonstrated in Ref.[1]. However, the distinct PT symmetry operator for the time-evolution operator has not been defined in the previous work. In the present work, we give an explicit definition of the PT symmetry operator and clarify conditions that the time-evolution operator is PT symmetric. We, then, study topological invariant of the non-unitary quantum walk. Finally, we show that the non-unitary quantum walk satisfies the bulk-boundary correspondence and it is possible to enhance probability amplitudes originating to only edge states. This makes observations of edge states in experiments easier.

[1].A. Regensburger, C. Bersch, M.A. Miri., et al Nature 488, 167 (2012).

Przemyslaw Sadowski (Instytut Informatyki Teoretycznej i Stosowanej Polskiej Akademii Nauk)

Title: Lively quantum walks

Abstract: The presented work introduces a family of quantum walks on cycles parametrized by their liveliness, i.e. the ability to execute long-range move. In particular, the introduced family contains lazy quantum walks, which can be introduced as quantum walks with liveliness equal to 0. We show that for non-zero liveliness parameter the walker cannot be trapped in one position. We investigate the behaviour of the probability distribution and time-averaged probability distribution for the introduced family. We show that the liveliness

parameter has a direct impact on the periodicity of the limiting distribution. We have also presented an application of the introduced model and demonstrated that the symmetry of the time-averaged limiting distribution vanishes in the situation where one of the links is not working properly. We show that the periodicity of the limiting distribution is easily destroyed by any disturbance in the network and thus can be used to detect broken links.

Masato Takei (Yokohama National University)

Title: Periodicity for the Hadamard walk on cycles

Abstract: The present poster treats the period T_N of the Hadamard walk on a cycle C_N with N vertices. Dukes (2014) considered the periodicity of more general quantum walks on C_N and showed T_2 =2, T_4 =8, T_8=24 for the Hadamard walk case. We prove that the Hadamard walk does not have any period except for his case, i.e., N=2, 4, 8. Our method is based on a path counting and cyclotomic polynomials which is different from his approach based on the property of eigenvalues for unitary matrix that determines the evolution of the walk. (Joint work with Norio Konno and Yuki Shimizu)

Takashi Komatsu (Mathematical Institute, Tohoku University)

Title: Limiting distributions of discrete-time quantum walks on the square lattice

Abstract: We study discrete-time quantum walks on the square lattice. In this poster, we will propose a model of discrete-time quantum walks on the square lattice without localization and give its limit distribution. Furthermore, we see that the Konno function appears as the density function with respect to radial direction in our quantum walk. We also discuss the relationship between our quantum walks and alternate quantum walks.

Kei Saito (Yokohama National University)

Title: The probability distribution of the quaternionic quantum walk

Abstract: The discrete-time quantum walk (QW) is determined by a unitary matrix where component is complex number. Konno (2015) extends the QW to a walk whose component is quaternion. We call this model quaternionic quantum walk (QQW). In this talk, we present probability distributions of a class of QQWs by using a combinational method.

Kei Saito (Yokohama National University)

Title: Quantum walks on truncated graphs

Abstract: In this talk, we consider the property of a discrete time quantum walk on a truncated graph given by replacing each vertex of the original graph with cycle. In particular, we deal with the periodicity of the walk considered here.

Norio Konno, Yuto Minowa, Seiya Yoshida (Yokohama National University)

Title: Stationary measures of discrete time quantum walks on cycles

Abstract: In this talk, we consider discrete time quantum walks on cycles. We present stationary measures of a class of quantum walks whose coin operators determined by the Hadamard, the Grover, or the identity matrices.