Open Quantum Walks
Salt Rock Hotel
27 November - 01 December 2017

Monday, 27 November

Mini-School on "An introduction to the theory of Open Quantum Systems"

$09^{00} - 12^{00}$ Arrival/Registration

$12^{00} - 14^{00}$ Lunch

$14^{00} - 15^{00}$ Ilya Sinayskiy (UKZN, South Africa), An introduction to the theory of Open Quantum Systems (lecture 1).

$15^{00} - 15^{30}$ Tea/Coffee

$15^{30} - 16^{30}$ Ilya Sinayskiy (UKZN, South Africa), An introduction to the theory of Open Quantum Walks (lecture 2).

Tuesday, 28 November

Session Chair: Ilya Sinayskiy

$9^{30} - 10^{30}$ Igor Jex (Czech Technical University in Prague, Czech Republic), Quantum walks and imperfection localization and transport.

$10^{30} - 11^{00}$ Tea/Coffee

$11^{00} - 12^{00}$ Igor Jex (continuation)/Discussion.

$12^{00} - 14^{00}$ Lunch

$14^{00} - 15^{00}$ Raffaella Carbone (University of Pavia, Italy), Irreducible decompositions, stationary states and asymptotic results for open quantum random walks.

$15^{00} - 15^{30}$ Tea/Coffee

$15^{30} - 16^{30}$ Raffaella Carbone (continuation)/Discussion.

Wednesday, 29 November

Session Chair: Francesco Petruccione

$9^{00} - 10^{30}$ Hugo Bringuier (University of Toulouse, France), Continuous Time Open Quantum Walk.

$10^{30} - 11^{00}$ Tea/Coffee

$11^{00} - 12^{30}$ Ilya Sinayskiy (UKZN, South Africa), From Unitary to Open Quantum Walks, on possible generalization and unification.

$12^{30} - 14^{30}$ Lunch

$14^{30} - 15^{30}$ Uwe Jaekel (University of Applied Sciences Koblenz, Germany), TBA.

$15^{30} - 16^{00}$ Tea/Coffee

$16^{00} - 17^{00}$ Uwe Jaekel (continuation)/Discussion.

Thursday, 30 November

Session Chair: Uwe Jaekel

$9^{30} - 10^{30}$ Matthias Wittemer (University of Freiburg, Germany), Quantum Walks with Trapped Ions.

$10^{30} - 11^{00}$ Tea/Coffee

$11^{00} - 12^{00}$ Matthias Wittemer (continuation)/Discussion.

$12^{00} - 14^{00}$ Lunch

$14^{00} - 15^{00}$ Yutaka Shikano (University of Tokyo, Japan), Nonlinear Quantum Walk.

$15^{00} - 15^{30}$ Tea/Coffee

$15^{30} - 16^{30}$ Yutaka Shikano (continuation)/Discussion.

Friday, 01 December

$9^{00} - \ldots$ Departure of delegates

Quantum walks and imperfection localization and transport

Igor Jex

Coherent transport of excitations along chains of coupled quantum systems represents an interesting problem with a number of applications ranging from quantum optics to solar cell technology. One convenient tool for studying such processes are quantum walks. Under realistic situations quantum walks, as any genuine quantum evolution, suffers from imperfections. The influences of imperfections on quantum walks can be model in a number of ways. Amon others phase noise and percolation the random formation or breaking of links between nodes was studied is quite detail [1-5]. We present several problems involving percolated walks and walks with phase noise. We present an all optical implementation of a quantum walk differing from the previous experiments by achieving dynamical control of the underlying graph structure and hence representing the simplest walk dynamics on a percolated graph. We demonstrate the evolution of an optical time-multiplexed quantum walk over six double steps, revealing the intricate interplay between the internal and external degrees of freedom. Next we report on the influence of percolation on the efficiency of transport, modelled by a quantum walk, on a ring. We show how the efficiency of a lazy walk can be restored when dynamical percolation is allowed. We comment on the general theory used to treat open system dynamics and point several general features.

1 G. Grimmett, 1999 Percolation, Die Grundlehren der mathematischen Wissenschaften in Einzeldarstellungen (Springer, New York)

2 G. Leung, P. Knott, J. Bailey and V. Kendon, New J. Phys. 12 (2010) 123018

3 F. Elster, S. Barkhofen, T. Nitsche, J. Novotny, A. Gabris, I. Jex, Ch. Silberhorn, Scientific Reports 5 (2015) 13495

4 M. Stefanak, J. Novotny, I. Jex, New J. Phys. 18 (2016) 023040

5 A. Schreiber, K. N. Cassemiro, V. Potocek, A. Gabris, I. Jex, Ch. Silberhorn, Phys. Rev. Lett. 106 (2011) 180403

Irreducible decompositions, stationary states and asymptotic results for open quantum random walks
Raffaella Carbone

For a quantum channel (completely positive, trace-preserving map), we discuss some standard probabilistic properties: subjects as reducibility and irreducible restrictions, period, transience and recurrence have a well-established theory for classical Markov chains but are still evolving for quantum channels. The connections with asymptotic behavior, structure of invariant states and environmental decoherence have been central issues in our research. Naturally, the case of open quantum random walks shows some interesting peculiarities, combining some quantum features with the elementary theory of classical Markov chains.

This is a work in collaboration (mainly) with A. Jencova and Y. Pautrat.

Continuous Time Open Quantum Walk
Hugo Bringuier

Open Quantum Walks (OQWs), originally introduced by S. Attal, F. Petruccione, C. Sabot, and I. Sinayskiy in 2012, are quantum generalizations of classical Markov chains. Recently, natural continuous time models of OQW have been developed by Pellegrini in 2014. These models, called Continuous Time Open Quantum Walks (CTOQWs), appear as natural continuous time limits of discrete time OQWs. In particular they are quantum extensions of continuous time Markov chains. This article is devoted to the study of homogeneous CTOQW on Z^d. We focus namely on their associated quantum trajectories which allow us to prove a Central Limit Theorem for the "position" of the walker as well as a Large Deviation Principle.

From Unitary to Open Quantum Walks, on possible generalization and unification

Ilya Sinayskiy

Open quantum walks (OQWs) were introduced as quantum analogs to classical Markov chains. In contrast to unitary quantum walks, OQWs are driven by the dissipative interaction with the environment and are formulated in the language of open quantum systems. The benefit of the OQWs is in the well defined classical limit, while the unitary quantum walks are gaining computational power from the quantum superposition between the nodes of a walk. In this talk, we will introduce a generalization of the QWs, which includes OQWs and unitary quantum walks as limiting cases. We will also demonstrate that in the generic case this walk is quantum on a small scale while having classical properties on a large scale.

Uwe Jaekel, TBA

Quantum Walks with Trapped Ions

Matthias Wittemer

We report on the experimental implementation of the quantum walk of one ion in a linear ion trap. Allowing the ion to take all classical paths simultaneously, quantum interferences enforce asymmetric, non-classical distributions in the entangled coin and position states. After three steps of an asymmetric walk on the line we clearly reveal the differences to the classical random walk. We theoretically study and experimentally observe the consequences of leaving the scope of the approximations made in our approach. By taking into account higher-order terms of the quantum evolution we reveal that these become significant after a few steps already. However, we propose altered protocols based on short laser pulses which allow to extend the quantum walk to many steps and higher dimensions. Historically, trapped ions have been extensively used to study (closed) quantum systems with near-perfect isolations from external surroundings, but, more recently, have also been proven to be well-suited for quantum simulations of open quantum systems. Analogously to these recent developments, our implementation of the quantum walk can be expanded by couplings to additional surroundings in order to take into account decoherence and dissipation effects. Based on these considerations, we will discuss prospects of our system to realize open quantum walks.

Nonlinear Quantum Walk

Yutaka Shikano

While the conventional quantum walk has the ballistic behavior, the nonlinear quantum walk does not in general. Due to the nonlinearity, the nonlinear quantum walk is different from the conventional Gaussian process. In this talk, I would like to explain several models to characterize the nonlinear quantum walk and how to implement this. Finally, I would like to discuss how to distinguish the nonlinear quantum walk and the open quantum walk.