### 2014 Mini-Workshop on Quantum information processing

**Aug. 28-29, 2014**

@ National Tsing-Hua University, Hsinchu, Taiwan

Venue: Lecture Room 4A, 4th Floor, The 3rd General Building, National Center of Theoretical Science (NCTS)

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<th>Aug. 28, 2014</th>
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| 10:00 – 10:05 | Ray-Kuang Lee (National Tsing-Hua University, Hsinchu, Taiwan)  
Min-Hsiu Hsieh (University of Technology, Sydney, Australia)  
Opening Remark |
| 10:05 – 10:45 | Giulio Chiribella (Tsinghua University, Beijing, China)  
Title | Quantum state transformation games |
| 10:45 – 11:00 | Coffee Break |
| 11:00 – 11:40 | Ludmila Praxmeyer (National Tsing-Hua University, Hsinchu, Taiwan)  
Title | Rate analysis for a hybrid quantum repeater |
| 12:00 – 2:00 | Lunch |
| 2:00 – 2:40 | Chung-Hsien Chou (National Cheng-Kung University, Tainan, Taiwan)  
Title | Decoherence Patterns of Topological Qubits from Majorana Modes |
| 2:40 – 3:00 | Coffee Break |
| 3:00 – 3:40 | YiChan Lee (National Tsing-Hua University, Hsinchu, Taiwan)  
Title | Local PT Symmetry Violates the No-Signaling Principle |
| 3:40 – 4:00 | Coffee Break |
| 4:00 – 4:40 | Ray-Kuang Lee (National Tsing-Hua University, Hsinchu, Taiwan)  
Title | Entangled Schrodinger Solitons |
<p>| 5:30 – 7:30 | Dinner |</p>
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<td>10:00 - 10:40</td>
<td>Runyao Duan (University of Tech,)</td>
<td>Zero-error classical channel capacity and simulation cost assisted by quantum non-signalling correlations, and an operational interpretation to Lovasz theta function</td>
<td>University of Technology, Sydney, Australia</td>
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<td>11:00 - 11:40</td>
<td>His-Sheng Goan (NTU, Taipei)</td>
<td>Quantum optimal control for open quantum systems</td>
<td>National Taiwan University, Taipei</td>
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<td>12:00 - 2:00</td>
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<td>2:00 - 2:40</td>
<td>You-Lin Chuang (National Tsing-Hua)</td>
<td>Quantum squeezing and entanglement in coherent population trapping system</td>
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<td>Min-Hsiu Hsieh (University of Tech,)</td>
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Quantum state transformation games

Giulio Chiribella

Tsinghua University, Beijing, China

A large number of tasks in Quantum Information can be viewed as "state transformation games", where the goal of the players is to transform a given input state in some desired way. This is the case of quantum state discrimination, quantum cloning, amplification, conjugation, and purification. The first part of this talk will present some general results about state transformation games, including the maximum payoff achievable with or without entanglement, using deterministic or probabilistic strategies. The second part of the talk will focus on the specific example of asymptotic cloning games, where a number of input copies of an unknown state is converted in a number of approximated copies at a given rate. In this asymptotic setting I will discuss the exact tradeoff between replication rate and probability of success, which leads to the curious phenomenon of quantum super-replication.
Rate analysis for a hybrid quantum repeater

Ludmila Praxmeyer

National Tsing-Hua University, Hsinchu, Taiwan

The hybrid quantum repeater protocol is based on atomic qubit-entanglement distribution through optical coherent-state communication [1]. We present an exact analytical formula for the rates of entanglement generation in a hybrid quantum repeater assuming perfect memories, probabilistic entanglement generation and deterministic swapping [2]. Furthermore, we extend this description to the case of imperfect memories and establish memory requirements on distillation-free quantum repeaters with deterministic swapping [3].

We investigate the decoherence patterns of topological qubits in contact with the environment by a novel way of deriving the open system dynamics other than the Feynman-Vernon. Each topological qubit is made of two Majorana modes of a 1D Kitaev's chain. These two Majorana modes interact with the environment in an incoherent way which yields peculiar decoherence patterns of the topological qubit. More specifically, we consider the open system dynamics of the topological qubits which are weakly coupled to the fermionic/bosonic Ohmic-like environments. We find that the topological qubits decohere completely in the Ohmic and sub-Ohmic environments but not in the super-Ohmic ones. Moreover, we find that the fermion parities of the topological qubits though cannot prevent the qubit states from decoherence in the sub-Ohmic environments, can prevent from thermalization turning into Gibbs state. This is in contrast to the cases of non-topological qubits for which they always decohere completely in all Ohmic-like environments unless the probe-environment is strong enough.
Local PT Symmetry Violates the No-Signaling Principle

YiChan Lee

National Tsing-Hua University, Hsinchu, Taiwan

Bender et al. [1] have developed PT-symmetric quantum theory as an extension of quantum theory to non-Hermitian Hamiltonians. We show that when this model has a local PT symmetry acting on composite systems, it violates the nonsignaling principle of relativity. Since the case of global PT symmetry is known to reduce to standard quantum mechanics [2], this shows that the PT-symmetric theory is either a trivial extension or likely false as a fundamental theory. In this talk, I will give a brief introduction of PT symmetry quantum mechanics and show how to use a local PT symmetric system to transmit information faster than the speed of light.

Reference:
Zero-error classical channel capacity and simulation cost assisted by quantum non-signalling correlations, and an operational interpretation to Lovasz theta function

Runyao Duan

University of Technology, Sydney, Australia

We study the one-shot zero-error classical capacity of quantum channels assisted by quantum non-signalling correlations, and the reverse problem of exact simulation. Both lead to simple semi-definite programmings whose solutions can be given in terms of the conditional min-entropies. We show that the asymptotic simulation cost is precisely the conditional min-entropy of the Choi-Jamiolkowski matrix of the given channel. For classical-quantum channels, the asymptotic capacity is reduced to a quantum fractional packing number suggested by Harrow, which leads to an operational interpretation of the celebrated Lovasz theta function as the zero-error classical capacity of a graph assisted by quantum non-signalling correlations. This talk is based on a joint work with Andreas Winter (UAB).
Quantum optimal control for open quantum systems

Hsi-Sheng Goan

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An essential prerequisite for quantum information processing (QIP) is precise coherent control of the dynamics of quantum systems or quantum bits (qubits). Most of the control sequences implemented in quantum experiments are developed and designed based on the assumption of having ideal (closed) quantum coherent systems. However, almost every quantum system interacts inevitably with its surrounding environment resulting in decoherence and dissipation of the quantum system. Thus precisely controlling realistic open quantum systems is one of the most important and timely issues in the field of QIP. Quantum optimal control theory (QOCT) is a powerful tool that provides a variational framework for calculating the optimally shaped pulse to maximize a desired physical objective (or minimize a physical cost function). Thus QOCT allows us to design and realize accurate quantum gates by selecting optimal pulse shapes for the external control within experimental capabilities. Here we employ QOCT based on the Krotov method to find control pulse sequences of fast and high-fidelity quantum gates taking into account decoherence from dissipative environment for fault-tolerant quantum computation in various promising physical quantum systems, such as superconducting Josephson-junction-based qubit systems and NV-center-based or donor-based spin-qubit systems. Furthermore, we also apply QOCT to some exactly solvable models of non-Markovian open quantum bit systems to achieve and construct high-fidelity quantum gates for moderate qubit decaying parameters. In most investigations where the environment effect is taken into account, the master equations for qubit systems are often derived perturbatively, involving Born and/or Markov approximations. Despite the broad applicability of the perturbative master equation, the approximations made in the derivation results in unwanted intrinsic error, which in turn contributes to the error in the constructed gate operations. With the help of the exact dynamics, we explore how the gate error is corrected in the open qubit system and determine the conditions for significant improvement.