Quantum Speed Limit With Forbidden Speed Intervals

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Abstract

The well-known time-energy uncertainty relation states that the evolution time τ needed to transform a state $|\phi\rangle$ to another state $|\psi\rangle$ must obey $\tau \geq \hbar \cos^{-1}(|\langle\phi|\psi\rangle|)/\Delta E$, where ΔE is the standard deviation of the system energy. Interestingly, this relation can be regarded as a fundamental limit on the quantum information processing speed of a quantum system. Many quantum speed limits have been found and they all take the form that the evolution time τ must be lower-bounded by a certain number depending on various measures of the system energy. Here I report for the first time new quantum speed limits that put the allowable evolution time τ in more than one speed intervals. I also briefly mention the existence of a novel first-order phase transition associated with this kind of quantum speed limits.
This work has been published in Phys. Rev. A 87, 052142 (2013).

Feedback Control of Rabi Oscillations in Circuit QED

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Abstract

We consider the feedback stabilization of Rabi oscillations in a superconducting qubit which is coupled to a microwave readout cavity. The signal is readout by homodyne detection of the in-phase quadrature amplitude of the weak-measurement output. By multiplying the time-delayed Rabi reference, one can extract the signal, with maximum signal-to-noise ratio, from the noise current. We further track and stabilize the Rabi oscillations by using Lyapunov feedback control to properly adjust the input Rabi drives. Theoretical and simulation results illustrate the effectiveness of the proposed control law.

Co-author Franco Nori (RIKEN)

Some Results on CSS-like Asymmetric Quantum Codes

Frederic Ezerman
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Abstract
We discuss an extension of the CSS construction for asymmetric quantum codes (AQCs) relaxing the linearity condition and including more inner products. An improved Linear Programming bound on the size of the resulting codes can then be used to certify optimality. Some constructions of optimal CSS-like AQCs capable of detecting single amplitude error will be outlined. Making use of an excellent family of nested polynomial classical codes called the Xing-Ling (XL) codes, we also present optimal CSS AQCs reaching the improved Linear Programming bound.

References

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Co-authors M. Grassl, S. Jitman, S. Ling, and D. V. Pasechnik

Time-Energy Measure for Quantum Processes

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Abstract
Quantum mechanics sets limits on how fast quantum processes can run given some system energy through time-energy uncertainty relations, and they imply that time and energy are tradeoff against each other. Thus, we propose to measure the time-energy as a single unit for quantum channels. We consider a time-energy measure for quantum channels and compute lower and upper bounds of it using the channel Kraus operators. For a special class of channels (which includes the depolarizing channel), we can obtain the exact value of the time-energy measure. One consequence of our result is that erasing quantum information requires $\sqrt{(n+1)/n}$ times more time-energy resource than erasing classical information, where n is the system dimension.

Co-author H. F. Chau (Department of Physics and Center of Theoretical and Computational Physics, The University of Hong Kong)

Discord Empowered Quantum Illumination

Mile Gu
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Abstract
Quantum illumination is a technique that uses entanglement to detect reflecting objects in environments so noisy that all entanglement is destroyed. This seems to defy standard intuition: the benefit of entanglement outlasts entanglement itself. Here, we connect the resilience of quantum illumination to noise with the resilience of an alternative quantum resource known as quantum discord. We show that discord persists in such conditions, and that in harnessing this discord, quantum illumination can outperform all conventional techniques. Furthermore, there is a direct equality between the performance gain in quantum illumination and the amount of discord which is expended to resolve the target. This simultaneously explains why quantum illumination thrives in entanglement-breaking noise, and establishes the practical significance of discord in quantum technology.

Co-authors Christian Weedbrook, Stefano Pirandola, and Jayne Thompson

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Recursive construction of noiseless subsystem for qudits

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Abstract
We give a full explanation of the noiseless subsystem that protects a single-qubit against collective errors and the corresponding recursive scheme described in Phys. Rev. A 84, 044301 (2011) from a representation theory point of view. Furthermore, we extend the construction to qudits under the influence of collective SU(d) errors. We find that under this recursive scheme, the asymptotic encoding rate is 1/d.

Local channels preserving the states without measurement-induced nonlocality

Yu Guo
Shanxi Datong University

Abstract
Measurement-induced nonlocality is a measure of nonlocality introduced by Luo and Fu. We present here sufficient and necessary condition for a quantum state for which this quantity is equal to zero. Furthermore it is shown that for such a state ρ_{ab} with $\dim H_a = d \geq 3$ any local channel acting on H_a cannot create measurement-induced nonlocality if and only if either it is a completely contractive channel or it is a nontrivial isotropic channel. For the qubit case this property is an additional characteristic of the completely contractive channel or the commutativity-preserving unital channel.

Co-author Jinchuan Hou (Taiyuan University of Technology)

Quantum simulation of dynamics of Landau-Zener model supporting Kibble-Zurek mechanism

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Abstract

The Kibble-Zurek mechanism (KZM) captures the key physics in the non-equilibrium dynamics of second order phase transitions, and accurately predicts the density of the topological defects formed in this process. However, despite of much effort, the central prediction of KZM, i.e., the scaling of the density production and the transition rate, still needs further experimental con rmation, especially for quantum transitions. Here, we performed a quantum simulation of a non-equilibrium dynamics of Landau-Zener Model, based on a nine-stage optical interferometer with an overall visibility up to 0.9750.008, that supports the adiabatic-impulse approximation which is the core part of Kibble-Zurek theory. In addition, the high- delity multi-stage optical interferometer can also help to push forward the linear optical quantum simulation.

Decomposition of unitary gates

Chi-Kwong Li
College of William and Mary

Abstract

In quantum information science, quantum gates acting on vector states are unitary transformations. It is descirable from the theoretical as well as practical point of view to decompose a general unitary transformation into simple ones that are easy to control and implement. In this talk, we will describe current research on this topic.

An Efficient Exact Quantum Algorithm for the Integer Square-free Decomposition Problem

Jun Li
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Abstract
The integer square-free decomposition problem is stated as: given an arbitrary integer N, find out N's largest factor which is a square number. Like the integer factorization problem, this problem is also thought to be classically intractable. We proposed a quantum algorithm that can polynomially solve this porblem. Our quantum algorithm relies on properties of Gauss sums, this is because that the evaluations of the Gauss sums associated with N are intimately related to factorization properties of N.

Experimental Demonstration of Polarization Encoding Measurement-Device-Independent Quantum Key Distribution

Hoi-Kwong Lo
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Abstract
We demonstrate the first implementation of polarization encoding measurement-device-independent quantum key distribution (MDI-QKD), which is immune to all detector side-channel attacks. Active phase randomization of each individual pulse is implemented to protect against attacks on imperfect sources. By optimizing the parameters in the decoy state protocol, we show that it is feasible to implement polarization encoding MDI-QKD over large optical ber distances. A 1600-bit secure key is generated between two parties separated by 10 km of telecom bers. Our work suggests the possibility of building a MDI-QKD network, in which complicated and expensive detection system is placed in a central node and users connected to it can perform con dential communication by preparing polarization qubits with compact and low-cost equipment. Since MDI- QKD is highly compatible with the quantum network, our work brings the realization of quantum internet one step closer.

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Co-authors Zhiyuan Tang, Zhongfa Liao, Feihu Xu, Bing Qi, Li Qian

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Quantum Error Correction with Mixed State Ancilla Qubits

Mikio Nakahara
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Abstract
It is commonly assumed that ancilla qubits must be in a pure state for successful quantum error correction. We show that they can be initially in any mixed state if a selected class of error operators $\{\sigma_x^{\otimes 3}, \sigma_y^{\otimes 3}, \sigma_z^{\otimes 3}\}$ acts simultaneously on the three physical qubits in its simplest case. In particular, the ancilla qubits can be in the uniformly mixed state, which makes implementation of our scheme extremely cheap. We also show that 1-qubit gate operations for a logical qubit can be implemented easily within the codeword. We experimentally demonstrated our scheme by using a liquid state NMR quantum computer with three qubits. The encoded state has an interesting nature in terms of quantum discord. Possible generalization is discussed.

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Yasushi Kondo (Kinki University), Chiara Bagnasco (Kinki University)

Quantum algorithms for the factoring problem

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Abstract
Factorization of large numbers is a computationally hard problem: the computational resources required to accomplish this task increase exponentially with the size of the problem. Quantum algorithms could be much faster than classical ones in solving the factoring problem. Shor's algorithm is the most famous one. There are other methods for this problem, for example, adiabatic quantum algorithm and the Gauss-sum algorithm using properties of Gauss sums. Here, we discuss these different quantum algorithms for the factoring problem and its implementations using nuclear magnetic resonance techniques, including factoring 143 by adiabatic quantum computation, which is, we believe, the largest number factored in quantum-computation realization.

Co-authors Zeyang Liao, Nanyang Xu and Jun Li, Gan Qin, Jing Zhu, Dawei Lu, Xianyi Zhou, Dieter Suter and Jiangfeng Du

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Some Results on Quantum Marginal problems

Yiu Tung Poon
Iowa State University

Abstract
We will discuss some results on Quantum Marginal problems.

Characterizing quantum measurements on the qubits

Xiaofei Qi
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Abstract
Let $\mathcal{D}(H)$ and $\mathcal{D}(K)$ be the sets of all states on H and K respectively. Assume that $M : H \to K$ is a bounded operator. A map $\Phi : \mathcal{D}(H) \to \mathcal{D}(K) \cup \{0\}$ is called a quantum measurement map if $\Phi(\rho) = \frac{M\rho M^\dagger}{\mathrm{Tr}(M\rho M^\dagger)}$ whenever $M\rho M^\dagger \neq 0$ and $\Phi(\rho) = 0$ whenever $M\rho M^\dagger = 0$. In this paper, we give a geometric characterization of the quantum measurement maps on the qubits $\mathcal{D}(2)$. It is shown that, up to the transpose, a map $\Phi : \mathcal{D}(2) \to \mathcal{D}(2) \cup \{0\}$ is a quantum measurement map if and only if Φ is convex combinations preserving, sends pure states into pure states or 0, and either $\Phi(\mathcal{P}ur(2))$ has at least 5 pure states or $\Phi(\mathcal{P}ur(2))$ has 2 elements and $\Phi^{-1}(\{0\})$ is a singleton, where $\mathcal{P}ur(2)$ stands for the set of all pure states in $\mathcal{D}(2)$.

Co-authors Man-Duen Choi (University of Toronto), Jinchuan Hou (Taiyuan University of Technology), Chi-Kwong Li (College of William and Mary)

Quantum computing with black-box subroutines

Jayne Thompson
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Abstract
Modern programming relies on our ability to treat preprogrammed functions as black boxes - we can invoke them as subroutines without knowing their physical implementation. Here we show it is generally impossible to execute an unknown quantum subroutine. This, as a special case, forbids applying black-box subroutines conditioned on an ancillary qubit. We explore how this limits many quantum algorithms - forcing their circuit implementation to be individually tailored to specific inputs and inducing failure if these inputs are not known in advance. We present a method to avoid this situation for certain computational problems. We apply this method to enhance existing quantum factoring algorithms; reducing their complexity, and the extent to which they need to be tailored to factor specific numbers. Thus, we highlight a natural property of classical information that fails in the advent of quantum logic; and simultaneously demonstrate how to mitigate its effects in practical situations.

Co-authors Mile Gu, Kavan Modi, Vlatko Vedral

Quantum process tomography via weak measurements

Shengjun Wu
Nanjing University

Abstract
Quantum process tomography (QPT) is vitally important for quantum information processing and quantum control. Here via weak measurements, we present a new QPT scheme, where a single parameter of the quantum process is determined with only one input state and two successive weak measurements, regardless of the dimension of the quantum system. This fact makes our scheme direct and good at reducing error accumulation. It is parallel in the sense that the scheme can be assembled in much fewer experimental configurations, and then the required sample size can be sharply reduced. In addition, we just need states in an orthonormal basis as the input for a complete QPT without ancillary quantum systems.

Inhomogeneous dynamic nuclear polarization in a quantum dot

Wenxian Zhang
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Abstract
By polarizing the nuclear spins in quantum dots, the central electron spins's coherence time may be extended significantly. We investigate the dynamic nuclear polarization process by frequently injecting polarized electron spins into a quantum dot. Due to the suppression of the direct dipolar and indirect electron-mediated nuclear spin interactions, by the frequently injected electron spins, the analytical predictions under the independent spin approximation agree well with quantum numerical simulations. We find that the acquired nuclear polarization is highly inhomogeneous, proportional to the square of the local electron-nuclear hyperfine interaction constant, if the injection frequency is high. Utilizing these inhomogeneously polarized nuclear spins as an initial state, we further show that the electron-polarization decay time can be extended 100 times even at a relatively low nuclear polarization ($< 20\%$), without much suppression of the fluctuation of the Overhauser field. Our methods may find more applications in future investigations of the effect of DNP in more complex spin systems, such as double quantum dots and nitrogen vacancy centers in diamonds.

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