Chengdu-Chongqing Quantum Workshop (CCQW-2021)

Quantum Sensing: Theory to Applications

29-31 October, Chengdu

Venue: 金开国际公寓（Jinkai International Apartment）

Address: 成都市青羊区北大街 2 号

Conference hall: 致诚厅（2nd floor）

Oct 29-31, Lunch, Canteen: 餐厅（3rd floor）

Oct 29, Dinner, Restaurant: 成都院子酒店（Chengdu Courtyard Hotel）

Address：青羊区五岳宫街 28 号

Oct 30, Dinner, Restaurant: 金芙蓉酒楼（文殊坊店）

Address：青羊区白云寺街 30 号附 1 号

Chengdu-Chongqing Quantum Workshop 2021 (CCQW-2021)

29-31 October, Chengdu

Day 1: Friday October 29

Time	Speaker	Title
09:00-09:15	Opening Remarks	
09:15-10:00	Xing Rong	Searching for Exotic Spin Interactions with Single Spin Quantum Sensors
10:00-10:30	Coffee Break	
10:30-11:15	Xiongjun Liu	BIS-Boundary Correspondence for Anomalous Floquet Topological Phases
11:15-12:00	Xinwei Li	Estimating Multiple Parameters with Time Reversal Measurement
12:00-14:00	Lunch (3rd floor canteen)	
14:00-14:45	Zhibo Hou	Fighting the Precision Tradeoffs in Multi-Parameter Quantum Estimation
14:45-15:30	Rubem Mondaini	Many-Body Localization: When Thermalization Fails and How to Experimentally Observe It
15:30-16:00	Coffee Break	
16:00-16:45	Qi Zhang	Single-Molecule Magnetic Resonance Spectroscopy
16:45-18:00	Poster Session	
18:00-20:00	Dinner (成都院子酒店)	

Chengdu-Chongqing Quantum Workshop 2021 (CCQW-2021)

29-31 October, Chengdu

Day 2: Saturday October 30

Time	Speaker	Title
09:15-10:00	Ying Hu	Quantum Sensing with Microwave-Dressed Rydberg Atoms
10:00-10:30	Coffee Break	
10:30-11:15	Victor Montenegro	Precision Limits on Optimal Global Quantum Sensing
11:15-12:00	Wen Yang	The Power of Non-Hermitian Quantum Sensing
12:00-14:00	Lunch (3rd floor canteen)	
14:00-14:45	Jingyun Fan	Loophole Free Bell Test
14:45-15:30	Nana Liu	Advances in Adversarial Quantum Learning
15:30-16:00	Coffee Break	
16:00-16:45	Oscar Dahlsten	Universal Bound on Energy Cost of Bit Reset in Finite Time
16:45-17:30	Junhong An	Generating Stable Spin Squeezing by Squeezed-Reservoir Engineering
17:30-18:00	Break	
18:00-20:00	Dinner (金芙蓉酒楼文殊坊店)	

Chengdu-Chongqing Quantum Workshop 2021 (CCQW-2021)

29-31 October, Chengdu

Day 3: Sunday October 31

Time	Speaker	Title
09:15-10:00	Chaohong Lee	Many-Body Quantum Lock-In Amplifier
10:00-10:30	Coffee Break	
10:30-11:15	Xiaotong Lu	Strontium Optical Lattice Clock in National Time Service Center
11:15-12:00	Shujin Deng	Light Induced Space-Time Patterns in a Superfluid Fermi Gas
12:00-12:10	Closing Remarks	
12:10-14:00	Lunch and Leaving (3rd floor canteen)	

Speaker: Junhong An

Affiliation: School of Physical Science and Technology, Lanzhou University

Title: Generating Stable Spin Squeezing by Squeezed-Reservoir Engineering

Abstract: A quantum science and technology revolution is currently in the making. It is expected to bring a lot of scientific and societal benefits. A distinguished example is quantum sensing, which pursues to develop measurement protocols with higher precisions than the classical shot-noise limit by using quantum resources. Having exhibited its power in beating the shot-noise limit, spin squeezing (SS) has promising application in next-generation gyroscope, atomic clock, magnetometers, and gravimetry. The efficient generation of SS is a prerequisite for its application. Therefore, how to generate the SS has attracted a wide attention in recent years. The widely used schemes to generate SS exploit the coherent spin-spin coupling. However, the generated SS there is dynamically transient and experiences severe degradation under the realistic decoherence. Although some recent schemes revealed that a SS can be created by the reservoir engineering technique, a coherent laser driving on each spin is needed to stabilize the SS, which is impractical when a large number of spins are involved. We here propose a scheme to generate stable SS in a waveguide QED system without resorting to either the coherent spin-spin coupling or the laser driving on each spin. Its main idea is based on the combined action of the technique of squeezed-reservoir engineering and the mediation role of the waveguide. The generated SS parameter scales with the spin number N as 1.64N^{-0.54}, which beats the ones in the conventional schemes. The highly spatial nonlocality of the SS along the waveguide in our scheme endows it with certain superiority in quantum sensing, e.g., improving the sensing efficiency of spatially unidentified weak magnetic field because the contact area is effectively increased.

References:

[1] Si-Yuan Bai and Jun-Hong An, Generating stable spin squeezing by squeezed-reservoir engineering, Phys. Rev. Lett. 127, 083602 (2021).

Speaker: Zhibo Hou

Affiliation: University of Science and Technology of China

Title: Fighting the Precision Tradeoffs in Multi-Parameter Quantum Estimation

Abstract: The precision limit for the single parameter quantum precision measurement, such as the phase estimation, has been extensively studied previously. However, realistic scenarios, such as magnetometry, quantum gyroscope, quantum imaging, e.t.c., typically involve multiple parameters. A distinguishing feature of multi-parameter quantum estimation is the existence of precision tradeoff among different parameters, which could originate from the incompatibility of optimal quantum measurements, quantum probe states or evolution dynamics. We have been dedicated to counteracting the tradeoffs in multi-parameter estimation. We developed new experimental measurement techniques of collective measurements, which successfully reduced the tradeoffs in quantum state tomography [1] and quantum orienteering [2]. Then we completely optimized the entangled probe states in quantum magnetometry and obtained the ultimate precision limit for three magnetic components with minimum tradeoff [3]. However, the tradeoffs still exist in these multi-parameter estimation tasks although they are diminished. To completely counteract the tradeoffs, we extended the control-enhanced sequential measurement scheme from single-parameter estimation [4] to multi-parameter estimation and achieved the highest precisions for the estimation of all three parameters in SU(2) operators simultaneously with zero tradeoff and a 13.27 dB improvement over the shot-noise limit [5]. The quantum controls are also used to demonstrate the coexistence of Heisenberg and “super-Heisenberg” scalings via the simultaneous estimation of the magnitude and frequency of a rotating field [6].

References:

[1] Zhibo Hou, Jun-Feng Tang, Jiangwei Shang, etal, Nat. comm. 9 (1), 1-7(2018)

[2] Jun-Feng Tang(#), Zhibo Hou(#), Jiangwei Shang(*), etal, PRL 124 (6), 060502(2020)

[3] Zhibo Hou(#), Zhao Zhang, Guo-Yong Xiang(*), etal, PRL 125 (2), 020501(2020)

[4] Zhibo Hou, Rui-Jia Wang, Jun-Feng Tang, etal, PRL 123 (4), 040501(2019)

[5] Zhibo Hou(#), Jun-Feng Tang(#), Hongzhen Chen, etal, Sci. Adv. 7 (1), eabd2986(2021)

[6] Zhibo Hou(#), Yan Jin(#),Hongzhen Chen, etal, PRL 126, 070503 (2021).

Speaker: Shujin Deng

Affiliation: East China Normal University

Title: Light Induced Space-Time Patterns in A Superfluid Fermi Gas

Abstract: Modulation instability (MI) has been a long standing subject of interest in physics, which has been widely studied in the nonlinear optics, liquids, and biology. A quantum fluid with frictionless flow provides an ideal system to investigate these phenomena. Patterns resulted from modulation instability are ubiquitous and have been extensively studied in optics and Bose-Einstein condensates. However, these patterns have not been realized in ultracold Fermi gases, although there has been considerable theoretical interest in this field. In this talk I'll introduce the experimental observation of space-time patterns in a superfluid Fermi gas excited by red-detuned laser light. Longitudinal spatially fluctuated laser beams induce the spontaneous formation of two different kinds of patterns. For strongly interacting Fermi gas, the induced patterns accompanied by phonon excitations demonstrate a striking "X"-type dispersion relation between frequency and wavevector. Then, the propagation of such patterns in the Bose-Einstein condensate to Bardeen-Cooper-Schrieffer crossover is investigated, which is related to the speed of sound and agrees well with theoretical calculations. The observed patterns in noninteracting Fermi gases are stationary without phonon excitations and show a much longer lifetime.

Speaker: Oscar Dahlsten

Affiliation: Southern University of Science and Technology

Title: Universal Bound on Energy Cost of Bit Reset in Finite Time

Abstract: We consider how the energy cost of bit reset scales with the time duration of the protocol. Bit reset necessarily takes place in finite time, where there is an extra penalty on top of the quasistatic work cost derived by Landauer. This extra energy is dissipated as heat in the computer, inducing a fundamental limit on the speed of irreversible computers. We formulate a hardware-independent expression for this limit. We derive a closed-form lower bound on the work penalty as a function of the time taken for the protocol and bit reset error. It holds for discrete as well as continuous systems, assuming only that the master equation respects detailed balance.

Reference: Yi-Zheng Zhen, Dario Egloff, Kavan Modi, Oscar Dahlsten, arxiv:2106.00580 (To appear in PRL)

Speaker: Jingyun Fan

Affiliation: Southern University of Science and Technology

Title: Loophole Free Bell Test

Abstract: I will talk about our recent experimental progress in loophole free Bell test and its applications in information science.

Speaker: Ying Hu

Affiliation: Shanxi University

Title: Quantum Sensing with Microwave-Dressed Rydberg Atoms

Abstract: In this talk, I will present our recent breakthrough [1] in realizing the long sought-after microwave quantum sensors, which simultaneously offer quantum projection noise limited sensitivity, SI-traceability, and phase resolutions. In particular, we have developed a conceptually new microwave sensor based on microwave-dressed Rydberg atoms and engineered optical spectrum. This new sensor scales favorably, with the minimum detectable microwave field three orders of magnitude smaller than what can be reached with existing atomic electrometers. It enables SI-traceable measurements, reaching uncertainty levels that has been inaccessible so far with atomic sensors. Moreover, it allows for a high precision in sensing Doppler frequencies. We believe our innovative technique will benefit a wide range of fields including quantum simulation, quantum metrology, and astronomical explorations.

[1]. Nature Physics 16, 911–915 (2020)

Speaker: Chaohong Li

Affiliation: Sun Yat-Sen University

Title: Many-body quantum lock-in amplifier

Abstract: Not provided.

Speaker: Xinwei Li

Affiliation: Tsinghua University

Title: Estimating Multiple Parameters with Time Reversal Measurement

Abstract: Simultaneous estimation of multiple parameters extracts more information in a single experiment and sometimes can provide a better precision than estimating them individually. However, for a given probe state the multi-parameter quantum Cramér − Rao bound (QCRB) is not always saturable due to the possible non-commutativity of measurement observables. In this talk I will introduce examples of simultaneously multi-parameter estimation with measurement schemes based on time reversed evolution. For multiple phases associated with multiple modes, we propose a multimode Ramsey interferometer for unentangled particles. We further present a scheme that estimate two parameters generated by non-commuting operators in spin-1 BEC.

Speaker: Nana Liu

Affiliation: Shanghai Jiaotong University

Title: Advances in Adversarial Quantum Learning

Abstract: In this talk, I'll introduce the emerging area of adversarial quantum learning, which asks questions at the overlap between security, quantum computation and machine learning. I'll also present some key open questions and present some fundamental bounds on robustness of quantum algorithms for classification based on quantum hypothesis testing. In addition, I'll formulate a relationship between robustness and symmetries of the quantum algorithms with the accuracy of the algorithm for classification.

Speaker: Xiongjun Liu

Affiliation: Peking University

Title: BIS-Boundary Correspondence for Anomalous Floquet Topological Phases

Abstract: Not provided.

Speaker: Xiaotong Lu

Affiliation: National Time Service Center, CAS

Title: Strontium Optical Lattice Clock in National Time Service Center

Abstract: One of the most successful quantum technologies is the quantum frequency standard, which defines the units of time by quantum transitions of particles (such as atoms, molecules, and ions) from one energy state to another. Optical lattice clocks, using the transitions of many neutral atoms as the frequency reference, are one of the most accurate and stable atomic clocks. This report shows the progress of 87Sr optical lattice clock in National Time Service Center, including the preparation of quantum reference system, synchronous frequency comparison based on one-dimensional optical lattice clock, the probe Stark shift evaluation by frequency modulation spectroscopy, and the optical lattice clock toward space station. The double frequency modulation based on optical lattice clock is demonstrated, which reveals the interference effect between Floquet quasi-particles and can easily simulate (1D or 2D) topological insulators with high winding number.

Speaker: Rubem Mandaini

Affiliation: Beijing Computational Science Research Center

Title: Many-Body Localization: When Thermalization Fails and How to Experimentally Observe It

Abstract: The observation of many-body localization is a paradigmatic example of the amount of time an idea takes to get mature enough, and the numerical and experimental methods to sufficiently develop, in order to settle its existence. After the original study of Philip Anderson in 1958, demonstrating localization of non-interacting quantum particles in disordered settings, a natural question is on the resulting effects of the inter-particle interactions on this phenomenon. Only after 50 years, substantial theoretical progress was made in solving this puzzle and, in 2016 the first experimental observation of this phenomenon was realized. The advent of platforms involving ultracold atoms trapped by optical lattices allowed the inspection of an inherently dynamical quantum phase transition, that goes beyond the standard ground-state classification of the quantum matter, and its associated low-lying excitations. Instead, it is described by a high-energy phase transition, inherently manifested via the unitary dynamics of an isolated quantum system, wherein by tuning the strength of disorder, one is able to halt the onset of ergodic behavior and thermalization. In this talk, after introducing the general conditions where it occurs, and review the experiments tackling it so far, I will show numerical and experimental results using quantum circuits of superconducting qubits that shed light on yet two other debated aspects: the possible existence of many-body mobility edges and on the localization without quenched disorder.

References:

[1] Q. Guo, C. Cheng, Z.-H. Sun, Z. Song, H. Li, Z. Wang, W. Ren, H. Dong, D. Zheng, Y.-R. Zhang, R. Mondaini, H. Fan, H. Wang, Observation of energy resolved many-body localization, Nature Physics 17, 234 (2021).

[2] [2] Q. Guo, C. Cheng, H. Li, S. Xu, P. Zhang, Z. Wang, C. Song, W. Liu, W. Ren, H. Dong, R. Mondaini, H. Wang, Stark many-body localization on a superconducting quantum processor, arXiv preprint, arXiv:2011.13895

Speaker: Victor Montenegro

Affiliation: University of Electronic Science and Technology of China

Title: Precision Limits on Optimal Global Quantum Sensing

Abstract: Most quantum sensors perform optimally only over a narrow range of the unknown parameter to be sensed. This is because the optimal measurement basis, as a key element of any sensing protocol, generally depends on the unknown parameter. As this parameter is unknown, the measurement can be adjusted to the optimal basis only when the parameter varies over a small region, the so-called “local” sensing. Therefore, significant prior information about the unknown parameter is needed to reach efficient high precision sensing. In the opposite scenario, known as “global” sensing, the prior information is minimal, and thus, the unknown parameter varies over a wide range. Since no measurement setup can be optimal for the whole range, the key open question is to find the best global sensing protocol which can provide maximum precision over the entire interval.

In this talk, we first introduce a new quantity, called average uncertainty, whose minimization defines a figure of merit for optimal multi-parameter global quantum sensing. This formulation is very general and can be applied to any quantum sensing protocol independent of the choice of the probe. To illustrate the application of our protocol, we exploit strongly correlated quantum many-body probes. The importance of such probes is due to the presence of Heisenberg quantum-enhanced sensing precision around their quantum phase transition point, which makes them ideal for local sensing when the unknown parameters vary around the criticality. Interestingly, the quantum-enhanced precision reduces to the standard limit when the probe operates far away from criticality. This makes the formulation of global sensing most suitable for such sensors. Indeed, our protocol provides a systematic approach for optimizing the probe such that independent of the sensing interval can harness the criticality and significantly reduce the average uncertainty over the entire sensing interval. We can also specify a threshold that clearly defines a sensing interval for which the quantum-enhanced sensing precision is achievable. Remarkably, even when the sensing interval is large so that the achievable precision is bounded with the standard limit, our optimized global sensing protocol guarantees the best obtainable performance of the probe over the entire interval.

Reference: V. Montenegro, U. Mishra, and A. Bayat, Phys. Rev. Lett. 126, 200501 (2021).

Speaker: Xing Rong

Affiliation: University of Science and Technology of China

Title: Searching for Exotic Spin Interactions with Single Spin Quantum Sensors

Abstract: Searching for new particles beyond the standard model is crucial for understanding several fundamental conundrums in physics and astrophysics. Several hypothetical particles can mediate exotic spin-dependent interactions between ordinary fermions, which enable laboratory searches via the detection of the interactions. We present a platform based on single spin quantum sensors for investigating exotic spin-dependent interactions with micrometer scales.

Speaker: Wen Yang

Affiliation: Beijing Computational Science Research Center

Title: The Power of Non-Hermitian Quantum Sensing

Abstract: Hermiticity of a Hamiltonian is one of the key postulates in quantum mechanics. It leads to two key consequences: (i) The energy eigenvalues must be real, which ensures the conservation of the probability. (ii) The eigenstates form an orthonormal complete basis, so that the response of the eigenenergy and the eigenstates to external perturbations are bounded. In recent years, there has been widespread interest in open quantum systems described by a non-Hermitian Hamiltonian, which breaks both (i) and (ii). In particular, at the exceptional points where multiple eigenvalues and eigenstates coalesce, the energy eigenvalues show divergent response to external perturbations. This causes recent debates about whether unlimited sensitivity is possible by operating the non-Hermitian quantum sensors near the exceptional point. In this talk, I will try to convey my understanding about these issues, including how to calculate the non-Hermitian evolution, how to simulate a non-Hermitian Hamiltonian through the use of ancilla qubits, and why the eigenvalues and eigenstates of non-Hermitian Hamiltonian are much more sensitive to small perturbations than their Hermitian counterparts.

Speaker: Qi Zhang

Affiliation: University of Science and Technology of China

Title: Single-Molecule Magnetic Resonance Spectroscopy

Abstract: The past half century has seen rapid emergence and advances of single-molecule techniques, which have brought revolution to studies in physics, materials and biology. Magnetic resonance (MR) spectroscopy is a widely used technique for non-invasively extracting conformational and structural information from the molecules of interest. However, conventional MR relies on signal accumulation from billions of molecules. Here I will introduce our efforts on pushing the sensitivity of MR techniques to single molecule level, using a solid-state quantum sensor, named NV center in diamond. I will also discuss the challenges on this direction and our recent works on achieving high efficiency quantum sensor readout. Prospects and preliminary results on quantum sensing under bio-compatible conditions will also be introduced.