**B5. Quantum Computing**

Chair(s): Io Chun HOI, National Tsing Hua University, Taiwan  
Hou IAN, University of Macau, Macao

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Session Chair(s): Name (Affiliation), Name (affiliation),

Session Chair: Hou IAN

Affiliation: University of Macau, Macao

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<td>09:15</td>
<td>B5-1 (Keynote)</td>
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**Title of Talk:** Parity-Time-Symmetric Optics, extraordinary spin in evanescent waves, and the quantum spin Hall effect of light.

**Authors’ Names:** Franco Nori

**Affiliation**

RIKEN, Saitama, Japan  
University of Michigan, Ann Arbor, USA.

**Abstract:**

(1) Optical systems combining balanced loss and gain provide a unique platform to implement classical analogues of quantum systems described by non-Hermitian parity–time (PT)-symmetric Hamiltonians [1-5]. Such systems can be used to create synthetic materials with properties that cannot be attained in materials having only loss or only gain. We report PT-symmetry breaking in coupled optical resonators. We observed [1] non-reciprocity in the PT-symmetry-breaking phase due to strong field localization, which significantly enhances nonlinearity. In the linear regime, light transmission is reciprocal regardless of whether the symmetry is broken or unbroken. We show that in one direction there is a complete absence of resonance peaks whereas in the other direction the transmission is resonantly enhanced, which is associated with the use of resonant structures. Our results could lead to a new generation of synthetic optical systems.
enabling on-chip manipulation and control of light propagation.

(2) Maxwell’s equations, formulated 150 years ago, ultimately describe properties of light, from classical electromagnetism to quantum and relativistic aspects. The latter ones result in remarkable geometric and topological phenomena [6-16] related to the spin-1 massless nature of photons. By analyzing fundamental spin properties of Maxwell waves, we show [6] that free-space light exhibits an intrinsic quantum spin Hall effect — surface modes with strong spin-momentum locking. These modes are evanescent waves that form, for example, surface plasmon-polaritons at vacuum-metal interfaces. Our findings illuminate the unusual transverse spin in evanescent waves and explain recent experiments that have demonstrated the transverse spin-direction locking in the excitation of surface optical modes. This deepens our understanding of Maxwell’s theory, reveals analogies with topological insulators for electrons, and offers applications for robust spin-directional optical interfaces.

References


Some related work by our group can be found in the following references:


09:45 B5-2(Keynote)

Title of Talk: Quantum Information Processing with Superconducting Circuits

Authors’ Names: Andreas Wallraff

Affiliation: ETH Zurich

Abstract:
The high level of control achievable over quantized degrees of freedom have turned superconducting circuits into one of the prime physical architectures for quantum computing and simulation. Using modern micro and nano-fabrication techniques combined with superconducting materials we realize quantum electronic circuits in which we create, store, and manipulate individual microwave photons. Making use of the strong interaction engineered between photons and superconducting quantum two-level systems we probe fundamental quantum effects of microwave radiation and develop components for applications in quantum technology. In this talk, I will give an introduction to the field and discuss a selection of recent results.

10:15 Coffee Break

10:45 B5-4 (invited)

Title of Talk: Nonadiabatic spin manipulation with adiabatic protocols

Authors’ Names: Xuedong Hu

Affiliation:
Department of Physics, University at Buffalo

Abstract:

Experimental and theoretical research on spin qubits in quantum dots have achieved significant progress over the past decade. In particular, single-spin manipulation involves ESR or EDSR techniques, which are relatively slow; while two-spin manipulation uses exchange interaction and could be very fast. Here I discuss explorations we have pursued in implementing adiabatic spin control protocols nonadiabatically. We show that for both single-spin rotation and three-spin state transfer, when we push the adiabatic protocols very fast, they can still work, albeit only resonantly. Specifically, in the case of single-spin control, we find that the spin trajectory on the Bloch sphere displays some interesting properties. The three-spin state transfer, on the other hand, can be mapped onto the adiabatic population transfer in a three-level atom in quantum optics, or a rotating spin with S=1 in the adiabatic frame. In short, our results show that it is possible for a spin-control protocol to be both fast and robust, and point to a potential new way to perform other quantum gates.

11:15

Title of Talk: Probing the quantum vacuum with an artificial atom in front of a mirror

Authors’ Names: IoChun Hoi

Affiliation: National Tsing Hua University, Taiwan
Abstract:
Quantum fluctuations of the vacuum are a fundamental phenomenon in nature. The virtual photons flitting in and out of existence can have a very real impact, as seen in, *e.g.*, the Casimir effects and the decoherence of atoms. It is therefore desirable to be able to probe the quantum effects of the vacuum. Here, we present a new approach to sensing the vacuum modes, based on a setup with an artificial atom placed in front of a mirror. We embed a superconducting transmon qubit at a distance from the end of a one-dimensional (1D) transmission line. The distance between the atom and the end (the mirror) determines the electromagnetic (EM) environment coupled to the atom. By tuning the transition wavelength of the atom, we effectively change the distance to the mirror. As a result, the atom can be moved from a node to an antinode of the EM field. Measuring the relaxation rate of the atom as its transition wavelength is tuned gives information about the quantum fluctuations of the vacuum, since the relaxation rate is proportional to the strength of the fluctuations. We observe a change in the atom relaxation rate by a factor of 9.8, showing that we can tune the coupling to the vacuum over a large range and effectively hide the atom from the vacuum. The lower limit of vacuum we observe is 0.02 quanta.
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<td>10:15</td>
<td>B5-6 (invited)</td>
<td>Energy localization and ground-state cooling of mechanical resonator in optomechanics using a gain cavity</td>
<td>Yu-xi Liu</td>
<td>Institute of Microelectronics, Tsinghua University and Tsinghua National Laboratory for Information Science and Technology (TNList), Beijing 100084, China</td>
<td>It is well known that the energy flows from the hot (gain) system to the cold (loss) one when they are coupled to each other. We present a counterintuitive theory for the ground-state cooling of the mechanical resonator in optomechanics via a gain cavity. Here, the energy flows first from the mechanical resonator to the loss cavity, then to the gain cavity, and finally localizes there. The energy localization in the gain cavity dramatically enhances the cooling rate of the mechanical resonator. Moreover, we show that unconventional optical spring effect, e.g., giant frequency shift and optically induced damping of the mechanical resonator, can be realized. Those feature a pre-cooling free ground-state cooling, i.e., the mechanical resonator can directly be cooled to the ground state from the room temperature.</td>
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<td>10:45</td>
<td>B5-7 (invited)</td>
<td>Observation of collective Coulomb blockade in gate-controlled linear quantum-dot arrays</td>
<td>Jeng-Chung Chen</td>
<td>National Tsing Hua University, Taiwan</td>
<td>Coherent control and probing of quantum states either in a static or dynamic manner is a formidable challenge for contemporary physicists, not only because this task offers a tool for exploring fundamental principles in physics but also it lies at...</td>
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the core of realizing quantum information technology. A physical implementation of a controllable quantum mechanical system based on semi-conductor quantum dots (QDs) holds several distinct advantages in comparison with other approaches, including a genuine Fermion system, the capability of individual control and readout. However, there are few obstacles which significantly limit the feasibility of a large quantum system by integrating the QDs. The confining potential of a quantum dot array (QDA) formed by the gate voltages may vary from one dot to another, so the key issue is how to overcome this spatial fluctuation-induced disorder. Not mention that a reliable means must be concurrently developed to protect the coherence of the quantum states prepared for further operations during the size scale-up.

In this talk, I will present a novel approach to manipulate and detect collective quantum states of six quantum dots by employing coherent electronic edge channels arranged in the integer quantum Hall regime. Due to the protection of the topological invariant, the edge states are immune to environmental disorders and provide an amenity for coherent control of quantum states, analogous to coherent laser light in quantum optics. The inter-dot coupling and the dot-edge channel coupling are tuned by magnetic fields and gate voltages. A variety of intriguing transport behaviors are observed, representing the formation of the collective quantum states in the studied QDA. We find a competition between the charging effect and the interference effect, and the interplay of the localized or delocalized states of the six dots with the extended edge channels. Our findings demonstrate the generic interacting features in a quantum dot network mediated by the edge channels, and open a new avenue to coherently control and probe collective quantum states.
Quantum annealing is a heuristic approach to quantum computing that promises computational speed-up for hard optimization problems. At Google Quantum AI Lab, we are building a quantum annealing processor (v2.0) with superconducting technology. In this talk, I discuss some design criteria for a computationally powerful quantum annealer, an overview of the hardware and architecture of our annealer, and also some early experimental results.

We report the experimental demonstration of the magnon Kerr effect in a cavity quantum electrodynamics system, where magnons in a small yttrium iron garnet (YIG) sphere are strongly but dispersively coupled to the microwave photons in a three-dimensional cavity. When considerable magnons are generated by pumping the YIG sphere, the Kerr effect gives rise to a shift of the cavity central frequency and yields more appreciable shifts of the magnon modes, including the Kittel mode (i.e., the ferromagnetic resonance mode), which holds...
homogeneous magnetization, and the magnetostatic (MS) modes, which have inhomogeneous magnetization. We derive an analytical relation between the magnon frequency shift and the pumping power for a uniformly magnetized YIG sphere and find that it agrees very well with the experimental results of the Kittel mode. In contrast, the experimental results of MS modes deviate from this relation owing to the spatial variations of the MS modes over the sample. This finding provides a method to characterize the deviations of MS modes from the homogeneous magnetization.

15:15
B5-10 (invited)

Title of Talk: Simulating Topological physics by using synthetic dimensions based on optical orbital angular momentum

Authors’ Names: Zheng-Wei Zhou

Affiliation: University of Science and Technology of China, Hefei

Abstract:
Quantum simulation is one of the most important research fields in quantum information science, which not only allows the study of the existed physical systems, but also new physical modes with new phenomena. Currently, there are various experimental platforms used for quantum simulation, such as ultra-cold neutral atom, trapped ion, integrated optical system et al.

Orbital angular momentum of light is a fundamental optical degree of freedom. It is characterized by unlimited number of available angular momentum states, and has proved invaluable in diverse recent studies ranging from quantum information to optical communication.

In this talk, we will introduce fully new applications of photon’s orbital angular momentum in quantum simulation of topological physics. The basic idea is to design a degenerate cavity supporting photonic modes carrying different orbital angular momentum (i.e. the Laguerre-Gaussian modes), whose resonance frequencies are the same. By coupling photons in different orbital angular momentum states, a single degenerate cavity is equivalent
to a 1D coupled-cavity array. Consequently, 1D coupled degenerate cavity array can be used to simulate 2D physics. We proposed some schemes to realize arbitrary Abelian gauge field, SU(2) non-Abelian gauge field, to detect topological invariants such as edge state and Chern number, and to observe topological quantum phase transition. In contrast to other 2D proposals, this 1D structure greatly reduces the complexity of the simulator, and feasible scale of simulation is also increased.

Furthermore, we also investigate 1D topological models by using single degenerate cavity. By designing the boundary of such kind of synthetic dimension, we may observe the dynamics of edge modes which will exhibit topological phase transition of models.

**Title of Talk:** Superadiabatic protocol in a superconducting qubit

**Authors’ Names:** Yi Yin

**Affiliation:** Zhejiang University

**Abstract:**

Adiabatic quantum manipulation provides a possibility of realizing quantum computation against noises. The slow process required in the adiabatic procedure can however become a bottleneck in practice. With an additional counter-diabatic correction, the superadiabatic protocol proposes a fast adiabatic realization. In a superconducting phase qubit, the superadiabatic protocol is experimentally performed. The geometric Berry phase is precisely generated and measured. The protection against noise is also explored.