RIKEN Berkeley Workshop: Quantum Information Science

Report of Contributions

Contribution ID: **4** Type: **not specified**

Emergence of excitonic superfluid at topological-insulator surfaces

Sunday, 27 January 2019 17:30 (25 minutes)

Excitons are spin integer particles that are predicted to condense into a coherent quantum state at sufficiently low temperature, and exciton condensates can be realized at much higher temperature than condensates of atoms because of strong Coulomb binding and small mass. Signatures of exciton condensation have been reported in double quantum wells, microcavities, graphene, and transition metal dichalcogenides. Nonetheless, transport of exciton condensates is not yet understood and it is unclear whether an exciton condensate is a superfluid or an insulating electronic crystal. Topological insulators (TIs) with massless particles and unique spin textures have been theoretically predicted as a promising platform for achieving exciton condensation. Here we report experimental evidence of excitonic superfluid phase on the surface of three-dimensional (3D) TIs. We unambiguously confirmed that electrons and holes are paired into charge neutral bound states by the electric field independent photocurrent distributions. And we observed a millimetre-long transport distance of these excitons up to 40 K, which strongly suggests dissipationless propagation. The robust macroscopic quantum states achieved with simple device architecture and broadband photoexcitation at relatively high temperature are expected to find novel applications in quantum computations and spintronics.

Primary author: Prof. YU, Dong (U.C. Davis)

Presenter: Prof. YU, Dong (U.C. Davis)

Session Classification: Condensed Matter II

Track Classification: Condensed matter applications

Contribution ID: **7** Type: **not specified**

VanQver: Variationally and Adiabatically Navigated Quantum Eigensolver

Sunday, 27 January 2019 10:15 (25 minutes)

While quantum algorithms are believed to be more powerful than classical algorithms, the computational power of near term quantum devices is highly restricted because of noise.
In order to overcome the limitations and exploit quantum advantages on noisy quantum devices, it is important to develop algorithms which complete each run of quantum computation within a short coherence time.
Quantum-classical hybrid methods have attracted a lot of attention for this purpose.

In this talk, a variational method (VanQver) is introduced in adiabatic quantum computation.
In particular, the efficiency of the algorithm is demonstrated in simulating molecular systems. It is shown that each run time required to reach chemical accuracy is reduced by two or three orders of magnitude compared to that of the standard AQC.

Primary author: Dr MATSUURA, Shunji (1QBit)

Co-authors: ZARIBAFIYAN, Arman (1QBit); YAMAZAKI, Takeshi (1QBit); SENICOURT, Valentin (1QBit)

Presenter: Dr MATSUURA, Shunji (1QBit)

Session Classification: Quantum Enhanced Optimization I

Track Classification: Quantum enhanced optimization

Contribution ID: **8** Type: **not specified**

Faster classical sampling from distributions defined by quantum circuits

Saturday, 26 January 2019 11:30 (40 minutes)

The leading candidate task for benchmarking quantum computers against classical computers entails sampling from the output distribution defined by a random quantum circuit. We develop a massively-parallel simulation package that does not require inter-process communication (IPC) or proprietary hardware. We introduce two ways to trade circuit fidelity for computational speedups, so as to match the fidelity of a given quantum computer. Our software achieves massive speedups for the sampling task over prior software from Microsoft, IBM, Alibaba and Google, as well as supercomputer and GPU-based simulations. By using publicly available Google Cloud Computing, we price such simulations and enable comparisons by total cost across hardware platforms. We simulate approximate sampling from the output of a circuit with 7×8 qubits and depth 1+40+1 by producing one million bitstring probabilities with fidelity 0.5 percent, at an estimated cost of USD 35184. Simulating circuits of depth to 1+48+1 would cost one million dollars.

Primary author: MARKOV, Igor (University of Michigan)

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Presenter: MARKOV, Igor (University of Michigan)

Session Classification: Foundations of Quantum Computing

Track Classification: Foundations of quantum computing

Contribution ID: **12** Type: **not specified**

Quantum information processing with trapped ions

Monday, 28 January 2019 14:30 (25 minutes)

With exceptional coherence and gate fidelities, trapped ions offer unique opportunities to process quantum information. As a consequence quantum algorithms with up to 20 ions have been implemented on trapped-ion quantum computers. To take the next steps will require the research community to take on the engineering challenges as well as exploring improving fundamental aspects.

I will describe our new effort on learning how to handle a larger number of qubits by means of splitting, transporting and merging ion crystals in a chip trap. To aid in miniaturization and speeding up these operations, the ions need to be trapped within about 50 micrometers from the surface. I will discuss how to mitigate the ensuing electric field noise via surface treatment of the trap electrodes. Finally, I will argue that replacing the ions with trapped electrons would speed up ion trap quantum computers by more than two orders of magnitude while at the same reducing some of the engineering challenges of trapped ions by removing the need for laser sources.

Primary author: Prof. HAEFFNER, Hartmut (UC Berkeley)

Presenter: Prof. HAEFFNER, Hartmut (UC Berkeley)

Session Classification: Architecture II

Track Classification: Qubit architectures

Contribution ID: **13** Type: **not specified**

Open-source scientific computing for quantum technology: QuTiP

Saturday, 26 January 2019 14:30 (40 minutes)

I address the growth of open-source software in scientific research and quantum technology research in particular, both in academia and industry. I will give a brief overview of multiple open-source libraries being developed to study quantum systems, using a variety of hybrid techniques, from chemistry to machine learning. QuTiP, the Quantum Toolbox in Python, has established itself as a major tool in the quantum optics community to study open quantum systems. Due to its capability to model noisy quantum systems, QuTiP is also being used by many players in the field of quantum computing, from startups to corporate research labs. The success of QuTiP lies in the development of an integrated environment to address quantum-specific tasks such as solving complex-valued ODEs and dealing with special algebras. I will give an overview of recent developments in QuTiP, focusing on the integration of permutational invariant techniques, which allow us to efficiently study cooperative effects in driven-dissipative many-body quantum systems out of equilibrium. Finally, I show the simple steps leading to the development of open-source tools for scientific exploration in quantum technology and how this can benefit the research community.

Primary author: Dr SHAMMAH, Nathan (RIKEN)

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Presenter: Dr SHAMMAH, Nathan (RIKEN)

Session Classification: Open-source tools and quantum machine learning

Track Classification: Open-source tools and quantum machine learning

Contribution ID: **14** Type: **not specified**

Cherenkov and scintillation light detection in large array bolometers, and potential synergy with QIS

Tuesday, 29 January 2019 11:30 (25 minutes)

CUPID (CUORE Upgrade with Particle ID) is a next-generation tonne-scale experiment that will use arrays of low-temperature calorimeters to search for rare processes like neutrinoless double beta decay. While CUORE (Cryogenic Underground Observatory for Rare Events) has already demonstrated the concept of operating a tonne-scale array at low temperatures (~10 mK), CUPID aims to significantly improve on the search sensitivity by using novel methods for background rejection. One technique is to enable event-by-event background rejection by reading out phonon and photon signals simultaneously from a scintillating crystal or a Cherenkov light-emitting crystal. We have an ongoing R&D effort at ANL, LBNL, and UCB towards developing sensitive optical-photon detectors that can measure tiny amounts of scintillation/Cherenkov light from low-temperature calorimeters. The detectors use a novel Iridium/Platinum bilayer superconducting transition-edge-sensor (TES) that can be operated at temperatures below ~ 40 mK, and have shown promising results in terms of energy and timing resolution. There is significant synergy between this detector R&D and QIS: from our experience in deploying customized large-scale millikelvin infrastructure, to the development of low-noise SQUIDs and their multiplexing electronics, to cryogenic high quantum efficiency detectors with single-photon resolution.

Primary author: Dr SINGH, Vivek (University of California, Berkeley)

Presenter: Dr SINGH, Vivek (University of California, Berkeley)

Session Classification: Sensing IV

Track Classification: Quantum sensing

Contribution ID: **15** Type: **not specified**

Shortcut to generation of macroscopic superposition states via coherent driving field

Monday, 28 January 2019 12:35 (25 minutes)

We propose a scheme to generate macroscopic superposition states (MSSs) of two classically distinct states in spin ensembles where a coherent driving field is applied to accelerate the process of generating MSSs via a nonlinear interaction [1]. The numerical calculation demonstrates that this approach allows one to generate a superposition of coherent spin states (CSSs) of the spin ensemble with a high fidelity above 0.97 for 300 spins. For a larger spin ensemble, the fidelity stays above 0.84 for an ensemble of 500 spins. The generated MSSs exhibit nonclassicality even when the number of spin fluctuates: With a 5% fluctuation of in the number of spins, the parity of the number of $+x$ and $-x$ directed spins exhibits a fringe with respect to the rotation angle about the z axis. The nonclassicality of the generated MSSs is also robust against the fluctuation in the coherent driving strength. The time to generate an MSS is also estimated, which shows that the significantly shortened state-preparation time allows one to achieve such MSSs within a typical coherent time of the system [2,3].

[1] E. Yukawa et al., Phys. Rev. A **97**, 013820 (2018); [2] H. Strobel et al., Science **345**, pp. 424-427 (2010); [3] J. G. Bohnet et al., Science **352**, pp. 1279-1301 (2016).

Primary author: Dr YUKAWA, Emi (CEMS, RIKEN)

Co-authors: Prof. MILBURN, G. J. (School of Mathematics and Physics, the University of Queensland); Prof. NEMOTO, Kae (National Institute of Informatics)

Presenter: Dr YUKAWA, Emi (CEMS, RIKEN)

Session Classification: Architecture I

Track Classification: Qubit architectures

Contribution ID: **16** Type: **not specified**

Advancing quantum computing as a platform for scientific discovery in chemical sciences

Saturday, 26 January 2019 15:15 (40 minutes)

The Quantum Algorithms Team led out of Lawrence Berkeley National Laboratory is an integrated team of quantum algorithm developers, mathematicians, and computer scientists with a mission to deliver algorithmic, computational and mathematical advances to enable scientific discovery in chemical sciences on quantum computers. Our focus is on quantum chemistry simulations, which are an early exemplar of quantum computing, demonstrating the potential of various types of quantum devices to aid in scientific discovery in the chemical sciences.
Our team has assessed the robustness of state preparation (https://arxiv.org/abs/1809.05523), devised new sparse techniques with lower gate depth (https://arxiv.org/abs/1810.02327), and have explored the use of tensor networks (https://arxiv.org/abs/1803.11537). Preparation of scientifically relevant states is a key challenge for chemical simulations. We have developed a protocol to discriminate between decoherence and information scrambling as a way to verify quantum circuits, which was experimentally validated on an ion trap (https://arxiv.org/abs/1807.09087). Our team is exploring a quantum autoencoder and its strongly reduced latent space for a quantum machine learning model. Gate depth of a quantum circuit plays a critical role in achieving results with high fidelity. The QAT team, in partnership with NASA, has demonstrated low depth circuits for k-local gates in QAOA and Trotterized fermionic Hamiltonians. We extended the open-source quantum simulation software framework ProjectQ with gate-level noise injection capabilities for error analysis, and used it to demonstrate that a rudimentary approach to mitigate errors in a CNOT gate operation can improve the gate fidelity. Additional efforts for error mitigation are ongoing. We have developed a large suite of stochastic classical optimizers, needed for variational quantum eigensolvers and qubit gate optimization. The optimizers have been packaged (github.com/scikit-quant) for integration in quantum computing software stacks. We are continuing to develop new and better stochastic optimizers.

Primary author: DE JONG, Wibe

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Presenter: DE JONG, Wibe

Session Classification: Open-source tools and quantum machine learning

Track Classification: Open-source tools and quantum machine learning

Contribution ID: **17** Type: **not specified**

Exploring a potential link between environmental radiation and excess quasiparticles in superconducting qubits

Tuesday, 29 January 2019 12:00 (25 minutes)

Excess quasiparticles are universally observed to limit coherence times in superconducting qubits. It is hypothesized that natural radiation in the laboratory environment could be the cause. We will review the evidence for excess quasiparticles and explore our hypothesis that environmental radiation is the source of them. Plans for an imminent experiment to test the hypothesis by placing a series of radioactive sources in close proximity to qubit specimens will be presented.

Primary author: Dr VANDEVENDER, Brent (Pacific Northwest National Laboratory)

Co-authors: Prof. FORMAGGIO, Joe (Massachusetts Institute of Technology); Dr ORRELL, John (Pacific Northwest National Laboratory); Prof. OLIVER, Will (Massachusetts Institute of Technology and Lincoln Labs)

Presenter: Dr VANDEVENDER, Brent (Pacific Northwest National Laboratory)

Session Classification: Sensing IV

Track Classification: Quantum sensing

Contribution ID: **19** Type: **not specified**

Pear-Shaped Qubits: Quantum Computing with Dipolar Molecules

Monday, 28 January 2019 15:00 (25 minutes)

Electrically neutral dipolar molecules prepared in the absolute ground state represent one of the newest additions to the quantum-information and simulation family tree. Prepared in the lowest rotational state ($N = 0$), and in the absence of a polarizing electric field, neutral dipolar molecules lack a lab-frame electric dipole moment (EDM). However, admixing components of higher rotational states generates an EDM of order a Debye (for the bialkalis) which provides a route to controllable long-range interactions. It is the tunability of this interaction that makes these molecules an ideal candidate for qubits. Furthermore, using the same scheme one can add a long-range interaction term to the optical-lattice Hubbard Hamiltonian creating the opportunity to study dipolar exchange physics. One can also choose to polarize the molecules with a strong electric field in order to, for example, investigate quantum magnetism in the XXZ-Hamiltonian.

Bialkali molecules represent an excellent opportunity to apply state of the art techniques from the world of degenerate gasses to advance the field of quantum computation. I will discuss our current effort towards creating ground state bosonic Lithium-Rubidium molecules and present some technical challenges we think could benefit from collaboration with the LBL community.

Primary author: Dr ISAACS, Joshua (UC Berkeley)

Co-authors: Mr SMULL, Aaron (UC Berkeley); Prof. STAMPER-KURN, Dan (UC Berkeley, LBL); Ms FANG, Fang (UC Berkeley)

Presenter: Dr ISAACS, Joshua (UC Berkeley)

Session Classification: Architecture II

Track Classification: Qubit architectures

Contribution ID: **20** Type: **not specified**

A high-temperature silicon qubit and its quantum interference

Monday, 28 January 2019 12:10 (25 minutes)

Spin qubits are attractive building blocks for quantum computers. Si is a promising host material for spin qubits since it could enable long coherence, high-density integration, and high compatibility with classical computers. Spin qubits have been implemented in Si using gate-defined quantum dots or shallow impurities. However, these qubits must be operated at temperatures <0.1 K, limiting the expansion of qubit technology. We used deep impurities in Si to achieve room-temperature single-electron tunnelling and spin qubit operation at 5–10 K [1]. We employed tunnel field-effect transistors (TFETs) instead of conventional metal–oxide–semiconductor field-effect transistors and achieved strong confinement of the single quantum dots embraced in TFETs up to 0.3 eV. Furthermore, double-quantum-dot devices were operated as spin qubits, and read-out was realized using a spin blockade. These results will enable broadening of the range of spin qubit applications such as sensing, security, and quantum computing.

We also study quantum interference effects of a qubit whose energy levels are continuously modulated [2]. The qubit energy levels are modulated via its gate-voltage-dependent g-factors, with either rectangular, sinusoidal, or ramp radio-frequency waves. The energy-modulated qubit is probed by the electron spin resonance. Our results demonstrate the potential of spin qubit interferometry that is implemented in a Si device and is operated at a relatively high temperature

[1] K. Ono, T. Mori, S. Moriyama, High-Temperature Operation of Spin Qubits based on Silicon Tunnel Field-Effect Transistors, arXiv:1804.03364, Scientific reports, in print.
[2] K. Ono, S. N. Shevchenko, T. Mori, S. Moriyama, Franco Nori, Quantum interferometry with a high-temperature single-spin qubit, arXiv:1809.02326.

Primary author: Dr ONO, Keiji (RIKEN)

Presenter: Dr ONO, Keiji (RIKEN)

Session Classification: Architecture I

Track Classification: Qubit architectures

Contribution ID: **21** Type: **not specified**

The dc SQUID as a Quantum Limited Amplifier

Monday, 28 January 2019 09:30 (40 minutes)

The Josephson tunnel junction consists of two superconductors separated by a thin insulating barrier through which, at low electrical currents, Cooper pairs of electrons can tunnel without producing a voltage. When the applied current is increased above a value known as the critical current, however, a voltage is developed. The dc Superconducting QUantum Interference Device (SQUID) consists of two Josephson junctions connected in parallel on a superconducting loop. The SQUID is operated by passing a current through the two junctions. When an external magnetic field is applied to induce a magnetic flux in the loop, the critical current of the SQUID oscillates as a function of the flux with a period of one flux quantum, $h/2e$. Here, h is the Planck constant and e the electronic charge. With appropriate electronics one can detect changes in flux of a millionth of a flux quantum—or even less—in a bandwidth of 1 Hz. To make an amplifier one inductively couples the SQUID loop to a superconducting input circuit in series with an oscillating voltage source and appropriate circuitry, and detects the amplified voltage developed across the current-biased SQUID. I discuss in detail the theory of intrinsic noise in the SQUID, which originates as Nyquist noise in the shunt resistor connected across each Josephson junction. The noise at the signal frequency arises from two components of noise generated in the shunt resistors: one at the signal frequency and the other at the much higher Josephson frequency $2eV/h$, where V is the bias voltage of the SQUID, mixed down to the signal frequency by the nonlinearity of the junctions. For a single junction with appropriate design parameters and bias current, I illustrate the second term with the direct observation of zero-point fluctuations. The theory of the noise temperature for a quantum-limited SQUID amplifier yields hf/k at signal frequency f, where k is the Boltzmann constant. Finally, I show results for a SQUID amplifier operating at 50 mK with a measured noise temperature close to the quantum limit.

Primary author: CLARKE, John (University of California, Berkeley)

Presenter: CLARKE, John (University of California, Berkeley)

Session Classification: Sensing II

Track Classification: Quantum sensing

Contribution ID: **22** Type: **not specified**

Continuous Quantum Error Correction for Quantum Annealing enabled by measurement-based feedback

Sunday, 27 January 2019 11:30 (25 minutes)

I shall present an approach to continuous error correction with application to error correction of quantum annealing. Our approach is based on use of weak measurements and quantum feedback, together with quantum error correcting codes. I shall present preliminary results using both error detecting and error correcting codes, and discuss the relative benefits of different paradigms of quantum encoding, e.g., via subspace and subsystem codes.

Primary author: Prof. WHALEY, K. Birgitta (UC Berkeley)

Presenter: Prof. WHALEY, K. Birgitta (UC Berkeley)

Session Classification: Quantum Enhanced Optimization II

Track Classification: Quantum enhanced optimization

Contribution ID: **23** Type: **not specified**

Light dark matter detection with superfluid helium

Tuesday, 29 January 2019 10:30 (25 minutes)

We propose a new technology for dark matter direct detection, using superfluid helium as the target material. Superfluid helium has many merits as a detector target; these include good kinematic matching to low mass dark matter, feasibility for achieving good intrinsic radiopurity, multiple signals to enable radioavtive and instrumental background rejection, and its unique ability to be cooled down to milli-Kelvin temperatures while remaining a liquid. To measure the 16 eV prompt scintillation photons, we will submerge calorimetric photodetectors in the liquid, while rotons and phonons will be detected through the quantum evaporation of helium atoms off the liquid surface, into vacuum, and then their adsorption onto a calorimeter. The binding energy from helium adsorption to the calorimeter surface allows for the amplification of these quantum evaporation signals, allowing us to potentially reach recoil energy thresholds down to 1 meV. Taking into account the relevant backgrounds and the detector discrimination power, sensitivity projections show that a small detector (~100 g scale) can already explore new dark matter parameter space. I will discuss the technology and instrumentation underlying this proposal, as well as the R&D we are performing to advance this campaign.

Primary author: Prof. MCKINSEY, Daniel (UC Berkeley)

Presenter: Prof. MCKINSEY, Daniel (UC Berkeley)

Session Classification: Sensing III

Track Classification: Quantum sensing

Contribution ID: **24** Type: **not specified**

Manipulation of electron waves and solid-state flying qubits

Monday, 28 January 2019 17:45 (25 minutes)

Varieties of solid-state quantum bits have been investigated, among which the most prominent are superconducting quantum circuits and semiconductor quantum dots. All of them are defined as "localized"quantum two-level systems. Benefits of using such localized systems are isolation of qubits from their environment and potential ability to control individual qubits and inter-qubit coupling with high fidelity. On the other hand, it has been revealed that quantum error correction requires numerous physical qubits to construct a protected logic qubit. For localized systems, one needs hardware for all localized physical qubits being operated continuously to keep protection from errors. In contrast, delocalized quantum two-level systems offer a completely different architecture. In photonic qubits, qubits are created on-demand. The number of qubits is not determined by the hardware size. Manipulation of electron waves allows us to construct electrically tunable delocalized qubits in scalable solid-state systems, where qubits are created on-demand by short voltage pulses. Manipulation of electron waves can also be used to solve problems in condensed matter physics in terms of the quantum interference and phase measurement.

In this talk, we present our projects on manipulation of electron waves. We also apply it on the Kondo physics, demonstrating the most fundamental properties of the Kondo state, the pi/2 phase shift and spatial extension of a Kondo cloud.

Primary author: Dr YAMAMOTO, Michihisa (RIKEN Center for Emergent Matter Science)

Presenter: Dr YAMAMOTO, Michihisa (RIKEN Center for Emergent Matter Science)

Session Classification: Architecture III

Track Classification: Qubit architectures

Contribution ID: **25** Type: **not specified**

Quantum annealing for polynomial systems of equations

Sunday, 27 January 2019 10:45 (10 minutes)

Numerous fields require numerically solving a system of linear equations. For equations stemming from large, sparse matrices, this is classically done with iterative methods and judicious preconditioning. Convergence of such algorithms can be highly variable and depends in part, on the condition number of the matrix. With the arrival of quantum computing in the Noisy Intermediate-Scale Quantum era, we present a quantum annealing algorithm which directly solves systems of linear equations with favorable scaling with respect to condition number. The algorithm can also be extended to solve systems of polynomial equations. We discuss the theoretical framework for this method and perform experiments of the algorithm with a quantum annealer. Scaling with respect to matrix rank, condition number, and search precision is studied. Finally, we define an iterative annealing process and demonstrate its efficacy in solving a linear system to a tolerance of 10−8.

Primary author: Dr GAMBHIR, Arjun (Lawrence Livermore National Laboratory)

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Presenter: Dr GAMBHIR, Arjun (Lawrence Livermore National Laboratory)

Session Classification: Quantum Enhanced Optimization I

Track Classification: Quantum enhanced optimization

Contribution ID: **26** Type: **not specified**

Valley-Mechanical Coupling in a Monolayer Semiconductor

Sunday, 27 January 2019 15:30 (25 minutes)

The interaction of macroscopic mechanical object with electron charge and spin plays a vital role in today's information technology and fundamental studies of the quantum-classical boundary. Recently emerged valleytronics encodes information to the valley degree-of-freedom and promises exciting applications in communication and computation. We realize valley-mechanical coupling in a monolayer MoS2 resonator and demonstrate transduction of valley information to the mechanical states. The valley and mechanical degrees-of-freedom are coupled through the magnetic moment of the valley carriers under a magnetic field gradient. We identify the valley-actuated mechanical motion by optical interferometry and attain a transduction confidence level near unity. Our experiment lays the foundation for a new class of valley-controlled mechanical devices and facilitates realization of hybrid quantum valley-mechanical systems.

Primary authors: Mr LI, Haokun (University of California, Berkeley); Dr FONG, King Yan (University of California, Berkeley)

Co-author: Prof. ZHANG, Xiang (University of California, Berkeley)

Presenter: Mr LI, Haokun (University of California, Berkeley)

Session Classification: Condensed Matter I

Track Classification: Condensed matter applications

Contribution ID: **27** Type: **not specified**

Quantum circuit learning: a variational quantum algorithm for machine learning

Saturday, 26 January 2019 16:30 (25 minutes)

We propose a classical-quantum hybrid algorithm for machine learning on near-term quantum processors, which we call quantum circuit learning. A quantum circuit driven by our framework learns to perform a given task by tuning parameters implemented on it. We also provide a way to obtain an analytical gradient of an expectation value of an observable for gradient-beased optimization of parameters. Theoretical investigation shows that a quantum circuit can approximate nonlinear functions, which is further confirmed by numerical simulations. Quantum circuits can provide feature maps that have not been accessible with classical approach. Hybridizing a low-depth quantum circuit and a classical computer for machine learning.

Primary author: Mr MITARAI, Kosuke (Osaka University)

Co-authors: Dr FUJII, Keisuke (Kyoto University); Dr NEGORO, Makoto (Osaka University); Prof. KITAGAWA, Masahiro (Osaka University)

Presenter: Mr MITARAI, Kosuke (Osaka University)

Session Classification: Quantum machine learning and quantum sensing

Track Classification: Open-source tools and quantum machine learning

Contribution ID: **28** Type: **not specified**

Noise magnetometry with spin qubits: A window into fractionalization and anyonic statistics in magnetic insulators

Tuesday, 29 January 2019 15:30 (25 minutes)

Two-dimensional magnetic insulators exhibit a plethora of competing ground states, such as ordered (anti)ferromagnets, quantum spin liquids characterized by topological order and anyonic excitations, and random singlet phases emerging in the presence of disorder and frustration. Single spin qubits, which interact directly with the low-energy spin-excitations of magnetic insulators, can be used as a diagnostic of magnetic ground states. Experimentally tunable parameters, such as qubit level splitting, sample temperature, and qubit-sample distance, can be used to measure spin correlations with energy and wavevector resolution. Such resolution can be exploited to distinguish between fractionalized excitations in spin liquids and spin waves in magnetically ordered states, or to detect anyonic statistics in systems with a finite energy gap.

Primary author: Mr CHATTERJEE, Shubhayu (UC Berkeley)

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Presenter: Mr CHATTERJEE, Shubhayu (UC Berkeley)

Session Classification: Sensing V

Track Classification: Quantum sensing

Contribution ID: **29** Type: **not specified**

Real-space renormalization group analysis of the frustrated Ising ladder in a transverse field

Sunday, 27 January 2019 12:30 (25 minutes)

Studying phase transitions of the transverse-field Ising model is significant from the viewpoint of quantum annealing. Presence of a first-order phase transition is one of the most serious problems because it makes computation time of quantum annealing exponentially large as a function of the system size. We consider the frustrated Ising ladder in a transverse field, which is known to exhibit a first-order phase transition by means of numerical diagonalization. In this presentation, we study the phase transition of this model using the real-space renormalization group (RG) method to understand this transition more deeply. We propose an RG procedure in which a variational method is used after block partition of the ladder to find a low-energy space. Calculating the solution to the RG equation, we find a critical point not far from the value obtained by the numerical diagonalization. In addition, we show that the scaling exponent of the longitudinal field on the bottom row of the ladder is equal to one, the dimension of the system. This indicates that the phase transition is of first order. As a future work, it may be possible to study the system with transverse interactions or inhomogeneous transverse field in order to investigate whether the first-order phase transition can be avoided.

Primary author: Mr TAKADA, Kabuki (Tokyo Institute of Technology)

Co-authors: Prof. LIDAR, Daniel (University of Southern California); Prof. NISHIMORI, Hidetoshi (Tokyo Institute of Technology)

Presenter: Mr TAKADA, Kabuki (Tokyo Institute of Technology)

Session Classification: Quantum Enhanced Optimization II

Track Classification: Quantum enhanced optimization

Contribution ID: **30** Type: **not specified**

Quantum Amplifiers for the Axion Dark Matter Experiment (ADMX)

Monday, 28 January 2019 10:35 (25 minutes)

One of the most interesting problems in physics and cosmology today is what makes up dark matter. The QCD axion is a well motivated candidate and is predicted to be very light (μeV mass) and very cold, meaning it would interact more like a radio wave then an ionizing particle. The Axion Dark Matter Experiment (ADMX) uses the "haloscope technique" to search for axions resonantly converting to detectable photons in a microwave cavity immersed in a strong magnetic field. The critical components for enabling an efficient search for dark matter axions are near quantum limited superconducting amplifiers. Here I will describe the implementation in ADMX of both a Microstrip SQUID amplifiers (MSA) and a Josephson Parameteric Amplifiers (JPAs), both of which were developed at UC Berkeley. These quantum amplifiers enable ADMX to cover the entire range of potential axion couplings for the first time. I will also discuss the potential to use single-photon counting to enable higher frequency axion searches where the standard-quantum limit may become the limiting factor.

Primary author: Dr CAROSI, Gianpaolo (Lawrence Livermore Natl Lab)

Presenter: Dr CAROSI, Gianpaolo (Lawrence Livermore Natl Lab)

Session Classification: Sensing II

Track Classification: Quantum sensing

Contribution ID: **31** Type: **not specified**

Quantum simulation with ultracold atoms in optical lattices

Monday, 28 January 2019 17:15 (25 minutes)

Ultracold atoms, which are gaseous atoms cooled to the quantum regime by laser cooling and evaporative cooling, provide ideal platforms to study many-body quantum systems. Especially, such atoms loaded into in periodic potential (optical lattice) created by laser beams can be used to “simulate”fundamental condensed-matter models, such as the Hubbard model or the Heisenberg spin model. In this talk I explain ultracold atoms in optical lattices as a quantum simulator. I also report recent activities of our experiments with bosonic Rb atoms towards quantum simulation.

Primary author: Dr FUKUHARA, Takeshi (RIKEN CEMS)

Presenter: Dr FUKUHARA, Takeshi (RIKEN CEMS)

Session Classification: Architecture III

Track Classification: Qubit architectures

Contribution ID: **32** Type: **not specified**

Materials design for dark matter detection

Tuesday, 29 January 2019 10:00 (25 minutes)

The direct detection of light dark matter (DM) relies on harnessing low-threshold events in target materials. Here I will discuss two proposals for the direct detection of light DM; Dirac materials and polar semiconductors. Using first-principles methods, we calculate the material-specific matrix elements, and show that DM scattering in an anisotropic crystal has a strong directional dependence. We find that both Dirac electron and phonon-based detectors have comparable or greater sensitivity to sub-MeV dark matter scattering and sub-eV dark matter absorption than other current proposals.

Primary author: Dr GRIFFIN, Sinéad (Lawrence Berkeley National Laboratory)

Co-authors: ZUREK, Kathryn; KNAPEN, Simon (IAS Princeton); LIN, Tongyan (UCSD); KAHN, Yoni (University of Chicago)

Presenter: Dr GRIFFIN, Sinéad (Lawrence Berkeley National Laboratory)

Session Classification: Sensing III

Track Classification: Quantum sensing

Contribution ID: **33** Type: **not specified**

SQUID based frequency multiplexing readout and commercial fabrication for superconducting sensors

Monday, 28 January 2019 10:10 (25 minutes)

Transition edge sensors (TES) are work horses of physics experiments. In pursuit for more sensitivity, experiments such as Cosmic Microwave Background (CMB) polarimetry experiments and neutrino-less double beta decay experiments are increasing number of sensors. As TES operate at sub-Kelvin temperature, highly multiplexed, low-noise and low power dissipation multiplex readout technique is a key for successful operation. CMB experiments have been implementing frequency multiplexing (fmux) readout scheme. The current deployed fmux system readout up to 68 TES bolometers per single SQUID amplifier.
I will describe on-going development to improve fmux system for future experiments that goes beyond CMB experiments. We have designed and fabricated custom SQUID amplifier with STAR Cryoelectronics that has low input impedance, low power dissipation and high transimpedance. Using this amplifier, we are exploring new fmux readout configuration to further lower readout noise contribution, increase multiplexing factor and simply sub-Kelvin integration. We have been testing readout system while coupling them to TES bolometers fabricated by HYPRES, a commercial foundry. I will describe how these development will enable future CMB experiment and possibly neutrino-less double beta decay experiment and light Dark Matter experiments.
I will also share experience with commercial foundry to fabricate superconducting devices as these maybe attractive way to develop devices for future QIS devices.

Primary author: Dr SUZUKI, Aritoki (Lawrence Berkeley National Lab)

Presenter: Dr SUZUKI, Aritoki (Lawrence Berkeley National Lab)

Session Classification: Sensing II

Track Classification: Quantum sensing

Contribution ID: **34** Type: **not specified**

Performance enhancement of quantum annealing by non-traditional quantum driving

Sunday, 27 January 2019 09:30 (40 minutes)

After an introduction and an overview of quantum annealing, I describe recent developments in non-traditional protocols to control quantum effects for enhanced performance: (i) non-stoquastic drivers [1], (ii) spatially inhomogeneous driving of the field [2], and (iii) reverse annealing [3]. I will show explicit examples in which first-order quantum phase transitions can be avoided by these methods, implying an exponential speedup in comparison with the traditional simple transverse-field driving.

[1] Y. Seki and H. Nishimori, Phys. Rev. E 85, 05112 (2012), J. Phys. A48, 335301 (2015), B. Seoane and H. Nishimori, J. Phys. A45, 435301 (2012), H. Nishimori and K. Takada, Frontiers in ICT, 4, 2 (2017), M. Ohkuwa and H. Nishimori, J. Phys. Soc. Jpn. 86, 114004 (2017). Y. Susa, J.F. Jadebeck and H. Nishimori, Phys. Rev. A 95, 042321 (2017).

[2] Y. Susa, Y. Yamashiro, M. Yamamoto and H. Nishimori, J. Phys. Soc. Jpn. 87, 023022 (2018), Susa, Y. Yamashiro, M. Yamamoto, I. Hen, D.A. Lidar and H. Nishimori, Phys. Rev. A 98, 042326 (2018)

[3] M. Ohkuwa, H. Nishimori, and D.A. Lidar, Phys. Rev. A 98, 022314 (2018).

Primary author: Prof. NISHIMORI, Hidetoshi (Tokyo Institute of Technology)

Presenter: Prof. NISHIMORI, Hidetoshi (Tokyo Institute of Technology)

Session Classification: Quantum Enhanced Optimization I

Track Classification: Quantum enhanced optimization

Contribution ID: **35** Type: **not specified**

Quantum Algorithmic Breakeven: on scaling up with noisy qubits

Sunday, 27 January 2019 12:00 (25 minutes)

As quantum computing proceeds from perfecting physical qubits towards testing logical qubits and small scale algorithms, an urgent question being confronted is how to decide that critical milestones and thresholds have been reached. Typical criteria are gates exceeding the accuracy threshold for fault tolerance, logical qubits with higher coherence than the constituent physical qubits, and logical gates with higher fidelity than the constituent physical gates. In this talk I will argue in favor of a different criterion I call "quantum algorithmic breakeven", which focuses on demonstrating an algorithmic scaling improvement in an error-corrected setting over the uncorrected setting. I will present evidence that current experiments with commercial quantum annealers have already crossed this threshold. Time permitting, I will also discuss our latest evidence for a scaling advantage for a quantum annealer over simulated annealing with such devices. The lessons we have learned from experimenting with commercial devices with many noisy qubits will hopefully inform other approaches to quantum computing.

Primary author: Prof. LIDAR, Daniel (USC)

Presenter: Prof. LIDAR, Daniel (USC)

Session Classification: Quantum Enhanced Optimization II

Track Classification: Quantum enhanced optimization

Contribution ID: **36** Type: **not specified**

Si platform for fault tolerant spin-based quantum computation with quantum dots

Monday, 28 January 2019 11:30 (40 minutes)

To date basic techniques of implementing spin-based quantum computing have been developed using quantum dots, including single and two-qubit gates, initialization and readout. But improving the operation fidelity as well as increasing the qubit number is still a challenge in realizing fault-tolerant quantum computing. We have developed a fast gating technique for Si quantum dots to operate the qubits with high fidelity. I will first talk about our approach to improve the gate fidelity for single and two qubit gates and discuss the limiting factor of the fidelity. I will then review the current research and development to scale up the qubit system.

Primary author: Prof. TARUCHA, Seigo (RIKEN CEMS / University of Tokyo)

Presenter: Prof. TARUCHA, Seigo (RIKEN CEMS / University of Tokyo)

Session Classification: Architecture I

Track Classification: Qubit architectures

Contribution ID: **37** Type: **not specified**

Engineering topological states of exciton-polaritons with Non-Hermitian potentials

Sunday, 27 January 2019 16:30 (25 minutes)

Emerging research in topological photonic systems promises new ways to control light flow without dissipation and the possibility of creating new functional photonic devices exploiting topology. Creating topological states in the microcavity exciton-polariton system would represent a topological photonic platform where interactions might further be used to control strongly-correlated topological states of matter.

We explore the possibility of creating topological states in exciton-polaritons by the use of non-Hermitian, or engineered 'complex' potentials. Specifically, I will describe our fabrication efforts using 'proton-enhanced interdiffusion' to spatially modulate independently the exciton and photon components of the polariton, creating landscapes not only of energy, but also polariton lifetime. We theoretically study the spontaneous emergence of time-reversal symmetry breaking and vortical flow in these complex potentials. Here, the handedness is controlled by the imaginary potential energy terms, and may be used as an element in larger 'topological complex lattices'.

Primary author: Dr FRASER, Michael (RIKEN CEMS / JST PRESTO)

Presenter: Dr FRASER, Michael (RIKEN CEMS / JST PRESTO)

Session Classification: Condensed Matter II

Track Classification: Condensed matter applications

Contribution ID: **38** Type: **not specified**

Characterization of magnetic structures using (coherent) x-rays

Sunday, 27 January 2019 14:30 (25 minutes)

I will lead in by giving a brief overview over the Advanced Light Source and over techniques that may be of interest to the QIS and in particular the quantum materials community. I will then discuss two examples: Photoemission Electron Microscopy (PEEM), which was used to study the ground state and thermal dynamics of artificial spin ice systems and soft x-ray interferometry, which we used to determine material properties in a prototypical Young's double slit experiment. The systems are classical in nature but the discussed techniques could be of interest to this community as well. I will in particular concentrate on the opportunities provided by the high coherent x-ray flux provided by next generation, diffraction-limited storage rings. e.g., ALS-U.

Primary author: SCHOLL, Andreas (Lawrence Berkeley Lab)

Presenter: SCHOLL, Andreas (Lawrence Berkeley Lab)

Session Classification: Condensed Matter I

Track Classification: Condensed matter applications

Contribution ID: **39** Type: **not specified**

Spontaneous spin-chain fluctuation observed with coherent x-ray scattering

Sunday, 27 January 2019 15:00 (25 minutes)

As we explore new materials harboring entangled quantum states, an efficient probe for their detection is necessary. Coherent x-rays are a direct probe for equilibrium and nonequilibrium dynamics that can simultaneously measure a large number of particles. In my talk, I will use our recent work on dipolar-coupled artificial spin lattices (ASL) and explore the possible route to use coherent x-rays as a probe for entangled spintronic system. Dipolar-coupled systems are receiving considerable interest lately due to their possible application to quantum storage device and quantum computing. However, their collective dynamics in the vicinity of phase transitions is still an under-explored area. We studied magnetic dynamics in ASL using coherent soft x-rays. Our analysis revealed spontaneous nucleation and annihilation of spin-chains with a 3 ms fluctuation time.

Primary author: CHEN, Xiaoqian (Lawrence Berkeley National Laboratory)

Co-authors: Prof. HASTINGS, J. Todd (University of Kentucky); Dr ROY, Sujoy (Lawrence Berkeley National Laboratory)

Presenter: CHEN, Xiaoqian (Lawrence Berkeley National Laboratory)

Session Classification: Condensed Matter I

Track Classification: Condensed matter applications

Contribution ID: **40** Type: **not specified**

Quantum technology to measure the fine structure constant and illuminate biology

Tuesday, 29 January 2019 12:30 (25 minutes)

Quantum technology enables new measurements and thus new insights in fundamental physics, applied physics, chemistry, and biology. We will discuss two examples:

Using interference of matter waves, we have recorded the most precise measurement of the fine structure constant, at 0.20-part-per-billion accuracy. Comparison with Penning trap measurements of the electron gyro-magnetic anomaly is a broad and deep test of the Standard Model of particle physics, and sets bounds on dark-sector candidates that are competitive with accelerator tests.

In transmission electron microscopy, using lasers to manipulate the electron wave function can be used to extract all information that is physically present in the electron stream. We have developed Zernike phase contrast in electron microscopy. We will discuss implications for structural biology and future plans to attain Heisenberg-limited imaging with electrons.

Primary author: Prof. MÜLLER, Holger (UC Berkeley)

Presenter: Prof. MÜLLER, Holger (UC Berkeley)

Session Classification: Sensing IV

Track Classification: Quantum sensing

Contribution ID: **41** Type: **not specified**

Quantum metrology using a strongly interacting spin ensemble

Tuesday, 29 January 2019 15:00 (25 minutes)

One of the most promising routes towards high-sensitivity quantum metrology is to utilize high density spin ensembles. However, as the density of a spin ensemble is increased, strong spin-spin interactions can impose a limit to the coherence time and thus the maximum achievable sensitivity. In this talk, we will discuss two promising methods to overcome this limitation. In the first approach, a spin ensemble is periodically manipulated in order to effectively decouple spin-spin interactions while keeping its sensitivity to an external probe signal. We present a novel framework to design such a control sequence that is fault-tolerant against both disorder in the system and imperfections in the control parameters. We demonstrate this method using an ensemble of dipolar interacting nitrogen-vacancy color centers and improve the sensitivity beyond that of conventional protocols such as the XY-9 sequence. Our second approach actively utilizes interactions and is based on stable non-equilibrium states of quantum matter such as discrete time crystals. We present explicit protocols to perform Floquet enhanced measurements of an oscillating magnetic field, in which quantum correlations stabilized by strong interactions and periodic driving allow to enhance the sensitivity and/or bandwidth of the protocol beyond the standard quantum limit.

Primary author: CHOI, Soonwon (University of California Berkeley)

Co-authors: JELEZKO, Fedor (Ulm University); KNOWLES, Helena (Harvard University); ZHOU, Hengyun (Harvard University); SUMIYA, Hitoshi (Sumitomo Electric Industries Ltd.); CHOI, Joonhee (Harvard University); ISOYA, Junichi (University of Tsukuba); LUKIN, Mikhail (Harvard University); YAO, Norman (University of California Berkeley); LANDIG, Renate (Harvard University); ONODA, Shinobu (Takasaki Advanced Radiation Research Institute)

Presenter: CHOI, Soonwon (University of California Berkeley)

Session Classification: Sensing V

Track Classification: Quantum sensing

Contribution ID: **42** Type: **not specified**

New Ideas in Dark Matter Detection

Tuesday, 29 January 2019 09:30 (25 minutes)

New Ideas in Dark Matter Detection

Primary author: ZUREK, Kathryn

Presenter: ZUREK, Kathryn

Session Classification: Sensing III

Track Classification: Quantum sensing

Contribution ID: **43** Type: **not specified**

Noisy Intermediate-Scale Quantum Computers

Saturday, 26 January 2019 12:15 (40 minutes)

The immense power of quantum computation is illustrated by flagship quantum algorithms that solve problems, such as factoring, much more efficiently than classical algorithms. The building of a quantum device with error rates well below the fault-tolerance threshold poses a challenge to the implementation of these quantum algorithms on near-term devices. In this talk, I will present the physics of superconducting circuits, one of the most promising technology for building Noisy Intermediate-Scale Quantum (NISQ) computers.
In particular, I will explain the single qubit control, parametric entangling gates, and how these come together in a cloud deployed system. Finally, I will present an unsupervised machine learning algorithm that we have run on our quantum processing unit [1].

[1] https://arxiv.org/pdf/1712.05771.pdf

Primary author: Dr MANENTI, Riccardo (Rigetti)

Presenter: Dr MANENTI, Riccardo (Rigetti)

Session Classification: Foundations of Quantum Computing

Track Classification: Foundations of quantum computing

Contribution ID: **45** Type: **not specified**

Opportunities for Quantum Information Research Using Angle-Resolved Photoemission Spectroscopy

Sunday, 27 January 2019 17:00 (25 minutes)

Angle-resolved photoemission spectroscopy (ARPES) is a premier tool for determining the charged excited states of quantum materials. It directly measures the single particle spectral function $A(k, \omega)$ that encodes the renormalized lifetime and energy of quasiparticle states as a function of momentum (k) and energy (ω). ARPES is complementary to both scanning tunneling microscopy (STM), which does not access the Bloch quantum numbers k, and transport measurements which are sensitive to excited states only near $\omega = 0$. In addition, ARPES is a highly sensitive probe of the symmetry of itinerant Bloch states.

Therefore, ARPES plays a key role in understanding the fundamental properties of emergent ground states in complex materials such as superconductors, 2D, and topological materials, all of which have potential applications in quantum information science. In this talk I will present a review of recent studies of candidate materials for quantum information at the ALS, and in particular I will focus on efforts to enhance spatial resolution, low temperature performance, and *in situ* sample preparation. These abilities will allow ARPES to provide fundamental information for quantum materials not only in pure materials, but also in practical forms such as devices and with tailored surface properties.

Primary author: Dr ROTENBERG, Eli (LBNL)

Presenter: Dr ROTENBERG, Eli (LBNL)

Session Classification: Condensed Matter II

Track Classification: Condensed matter applications

Contribution ID: **46** Type: **not specified**

Color centers for quantum sensing and communication - challenges and opportunities

Tuesday, 29 January 2019 14:30 (25 minutes)

Color centers, such as the nitrogen-vacancy center center in diamond are being used in early quantum sensing applications (e. g. as magnetometers) and they are promising spin-photon qubits with ms-scale coherence times at room temperature. In my presentation I will discuss challenges and opportunities for the further development of NV- centers (e. g. formation efficiency and deterministic placement) and discuss ideas for the search for color centers with properties that can rival and exceed those of the widely used NV- centers.

Primary author: SCHENKEL, Thomas

Presenter: SCHENKEL, Thomas

Session Classification: Sensing V

Track Classification: Quantum sensing

Contribution ID: **47** Type: **not specified**

Lab Overview

Saturday, 26 January 2019 09:30 (20 minutes)

Presenter: Dr SIMON, Horst (Lawrence Berkeley National Laboratory)

Session Classification: Welcome Session

Contribution ID: **48** Type: **not specified**

RIKEN National Science Institute: a brief introduction

Saturday, 26 January 2019 09:53 (20 minutes)

Presenter: Prof. KOTANI, Motoko (RIKEN)

Session Classification: Welcome Session

Contribution ID: **49** Type: **not specified**

RIKEN-Berkeley Workshop: Quantum Information Science

Saturday, 26 January 2019 10:16 (20 minutes)

Presenter: Dr HATSUDA, Tetsuo (RIKEN)

Session Classification: Welcome Session

Contribution ID: **50** Type: **not specified**

QIS Landscape at Berkeley & Advanced Quantum Testbed

Saturday, 26 January 2019 10:40 (20 minutes)

Presenter: CARTER, Jonathan (Lawrence Berkeley National Lab)

Session Classification: Welcome Session

Contribution ID: **85** Type: **not specified**

TBA

Presenter: Prof. MATT, Pyle (UC Berkeley)

Track Classification: Quantum sensing

Contribution ID: **93** Type: **Workshop Talk**

Device Design and Technology Developments for Quantum Sensing Charge-Coupled Devices

Saturday, 26 January 2019 17:00 (25 minutes)

We describe the development of charge-coupled devices (CCDs) capable of detecting single electrons. The CCDs utilize a non-destructive readout amplifier that allows for the multiple sampling of the signal charge with a corresponding reduction in the read noise by the inverse square root of the number of samples. The CCDs have been fabricated on high-resistivity silicon that enables the full depletion of substrates that to date have been as thick as 650 microns. The fully depleted CCD technology was originally developed for astronomy and astrophysics applications, e.g. the Dark Energy Camera, and more recently has been used for direct dark-matter detection given the single-electron sensitivity that the non-destructive readout capability allows. A 4126 x 866, (15 micron pixel)2 CCD developed by the authors achieved a read noise of 0.068 e- after the averaging of 4000 samples [1]. In this work we describe the device and technology design to allow for the operation of the electron counting CCDs at large substrate-bias voltages, typically in the range of 50 −100V, as well as efforts to improve the performance especially as regards to improving the readout times needed for single-electron detection.

[1] J. Tiffenberg, M. Sofo-Haro, A. Drlica-Wagner, R. Essig, Y. Guardincerri†, S. Holland, T. Volansky, and T.-T. Yu, "Single-Electron and Single-Photon Sensitivity with a Silicon Skipper CCD,"PRL 119, 131802, 2017.

Primary author: Dr HOLLAND, Stephen (LBNL)

Presenter: Dr HOLLAND, Stephen (LBNL)

Session Classification: Quantum machine learning and quantum sensing

Track Classification: Quantum sensing

Contribution ID: **94** Type: **Workshop Talk**

Progress Towards sub-eV Phonon and Photon Sensitivity with Athermal Phonon Detector for Light Mass Dark Matter Searches and Other Applications

Saturday, 26 January 2019 17:30 (25 minutes)

Searching for dark matter in the 10meV-100MeV mass range requires sensitivity to small energy depositions. In particular, sensitivity to a single optical phonon quanta in Sapphire (~ 50meV) or 2 roton quanta in superfluid He would enable searches deep into an entirely unexplored parameter space. Over the past year, we've made significant progress towards these goals. In particular, we've developed a 45cm^2 Si athermal phonon detector with a baseline energy resolution of 3.5eV. After scaling for size, this device represents an order of magnitude leap in sensitivity compared to previously measured sensitivities. Analysis is currently ongoing on a 33 gd above ground light mass dark matter search using this prototype. Additionally, we've begun testing the transition edge sensor test structures for the following generation prototype design. Measured baseline resolution was 50meV; after scaling for size this device also represents nearly an order of magnitude improvement compared to currently available world leading devices.

Primary author: Prof. PYLE, Matt (University of California Berkeley)

Presenter: Prof. PYLE, Matt (University of California Berkeley)

Session Classification: Quantum machine learning and quantum sensing

Track Classification: Quantum sensing

Contribution ID: **95** Type: **Workshop Talk**

A transmon based five-qutrit processor for simulations in high energy physics

Monday, 28 January 2019 15:30 (25 minutes)

Encoding quantum information in the higher energy levels of the transmon circuit provides a hardware efficient way to harness a larger Hilbert space in existing quantum processors while also increasing their connectivity. Furthermore, a network of qutrits (three-level systems) is naturally suited to experimentally demonstrate recently identified connections between high energy physics and quantum information, such as holographic quantum error correction codes and the physics of scrambling. Here we report on the control of a five-qutrit processor and our progress toward characterizing the scrambling of quantum information. We implement a circuit to measure the decay of out-of-time ordered correlators, a hallmark of scrambling, in a method that distinguishes between decoherence and scrambling. The same circuit can be viewed as a teleportation protocol where quantum information is scrambled by a black hole and then decoded through measurement of emitted Hawking photons.

Primary author: Dr BLOK, Machiel (UC Berkeley)

Co-authors: Prof. SIDDIQI, Irfan (UC Berkeley); Prof. YAO, Norman (UC Berkeley); Prof. RAMASESH, Vinay (UC Berkeley)

Presenter: Dr BLOK, Machiel (UC Berkeley)

Session Classification: Architecture II

Track Classification: Qubit architectures

Contribution ID: **96** Type: **not specified**

Ultra-strong coupling regime in cavity quantum electrodynamics

Monday, 28 January 2019 16:30 (40 minutes)

Ultrastrong coupling between light and matter has, in the past decade, transitioned from a theoretical idea to an experimental reality. It is a new regime of quantum light–matter interaction, which goes beyond weak and strong coupling to make the coupling strength comparable to the transition frequencies in the system. The achievement of weak and strong coupling has led to increased control of quantum systems and to applications such as lasers, quantum sensing, and quantum information processing. After a brief introduction to some of its basic ideas, I will describe two examples. Our works on this topic are available here: https://dml.riken.jp/pub/Ultra-strong/ A pedagogical review on this was published a few weeks ago: Ultrastrong coupling between light and matter, Nature Reviews Physics 1, pp. 19–40 (2019).

Presenter: Prof. NORI, Franco (RIKEN)

Session Classification: Architecture III