Materials and Processes for Quantum Information Science Focus Topic
Room On Demand - Session QS-Invited on Demand
Materials and Processes for Quantum Information Science Invited On Demand Session

QS-Invited on Demand-1 Quantum Matter, Simulation, and Clock*, Jun Ye,* JILA and University of Colorado Boulder **INVITED**

Precise engineering of quantum states of matter and major advances in optical coherence and laser technology are elevating the performance of optical atomic clocks to new levels. A low-entropy Fermi gas of Sr atoms loaded into a three-dimensional optical lattice represents a powerful platform to discover, understand, and utilize many-body quantum systems that are metrologically powerful and lay the foundation for the connection between quantum simulation and quantum sensing. These increasingly powerful measurement capabilities are promising greater opportunities for probing fundamental and emerging phenomena.

QS-Invited on Demand-7 Photonic Interfaces for Ion-trap Quantum Computers*, Tracy Northup,* University of Innsbruck, Austria **INVITED**

Trapped ions are among the most promising quantum computing platforms, but there are technical limits to the number of ions, and thus the number of quantum bits (qubits), that can be stored in a single trap. One approach to scale up the number of qubits beyond these limits is to link together multiple ion-based processors in a network via photonic quantum interfaces. I will describe how optical cavities provide efficient quantum interfaces between ions and photons and how we integrate these cavities with ion traps. An important materials question is whether the presence of dielectric cavity mirrors compromises the computing performance of nearby ions. To address this question, I will present recent work in which we model and experimentally measure the heating rate of a trapped ion placed in the vicinity of a cavity mirror. This work not only has implications for ion-based quantum networks but also may provide new insight into the heating mechanisms in microfabricated ion traps.

QS-Invited on Demand-13 Empowering Quantum Photonics with Nanoplasmonics and Machine Learning*, Vladimir Shalaev,* *A. Boltasseva,* Purdue University **INVITED**

New approaches to address major challenges in quantum photonics by employing plasmonic metamaterials and machine learning will be discussed.

QS-Invited on Demand-19 Engineering Silicon Qubits at the Atomic Scale*, Sven Rogge,* University of New South Wales, Australia **INVITED**

Spins in silicon are attractive candidates for scalable quantum information devices, because of their long coherence times and potential for high-density integration. This talk focuses on challenges in scaling from the device to the circuit level. While quantum information devices in spin based systems have been shown to be promising, the small dipole moment of spins make interaction of multiple qubits challenging to implement. Recently, artificial spin-orbit coupling induced by micro-magnets in double quantum dot devices has been successfully implemented to couple spin qubits in silicon to a microwave cavity on the single photon level. The presence of intrinsic spin-orbit coupling in acceptors however, could allow for fast quantum-gate manipulations and effective long-range inter-qubit coupling with a simple device layout. Recent acceptor qubit proposals suggest the possibility of maintaining the dipole moment between the spin-orbit states, without suffering from short coherence times. By coupling a bulk 28Si crystal to a superconducting coplanar waveguide resonator, we measured a coherence time (T2) of 0.7 ms for an acceptor spin ensemble in bulk 28Si crystal under strain. This value for this coherence time is over 4 orders of magnitude higher than previously found in boron-doped silicon devices, and demonstrates the potential of boron-based acceptor spins in silicon as a candidate for scalable, electrically-driven qubits with long coherence times. The second part of the talk focuses on single dopant atom placement. Atomic-scale engineering reached a level of control where single-atom devices can be reproducibly fabricated. The indirect band gap of silicon and the resulting valley degree of freedom has been considered to be challenging for donor qubit architectures. This is due to the fast oscillations of the valley component of the donor wave function that is incommensurate with the silicon lattice. Single-electron spectroscopy maps obtained on fully integrated donor devices in ultra-high vacuum allow a direct measurement of the valley phase difference between two donors. Such quantum-state images of two-donor devices led to a donor based two qubit gate design that is robust in regard to variability in dopant placement.

QS-Invited on Demand-25 Reproducible Superconducting Circuits for Quantum Information Processors*, Eric Zhang,* IBM T. J. Watson Research Center **INVITED**

Superconducting quantum processors based on fixed-frequency transmon architectures are attractive for their simplicity of fabrication and long coherence times. However, the frequency precision of as-fabricated transmon qubits range from 1 - 2%, which results in significant frequency crowding and reduced two-qubit gate-fidelity. In this talk, we describe selective laser annealing to assign transmon frequencies into desired frequency patterns and describe both the practical (~18 MHz) and fundamental (~5 MHz) precision of the laser annealing process. We combine precision studies with Monte-Carlo yield modeling to ascertain the desired tuning performance metrics required for high-yield of collision-free chips. We will present laser-annealing on our largest multi-qubit processor to date, our 65-qubit Hummingbird processor, with a post-annealed median two-qubit gate fidelity of 98.7%. As a scalable post-fabrication frequency trimming technique, we anticipate laser-annealing to play a central role in the production and scaling of high-fidelity superconducting quantum processors up to and beyond 1000-qubit levels.

Acknowledgements The authors acknowledge support under IARPA (Contract No. W911NF-16-1-0114) for collision yield modeling and multi-qubit device characterization.

QS-Invited on Demand-31 Materials Loss Measurements Using Superconducting Microwave Resonators*, Corey Rae McRae,* NIST Boulder / CU Boulder **INVITED**

Two level system (TLS) loss in dielectric materials and interfaces remains at the forefront of materials research in quantum information science. The identification of low loss fabrication techniques, materials, and thin film dielectrics is critical to achieving scalable architectures for superconducting quantum computing. Superconducting microwave resonators provide a convenient qubit proxy for assessing loss performance and studying loss mechanisms such as TLS loss, non-equilibrium quasiparticles, and magnetic flux vortices. In this talk, an overview of design considerations for accurate resonator loss measurements will be given, summarizing techniques that have been evolving for over two decades, and will conclude with recommendations for future measurements in this field.

QS-Invited on Demand-37 Organic Color Center: A New Class of Quantum Materials*, Han Htoon,* Los Alamos National Laboratory **INVITED**

Color centers in diamond and SiC are now standing as a key material system for realization of quantum information technologies ranging from ultrasensitive sensing of electric/magnetic fields to eavesdropping-proof communication and quantum computing.Recent studies have shown that defects capable of mimicking some of the key quantum mechanical properties of these color centers can also be created via covalent bonding of organic functional groups onto the side-wall ofSWCNTs.Here in this talk I will provide a brief over view on our recent accomplishments in understanding and controlling quantum optical properties of these covalent defects, which are often referred to as "organic color centers."[1] Firstly, I will describe our low temperature single defect PL and magneto PL spectroscopies revealing a molecularly tunable electronic structure of these defects[2] and magnetic brightening of spin-sensitive optical transitions. Secondly, Hanbury-Brown-Twiss quantum optic experiment demonstrating the first room temperature single photon generation in O- to C- telecom optical wavelength bands with 99% single photon purity will be presented.[3,4]I will then provide an update on integration of these quantum defects into photonic, plasmonic and electronic nano devices.[5,6] Finally, I will report our most recent Hong-Ou-Mandel quantum optic experiment performed on quantum defects coupled to plasmonic cavities.We were able to realize indistinguishable single photon generation by exploiting the Purcell enhancement of the radiative decay rate of individual defects.[7]

[1] Nat. Photon 11, 535 2017; [2] ACS NanoNat. Chem. 10, 1089 2018; [3] Nat. Photon. 11, 577 2017; [4] Nat. Mater. 17, 663 2018;

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