QuILT Day
Tuesday, March 10, 2020

MEETING ROOM

All lectures from 9:30am–5pm will be held in the theater on the first floor of the Louisiana Digital Media Center. A projector is available for presentations during these lectures.

PROGRAM

9:20–9:30	LSU CCT Director Prof. Ram Ramanujam — Introductory Remarks
9:30–10:00	Safura Sharifi — Design of microresonators to minimize thermal noise below the standard quantum limit
10:00–10:30	Gerard McCaul — Using tracking control for optical discrimination
10:30–11:00	Coffee Break — Louisiana Digital Media Center
11:00–11:30	Anthony Brady — Spooky action at a global distance — resource-rate analysis of a space-based entanglement-distribution network for the quantum internet
11:30–12:00	Vishal Katariya — Evaluating the advantage of adaptive strategies for quantum channel distinguishability
12:00–14:00	Lunch Break — catered at Louisiana Digital Media Center for registered participants
14:00–14:30	Alex Schimmoller — Towards a quantum theory of entropic gravity
14:30–15:00	Daniel Sheehy — Chiral Majorana fermions in condensed matter materials
15:00–15:30	Coffee Break — Louisiana Digital Media Center
15:30–16:00	Onur Danaci — Classical and quantum treatment of self-healing paraxial beams interacting with nonlinear optical systems for multi-spatial mode quantum information processing
16:00–16:30	Eneet Kaur — Multipartite entanglement and secret key distribution in quantum networks
16:30–17:00	Arshag Danageozian — Using coherent population trapping in a nitrogen-vacancy center to model the nuclear spin noise affecting a qubit

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ABSTRACTS
(in alphabetical order by speaker surname)

Speaker: **Anthony Brady** (Louisiana State University)
Title: *Spooky action at a global distance — resource-rate analysis of a space-based entanglement-distribution network for the quantum internet*
Abstract: Recent experimental breakthroughs in satellite quantum communications have opened up the possibility of creating a global quantum internet using satellite links. This approach appears to be particularly viable in the near term, due to the lower attenuation of optical signals from satellite to ground, and due to the currently short coherence times of quantum memories. These drawbacks prevent ground-based entanglement distribution using atmospheric or optical-fiber links at high rates over long distances. In this work, we propose a global-scale quantum internet consisting of a constellation of orbiting satellites that provides a continuous on-demand entanglement distribution service to ground stations. The satellites can also function as untrusted nodes for the purpose of long-distance quantum-key distribution. We determine the optimal resource cost of such a network for obtaining continuous global coverage. We also analyze the performance of the network in terms of achievable entanglement-distribution rates and compare these rates to those that can be obtained using ground-based quantum-repeater networks.

Speaker: **Onur Danaci** (Tulane University)
Title: *Classical and quantum treatment of self-healing paraxial beams interacting with nonlinear optical systems for multi-spatial mode quantum information processing*
Abstract: Quantum key distribution and quantum network applications using discrete or continuous variables require robust error-correcting channels. Contemporary implementations utilize laser beams in free-space where obstructions and/or turbulence can act as an error channel. An obstruction or turbulence near the propagation axis of a paraxial beam leads to physical information dissipation to the environment in the form of multi-spatial mode cross-talk. Self-healing beams (SHB) retain a large portion of their information as they are composed of modes that are more robust to propagation compared to cross-talk between modes induced by obstruction. By using a Laguerre-Gauss expansion and nonhomogeneous paraxial Maxwell-Bloch equations under the 1st Born approximation, we model various seeded nonlinear optical processes driven by various structured, SHB pump and probe beams that were previously obstructed or passed through turbulence to study quantum properties of emerging two-mode squeezed or OAM entangled beams. We find good agreement with previous experimental work.

Speaker: **Arshag Danageozian** (Louisiana State University)
Title: *Using coherent population trapping in a nitrogen-vacancy center to model the nuclear spin noise affecting a qubit*
Abstract: Nitrogen-vacancy (NV) centers in diamond have shown to be a very promising candidate for applications of quantum information processing. Given that the natural abundance of carbon-13 isotopes (carrying non-zero nuclear spin) in the diamond lattice is about 1%, we consider how this sparse nuclear spin bath affects our computational qubit, which is taken to be the nuclear spin of nitrogen in the NV center. By observing the phenomenon of coherent population trapping in the NV center, we construct a noise model of the spin bath and determine the noise parameter. The latter can be updated in real time and fed into a machine learning algorithm that is designed to generate the optimum dynamical decoupling pulse sequence to maintain a high fidelity for the computational qubit.

Speaker: **Vishal Katariya** (Louisiana State University)
Title: *Evaluating the advantage of adaptive strategies for quantum channel distinguishability*

Abstract: This work contributes further to the resource theory of asymmetric distinguishability for quantum strategies, as introduced recently by [Wang et al., Phys. Rev. Research 1, 033169 (2019)]. The fundamental objects in the resource theory are pairs of quantum strategies, which are generalizations of quantum channels that provide a framework to describe any arbitrary quantum interaction. We provide semi-definite program characterizations of the one-shot operational quantities in this resource theory. We then apply these semi-definite programs to study the advantage conferred by adaptive strategies in discrimination and distinguishability distillation of generalized amplitude damping channels.

Speaker: **Eneet Kaur** (Louisiana State University)
Title: *Multipartite entanglement and secret key distribution in quantum networks*
Abstract: Distribution and distillation of entanglement over quantum networks is a basic task for Quantum Internet applications. A fundamental question is then to determine the ultimate performance of entanglement distribution over a given network. Although this question has been extensively explored for bipartite entanglement-distribution scenarios, less is known about multipartite entanglement distribution. Here we establish the fundamental limit of distributing multipartite entanglement, in the form of GHZ states, over a quantum network. In particular, we determine the multipartite entanglement distribution capacity of a quantum network, in which the nodes are connected through lossy bosonic quantum channels. This setting corresponds to a practical quantum network consisting of optical links. The result is also applicable to the distribution of multipartite secret key, known as common key, for both a fully quantum network and trusted-node based quantum key distribution network. Our results set a general benchmark for designing a network topology and network quantum repeaters (or key relay in trusted nodes) to realize efficient GHZ state/common key distribution in both fully quantum and trusted-node-based networks. We show an example of how to overcome this limit by introducing a network quantum repeater. Our result follows from an upper bound on distillable GHZ entanglement introduced here, called the "recursive-cut-and-merge" bound, which constitutes major progress on a longstanding fundamental problem in multipartite entanglement theory. This bound allows for determining the distillable GHZ entanglement for a class of states consisting of products of bipartite pure states.

Speaker: **Gerard McCaul** (Tulane University)
Title: *Using tracking control for optical discrimination*
Abstract: Here we outline the technique of tracking control in quantum systems. A particular application of tracking control is presented, where an unknown mixture of materials can be discriminated between using their optical response to a laser pulse. The problem of determining relative concentrations from optical responses is an example of an overdetermined problem where the difficulty in finding a solution may depend on the pulse used to excite the systems. Using tracking control it is possible to design a pulse which efficiently determines the relative concentrations of materials in a mixture. The applications of this technique, and its relation to quantum information are also discussed.

Speaker: **Safura Sharifi** (Louisiana State University)
Title: *Design of microresonators to minimize thermal noise below the standard quantum limit*
Abstract: We present a design for a new microresonator whose geometry is optimized to maximize sub-Standard Quantum Limit (SQL) performance. The new design is predicted to have thermal noise well below the SQL across a broad range of frequencies when operated at 10K. The performance of this designed microresonator will allow it to serve as a test-bed for quantum non-demolition measurements, and to open new regimes of precision measurement that are relevant for many practical sensing applications, including advanced gravitational wave detectors.

Speaker: **Alex Schimmoller** (Tulane University)
Title: *Towards a quantum theory of entropic gravity*
Abstract: Quantum mechanics and general relativity are two of physics' most comprehensive descriptions of the universe. However, a leading theory of quantum gravity is yet to be established. Several theories

which probe at the fundamental assumptions of gravitation have been proposed, including Erik Verlinde's theory of entropic gravity. Entropic gravity presumes that gravity is not a fundamental force, but rather emerges as a consequence of the second law of thermodynamics. While a full quantum theory of entropic gravity is yet to be established, some have ruled it out on grounds that entropic forces are by nature noisy and entropic gravity would break quantum coherence. Others argue that testing such a theory on Earth would be practically impossible. In this talk, I propose a quantum theory of entropic gravity acting near Earth's surface by modeling gravity as an open quantum system, arrive at a master equation which can mimic conservative gravity with arbitrarily high precision and low decoherence, and compare theoretical results to data from ultra-cold neutron experiments.

Speaker: **Daniel Sheehy** (Louisiana State University)
Title: Chiral Majorana fermions in condensed matter materials
Abstract: Recent experimental and theoretical work has investigated the possibility of realizing Majorana fermions in condensed matter systems. The interest in these particles follows from the fact that localized Majorana zero modes (MZMs) may form a realization of a qubit that is intrinsically fault-tolerant. However, the braiding of these MZMs, required for implementing quantum operations, has turned out to be experimentally difficult. This has led to the study of itinerant chiral Majorana fermions, which can be realized in systems such as topological superconducting materials. I will present a broad discussion of Majorana fermions in condensed matter as well as recent theoretical work attempting to understand experiments that observed evidence of topological chiral Majoranas along with additional low-energy excitations. Based on "Volkov-Pankratov states in topological superconductors," by David J. Alspaugh, Daniel E. Sheehy, Mark O. Goerbig, and Pascal Simon, available at arXiv:2002.05236.