QuILT Day
Monday, December 7, 2020

MEETING ROOM

All lectures from 9:25am–4:25pm CST will be held online on Zoom.

PROGRAM

9:25–9:30	Peter Bierhorst — Introduction
9:30–10:00	Vishal Katariya — Guesswork with quantum side information
10:05–10:35	Soumyadip Patra — Bounding key rates of device-independent quantum key distribution protocols from above
10:35–11:00	Break
11:00–11:30	Sumeet Khatri — Policies for elementary link generation in quantum networks
11:35–12:05	Victor Bankston — Wigner functions and an uncertainty principle
12:05–13:15	Lunch Break
13:15–13:45	Ezad Shojaee — Tomography of entangled macroscopic mechanical objects
13:50–14:20	Lior Cohen — Quantum imaging with a camera: developing a multimode framework
14:25–14:55	Chenglong You — Multiphoton quantum metrology with neither pre- nor post-selected measurements
14:55–15:20	Break
15:20–15:50	Kunal Sharma — Optimal tests for continuous-variable quantum teleportation and photodetectors
15:55–16:25	Wenlei Zhang — Violating the Leggett-Garg inequality with classical light

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ABSTRACTS
(in alphabetical order by speaker surname)

Speaker: **Victor Bankston** (Tulane University)
Title: *Wigner functions and an uncertainty principle*
Abstract: We will illustrate the Wigner function and prove a case of the entropic uncertainty principle for mutually unbiased bases. For qutrit systems, the analysis will generalize to an uncertainty principle for stabilizer measurements.

Speaker: **Lior Cohen** (Louisiana State University)
Title: *Quantum imaging with a camera: developing a multimode framework*
Abstract: Quantum imaging exploits quantum correlations to provide better sensitivity than possible with just classical optics. This improvement is required for imaging fragile samples like biological content. In this talk, I will present the theory of multimode quantum interference of squeezed and laser light on every pixel of the camera. One application of the theory, detection of the amount of squeezing, will be shown. Then, theoretical results of quantum imaging will be presented and compared to experimental data.

Speaker: **Vishal Katariya** (Louisiana State University)
Title: *Guesswork with quantum side information*
Abstract: What is the minimum number of guesses needed on average to correctly guess a realization of a random variable? The answer to this question led to the introduction of the notion of a quantity called guesswork by Massey in 1994, which can be viewed as an alternate security criterion to entropy. In this paper, we consider the guesswork in the presence of quantum side information, and show that a general sequential guessing strategy is equivalent to performing a single measurement and choosing a guessing strategy from the outcome. We use this result to deduce entropic one-shot and asymptotic bounds on the guesswork in the presence of quantum side information, and to formulate a semi-definite program (SDP) to calculate the quantity. We evaluate the guesswork for a simple example involving the BB84 states, both numerically and analytically, and prove a continuity result that certifies the security of slightly imperfect key states when the guesswork is used as the security criterion.

Speaker: **Sumeet Khatri** (Louisiana State University)
Title: *Policies for elementary link generation in quantum networks* (arXiv:2007.03193)
Abstract: Protocols in a quantum network involve multiple parties performing actions on their quantum systems in a carefully orchestrated manner over time in order to accomplish a given task. This sequence of actions over time is often referred to as a strategy, or policy. In this work, we consider policy optimization in a quantum network. Specifically, as a first step towards developing full-fledged quantum network protocols, we consider policies for generating elementary links in a quantum network. We start by casting elementary link generation as a quantum partially observable Markov decision process, as defined in [Phys. Rev. A 90, 032311 (2014)]. Then, we analyze in detail the commonly used memory cutoff policy. Under this policy, once an elementary link is established it is kept in quantum memory for some amount of time, called the cutoff, before it is discarded and the elementary link generation is reattempted. For this policy, we determine the average quantum state of the elementary link as a function of time for an arbitrary number of nodes in the link, as well as the average fidelity of the link as a function of time for any noise model for the quantum memories. Finally, we show how optimal policies can be obtained in the finite-horizon setting using dynamic programming. By casting elementary link generation as a quantum decision process, this

work goes beyond the analytical results derived here by providing the theoretical framework for performing reinforcement learning of practical quantum network protocols.

Speaker: **Kunal Sharma** (Louisiana State University)
Title: *Optimal tests for continuous-variable quantum teleportation and photodetectors*
Abstract: Quantum teleportation is a primitive for several important applications, including quantum communication, quantum computation, error correction, and quantum networks. In this work, we propose an optimal test for the performance of continuous-variable (CV) quantum teleportation in terms of the energy-constrained channel fidelity between ideal CV teleportation and its experimental implementation. All work prior to ours considered suboptimal tests of the performance of CV teleportation, focusing instead on its performance for particular states, such as coherent states, squeezed states, cat states, etc. Here we prove that the optimal state for testing CV teleportation is an entangled superposition of twin-photon states. We establish this result by reducing the problem of estimating the energy-constrained minimum fidelity between ideal CV teleportation and its experimental approximation to a quadratic program and solving it. As an additional result, we obtain an analytical solution to the energy-constrained distance between a photodetector and its experimental approximation. These results are relevant for experiments that make use of CV teleportation and photodetectors.

Speaker: **Ezad Shojaee** (National Institute of Standards and Technology, Boulder, Colorado)
Title: *Tomography of entangled macroscopic mechanical objects*
Abstract: In this talk I will discuss our recent work [arXiv:2004.05515] on witnessing deterministically generated entanglement among two mechanical drumheads. The drumheads are entangled by pulsed coupling to a microwave cavity, one via a beam-splitter interaction and the other via two-mode squeezing. We use heterodyne-style measurements to measure the drumheads' positions and momentums. From those measurements, we reconstruct the full covariance matrix of the drumheads' state and witness entanglement. I will also introduce my current research on generating entanglement between remote, optically-coupled, microwave currents as part of a transduction mechanism for quantum networks.

Speaker: **Soumyadip Patra** (University of New Orleans)
Title: *Bounding key rates of device-independent quantum key distribution protocols from above*
Abstract: CHSH-based Device Independent Quantum Key Distribution (DIQKD) protocols involve two separated honest parties performing measurements on shared entangled particles emitted from a common source. In such scenarios not only do the two parties distrust the source of particles but also their measurement devices. The security of such protocols relies upon obtaining outputs that are correlated non-locally in a sense that they violate a Bell inequality. We study the derivation of upper bounds on the secret key rate of a CHSH-based DIQKD protocol using two secrecy monotones, the recently introduced Quantum Intrinsic Non-locality (QINL) by Kaur et al., and the Intrinsic Information. The latter has been used by Arnon-Friedman et al. in a recent work which involves direct computation of the quantum conditional mutual information using states and measurements saturating the lower bound on the secret key rate.

Speaker: **Chenglong You** (Louisiana State University)
Title: *Multiphoton quantum metrology with neither pre- nor post-selected measurements*
Abstract: The quantum statistical fluctuations of the electromagnetic field establish a limit, known as the shot-noise limit, on the sensitivity of optical measurements performed with classical technologies. Here, we surpass this limit and demonstrate the first universal protocol for quantum metrology to perform estimation of optical phases with neither pre- nor post-selected measurements. This is achieved through the efficient design of a source of spontaneous parametric down-conversion in combination with photon-number-resolving detection. The efficiency of our experiment enables us to demonstrate unconditional quantum enhancement of the broadest range of optical phases. We report sensitivities beyond the shot-noise limit for almost 62% of the phase space even in the presence of losses. Our work is important for quantum technologies that rely on multiphoton interference.

Speaker: **Wenlei Zhang** (Tulane University)
Title: *Violating the Leggett-Garg inequality with classical light*
Abstract: In contrast to Bell's inequalities which test the correlations between multiple spatially separated systems, the Leggett-Garg inequalities test the temporal correlations between measurements of a single system. We experimentally demonstrate the violation of a Leggett-Garg inequality using classical light by simulating the unitary time evolution of a single-qubit density matrix via the propagation of the polarization coherency matrix. Our results show maximum violations of the Leggett-Garg inequality, which also confirms that classical wave mechanics is not a macroscopic-real theory.