QuILT Day
Friday, November 2, 2018

MEETING ROOM

All lectures will be held in Rm 1034, Louisiana Digital Media Center. A projector and a whiteboard are available for presentations.

PROGRAM

Thursday

17:00–20:00	Mark M. Wilde — QuILT's Eve tutorial on quantum information theory (free tacos)

Friday

9:00–9:30	Nicholas Lanning — Transverse-spatial-mode correlations in nonlinear optics
9:30–10:30	Ryan Glasser, Mark M. Wilde, Thomas Corbitt, Ravi A. R. P. Rau, Jonathan P. Dowling — Overview of research activities (10 min each)
10:30–11:00	Coffee Break
11:00–11:30	Denys I. Bondar — How to deduce a physical dynamical model from expectation values
11:30–12:00	Omar Magaña-Loaiza — Multiphoton quantum metrology without post-selection
12:00–13:30	Lunch Break
13:30–14:00	Elisha S. Matekole — Room-temperature photon-detection techniques
14:00–14:30	Peter Bierhorst — Bell nonlocality and quantum information theory
14:30–15:00	Kunal Sharma — Characterizing the performance of continuous-variable quantum gates
15:00–15:30	Coffee Break
15:30–16:00	Sanjaya Lohani — Machine learning for quantum optics
16:00–16:30	Brian La Cour — Local hidden-variable model for a recent experimental test of quantum nonlocality and local contextuality
16:30–17:00	Giovanni Caru — Towards a complete cohomology invariant for non-locality and contextuality

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ABSTRACTS
(in alphabetical order by speaker surname)

Speaker: **Peter Bierhorst** (University of New Orleans)
Title: *Bell nonlocality and quantum information theory*
Abstract: Bell nonlocality is a physical phenomenon where distant, quantum-entangled particle pairs behave in ways that are not possible for any system obeying classical physical principles. Since no classical system can simulate this phenomenon, it is a perfect candidate for application to quantum information protocols that are meant to transcend what is possible in classical physics. I will explain how this works through the example of random number generation: while basic quantum random number generators are now easy to build, one that is based on a Bell Nonlocality experiment can definitively rule out predictable classical noise contaminanting the device, which is not so easy to do for a basic quantum random number generator.

Speaker: **Denys I. Bondar** (Tulane University)
Title: *How to deduce a physical dynamical model from expectation values*
Abstract: abstract. In this talk, we will provide an answer to the question: "What kind of observations (i.e., expectation values) and assumptions are minimally needed to formulate a physical model?" Our answer to this question leads to the new systematic approach of Operational Dynamical Modeling (ODM), which allows deducing equations of motions from time evolution of observables. Using ODM, we are not only able to re-derive well-known physical theories, but also solve open problems in quantum non-equilibrium statistical dynamics. Furthermore, ODM has revealed unexplored flexibility of nonlinear optics: A shaped laser pulse can drive a quantum system to emit light as if it were a different system (e.g., making lead look like gold).

Speaker: **Giovanni Caru** (Tulane University)
Title: *Towards a complete cohomology invariant for non-locality and contextuality*
Abstract: The sheaf theoretic description of non-locality and contextuality by Abramsky and Brandenburger sets the ground for a topological study of these peculiar features of quantum mechanics. This viewpoint has been recently developed thanks to sheaf cohomology, which provides a sufficient condition for the contextuality of empirical models in quantum mechanics and beyond. Subsequently, a number of studies proposed methods to detect contextuality based on different cohomology theories. However, none of these cohomological descriptions succeeds in giving a full invariant for contextuality. In the present work, we introduce a cohomology invariant for possibilistic and strong contextuality which is applicable to the vast majority of empirical models.

Speaker: **Brian R. La Cour** (Applied Research Laboratories, University of Texas at Austin)
Title: *Local hidden-variable model for a recent experimental test of quantum nonlocality and local contextuality*
Abstract: An experiment has recently been performed to demonstrate quantum nonlocality by establishing contextuality in one of a pair of photons encoding four qubits; however, low detection efficiencies and use of the fair-sampling hypothesis leave these results open to possible criticism due to the detection loophole. In this Letter, a physically motivated local hidden-variable model is considered as a possible mechanism for explaining the experimentally observed results. The model, though not intrinsically contextual, acquires this quality upon post-selection of coincident detections. Paper available at `https://doi.org/10.1016/j.physleta.2017.05.010`

Speaker: **Nicholas Lanning** (Louisiana State University)
Title: *Transverse-spatial-mode correlations in nonlinear optics*
Abstract: I will present a second quantization procedure for multi-transverse-spatial mode Gaussian beam dynamics in nonlinear interactions. Previous treatments have focused on the spectral density and angular distribution of spatial modes. I will go a layer deeper by investigating the complex transverse-spatial mode in each angular-spatial mode. Furthermore, to demonstrate the theory, I will discuss four-wave mixing and parametric down-conversion schemes, showing how one can elucidate and tailor the underlying multi-transverse-spatial mode structure along with its quantum properties. Paper available at `https://journals.aps.org/pra/abstract/10.1103/PhysRevA.98.043824`

Speaker: **Omar Magaña-Loaiza** (Louisiana State University)
Title: *Multiphoton quantum metrology without post-selection*
Abstract: The maturity of fields such as optical physics and quantum optics has brought with it a new era where the photon represents a promising information resource. However, modern applications exploit very little of the enormous potential of the photon. Unfortunately, most protocols for quantum metrology discard information encoded in quantum states of light, through a process known as post-selection. In this talk, I will report on our recent results on quantum phase estimation. I will introduce the first protocol for multiphoton quantum-enhanced estimation without post-selection. The efficient design of our source of spontaneous parametric down-conversion in combination with an efficient scheme for photon-number resolving detection allows us to use two-mode squeezed vacuum states for estimation of optical phase shifts. In contrast to other protocols, in which the loss of a single photon is enough to remove all phase information from the state, the robustness of two-mode squeezed vacuum states allows us to surpass the standard quantum limit in the presence of loss.

Speaker: **Sanjaya Lohani** (Tulane University)
Title: *Machine learning for quantum optics*
Abstract: We present how Machine Learning (ML) techniques can be used to explore various quantum/classical optics protocols. Noise in experimental setups is inevitable and often destroys possible quantum advantages. In these situations, handling of noisy optical schemes with some correction technique is crucial in the quantum information regime. Here we discuss the ability of ML to efficiently optimize various information processing schemes including turbulent/dispersive media, and a variety of detection methods at the receiver. We are hopeful that the present results combining the fields of ML and quantum optics will greatly enhance the robustness of future quantum information/communication links.

Speaker: **Elisha S. Matekole** (Louisiana State University)
Title: *Room-temperature photon-detection techniques*
Abstract: Photon-number-resolving detectors (PNRD) are crucial to the field of quantum optics and quantum information processing. In this talk I will give a brief overview of state of the art photon detection techniques with primary focus on room-temperature PNRD. I will discuss two proposals for the same: (1) Two-mode squeezer based PNRD, and (2) Atom-vapor based PNRD. Paper available at `https://journals.aps.org/pra/abstract/10.1103/PhysRevA.96.053815`

Speaker: **Kunal Sharma** (Louisiana State University)
Title: *Characterizing the performance of continuous-variable quantum gates*
Abstract: The required set of operations for universal continuous-variable quantum computation can be primarily be divided into two categories: Gaussian and non-Gaussian operations. Furthermore, any Gaussian operation can be decomposed as a sequence of phase-space displacements and symplectic transformations. Although Gaussian operations are ubiquitous in quantum optics, their experimental realizations are generally approximations of the ideal Gaussian unitaries. In this work, we study different performance metrics to analyze how well these experimental approximations simulate the ideal Gaussian operations. In particular, we find that none of these experimental approximations converge uniformly to the ideal Gaussian processes.

However, the convergence is in the strong sense, or if the discrimination strategy is energy bounded, then the convergence is uniform. We indicate how these energy-constrained bounds could be used for experimental implementations of these Gaussian operations in order to achieve any desired accuracy. Paper available at `https://arxiv.org/abs/1810.12335`

Speaker: **Mark M. Wilde** (Louisiana State University)
Title: *Quantum Information Theory Tutorial*
Abstract: What are the ultimate limits that nature imposes on communication and what are effective procedures for achieving these limits? In order to answer these questions convincingly, we must reassess the theory of information under a quantum lens. That is, since quantum mechanics represents our best understanding of microscopic physical phenomena and since information is ultimately encoded into a physical system of some form, it is necessary for us to revise the laws of information established many years ago by Shannon. This is not merely an academic exercise, but instead represents one of the most exciting new frontiers for physics, mathematics, computer science, and engineering. Entanglement, superposition, and interference are all aspects of quantum theory that were once regarded as strange and in some cases, nuisances. However, nowadays, we understand these phenomena to be features that are the enabling fuel for a new quantum theory of information, in which seemingly magical possibilities such as teleportation are becoming reality. Two other notable examples are increased communication capacities of noisy communication channels and secure encryption based on physical principles. Concepts developed in the context of quantum information theory are now influencing other areas of physics as well, such as quantum gravity, condensed matter, and thermodynamics. Furthermore, quantum information theory has given us a greater understanding of the foundations of quantum mechanics and might eventually lead to a simpler set of postulates for quantum mechanics.

This tutorial will review the basics of quantum information. An outline is as follows:

1. background on quantum information and connections to classical information, including density operators, channels, measurements, purification, isometric extension, coherent measurement;

2. noiseless protocols of entanglement distribution, teleportation, superdense coding;

3. distance measures including trace distance and fidelity. Uhlmann's theorem and gentle measurement;

4. quantum entropy and entropy inequalities;

5. protocols including Schumacher compression, classical communication, entanglement-assisted classical communication, quantum communication. Nonadditivity of capacities and superactivation.