JONATHAN P. DOWLING MEMORIAL CONFERENCE ON QUANTUM SCIENCE AND TECHNOLOGY

MAY 12-13, 2022

LOUISIANA STATE UNIVERSITY

SPEAKERS

Scott Aaronson
The University of Texas at Austin

Verification of BosonSampling

After Alex Arkhipov and I introduced BosonSampling in 2011, Jon Dowling helped to explain and champion our proposal in the quantum optics community. Then, just within the past two years, USTC announced that it had achieved quantum supremacy via Gaussian BosonSampling. But how do we verify that a classically hard problem was actually solved? In this talk I'll share some thoughts about that question, informed both by recent experiments and simulations and by theoretical progress over the past decade.

Scott Aaronson

Scott Aaronson is David J. Bruton Centennial Professor of Computer Science at the University of Texas at Austin. He received his bachelor's from Cornell University and his PhD from UC Berkeley. Before coming to UT Austin, he spent nine years as a professor in Electrical Engineering and Computer Science at MIT. Aaronson's research in theoretical computer science has focused mainly on the capabilities and limits of quantum computers. His first book, Quantum Computing Since Democritus, was published in 2013 by Cambridge University Press. He's received the National Science Foundation's Alan T. Waterman Award, the United States PECASE Award, the Tomassoni-Chisesi Prize in Physics, and the ACM Prize in Computing, and is a Fellow of the ACM.

Katherine L. Brown
CMS Cameron McKenna Nabarro Olswang LLP

Jon's lessons in Americanism

This is the story of how Jon convinced a skeptical Brit on the value of American confidence, the lessons in physics and life learnt along the way and how the skills I learned from Jon helped me go and develop a career as a patent attorney.

Katherine L. Brown

Katherine is a UK and European patent attorney with a PhD in quantum computing. She has a range of experience prosecuting patents in the UK and Europe for a wide variety of clients. She specializes in computer related inventions and has previously worked on patents in the aerospace and oil industry. She is now putting her PhD in quantum computing to good use and prosecuting a range of patents in that area as well as working on computer related inventions in general.

Katherine has experience in private practice where she qualified as a UK Patent Attorney and a European Patent Attorney. Before becoming a patent attorney, she studied physics at Durham University before completing a PhD in quantum computing at The University of Leeds and a postdoc, also in quantum computing, at Louisiana State University.

Hugo Cable
PsiQuantum

Switch Networks for Photonic Fusion-based Quantum Computing

Fusion-based quantum computing (FBQC) provides a compelling approach to building a fault-tolerant universal quantum computer, and is well suited to hardware implementation using photonic components — single-photon sources, linear-optical circuits, single-photon detectors, and optical switches. Sophisticated switch networks are needed in the architecture of the quantum computer to perform operations using feedforward, conditioned on previous photon-detection outcomes. One important application of switch networks is as key subsystems of hardware used to implement fault-tolerant operations at the level of logical qubits (which are needed in turn for useful quantum algorithms). Another is multiplexing ("muxing") stages used with circuits for generating small entangled resource states to boost the probabilities for allocating quantum states. The performance of these switch networks heavily impacts the machine footprint, due not only to routing efficiency, but also critically to qubit losses and errors. In this talk, I will present a wide range of new techniques and schemes which enable major improvements in terms of muxing efficiency and reductions in hardware requirements, representing many conceptual developments on switch networks at *PsiQuantum* over the past few years (arXiv:2109.13760).

Hugo Cable

I have worked at *PsiQuantum* since 2017 as a Quantum Architect, focusing on the development of switch networks. Prior to this, I was a postdoctoral researcher first at LSU with Jon Dowling, and then at the Centre for Quantum Technologies in Singapore, and the Centre for Quantum Photonics at the University of Bristol in the UK – working on topics in quantum metrology, quantum sensing, quantum imaging and quantum computation.

Charles Clark
Joint Quantum Institute

Charles W. Clark (b. 1952 in Minneapolis, Minnesota) is a NIST Fellow (awarded in 2010) and a Fellow of the Joint Quantum Institute of NIST and the University of Maryland (awarded in 2007). He is also Physical Sciences Editor for the DLMF project. A graduate of the Seattle Public Schools, he received his B.A. in mathematics and physics from Western Washington University, and a Ph.D. in physics from the University of Chicago. After a postdoctoral research associateship at Daresbury Laboratory in the U.K., he joined the staff of the National Bureau of Standards (now NIST).

Clark's current research interests are the dynamics of ultracold atoms and its application to quantum information, applications of synchrotron radiation, and the exploitation of atomic and molecular physics processes for new methods of neutron detection. He is coeditor of the following books: *Atomic Excitation and Recombination in External Fields* (with M. H. Nayfeh), published by Gordon and Breach in 1985, *Atomic Spectra and Collisions in External Fields* (with M. H. Nayfeh and K. T. Taylor), published by Plenum Press in 1988, and *Atoms in Strong Fields* (with M. H. Nayfeh and C. A. Nicolaides), published by Plenum Press in 1990.

Clark was elected a Fellow of the American Physical Society (APS) in 1992, of the Optical Society of America (OSA) in 1994, of the Institute of Physics in 1999, of the American Association for the Advancement of Science (AAAS) in 2001, and of the Washington Academy of Sciences in 2003. He has been a Visiting Fellow at the Australian National University, a Dr. Lee Fellow at Christ Church College of the University of Oxford, and Visiting Professor at the National University of Singapore.

Clark received the R&D 100 Award, Distinguished Presidential Rank Award of the U.S. Civil Service, Archie Mahan Prize of the OSA, the Physical Sciences Award of the Washington Academy of Sciences, the Gold and Silver Medals of the U.S. Department of Commerce, and the NIST Bronze Medal and Edward U. Condon, Safety, and Equal Opportunity Awards. He has served as Chair of the Division of Atomic, Molecular, and Optical Physics of the APS, Chair of the Physics Section of the AAAS, and as Program Manager for Atomic, Molecular, and Quantum Physics at the U.S. Office of Naval Research.

Lior Cohen
University of Colorado Boulder

Quantum LIDAR and my work experience with Jonathan Dowling

In this talk, I will discuss our theoretical findings regarding the quantum-enhanced LIDAR. I will try to convey the unique interaction Jon had with his students and colleagues, and how it made me a better scientist.

The quantum LIDAR is based on photon-number-resolving detectors (PNRDs), detectors that are sensitive to single photons but can also resolve the number of photons. I will present experimental results of a PNRD-based rangefinder and LIDAR, the improvement over classical devices and why I now think this is an important discovery, all of that in the context of working with Jon.

Lior Cohen

Lior Cohen is a research assistant professor at the University of Colorado Boulder. He received a Ph.D. degree in physics from the Hebrew University of Jerusalem. Thereafter, Lior joined Prof. Jonathan Dowling's group at Louisiana State University, working on quantum remote sensing, imaging, and simulations of quantum gravity. His current research focuses on quantum simulation and sensing on photonic chips and in fibers.

Michael Dowling
University of Regensburg

The Business of Quantum

The performance of Quantum Technology is improving exponentially (Dowling´s Law, 2013). As forecast by Dowling and Milburn (2003):

> "We are currently in the midst of a second quantum revolution. The first quantum revolution gave us new rules that govern physical reality. The second quantum revolution will take these rules and use them to develop new technologies."

In this talk, Michael Dowling will discuss the rapid growth on investment by establish companies and also by new ventures to develop a broad range of quantum technologies. Investment in new quantum ventures is highest in the United States, but China and Europe are leading in public investments. Germany is leader in Europe and the State of Bavaria leads in Germany.

Europe has developed a common strategy to improve research and develop a quantum industry in a number of application areas. To achieve these goals, improvements must be made in the areas of education, skill development, standards and intellectual property protection. Quantum Technology has great potential to change the world!

Michael Dowling

Prof. Dr. Michael Dowling is a Professor for Innovation and Technology Management in the Faculty of Business and Economics at the University of Regensburg, Germany.

He currently serves as the Chairman of the Board and a member of the Research Committee of the MÜNCHNER KREIS, a non-profit association providing orientation for decision makers in the digital world. www.muenchner-kreis.de

His research interests include the strategic management of technology, high technology entrepreneurship, and the relationships between technology, public policy and economic development.

James Franson
University of Maryland, Baltimore County

Third Quantization of the Electromagnetic Field

Early in his career, Jonathan Dowling was involved in research into alternatives to conventional quantum electrodynamics. As a result, it seems appropriate to discuss a recent generalization of quantum optics and quantum electrodynamics that is based on an additional or third quantization of the electromagnetic field. It will be shown that an approach of this kind is required for a complete description of quantum optics in the Heisenberg picture. Although the basic technique is equivalent to the conventional theory, this approach also allows a generalization of quantum electrodynamics that is based on a single unknown parameter (a mixing angle) that is analogous to the Cabibbo angle or the Weinberg angle in elementary particle theory. The generalized theory predicts new phenomena that could be tested experimentally, including a new form of inelastic photon scattering. A recent experimental test that sets an upper bound on the value of the mixing angle will be discussed.

James Franson

James Franson is involved in both experimental and theoretical research in quantum optics and quantum information. He proposed a new kind of nonlocal interferometer (the Franson interferometer) that is widely used in quantum communications and tests of nonlocality. He has also predicted several other new phenomena that have been experimentally demonstrated, including nonlocal cancellation of dispersion. Dr. Franson and his group were the first to demonstrate quantum key distribution in optical fibers and the first to demonstrate it in free space. His group was also the first to experimentally demonstrate quantum logic operations, such as a CNOT gate, using single photons as the qubits. He is a Fellow of the American Physical Society and the Optical Society of America.

Ryan Glasser
Tulane University

Quantum Science and Technologies, and People: A (very incomplete) Overview of JPD's Impact

In this talk I will describe the early years of Jon's time at LSU, from a graduate student perspective. We will hear about many of the folks that he mentored, how he helped shape their careers, and where they are now. While he provided us with countless opportunities, he arguably generated even more stories, many of which will be told.

Ryan Glasser

Ryan is an associate professor at Tulane University in New Orleans. He received his Ph.D. in Physics from Louisiana State University, under the advisement of Prof. Jonathan Dowling, in 2009. He was then a researcher at Harris Corporation for 2.5 years, working experimentally on the DARPA Quantum Sensors program, non-line-of sight free-space communications, and quantum communications. In 2011 he was awarded National Research Council Postdoctoral Associateship at NIST and the University of Maryland. He was a postdoctoral researcher at NIST and UMD in Bill Phillips' and Paul Lett’s Laser Cooling and Trapping Group, performing research in quantum information, quantum optics, and quantum communication prior to joining the faculty at Tulane University in 2014. He joined Tulane in 2014 and established the Quantum Information and Nonlinear Optics group, whose research areas include quantum technologies and machine learning.

Deborah Jackson
National Science Foundation

The Dowling JPL Odyssey

This is the story of how a minor Jonathan Dowling CLONE rose from the Hollows of The JPL Canyon to become a Program Director at the National Science Foundation. The three-part story includes a Journey through the JPL-Years, Wisdom Gleaned during the Journey, and Tips on how to become an NSF Program Director at Journey's End.

Deborah Jackson

Dr. Jackson is a hands-on professional with more than 20 years of broad-based experience in research and development, project management, strategic planning, and product delivery. Currently at NSF, she leads the Microelectronics, Sensors, and Information Technologies Cluster within the Engineering Research Center's (ERC) Program office. In that capacity, she manages the ERC Industrial Liaison Officer's working group, whose purpose is to strategically develop the Centers for optimal innovation and to speed the commercialization or utilization of the ERC's research findings and technology. She is also helping to define the role of Stakeholders in the Gen-4 context of convergent research with strong impacts to society. It is this mission of translating discovery into innovative real-world applications that attracted her to the ERC program office.

Before arriving at NSF, Dr. Jackson held research appointments at the IBM Watson Research Laboratory, the Hughes Research Laboratory, the RAND Corporation and the Jet Propulsion Laboratory. Deborah J. Jackson received a bachelor's degree in Physics from MIT in 1974, followed by a PhD in Physics from Stanford University in 1980. Though her initial graduate training was in nonlinear optics, her research and development career spanned the full range of the electromagnetic phenomena from materials studies using hard x-ray wavelengths, to quantum computing at visible wavelengths, to the fielding of radio frequency instrumentation on deep space missions such as Cassini and Mars Observer.

Pieter Kok
University of Sheffield

Quantum Imaging: from concept to implementation

In this talk I will introduce the idea of quantum imaging as a multi-parameter estimation problem, which allows us to precisely benchmark its performance over conventional metrics like the Abbe or Rayleigh limit. I will show how we can achieve super-resolution in the imaging of distant classical objects by exploiting the greater flexibility of optical interferometers in tailoring the right observables that give us the maximum amount of information about the objects. I will conclude with some experimental results that demonstrate the practical viability of quantum imaging.

Pieter Kok

Pieter Kok is Professor of Theoretical Physics at the University of Sheffield in the United Kingdom. After completing his Masters in Physics at Utrecht University in the Netherlands and his PhD at the University of Wales, Bangor, he joined Jon Dowling’s group at JPL in Pasadena. Jon’s letters of recommendation helped him get subsequent jobs at Hewlett-Packard Labs in Bristol (UK), Oxford University, and finally in Sheffield. These letters also prompted interviewers to ask Kok about the proper pronunciation of the name “Christiaan Huygens”, the famous Dutch 17th century physicist and inventor.

Paul Kwiat
University of Illinois Urbana-Champaign

Quantum-enhanced Metrology: Better sensing through entanglement

Quantum metrology involves the use of nonclassical states to achieve improved sensing performance. For example, by incorporating very non-degenerate energy entangled photons, we can create a two-photon interferometer that combines the best traits of robustness against noise and loss, with ultrahigh sensitivity, yielding attosecond-scale timing resolution. Distributed nonlocal states to separated telescopes can enable very very long baseline interferometry, and angular resolutions unachievable by other means. In this talk I'll present our progress at demonstrating these novel improved optical measurements.

Paul Kwiat

Paul G. Kwiat is the Bardeen Chair in Physics, at the University of Illinois Urbana-Champaign, and the inaugural Director of the Illinois Quantum Information Science and Technology Center (IQUIST). A Fellow of the American Physical Society and the Optical Society of America, and recipient of the OSA 2009 R. W. Wood Prize, he has given invited talks at numerous national and international conferences, and has authored over 160 articles on various topics in quantum optics and quantum information, including several review articles. His research includes optical realizations of various quantum information protocols, particularly using entangled—and hyperentangled—photons to implement advanced quantum communication.

Chao-Yang Lu
University of Science and Technology of China

Dowling and his quantum link to USTC

In this talk, I will review the fruitful interaction of Professor Jonathan Dowling with the Chinese quantum community, in particular the group based on the University of Science and Technoloy of China.

Chao-Yang Lu

Chao-Yang Lu obtained his Bachelor's degree from the University of Science and Technology of China (USTC) in 2004, and PhD in Physics from the Cavendish Laboratory, University of Cambridge in 2011.He is currently a Professor of Physics at USTC focusing on quantum computation, solid-state quantum photonics, superconducting circuits, and atomic arrays. He has been awarded an OSA Fellow (2017), Fresnel Prize (2017), AAAS Newcomb Cleveland Prize (2018), Nishina Asian Award (2019), IUPAP-ICO Young Scientist Prize in Optics (2019), OSA Adolph Lomb Medal (2020), APS Rolf Landauer and Charles H. Bennett Award in Quantum Computing (2021), and James P. Gordon Memorial Speakership (2021).

Elisha Siddiqui-Matekole
Brookhaven National Laboratory

The Dowling Nest

This talk is a synopsis of how Jon the “eagle” prepared and urged his PhD “eaglet” to fly out of the nest. I will reflect on how my interactions with Jon continue to shape me as a quantum physicist. I will give an overview of my current research at BNL as well as the responsibilities at the workplace, appreciating Jon’s constant desire to see all his “eaglets” succeed.

Elisha Siddiqui-Matekole

Dr. Elisha Siddiqui-Matekole received her Ph.D. from Louisiana State University in May 2020. She was one of the last students to have graduated under Dr. Jonathan Dowling. Her Ph.D. work focused on quantum optics and sensing. She joined Brookhaven National Laboratory (BNL) in July 2020. She is part of the High-Performance Computing and Quantum computing group at BNL. Her research interests include low-level programming models for optimization of NISQ-devices, quantum machine learning assisted quantum-error correction and quantum networking. She actively participates in Brookhaven-Stony Brook University lecture series for Women in Science and Engineering (WISE), sharing her experiences in research, and encouraging high-school and college students to be a part of the exciting field of quantum.

Irina Novikova
College of William and Mary

Seeing a quantum shadow: quantum noise imaging for low-light applications.

It is hard to see anything without light. Yet, some light-sensitive substances can only tolerate very limited light exposure. Measuring their optical properties becomes very challenging, in part due to the dark noise of a CCD camera. This talk describes an imaging technique based on quantum fluctuation analysis that enables imaging opaque objects in a low-photon environment. At the same time, we successfully eliminate the camera dark noise problems by realizing a camera-based homodyne detection. We demonstrate that both squeezed vacuum and few-photon thermal state can be effectively used for this purpose. Moreover, for the squeezed vacuum it may be possible to forgo the camera completely by using structured local oscillator.

Irina Novikova

Irina Novikova received her Ph.D. in 2003 in experimental Atomic and Molecular Optics at Texas A&M University. After spending three years as a postdoctoral fellow at the Harvard-Smithsonian Center for Astrophysics, she joined the physics faculty at the College of William&Mary. Irina's research is focused on investigations of coherent light–atom interactions and their applications for quantum optics, precision metrology, and pretty much anything else.

Jonathan Olson
Zapata Computing

One Does Not Simply *Walk* into Jon's Office

My PhD began with "Do you want to be rich and bored or do you want to enjoy your career?" and ended by trolling *Physical Review* with a paper called "Mordor." Jon's approach to mentorship gave his students a wild ride, and his lessons one cannot easily forget. This is a story of what happened when a student took perhaps *too much* of Jon's advice and a glimpse of what happened after.

Jonathan Olson

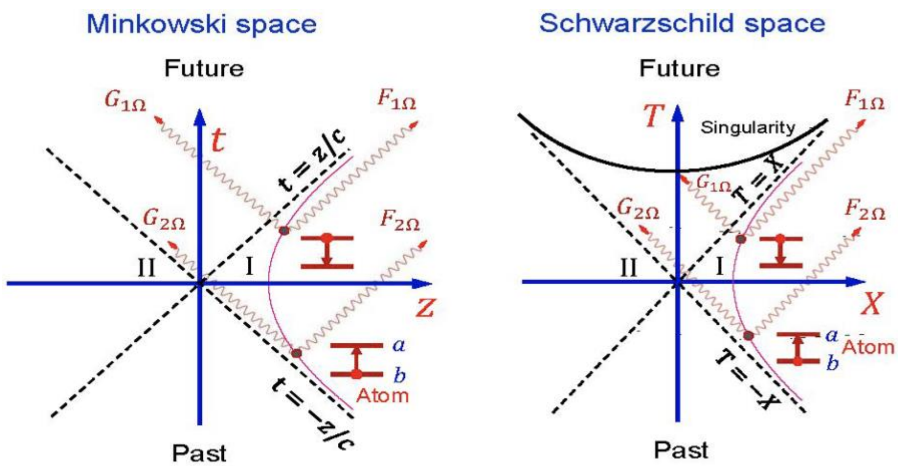
Jonathan Olson is a former student of Jonathan Dowling graduating in 2016, having developed near-term theoretical methods for quantum metrology. Subsequently, Jonny worked as a postdoctoral fellow at Harvard University in the Aspuru-Guzik group working on NISQ quantum algorithms and quantum machine learning. After founding Zapata in early 2018, he developed a handful of other quantum methods before transitioning into "quantum intellectual property."

Marlan Scully
Texas A&M University

Entanglement in Unruh, and Hawking radiation from a Quantum Optical Perspective

Marlan O. Scully1,2, Anatoly Svidzinsky1, and William Unruh1,3
1Texas A&M University, College Station, Texas
2Princeton University, Princeton, New Jersey
3University of British Columbia, Vancouver, Canada

Free quantum field theory in flat space-time is often believed to be well established holding no surprises. We hope to convince you fellow Dowling fans that surprises still exist. For example, we will show that a uniformly accelerated atom in Minkowski space-time emits entangled photon pairs in a squeezed state which mimics entanglement of the Minkowski vacuum in that the entanglement is between Minkowski modes which are dominantly in opposite causal wedges of the spacetime. Similar emission of photon pairs occurs if an atom is held above the black hole event horizon. Namely, a ground-state atom becomes excited by emitting a "negative" energy photon under the horizon and then spontaneously decays back to the ground state by emitting a positive energy photon outside the horizon which propagates away from the black hole, as in the following figure.



Marlan O. Scully

Marian 0. Scully is Distinguished Professor of Physics and Astronomy at Texas A&M University. He has been instrumental in many seminal contributions to laser science and quantum optics. He has been elected to the National Academy of Sciences, the Academia Europaea, the Russian Academy of Sciences, the Chinese Academy of Sciences, and the Max Planck Society and has received numerous awards including the Charles H. Townes Award of the OSA, the Quantum Electronics Award of IEEE, the Elliott Cresson Medal of the Franklin Institute, the Adolph E. Lomb Medal of the OSA, a Guggenheim Fellowship, the Alexander von Humboldt Distinguished Faculty Prize, and the APS Schawlow Prize. More recently, he was awarded the OSA Frederic Ives Medal I Quinn Prize which recognizes overall distinction in optics and is the highest award of the society, was named Einstein Professor by the Chinese Academy of Sciences, and received the Commemorative Medal of the Senate of the Czech Republic.

Andrew White
University of Queensland

Rise of the Machines: Making better photons by getting rid of experimentalists

There is now an enormous opportunity to interconnect quantum components together into complex, short- and long- range networks of sensing, communication, and computational elements. Photons are a natural choice for networking quantum technologies as their quantum nature survives at room temperature and long-distance propagation is possible, either via optical fibre or through free space.

Here we explore using machine learning (ML) to optimize production, coupling, routing, and circuitry for single photons. Our single-photon source platform is resonant excitation of individual quantum dots coupled to a micropillar cavity. Multiphoton suppression in the quantum dot emission—as well as single-photon indistinguishability and brightness—are directly influenced by the spatiotemporal characteristics of the optical excitation pulses. We use ML techniques to tailor the excitation laser pulse properties in real-time, significantly reducing the search time for optimal parameters. We also employ ML to control a deformable mirror, correcting for aberration on the single-photon wavefront field to maximize the coupling between the source output and a single-mode fibre. This combination provides a toolbox for enhancing the performance of any solid-state single-photon source.

Photonic integrated circuits (PICS) will be essential for scalaby realising photonic quantum technologies. Actively coupling photons into PICS requires high-fidelity integrated switches. Current best practice—manual optimization of electronic signals for each individual switch on a chip—is slow and unscalable. We use ML—simulated annealing—to optimize driving parameters for up to 4 switches on a single chip, achieving a significant speed up in tuning while retaining optimal performance. PICS often interface light in and out of the chip using edge coupling, which severely limits chip geometry as well as adding complication to fabrication. Using ML—inverse design—we are developing efficient out-of-plane couplers and small-footprint waveguide crossings that are easier to manufacture and have higher circuit density. This new architecture lowers entry costs for photonic integrated circuitry development.

Andrew G. White

Andrew G. White is Professor of Physics and an Australian Laureate Fellow at the University of Queensland. He was raised in a rural dairy town on the east coast of Australia, before heading south to Brisbane to study chemistry, math, physics and—during World Expo—the effects of alcohol on uni students from around the world. Deciding he wanted to know what the cold felt like, for his PhD he first moved to Canberra, then Germany, before postdocing at Los Alamos National Lab in New Mexico—where he quickly discovered that there is more than enough snow to hide a cactus, but not nearly enough to prevent amusing your friends when you sit down. Over the years he and his team have conducted research on various topics including shrimp eyes, nuclear physics, optical vortices, and many things quantum. He likes quantum weirdness for its own sake, and his current research aims to explore and exploit the full range of quantum behaviours—notably entanglement—with an eye to engineering new technologies and scientific applications.