HIAS – IQSE – Trotter

SYMPOSIUM ON QUANTUM PHYSICS AND QUANTUM COMPUTING

IQSE Seminar Room (MPHY 578)

Texas A&M University

February, 27, 2020

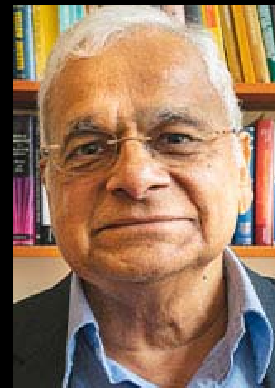
PROGRAM

7:30 a.m.	*Breakfast*
Session I:	*Robert Kennicutt, Chair*
7:50 a.m.	*Intro*, John Junkins, Director, HIAS
	Welcome, Michael Young, President, TAMU
8:00 a.m.	Peter Shor
8:35 a.m.	Bill Unruh
9:10 a.m.	Chris Monroe
9:45 a.m.	*Break*
Session II:	*Alan Lightman, Chair*
10:05 a.m.	Marlan Scully
10:40 a.m.	Yanhua Shih
11:15 a.m.	Wolfgang Schleich
11:50 a.m.	*Lunch*
Session III:	*David Lee, Chair*
12:50 p.m.	*Intro*, Marlan Scully, Director, IQSE
	Welcome, John Sharp, Chancellor, TAMUS
1:00 p.m.	Andrew Steane
1:30 p.m.	Luiz Davidovich
2:00 p.m.	*Break*
Session IV*:*	*Olga Kocharovskaya, Chair*
2:20 p.m.	M. Suhail Zubairy
2:50 p.m.	Girish Agarwal
3:20 p.m.	Aleksei Zheltikov
4:00 p.m.	Alexey Kitaev, Physics Distinguished Lecture (MIST Hawking Auditorium)
7:00 p.m.	Alan Lightman and Andrew Steane, 2020 Recipients Trotter Prize and Endowed Lecture Series (ILSB 1105).

Quantum Interference Induced Photon Blockade

ABSTRACT

It is known that the quantum mechanical transition probabilities have to be calculated by coherently summing over all transition amplitudes. Such a coherent sum leads to a variety of interference processes especially in nonlinear process. Interferences can occur in linear processes in systems which are prepared in entangled states. It is thus possible that one has nonzero one photon absorption zero two photon absorption. This can be referred to as photon blockade. I would discuss various realizations of photon blockade in cavity quantum electrodynamics both in weak coupling and strong coupling conditions. Photon blockade is considered to be a good method to generate single photons from classical weak fields. Photon blockade in other contexts like in Rydberg atoms leads to the generation of multiparticle entangled states.



Girish Agarwal

Girish Agarwal is a Professor of Biological and Agricultural Engineering at Texas A&M University. He is best known for his seminal contributions in the areas of quantum optics and plasmonics - nano photonics. He is a Fellow of the Royal Society (UK), the World Academy of Sciences, and the National Academy of Sciences (India). He has received the OSA Max-Born Award; the Humboldt Research Award; the Einstein Medal; the Shanti Swaroop Bhatnagar Award in Physical Sciences by the Govt. of India; and the eminent faculty award of the Oklahoma State University.

Luiz Davidovich

Luiz Davidovich is a TAMU HIAS Fellow and Professor of Physics at the Instituto de Física at the Universidade Federal do Rio de Janeiro, Brazil. He is best known for his seminal contributions in the areas of decoherence, dynamics of entanglement, laser theory, and quantum metrology. He is a member of the NAS (foreign associate), the World Academy of Sciences, and the Brazilian Academy of Sciences where he currently serves as its president. He has also received the Brazilian Grand-Cross of the National Order of Scientific Merit and the Brazilian National Prize of Science and Technology.

FROM QUANTUM TO CLASSICAL: Schrödinger Cats, Entanglement, and Decoherence

ABSTRACT

The emergence of the classical world from quantum mechanics is a subtle problem, which was raised by Schrödinger in one of his papers in 1926 [1], and to which he came back in a paper in 1935 [2], containing the famous discussion on coherent superpositions of classically distinguishable states of macroscopic systems ("Schrödinger cat"). The dynamical process by which these superpositions are transformed into a mixture of the two states, due to the interaction between the system and the environment, has been the subject of many theoretical investigations, and it has also been experimentally probed [3,4].

A closely related question concerns the dynamics of entangled systems under the action of the environment. What is the dynamical law? How does it scale with the number of particles? What is the impact on the environment? These questions are not only important from a conceptual point-of-view, but play an important role in the assessment of the robustness of quantum computers.

This talk will review recent work, theoretical and experimental, addressing these questions. For a review, see [5].

References: [1] E. Schrödinger, Die Naturwissenschaften 28, 664 (1926); [2] E. Schrödinger, 807 (1935).; [3] L. Davidovich, et al., Phys. Rev. A 53, 1295 (1996); M. Brune, et al., Phys. Rev. Lett. 77, 4887 (1996); [4] M. P. Almeida, L. Davidovich, et al., Science 316, 579 (2007); [5] G. H. Aguilar, L. Davidovich, et al., PRL 113, 240501 (2014); [5] Leandro Aolita, Fernando de Melo, and Luiz Davidovich, Rep. Prog. Phys. 78, 042001 (2015).

Quantum Computing and Simulation with Atoms

ABSTRACT

Trapped atomic ion crystals are among the most promising platforms for fully universal quantum computer systems as well as simulators of Hamiltonian spin models. Trapped ion spins/qubits have no practical limits to their idle coherence times, and because they are perfectly replicable atomic clocks, have the ability to be scaled. Small quantum algorithms and emulations of hard quantum problems with more than 50 quantum bits have been recently demonstrated, and I will speculate on how things might proceed in the next few years. While it remains a great challenge to build a quantum computer big enough to be useful for society, the good news with the trapped ion system is that there do not appear to be any fundamental limits ahead.

Christopher Monroe

Christopher Monroe is a Distinguished University Professor and the Bice Zorn Professor of Physics at U. Maryland. His group is a leading effort in the quest to build quantum information processors out of individual atoms, having demonstrated the first quantum gate in any system, teleportation between widely separated atoms, and small quantum computer systems. He is a co-founder and Chief Scientist at IonQ, Inc., a startup that manufactures full-stack quantum computers. He is a member of the NAS and has received the APS Schawlow and Rabi Prizes, a Presidential Early Career Award, and the International Quantum Communication Award.

Wolfgang Schleich

Wolfgang Schleich (HIAS Fellow 2013-2014) is professor of theoretical physics and director of the Institut für Quantenphysik Center for Integrated Quantum Science and Technology at the University of Ulm. He is best known for his work related to the physics of phase space, in particular Wigner functions, cold atoms, and the interface to solid-state physics. He is a member of the Deutsche Akademie der Natur-forscher Leopoldina, Academia Europaea, the Austrian Academy of Sciences and has received the Otto Hahn Medal, the DPG Physics Award, the Leibniz Prize, and the Lamb Medal in Laser Science and Quantum Optics.

Factorization of numbers, Schrödinger cats and the Riemann hypothesis

ABSTRACT

In this talk we connect the three different topics of factorization of numbers, Schrödinger cats and the Riemann hypothesis. The bridge between these areas is the concept of a Gauss sum.

Gauss sums manifest themselves in various phenomena such as the Talbot effect, wave packet dynamics or quantum carpets. Moreover, Gauss sums can be used to efficiently factor numbers. The talk summarizes these activities [1] and discusses a new approach [2] based on a potential with a logarithmic energy spectrum.

Moreover, we propose an elementary quantum system which provides us with the Riemann zeta function. We show [3] that its zeroes are a consequence of the interference of two quantum systems with opposite phases. However, the preparation of such a superposition state (Schrödinger cat) is impossible unless one takes advantage of entangled quantum systems. In this sense analytic continuation familiar from complex analysis finds entanglement as its analogue in quantum mechanics.

We conclude by introducing a geometrical approach [4] towards the Riemann hypothesis based on the lines of constant phase.

References: [1] NJP. 13, 103007 (2011), NJP, 13, 103008 (2011), NJP, 14, 013049 (2012); [2] NJP, 15, 023037 (2013), Phys. Lett. A 379, 2556-2560 (2015), J. Phys. B: At. Mol. Opt. Phys. 51, 035009 (2018); [3] NJP, 15, 063009 (2013); [4] NJP. 16, 103023 (2014), Phys. Scr. 90, 108015 (2015).

Time and the Quantum

(with Y. Aharonov, W. Schleich, and M. S. Zubairy)

ABSTRACT

In their *Science* paper Aharonov and Zubairy [1] say:

> "The quantum eraser effect of Scully and Drühl dramatically underscores the difference between our classical conceptions of time and how quantum processes can unfold in time. Such eyebrow-raising features of time in quantum mechanics have been labeled "the fallacy of delayed choice and quantum eraser" on the one hand and described "as one of the most intriguing effects in quantum mechanics" on the other. In the present paper, we discuss how the availability or erasure of information generated in the past can affect how we interpret data in the present."

Perhaps the best and most insightful Lehrbeispiel of how to think about before and after issues comes from the quantum eraser. In this case, Baysian logic helps clear up before and after confusion via detailed, but simple calculations [2].

References:

[1] Y. Aharonov and M. S. Zubairy, Science, 2005.

[2] M. Scully, D. Greenberger, W. Schleich, Enrico Fermi Course 197, Foundations of Quantum Theory (2019).

Marlan Scully

Marlan Scully is a University Distinguished Professor and Director of the Institute for Quantum Science and Engineering at Texas A&M University. His work includes the Scully-Lamb quantum theory of the laser, the theory of the laser gyroscope , the theory of correlated spontaneous emission noise quenching in such devices, the quantum eraser concept, lasing without inversion, and FAST CARS anthrax detection. He is a member of the NAS, RAS, the Max Planck Society, and Academia Europia, and has received*, e.g*., the OSA Ive's Medal/Quinn Prize, the APS Schawlow Prize, IEEE Quantum Electronics Award, *etc.*

Yanhua Shih

Yanhua Shih is a Professor of Physics at the UMBC. His work includes use of modern optical technologies to study and to probe the foundations of quantum theory. His current research interests are focused on quantum entanglement, multi-photon interferometry, and quantum imaging. His pioneering experimental demonstrations of ghost imaging and ghost interference stimulated the foundation of quantum imaging. Other interests include experimental general relativity, specifically the experimental study of light propagation in rotating coordinate system. He has received many awards including the Lamb Medal for Laser Science and Quantum Optics.

Delayed-Choice Quantum Eraser with Thermal Light

ABSTRACT

A thermal light delayed-choice quantum eraser experiment is counter-intuitive because most quantum erasure experiments involve entangled light. In a Young's double-slit interferometer, the which-slit information is learned from the photon-number fluctuation correlation of thermal light. The reappeared interference indicates that the which-slit information of a photon, or wave packet, can be "erased" by a second photon or wave packet, even after the annihilation of the first. Different from an entangled photon pair, the jointly measured two photons, or wave packets, are just two randomly distributed and randomly created photons of a thermal source that fall into the coincidence time window. The experimental observation can be explained as a nonlocal interference phenomenon in which a random photon or wave packet pair, interferes with the pair itself at distance. Such observation is the subject of current debate.

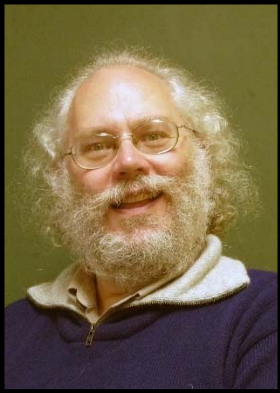
References:

[1] Tao Peng, Hui Chen, Yanhua Shih and Marlan Scully, Phys. Rev. Lett. 112, 180401 (2014).

Quantum Money

ABSTRACT

Abstract: Quantum money is a cryptographic protocol for quantum computers. A quantum money protocol consists of a quantum state which can be created (by the mint) and verified (by anybody with a quantum computer who knows what the "serial number" of the money is), but which cannot be duplicated, even by somebody with a copy of the quantum state who knows the verification protocol. Several previous proposals have been made for quantum money protocols. We will discuss the history of quantum money and give a protocol which cannot be broken unless lattice cryptosystems are insecure.



Peter Shor

Peter Shor is a TAMU HIAS Fellow and Morss Professor of Applied Mathematics at M.I.T. He is best known for his work in theoretical computer science including algorithms, quantum computing, computational geometry and combinatorics, in general, and for his famous “Shor's algorithm” (a quantum algorithm for factoring exponentially faster than current algorithms running on classical computers) in particular. He is a member of the NAE, NAS and the American Academy of Arts and Sciences and has received the King Faisal International Prize, the International Quantum Communication Award, the Dirac Medal, and the Micius Quantum Prize.

Andrew Steane

Andrew Steane is TAMU Trotter Prize recipient (with Alan Lightman) and Professor of Atomic and Laser and Fellow at Exeter College, University of Oxford. He is best known for his work regarding the nature of quantum mechanics. Specifically, he has developed high-precision experiments in which quantum systems under precise and coherent experimental control. His work bringing together classical information theory and quantum mechanics and has led to the discovery of, *e.g.,* the quantum error correction including the "Steane codes." He has received many awards including the Maxwell Medal and Prize of the Institute of Physics.

Limits to Quantum Coherence Owing to Unruh Radiation

ABSTRACT

I investigate the influence of Unruh radiation on matter-wave interferometry experiments using neutral objects modeled as dielectric spheres. The Unruh effect leads to a loss of coherence through momentum diffusion. This is a fundamental source of decoherence that affects all objects having electromagnetic interactions. Hence it is a mechanism which renders some forms of macroscopic quantum interference unobservable. However, an approximate calculation suggests the effect is not large enough to prevent the observation of interference for objects of any size, even when the path separation is larger than the size of the object. When the acceleration in the interferometer arms is large, inertial tidal forces will disrupt the material integrity of the interfering objects before the Unruh decoherence of the centre of mass motion is sufficient to prevent observable interference.

Bell's Theorem, Hardy's Model and Quantum Locality

ABSTRACT

There is a common interpretation of Bell's theorem that it proves that quantum mechanics must be non-local. Instead I argue that it is local, but must be non-realistic (existence is not independent of measurement). This is most strongly demonstrated by an extension of Hardy's model in which the difference between quantum and classical is greatest when the system is least entangled.

William Unruh

William Unruh is a TAMU HIAS Fellow and professor of physics at the University of British Columbia. He is best known for his seminal contributions to general relativity, *e.g.,* the “Unruh effect”, black holes, cosmology, quantum fields in curved spaces, and the foundations of quantum mechanics. His research into the foundations of quantum mechanics has yielded many insights, including quantum computation. He is a Fellow of the Royal Society of both London and Canada, foreign honorary member of the American Academy of Arts and Sciences, and has received the Rutherford Medal and the Herzberg Medal.

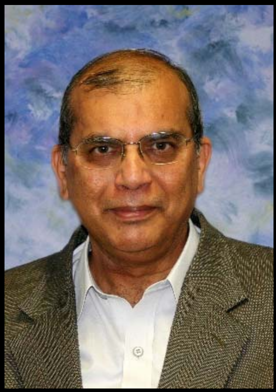
Aleksei Zheltikov

Aleksei Zheltikov is a professor of physics at Texas A&M University. He is also the head of the international laboratory of ultrafast optics and photonics at Moscow State University and Russian Quantum Center. He is known for his work in ultrafast nonlinear optics, quantum laser - matter interactions, nonlinear microscopy, and neurophotonics. He is a winner of the Lamb Award for Laser Science and Quantum Optics, the Russian Federation State Prize, the Shuvalov Prize for pioneering contribution to optical physics, and the Kurchatov Prize for achievements in neurophotonics.

Quantum Paths Toward Brain Imaging

ABSTRACT

This talk will show how advanced concepts of quantum science and engineering combined with the latest achievements in biotechnologies pave the way to new modalities of optical bioimaging, helping confront long-standing challenges in neurosciences. En route toward realizing the full potential of this strategy, methods of quantum-state engineering are being applied to optical fields and molecular systems to enhance the brightness, contrast, spatial resolution, and cell specificity of the optical readout. New red-shifted fluorescent proteins designed with the use of these methods open the routes toward high-resolution, cell-specific imaging reaching for the deepest brain areas. Extended to guided-wave fields in optical fibers, methods of quantum-state engineering enable high-brightness generation of quantum states of light needed for quantum imaging. The photon entanglement in such fields can be finely tailored in time and space, as well as in temporal, spectral, and polarization modes. Innovative optical fibers are being integrated with new diamond-photonics quantum materials into a versatile platform for quantum biosensing, offering unique solutions for biophotonics and neuroscience.



M. Suhail Zubairy

M. Suhail Zubairy is a University Distinguished Professor and holder of the Munnerlyn-Heep Chair in Quantum Optics at Texas A&M University. He is best known for seminal contributions in quantum coherence, quantum informatics, and optical microscopy and lithography. He has made transformational contributions ranging from noise-free amplification to super Rayleigh resolution. He is a member of the Pakistan Academy of Sciences and has received the Lamb Award for Laser Science and Quantum Optics, the Humboldt Research Prize, and two medals from the President of Pakistan, the Khwarizmi Prize from the President of Iran

Counterfactual Communication: Optical Communication with Invisible Photons

ABSTRACT

It has long been assumed in physics that for information to travel between two parties in empty space, physical particles have to travel between them. Here, using the ‘‘chained’’ quantum Zeno effect, we show how information can be transferred between the two parties without any physical particles traveling between them.

Notes