Invited and Contributed Talks Booklet

Table of Contents

Monday, Dec. 16

8:30 Registration and Morning coffee

Session I: Quantum Photonics and Optomechanics

9:00-9:40
Alexander L. Gaeta, Columbia University, USA
Quantum Photonics in the Frequency Domain

Quantum frequency conversion is the process by which the wavelength of a light beam is converted to another wavelength while still maintaining its quantum state. Until recently, achieving this process with high conversion efficiency and low noise had been achieved only with second-order nonlinear materials. Here, we describe our recent research that utilizes four-wave mixing in an optical fiber to perform ultralow noise quantum frequency conversion with efficiencies approaching 100%. More importantly, we show how this nonlinear process can be used to realize other quantum phenomena including creating a single-photon Ramsey interferometer, frequency multiplexing for deterministic single-photon generation, and temporally magnifying single-photon pulses.

9:40-10:20
Efi Shahmoon, Weizmann Institute of Science, Rehovot, Israel

Quantum optomechanics with the "lightest possible mirror": atom-array optomechanics

Optomechanics deals with nonlinear phenomena formed by the backaction of radiation pressure on light: light pushes a movable mirror/reflector, whose position then determines the phase of light. I will present our studies on a novel platform for optomechanics, wherein the movable solid reflector is replaced by a dilute 2D array of laser-trapped atoms (e.g. optical lattice or tweezer array). We find that such arrays combine the advantages of both a solid mirror and an atomic system, with nearly perfect reflectivity and ultralight mass, respectively. This introduces several novelties: (i) quantitatively, it should allow to achieve unprecedented strengths of optomechanical nonlinearities, potentially reaching, for the first time, the ultimate single-photon regime, wherein the radiation pressure exerted by a single photon significantly influences a subsequent photon; (ii) qualitatively, such a reflector is made of a quantum-coherent "dielectric" whose many-body state can become entangled due to the optomechanical nonlinearity. This leads to the possibility of extending the study of optomechanics to consider the backaction, not only on light, but also on the internal, electronic state of the reflector itself; a non-existent possibility in current bulk systems.

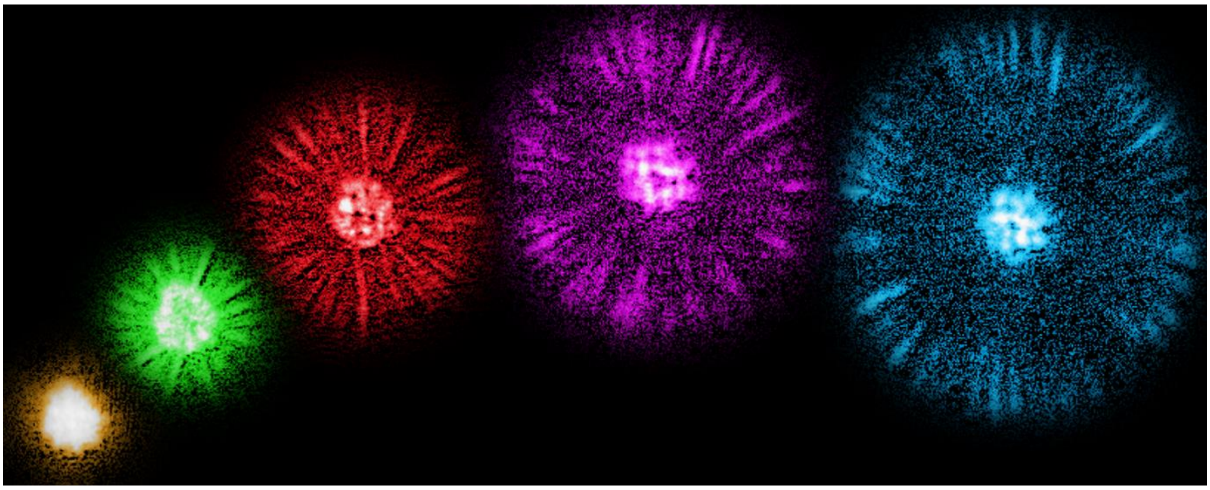
10:20 – 10:45 Coffee break

Session II: Quantum Simulations

10:45 – *Welcome from the Vice President for Research, Prof. Shulamit Michaeli*

10:55 – 12:00 *Physics colloquium*
Cheng Chin, James Franck institute, Enrico Fermi institute, Department of Physics, University of Chicago
Bose fireworks and Hawking-Unruh radiation

Quantum phenomenon in curved spacetimes is an intriguing research topic that aims to offer hints to the not-yet-known theory of quantum gravity. One famous prediction is the Hawking-Unruh effect, the manifestation of Minkowski vacuum in a reference frame with high acceleration.
We simulate the transformation to an accelerating frame by parametrically driving a Bose-Einstein condensate of atoms. Above the critical threshold, the driven condensate suddenly emits many jets of matterwaves in all directions. The emission resembles fireworks and displays a Boltzmann distribution that resembles the Unruh radiation. The measured temperature and entropy are in excellent agreement with Unruh's predictions.
We further detect non-local quantum coherence and temporal reversibility of the matterwave emission, which are hallmarks that distinguish Unruh radiations from the classical blackbody radiation. Our results confirm the quantum nature of Unruh effect.



12:00 – 13:00 Lunch

13:00 – 14:40. Poster Session (see the list of posters in the Posters' Booklet)

Session III: Quantum Computation and May-Body Entanglement

14:40 - 15:20
Nadav Katz, Hebrew University of Jerusalem (HUJI), Israel

Travelling wave amplifiers based on high kinetic inductance devices for quantum computing systems

High kinetic inductance materials are an interesting addition to the arsenal of coherent superconducting devices. They are based on inductive reactance of the material due to kinetic energy of the charge carriers. This is usually neglected in standard conductors at frequencies below THz. However, in specific superconductors this effect can overwhelm the conventional magnetic inductance by orders of magnitude. I will show HUJI's implementation of such devices (resonators and travelling wave amplifiers) based on amorphous Tungsten Silicide films grown by sputtering. I will discuss wave mixing phenomena in these devices, both 4wave and 3wave, driven by appropriate biasing, and show our recent results.

15:20 – 15:40
Jonathan Ruhman, Bar-Ilan University, QUEST center, Israel

Measurement induced phase transition in the entanglement-dynamics of many-body systems

Individual degrees of freedom in a closed many-body system tend to get more and more entangled with each other as time goes by. On the other hand, a protective measurement of the state of one of these degrees of freedom disentangles it from the rest of the system and thus, reduces the overall entanglement. It is natural to ask, which one of these effects is dominant? I will show that in the thermodynamic limit there exists a sharp phase transition, controlled by the measurement rate, separating between a phase where entanglement grows without bound (volume law) and a phase where it saturates to a non-extensive value (area law).

15:40 – 16:00
Richard Berkovits, Bar-Ilan University, QUEST center, Israel

Extracting many-particle entanglement entropy from observables using supervised machine learning

Entanglement, which quantifies non-local correlations in quantum mechanics, is the fascinating concept behind much of aspiration towards quantum technologies. Nevertheless, directly, measuring the entanglement of a many-particle system is very challenging. In this talk we show that via supervised machine learning using a convolutional neural network (all these concepts will be explained during the talk), we can infer the entanglement from a measurable observable for a disordered interacting quantum many-particle system. Excellent agreement was found, except for several rare region which in a previous study were identified as belonging to an inclusion of a Griffiths-like quantum phase. Training the network on a test set with different parameters (in the same phase) also works quite well. General thoughts on the application of machine learning to physics will be discussed.

16:00 – 16:30 Coffee break

Session IV: Quantum Foundations

16:30 – 17:10

Peter D. Drummond, Swinburne University, Australia

Time evolution with symmetric stochastic action

Quantum dynamical time-evolution is shown to be equivalent to a stochastic trajectory in space-time, corresponding to sampling a statistical steady-state evolving in a higher dimensional quasi-time. This is proved using the Q-function of quantum theory, and is equivalent to a forward-backward stochastic process in both the directions of time, which has other multidisciplinary applications. The probability distribution has a positive, time-symmetric action principle and path integral, whose solution corresponds to a classical field equilibrating in an additional dimension. Retro-causal action for quantum fields is also related to electrodynamical absorber theory, first introduced by Dirac, Wheeler and Feynman. This is known to lead to violations of a Bell inequality. I give numerical methods and examples of solutions to the resulting stochastic partial differential equations in a higher time-dimension, giving agreement with exact solutions for soluble boson field quantum dynamics, including some entangled systems. This novel approach to quantum dynamics may lead to useful computational techniques for technology, as the action principle is real, and corresponds to a probability. Of more fundamental significance is that it leads to a complete, relativistically invariant, ontological model of physical reality and cosmology in the form of fluctuating fields, and a solution to the Coppenhagen measurement paradox without a need for collapsing wavefunctions.

17:10 – 17:50

Lev Vaidman, Tel Aviv University, Israel

Experimental demonstrations of exotic quantum measurements

I will report first demonstrations of various types of quantum measurements. Nonlocal measurement - measurement of a property of a composite quantum system with spatially separated parts. Protective measurement - measuring expectation value of an observable with a single click. Robust weak measurement - measuring weak value of an observable with a single click. Modified interaction-free measurement: measurement that tells us that the place is empty without any particle passing through it.

Tuesday, Dec. 17

8:30 Registration and Morning coffee

Session V: Quantum Information and Atom Interferometry

9:00 – 9:40
G. Rempe, Max-Planck Institute of Quantum Optics, 85748 Garching, Germany
Memories, Memories, Memories, …

The development of quantum memories for (entangled) photonic qubits is one of the grand challenges of modern quantum information science and technology. Once available, they could promote a distributed computation and communication network with hitherto classical sending and receiving nodes into quantum-mechanical territory. Elementary quantum networks exist [1], but their memories are inefficient, and/or unfaithful, and/or fugacious. Better memories would allow one to realize long-distance quantum repeaters and possibly a quantum internet on a worldwide scale. Towards these goals, neutral-atom registers in optical cavities are ideal memory systems. Compared to other platforms, they exhibit less dephasing than thermal ensembles, are largely insensitive to perturbations from the environment, incorporate a directional communication interface, and enables the processing of quantum information [2]. Against this backdrop, the talk reports on recent developments like the demonstration of memory times compatible with global teleportation [3], the deterministic shaping of single photons by means of two controlled half-collisions with a memory atom [4], the implementation of a passive and heralded fiber-based memory, and the realization of a random-access memory. The latter achieves more than ten write-read cycles without the need for re-initialization/cooling.

[1] A. Reiserer et al., Rev. Mod. Phys. 87, 1379-1418 (2015).
[2] S. Welte et al., Phys. Rev. X 8, 011018 (2018).
[3] M. Körber et al., Nat. Photon 12, 18-21 (2018).
[4] O. Morin et al., Phys. Rev. Lett. 123, 133602 (2019).

9:40 – 10:20
Ron Folman and the Atom Chip group / Ben-Gurion University of the Negev, Israel
Matter wave interferometers on the atom chip

Matter-wave interferometry provides an excellent tool for fundamental studies as well as technological applications. We will present several interferometry experiments done with a BEC on an atom chip [1] and in which different effects of the external world on the atoms have been investigated. First, we will discuss fluctuations in the nearby environment probed by an interference of atoms trapped in a magnetic lattice very close (5 μm) to a room temperature surface [2,3]. Here an order-of-magnitude improvement has been obtained over previous atom-surface distances for which spatial interference has been observed. Next, we will present a new interferometry of self-interfering clocks and show, in a proof-of-principle experiment, how it could probe the interplay of QM and GR [4]. We will also describe a rule for “clock complementarity”, which we deduce theoretically and verify experimentally [5]. Furthermore, we will discuss Stern-Gerlach interferometry [6-8] and describe it in the context of time irreversibility [9]. To the best of our knowledge, this is the first time spatial full-loop

Stern-Gerlach interferometry (as originally envisioned) has been realized. Time permitting, we will also describe the appearance of a geometrical phase [10].

[1] M. Keil et al., “Fifteen years of cold matter on the atom chip: Promise, realizations and prospects”, Journal of Modern Optics **63**, 1840 (2016).
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[3] Y. Japha et al., “Suppression and enhancement of decoherence in an atomic Josephson junction”, New J. Phys. **18**, 055008 (2016).
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[5] Z. Zhou et al., “Clock complementarity in the context of general relativity”, Classical and Quantum Gravity **35**, 185003 (2018).
[6] S. Machluf et al., “Coherent Stern-Gerlach momentum splitting on an atom chip”, Nature Communications **4**, 2424 (2013).
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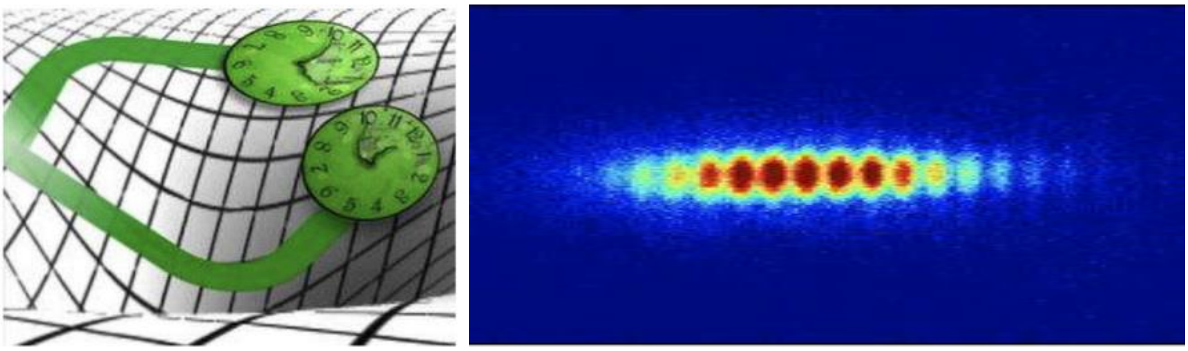
[8] O. Amit et al., “T3-Stern-Gerlach Matter-Wave Interferometer”, Phys. Rev. Lett. **123**, 083601 (2019).
[9] Y. Margalit et al., “Realization of a complete Stern-Gerlach interferometer”, https://arxiv.org/abs/1801.02708.
[10] Zhifan Zhou, Yair Margalit, Samuel Moukouri, Yigal Meir, and Ron Folman “An experimental test of the geodesic rule proposition for the non-cyclic geometric phase”, submitted (2019), https://arxiv.org/abs/1908.03008



Spatial clock interferometry [4].

10:20 – 10:40

Y. Yudkin, R. Elbaz and L. Kaykovich, Bar-Ilan University, QUEST Center, Israel

Coherent superposition of diatomic and triatomic molecules

One of the most basic but profound paradigms of quantum mechanics is superposition. It is an essential ingredient for quantum interference and can give rise to entanglement. In the prototypical experiment a particle (or an entire system) is cast into a superposition of internal states.

Here we show that the notion of superposition reaches much further by creating a coherent superposition of diatomic and triatomic molecules – chemically different bound states. Since the three-body problem is intrinsically non-separable, i.e. it cannot be written in the form of one effective particle, this goes beyond any previous superposition experiment.

More specifically, by means of rf-modulation we cast a system of three Li-7 atoms in an ultracold atomic gas into a superposition state where either two atoms form a Feshbach dimer and one is free or all three form an Efimov trimer. By measuring the coherent evolution in an interferometer-like experiment we demonstrate the coherence of the superposition state. As an application we are able to determine the binding energy of the Efimov trimer with unprecedented precision in a so-far inaccessible region.

10:40 – 11:10 Coffee break

11:10 – 11:50

David Gershoni*, The Physics Department and the Solid-State Institute, Technion–Israel Institute of Technology, 32000 Haifa, Israel

On Demand Source of Cluster States of Entangled Photons

Photonic cluster states are a resource for quantum computation based solely on single-photon measurements [1]. We use semiconductor quantum dots to deterministically generate long strings of polarization-entangled photons in a cluster state by periodic timed excitation of a precessing matter qubit [1-2]. In each period, an entangled photon is added to the cluster state formed by the matter qubit and the previously emitted photons. In our prototype device, the qubit is the confined dark exciton [3-4], and it produces strings of hundreds of photons at rates which exceed 1 GHz. The entanglement in the string currently persists over five sequential photons [5], but it can be increased substantially. We developed a novel method for characterizing this multi-photon quantum state using three qubits correlation measurements only [7].

*Work done in collaboration with Dan Cogan, Giora Penaikov and Zu-En Su

References:

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[5] D. Cogan, et al „Depolarization of Electronic Spin Qubits Confined in Semiconductor Quantum Dots“. Phys. Rev. X 8, 041050 (2018)
[6] I. Schwartz, et al, „Deterministic generation of a cluster state of entangled photons.” Science, 354, 434 (2016)
[7] D. Cogan et al, "Complete state tomography of a quantum dot confined spin qubit" arXiv:1910.05024 (2019)

11:50 – 12:30

Arno Rauschenbeutel, Humboldt-Universität zu Berlin, 10099 Berlin, Germany

Correlating photons using the collective nonlinear response of atoms weakly coupled to an optical mode

Typical schemes for generating correlated states of light require a highly nonlinear medium that is strongly coupled to an optical mode. However, unavoidable dissipative processes, which cause photon loss and blur nonlinear quantum effects, often impede such methods. In this seminar, I will report on our recent experimental demonstration of a proposal that takes the opposite approach [1]. Using a strongly dissipative, weakly coupled medium, we generate and study strongly correlated states of light [2]. Specifically, we study the transmission of resonant light through an ensemble of non-interacting atoms that weakly couple to a guided optical mode. Dissipation removes uncorrelated photons while preferentially transmitting highly correlated photons created through collectively enhanced nonlinear interactions. As a result, the transmitted light constitutes a strongly correlated many-body state of light, revealed in the second-order correlation function. The latter exhibits strong antibunching or bunching, depending on the optical depth of the atomic ensemble. The demonstrated mechanism opens a new avenue for generating nonclassical states of light and for exploring correlations of photons in non-equilibrium systems using a mix of nonlinear and dissipative processes. Furthermore, our scheme may turn out useful in quantum information science. For example, it offers a fundamentally new approach to realizing single photon sources, which may outperform sources based on single quantum emitters with comparable coupling strength [3].

References

[1] S. Mahmoodian, M. Čepulkovskis, S. Das, P. Lodahl, K. Hammerer, and A. S. Sørensen, Phys. Rev. Lett. **121**, 143601 (2018).
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[3] European patent pending (PCT/EP2019/075386)

12:30 – 14:00 Lunch

Session VII: Precision Tests of Fundamental Laws of Physics

14:00 – 14:40
Christophe Salomon, ENS Paris, France
High precision clocks and fundamental tests

For several millennia, the measurement of time has been at the heart of social and economical life. Initially based on the observation of periodic natural phenomena like the Earth rotation or lunar cycles, with the invention of the pendulum Galileo and Huygens have opened the era of man-made precision clocks. Today quantum technologies and cold atoms form the core of ultra-stable modern clocks which display an error of less than a second over the age of the Universe, 14 billion years.
In this presentation, we will discuss the principles of atomic clocks and present a few tests of fundamental physical laws such as precision measurements of the Einstein effect (clock gravitational shift) or searches for the variability of fundamental constants of Physics. We will finish with a few perspectives for clocks based on quantum degenerate gases or quantum correlated atoms.

14:40 – 15:20
Thomas Udem, Max Plank Institute for Quantum Optics, Germany
Challenging QED with atomic Hydrogen

Precise determination of transition frequencies of simple atomic systems are required for a number of fundamental applications such as tests of quantum electrodynamics (QED), the determination of fundamental constants and nuclear charge radii. The sharpest transition in atomic hydrogen occurs between the metastable 2S state and the 1S ground state with a natural line width of only 1.3 Hz. Its transition frequency has been measured with almost 15 digits accuracy using an optical frequency comb and a cesium atomic clock as a reference [1]. A measurement of the Lamb shift in muonic hydrogen is in significant contradiction to the hydrogen data if QED calculations are assumed to be correct [2]. In order to shed light on this discrepancy the transition frequency of one of the broader lines in atomic hydrogen has to be measured with very good accuracy [3].
References
[1] C. G. Parthey et al., Phys. Rev. Lett. 107, 203001 (2011).
[2] A. Antognini et al., Science 339, 417, (2013).
[3] A. Beyer et al., Science 358, 79 (2017).

15:20 – 16:00
R. Ozeri, Weizmann Institute of Science, Rehovot, Israel
Precision isotope shift spectroscopy for new physics searches

In this talk I will review recent ideas to use isotope shift spectroscopy for the search of new forces beyond the standard model and will show the results of a recent experiment at the Weizmann Institute of Science in which a two isotope entangled state of two trapped ions was used to measure the isotope shift of an optical clock transition with 10^{-11} relative accuracy.

16:00 – 16:30 Coffee

Wednesday, Dec. 18

8:30 Registration and Morning coffee

Session VIII: Quantum Nonlocality

9:00 – 9:40
Nicolas Gisin, University of Geneva, Switzerland
Quantum Non-Locality in Networks

Quantum non-locality, i.e. the violation of some Bell inequality, has proven to be an extremely useful concept in analyzing entanglement, quantum randomness and cryptography, among others. In particular, it led to the fascinating field of device-independent quantum information processing.
Historically, the idea was that the particles emitted by various quantum sources carry additional variables, known as local hidden variables. The more modern view, strongly influenced by computer science, refers to these additional variables merely as shared randomness. This, however, leads to ambiguity when there is more than one source, as in quantum networks. Should the randomness produced by each source be considered as fully correlated, as in most common analyses, or should one analyze the situation assuming that each source produces independent randomness, closer to the historical spirit?
The latter is known, for the case of n independent sources, as n-locality. For example, in entanglement swapping there are two sources, hence “quantumness” should be analyzed using 2-locality (or, equivalently, bi-locality). The situation when the network has loops is especially interesting. Recent results for triangular networks will be presented.

9:40 – 10:20
Yuval Gefen, Weizmann Institute of Science, Israel
Weak Measurement Induced Steering

10:20 – 10:40
Eliahu Cohen, Bar-Ilan University, QUEST center, Israel
Locality of uncertainty relations determines the strength of nonlocal correlations

Any statistically reasonable theory obeying a principle we call "relativistic independence" must give rise to nonlocal correlations similar to those of quantum mechanics [1,2]. I will prove this claim and then derive some new bounds on quantum entanglement [1-4]. These bounds will then be generalized to address correlations and causal relations between signaling, non-Hermitian operators [5], between dynamical agents and between nodes of a quantum network. If time allows, I will discuss forthcoming experiments (based on sequential weak measurements [6]), as well as further implications for entanglement detection and quantum sensing.

[1] A. Carmi, E. Cohen, Sci. Adv. 5, eaav8370 (2019).
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[4] A. Te'eni, B.Y. Peled, A. Carmi, E. Cohen, Phys. Rev. A 99, 040102(R) (2019).
[5] A. Carmi Y. Herasymenko, E.Cohen, K. Snizhko, New J. Phys. 21, 073032 (2019).
[6] F. Piacentini et al., Phys. Rev. Lett. 117, 170402 (2016).

11:50 – 12:10

10:40 – 11:10 Coffee break

Session IX: Quantum Information and Quantum Photonics

11:10 – 11:50

Margaret Reid, Swinburne University, Australia

Macroscopic reality, time and the Q-function model of reality

According to quantum mechanics, when a measurement is made on a quantum system, a macroscopic system interacts with the quantum system to create an entangled state. If the measurement is of a spin ½ system (qubit), then this entangled state is the “Schrodinger cat” discussed in Schrodinger’s essay of 1935. The Schrodinger cat state is a superposition of two macroscopically distinguishable states. This cat state is paradoxical because according to quantum mechanics, such a system cannot be regarded as being in one state or the other, prior to a measurement. Here, we discuss the interpretation of the macroscopic superposition state and of a quantum measurement of a qubit system. A definition of macroscopic reality is given in terms of hidden variables and the relationship to Leggett-Garg’s macro-realism [1] is briefly summarized. Using an element of reality approach, we then justify that the “collapse” occurs as a result of the amplification associated with the coupling to the macroscopic system, regardless of decoherence [2]. We then discuss an apparently contradictory result, by showing how one can falsify macroscopic local realism, using Bell inequalities for macroscopic qubits (a NOON or cat-state) where the polarizer setting is replaced with a time of evolution [3]. This motivates us to introduce a model of reality based on the Q function [4]. In this picture, a physical universe exists in space-time without observers. The measurement is described by dynamical evolution where sharp eigenvalues emerge for sufficient amplification. We show how the model is not inconsistent with Bell's theorem, because of the backwards in time causation which occurs in Q- function dynamics through negative diffusion terms [5].

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[2] M. D. Reid, Journal of Physics A: Mathematical and Theoretical 50, 41LT01 (2017).
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11:50 – 12:10

Yoad Michael, Bar-Ilan University, QUEST center, Israel

Squeezing enhanced Raman Spectroscopy

The sensitivity of classical Raman spectroscopy methods, such as coherent anti-stokes Raman spectroscopy (CARS) or stimulated Raman spectroscopy (SRS), is ultimately limited by shot-noise from the stimulating fields. We present the complete theoretical analysis of a squeezing-enhanced version of Raman spectroscopy that overcomes the shot-noise limit of sensitivity with enhancement of the Raman signal and inherent background suppression, while remaining fully compatible with standard Raman spectroscopy methods. By incorporating the Raman sample between two phase-sensitive parametric amplifiers that squeeze the light along orthogonal quadrature axes, the typical intensity measurement of the Raman response is converted into a quantum limited, super-sensitive estimation of phase. The resonant Raman response in the sample induces a phase shift to signal-idler frequency-pairs within the fingerprint spectrum of the molecule, resulting in amplification of the resonant Raman signal by the squeezing factor of the parametric amplifiers, whereas the non-resonant background is annihilated by destructive interference. Seeding the interferometer with classical coherent light stimulates the Raman signal further without increasing the background, effectively forming squeezing-enhanced versions of CARS and SRS, where the quantum enhancement is achieved on top of the classical stimulation.

12:10 – 12:30

Marcello Calvanese Strinati, Bar-Ilan University, QUEST center, Israel

Persistent coherent beating in coupled parametric oscillators

Coupled parametric oscillators were recently employed as simulators of artificial Ising networks, with the potential to solve computationally hard minimization problems. We demonstrate a new dynamical regime within the simplest network - two coupled parametric oscillators, where the oscillators never reach a steady state, but show persistent, full-scale, coherent beats, whose frequency reflects the coupling properties and strength. We present a detailed theoretical and experimental study and show that this new dynamical regime appears over a wide range of parameters near the oscillation threshold and depends on the nature of the coupling (dissipative or energy preserving). Thus, a system of coupled parametric oscillators transcends the Ising description and manifests unique coherent dynamics, which may have important implications for coherent computation machines.

12:30 – 14:00 Lunch

Session X: Quantum Optics and Quantum Communication

14:00 – 14:40

Paulo A. Nussenzveig, University of Sao Paolo, Brazil

Challenging conventional wisdom with optical parametric oscillators

Optical parametric oscillators (OPOs) are among the most widely used sources of nonclassical light. In this talk, we will discuss the generation of multiple entangled modes of light and how they can be used for processing and communicating (quantum information). In the process of overcoming imperfections in the physical realizations of this system, we have uncovered subtle lessons that challenge wisdom based on idealized descriptions.

14:40 – 15:00

Ofek Gillon, Alon Eldan, Avi Pe'er, Bar-Ilan University, QUEST Center, Israel

Highly Multiplexed Quantum Communication With Ultra-Broadband Parametric Homodyne

QKD enables a physically-secure exchange of cryptographic keys, relying on the principle of wave-function collapse. In continuous variable QKD, information is modulated on a continuous quantity, such as the phase quadratures of squeezed vacuum light, and detected with homodyne measurement. *We demonstrate enhancement of the information rate in continuous-variable quantum key distribution (QKD) by a factor of >40 compared to standard techniques (and potentially by 4-6 orders of magnitude) using broadband squeezed vacuum and broadband parametric homodyne detection with a single local oscillator.*

Although broadband squeezed light (tens of THz) can be easily generated by spontaneous parametric down conversion, the maximum data rate is limited by the bandwidth of the homodyne measurement, which is in the MHz-to-GHz range. In our scheme, we measure the entire bandwidth of the light with a single local-oscillator using broadband parametric homodyne detection [1]. The phase of the local oscillator sets the measured quadrature, and hence the measurement basis. In the experiment, we generated a broad bandwidth of squeezed vacuum from a nonlinear crystal (LiNbO3), encode information on the light with a Fourier-domain pulse-shaper and simultaneously measure the chosen quadrature across the spectrum with parametric homodyne. We generate the squeezed light using a 6W CW pump laser at 780nm, producing broadband two-mode squeezed light in the range of 1480-1650nm, allowing future employment with standard telecom fibers. Deciphering the data is performed by passing the pump and the bi-photons in another nonlinear crystal: controlling the phase of the pump determines the measurement basis, and the measurement itself is implemented by recording the spectrum of light.

References

[1] Y. Shaked, Y. Michael, R. Z. Vered, L. Bello, M. Rosenbluh & A. Pe'er, *Nature Communications* **9**, 609 (2018)

15:00 – 15:20

Sharon Shwartz, Bar-Ilan University, QUEST Center, Israel

Quantum enhanced x-ray detection

Generation of quantum states of light have great interest in fundamental science and in implementation of quantum technologies that improve measurements substantially with respect to classical methods. Despite the high potential to lead to novel research frontiers and to advances fascinating applications, the extension of those concepts to x-ray wavelengths has never been demonstrated. This is because statistical properties of radiation that are associated with the quantum nature of radiation such sub-Poisson statistics of the emitted photons have never been measured with at those wavelengths. Here we show for the first time that x-ray pairs that are generated by spontaneous down-conversion can be used for the generation of heralded photons and measure the sub-Poissonian statistics of the single photons. We utilize the properties of the entangled photons to demonstrate the ability to improve the signal-to-noise ratio of an image with a small number of photons in an environment with a noise level that is higher than the signal by many orders of magnitude. Our work demonstrates the advantages that the x-ray regime offers for experiments aiming at testing fundamental concepts in quantum optics and opens the possibility to perform advanced experiments at those very short wavelengths.

15:20 – 15:50 Coffee break

Session XI: Quantum Computation

15:50 – 16:30
M. F. Goffman, CEA Saclay, France

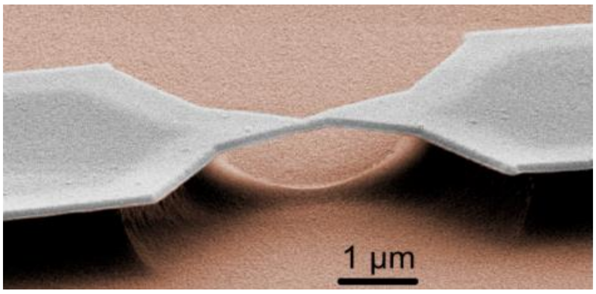
Probing and manipulating Andreev states with microwaves

L. Tosi, C. Metzger, **M. F. Goffman**, Hugues Pothier and C. Urbina
Quantronics group
SPEC, CEA Saclay, France

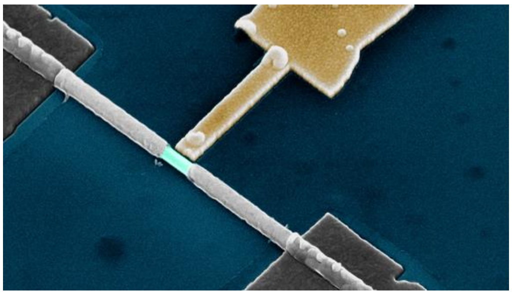
Sunghun Park and A. Levy Yeyati
Departamento de Física Teórica de la Materia Condensada,
Condensed Matter Physics Center (IFIMAC) and Instituto Nicolás Cabrera, Universidad Autónoma de Madrid, Spain

J. Nygård and P. Krogstrup
Center for Quantum Devices and Station Q Copenhagen, Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark

Andreev states are at the basis of the description of Josephson weak links. Circuit-QED setups, which have been developed for superconducting qubits, allow detailed spectroscopy and manipulation of the Andreev states. I will present experiments performed on the simplest weak links, single atom contacts, and on InAs nanowires in which spin-orbit coupling gives rise to spin-split states.



Al atomic contact [1-3]


InAs nanowire junction [4]

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[3] "*Coherent manipulation of Andreev states in superconducting atomic contacts*", C. Janvier, L. Tosi, L. Bretheau, Ç. Ö. Girit, M. Stern, P. Bertet, P. Joyez, D. Vion, D. Esteve, M. F. Goffman, H. Pothier, and C. Urbina, Science **349**, 1199 (2015).
[4] "*Spin-Orbit Splitting of Andreev States Revealed by Microwave Spectroscopy*", L. Tosi, C. Metzger, M. F. Goffman, C. Urbina, H. Pothier, Sunghun Park, A. Levy Yeyati, J. Nygård, and P. Krogstrup, Phys. Rev. X **9**, 011010 (2019).

16:30 – 17:10

Nir Bar-Gill, Hebrew University of Jerusalem (HUJI), Israel

Enhanced polarization transfer and many-body dynamics in spin ensembles in diamond

The study of open quantum systems, quantum thermodynamics and quantum many-body spin physics in realistic solid-state platforms, has been a long-standing goal in quantum and condensed-matter physics.

In this talk, I will describe our work on nuclear hyper-polarization, potentially relevant for enhanced MRI contrast, and research into open quantum systems and quantum thermodynamics [1]. I will then address the requirements for the study of quantum many-body spin physics using this platform, and demonstrate separate steps required to reach this goal, including TEM electron irradiation for improved N to NV conversion efficiencies, robust dynamical decoupling and simulations of noisy many-body spin systems [2-5]. Finally, I will present a general theoretical framework for Hamiltonian engineering in such an interacting spin system [6].

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