BGU-QST
First Conference for Young Researchers in Quantum Science and Technology

LIST OF ABSTRACTS

<u>Mohammad Abutoama</u>

Improving the Efficiency of Single Photon Sources and Detectors using Plasmonic Ultrahigh Field Enhancement Configurations

Mohammad Abutoama

Prof. Ibrahim Abdulhalim Group

Department of Electro-Optic Engineering and The Ilse Katz Institute for Nanoscale Science and Technology, Ben Gurion University of the Negev, Beer Sheva 84105, Israel

Having a bright single photon sources and highly efficient single photon detectors is crucial to quantum devices. Several works [1-7] have showed enhanced emission and/or detection of single photons when an emitter or detection element is located in the vicinity of plasmonic particle or cavity where high density of electromagnetic (EM) field is generated which enhances the emission of the single photon source like a quantum dot. In the last few years, our group has proposed several unique configurations [8-11] for generating ultrahigh enhancement of the local EM when the localized plasmons on the surface of metallic nanoparticles are excited not from free space but from extended surface plasmon waves of the underling thin metal film. This ultrahigh EM field enhancement was obtained both in the prism and grating coupling. Having the ultrahigh enhancement of the local EM field can effectively shorten the lifetime of the emission of the existing quantum emitters located in the hot spots generated using our proposed configurations; a fact that makes the quantum devices faster. Our purpose is to harness our unique schemes for improved single photon emission/detection devices both in efficiency and speed.

Furthermore, the spectral range over which the ultrahigh enhancement achieved can be easily controlled using our configurations by simply tuning the geometrical parameters. This is important for many applications, in particular there is an interest to make the single photon sources at the telecomm wavelengths because most of the technologies already exist for this range. Using our ultrahigh enhancement configurations, we can design the structure to have maximum field enhancement at 1550nm to be used in the optical telecomm window. For example we can use the grating coupling configuration decorated with metallic nano-spheres or many other possible shapes on top as well as the prism coupling decorated with nano-antennas on top.

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Omer Amit

Realization of a T3 Matter-Wave Interferometer on an Atom Chip

O. Amit, Y. Margalit, O. Dobkowski, Z. Zhou and R. Folman
Department of Physics, Ben-Gurion University, Be'er Sheva, Israel

Matter-wave interferometers that are used to measure acceleration are normally sensitive to the interferometer time, T, with a scaling of T2. In 1927, Kennard [1] showed that a faster scaling of T3 was possible when a particle is exposed for time T to a linear potential. A calculation noting the cubic phase was later reported by several others [2, 3, 4], and was recently measured in an atom interferometer based on Bloch oscillations [5]. We present here, our own Unique realization of a T3 matter-wave interferometer based on a Bose-Eisenstein Condensate (BEC) near an atom chip. We utilize the Stern-Gerlach e_ect in order to create a state dependent force on a wave-packet in an internal superposition. Our experiment shows good agreement with theory.

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Nimrod Benshalom

Quantum Weak Values in Classical Interferometry

Nimrod Benshalom, Demitry Farfurnik, Yonatan Efroni, Shimshon Bar-Ad and Lev Vaidman
School of Physics and Astronomy, Tel-Aviv University, Tel-Aviv

We present a novel interferometric alignment method based on a weak value analysis of an optical projection operator, performed within the framework of the Two-State Vector formalism. When two beams interfere their corresponding spots on a detector can fall exactly in the same place, and yet, the beams might not have parallel propagation directions. We use the concept of the weak value of a pre- and post-selected photon to describe an interferometer working in the classical regime. This analysis provides a simple way to extract all misalignment parameters between the two optical arms. Specifically, we consider the interference pattern of two closely overlapping Gaussian beams inside a Mach-Zehnder interferometer. Applying the Two-State Vector formalism we calculate the quantum weak value for a projection operator for one optical arm and derive a formula for the location of the output beam as a function of the relative phase difference between the two arms. Scanning over this phase and fitting the beam position to our formula reveals many of its physical characteristics as well as its misalignment parameters. This affords us a novel alignment protocol based on a single stationary detector which allows to correct both spatial and angular deviations. We confirm our weak value analysis by reproducing it analytically within classical electromagnetic theory, and by empirically demonstrating the validity of the proposed alignment method.

Itay Bloch

Probing New Physics Using Quantum Metrology

Collaborators (in alphabetical order)

Yonit Hochberg[3], Or Katz[2,4], Eric Kuflik[3], Tomer Volansky[1]

Affiliations
1Department of Physics, Tel Aviv University, Tel Aviv, Israel.
2The Rafael Center of Quantum Optics
3Racah Institute of Physics, Hebrew University of Jerusalem, Jerusalem, Israel
4Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot, Israel

Abstract
The Standard Model (SM) is a model that explains an abundance of observations in the field of particle physics, and is considered the fundamental theory of the field. Even so, there are still phenomena that are either not addressed by the SM, or outright contradict it. Thus, for years particle physicists have researched different ways to probe what lies beyond the SM, searching for so called "New Physics". One avenue to search for these new physics is to look for new interactions that do not exist in the SM, between the already familiar particles of the SM.
The existence of new, long-range spin-dependent interactions are implied by many theories that generate a new particle that can mediate such interaction. In particular, the theorized axions and Axion-Like Particles (ALPs), which may also serve as dark matter, could generate new, long-range spin-dependent interactions between the SM particles.
This talk will present experimental and theoretical progress towards building a so called Co-Magnetometer to look for such interactions. The Co-Magnetometer enables to distinguish between neutron-spin and electron-spin interaction with high sensitivity, which allows to probe many different theorized SM extensions, such as those that generate ALPs. The Co-Magnetometer is based on a precision atomic magnetometer, operated in the spin-exchange relaxation-free (SERF) regime, resonant with hyperpolarized noble-gas spins, and utilizes quantum non-demolition measurements. The talk will discuss how the new Co-Magnetometer could increase the current reach of terrestrial experiments of such interactions by three orders of magnitude compared to the best existing experiments.

<u>Marcello Calvanese Strinati</u>

Spectroscopy in one-dimensional systems using time-dependent Matrix Product States-based algorithms

Marcello Calvanese Strinati (*), Fabrice Gerbier, and Leonardo Mazza
(*) Presenting author.
Affiliation: Department of Physics, Bar-Ilan University, 52900 Ramat Gan (Israel)

In the recent years, the question whether one-dimensional setups may give rise to pristine twodimensional exotic phenomena, like the quantum Hall effect [1], has triggered an incredible amountof both experimental and theoretical research. On the experimental side, the renewed interest in one-dimensional models has been pushed by the amazing progresses in the field of ultra-cold atomic gases and condensed-matter physics, which allow to create one-dimensional setups with a high degree of control [2,3]. On the theoretical side, the study of one-dimensional systems often finds its natural framework in effective field theories such as bosonization [4]. Alongside with bosonization, the development of ad-hoc numerical algorithms such as the Density Matrix Renormalization Group (DMRG) [5] and algorithms based on the formalism of Matrix Product States (MPS) [6] has provided unprecedented possibilities to access several properties of such onedimensional systems, thus paving the way to a deeper and more complete understanding of the physics involved. In this talk, I will discuss the possibility of using time-dependent MPS algorithms in order to access partial gaps (spectroscopy) that are found in the spin sector of the bosonic two-leg ladder in a gauge flux [7]. Such spectroscopic method finds a natural application in cold-atoms setups, and thus provides also an experimentally-feasible way to access gaps in any generic systemwhere gapped and gapless excitations of different nature coexist.

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Daniel Cohen

Towards sensing the macroscopic properties of fluids using a nitrogen-vacancy center

Authors: D. Cohen, A. Retzker, M. Khohdas – Huji, O. Kenneth – Technion

The emerging field of nano scale nuclear magnetic resonance (nano NMR) aims at adapting the well-studied technics of classical NMR to the nano scale which is probed by quantum sensors in order to develop a new tool to investigate solid and liquid matter. This scale change, which relaxes the basic assumptions of NMR - large background magnetic field, macroscopic number of spins, net magnetization that can be measured classically, opens the door to new applications of NMR incorporating quantum sensing like probing molecular structure or microfluidic channels.

In our work we were interested in measuring the macroscopic properties of a liquid flowing near a surface (e.g. temperature, polarization, diffusion coefficient, drift velocity), using the magnetic dipole-dipole interaction between nuclear spins inside the liquid and a nitrogen vacancy (NV) center, imbedded in the surface. We calculate the temporal correlations of the local magnetic field induced on the NV by the nuclear spins (analytically in simplified/limiting cases) and suggest how to use them in order to estimate the macroscopic parameters of the liquid and the depth of the NV (below the surface). We are currently working on calculating the associated Fisher information of these parameters in order to quantify the sensitivity of the estimation.

This work touches both practical aspects of liquid flow in a nanotubes and might provide a door to fundamental questions regarding fluid dynamics near a surface.

Or Dobkowski

Realization of a complete Stern-Gerlach interferometer

Yair Margalit, Zhifan Zhou, Or Dobkowski, Yonathan Japha, Daniel Rohrlich, Samuel Moukouri, and Ron Folman.

The Stern-Gerlach (SG) effect, discovered almost a century ago, has become a paradigm of quantum mechanics. Surprisingly there is little evidence that the original scheme with freely propagating atoms exposed to gradients from macroscopic magnets is a fully coherent quantum process. Specifically, no high-visibility spatial interference pattern has been observed with such a scheme, and furthermore no full-loop SG interferometer has been realized with the scheme as envisioned decades ago. On the contrary, numerous theoretical studies explained why it is a near impossible endeavor. Here we demonstrate for the first time both a high-visibility spatial SG interference pattern and a full-loop SG interferometer, based on an accurate magnetic field, originating from an atom chip, that ensures coherent operation within strict constraints described by previous theoretical analyses. This also allows us to observe the gradual emergence of time irreversibility as the splitting is increased. Finally, achieving this high level of control over magnetic gradients may facilitate technological applications such as large-momentum-transfer beam splitting for metrology with atom interferometry, ultra-sensitive probing of electron transport down to shot noise and squeezed currents, as well as nuclear magnetic resonance and compact accelerators.

Dmitry Farfurnik

Spin Ensembles in Diamond for Sensing and Many-Body Physics

Demitry Farfurnik, Nir Bar-Gill
Racah Institute of Physics, Department of Applied Physics and The Center for Nanoscience and Nanotechnology, The Hebrew University of Jerusalem

The unique spin and optical properties of Nitrogen-Vacancy (NV) centers in diamond position them as leading candidates for magnetic nano-sensors and quantum information building blocks (qubits). I will describe experimental techniques for generating ensembles of NV centers with high fidelity: Electron irradiation using the transmission electron microscope (TEM) introduces

more than an order-of-magnitude enhancement in NV concentrations [1], and microwave-based sequences borrowed from NMR with optimized phases are used to overcome the effects of environmental noise [2,3]. I will present the potential of the created NV ensembles for magnetic sensing [4], as well as for the studies of many-body physics [5]. In particular, the application of additional modified NMR-based sequences might lead to the future creation of the unique ``spin-squeezed'' states. Using such states, not yet demonstrated in the solid-state and exhibiting many-body entanglement, the scaling of magnetic sensitivity with the number of sensors may break the classical limit toward the ultimate quantum (Heisenberg) limit.

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Ran Finkelstein

Fast, noise-free memory for photon synchronization at room temperature

Ran Finkelstein, Eilon Poem, Ohad Michel, Ohr Lahad and Ofer Firstenberg

Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot 7610001, Israel.

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Future quantum photonic networks require coherent optical memories for synchronizing quantum sources and gates of probabilistic nature. We demonstrate a fast ladder memory (FLAME) mapping the optical field onto the superposition between electronic orbitals of rubidium vapor. Employing a ladder level-system of orbital transitions with nearly degenerate frequencies simultaneously enables high bandwidth, low noise, and long memory lifetime. We store and retrieve 1.7-ns-long pulses, containing 0.5 photons on average, and observe short-time external efficiency of 25%, memory lifetime (1/e) of 86 ns, and below 10^{-4} added noise photons. One immediate consequence is that coupling this memory to a probabilistic source would enhance the on-demand photon generation probability by a factor of 12, the highest number yet reported for a noise-free, room-temperature memory. This paves the way towards the controlled production of large quantum states of light from probabilistic photon sources [1]. As a next step, we are introducing a tapered _fiber into the atomic vapor, enabling simultaneously both tightly focused beams with extremely high Rabi frequency and high OD. This would enable operating this scheme at an even higher bandwidth as well as extending the ladder scheme to high lying Rydberg states for quantum non-linear optics experiments.

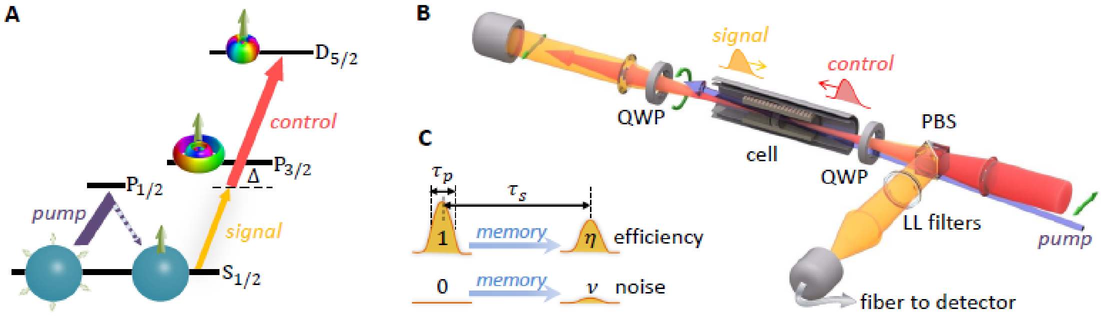

Figure 1: FLAME scheme. (A) A ladder level structure comprising purely orbital transitions (the surface colors display the phase structure of the orbitals $5s$, $5p$, and $5d$) is achieved by optical pumping (purple) of the nuclear and electronic spins (green arrows) to the maximally-polarized state. Nonzero detuning Δ from the intermediate level can be introduced. (B) Experimental setup. (C) The parameters governing the synchronization capability of the memory are pulse duration τ_p, memory lifetime τ_s, retrieval efficiency η, and noise ν.

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Ofek Gillon

Multiplexed Continuous-Variable Quantum Key Distribution with a Single Local Oscillator

Ofek Gillon, Alon Eldan and Avi Pe'er,

Physics department and BINA center for Nanotechnology, Bar Ilan University, Ramat Gan 52900, ISRAEL

Abstract: We demonstrate enhancement of the information rate in continuous-variable quantum key distribution (QKD) by a factor of 20 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. QKD enables a physically-secure exchange of cryptographic keys, relying on the principle of wave-function collapse. If an eavesdropper (Eve) attempts to measure the data sent from Alice to Bob, she will inevitably disturb the state of the light in a way that can be detected by the communicating parties, thus exposing the presence of the eavesdropper. QKD protocols are either discrete or continuous. In discrete QKD, single photons are manipulated, e.g. in polarization, but to ensure detection of the eavesdropper, single photon sources are required (or very weak), which limits the information rate drastically because of the low generation and detection rate of single-photon sources and detectors. 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. 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 ($LiNbO_3$), 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 1520-1600nm, 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.

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Itamar Holtzman

Multi-stable quantum states in a three-terminal nano superconducting device

Itamar Holzman[1,2],* and Yachin Ivry[1,2]

1. Solid State Institute, Technion – Israel Institute of Technology.

2. Department of Materials Science & Engineering, Technion – Israel Institute of Technology.

Controlling the complex order parameter (Ψ=Δeiθ) in superconductors is essential for quantum technologies, such as sensing, computation, communication as well as for quantum electronics. The macroscopic quantum behavior superconductors exhibit offers a promising platform for controlling Ψ. The lack of resistance, which is helpful for some applications, thanks to the associated low power consumption, prevents voltage gating of superconducting device, hence encumbering tunability of Ψ. Recently, we demonstrated successful local tunability of both the phase and amplitude of Ψ by gating directly a superconducting weak-link [1]. The coupling between the currents in the gate and in the weak-link gave rise to a surprising multistable quantum state. Here, we clarify the origin of this multistablility by means of high-resolution time-dependent stability map of θ and Δ. Our results elucidate the yet unexplained nature of current coupling in nano-superconducting quantum devices.

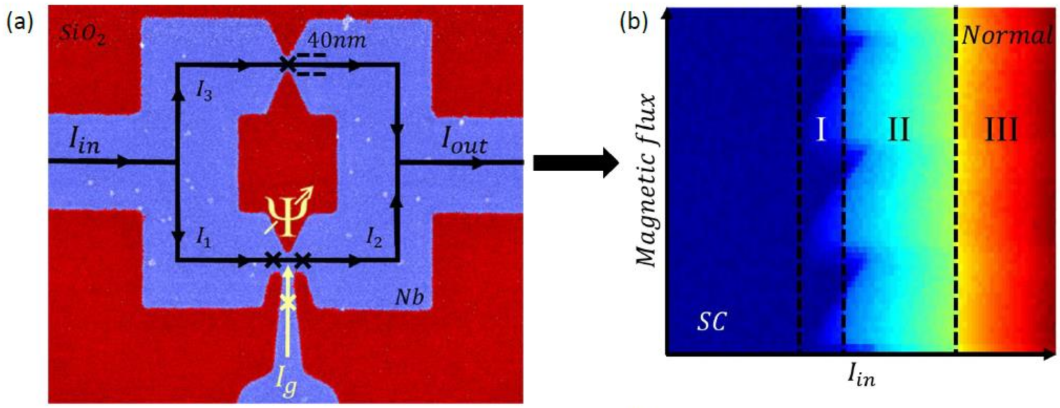
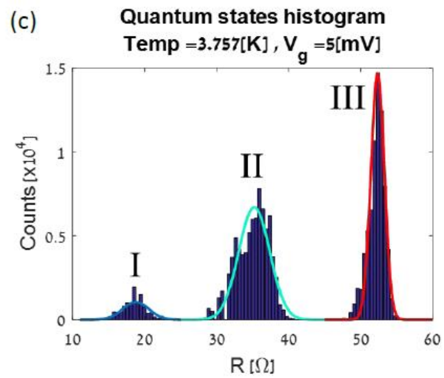


Figure 1| Multistablility of the quantum state in three-terminal nano SQUID. ***(a)*** *A SEM micrograph (false color) of a gated Nb DC-SQUID on SiO_2. The order parameter ($\Psi = \Delta e^{i\theta}$) is tuned by direct injunction of current to one of the weak links (designated as X). The current flow is added schematically to guide the eye.* ***(b)*** *Measured interference output from a gated three-terminal SQUID ($V_{gate} = 5\ [mV]$).* ***(c)*** *Time-dependent analysis of the interference map in (b) reveals clearly three stable states of the order parameter (I, II, III). The regions at which each state exists are shown in (b) (separated by the dashed lines).*



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<u>Christine Khripkov</u>

Thermalization and many-body localization in isolated quantum systems

Christine Khripkov (1), Amichay Vardi (1), Doron Cohen (2)

Departments of Chemistry (1) and Physics (2), Ben-Gurion University of the Negev, Beer-Sheva

We aim to understand and quantify the transition from reversible microscopic mechanics to irreversible macroscopic thermodynamics, using small quantum systems for which a complete description of their many-body dynamics is possible.
In the canonical approach to thermalization, a large bath of fluctuations is coupled to a small test system. By contrast, we consider an isolated system with two similarly-sized subunits, one of which is classically chaotic, thus providing the necessary fluctuations. Using a tight-binding Bose-Hubbard model, where N nonlinearly interacting particles occupy M modes, we construct the simplest scheme that should admit

thermalization: a three-mode trimer unit weakly coupled to a monomer
unit. The isolated trimer contains two degrees of freedom, satisfying the
minimal requirement for a classical chaos in the absence of timedependent
forces. The weak coupling should ensure a linear response,
which predicts a diffusive energy transfer between subunits.
When the system is chaotic, the classical dynamics of the trimer
population x obeys a Fokker-Planck diffusion equation with a diffusion
coefficient D(x). Under the same conditions the quantum dynamics
displays a mobility edge, with a sharp division between quantumergodic
and quantum-localized regimes. We demonstrate that the
quantum breaktime and the mobility edge can both be determined with a
high degree of accuracy from the classical description alone. For this to
be done we must account for the geometry of the energy shell, and also
to distinguish between different descriptions of phase space exploration.

Boaz Lubotzky

Nitrogen vacancy center coupled to hybrid metal-dielectric bullseye nanoantenna for stable, high brightness single photon sources

Boaz Lubotzky(1); Niko Nikolay(2); ; Hamza Abudayyeh(1); Alexander Dohms(2); Nikola Sadzak(2); Florian Böhm(2); Bernd Sontheimer(2); ; Oliver Benson(2); Ronen Rapaport(1)

1. Hebrew University of Jerusalem, Jerusalem, Israel.
2. Humboldt-Universität zu Berlin, Berlin, Germany.

Poster abstract

Single photons qubits, emitted from solid-state-based quantum emitters, have proved one of promising physical realizations for quantum technologies and quantum information sciences. However, typical free-standing quantum emitters have isotropic angular emission patterns. This low directivity emission strongly reduces the ability to collect the emitted photons efficiently, especially when using standard, low numerical aperture (NA) optics which is detrimental for practical SPS applications.
By using an advanced atomic force microscope (AFM) technique we managed to place a nitrogen-vacancy center (NV center) hosted by nanodiamond at the center of a circular nanoantenna, resulting in a significant enhancement in the directionality.
The structure features an emission with divergence angle below 3◦ which is a promising step towards extremely reliable high-efficiency quantum light sources.
The concept presented here can be extended to many other types of nano-particle quantum emitters. Such a device offers a promising route for a high brightness, on-chip single photon source operating at room temperature.

Yair Margalit

A self-interfering clock as a "which path" witness

Yair Margalit, Zhifan Zhou, Shimon Machluf, Daniel Rohrlich, Yonathan Japha, and Ron Folman

Department of Physics, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel

Abstract: In Einstein's general theory of relativity, time depends locally on gravity; in standard quantum theory, time is global—all clocks "tick" uniformly. We demonstrate [1] a new tool for investigating time in the overlap of these two theories: a self-interfering clock, comprising two atomic spin states. We prepare the clock in a spatial superposition of quantum wave packets, which evolve coherently along two paths into a stable interference pattern. If we make the clock wave packets "tick" at different rates, to simulate a gravitational time lag, the clock time along each path yields "which path" information, degrading the pattern's visibility. In contrast, in standard interferometry, time cannot yield "which path" information. This proof-of-principle experiment may have implications for the study of time and general relativity and their impact on fundamental effects such as decoherence and the emergence of a classical world.

[1] Yair Margalit, Zhifan Zhou, Shimon Machluf, Daniel Rohrlich, Yonathan Japha, and Ron Folman, Science **349,** 6253 (2015).

Yoad Michael

Sub-Shot Noise Stimulated Raman Spectroscopy with Parametric Homodyne Detection

Yoad Michael, Leon Bello, Michael Rosenbluh, Avi Pe'er

Department of Physics and BINA Center of nano-technology, Bar-Ilan university, Ramat-Gan 52900, Israel

Coherent anti-Stokes Raman Spectroscopy (CARS) has become one of the most useful label-free spectroscopic techniques whereby chemical composition can be determined based on molecular vibrational spectra. While providing greatly enhanced signal over standard Raman spectroscopic methods, a major technical difficulty in this method has been the usual presence of a strong non-resonant background spectrum from surrounding molecules, such as a solvent or a background lattice, which greatly outnumber the molecules of interest and thus can completely mask the vibrationally resonant spectra.

We present the theoretical study of a new method for Raman spectroscopy by measuring the nonlinear phase shift induced by the resonant Four-Wave mixing (FWM) Raman interaction, using an SU(1,1) interferometer, as shown in Fig. 1. We show that addition of a non-linear medium (such as a Raman sample) in-between the two OPAs (Optical parametric amplifiers) of the interferometer couples between the gain of the amplifiers and the Raman sample, resulting in sub-shot noise signal detection. In addition to the enhancement of the resonant Raman signal by the squeezed light generated inside the interferometer, this scheme distinguishes the inherent phase shift between the resonant Raman signal and the non-resonant FWM background, allowing for complete suppression of the non-resonant background.
Additionally, we show that the quantum-enhanced gain achieved by this scheme can be further augmented by using classical light as a seed to the interferometer. We show that coherent idler (instead of vacuum input) input further increases the resonant Raman signal while the non-resonant signal remains suppressed, effectively creating a background-free CARS configuration.

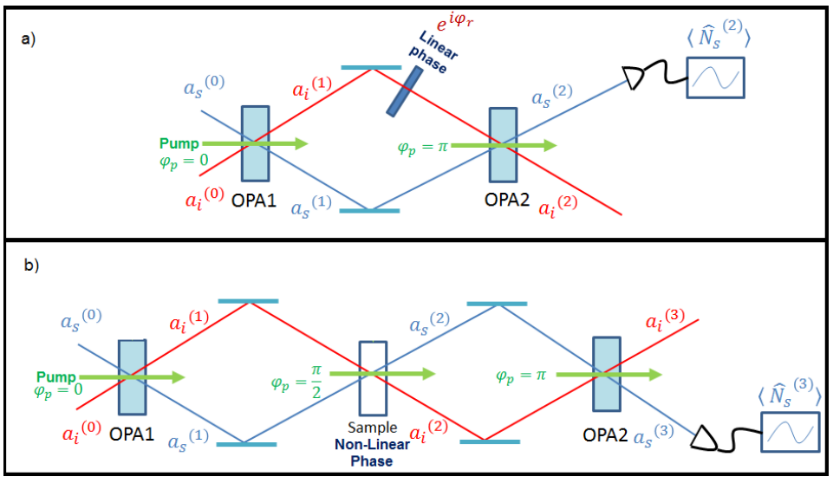

Fig.1: The SU(1,1) interferometer. a) Standard SU(1,1) interferometer for linear phase detection. b) Our suggested Crossed-Raman interferometer. In this configuration, we use a scheme similar to the SU(1,1) interferometer, where the phase shift is induced by out-of-phase amplification in the Raman sample. If no phase shift is present, the average intensity is 0. Thus, any changes in the signal intensity always correspond to a phase shift induced by the sample.

Mor Roses

Signatures of a counter-lasing transition in a cavity QED experiment

Mor M. Roses,[1] Yulia Shchadilova,[2] Eugene Demler,[2] and Emanuele G. Dalla Torre[1]

1Department of Physics and Center for Quantum Entanglement Science and Technology, Bar-Ilan University, 529000 Ramat Gan, Israel
2Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

Recent experiments in quantum optics provide an ideal platform to study non-equilibrium phase transitions. In particular, these experiments provided the first realization of a fundamental model of statistical mechanics, the Dicke model, and demonstrated its second-order phase transition. A detailed analysis of the experimental observations, however, reveals important discrepancies

from the Dicke model. This is due to decay and dephasing processes, which cannot be taken into account in the framework of the common mean-field approximation. We include these effects by an appropriate cumulant expansion of the Lindblad master equations and find significant modifications to the stability diagram of the system. We find that in addition to the known Dicke phase transition, the model can undergo a distinctive non-equilibrium transition. This instability is analogous to a lasing transition, but is induced by counter-rotating terms. This novel effect is demonstrated by recent experiments on trapped atoms in optical cavities.

Amit Rotem

Fast dynamical decoupling of the Molmer-Sorensen entangling gate

Tom Manovitz, Ravid Shaniv, Yotam Shapira, Nitzan Akerman, and Roee Ozeri
Department of Physics of Complex Systems,
Weizmann Institute of Science, Rehovot 76100, Israel
Amit Rotem,—————————— Itsik Cohen, and Alex Retzker

Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Givat Ram, Israel

Engineering entanglement between quantum systems often involves coupling through a bosonic mediator, which should be disentangled from the systems at the operation's end. The quality of such an operation is generally limited by environmental and control noise. One of the prime techniques for sup- pressing noise is by dynamical decoupling, where one actively applies pulses at a rate that is faster than the typical time scale of the noise. However, for boson-mediated gates, current dynamical decoupling schemes require executing the pulses only when the boson and the quantum systems are disentangled. This restriction implies an increase of the gate time by a factor of square root of N, with N being the number of pulses applied. Here we propose and realize a method that enables dynamical decoupling in a boson mediated system where the pulses can be applied while spin-boson entanglement persists, resulting in an increase in time that is at most a factor of pi/2, independently of the number of pulses applied. We experimentally demonstrate the robustness of our entangling gate with fast dynamical decoupling to σ_z noise using ions in a Paul trap.

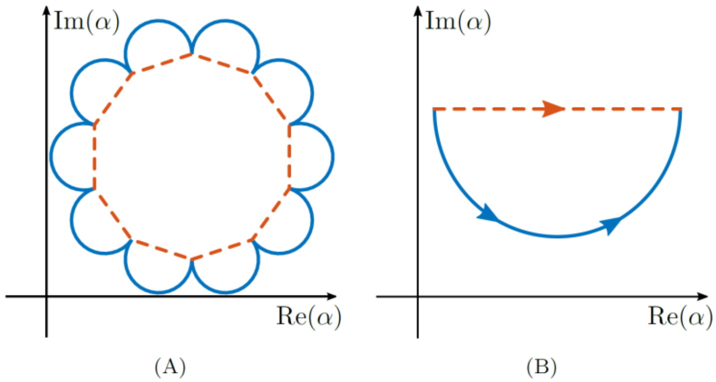

Figure 1. Phase space trajectory of a spin under the MS Hamiltonian (Eq. 1) dynamics and multiple DD pulses, where α is the coherent state of the trap. (A). Utilizing DD pulses for enlarging the area in phase space. A flower shaped area is generated by applying N DD pulses with a specific time separation. The area enclosed by the flower shape, which circumscribes a polygon (orange dashed line) and flower petals (blue line), is proportional to the accumulated geometric phase. At the limit of many pulses N >> 1, the polygon can be approximated as a circle and the petals' area contribution nulls. (B) Every two π pulses separated by $\Delta \Delta t \approx \pi / \varepsilon$ give rise to a spin dependent displacement (orange dashed line) $2\tilde{\Omega}/\varepsilon$, where the path effective velocity is $2\tilde{\Omega}/\varepsilon$. In comparison to the regular strong coupling entangling gate where the path effective velocity is $\tilde{\Omega}$ (Eq. 1) we find a factor of π/2
in the gate durations.

$$H\left(t\right)=\tilde{\Omega}\sum_{i}\sigma_{\phi,i}\left(b^{\dagger}e^{i\varepsilon t}+h.c.\right)$$

Yoni Sher

Low Intensity LiDAR using Compressed Sensing and a Photon Number Resolving Detector

Yoni Sher, Lior Cohen, Daniel Istrati, Hagai S. Eisenberg

School of Computer Science and Engineering (Yoni) The Racah Institute of Physics (Yoni, Lior, Daniel, Hagai), Hebrew University of Jerusalem, Jerusalem 91904, Israel

LiDAR (laser based radar) systems are a major part of many new real-world interactive systems, one of the most notable being autonomous cars. The current market LiDAR systems are limited by detector sensitivity: when output power is at eye-safe levels, the range is limited. Long range operation also slows image acquisition as flight-time increases.
We present an approach that combines a high sensitivity photon number resolving diode with machine learning and a micro-mechanical digital mirror device to achieve safe and fast long range 3D scanning.

Sivan Trajtenberg-Mills

Simulating spatial distribution of spontaneously down converted photon pairs in nonlinear crystals

Sivan Trajtenberg-Mills,[1,*] Noa Voloch-Bloch, [2,3] Eli Megidish[2], Hagai S. Eisenberg[2] and Ady Arie[4]

[1]*Sackler School of Physics, Faculty of Exact Sciences, Tel-Aviv University, Tel-Aviv 69978, Israel*
[2]*Racah Institute of Physics, Hebrew University of Jerusalem, Jerusalem 91904, Israel*
[3] *Department of Physics, Faculty of Natural Sciences, Ariel University, Ariel, Israel*
[4]*School of Electrical Engineering, Fleischman Faculty of Engineering, Tel-Aviv University, Tel-Aviv 69978, Israel*

Spontaneous parametric down conversion (SPDC), where one photon is spontaneously split into two photons through interaction with a non-linear media, is today one of the leading technologies for creating non-classical light for various quantum applications. The created photons are naturally entangled in many degrees of freedom, making them useful for quantum computation, quantum cryptography, quantum communication and more.

The use of sophisticated crystal configurations in order to shape the spatial properties of the bi-photons is a desirable trait for improving the efficiency of the process as well as controlling different degrees of entanglement and tailoring different states. Also, the use of structured light beams enables the creation of higher dimensional entanglement.

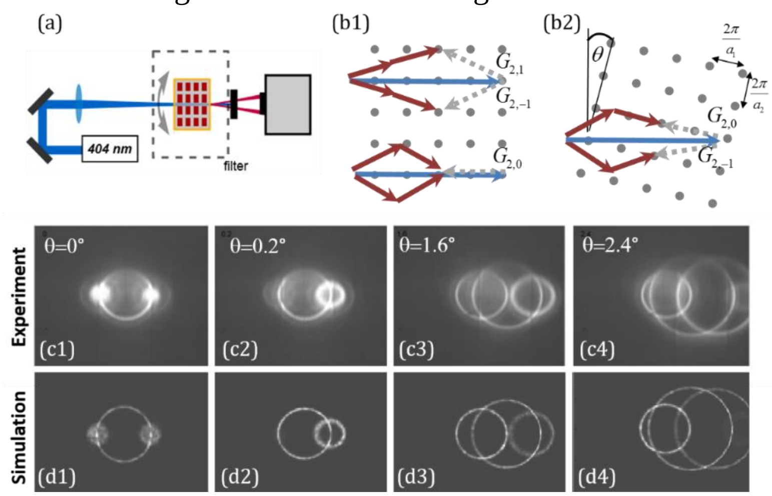

Figure. 3. Simulation and experimental results for SPDC in 2-dimensional rectangular nonlinear photonic crystal. (a) Experimental setup. (b) Reciprocal lattice representation of the crystal (b1) for θ=0° (b2) for θ≠0°. (c) Experimental results and (d) Simulation results for varying values of θ.

We present an efficient numerical method essential for simulating and designing the spatial distribution of the generated bi-photon state. We reproduce the spatial distribution of the down-converted photons for different nonlinear photonic crystals with complex geometries and varying pumping configurations. We study the effect of structured sources, including Laguerre-Gaussian and Hermite-Gaussian beams, and test conservation rules between different degrees of freedom of the beams. This scheme can facilitate the design of nonlinear crystals and pumping conditions for generating non-classical light with desired properties.

Konstantin Yavilberg

Hybridization of Bound States in a TSC/TI/TSC Junction

Konstantin Yavilberg

It has been shown previously that a highly isolated and coherent qubit can be engineered by combining a topological superconducting Josephson junction with a microwave resonator into a device known as the Majorana-Transmon. Here we consider a related device where a topological insulator nanowire of type Bi2Se3 is proximitized to an s-wave Josephson junction. The resulting system is a topological superconducting junction with a topological insulator as the weak link. The Bi2Se3 nanowire is known for its signi_cant surface states bandwidth and thus is an ideal candidate for a realization of the topologically protected Majorana edge states. We investigate the low energy Andreev bound states and the accompanying Majorana edge states residing in the junction. The hybridization between these states has a notable e_ect on the fermionic parity of the superconductors, and as a result on the dipole coupling between the junction and the cavity, which is evident in its electromagnetic signatures.

Zhifan Zhou

Quantum complementarity with clocks in the context of general relativity

Zhifan Zhou, Yair Margalit, Daniel Rohrlich, Yonathan Japha, and Ron Folman

Department of Physics, Ben-Gurion University of the Negev, Be'er Sheva 84105 Israel

Quantum complementarity with interferometers stands at the heart of quantum mechanics (QM). Clocks are a key tool for interrogating the e_ects of general relativistic (GR) such as gravitational time dilation. At the interface between QM and GR, how a clock stores which-path information remains poorly understood, thereby triggering intense and fundamental debates. Here we prepare a clock interferometer with a spatial superposition of two quantum wave-packets with an e_ective time-lag di_erence, to theoretically derive and experimentally test a complementarity relation for quantum clocks in the context of the gravitational time-lag: V 2 + (C _ D)2 _ 1. V is the inteferometric visibility, and D is the distinguishability arising from the time-lag di_erence. C indicates the clock's capability of creating distinguishability and is decided by the internal population of clock spin states. We study in detail this complementary relation by independently measuring V , C and D and prove that the quantum clock complementarity rule is sound. These results demonstrate a simpli_ed and e_cient platform for studying the fundamental physics at the intersection of QM and GR, which may be applied, for example, to discussions about the Compton clock and gravitationally-induced decoherence.