RESEARCH INSTITUTE FOR FUNDAMENTAL SCIENCES

International Workshop on

Quantum Frontiers of Technology

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Over the last century, humankind has gained the ability not only to understand the realms of quantum, which go far beyond our everyday experience and imagination, but also to manipulate them. Nowadays, the growing power of this manipulation is paving the way for a new technological revolution where engineering and coherent control of specific quantum states can be harnessed to provide the greatest benefits for information processing, transmission, sensing and metrology. The goal of this workshop is to bring together world class experts and senior scientists, early career researchers and graduate students to discuss the latest developments in the area of quantum technologies, such as quantum communication, computation, simulation and measurement.

Title and Abstract of Talks

Plenary Talks

Developing a Modular Microwave Trapped Ion Quantum Computer

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Trapped ions are arguably the most mature technology capable of constructing practical large scale quantum computers. We are now moving away from fundamental physics studies towards tackling the required engineering tasks in order build such machines.

By inventing a new method where voltages applied to a quantum computer microchip are used to implement entanglement operations, we have managed to remove one of the biggest barriers traditionally faced to build a large-scale quantum computer using trapped ions, namely having to precisely align billions of lasers to execute quantum gate operations. This new approach, quantum computing with global radiation fields, is based on the use of well-developed microwave technology [1].

In order to be able to build large scale device, a quantum computer needs to be modular. One approach features modules that are connected via photonic interconnect, however, only very small connection speeds between modules demonstrated have been demonstrated so far. We have invented an alternative method where modules are connected via electric fields, allowing ions to be transported from one module to another giving rise to much faster connection speeds [2].

Incorporating these two inventions, we recently unveiled the first industrial blueprint on how to build a large-scale quantum computer which I will discuss in this talk [2]. I will show progress in constructing a quantum computer prototype at the University of Sussex featuring this technology and I will discuss a new method we have demonstrated recently in order to make quantum gates with trapped ions more resilient to sources of decoherence such as motional heating, stray magnetic fields and noise in electrical components [3].

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Schrödinger Cats in Quantum Optics and Quantum Technology

Alexander Lvovsky
University of Oxford

Schrödinger's famous Gedanken experiment has inspired multiple generations of physicists to think about apparent paradoxes that arise when the logic of quantum physics is applied to macroscopic objects. The development of quantum technologies enabled us to produce physical analogues of Schrödinger's cats, such as superpositions of macroscopically distinct states as well as entangled states of microscopic and macroscopic entities. The optical incarnation of Schrödinger's cat – the superposition of two opposite-amplitude coherent states – is also the backbone of quantum information processing in the continuous-variable domain. I will show how we prepare these states, increase their amplitudes, and use them to encode and exchange quantum information. I will also discuss how Schrödinger's cats can be useful in solving one of the big mysteries of modern physics: the validity limits of quantum mechanics in application to microscopic states.

Measurement of Motion in the Negative Mass Reference Frame

Eugene S. Polzik
Neils Bohr Institute

It has been known from the dawn of physics that results of a measurement depend on the chosen reference frame. And yet, in quantum mechanics position and momentum have been almost always defined without particular attention to the reference coordinate system. It turns out that choosing a rather exotic reference frame associated with a spin opens up completely new possibilities for quantum measurements. A spin precessing in magnetic field has properties of a negative mass oscillator [1]. Motion of an object in such a reference frame can be measured without quantum backaction of the measurement. Ideas and experiments involving a hybrid quantum system of a mechanical oscillator and a spin ensemble coupled by light will be presented in this talk. Those range from backaction-free measurements [2] to entanglement between motion and spins [3], to measurements beyond the standard quantum limit. Progress towards generation of entanglement between distant mechanical and spin objects and its applications, including gravitational wave detection beyond the standard quantum limit [4] will be overviewed.

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Integrated Optomechanics and Linear Optics Quantum Circuits

Menno Poot
Technical University of Munich, Munich Quantum Center

Integrated optics provides unprecedented flexibility, scaling possibilities, and stability of optical circuits. In this talk, I will address two topics in this rapidly developing field. By combining movable structures with electrostatic actuation, we developed an opto-electromechanical platform that can be employed as a broadband integrated phase shifter. In vacuum, quality factors up to 300 000 are observed in these devices, which provides an excellent test ground for optomechanical experiments directed towards the quantum regime.. Their motion can be resolved with femtometer resolution, and parametric squeezing is used to reduce the thermal motion. However, when increasing the pump strength, instabilities occur that limit the amount of squeezing that can be realized. By parametrically pumping in the presence of a real-time stabilization of the unstable quadrature, 15 dB of thermo-mechanical noise squeezing is demonstrated. The prospects of using this technique for quantum squeezing are discussed. A different approach to optomechanics is to use two-dimensional structures as the mechanical elements. Our progress towards this are also briefly discussed.

In the second part, our efforts towards fully-integrated linear-optics quantum circuits will be addressed. We show the design, fabrication, and characterization of the essential elements, including directional couplers, photonic CNOT gates, phase detection, and superconducting single photon detectors. All of these are monolithically embedded on the same chip. Optomechanical devices also play an important role in this research, as they will enable programmable initialization and tomography of photonic qubits at cryogenic temperatures.

Permutational Quantum Computing

Sergii Strelchuk
University of Cambridge

I will provide an introduction to the Schur Transform and survey its recent applications in the context of Permutational Quantum Computing (PQC). I will further show that most of its widely-believed quantum features are classically tractable: the outputs of Schur sampling circuits are unconditionally strongly simulatable and weakly simulatable under certain sparsity assumptions. I will also discuss the Kushilevitz-Mansour algorithm which is used to estimate heavy Fourier/Clebsch-Gordan coefficients of the output states of quantum circuits and discuss possible ways of regaining supra-classical power in PQC.

Invited Talks

Nonabelian Excitations at the Topological Edge: Time-resolved Electrical Detection of Chiral Edge Vortex Braiding

İnanç Adagideli
Sabancı University

A 2π phase shift across a Josephson junction in a topological superconductor injects vortices into the chiral edge modes at opposite ends of the junction. When two vortices are fused they transfer charge into a metal contact. We calculate the time dependent current profile for the fusion process, which consists of ±e/2 charge pulses that flip sign if the world lines of the vortices are braided prior to the fusion. This is an electrical signature of the non-Abelian exchange of Majorana zero-modes.

Optical Properties of Single Defects in Hexagonal Boron Nitride

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Photonics technology has reached a stage in which complex functional devices for the generation and detection of light signals can be routinely produced. Especially, the search for novel computation and communication schemes has created applications in which the manipulation and detection of extremely weak optical signals at single-photon level are crucial. Among several systems, quantum emitters in atomically thin 2D based materials, i.e., transition metal di-chalcogenides and defects in hexagonal boron nitride (hBN), have recently attracted a great interest as potentially bright and stable solid-state single-photon sources.

In this talk, recent activities on optical properties of single quantum emitters in bulk hBN will be discussed. Because of its large bandgap, hBN is known to be a good insulator, which also becomes an ideal candidate for exploring optically active defects with energies from UV to NIR. Isolated color centers in hBN are especially promising as efficient single photon sources for quantum photonic circuits. To gain insight about the single photon emission from color centers, we study the temperature dependent optical properties of a single defect and observe that the emission spectra show characteristic features governed by the phonon dispersion of the host material. In addition, our recent results on interaction of single quantum emitters in hBN with two-dimensional graphene will be presented.

Quantum Coherence and Control of Self-assembled Quantum Dots from a Computational Standpoint

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Self-assembled quantum dots (SAQDs) are proven to be one of the most mature solid-state platforms for quantum information applications as indistinguishable single-photon sources. They have high brightness values especially when coupled to microstructures. They can also emit entangled photons pairs which is an essential component for the quantum key distribution implementations.

As opposed to these very appealing photonic features, for spin-qubit applications several obstacles need to be overcome to improve the coherence times in SAQDs. To begin with, through the hyperfine interaction carrier spins are inherently coupled to spinful nuclear background in III-V semiconductors. Furthermore, SAQDs are made up of latticed mismatched ingredients so that the nuclear spins are significantly influenced by the strain through the electric quadrupolar coupling. Under such an inhomogeneous environment, taming the nuclear spin bath is one of the major goals for semiconductor qubits. Thus, it is the structural diversity within the embedded SAQDs where atomic level alloying of cation clusters gives rise to complicated spin noise spectra. Therefore, it is essential to improve our understanding of how central spin coherence is governed by the key structural parameters.

This talk addresses our computational approaches in three directions that serve for this general purpose. In the first part we describe a novel so-called inverse spectra optically detected NMR technique, and how it is successfully used to obtain atomistic level structural information of InGaAs SAQDs.

Next, we investigate variations in the *g*-factor which is the key parameter for demonstrating electron spin resonance (ESR) by structural changes in InGaAs SAQDs. Here, the novelty of our approach relies in an atomistic pseudopotential method, namely linear combination of bulk bands, together with the Roth's seminal *g*-tensor expression which is compatible with an atomistic framework. With this tool we form a *g*-tensor database for a large number of GaAs-capped InGaAs SAQD structures with different lens shape and sizes as well as a broad collection of indium composition, clustering and local strain combinations. When this structural dependence of *g*-tensor is taken into account in their growth control or post-selection, it can render ESR a robust tool for direct quantum logic operations for SAQDs.

Finally, we present the spectral analysis of the nuclear spin bath dynamics in SAQDs. The model spin-Hamiltonian consists of both hyperfine and quadrupolar interactions together with dipolar couplings among the nuclei. For this so-called central spin problem involving large number of spins exact diagonalization is not amenable, so we resort to a recently suggested cluster correlation expansion technique. Our Fourier analysis of the qubit coherence sheds light on how the spectral profile is synthesized through various interactions. This provides an invaluable insight on the qubit decoherence and control of the nuclear spin reservoir.

This work is supported by TÜBİTAK, The Scientific and Technological Research Council of Turkey through the project No. 116F075.

Entanglement; as a Resource for Communication and Sensing

Kadir Durak
Özyeğin University

Entanglement is one of the miracles of quantum physics which does not only fascinate with its counter intuitive nature, but also has practical applications in the fields of cryptography, computation and sensing. The commonly used quanta for entanglement are the photons due to their non-local coherence and easy manipulation in atmospheric and fiber channels. We analyze the emission rate, profile and collection optics dependency on brightness of entangled photons created within a nonlinear Beta-BBO crystal via spontaneous parametric down conversion process. We show that the brightness of down-conversion is under-estimated in the literature but the asymmetric emission profile of down converted photons limits the collection efficiency. Such a bright source can be used for sensing applications like position and velocity acquisition of distant object using time, polarization and momentum correlations of entangled photons, i.e. quantum radar. In this talk, the proof-of-principle experimental results of quantum radar concept will be presented and some possible limitations will be elaborated.

Generalized Measurements and Quantum Computation

Zafer Gedik
Sabancı University

In this talk, we will first present an elementary introduction to Mutually Unbiased Bases (MUB's) and Symmetric Informationally Complete Positive Operator Valued Measures (SIC-POVM's). Then, we will discuss some simple quantum algorithms by using MUB's. Finally, we will show how uncertainty principle can be generalized by means of MUB's.

Exploring 2D Materials for Novel Applications from First-Principles

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Two-dimensional materials are expected to become key components for novel applications for not only electronic devices but also for energy storage applications including super capacitors and batteries because of their exotic properties. Fully understanding of most of material properties needs an atomistic description from quantum mechanics. In this respect, we present the investigation of several state-of-the-art 2D systems from first-principles calculations based on the density functional theory. Examples will include mechanical properties for friction of sliding of graphene or transition metal dichalcogenide layers, the electronic transport properties of the hybrid metallic-semiconducting lateral junctions formed between metallic (1T and 1Td) and semiconducting (2H) phases of MoS2, energy applications as high capacity anode material for battery and supercapacitors, peculiar piezoelectric properties of various 2D systems, and layered perovskites for solar cells [1-11].

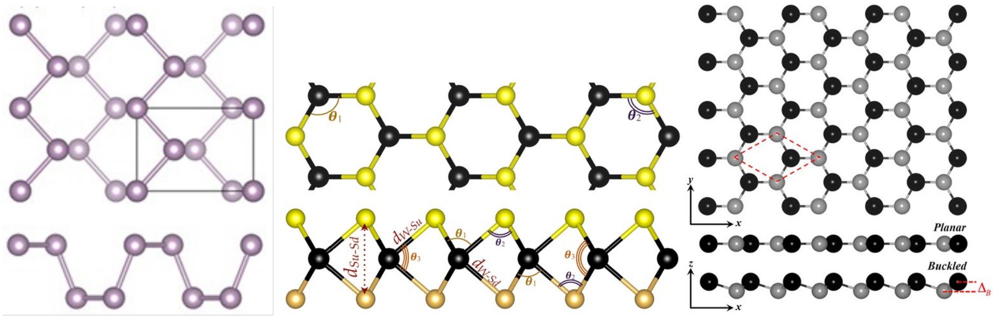

Fig. 1. Atomistic models of various 2D systems.

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Quantum Thermodynamics and Limits of Quantum Machines

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The development of quantum computers is one of the most ambitious and active research fields, reflecting their unprecedented promise to fulfill our historical desire of increasing the efficiency of our computational power using machines. Progress of civilization involves a series of industrial revolutions, each of which can be connected with the invention of the game-changing machine, such as steam engine or laser. Following their developments, questions of their limits were naturally asked and associated conceptual joint progress of thermodynamics and information theory was gained momentum. Interestingly lasers, computers, and steam engines share common characteristics from the perspective of heat engines, and it has been shown that they have to operate within the fundamental bounds set by laws of thermodynamics. The question of if such bounds can be broken in the quantum regime, where thermodynamics is in principle does not apply, fueled the rapidly emerging field of quantum thermodynamics. In this talk, after a brief introduction to quantum thermodynamics, we will discuss its potential innovative applications ranging from quantum information fueled Otto engines, quantum photovoltaics, topological heat manipulation to phononic quantum computation. We will argue how the apparent breaking of classical thermodynamic limits is in fact establishing a new set of limits surprisingly is exactly of the same form with the infamous "second law".

Materials and Devices for Integrated Topological Quantum Spintronics

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Recent advances in precise stoichiometry control and high-resolution characterization of functional materials allowed for the development of integrated spintronic devices, which might enable more than an order of magnitude lower energy consumption per logic device switching than Si CMOS, multi-THz spin wave transmission bandwidth, single molecule sensing and topologically protected spin wavefunctions that are robust for fabrication imperfections. In this presentation, I first present our advances in spintronic materials growth and characterization with a focus on insulating magnetic iron garnets with low damping, high magnetooptical figure-of-merit and built-in magnetic anisotropy. Next, I present our device demonstrations on current-induced spin Hall switching and ultrawide bandwidth generation and detection of topologically protected few-nanometer size chiral spin structures called skyrmions for information processing and sensing. Finally, I present a brief overview of challenges and opportunities in all-electric quantum spintronic devices operating at room temperature.

This film insulating magnetic iron garnets allow for spin wave transmission between 2 GHz to at least 7 THz (1^{st} Brillouin zone of Yttrium iron garnet YIG, $Y_3Fe_5O_{12}$) and minimal Joule heating and spin wave damping. These merits allow for ultrawideband spintronic logic gates [1] with ultralow power consumption. Engineering the defect chemistry, film lattice strain and the precise stoichiometry of garnets allows for obtaining the desired in-plane or out-of-plane magnetic anisotropy needed for classical and quantum magnetic random access memory devices [2]. Large magnetooptical Faraday or Kerr rotation and low optical absorption of garnets also allow for voltage-controlled encoding of information in photons [3,4]. With the nanoscale engineering of device structures, spin wave modes could be manipulated in the quantum regime instead of classical and help obtain fundamental properties of materials such as spin chemical potential [5].

I first present the structural, magnetic and optical properties of insulating magnetic iron garnets that allow for such unique functional properties. Pulsed laser deposition of these garnets allow for miniaturized device integration for sensing and logic [6]. By controlling thickness and the film strain from the lattice-matched substrate, we engineer the magnetic anisotropy of garnets which allow for efficient voltage-based readout of spins in magnetic media using spin Hall effect.

Next, I present our computational and experimental spintronic device demonstrations. The demonstrations include current-induced spin Hall switching [2,4] and ultrawide bandwidth generation and detection of topologically protected few-nanometer size chiral spin structures called skyrmions for information processing and sensing [7]. Spin Hall effect originates from the external or built-in magnetic fields which lift the time-reversal symmetry in the materials. By applying charge currents on a heavy-metal with large spin-orbit coupling on the magnetic insulator garnet, we obtain spin torques which switch the spin orientations in the magnetic layer. In the second part of our devices, I explain how nanoscale engineering of demagnetizing fields could allow for encoding information in few-nanometer, topologically protected chiral spin structures called skyrmions [7]. By applying charge currents, we use spin torques again to generate skyrmions over more than 7 octaves of frequencies with near 65 k_BT per skyrmion at room temperature.

Finally, I present a brief overview of challenges and opportunities in all-electric quantum spintronic devices operating at room temperature. The challenges include obtaining large, voltage-controlled and thermally robust quantum nonlinearities in the system Hamiltonian. We propose new quantum terms including large spin-orbit coupling for resolving these challenges.

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Public Talks

Quantum Physics: From Paradox to Technology

Alexander Lvovsky
University of Oxford, UK

We will discuss:
- what drove Professor Max Planck to despair;
- what will happen if you try to photograph a quantum;
- how a football match would look like in the microcosm;
- how you can detect a hypersensitive bomb and avoid an explosion;
- who is stronger: Bruce Willis or the quantum computer;
- why quantum theory contradicts common sense;
- how to cope with these contradictions without harming yourself or society;
- and whether Schrödinger’s cat is alive.

Beyond Quantum Limits: Teleportation and Other Tricks

Eugene S. Polzik
Neils Bohr Institute, Denmark

Quantum Mechanics invented about 100 years ago is one of the most successful and yet one of the most difficult to comprehend theories. It puts limits, called Quantum Uncertainties, on the accessible knowledge we can obtain about the world. Quantum Uncertainties become visible when we carefully look at everything, from atoms to large objects. Those uncertainties prohibit making identical copies of objects, predicting trajectories of their motion and transmitting their properties without distortions. Nonetheless, recently scientists have learnt to achieve some of those seemingly unattainable goals. The talk will cover the principles and experimental realizations of Quantum Teleportation - transmission of unmeasurable properties of objects, Quantum Entanglement, and measurements beyond the Standard Quantum Limits. Besides moving the boundaries of knowledge, those achievements are at the core of Quantum Technologies, with applications ranging from quantum communication, to quantum sensing to quantum computing.

Poster Presentations

Quantum Control via Feedback Algorithms

Sergey Borisenok
Abdullah Gül University, Electrical And Electronics Engineering

Driven qubits serve as basic elements for quantum computation, quantum sensors and many other quantum devices. Different optimal and sub-optimal control approaches, including speed gradient and target-attractor feedback algorithms, can be successfully applied to stabilize or track the qubit states. We make a review of some control approaches and discuss pros and cons for each of them. We discuss few application of the discussed control methods for cooling qubits, quantum sensoring, quantum computation purposes. The set of control algorithms can be also extended for the systems of few qubits, qutrits, multi-level quantum systems, memristors, quantum heat engines and quantum networks.

Quantum and Art

Mehmet Keçeci
Gebze Technical University, Physics

In this artwork, trying to look at quantum results with an artistic perspective, especially from the laboratory. Here I am trying to be simple and straightforward image is specially selected. Because the transformation result using a mathematical symmetries of images to come to our mind than perhaps ever simple image are not obtained. No interventions, plays or manipulations have been performed on these images other than the effects previously prepared by programmers. The results of the different images can be handled in future studies will be a study in how to change.

Multiple Electro-Mechanical Induced Transparency and Fano Resonances in Hybrid Optomechanical System

Kamran Ullah
Koç University, Physics

We show multiple electromechanically-induced transparency (EMIT) windows in a hybrid nano-electro-optomechanical system in the presence of two-level atoms coupled to a single-mode cavity field. The multiple EMIT-window profile can be observed by controlling the atom field coupling as well as Coulomb coupling between the two charged mechanical resonators. We derive the analytical expression of the multiple-EMIT-windows profile and describe the splitting of multiple EMIT windows as a function of optomechanical coupling, atom-field coupling, and Coulomb coupling. In particular, we discuss the robustness of the system against the cavity decay rate. We compare the results of identical mechanical resonators to different mechanical resonators. We further show how the hybrid nano-electro-optomechanics coupled system can lead to the splitting of the multiple Fano resonances (MFR). The Fano resonances are very sensitive to decay terms in such systems i.e., atoms, cavities, and mechanical resonators.

Topological and Finite Size Effects in Kitaev Chain Heat Engine

Elif Yunt
Koç University, Physics

We investigate a heat engine with a finite length Kitaev chain in an Otto cycle. Finite size effects are taken into account using method of Hill's nanothermodynamics as well as using the method of temperature dependent energy levels. We distinguish the bulk and boundary contributions to the efficiency and work output of Kitaev chain engine and identify them as non-Otto heat engine and refrigerator cycles, respectively. We show that the first order phase transition in the boundary and the second order phase transition in the bulk can be identified in their respective contributions to the engine work output. Possibility of separately running Otto engine cycles associated with the bulk and the whole system, and an Otto refrigerator at the boundary is pointed out. It is found that the critical point of the topological phase coincides with the extremum of the efficiency and the work output of the bulk and the total Otto engine.

The Landscape of Academic Literature in Quantum Information Technologies

Zeki Seskir
Middle East Technical University, Physics

In this study, we have investigated the landscape of academic literature in quantum information technologies (QIT) using bibliometric tools of analysis. In the first part of the study, we have used an initial set of 50,822 articles obtained from the Web of Science using an extensive search query constructed through expert opinion. Analysis of this section revealed that QIT is deeply rooted in the field of physics and over 80% of the articles are published in journals mainly reserved for publication in physics. Additionally, it can be seen from this initial set that on a quantitative level based on the number of published scientific articles, the US, China, and Europe are almost on par. Furthermore, a keyword analysis on this set revealed that the main academic literature can be clustered into three distinct sets, which are (i) quantum communication/cryptography, (ii) quantum computation, and (iii) physical realizations of quantum systems. Finally, for the first section, a burst analysis on this set using different density parameters showed the emergence and fading away of certain key concepts in the literature. In the second part, we focused on 808 "highly cited" articles provided by the Web of Science. Using the co-citation analysis of these articles we have devised a set of core corpus of 34 publications for QIT literature and showed how this core corpus is clustered in itself. Finally for the second section, using bibliographic coupling we have mapped collaboration networks on the country and institutional levels. Search queries and access to enhanced views of figures are provided in appendix. https://arxiv.org/abs/1910.06969

Particle Track Reconstruction with Quantum Algorithms

Cenk Tüysüz
Middle East Technical University, Physics

The Large Hadron Collider (LHC) at CERN is producing collisions at unprecedented collider energy. The hundreds to thousands of particles created during the collisions are recorded by large detectors composed of several sub-detectors. The core of which is a tracker detector, recording the sparse signal of the passage of charged particles through thin layers of active material. The trajectories of particles are bent using magnetic field, so as to have a handle at measuring transverse momentum. There is an expected ten-fold increase in the number of tracks produced per collision after high luminosity upgrade of the LHC. Classical algorithms to perform the reconstruction of the trajectory of charged particles are making use of Kalman filter formalism and even though quite accurate, scale worse than quadratically with the number of tracks. There are several ways to mitigate the increase in the computing needs, such as new detector layout, deep learning and code parallelization. Quantum computing is shown to provide speed-ups for certain problems. In fact, different R&D initiatives are exploring how Quantum Tracking Algorithms could leverage such capabilities. In this poster, we present our work on the implementation of a quantum-based track finding algorithm aimed at reducing combinatorial background during the initial seeding stage. We use the publicly available dataset designed for the kaggle TrackML challenge.

Object Tracking, Identification and Imaging by Quantum Radar

Çağrı Dindar
Özyeğin University, Electrical And Electronics Engineering

Quantum Radar is a promising technology that could have a strong impact on the civilian and military realms. In this study we introduce a new concept design for implementing a Quantum Radar, based on the time and polarization correlations of the entangled photons for detection and identification and tracking of high-speed targets. The design is focused on extracting high resolution details of the target with precision timing of entangled photons that provides important operational capabilities like distinguishing a target from a decoy. We also mention quantum ghost imaging method by using multi-pixel detector with Quantum Radar. The quantum entanglement properties guarantee the legitimacy of the photons captured by the search telescope. Time correlations of the photon detection events can be extracted via cross-correlation operation between two sets of photon detection time-tags for the entangled photons. The fact that the wavelengths of the entangled photons can be tuned also makes the Quantum Radar concept an enticing candidate for tracking stealth objects. We present the proof-of-principle test results of the Quantum Radar and discuss the technical challenges and limitations of the design.

Strongly Coupled Magnon-Photon System for Quantum Converter Applications

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Towards Optical Post Processing for High Speed Quantum Random Number Generators

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The speed of quantum random number generators is a major concern for practical quantum applications. However, the bit extraction process limits the final bit rate due to lack of comparably fast electronics. Here we introduce optical scattering as a method to perform optical bit extraction. Scattering is a probabilistic phenomenon and it increases the chaotic behaviour of coherent sources. As a result, it broadens the distribution of photon statistics and makes it super-Poissonian. We show that the raw signal of the sources with super-Poissonian distribution have better randomness compared to Poissonian, indicated by their autocorrelation characteristics. Therefore, the optical bit extraction process allows faster sampling of raw signal without compromising the randomness quality. The use of scattering mechanisms as an entropy source eases the miniaturization of quantum random number generators, it also makes them compatible and adaptable to existing technologies.

Work Extraction and Landauer's Principle in a Quantum Spin Hall Device

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Landauer's principle states that erasure of each bit of information in a system requires at least a unit of energy kBTln2 to be dissipated. In return, the blank bit may possibly be utilized to extract usable work of the amount kBTln2, in keeping with the second law of thermodynamics. While in principle any collection of spins can be utilized as information storage, work extraction by utilizing this resource in principle requires specialized engines that are capable of using this resource. In this work, we focus on heat and charge transport in a quantum spin Hall device in the presence of a spin bath. We show how a properly initialized nuclear spin subsystem can be used as a memory resource for a Maxwell's demon to harvest available heat energy from the reservoirs to induce charge current that can power an external electrical load. We also show how to initialize the nuclear spin subsystem using applied bias currents which necessarily dissipate energy, hence demonstrating Landauer's principle. This provides an alternative method of "energy storage" in an all-electrical device. We finally propose a realistic setup to experimentally observe a Landauer erasure/work extraction cycle.

Can One Hear The Shape of a Majorana Billiard?

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We study the fermioN parity switches of the ground state of Majorana billiards, i.e. finitely sized, arbitrarily shaped superconducting islands that host Majorana fermions. These parity switches signal zero dimensional topological phase transitions. In particular, we study the den- sity and statistics of these parity switches as a function of the applied magnetic field and chemical potential. We derive formulae that specify how the average density of parity switches depends on the geometrical size of the billiard as well as its boundary. Moreover, we show how the oscillations around this average value is determined by the classical periodic orbits of the billiard. Finally, we find that the statistics of the spacings of these parity switches are universal and are described by an appropriate random matrix ensemble, the choice of which depends on the antiunitary symmetries of the system in its normal state. We thus demonstrate that “one can hear (information about) the shape of a Majorana billiard” by investigating its “parity switch spectrum”.

Fabrication and Characterization of Miniature Glass-blown Cs Vapor Cells

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Alkali metal vapor cells are the core of atomic physics-based precise measurement devices such as atomic clocks, atomic magnetometers and, atomic spin gyroscopes, all of which consist of alkali metal atoms with long-lasting polarization. They have been oriented by optical pumping method for nearly seventy years since the spin polarization is the operation requirement of many atomic devices. The atomic sensor sensitivity is associated with the density of atoms and transverse lifetime T2 of the spin coherence in alkali vapor ensemble. The destruction of the polarization of optically pumped alkali atoms and T1 - T2 relaxation times are affected by various mechanisms. The collisions with other alkali atoms, buffer gas atoms, quenching gas molecules and diffusion to depolarizing wall are the most important ones. Reduction of the relaxation rates of atomic ground-state polarization is the essential solution for enhancement of the sensitivity and increment of the polarization lifetime. Two fundamental methods are utilized to decelerate the fast depolarizing mechanism. The first method is filling the vapor cell with buffer gases such as neon, argon, krypton, xenon to prevent alkali atoms to make spin destructive wall collision. Atoms disperse slowly as a result of the alkali-buffer collision and buffer gases prevent alkali atoms to reach the cell walls permanently. The second method is the application of anti-relaxation coatings like paraffin and octadecyl-trichlorosilane (OTS) which have the ability to preserve spin polarization of atom during wall collision. The vapor density was increased by heating the atomic vapor cell for enhancing the sensitivity. However, high temperature affects the performance of the coating by damaging its structure. Therefore, the buffer gas method is more preferable for high temperature applications. In this study, the fabrication and the characterization of nitrogen buffered and pure cesium vapor cells were reported. The natural linewidth of F=4 to F=5’ transition was measured as 5.36 MHz by using Doppler-free saturated absorption spectroscopy. In addition, an Mx type magnetometer setup was used to measure and compare the magnetic resonance lineshapes of the pure and buffered Cs vapor cells for cardiomagnetometer applications. The halfwidths at half maxima of the phase signals were measured as 1039 Hz and 4450 Hz for 10 torr N2 buffered and pure Cs vapor cells, respectively. The calculated sensitivities for these lineshapes are 22.4 pT/√Hz and 76 pT/√Hz, respectively. The sensitivities of both cells are optimized for cardiomagnetometric measurements.