ABSTRACTS

The Sixth Poznań Symposium on *Quantum Information and Quantum Technologies* QIQTec 2024

10-13 May, 2024

Regular Sessions

1. Speaker: **Prof. Franco Nori** (keynote speaker)

   Title: Quantum Nonlinear Optics without Photons, how to excite two or more atoms simultaneously with a single photon, and other unusual properties of ultra-strongly-coupled QED systems.

Affiliations:
[1]Theoretical Quantum Physics Laboratory, Center for Quantum Computing, RIKEN, Japan
[2]Physics Department, The University of Michigan, Ann Arbor, USA

Abstract: [PDF] How to excite two or more atoms simultaneously with a single photon: We consider two separate atoms interacting with a single-mode optical or microwave resonator. When the frequency of the resonator field is twice the atomic transition frequency, we show that there exists a resonant coupling between one photon and two atoms, via intermediate virtual states connected by counter-rotating processes. If the resonator is prepared in its one-photon state, the photon can be jointly absorbed by the two atoms in their ground state which will both reach their excited state with a probability close to one. Like ordinary quantum Rabi oscillations, this process is coherent and reversible, so that two atoms in their excited state will undergo a downward transition jointly emitting a single cavity photon. This joint absorption and emission process can also occur with three atoms. The parameters used to investigate this process correspond to experimentally demonstrated values in circuit quantum electrodynamics systems. Quantum nonlinear optics without photons: Spontaneous parametric down-conversion is a well-known process in quantum nonlinear optics in which a photon incident on a nonlinear crystal spontaneously splits into two photons. Here we propose an analogous physical process where one excited atom directly transfers its excitation to a pair of spatially separated atoms with probability approaching 1. The interaction is mediated by the exchange of virtual rather than real photons. This nonlinear atomic process is coherent and reversible, so the pair of excited atoms can transfer the excitation back to the first one: the atomic analog of sum-frequency generation of light. The parameters used to investigate this process correspond to experimentally demonstrated values in ultrastrong circuit quantum electrodynamics. This approach can be extended to realize other nonlinear interatomic processes, such as four-atom mixing, and is an attractive architecture for the realization of quantum devices on a chip. We show that four-qubit mixing can efficiently implement quantum repetition codes and, thus, can be used for error-correction codes.

2. Speaker: **Prof. Huan-Yu Ku** (invited speaker)

   Title: Measurement incompatibility cannot be distilled

Affiliation: Department of Physics, National Taiwan Normal University, Taipei 11677, Taiwan

Abstract: The abstract of my talk is: We show that the incompatibility of a set of measurements cannot be increased by subjecting them to a filter, namely, by combining them with a device that post-selects the incoming states on a fixed outcome of a stochastic transformation. This result holds for several measures of incompatibility, such as those based on robustness and convex weight. Expanding these ideas to Einstein-Podolsky-Rosen steering experiments, we are able to solve the problem of the maximum steerability obtained with respect to the most general local filters in a way that allows for an explicit calculation of the filter operation. Moreover, our results generalize to nonphysical maps, i.e., positive but not completely positive linear maps.

3. Speaker: **Dr. Po-Chen Kuo** (invited speaker)

   Title: Non-Markovian skin effect

Affiliation: Department of Physics, National Cheng Kung University, Tainan 70101, Taiwan

Abstract: The Liouvillian skin effect and the non-Hermitian skin effect have both been used to explain the localization of eigenmodes near system boundaries, though the former is arguably more accurate in some regimes due to its incorporation of quantum jumps. However, these frameworks predominantly focus on weak Markovian interactions, neglecting the potentially crucial role of memory effects. To address this, we investigate, utilizing the powerful hierarchical equations of motion method, how a non-Markovian environment can modify the Liouvillian skin effect. We demonstrate that a non-Markovian environment can induce not only a "thick skin effect", where the skin mode broadens and shifts into the bulk, but also skin-mode coherence, leading to the coherence-delocalization and oscillatory relaxation with a characteristic linear scaling with system size. Remarkably, both the skin-mode and steady-state coherence exhibit resistance to decoherence from additional environmental noise. These findings highlight the profound impact of system-bath correlations on relaxation and localization, revealing unique phenomena beyond conventional Markovian approximations.

4. Speaker: **Dr. Jhen-Dong Lin** (invited speaker)

   Title: Non-Markovian Quantum Exceptional Points

Affiliations:
[1]Department of Physics, National Cheng Kung University, 701 Tainan, Taiwan

[2]Center for Quantum Frontiers of Research Technology, NCKU, 70101 Tainan, Taiwan

Abstract: Exceptional points (EPs) are singularities in the spectra of non-Hermitian operators, where eigenvalues and eigenvectors coalesce. Recently, open quantum systems have been increasingly explored as testbeds for quantum EPs due to their natural non-Hermitian nature. However, existing works mostly focus on the Markovian limit, leaving a gap in understanding EPs in the non-Markovian regime. In this work, I will present our new results, where we address this gap by proposing a theoretical framework based on two numerically exact descriptions of non-Markovian dynamics: the pseudomode mapping and the hierarchical equations of motion. We unveil pure non-Markovian EPs that are unobservable in the Markovian limit. Remarkably, the EP aligns with the Markovian-to-non-Markovian transition. Moreover, we show that structured environments can elevate EP order, thereby enhancing the system's sensitivity.

5. Speaker: **Prof. Wiesław Leoński** (invited speaker)

Authors: W. Leoński[1], J. K. Kalaga[1], A. Kowalewska-Kudłaszyk[2] and J. Perina Jr.[3]

Title: Two-mode entangled bosonic system and Legget-Garg inequality

Affiliations:
[1]Quantum Optics and Engineering Division, Institute of Physics, University of Zielona Góra, Zielona Góra, Poland
[2]Nonlinear Optics Division, ISQI, Faculty of Physics, A. Mickiewicz University, Poznan, Poland
[3]Joint Laboratory of Optics, Faculty of Science, Palacký University, Olomouc, Czech Republic

Abstract: [PDF] We consider a system involving two quantum nonlinear oscillators mutually coupled and continuously driven by an external coherent field. For such a model, we discuss temporal correlations. In particular, we examine the Leggett-Garg inequality's (LGI) violation. We analyze various scenarios of measurements based on projection onto different Bell states, showing that the possibility of violating LGI inequalities is related to the use of different projectors.

6. Speaker: **Prof. Zbigniew Ficek** (invited speaker)

Title: Controlled generation of coherence and entanglement in a three-mode system

Affiliation: Quantum Optics and Engineering Division, Institute of Physics, University of Zielona Góra, Zielona Góra, Poland

Abstract: We investigate a method for a controlled generation of coherence and entanglement in a three-mode system with closed-loop coupling between the modes. We assume that two of the three possible coupling channels are of the squeezing-type, whereas the remaining is a beam-splitter type. The results show that the competition between the induced coherence and the already existing coherence in the beam-splitter type coupling channel leads to phase dependent oscillations of the maximal entanglement generated the other channels. In other words, generated entanglement in the system can be phase controlled and completely transferred to a given pair of modes.

7. Speaker: **Prof. Artur Barasiński** (invited speaker)

Title: Efficient and Reliable Detection of Nonlocal Quantum Correlations via Random Measurements

Affiliation: Institute of Theoretical Physics, University of Wrocław, 50-204 Wrocław, Poland

Abstract: We present a comprehensive numerical analysis exploring violations of local realism across various non-equivalent models of local hidden variables. Specifically, we delve into a recently proposed operational measure of nonlocality, which assesses both the probability of violating local realism under randomly sampled observables and the strength of such violation in the face of white noise admixture. Our findings demonstrate that both metrics can be effectively estimated using a simplified model of nonlocality based solely on the violation of a specific class of Bell inequalities. The simplicity of these inequalities, expressed in terms of correlation coefficients, renders them invaluable for practical experimental investigations encompassing the themes discussed in this paper. Notably, the nonlocal fraction derived from these inequalities serves as a robust witness of genuine multipartite entanglement, eliminating the need for distant parties to share a common reference frame.

8. Speaker: **Prof. Andrzej Grudka**

Title: Superluminal observers and quantum superpositions

Affiliation: Nonlinear Optics Division, Institute of Spintronics and Quantum Information, Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

Abstract: Recently Dragan and Ekert proposed that superluminal observers can explain quantum superpositions. We construct system of emitters and detectors and analyse their proposal in two reference frames - one of usual subluminal observers ant the other one of superluminal observers. We show that what they claim to be superposition of two single photon paths from the point of view of superluminal observers are in fact two paths of two photons.

9. Speaker: **Prof. Paweł Kurzyński**

Title: Non-classicality Primitive in a Quasi-probabilistic Toy Model

Affiliation: Nonlinear Optics Division, Institute of Spintronics and Quantum Information, Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

Abstract: We demonstrate a basic non-classical effect in a quasi-probabilistic toy model with local Alice and Bob who share classical randomness. Our scenario differs from the orthodox demonstrations of non-classicality such as violations of Bell inequalities where both local observers have a free will and randomly choose their measurement settings. The core of the argument are modified algorithms by Abramsky and Brandenburger [in Horizons of the Mind, Springer, Cham (2014)], and Pashayan et. al. [Phys. Rev. Lett. 115, 070501 (2015)] we use to show that if Bob deterministically performs a quasi-stochastic operation, Alice and Bob require classical communication to simulate it.

10. Speaker: **Prof. Anna Kowalewska-Kudłaszyk**

Title: On some examples of blocking photons and phonons

Affiliation: Nonlinear Optics Division, Institute of Spintronics and Quantum Information, Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

Abstract: Photon blockades are the bosonic analogues of well known Coulomb blockades for electrons. Systems in which photon blockades appear may be used for example as perfect single (or two) photon sources due to the fact that generation of one (or two) photons blocks generation of more photons in the same system. For successful blockades a presence of nonlinearity is necessary. We will show that one of the possible sources of nonlinearity may come from the interaction with squeezed reservoir [1]. Nonlinearity is also responsible for generation blockades and other effect related to quantum correlations in hybrid modes of optomechanical system [2]. Possible improvement of two-photon blockade via quantum interference within a cavity with many emitters will also be mentioned.
[1] A. Kowalewska-Kudłaszyk, S.I. Abo, G. Chimczak, J. Perina Jr., F. Nori, A. Miranowicz Phys. Rev. A 100, 053857 (2019).
[2] S.I. Abo, G. Chimczak, A. Kowalewska-Kudłaszyk, J. Perina Jr., R. Chhajlany and A. Miranowicz, Sc.Rep. 12, 17655 (2022).

11. Speaker: **Prof. Ireneusz Weymann**

    Title: Kondo cloud in superconductors

    Affiliation: Department of Mesoscopic Physics, Institute of Spintronics and Quantum Information, Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

    Abstract: (...)

12. Speaker: **Prof. Ravindra Chhajlany**

    Title: Artificial quantum matter under control: from excitons to atoms

    Affiliation: Nonlinear Optics Division, Institute of Spintronics and Quantum Information, Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

    Abstract: (...)

13. Speaker: **Prof. Karol Bartkiewicz**

    Title: Experimental exploration of Liouvillian exceptional points on a quantum computer

    Affiliation: Nonlinear Optics Division, Institute of Spintronics and Quantum Information, Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

    Abstract: (...)

14. Speaker: **Dr. Kacper Wrześniewski**

    Title: Dynamics and cross-correlations in quantum dot-Majorana wire systems

    Affiliation: Department of Mesoscopic Physics, Institute of Spintronics and Quantum Information, Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

    Abstract: We theoretically investigate quench dynamics in quantum dot system coupled to topological superconducting nanowire hosting Majorana bound states. For the single quantum dot system, we predict non-trivial competition between Majorana physics and ferromagnetic correlations. High tunability of the system gives precise control of discussed effects and opens many possibilities for novel applications in spintronic quantum devices. Furthermore, we analyze spin-polarized currents and associated cross-correlations, and show that ferromagnetic contacts can indicate imprints of Majorana physics. When another quantum dot is attached to opposite edge of the nanowire, a non-local nature of Majorana bound states is uncovered, evident in both dynamical effects and in transport spectroscopy.

15. Speaker: **Dr. Javid Naikoo**

    Title: Enhancing quantum sensors by capitalising on dynamical instabilities

    Affiliation: Nonlinear Optics Division, Institute of Spintronics and Quantum Information, Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

    Abstract: In my presentation, based on Phys. Rev. Lett. 131, 220801 (2023), I will delve into the cutting-edge realm of quantum sensing, focusing on the utilization of dynamical singularities to achieve unbounded sensitivity in the estimation of unknown parameters. By integrating the multiparameter estimation theory of Gaussian quantum systems with the study of singular-matrix perturbations, I will discuss a novel framework for analyzing the ultimate limits of precision attainable by singularity-tuned sensors. This will allow us to identify the conditions under which sensitivity diverges and at what rate, shedding light on the fundamental capabilities of these quantum sensors. Moreover, I will highlight the significance of accounting for nuisance parameters in the analysis, as their presence may significantly impact the scaling of error with the estimated parameter.

16. Speaker: **Dr. Arnab Laha**

    Title: Speciality optical waveguide systems exhibiting conjugate exceptional points

    Affiliation: Nonlinear Optics Division, Institute of Spintronics and Quantum Information, Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

    Abstract: The occurrence of Exceptional Points (EP) is one of the distinctive features of open (non-Hermitian) systems [1, 2]. The understanding of the level-repulsion phenomenon within such a system is associated with the occurrence of an EP and its time-reversal (T) conjugate pair (say, EP*) in the underlying parameter space [3, 4]. Here, we exploit the concept of conjugate EPs in reporting a time (T)-symmetric correlation in all-optical nonreciprocal light transmission [4]. Without any magneto-optical effect, nonreciprocity is achieved based on a controlled Kerr-type local nonlinearity in a planar gain-loss assisted waveguide. Especially, we reveal a correlation between two T-symmetric variants of the designed nonlinear waveguide, where dynamic gain-loss variations around two conjugate EPs (in their respective parameter spaces) allow asymmetric transfer of two different modes through two waveguide variants, while considering the light propagation in the same direction [4]. Here, both waveguide variants block light in the reverse directions. The physical aspects behind engineering conjugate EPs in such nonlinear optical systems would enrich the platform for building nonreciprocal components like isolators and circulators for all-photonic circuits.
    [1] Ş K. Özdemir, S. Rotter, F. Nori, and L. Yang, Nat. Mater. 18, 783 (2019)
    [2] M.-A. Miri and A. Alu, Science 363, eaar7709 (2019)

[3] A. Laha, S. Dey, and S. Ghosh, Phys. Rev. A 105, 022203 (2022)
[4] A. Laha, A. Miranowicz, R. K. Varshney, and S. Ghosh, Phys. Rev. A 109, 033511 (2024)

17. Speaker: **Dr. Grzegorz Chimczak**

Title: Good two-photon blockade displayed in the presence of a cloud of emitters

Affiliation: Nonlinear Optics Division, Institute of Spintronics and Quantum Information, Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

Abstract: We show that it is possible to observe an almost perfect two-photon blockade in a quantum system consisting of an optical cavity, a single atom, and a cloud of two-level emitters. This result might seem surprising because, according to the Holstein-Primakoff transformation, a big number of emitters trapped inside the cavity should behave like quantum harmonic oscillator, which is a linear system, while nonlinearity is essential to observe any photon blockade phenomenon. We explain this behavior by showing that the third-order correlation function can have a negligibly small value in this system because of the destructive interference phenomenon. The presented scheme exhibits this almost perfect two-photon blockade for experimentally feasible parameters.

18. Speaker: **Dr. Marcin Karczewski**

Title: Heralded entanglement generation with indistinguishable particles

Affiliation: Nonlinear Optics Division, Institute of Spintronics and Quantum Information, Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

Abstract: I am going to present my recent results concerning heralded entanglement generation with identical particles. The basic problem can be stated like this: consider a multiport given by a unitary U. We cast N identical photons into its input modes and measure the resulting photon numbers in some of its output modes. How to design this process in such a way that a specific pattern of registered photons will herald a target entangled state in the modes with no detectors?

19. Speaker: **M.Sc. Kuan-Yi Lee**

Title: Unveiling quantum steering by quantum-classical uncertainty complementarity

Affiliation: Center for Quantum Frontiers of Research and Technology (QFort), National Cheng Kung University, Tainan 701, Taiwan

Abstract: One of the remarkable aspects of quantum steering is its ability to violate local uncertainty complementarity relations. In this vein of study, various steering witnesses employing different uncertainty relations have been developed including the famous Reid's criteria. Here, we introduce a novel complementarity relation between a system's quantum and classical uncertainties corresponding to the distillable coherence and von-Neumann entropy, respectively. We demonstrate its superior steering detection efficiency compared to the entropic uncertainty relation. Notably, our proposed steering witness can

20. Speaker: **M.Sc. Yi-Te Huang**

Title: An efficient Julia framework for hierarchical equations of motion in open quantum systems

Affiliation:
[1]Department of Physics, National Cheng Kung University, 701 Tainan, Taiwan.
[2]Center for Quantum Frontiers of Research and Technology, NCKU, 701 Tainan, Taiwan.

Abstract: The hierarchical equations of motion (HEOM) approach can describe the reduced dynamics of a system simultaneously coupled to multiple bosonic and fermionic environments. The complexity of exactly describing the system-environment interaction with the HEOM method usually results in time-consuming calculations and a large memory cost. Here, we introduce an open-source software package called HierarchicalEOM.jl: a Julia framework integrating the HEOM approach. HierarchicalEOM.jl features a collection of methods to compute bosonic and fermionic spectra, stationary states, and the full dynamics in the extended space of all auxiliary density operators (ADOs). The required handling of the ADOs multi-indexes is achieved through a user-friendly interface.

21. Speaker: **M.Sc. Patrycja Tulewicz**

Title: Advancing Generative Machine Learning with Quantum Computing

Authors: Patrycja Tulewicz[1], Karol Bartkiewicz[1], Jan Roik[2], Karel Lemr[2]

Affiliations:
[1]Nonlinear Optics Division, Institute of Spintronics and Quantum Information, Faculty of Physics, Adam Mickiewicz University, Poznań, Poland
[2]RCPTM, Joint Laboratory of Optics of Palacký University and Institute of Physics of Czech Academy of Sciences, Olomouc, Czech Republic

Abstract: [PDF] The main difference between classical programming and machine learning (ML) is the reliance on explicit instructions for the former, as opposed to ML. The implicit operation of ML can be particularly useful for complex problems resistant to conventional methods, such as those in quantum systems. The integration of quantum computing and machine learning appears to offer a promising solution to these challenges, with additional benefits for the advancement of quantum information research. This talk will discuss how a new approach to generative machine learning emerges from quantum state discrimination [1]. A novel approach, the Synergic Generative Adversarial Network (SGAN), significantly reduces the number of hyperparameters required for generative quantum machine learning. This method supports collaboration between generators and discriminator, outperforming traditional quantum generative adversarial learning in some scenarios. Experimental results, both from quantum simulators and real quantum computers of IBMQ [2], show the effectiveness of our approach. A system trained with our algorithm successfully learns to recognize and generate maximally entangled states.
[1] Karol Bartkiewicz, Patrycja Tulewicz, Jan Roik, and Karel Lemr. Synergic quantum generative machine learning. Scientific Reports, 13(1):12893, Aug 2023.
[2] IBM Quantum. https://quantum-computing.ibm.com/. 2021.

22. Speaker: **M.Sc. Shilan Abo**

Title: Pure dephasing of light-matter systems in the ultrastrong and deep-strong coupling regimes

Affiliation: Nonlinear Optics Division, Institute of Spintronics and Quantum Information, Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

Abstract: The field of cavity quantum electrodynamics holds great promise for studying strong inter- actions between light and matter. However, there is still a lot to be understood about pure dephasing in quantum systems, especially in the strong coupling regimes where new physical phenomena and quantum applications can arise. In weak interaction scenarios, the difference in perturbation forms between the dipole gauge and the Coulomb gauge is often negligible. However, ignoring this difference can result in incorrect and unphysical outcomes in ultra-strong and deep-strong coupling regimes. In this talk I will address this issue, focusing on calculating the pure dephasing rate in two different models: the quantum Rabi model and the Hopfield model. I will explain that the interaction in a light-matter system in ultra- strong and deep-strong coupling regimes can significantly impact the form of the stochastic perturbation that describes the dephasing of a subsystem, depending on the gauge that is adopted [1].
[1] A. Mercurio, S. Abo, F. Mauceri, E. Russo, V. Macri, A. Miranowicz, S. Savasta, and O. Di Stefano, Pure Dephasing of Light-Matter Systems in the Ultrastrong and Deep-Strong Coupling Regimes, Phys. Rev. Lett. 130, 123601 (2023).

23. Speaker: **B.Sc. Jędrzej Stempin**

Title: Exploring position-dependent quantum random walks

Affiliation: Nonlinear Optics Division, Institute of Spintronics and Quantum Information, Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

Abstract: Quantum Random Walks serve as simplified models for understanding complex physical systems, such as solutions of the Dirac equation. Drawing parallels with Classical Random Walks, commonly used in search algorithms, highlights their potential applications. Notably, Quantum Random Walks demonstrate superior propagation speed compared to classical counterparts. Moreover, incorporating position-dependent parameters leads to a faster wave function spread. To get a deeper insight into the problem, we explore the symmetries acquired by the evolution operator to analyze Quantum Random Walks with position-dependent parameters. Our investigation also includes discrete Wigner functions and decoherence mechanisms, revealing the relationship between Quantum and Classical Random Walks.

24. Speaker: **B.Sc. Jan Wójcik**

Title: Electrically coupled optomechanical cavities as a tool for quantum nondemolition measurement

Affiliation: Nonlinear Optics Division, Institute of Spintronics and Quantum Information, Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

Abstract: We present a new model of two electrically coupled optomechanical cavities. We will show that coupling two optomechanical cavities via Coulomb force leads to cross-Kerr interactions between those cavities. We will further more prove that such systems are perfect for a protocol of quantum non-demolition measurement because the elimination of the self-phase modulation effect is extremely simple. Moreover, nonlinearities in our model are based on easily adjustable parameters, and therefore, given recent experimental studies, we believe that experimental realization of a cross-Kerr interaction via Coulomb force coupling is feasible.

Satellite Talks

25. Date: Thursday 2024.05.09 at 15:00

Venue: Prof. S. Kielich's Auditorium

Satellite Talk in the series of the ISIK Seminars

Speaker: **Prof. Franco Nori** (keynote speaker)

Title: Quantum Optics with Giant Atoms: Decoherence-Free Interaction between Giant Atoms in Waveguide Quantum Electrodynamics

Affiliations:
[1]Theoretical Quantum Physics Laboratory, Center for Quantum Computing, RIKEN, Japan
[2]Physics Department, The University of Michigan, Ann Arbor, USA

Abstract: [PDF] In quantum optics, atoms are usually approximated as point-like compared to the wavelength of the light they interact with. However, recent advances in experiments with artificial atoms built from superconducting circuits have shown that this assumption can be violated. Instead, these artificial atoms can couple to an electromagnetic field in a waveguide at multiple points, which are spaced wavelength distances apart. Such systems are called giant atoms. They have attracted increasing interest in the past few years (e.g., see the review in [1]), in particular because it turns out that the interference effects due to the multiple coupling points allow giant atoms to interact with each other through the waveguide without losing energy into the waveguide (theory in [2] and experiments in [3]). This talk will review some of these developments [1-4]. Finally, we will also show how a giant atom coupled to a waveguide with varying impedance can give rise to chiral bound states [5].
[1] A.F. Kockum, Quantum optics with giant atoms - the first five years, arxiv:1912.13012
[2] A.F. Kockum, G. Johansson, F. Nori, Decoherence-Free Interaction between Giant Atoms in Waveguide Quantum Electrodynamics, Phys. Rev. Lett. 120, 140404 (2018).
[3] B. Kannan, et al., Waveguide quantum electrodynamics with superconducting artificial giant atoms, Nature 583, pp. 775 (2020).
[4] S. Terradas-Brianso, et al., Ultrastrong waveguide QED with giant atoms, Phys. Rev. A 106, 063717 (2022).
[5] X. Wang, T. Liu, A.F. Kockum, H.R. Li, F. Nori, Tunable Chiral Bound States with Giant Atoms, Phys. Rev. Lett. 126, 043602 (2021).

Chair: Prof. Ireneusz Weymann

26. Date: Monday 2024.05.13 at 16:00

Venue: Auditorium Maximum

Speaker: **Prof. Franco Nori** (keynote speaker)

Satellite Talk in the series of Stanislaw Ulam's Lectures

Title: Artificial neural networks and Machine Learning applied to Quantum Physics

Affiliations:
[1]Theoretical Quantum Physics Laboratory, Center for Quantum Computing, RIKEN, Japan
[2]Physics Department, The University of Michigan, Ann Arbor, USA

Abstract: This talk is geared to an audience of mostly physicists, mathematicians, and computer scientists. It turns out that, over 70 years ago, a physicist (Fermi), a mathematician (Ulam), and a computer scientist (Pasta) worked together in a very important problem, that had a huge impact in the development of nonlinear dynamics, chaos, solitons, and studies of thermalization in statistical mechanics. Thus, I would like to briefly summarize the initial history of this very interesting problem, involving Stanislav Ulam and his collaborators. The Fermi-Pasta-Ulam problem initially posed a paradox but ultimately led to a significant discovery. Enrico Fermi, John Pasta, and Stanislav Ulam introduced it in the early 1950s to explore fundamental principles of equilibrium statistical mechanics, such as energy equipartition and ergodicity. Employing the MANIAC-I computer at Los Alamos, they numerically integrated equations of motion for a carefully selected one-dimensional harmonic chain of mass points subject to weak nonlinear forces. Their expectation was that the system would converge towards equilibrium, with energy evenly distributed across all degrees of freedom. However, contrary to their anticipation, the system displayed nearly periodic behavior. This apparent contradiction was later elucidated by the revelation of solitons—localized waves that maintain their shape as they propagate. Consequently, the Fermi-Pasta-Ulam problem has evolved into a pivotal aspect of modern nonlinear mechanics and has undergone extensive scrutiny and analysis for the past 70 years. The solution to the puzzle they were studying involved the use of computers, at that time relatively new. This is because complex problems require the use of powerful computational tools. Most of this talk will be devoted to presenting (far more recent and far more powerful) computational techniques in artificial intelligence (AI), which are impacting all aspects of science, engineering, and society in general. The talk will present some basic aspects of simple artificial neural networks and machine learning (ML), and how these can be applied to the study of several problems in quantum physics and quantum information science. Entire flagship research programs are being devoted all over the world to study these two areas of research (AI and quantum information), and we will very briefly overview some aspects of both.

Chair: Prof. Michał Banaszak

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