tcg crest
Inventing Harmonious Future

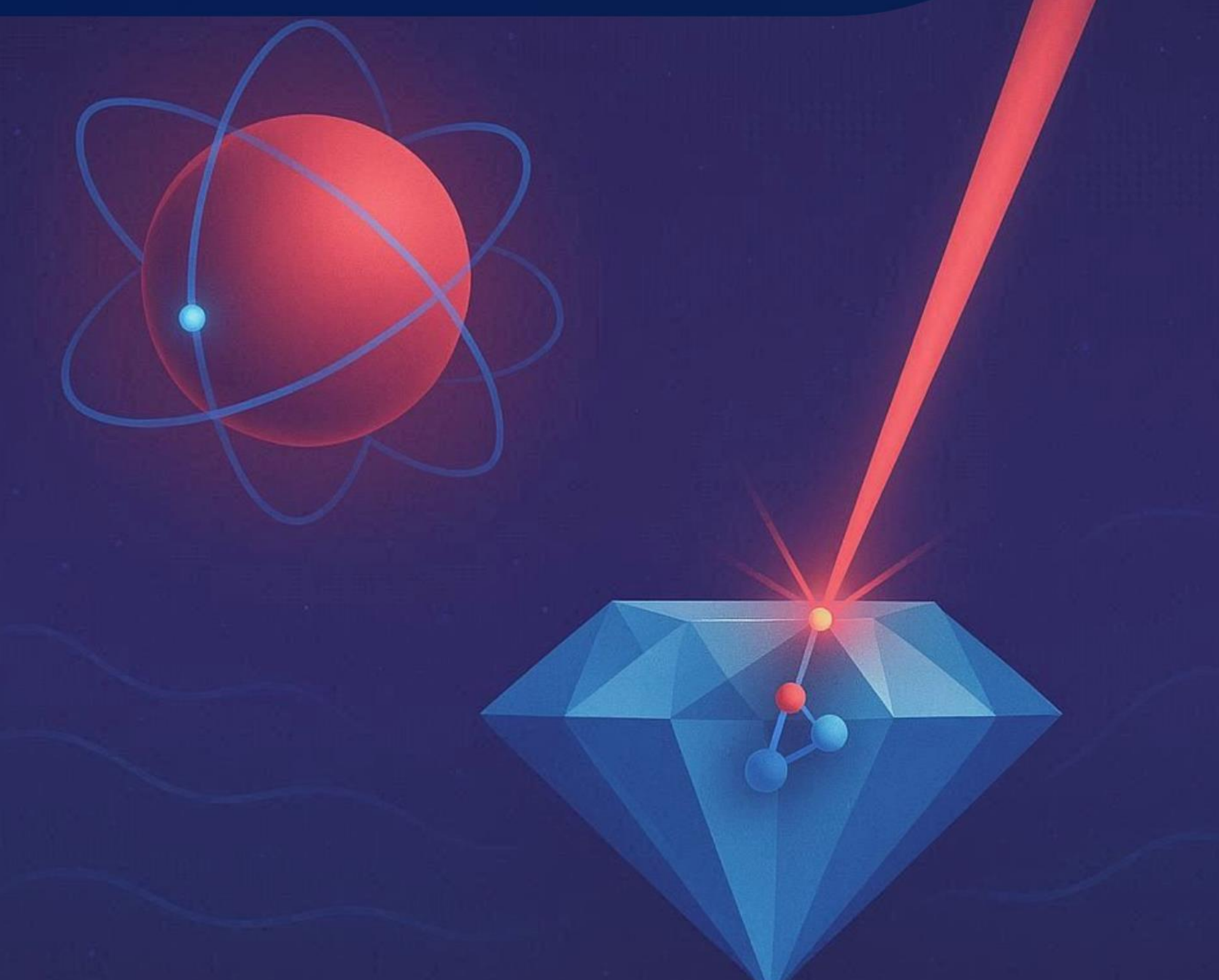
QuERE
Centre for Quantum Engineering Research and Education

ICE QSM

INTERNATIONAL YEAR OF
Quantum Science and Technology
100 years of quantum is just the beginning...

International Conference & Exposium on Quantum Sensing & Metrology 2025

Abstract Book



Invited Speaker Abstracts

Ian Petersen

Australian National University (ANU), Australia

Title:

Memory Decoherence in Linear and Finite Level Quantum Systems.

Abstract:

This talk is concerned with open quantum harmonic oscillators and finite-level quantum systems described by linear and quasi-linear Hudson-Parthasarathy quantum stochastic differential equations. This framework includes isolated systems with zero Hamiltonian, whose internal variables remain unchanged (in the Heisenberg picture of quantum dynamics) over the course of time, making such systems potentially applicable as quantum memory devices. In a more realistic case of system-environment coupling, we define a memory decoherence horizon as the time for a weighted mean square of the deviation of the vector of self-adjoint system variables on the system-field Hilbert space from its initial value to become relatively significant as specified by a real positive semi-definite symmetric weighting matrix and a fidelity parameter. The reference scale in this definition uses the real part of the matrix of second moments of the initial system variables. We consider a problem of maximizing this decoherence time or its approximation from a truncated Taylor series expansion involving the first and second derivatives of the decoherence time with respect to the fidelity parameter. The maximization of the decoherence time or its approximate version is carried out at a given value of the fidelity parameter over the energy and coupling parameters of the open system as a model of quantum memory in its storage phase. Conditions are discussed under which the zero Hamiltonian delivers a suboptimal solution. This optimization problem is also considered for system interconnections.

Ron Folman

Ben-Gurion University of the Negev, Israel

Title:

Experiments at the Interface of General Relativity and Quantum Mechanics.

Abstract:

The two pillars of modern physics are the theories of General Relativity (GR) and Quantum Mechanics (QM). After decades of theoretical attempts to unify these two pillars under one theoretical framework (often referred to as quantum gravity), these pillars remain independent. To some this situation is so unnatural that they claim it actually hints that at least one of the theories is wrong in some fundamental way. As technology in quantum-optics labs improves, new experiments—working at the interface of these two theories—can be realized. Such experiments will hopefully provide new insights that will eventually allow for the sought-after unification to be finally achieved.

In this talk, I will present three experiments conducted at this interface, two already realized and one planned. The first involves clock interferometry, in which a single clock in a spatial superposition experiences two different proper times due to gravitationally induced redshift. The second involves the observation of the Einsteinian equivalence principle, measured in the quantum domain. While the first two were realized with atoms, the third involves massive objects, specifically, nano-diamonds. Leaping by ten orders of magnitude in mass relative to the atomic experiments, the third experiment makes use of so-called active mass, where not only the gravitational field of Earth needs to be taken into account.

The experiments are based on Stern-Gerlach interferometry. Time permitting, I will be happy to also address more technical questions. For example, interesting issues concerning decoherence arise.

Howard Wiseman

Griffith University, Australia

Title:

Optimized mitigation of random-telegraph-noise dephasing by spectator-qubit sensing and control

Abstract:

Spectator qubits (SQs) are a tool to mitigate noise in hard-to-access data qubits. The SQ, designed to be much more sensitive to the noise, is measured frequently, and the accumulated results are used rarely to correct the data qubits. For the hardware-relevant example of dephasing from random telegraph noise (RTN), we introduce a Bayesian method employing complex linear maps, which leads to a plausibly optimal adaptive measurement and control protocol, MOAAAR (Map-based Optimized Adaptive Algorithm in the Asymptotic Regime). In the asymptotic regime, where the ratio of the SQ sensitivity to the RTN transition rates is large, the decoherence rate of the data qubits is suppressed by 1.254 times the square of this ratio. This establishes that the SQ paradigm works arbitrarily well in the right regime. We also analyze MOAAAR (and modifications) under non-ideal conditions, including parameter uncertainties in the system, efficiency and time delay in readout and reset processes of the SQs, and additional decoherence on the SQs. We derive bounds on the imperfections such that the decoherence suppression remains approximately the same as under ideal conditions.

Dmitry Budker

Johannes Gutenberg University, Mainz, Germany

Title:

Spin-based quantum sensors for fundamental science and applications

Abstract:

We will begin by briefly introducing the research areas being pursued by our group and collaborators, ranging from magnetic-resonance-based searches for dark matter to biomagnetic measurements of humans, animals, and plants. We will then discuss zero- to ultralow-field nuclear magnetic resonance (ZULF NMR) and some recent developments, including self-oscillating devices operating on nuclear spin-spin coupling frequencies, the so-called J-oscillators.

Manas Mukherjee

National University of Singapore (NUS), Singapore

Title:

Trapped ion quantum processor: a role in quantum networking.

Abstract:

Trapped and laser cooled ions provide a pristine environment to initialize, control and measure quantum states with extreme high precision. Over the last couple of decades, our ability to control quantum states progressed rapidly giving rise to new quantum technology applications in computation, simulation and metrology/sensing. Although, metrology and sensing may seem to be distant field of research from quantum information processing, but it is by now well established that these are intricately related fields. I'll first introduce the learnings from the later proving an enhanced ability to sense tiny noise signals. However, joining multiple quantum sensor requires knowledge about quantum networking. The trapped ion processors are unique nodes to such network while emitted photons are the flying information providers. We will discuss on the recent developments towards achieving a distributed processor network which can be doubly used for sensing.

Arka Majumdar

University of Washington, USA

Title:

Programmable Quantum Nanophotonics.

Abstract:

Analog quantum simulators present a unique opportunity: instead of simulating a complex many-body system on a computer, we can program a scalable, controllable, and measurable "model quantum system" to mimic the behavior of another quantum system and design new "synthetic quantum metamaterials" with properties not realizable in naturally occurring materials. Photons present an attractive physical system for analog quantum simulation, as quantum states of photons are easily maintained due to their high energy and extremely weak interaction with the environment. Optical photons also allow direct measurement of multi-particle correlations and preserve the quantum states even at room temperature thanks to their high energy. Thanks to semiconductor fabrication, it is now possible to create large-scale photonic integrated circuits (PIC) to pack many optical functionalities on a chip. Unfortunately, PICs lack two critical components for quantum simulation: programmability and nonlinearity. In this talk, I will describe our efforts to mitigate these two issues and create a programmable quantum nanophotonic platform. Specifically, using a silicon photonic coupled cavity array made of 8 high-quality factor resonators and equipped with specially designed thermo-optic island heaters for independent control of cavities, we demonstrated a programmable device implementing tight-binding Hamiltonians with access to the full eigen-energy spectrum. We report a ~50% reduction in the thermal crosstalk between neighboring sites of the cavity array compared to traditional heaters and then present a control scheme to program the cavity array to a given tight-binding Hamiltonian. We also developed a boundary tomography algorithm to characterize the whole Hamiltonian with accessing nodes only at the edge/boundary. Finally, I will discuss our efforts to achieve quantum nonlinearity in nanophotonic platforms.

Hidehiro Yonezawa

RIKEN Center for Quantum Computing, Japan

Title:

Demonstration of Quantum Estimation in Optical Systems.

Abstract:

Quantum estimation is an essential technique in quantum optical technology. It allows us to estimate parameters or systems beyond conventional limits, which in turn helps us gain better control over quantum systems. In our research, we employed detector tomography technique to estimate and characterise two-mode quantum detector, specifically evaluating its entangling capability. We also explored the estimation of quantum states in an optical parametric oscillator using quantum state smoothing techniques. Through this work, we improved the purity and squeezing of the state, which had been degraded by environmental interactions. Furthermore, we identified a trade-off between the recovery of purity and squeezing.

Guofeng Zhang

Hong Kong Polytechnic University, Hong Kong

Title:

Optimal Control of Flying Qubits.

Abstract:

The transmission of flying qubits carried by itinerant photons is ubiquitous in quantum communication networks. In addition to their logical states, the temporal/frequency profiles of flying qubits must also be tailored into proper shapes to match remote receiver qubits. In this talk, we report a general framework for optimal control of flying qubits. The framework is based on quantum stochastic differential equations (QSDEs) that describe the flying qubit input-output relations actuated by a standing quantum system (e.g., a superconducting qubit or quantum dot). Under the continuous time-ordered photon-number basis, the infinite-dimensional QSDE is reduced to a system of low-dimensional deterministic ordinary differential equations for the non-unitary state evolution of the standing quantum system, and the outgoing flying qubit states can be calculated in the form of randomly occurring quantum jumps. This makes it possible to analyze general cases when the number of excitations is not reserved. The proposed framework lays the foundation for the design of flying-qubit control systems from an optimal control point of view, within which advanced optimal control techniques can be incorporated for practical applications. Some examples, such as the generation, catching and steering of flying photons by two- or three- level artificial atoms, are studied.

Animesh Datta

University of Warwick, UK

Title:

A tensor network approach to sensing quantum light-matter interactions.

Abstract:

When a quantum matter system is probed by light, some of the scattered light is inevitably lost. It is essential to quantify the fundamental limits to the precision of estimating parameters in this practical scenario. This practically inevitable scenario, however, leads to a tripartite quantum system of the matter and light —detected and lost. Evaluating quantum information theoretic quantities such as the quantum Fisher information were heretofore impossible.

I will show this impossibility has fundamental quantum information theoretic roots. I will then show how we succeed by expressing the final quantum state of the detected light as a matrix product operator. We apply our method to resonance fluorescence and pulsed spectroscopy. For both, we quantify the sub-optimality of continuous homodyning and photo-counting measurements in parameter estimation. For the latter, we find that single-photon Fock state pulses allow higher precision per photon than pulses of coherent states. Our method should be useful in the study of quantum light-matter interactions, quantum light spectroscopy, quantum stochastic thermodynamics, and quantum clocks.

Luiz Davidovich

Universidade Federal do Rio de Janeiro, Brazil

Title:

Quantum Metrology for Open Systems: Entanglement-Enhanced Quantum Sensors for the Estimation of Noise Parameters

Abstract:

Quantum sensors are used to estimate parameters with precision higher than the best possible result for classical sensors. For noiseless systems, the Cramér-Rao bound, which relates the uncertainty in the estimation to the Fisher information, is a useful benchmark. Extension of this bound to open systems has been proposed and applied to several systems of interest [1–4], a relevant generalization in view of the omnipresence of the environment. Entanglement may then play an important role, in spite of its fragility. Interestingly, when the parameter to be estimated is related to noise itself, fragility of entanglement may actually increase the precision. This talk reviews recent developments in this field, leading to precision bounds for noisy systems, with applications to the estimation of absorption and depolarization of light.

Kensuke Kobayashi

University of Tokyo, Japan

Title:

Exploring Condensed Matter Physics with a Quantum Spin Microscope.

Abstract:

Understanding the magnetic properties of various materials is a central topic in condensed matter physics. In recent years, with the advancement of spintronics and two-dimensional materials research, quantitative methods for investigating nanoscale magnets have become increasingly important.

A wide range of techniques has been developed for imaging local magnetic fields (magnetization), including Lorentz microscopy, magneto-optical Kerr microscopy, X-ray magnetic circular dichroism microscopy, magnetic force microscopy (MFM), scanning Hall probe microscopy, and scanning SQUID microscopy. These methods have yielded a wealth of knowledge. However, the very fact that so many different approaches exist indicates that no single definitive method has yet been established. Thus, the development and application of local magnetic field measurement techniques remain highly attractive challenges for experimental researchers.

Recently, there has been growing interest in probing material properties using nitrogen vacancy (NV) centers in diamond as quantum magnetic field sensors. NV centers possess unique internal energy levels, and their spin states can be optically read out via optically detected magnetic resonance (ODMR). Because the ODMR spectrum of NV centers exhibits Zeeman splitting in a magnetic field, analyzing the spectrum enables high-precision measurements of the local magnetic fields experienced by the NV centers. We are developing a "quantum spin microscope," namely a microscope based on diamond quantum sensors, to quantitatively evaluate and visualize the magnetic properties of various materials. In this presentation, we will introduce our recent efforts in quantum spin microscopy, including:

(1) Observation of superconducting quantum vortices,

(2) Spin-wave propagation,

(3) Observation of chiral magnetic domain walls in the antiferromagnet Mn3Sn.

Daniel Moraru

Shizuoka University, Japan

Title:

Fabrication and characterization of silicon-on-insulator nanoscale devices for single-electron tunneling functionalities mediated by dopants

Abstract:

Silicon nanodevices form the building blocks of present-day nanoelectronics, either as metal-oxide-semiconductor field-effect transistors (MOSFETs) or as p-n junction diodes. As technology advances, quantum tunneling becomes more and more dominant in developing new functionalities because of the low-dimensionality of the nanostructures working as active elements of the devices. At such reduced dimensions, the presence of quantum dots due to impurities (dopants) can promote single-electron tunneling in transistors, while high doping concentration can lead to ultra-narrow depletion layers in tunnel diodes promoting band-to-band tunneling.

In our lab, we investigate such quantum-tunneling functionalities emerging in both transistors and diodes, all fabricated in silicon-on-insulator (SOI) substrates using our cleanroom technology.

In nanoscale SOI transistors, we rely on doping to modulate the conductivity in the leads, but also – and most importantly – to create the quantum dots (QDs) in the low-dimensional channels. Based on our reports on single-electron tunnelling (SET) via individual P-donors [1-8], when doping concentration is relatively low, we can demonstrate an ultimate level of electronics dealing with elementary charges and dopant-atom-induced QDs, which includes concepts of single-electron memory, single-photon detection and single-electron transfer. When concentration is increased, clusters of P-donors can act as QDs and they may have higher barriers under certain conditions [9,10]. With such structures, we demonstrated for the first time SET operation at elevated temperatures and even at room temperature, by combining very high doping concentrations with very low dimensionality [11,12]. Furthermore, when counter-doping is done (with B-acceptors), SET functionalities emerge with higher yield [13], especially at low temperatures. Such devices are also suitable for working as single-photon detectors in a wide range of wavelengths [14].

The above devices are typically designed as junctionless transistors. However, p-n junctions are critical structures for developing diodes with a variety of functionalities. In nanoscale diodes, when doped at low concentrations, the individuality of the dopants plays a critical role and can be detected in the low-temperature electrical characteristics [15,16].

More recently, we aim for high concentrations of both P-donors and B-acceptors to form the n-type and p-type regions in the SOI layer, so that tunnel (Esaki) diodes can be formed [17]. Under such conditions, band-to-band tunnelling (BTBT) emerges as a key mechanism for transport, with applications possibly extended to tunnel FETs [18]. We reported BTBT mediated by dopant states [19], as well as dopant-induced QDs [20] in the nanoscale depletion layer of our SOI p-n diodes, which suggests the possibilities for current enhancement by suitable arrangement of dopants.

The technologies demonstrated in our works build up a platform on which atomic-level physics can be explored based on silicon nanodevices to develop the next-generation electronics functionalities. Such functionalities will allow the introduction of new computing schemes, including quantum computing.

References

1. M. Tabe, D. Moraru et al., Phys. Rev. Lett. 105, 016803 (2010).

2. D. Moraru et al., Nanoscale Research Letters 6, 479-1-9 (2011).

3. A. Udhiarto, D. Moraru et al., Appl. Phys. Lett. 99, 113108 (2011).

4. E. Hamid, D. Moraru et al., Phys. Rev. B 87, 085420 (2013).

5. A. Samanta, D. Moraru et al., Sci. Rep. 5, 17377 (2015).

6. P. Yadav, S. Chakraborty, D. Moraru, and A. Samanta, Nanomaterials 12, 4437_1-12 (2022).

7. P. Yadav, S. Chakraborty, D. Moraru, and A. Samanta, J. Vac. Sci. & Technol. B 41, 012208_1-8 (2023).

8. P. Sudha, S. Chakraborty, D. Moraru, and A. Samanta, Appl. Phys. Lett. 127, 023506 (2025).

9. D. Moraru et al., Nanoscale Res. Lett. 10, 377 (2015).

10. A. Afiff et al., and D. Moraru, Appl. Phys. Express 12, 085004_1-5 (2019).

11. A. Samanta et al., D. Moraru, Appl. Phys. Lett. 110, 093107 (2017).

12. T. T. Jupalli et al., and D. Moraru, Appl. Phys. Express 15, 065003 (2022).

13. D. Moraru et al., Nanomaterials 13, 1911_1-15 (2023).

14. P. Sudha, S. Miyagawa, A. Samanta, and D. Moraru, Adv. Electron. Mater. 11, 2400714 (2025).

15. A. Udhiarto, D. Moraru et al., Appl. Phys. Express 5, 112201 (2012).

16. S. Purwiyanti, R. Nowak, D. Moraru, T. Mizuno, D. Hartanto, R. Jablonski, and M. Tabe, Appl. Phys. Lett. 103, 243102-1-4 (2013).

17. L. Esaki, Phys. Rev. 109, 603 (1958).

18. A. M. Ionescu and H. Riel, Nature 479, 329 (2011).

19. M. Tabe et al., and D. Moraru, Appl. Phys. Lett. 108, 093502-1-5 (2016).

20. G. Prabhudesai et al., and D. Moraru, Appl. Phys. Lett. 114, 243502_1-5 (2019).

Areeya Chantasri

Mahidol University, Bangkok, Thailand

Title:

Experimental parameter tracking for continuous quantum measurement via sequential Monte-Carlo estimation.

Abstract:

Time evolutions of an open quantum system are of crucial interest in the field of quantum control. Such evolutions are governed by the system's parameters, dynamical equations, and measurement outcomes over time. For a system with unknown parameters, we can utilise records of continuous weak measurements to extract information about the parameters. Our work demonstrates a method of calibrating Hamiltonian parameters of transmon-qubit experiments using the Sequential Monte Carlo method. We start by generating random particles on the parameter space and allow them to evolve through time according to the Stochastic Master Equation. Given the measurement results, we can construct the probability weights of such random particles and then estimate the parameters using the Bayesian estimator. Our result agrees with the empirical values and enables us to gain insight into the stability of the parameters.

Dominik Bucher

Technical University of Munich (TUM), Germany

Title:

Optically addressable spin systems in diamond and proteins for sensing and imaging.

Abstract:

Optically addressable spins have attracted significant interest for their potential in quantum sensing technologies. In the first part of this talk, I will present our recent advances using nitrogen-vacancy (NV) centers in diamond chips for nuclear magnetic resonance (NMR) microscopy. NV-doped diamond platforms enable the transduction of local magnetic resonance signals into optical signals, which can be captured over a wide field using a camera. This novel approach eliminates the need for traditional k-space sampling with magnetic field gradients, as used in conventional MRI. I will discuss the current limitations of this novel microscopy technique and outline prospects for future developments.

In the second part, I will highlight our latest research on optically addressable spins in proteins—specifically flavin-based cryptochrome proteins. Upon excitation, these proteins generate radical pairs that can be detected optically and manipulated through radio wave-controlled spin chemistry. We further show that this optical spin interface is tunable by the protein structure. I will explain how these systems differ from the well-established NV center and discuss their potential as genetically encoded quantum sensors for future applications.

Bijoy Krishna Das

IIT Madras

Title:

Silicon Photonics Technology for Chip-Scale Quantum Information Processing: Prospect and Challenges

Abstract:

Photonic Integrated Circuits or Integrated Photonics has been evolving very fast, thanks to the CMOS fabrication process compatibility of Silicon Photonics Technology. As the silicon photonics-based transceiver modules are occupying data center and communication market space, many other potential areas of applications are being explored to reap the full benefits of semiconductor foundry infrastructures. In recent years, there have been intense attention and investment observed from both academic and industry players for the development of quantum information processor chip by exploiting silicon photonics based low-loss optical interconnect solutions. In this talk, I shall discuss the pros and cons of silicon photonics technology focusing on quantum photonic solutions. Recent progress on silicon photonics technology developments at our CoE-CPPICS, IIT Madras will be also highlighted.

Vidya Praveen Bhallamudi

IIT Madras

Title:

Single-Photon and Superradiant Emission from NV Centers in Diamond.

Abstract:

Quantum, or non-classical, light emission—such as single photons, entangled photons, superradiant, and squeezed light—is of growing interest for emerging quantum technologies. These light sources are immensely valuable for quantum computation, communication, and precision sensing/metrology. In this talk, I will introduce these categories of quantum light and then focus on single-photon and potential superradiant emission from Nitrogen-Vacancy (NV) defect centers in diamond. A central aim is to understand the second-order correlation function ($g(2)$) of emission from these centers, as measured via a Hanbury Brown and Twiss (HBT) setup. I will present results demonstrating single-photon emission from NV centers in diamond nanopillars and discuss how the physical structure affects the canonical antibunching dip in the $g(2)$ measurement. I will then address emission that likely arises from a system of coupled NV centers, considering both fluorescence lifetimes and changes to the $g(2)$ function. Experimental results and a brief overview of our developed theoretical model will be presented. Finally, I will discuss quantum random number generation using emission from both single and coupled NV centers, comparing their measured differences and providing an explanation based on an entropic model.

Arup Samanta

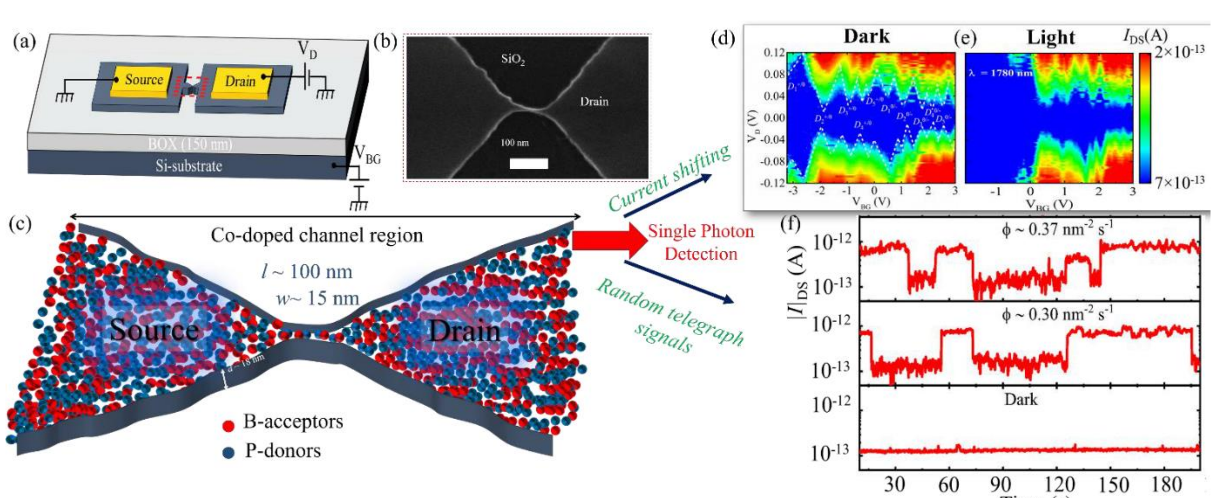
IACS, Kolkata

Title:

Ultra-Sensitive Short-Wave Infrared Single-Photon Detection Using Dopant-Atom-Based Silicon Single-Electron Transistor

Abstract:

Ultra-sensitive short-wave infrared (SWIR) photon detector is a crucial device for next-generation quantum communication. However, developing such detectors on a CMOS-compatible silicon technological platform has been challenging due to the negligible absorption coefficient for silicon in the SWIR range. In this direction, a dopant-atom based single electron transistor (SET) could play an important role [1-5]. Here, we present a dopant-atom-based single electron device, which can detect such SWIR signal. We have fabricated a co-doped silicon-based SET in a silicon-on-insulator field-effect transistor (SOI-FET) configuration, which successfully detects single photons in the SWIR range with ultra-high sensitivity [6]. The detection mechanism is evidenced by the shift in the onset of the SET current peaks and by the occurrence of random telegraph signals (RTS) under light irradiation, as compared to the dark condition as depicted figure below. The calculated sensitivity of our device, in terms of noise equivalent power (NEP), is ≈10−19 W Hz−1/2, which is significantly far higher than the reported sensitivity of similar SWIR detectors.



Device Design: (a) Schematic device design, (b) SEM image of the channel region of the device, (c) Schematic dopant distribution in the channel region of the device. Characteristics: Stability diagram of the device under dark (d) and light conditions (e). (f) Random telegraph signal under light of wavelength 1780nm with different dose rate.

References:

1. M. Fuechsle, J. A. Miwa, S. Mahapatra, H.N. Ryu, S. Lee, O. Warschkow, L. C. L. Hollenberg, G. Klimeck, and M. Y. Simmons, A single-atom transistor, Nat. Nanotechnol, 7, 242 (2012).

2. M. Tabe, D Moraru, M Ligowski, M Anwar, R Jablonski, Y Ono, T Mizuno, Single-Electron Transport through Single Dopants in a Dopant-Rich Environment, Phys. Rev. Lett. 105, 016803 (2010).

3. D. Moraru, A Samanta, LT Anh, T Mizuno, H Mizuta, M Tabe. Transport spectroscopy of coupled donors in silicon nano-transistors, Sci. Rep. 4, 6219 (2014).

4. A. Samanta, M Muruganathan, M Hori, Y Ono, H Mizuta, M Tabe, D Moraru, Single-electron quantization at room temperature in a-few-donor quantum dot in silicon nano-transistors, Appl. Phys. Lett. 110, 093107 (2017).

5. P. Sudha, S. Chakraborty, D. Moraru, A. Samanta, Quantum and dielectric confinement on phosphorus donors in silicon nano-transistors for high-temperature single-electron tunneling, Appl. Phys. Lett. 127, 023506 (2025).

6. P. Sudha, S. Miyagawa, A. Samanta, D. Moraru, Ultra-Sensitive Short-Wave

Arijit Sharma

IIT Tirupati

Title:

Progress towards a trapped ion-based all-optical, portable atomic clock

Abstract:

The pursuit of next-generation timekeeping technologies has driven significant progress in the development of optical atomic clocks, with trapped-ion systems emerging as one of the most precise and stable platforms. In this work, we report on the design and progress toward a transportable trapped-ion optical atomic clock based on a singly trapped calcium ion, engineered to combine state-of-the-art frequency accuracy with robust operation outside traditional laboratory settings. The transportable design has potential applications in chronometric geodesy, navigation, tests of fundamental physics, and synchronization of large-scale scientific facilities in the civil and strategic sectors. This work aims to take a step toward bringing laboratory-grade optical clock performance to field-deployable platforms, thereby expanding the utility of quantum timekeeping technologies.

The system integrates a compact ultra-high-vacuum package for ion trapping, low-noise laser systems for cooling and clock interrogation, and fiber-coupled optical frequency stabilization. Key innovations are expected to include miniaturized electronics for ion control, vibration and thermal-insensitive optical reference cavities, and modular components enabling portability. We will highlight preliminary simulation results on the design of a compact helical resonator to drive the trap, a compact high NA (Numerical Aperture) direction-limited optical imaging system, a dual axis transportable optical cavity and some initial calcium spectroscopy using a hollow cathode lamp.

Ashok Mahapatra

NISER, Bhubaneswar

Title:

Precision magnetometry based on magnetoelectric effect in thermal atomic vapour.

Abstract:

Magnetoelectric effect is a parametric interaction of optical electric and radio-frequency magnetic field with atomic vapor leading to the generation of new optical fields. Detection of newly generated optical field using optical heterodyne detection technique gives the information about the presence of unknown rf-magnetic field. The magnetoelectric effect can be enhanced by improving the ground state coherence between the Zeeman sub level which can ultimately be used for precision rf-magnetometry. In this talk, I will present the recent progress of using the system for magnetometry application in our lab at NISER Bhubaneswar.

Bijaya K Sahoo

PRL Ahmedabad

Title:

Understanding roles of atomic many-body methods to improve uncertainties of atomic clock candidates and probing fundamental physics

Abstract:

Atomic clocks are the highest precision instruments available on the earth today. Though Cs microwave clock is still considered to be the primary frequency standard, many other atomic clocks, operating both in the microwave and optical regime, are already established in the laboratories among which some of them are even eligible for replacing Cs microwave clock as the primary frequency standard. Albeit all optical clocks may not be suitable for serving as time keeping devices in long term, they can be very much useful to probe a number of fundamental physics owing to their unprecedented level of precision in the clock frequency measurements. It is possible to improve some of the major systematics such as electric quadrupole shifts, Stark shifts and BBR shifts of these clocks by determining electric quadrupole moments and dipole polarizabilities accurately. However, calculations of these quantities are sensitive to both atomic basis functions used and many-body methods employed. As a result, large discrepancies among the calculations from different methods are often noticed in the literature. Also, inferring nuclear properties and new physics by combining frequency measurements with theoretical calculations demand reliabilities in the determination of atomic wave functions and comprehensive understanding of behaviour of electron correlation effects in the clock candidate. In this talk, I shall discuss some of these aspects and demonstrate roles atomic many-body methods in the accurate calculations of a few selective clock and nuclear properties.

Sourav Dutta

TIFR, Mumbai

Title:

Observation of quantum interference in Doppler-free two-photon spectroscopy: implications for secondary portable optical clocks

Abstract:

Doppler-free two-photon spectroscopy is a standard technique for precision measurement of transition frequencies of dipole forbidden transitions, e.g. the s-s and s-d transitions in atoms. It also forms the basis for secondary portable optical clocks e.g. based on the rubidium 5s-5d transition at 778.1 nm. The accuracy of the clock frequency and/or transition frequency measurement depends critically on accurate fitting of the spectrum to a model lineshape and on proper estimation of systematic effects. We observe, for the first time, a subtle systematic effect arising from quantum interference of optical transition pathways in Doppler-free two-photon spectroscopy [1]. The interference manifests itself as asymmetric lineshapes of the hyperfine lines of the cesium 6s-7d spectra, observed through spontaneous emission following excitation by a narrow-linewidth CW laser. The interference arises because there are two or more allowed optical pathways that connect the initial quantum state to the final quantum state. Neglecting the effect and fitting the spectrum to a Lorentzian or Voigt lineshape results in apparent line-shifts of several 10 kHz in the cesium 6s-7d transition. On the other hand, fitting the spectrum to the quantum interference lineshape resolves the apparent line-shift. Additionally, we show that the quantum interference vanishes at a particular "magic angle" 54.7° between the laser polarization and the detection axis, providing an experimental alternative to full modeling of the quantum interference lineshape. The results have implications for optical clocks, measurement of hydrogen 1s-2s and 1s-3s transition frequencies and isotope shifts and hyperfine splittings of any element.

[1] Bubai Rahaman, Sid C. Wright, and Sourav Dutta, Phys. Rev. A 109, 042820 (2024).

Joyee Ghosh

IIT Delhi

Title:

Entangled/Correlated Photons (for Discrete Variable) and Squeezed Light (for Continuous Variable) applications in Quantum Sensing.

Abstract:

The generation, manipulation, and detection of nonclassical states of light is fundamental to modern quantum technologies, for a range of applications from secure quantum communication, quantum key distribution, quantum computing, quantum-enhanced sensing and metrology. These nonclassical states can be catergorised as continuous variable (CV) and discrete variable (DV). A widely employed mechanism for generating these states is spontaneous parametric down-conversion (SPDC) in nonlinear media that produce correlated paired photons which are then characterised as single photons for DV and as squeezed states for CV applications. Fully fiber-integrated waveguide-based quantum light sources based on SPDC, specially in periodically poled lithium niobate (PPLN) ridge geometries, are lucrative for both DV and CV applications. These sources are tailored for real-time implementation in secure quantum communication and quantum sensing systems. Such platforms provide compact, robust, and alignment-free architectures, essential for field-deployable quantum nodes. Based on such concepts, I would highlight the recent results from the Quantum Photonics group in IIT Delhi. In particular, for DV, I will talk about the fiber-integrated sources of switchable polarization entangled photon pairs (of fidelity >95%, typical $S = 2.654 \pm 0.0332$) for low-QBER (2-6%) quantum communication. For CV, we have recently explored fully-guided single-mode squeezing achieving -1.81 ± 0.05 dB of squeezing at 1550 nm, equating to -4.11 ± 0.05 dB of generated squeezing in the telecom C-band. We highlight its entanglement potential and sensing performance under realistic purity constraints.

Bikash Ghosal

ISRO Ahmedabad

Title:

India's First Indigenous Space-Qualified Rubidium Frequency Standard: Principles, Design, and In-Orbit Performance in satellite navigation.

Abstract:

Rubidium atomic clocks are critical components in satellite navigation systems, offering compactness, low power consumption, and high frequency stability. This lecture presents the journey behind the development of India's first indigenously designed and space-qualified Rubidium Frequency Standard (RFS), a key payload on board navigation satellites of the Indian Navigation Satellite System (NavIC).

The talk will begin with an overview of the fundamental principles of rubidium atomic clocks, including atomic transitions, buffer gas cell physics, optical pumping, and frequency locking techniques. It will then detail the design architecture of the indigenous RFS, covering subsystems such as the physics package, RF chain, servo electronics, and thermal management. The qualification process for space deployment, including environmental tests, electromagnetic compatibility, and long-duration stability assessment, will be discussed.

Finally, the lecture will highlight the in-orbit performance of the RFS on board navigation payload, which has successfully completed over one year of continuous operation. We achieved a short-term frequency stability of $3.3 \times 10^{-12}\ \tau^{-1/2}$, reaching 3.3×10^{-14} at 10,000 seconds, with a long-term frequency drift of less than 5×10^{-13} per day. The achievement marks a significant milestone in India's self-reliance in space-based timing systems, opening new frontiers in navigation and quantum sensing technologies.

Pratap Raychaudhuri

TIFR, Mumbai

Title:

Zero Point Fluctuations of vortices in a very weakly pinned superconducting thin film

Abstract:

In a type-II superconductor, the vortex core (VC) behaves like a normal metal. Consequently, the single-particle density of states in the VC of a conventional type-II superconductor remains either flat or (for very clean single crystals) exhibits a peak at zero bias due to the formation of the Caroli–de Gennes–Matricon bound state inside the core. Here, I discuss an unusual observation from scanning tunneling spectroscopy measurements in a weakly pinned thin film of the conventional s-wave superconductor a-MoGe, namely, that a soft gap in the local density of states continues to exist even at the center of the VC. We ascribe this observation to rapid fluctuation of vortices about their mean position that blurs the boundary between the gapless normal core and the gapped superconducting region outside. Analyzing the data as a function of magnetic field, we show that the variation of fluctuation amplitude is consistent with quantum zero-point motion of vortices.

Kaushalya Jhuria

IIT Roorkee

Title:

Telecom band quantum emitters in silicon.

Abstract:

Quantum emitters (color centers) in semiconductors are promising qubit candidates for applications in quantum sensing, computing, and communication. Color centers often form when dopants are introduced into the host crystal matrix combined with energetic radiation and thermal annealing. Quantum information science (QIS) applications benefit from color centers that can be formed reliably of high quality, and this poses new challenges and opportunities for material processing. This talk will be focused on our recent work to synthesize high-quality color centers using a wide range of processing conditions for lasers, ion beams, and plasmas. Using terawatt to petawatt laser-driven ion beams to implant various elements, including boron and other hydrocarbons, into silicon. Along with the laser-ion plasma-driven approach, the results from other conventional and non-conventional methods will also be presented (i.e. ion implantation followed by thermal annealing, H2 plasma, etc.). Finally, the most recent results on single fs laser pulse irradiation leading to the deterministic formation and passivation of high-quality color centers in Silicon will be presented. This approach will potentially pave the way toward scalable integration of Si color centers for QIS.

Poonam Arora

CSIR-NPL, Delhi

Title:

Defining Time: Quantum Advances in the Realization of the SI Second.

Abstract:

The definition and realization of the International System of Units (SI) second have progressed from astronomical observations to the forefront of quantum physics. Today, the microwave transition in Cesium atoms defines the SI second, realized through Cesium fountain clocks that underpin global timescales.

A new era is emerging with the application of quantum technologies in timekeeping. Optical clocks based on single ions and neutral atoms in optical lattices now exceed microwave standards by several orders of magnitude in accuracy and stability. Quantum-enabled frequency combs, ultra-stable lasers, and advanced cooling and trapping techniques are making such performance reproducible across laboratories worldwide. In parallel, quantum communication networks—via optical fiber and satellites—are enabling long-baseline clock comparisons at the 10^{-18} level, a prerequisite for adopting optical standards as the new definition of the second.

Recognizing this progress, the 26th General Conference on Weights and Measures (CGPM, 2022) adopted a resolution to prepare for the redefinition of the second. The Consultative Committee for Time and Frequency (CCTF), supported by its dedicated Task Group on Quantum Technologies, is steering international comparisons, protocols, and strategies for a smooth transition. Importantly, Cesium fountains will remain essential for at least the coming decade, ensuring continuity and traceability during this paradigm shift.

Beyond redefining the SI second, quantum technologies are expanding the role of timekeeping: enabling relativistic geodesy, probing dark matter, improving navigation, and supporting fundamental tests of physics. These advances demonstrate how precision timekeeping is becoming a central pillar of the emerging quantum technology landscape.

In conclusion, the talk will highlight how quantum technologies are reshaping timekeeping—from optical standards to quantum networks—while emphasizing the international collaboration required to redefine time itself for the 21st century and beyond.

Ajay Tripathi

Sikkim University

Title:

Understanding Electromagnetic Induced Resonances in Rb87 Vapor.

Abstract:

In this presentation, we will present the results obtained by investigating the electromagnetic induced resonances in Rb-87 vapor on application of external magnetic fields. In presence of high magnetic field, the effect of close lying states become significant and its effects are observed in the lineshape of electromagnetic induced transparency (EIT). We observed asymmetric features which is attributed to the impurities in the dark states because of the presence of close lying states. This asymmetry in the line shape can be controlled by tuning the parameters like laser power, magnetic field and by using anti relaxation coating (ARC) vapor cell. We have demonstrated that by tuning external parameters, we can limit the interaction of various velocity classes responsible for asymmetry. We established our result by performing the experiments in ARC coated cell, where by limiting the velocity dependent population distribution we can overcome the asymmetry. Finally, we also investigated the effect of third laser on EIT. The third laser converts a bi-chromatic Λ-type system into a four-level N-type system. Experimental studies reveal a switch from absorption to transmission depending on the detuning. This conversion is explained by light shift modification induced by the third laser. This presentation will present through understanding and optimisation of EIT phenomena in 87Rb which have promising applications in optical switching and quantum magnetometry, contributing to the advancement of technologies in these fields.

Kasturi Saha

IIT Bombay

Title:

3D magnetic field imaging with a quantum diamond microscope.

Abstract:

Quantum diamond microscopy (QDM) using nitrogen-vacancy (NV) centers in diamond offers wide-field, high-sensitivity imaging of magnetic and electric fields under ambient conditions. I will present recent advances that extend QDM from two-dimensional to three-dimensional (3D) imaging, enabling volumetric mapping of field distributions. This includes approaches using multi-depth NV ensembles, advanced optical excitation and detection, and computational reconstruction. Applications range from visualizing current flow in devices to probing magnetic textures and biomagnetic sources. I will also discuss key challenges—such as depth resolution and optical aberrations.

Rajalakshmi G

TIFR, Hyderabad

Title:

Atomic Magnetic Field Sensors and Their Application.

Abstract:

Atomic sensors exploiting precise atom–light interactions offer unprecedented measurement capabilities. We present advances in nonlinear magneto-optical rotation (NMOR) magnetometry, achieving 1 pT/√Hz sensitivity and 25 kHz bandwidth. This high performance enables detection of weak and transient magnetic signals, making our atomic magnetometer a powerful tool for zero-to-ultra-low-field NMR, where subtle nuclear spin signals can be measured without strong applied fields. The system's ability to resolve minute field variations also benefits advanced materials characterization. Beyond laboratory use, the same technology shows promise for biomagnetic sensing, including detection of neuronal and cardiac fields, and for geomagnetic mapping, such as identifying magnetic anomalies relevant to environmental monitoring and defence applications.

Satya Kesh Dubey

CSIR-NPL, Delhi

Title:

Rydberg atoms based SI-traceable field probes and communications receivers

Abstract:

Quantum-based standards are replacing physical artifacts in metrology to improve accuracy and stability. This abstract details the work of the Electromagnetic Metrology group at CSIRNPL in developing and implementing quantum techniques for measuring various electromagnetic quantities. These quantities include E-field and H-field measurements, attenuation, E-field sensing, antenna factors, and antenna gain. By leveraging the intrinsic quantum properties of atoms, our work aims to establish new primary standards that are inherently more precise and robust than conventional methods. Highly excited Rydberg states possess a distinctive property of responding to radio-frequency (RF) resonance. Even at room temperature, Rydberg atoms show great potential for the development of broadband RF electric field sensors traceable to Planck's constant. In this study, we investigate a coplanar strip line as a broadband uniform E-field generator and its impact on the Autler–Townes splitting (ATS) and the Electromagnetically Induced Transparency (EIT) phenomena-driven sensitivity of E-field measurement. The work presents the design and implementation of a broadband capacitively coupled microstrip transmission line. This structure ensures field uniformity across the region containing the Rydberg vapor cell. Using this setup, we demonstrate a minimum detectable electric field of 0.75 mV/cm, corresponding to an input power of 3.98 µW at 11.369 GHz and the achieved sensitivity is 41 µV/cm/√Hz. A coefficient of determination (R^2) of 0.98248, calculated across all readings, confirms a linear relationship between the square root of the input power and the measured electric field amplitude We further compare these results with E-fields generated using a coplanar broadband transmission line, achieving a minimum detectable field of 0.93 mV/cm with sensitivity 50.9 µV/cm/√Hz at 12.50 µW. Additionally, the work is also compared and validated with the measurements using an X-band waveguide adapter, which reveals a minimum field detection of 0.99 mV/cm with a sensitivity of 54.2 µV/cm/√Hz at 2.50 µW for near-field measurement. Whereas, the minimum detectable field is 0.86 mV/cm with a sensitivity of 47.1 µV/cm/√Hz at 1.58 µW for reactive near-field measurement. These results highlight the critical role of RF structure optimization in enhancing sensitivity and dynamic range in Rydberg atom-based E-field sensors. The outcomes indicate that RF structures can be characterised and worked through for the generation of the E-field for better sensitivity. The capacitively coupled stripline

has uniform field generation, which makes it well-suited for integration with vapor cells in E-field sensing, and it can be incorporated as an LO heterodyne detection system, leading to the advancement of compact, frequency-tunable, and sensitive quantum sensors. To study frequency agility of coplanar strip line, an E-field was measured across a vapor cell over a broad frequency range from 8 GHz to 18 GHz. E-field measurements are performed at 10.22 GHz, 13.43 GHz, and 17.04 GHz, covering the X and Ku bands. The minimum detectable E-field amplitude is 0.35 V/m at input powers of 630 μW and 40 μW for 10.22 GHz and 13.43 GHz, respectively, while an E-field of 0.36 V/m is measured for an input power of 251 μW at 17.04 GHz. The experimental results show good agreement with simulated field distributions. A linear relationship is observed between the measured E-field strength and the square root of the applied RF power, consistent with theoretical predictions. The proposed atomic E-field sensing platform enables accurate characterization of microwave structures and finds potential applications in electromagnetic compatibility (EMC) analysis, RF metrology, atomic RF receivers, quantum radar, and quantum communication.

Subhasis Panja

CSIR-National Physical Laboratory, India

Title:

Frequency Stabilized RF sources for Modulating Optical Frequencies to be used for Laser cooling of Yb ions.

Abstract:

Electro-Optic Modulators (EOM) are most commonly used for side band generation or modulations of optical frequencies in GHz ranges. EOM consists of a crystal that changes its refractive index when an external RF voltage is applied and depending on the applied RF frequency, it generates additional frequencies around the carrier optical frequency. However, the EOMs require stable RF frequency and voltage for producing precise and stable sideband frequencies. The present article describes about the development of voltage-controlled oscillators (VCO) based RF sources for generating tuneable RF frequencies and a phase-locked loop (PLL) for stabilizing the generated frequencies with respect to a reference signal. The reference signals are generated from a direct digital synthesis (DDS) evaluation board. Output frequency of the RF sources are tuneable with a resolution of 10MHz and the higher order harmonics have insignificant power. The effectiveness or acceptability of the RF sources was tested through characterization of the generated sidebands in the optical frequency domain.

Phani Kumar Peddibhotla

IISER Bhopal

Title:

Magnetometry with Diamond Quantum Sensors.

Abstract:

Nitrogen-vacancy (NV) centers in diamond have been used to measure a number of physical quantities such as magnetic field, electric field, temperature and stress/strain at ambient conditions [1-3]. They have also demonstrated high magnetic sensitivities in different NV magnetic sensing platforms due to their excellent susceptibility to magnetic fields [4]. My talk will focus on various sensing and imaging applications using dense NV ensembles in a quantum diamond microscope platform [5]. I shall also briefly discuss our efforts towards achieving pico-tesla sensitivity with a diamond magnetometer setup.

References

1. R. Schirhagl et al, Annual Reviews in Physical Chemistry, 2014, 65, 83.
2. P. Peddibhotla et al, Nano Letters, 2017, 17 (3), 1496.
3. S. Kumar et al, 2023 Quantum Sci. Technol. 8 025011.
4. J. Rovny et al, Nature Reviews Physics 6, 753-768 (2024).
5. P. Dubey et al, https://arxiv.org/abs/2506.17742

Umakant D Rapol

IISER Pune

Title:

Atom Interferometry and Gravimetry.

Abstract:

Atom interferometry is a versatile and highly sensitive technique that surpasses traditional optical interferometry by several orders of magnitude in both precision and sensitivity. Unlike light-based interferometers, which rely on the wave nature of photons, atom interferometers exploit the quantum wave properties of matter. This enables them to detect minute variations in gravity, acceleration, and rotation with unprecedented accuracy.

Owing to this exceptional sensitivity, atom interferometry has wide applications across multiple domains. In geological monitoring, it can help study tectonic activity, predict earthquakes, and track groundwater levels. In mineral exploration, it allows non-invasive detection of underground deposits. In civil engineering, it can be used to survey subsurface structures, enhancing safety in urban planning and construction. In defense and navigation, atom interferometers provide robust, GPS-independent positioning and navigation solutions.

In this talk, I will introduce the principles of atom interferometry and highlight its application in gravimetry—the precise measurement of gravitational acceleration. I will also present recent results from our ongoing work at IISER Pune, where we have demonstrated a technological proof-of-concept for gravimetry using atom interferometry with a Bose–Einstein condensate. This achievement marks a significant step toward the development of compact, field-deployable quantum sensors for real-world applications.

Ashok Vudayagiri

University of Hyderabad

Title:

Compact four-grating Magneto Optic Trap for laser cooling

Abstract:

Laser cooling is a technique of reducing average velocity of atoms and thus reducing the corresponding Boltzmann temperature. Standard configuration involves a laser beam divided into six parts and made to incident on the atomic vapour from six orthogonal directions. However, a different methodology involving ruled diffraction gratings and their 1st order diffractions, which make the system more compact are presented. Experiments in our laboratory and the results are discussed. The approach towards a compact laser cooling system and atom chip, with a goal to be used for atom interferometry are discussed in the talk.

Syamsundar De

IIT Kharagpur

Title:

Quantum Enhanced Sensing in Nonlinear Interferometry: Toward Its Practical Implementation in Thin-film Lithium Niobate Platform.

Abstract:

The sensitivity in optical interferometric measurements is usually limited by the so-called standard quantum noise, arising from the quantum nature of light. One approach to enhance the sensitivity beyond the standard-quantum limit is to use non-classical states of light at the input of the interferometer. On the other hand, another interesting approach is to change the interferometer architecture, in particular, to use a so-called SU (1,1) or nonlinear interferometer, in which the beamsplitters separating and recombining the two paths in the interferometer are replaced by nonlinear elements producing parametric amplification. This parametric amplifier generates the so-called signal and idler beams exhibiting quantum correlations either in photon numbers (discrete-variable) or in field quadrature (continuous-variable), contrary to an ordinary beam-splitter that creates two completely uncorrelated coherent states out of an incident coherent state. After recombination on a second parametric amplifier, the two modes can exhibit a sub-standard quantum limit noise, allowing phase measurements below the usual shot noise limit. In this talk, I will discuss sensitivity estimation in a nonlinear interferometer incorporating practical imperfections, in particular, losses inside and outside the interferometer, following an information-theoretic approach. To conclude, I will present a recipe for the practical implementation of a nonlinear interferometer using a thin-film lithium niobate waveguide, an emerging platform for quantum photonic technologies.

Goutam Pramanik

UGC DAE CSR, Kolkata

Title:

Optically Active Color Centres in Diamond

Abstract:

Diamond is a metastable allotrope of carbon, in which sp3 hybridized carbon atoms are arranged in a face-centered cubic crystal structure. Diamond-based materials are known for their high thermal stability and mechanical properties. However, it is the defects in the diamond crystal that have attracted much attention from the scientific communities around the world. Due to a very large band gap (5.5 eV), diamond can accommodate a variety of optically active defects, which are generically referred to as "colour centres". These individual colour centres are often referred to as 'artificial atoms' which can generate single photons per excitation and relaxation cycle on demand and studied as an independent quantum system. The optical properties of fluorescent diamond depend on the impurity atom, charge of the color centers.

The Nitrogen Vacancy (NV) centre is one of the most studied colour centres in diamond. What sets the NV centre apart from others is that its luminescence property is coupled to the spin state and optical readout of the NV electron spin places it into a special category of condensed matter systems exhibiting optically detected magnetic resonance (ODMR). The detection and manipulation of the electron spin of single NV at room temperature, the long coherence time of its electron spin state allowed the utilisation of these systems for photon-mediated entanglement, quantum teleportation over long distances, and biosensing. In this presentation, synthesis, characterization, optical properties, and functionalisation of fluorescent diamond towards biological applications will be discussed.

Brajesh Kumar Mani

IIT Delhi

Title:

Probing Atomic Clocks' Candidates Using Precision Structure Calculations agnetic Field Sensors and Their Applications

Abstract:

Atomic systems offer a plethora of fundamental and functional properties and therefore are of importance to several key implications. Some examples where atoms and ions can serve as important probes include, atomic clocks, parity and time-reversal violations, and the search for the variations in the fundamental constants. Atomic systems, however, form a many-body complex system for which the exact solution is nontrivial. This poses a serious challenge in the theoretical investigations of the properties of these systems. In this context, relativistic coupled-cluster (RCC) theory is one of the most reliable many-body theories for structure and properties calculations for atoms and ions.

In our group at IIT Delhi, we have developed RCC based theories for the properties calculations of closed-shell, one-valence and two-valence atomic systems. These theories are implemented as sophisticated parallel FORTRAN programs. In this talk, I shall present some of our recent works on the clock transition properties of neutral Sr and some highly charged ions.

Nirmalya Ghosh

IISER Kolkata

Title:

Quantum Weak measurement using Polarized photons

Abstract:

The weak measurements and weak value amplification (WVA) concept, introduced by Aharonov, Albert, and Vaidman, has proven to be fundamentally important and extremely useful for numerous metrological applications. This quantum mechanical concept can be understood using the wave interference phenomena and can therefore be realized in both classical and quantum optical settings. In this talk, I shall illustrate how the WVA concept can be integrated with several interference-related non-trivial optical wave phenomena through the common platform of wave interference. In this regard, I shall show how WVA can be realized in standard path interference by introducing a weak coupling between the path degree of freedom of an interferometer and the polarization degree of freedom of light. I shall present some of our recently developed concepts of weak measurements using various degrees of freedom of light such as weak measurements on spin orbit interaction (SOI) of light using weak coupling between transverse momentum and circular polarization (spin) states, natural WVA of Faraday effect in spectral domain interference of Fano resonance in hybridized magneto-plasmonic systems through weak coupling between polarization and interfering spectral modes, WVA using spectral line shape of resonance in precisely designed metamaterials using weak coupling between frequency (spectral line shape) and polarization and so on. Some useful device concepts using the above weak measurement approaches such as the “weak value polarimeter device” and “weak measurement microscope” will be presented and their potential applications in sensing and high precision metrology will be discussed.

Contributed Abstracts

Amit Kumar

TIFR Mumbai

An Experimental Study of NV Centers for Single-Photon Emission

Amit Kumar

July 2025

This work explores nitrogen-vacancy (NV) centers in fluorescent nanodiamonds as promising single-photon sources for quantum communication applications. Using time-correlated single-photon counting, we observe photon antibunching with a measured second-order correlation function, $g^2(0) < 0.5$, conclusively demonstrating true single-photon emission. To enhance photon collection efficiency—a critical requirement for practical quantum communication—we aim to couple these NV centers to optical cavities, particularly whispering-gallery-mode resonators. Additionally, determining the spin-lattice relaxation time (T_1) of NV centers remains an essential forthcoming step to characterize their suitability for quantum networks. This research lays foundational groundwork for robust and efficient NV-center-based quantum communication systems.

Anil Shaji

IISER Thiruvananthapuram, Kerala

Quantum Fisher Information and the Curvature of Entanglement

Zain H. Saleem,[1] Anil Shaji,[2] Anjala M Babu,[3] Da-Wei Luo,[4] Quinn Langfitt,[5] Ting Yu,[4] and Stephen K. Gray[6]

[1]*Mathematics and Computer Science Division, Argonne National Laboratory, Lemont, IL, USA*

[2]*School of Physics, IISER Thiruvananthapuram, Kerala, India 695551*

[3]*School of Physics and Applied Physics, Southern Illinois University, Carbondale, IL, USA*

[4]*Center for Quantum Science and Engineering and Department of Physics, Stevens Institute of Technology, Hoboken, New Jersey 07030, USA*

[5]*Department of Computer Science, Northwestern University, Evanston, IL, U.S.A.*

[6]*Center for Nanoscale Materials, Argonne National Laboratory, Lemont, IL, USA*

Abstract

We explore the relationship between quantum Fisher information (QFI) and the second derivative of concurrence with respect to the coupling between two qubits, referred to as the curvature of entanglement (CoE). The QFI characterises the theoretical limit on the achievable precision in quantum measurements and sensing. Entanglement in the quantum probe is typically required for saturating this bound in practical implementations of quantum limited metrology. We establish a direct connection between the QFI and entanglement in the quantum probe and its readout. For a two-qubit quantum probe used to estimate the coupling constant appearing in a simple interaction Hamiltonian, we show that at certain times CoE = −QFI; these times can be associated with the concurrence, viewed as a function of the coupling parameter, being a maximum. We examine the time evolution of the concurrence of the eigenstates of the symmetric logarithmic derivative and show that, for both initially separable and initially entangled states, simple product measurements suffice to saturate the quantum Cramér-Rao bound when CoE = −QFI, while otherwise, in general, entangled measurements are required giving an operational significance to the points in time when CoE = −QFI.

Anjali Bisht

CSIR NPL, New Delhi

Estimation of Statistical and Systematic Uncertainties of the Primary Frequency Standard

Anjali Bisht[1,2], Manoj Das[1,2], Amitava Sen Gupta[1,3] and Poonam Arora[1,2]
[1]CSIR-National Physical Laboratory, New Delhi, India
[2]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, India
[3] The North Cap University, Gurugram, Haryana, India

NPLI-CsF1 is a primary frequency standard developed in India that contributed to International Atomic Time (TAI) in 2015. In 2023, the system was successfully revived, and significant upgrades were implemented in the optical subsystems and detection electronics. A completely redesigned optical setup has been introduced to address the low signal-to-noise ratio (SNR), which was a limiting factor during its previous operation. After the system upgrades, we carried out a detailed evaluation of the cesium fountain atomic clock to verify its improved frequency stability and its capability for continuous participation in TAI. Multiple clock runs were conducted to determine the frequency stability and to re-evaluate the four major systematic uncertainties: second-order Zeeman shift, blackbody radiation shift, gravitational redshift, and cold collisional shift. The recent evaluation shows consistent results and has comparable performance to those obtained during the 2015 operation in terms of frequency stability and systematic uncertainty. However, the cold collisional shift continues to be the dominant source of uncertainty and requires more precise characterization. Despite improvements, achieving a high SNR remains a challenge, and further optimizations of the system are currently underway [1-3]. This paper presents the first comprehensive estimation of both statistical and systematic uncertainties following the revival and upgradation of the NPLI-CsF1 system.

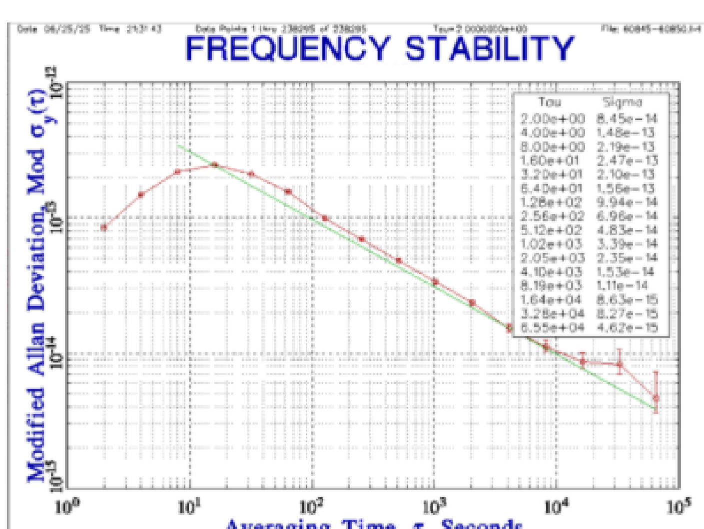


Fig : Modified Allan deviation plot corresponding to one of the clock runs.

[1] Wynands, R., & Weyers, S. (2005). Atomic fountain clocks. *Metrologia*, *42*(3), S64.
[2] Gerginov, V., Hoth, G. W., Heavner, T. P., Parker, T. E., Gibble, K., & Sherman, J. A. (2025). Accuracy evaluation of primary frequency standard NIST-F4. *Metrologia*, *62*(3), 035002.
[3] Acharya, A., Bharath, V., Arora, P., Yadav, S., Agarwal, A., & Gupta, A. S. (2017). Systematic uncertainty evaluation of the cesium fountain primary frequency standard at NPL India. *Mapan*, *32*, 67-76, doi.org/10.1007/s12647-016-0190-4

Aparajita Das

Durham University, England

Electric Field Sensing via Multi-Photon Rydberg Electromagnetically Induced Transparency in Cesium Vapor for L-Band Quantum Radar Receiver Applications

Aparajita Das[1], Kevin J. Weatherill[2]

Department of Physics, Durham University, South Road, Durham, DH1 3LE, England, UK

Email:[1]aparajita.das@durham.ac.uk, [2]k.j.weatherill@durham.ac.uk

Rydberg alkali atom-based sensing of radio-frequency (RF) and microwave (MW) electric fields is gaining increasing attention due to its precision measurement capabilities and emerging applications. This sensing method uses nonlinear optical effects in ensemble of alkali atoms such as Cesium (Cs) and Rubidium (Rb), which become highly sensitive to RF or MW fields when excited to Rydberg states with high principal quantum numbers (n). RF or MW sensing typically involves the use of two or more lasers to establish electromagnetically induced transparency (EIT) [1] condition and probe the atoms. The external RF or MW fields are detected by observing changes in the EIT window in spectral profile. In this regard, experimentally feasible multi-photon excitation schemes are particularly advantageous. For example, the three-photon EIT scheme [2] can reduce spectral Doppler broadening and enables access to higher Rydberg states using convenient diode laser systems. In the present work, we have studied RF or MW sensing, using a four-level cascade-type system with three-photon excitation involving Rydberg states in Cs vapor. A weak 894 nm probe beam connects states $|6S_{1/2}\rangle$ and $|6P_{1/2}\rangle$. Both the 1359 nm dressing beam and 780 nm coupling beam counter propagate with the probe to excite the transitions $|6P_{1/2}\rangle \rightarrow |7S_{1/2}\rangle$ and $|7S_{1/2}\rangle \rightarrow |nP_{3/2}\rangle$, respectively. Such a system exhibits three-photon EIT with two transparency windows when all the driving lasers are on resonance. Interestingly, when the coupling and dressing fields are equally and oppositely detuned, the system effectively reduces to a two-photon EIT with a single transparency window. Applying an external MW field between another higher Rydberg state (fifth state) and the $|nP_{3/2}\rangle$ state causes the single EIT peak to split into two. The separation between the peaks, dependent on MW field strength, can be used to measure the MW electric field strength. The theoretical predictions are experimentally realized through corresponding measurements. The results of this study show potential for application as a quantum receiver in atom-based radar systems [3]. Choosing a suitable principal quantum number for the fifth state allows this setup to be optimized for L-band (1–2 GHz) radar system for drone surveillance. The proposed Rydberg atom-based setup is also ideal for detecting pulsed RF or MW signals with high sensitivity and resolution. In conclusion, our study offers a promising route towards quantum receivers for advanced L-band radar systems.

Keywords: Electromagnetically induced transparency (EIT), Three-photon EIT, Two-photon EIT, Atom-based quantum receiver, L-band radar system

AD and KJW acknowledge EPSRC: UK Quantum Technology Research Hub in Sensing, Imaging and Timing for providing financial support.

References:

1. K. J. Boller, A. Imamoglu, and S. E. Harris, Physical Review Letter **64**, 1107 (1991)
2. C. Carr, M. Tanasittikosol, A. Sargsyan, D. Sarkisyan, C. S. Adams, and K. J. Weatherill, Optics Letters **37**, 18, (2012).
3. S. Borówka, W. Krokosz, M. Mazelanik, W. Wasilewski, and M. Parniak, Physical Review Applied **22,** 034067, **(**2024).

Archita Sahu

Nicolaus Copernicus University in Toruń, Poland

Progress Towards Dual Species Atomic Clock

A. Sahu,[1,*] A. Linek,[1] I. Nandi,[1]
R. Ciuryło,[1] M. Zawada,[1] and M. Witkowski[1]

[1] *Institute of Physics, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University in Toruń, Grudziądzka 5/7, PL-87-100 Toruń, Poland*

Optical atomic clocks have achieved remarkable progress, providing far greater precision than conventional microwave-based clocks by orders of magnitude. By relying on optical transitions with extremely narrow linewidths, they enable highly accurate measurements and deep insights into fundamental physical laws. The use of multiple components in an atomic clock offers the potential to improve its stability and accuracy. To enhance frequency accuracy, atoms with two reference transitions exhibiting significantly different sensitivities to external fields may be employed and mercury with extremely narrow metastable clock transitions ($^1S_0$-$^3P_0$ and $^1S_0$-$^3P_2$) stands out as an excellent candidate for an optical clock in this regard [1].

This work presents the experimental progress achieved in the dual trap Hg-Rb system, aimed at being utilized as a two-component atomic clock [2]. In this system, the two reference clock transitions ($^1S_0$-$^3P_0$) Hg and ($^1S_0$-$^3P_2$) Hg, corresponding to wavelengths of 266 nm and 227 nm, respectively will be generated through a fourth-harmonic frequency conversion process applied to two fundamental lasers (1064 nm and 908 nm), both being tightly stabilized to a dual-color (1064 nm and 908 nm) high-finesse ultra-stable ULE cavity [3] using the Pound–Drever–Hall technique.

---

[1] M. Witkowski *et al.*, *Joint Conference of the European Frequency and Time Forum and IEEE International Frequency Control Symposium (EFTF/IFCS)*, April 24-28, 2022, Paris, France: proceedings, doi: 10.1109/eftf/ifcs54560.2022.9850819.

[2] M. Witkowski *et al.*,*Opt. Express* **25** 3165-3179 (2017), doi: 10.1364/OE.25.003165.

[3] A. Linek, *et al.*, *Joint Conference of the European Frequency and Time Forum and IEEE International Frequency Control Symposium (EFTF/IFCS)* , 15-19 May, 2023, Toyama, Japan: proceedings, doi: 10.1109/EFTF/IFCS57587.2023.10272089.

* 503477@doktorant.umk.pl

Sudha

Kuvempu University, Karnataka

Noise resilience of Dicke superposition state probes in phase estimation tasks

Sudha,[1,2,*] B.N. Karthik,[1] A. R. Usha Devi,[3,2] and K. S. Akhilesh[4]

[1] *Department of Physics, Kuvempu University, Shankaraghatta-577 451, Karnataka, India*
[2] *Inspire Institute Inc., Alexandria, Virginia, 22303, USA.*
[3] *Department of Physics, Bangalore University, Bangalore-560 056, Karnataka, India*
[4] *School of Computer Science and Engineering, RV University, Bangalore, 560 059, Karnataka, India.*

(Dated: July 25, 2025)

We explore the metrological performance of superpositions of N-qubit Dicke states $|D_{N-k,k}\rangle = |\frac{N}{2}, \frac{N}{2} - k\rangle$, $k = 0, 1, \ldots N$ which are eigenstates of the collective angular momentum operators $\hat{J}^2$ and $\hat{J}_z$. Specifically, we examine their utility as probe states in quantum-enhanced phase estimation tasks involving phase encoding through the Hamiltonian $\hat{J} \cdot \hat{n}$, with $\hat{n}$ being a unit vector that sets the optimal quantization axis. We compute the maximal quantum Fisher information $I_{\max}$ and phase sensitivity $\Delta\theta$ for various Dicke superpositions. Our findings show that certain superpositions yield $I_{\max}$ values approaching N^2 thereby surpassing the shot-noise limit. Additionally, we demonstrate the robustness of these states against different types of noise, emphasizing their practical advantages for precision metrology in realistic environments.

Ekramul Hoque

Saha Institute of Nuclear Physics, Kolkata

Investigation of EIT and double resonance optical pumping effects in ladder-type transitions of ^{87}Rb atoms

Ekramul Hoque[1,*], Tanish Kaur[1], Priyabrata Seth[1], Dipankar Bhattacharyya[2], and Sankar De[1]

[1]*Saha Institute of Nuclear Physics, HBNI, 1/AF Bidhannagar, Kolkata 700064, India.*
[2]*Department of Physics, Santipur College, Santipur, Nadia, PIN 741404, India.*
* ekramul.hoque@saha.ac.in

We observed electromagnetically induced transparency (EIT) in a ladder-type three-level system involving the $5S_{1/2} \rightarrow 5P_{3/2} \rightarrow 5D_{5/2}$ transitions of ^{87}Rb atoms (Fig. 1). The experimental spectra, obtained using a weak probe laser and a strong coupling laser, reveal signatures of double resonance optical pumping (DROP) within the EIT signal [1]. Two-photon excitation to the $5D_{5/2}$ state is confirmed through the detection of 420 nm fluorescence signal using a photomultiplier tube (PMT), resulting from the radiative cascade $5D_{5/2} \rightarrow 6P_{3/2} \rightarrow 5S_{1/2}$ transitions [2]. We found the experimental observations to be in good agreement with the analytical predictions based on the density matrix formalism under strong probe conditions.

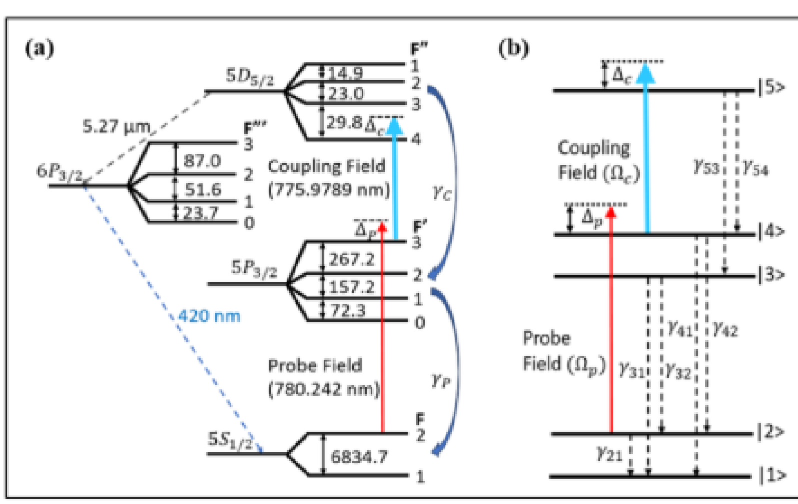


Fig. 1: (a) Ladder-type atomic level scheme in ^{87}Rb atoms, showing the cascade excitation via $5S_{1/2} \rightarrow 5P_{3/2} \rightarrow 5D_{5/2}$ transitions. The energy separation between hyperfine levels is on the order of megahertz (MHz). (b) Schemes of the ladder-type five-level atomic system.

Fig. 2(a) shows a typical probe transmission spectrum along with the blue fluorescence spectrum from PMT when the coupling beam has been scanned. When the probe intensity is weaker than the coupling intensity, three distinct peaks can be observed in the probe transmission corresponding to three different hyperfine levels F'' = 2, 3, and 4, respectively. Out of these three transmission peaks, we have found a dual structure in the transmission profile corresponding to the closed transitions $5S_{1/2}$ (F = 2) → $5P_{3/2}$ (F' = 3) → $5D_{5/2}$ (F'' = 4) of ^{87}Rb atoms. These dual structures are attributed to the DROP and EIT phenomena. The broad spectrum arises due to the optical pumping effect, and the narrow EIT spectrum arises due to atomic coherence. Distinct EIT features only appear on the closed transition because EIT in the cycling transition arises from atomic coherence, as the population of the F = 2 ground state remains mostly unaffected by optical pumping due to the selection rules.

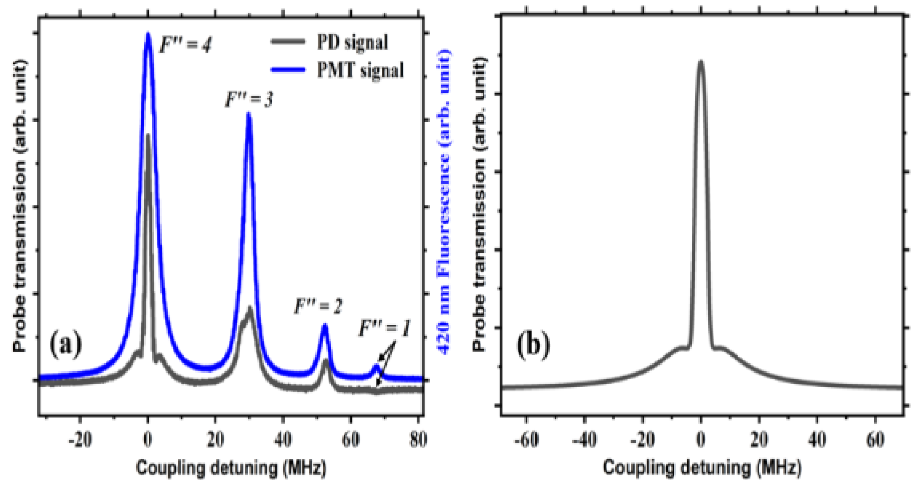


Fig. 2: (a) Experimental probe transmission signal along with the blue fluorescence spectrum detected with the PMT. (b) Theoretical probe transmission spectrum, derived with our theoretical formalism. Probe intensity is 1.64 mW/cm^2 with the coupling intensity of 534 mW/cm^2.

However, these features are not observed for F'' = 2 and 3 open transitions. For these energy levels, the population of one of the ground states, F = 2, becomes depleted as atoms are excited to the $5D_{5/2}$ state and subsequently undergo optical pumping into the other ground hyperfine state (F = 1) via the intermediate $5P_{3/2}$ state. The presence of multiple excitation channels breaks the condition for the formation of atomic coherence. Therefore, the observed signals corresponding to F'' = 2 and 3 primarily arise due to the DROP effect. By introducing a repumping laser resonant with the $F = 1 \rightarrow F' = 2$ transition, we can resolve a DROP-free EIT signal corresponding to $F' = 4$ closed transition. Additionally, this repumping effectively suppresses the DROP associated with F'' = 2 and 3 open transitions.

Both the photodiode (PD) and PMT signals revealed a fourth peak corresponding to the F'' = 1 level (Fig. 2(a)). This additional feature is attributed to a velocity-selective two-photon resonance, arising due to Doppler shifts. Fig. 1(b) presents a simulated EIT spectrum for the F'' = 4 transition, using the same laser intensities as in the experimental case. Furthermore, we are employing lock-in-amplifier (LIA) techniques to improve the signal-to-noise ratio.

---

[1] H. S. Moon, *et al.*, *Double resonance optical pumping effects in electromagnetically induced transparency*, Optics Express, **16**, 12163 (2008).

[2] River Beard, *et al.*, *Two-photon rubidium clock detecting 776 nm fluorescence*. Optics Express, 32, 7417 (2024).

Greeshma Gopinath

BITS Pilani, Hyderabad

Continuous variable entanglement using optomechanics

Greeshma Gopinath and Sankar Davuluri*

Department of Physics, Birla Institute of Technology and Science, Pilani, Hyderabad Campus, Hyderabad 500078, India.
Author e-mail address: sankar@hyderabad.bits-pilani.ac.in

Abstract: This study introduces a method to entangle two spatially separated propagating laser fields from an optomechanical cavity. Unlike standard methods that drive the two-mode squeezing part of the linearized optomechanical interaction, our approach utilizes the quantum back-action nullifying meter technique. This enables entanglement generation outside the blue sideband frequency in both resolved and unresolved sideband regimes. Notably, the optomechanical mirror does not need to be in the ground state to create entanglement. The system remains stable where the Duan criterion for inseparability is met. We also investigate the impact of thermal noise on the entanglement.

Guillem Műller-Rigat

The Barcelona Institute of Science and Technology, Spain

Spatial Leggett-Garg Inequalities

Guillem Müller-Rigat,[1] Donato Farina,[2] Maciej Lewenstein,[1,3] and Andrea Tononi[1,4]

[1] *ICFO-Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology, Castelldefels (Barcelona) 08860, Spain*

[2] *Physics Department E. Pancini, Università degli Studi di Napoli Federico II, Complesso Universitario Monte S. Angelo, I-80126 Napoli, Italy.*

[3] *ICREA, Pg. Lluís Companys 23, 08010 Barcelona, Spain*

[4] *Department de Física, Universitat Politècnica de Catalunya, Campus Nord B4-B5, E-08034, Barcelona, Spain*

(Dated: August 1, 2025)

We formulate a spatial extension of the Leggett-Garg inequality by considering three distant observers locally measuring a many-body system at three subsequent times. The spatial form, in particular, is specially suited to analyze propagation of quantum perturbations through spin chains, by capturing how a measurement at one site can later affect distant sites due to the interactions. We illustrate our proposal for a Heisenberg chain in a magnetic field, showing indeed that the first inequality-violation time scales proportionally to the distance between measuring parties. We attribute this phenomenon to Lieb-Robinson physics and, confirming this connection, we find that violations are anticipated when increasing the interaction range. The inequality violation, readily observable in current experiments, demonstrates the incompatibility between two-point correlation functions and the macrorealistic hypothesis. In outlook, spatial Leggett-Garg inequalities constitute a new tool for analyzing the non-relativistic dynamics of many-body quantum systems.

Himani Thakur

Guru Nanak Dev University, Punjab

Quantum Electrometric Sensors Based on Atomic Coherence in Hot Rydberg Alkali Atoms for Metrology and Radar Applications

Himani Thakur[1], Zubair Iqbal Dar[1], and Dr. Paramjit Kaur[*]

[1] *Guru Nanak Dev University, Amritsar (143005) Punjab, India.*

[*]*paramjit.phy@gndu.ac.in*

Abstract

Electric field measurement is a fundamental aspect of numerous technological applications, such as telecommunications, wireless networks and quantum information processing. Precise detection in the microwave and radio frequency regimes, is crucial for enhancing device performance and advancing research. However, existing measurement techniques often face challenges regarding sensitivity, accuracy, and non-invasiveness. One promising solution lies in Rydberg electromagnetically induced transparency (EIT) in atomic systems, a quantum interference phenomenon that enhances field sensitivity. Building on these findings, we aim to perform detailed theoretical analysis of Rydberg EIT electrometry using cesium (Cs) atoms in a four-level configuration by employing density matrix formalism.

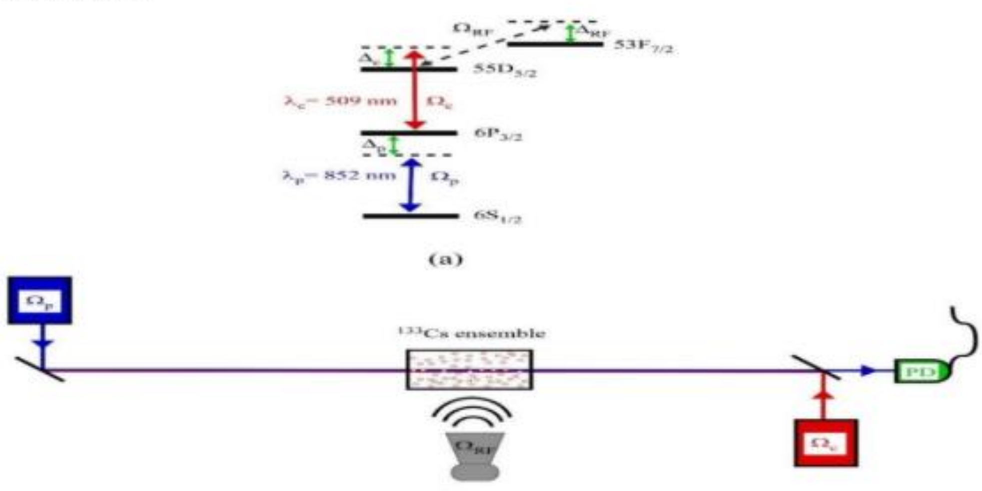


Figure 1: (a) Level diagram of a four-level system where probe (Δ_p), control (Δ_c) and RF (Δ_{RF}) fields detunings. Ω_j denotes the Rabi frequency of field j. (b) Geometric arrangement of probe, control and RF fields relative to the Cs vapor cell and photo detector in experimental setup.

Keywords: *Quantum interference, Quantum information processing, Electrometry*

References

[1] A. K. Mohapatra, T. R. Jackson, C. S. Adams, Phys. Rev. Lett., 98, 113003, (2007).

[2] J. Sheng, Y. Chao, S. Kumar, H. Fan, J. Sedlacek, J. P. Shaffer, *Phys. Rev. A*, **96**, 033813, (2017).

[3] Z. I. Dar, A. Kaur, B. Arora, P. Kaur, *Phys. Scr.*, **98**, 105106, (2023).

Indrajit Nandi

Nicolaus Copernicus University in Toruń, Poland

Dual-species optical dipole trap to explore fundamental interactions

Indrajit Nandi,[1,*] Archita Sahu,[1] Adam Linek,[1] Roman Ciuryło,[1] Michał Zawada,[1] and Marcin Witkowski[1]

[1] *Institute of Physics, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University in Toruń, ul.Grudziądzka 5/7, PL-87-100 Toruń, Poland*

The experimental setup based on a dual-species single-beam optical dipole trap (ODT) for cold Rb and Hg atoms enables the investigation of new hadron-hadron interactions [1] through both heteronuclear and homonuclear photo-association spectra. Rubidium and, especially, mercury atoms forming Hg_2, one of the heaviest two-atom molecules, are well-suited for this experiment. The Hg-Hg Van der Waals interaction is well characterized [2] and significantly weaker than in Sr_2 or Yb_2, reducing conventional interatomic effects and enhancing sensitivity to new physics beyond the Standard Model at the nanometer scale.

For the first time, two-color photo-association [3] spectroscopy will be conducted in a dual-species Rb-Hg ODT to investigate the bound states of Hg_2 and Rb-Hg molecules near the dissociation threshold. The experiment will be carried out using the double-species experimental setup [4]. Photo-association resonances can also be regarded as optical Feshbach resonances, which serve as a powerful tool for controlling atomic interactions [5]. The Hg_2 molecules will also be employed to investigate the potential for the realization of an optical molecular clock [6].

[1] E. G. Adelberger, *et al.*, *Annu. Rev. Nucl. Part. Sci* **53** 77 (2003)
[2] M. Krośnicki, *et al.*, *Phys. Rep* **591** 1 (2015).
[3] M. Kitagawa, *et al.*, *Phys. Rev. A* **77** 012719 (2008).
[4] M. Witkowski *et al.*, *Opt. Express* **25**, 3165 (2017).
[5] R. Ciuryło, *et al.*, *Phys. Rev. A* **77** 030701(R)-4 (2005).
[6] M. Borkowski, *et al.*, *Phys. Rev. Lett.* **120** 083202 (2018).

* indrajit@doktorant.umk.pl

Kavish Bhardwaj

RRCAT, Indore (DAE)

Title: *Two-photon Raman Spectra in a Cold 87Rb Atomic Fountain for Gravimetry Applications*

We report on the study of two-photon Raman transition spectra in a cold ^{87}Rb atomic fountain, conducted as part of the development of a portable cold atom gravimeter. The experiment utilizes stimulated Raman transitions between the hyperfine ground states (F=1 and F=2) of the $^{5}S_{1/2}$ manifold, driven by phase-coherent laser beams near the D2 line. A detailed analysis of the Raman spectra is carried out as a function of experimental parameters such as Raman pulse duration, detuning, magnetic bias field, and laser polarization. We compare the spectral characteristics under co-propagating and counter-propagating beam configurations, highlighting differences in Doppler sensitivity and velocity selection. Furthermore, we demonstrate magnetic field measurement based on a stimulated two-photon Raman transition. Ongoing efforts are focused on employing Raman spectroscopy for improved state preparation and velocity selection of Rb atoms in fountain. These studies aim to further enhance the performance and accuracy of cold atom based sensor for precision gravimetry.

Kuntal Samanta

University of Glasglow, UK

Realisation of an atom State Interferometer with Vector light beam

K.Samanta*[1], S.J. Svensson[1], N.Westerberg[1], S.F.Arnold[1],
[1] School of Physics and Astronomy, University of Glasgow, G12 8QQ, United Kingdom

Perhaps one of the most salient features of light is the fact that it can interfere, particularly vector light correlated with polarization and spatial degrees of freedom shows fascinating behaviour in the context of interference. [1, 2]. On the other hand, an atom can be a valuable interface to shape light because by its very nature the atomic dipole interactions are sensitive to polarization via selection rules [3]. In this work, our goal is to investigate the role of structured light for atom state interferometers, where it facilitates local interference dictated by the orientation of an external magnetic field, optical and atomic polarization.
Here, we realize an atom state interferometer in ^{87}Rb driven by a vector light beam which excites two optical transitions from $F = 1$ to $F' = 0$ hyperfine state in a Λ (fig1(a)) configuration and a transverse magnetic field couples between the ground levels creating a closed loop configuration to make a phase sensitive system. We consider a very generic form of light field embedded in left and right hand circular polarization to study internal dynamics of Rb^{87} atom delving into a fully analytical description. We investigate the inner atomic process observing transition probabilities between our derived partially dressed states according to some order of perturbation theory. The results show that the transition rates between the partially dressed states depends on the phase and polarization profile of the light, as specified by the coordinates on a Poincare sphere[4], and the direction of the external magnetic field.

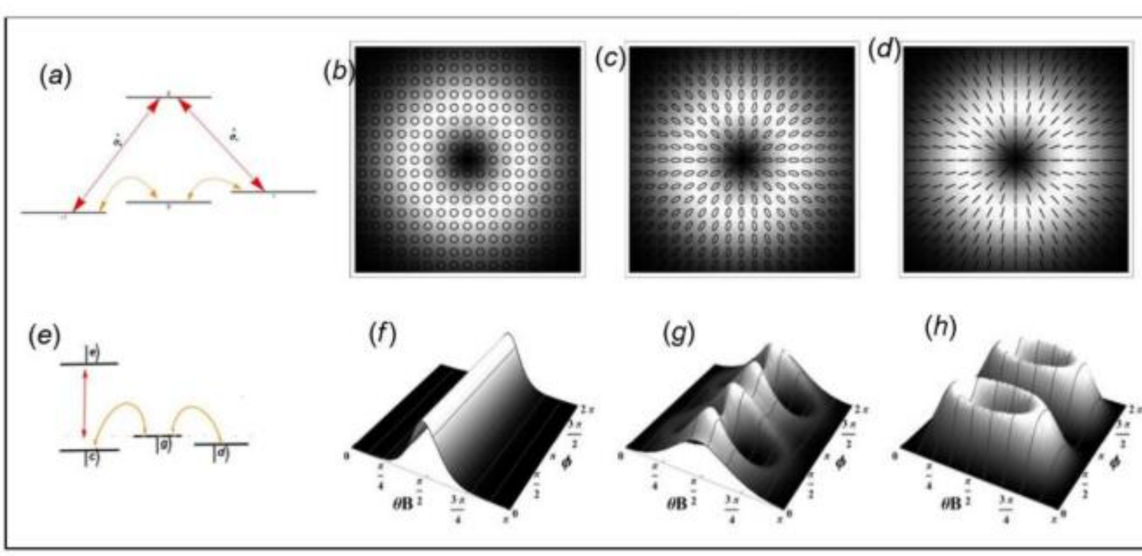


Fig. 1: (a): Atomic level scheme (Ground states ± 1 couples optically to the excited states and also the ground states$\pm 1, 0$ states are coupled by transverse component of an external magnetic field) , (e): partially dresssed state basis form a ladder like system, where the excited state $|e\rangle$ coupled optically and $|c\rangle$,$|g\rangle$ and $|d\rangle$ are magnetically coupled . (f), (g) and (h) show transition rates between $|d\rangle$ to $|e\rangle$ with varying magnetiic field angle (θ_B) corresponding to different beam profiles ((b)the probe is homogenously right circularly polarized (RCP), (c) Arbitrary polarized and (d) radially beam. It is also to be noted that for homogeneously RCP beam as the close loop configuration (fig1: a)disappears results in the vanishing of spatial phase dependency in absorption .

Our fully analytical model allows to associate parameters of the structured light with specific atomic transition rates, and hence absorption profiles. Our study enhances the understanding of vector light-atom interaction, and may pave the way to designing devices for quantum magnetometry and metrology.

References

[1] Carmelo Rosales-Guzmán *et al* 2018 *J. Opt.* **20** 123001
[2] Halina Rubinsztein-Dunlop *et al* 2017 *J. Opt.* **19** 013001
[3] Wang, J. *et al.* Measuring the optical concurrence of vector beams with an atomic-state interferometer.*PhysRevLett*.**132**.193803 (2024).
[4] Wang, J. *et al.* Vectorial light–matter interaction: exploring spatially structured complex light fields. *AVS Quantum Sci.* **2**, 031702 (2020).

Md Jalaluddin

Aliah University, Kolkata

Rydberg Atom-Based Electrometry in a Four-level Atomic System Under Electromagnetically Induced Transparency Regime

Md Jalaluddin[1, *], Jayanta K. Saha[1], Md Mabud Hossain[1]

[1]Department of Physics, Aliah University, II A/27, New Town, Kolkata-700160, India

E-mail: *mdjalaluddin4894@gmail.com

The precise measurement of electric (E) and magnetic (B) fields of the microwave (MW) or radio-frequency (RF) wave has played a vital role in the domains of quantum sensing and metrology [1]. Recently, the utilization of Rydberg atoms in a light-matter interaction system has emerged as powerful platforms for precision fields measurement under electromagnetically induced transparency (EIT) protocol [2, 3]. The key feature of Rydberg atoms is that it has an extremely large transition dipole moments (*i.e.,* high-lying energy states), making it highly sensitive to external electric or magnetic fields. In Rydberg-EIT system, the coupling between the probe, pump, control, and MW/RF fields with a multi-level atomic system allows high-resolution quantum sensing of E- or B-fields of MW or RF signal, where the changes in the spectral profile of EIT window or Autler-Townes (AT) splitting is monitored [4]. In this work, we theoretically measure the MW-electric field in a four-level atom-laser coupled system involving Rydberg states under EIT regime. The required optical Bloch equations (OBE) are derived from Liouville's equation of motion under semiclassical density matrix formalism. The OBEs are analytically solved using an iterative perturbative technique to obtain the probe coherence term. We have observed that the spectral resolution can be improved by using system parameters. The effect of Doppler-broadening has also investigated. Furthermore, minimum detectable strength of MW-electric field is theoretically measured. Moreover, we investigate the other effects on the high sensitivity of the system. Our findings demonstrate that this four-level scheme can significantly enhance electric field sensitivity and offers a promising platform for high-resolution quantum sensing and metrology.

Keywords: Rydberg atom, electromagnetically induced transparency (EIT), Autler-Townes (AT) splitting, microwave (MW), electrometry.

References:

[1] V I Yudin, A V Taichenachev, Y O Dudin, V L Velichansky, A S Zibrov, and S A Zibrov. *Physical Review A*, **82(3)**:033807, 2010.
[2] S E Harris, J E Field, and A Imamoglu. *Physical Review Letters*, **64**:1107, 1990.
[3] J A Sedlacek, A Schwettmann, H K¨ubler, R L¨ow, T Pfau, and J P Shaffer. *Nature Physics*, **8**:819–824, 2012.
[4] Yue Cui, Feng-Dong Jia, Jian-Hai Hao, Yu-Han Wang, Fei Zhou, and Xiu-Bin Liu. *Physical Review A*, **107**,043102(2023).

Monika Dhiman

IIT Roorkee

Ultra-low pressure CVD approach for the direct integration of crystalline silicon on SiO_2 for SOI applications

Crystalline silicon-on-insulator structures are becoming essential building blocks for modern technologies, including advanced transistors like FinFETs and TFETs, quantum devices like silicon qubits, and applications in 5G, high-performance computing, automotive electronics, MEMS, and energy-efficient processors. In this study, we demonstrate a simplified and scalable approach for fabricating high-quality SOI structures by directly depositing crystalline silicon thin films on thermally grown SiO_2/Si substrates using ultra-low pressure thermal chemical vapor deposition. The c-Si films were synthesized through the pyrolytic decomposition of hydrogen-diluted silane at 900 °C for 60 minutes under chamber pressures ranging from 7 to 150 mTorr. Field-emission scanning electron microscopy confirmed uniform pressure-controlled film thickness, while grazing-incidence X-ray diffraction and symmetric (400) ω-scans revealed a strong (100) peak and high crystallinity. Raman spectroscopy exhibited well-defined LO-TO phonon modes, and high-resolution cross-sectional transmission electron microscopy further verified the formation of a single-crystalline silicon layer atop the amorphous SiO_2, thereby confirming the formation of a crystalline SOI structure. Furthermore, a strong dependence of crystalline quality on deposition pressure was observed, with lower pressures yielding improved structural order. This work provides a cost-effective and controllable route for the direct fabrication of SOI structures, offering strong potential for integration into a wide range of next-generation electronic and quantum devices. This product can also be adapted for the manufacturing of silicon-on-insulator wafers enriched with Si-28, enabling applications in silicon-based quantum computing platforms.

Monirul Islam

IIT Ropar

Title

Vacuum induced coherence-based magnetometer via weak value amplification

Abstract

We propose a quantum-enhanced magnetometry scheme that combines vacuum-induced coherence (VIC) and weak-value amplification (WVA), further enhanced via photon recycling, to detect ultra-weak magnetic fields with high sensitivity and precession. VIC, arising from quantum interference between spontaneous decay channels in a multilevel atomic or molecular system, is utilized to enhance Faraday magneto-optical rotation (MOR). The MOR-induced phase shift is then converted into a measurable spectral shift using the WVA protocol, where nearly orthogonal pre- and post-selected polarization states yield large imaginary weak values. Building on this, we incorporate cyclic weak-value amplification (CWVA), where the probe undergoes multiple postselection cycles, boosting both signal strength and Fisher information without increasing photon budget. Simulation results show significant amplification of spectral shifts and enhanced sensitivity to magnetic fields, even under detector-limited conditions. Our analysis demonstrates the scalability of this approach, highlighting its potential to reach 10^{-14} T resolution. This hybrid VIC-WVA-CWVA framework establishes a new route for high-precision quantum magnetometry applicable to biomedical diagnostics, precision navigation, and fundamental physics.

Nandini Mondal

NISER, Bhubaneswar

Title

Microwave Field Sensing Using Rydberg Atoms in Thermal Atomic Vapor

Abstract

Atom-based sensors possess a high degree of accuracy and reproducibility. Rydberg atoms can be used to measure the electric field of electromagnetic waves ranging from DC to THz. Due to their large dipole moment and high polarizability, Rydberg atoms are sensitive to extremely small external electric fields. This kind of atom-based sensor doesn't need to be calibrated as it involves fundamental atomic properties. The strength of the microwave field is obtained from the Autler-Townes splitting of the electromagnetically induced transparency (EIT) spectrum. We will present the experimental outcome with the theoretical simulation regarding the sensing of the microwave field using the EIT-based method. It also allows us to calibrate the microwave field for further experiments. The line width of the EIT signal limits the sensitivity of the sensor in our case. To achieve better sensitivity, we perform another experiment on the parametric six-wave mixing process of optical and microwave fields, where a weak microwave field can be detected in the presence of a strong microwave field. We have observed the beat signals as a signature of the generation of new optical frequencies. The microwave electric field can be measured by measuring the amplitudes of these new optical components using the optical heterodyne detection technique.

Nidha Hind K K

Central University of Punjab, Punjab

Investigations on Morphological Evolution in Tellurium Nanostructures

Nidha hind K K[1], Pinki Rani[1], Manjima Sudheer[1], Shashikant P. Patole[2] and Prashant S. Alegaonkar[1]

[1]*Department of Physics, Central University of Punjab, Bathinda, Punjab, India – 151401*

[2]*Division of Physics and Applied Physics, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore – 637371*

[3]*Department of Physics, Khalifa University of Science and Technology, 127788, Abu Dhabi, United Arab Emirates*

nidhahindkk@gmail.com

Abstract

Tellurium nanostructures (TeNs) interact exclusively via van der Waals forces and exhibit a quasi-one-dimensional electronic band structure, yielding properties that differ markedly from bulk Tellurium (Te). Here, we report a facile, one-step, room-temperature wet-chemical synthesis of TeNs and systematically examine their morphological evolution. Building on Rani et al.[1] observation that Mo additives induce time-dependent phase transitions in Te nanotubes at 120 °C (and thermodynamic insights by Sudheer et al.[2]), we extended the investigation by varying the reaction temperature (ambient to 135 °C) and reaction time. Using field-emission SEM and high-resolution TEM, we found that at 120 °C Te initially forms nanotubes which convert into nanoflakes after 6 h and then revert in consistent with findings of Rani et al.[1]'s report. At 135 °C, however, the intermediate flake stage is entirely suppressed, and Te nucleates and grows directly as uniform one-dimensional nanorods. FTIR, XRD, and XPS analyses confirm that at 120 °C Mo–O–Te–O and Te–Mo–Te linkages form selectively at 6 h, whereas at 135 °C full reduction proceeds without intermediate bonding rearrangements. EDX shows higher elemental Te content at 135 °C, and thermal conductivity measurements reveal that the nanorods possess enhanced thermal stability. This work thus introduces a novel, solution-based route to stable Te nanorods with improved structural and thermal properties.

Keywords: Structural phase transformation, Temperature, Time, catalysis, Nanorods, Nanoflakes, Nanotubes, Morphological evolution

Palki Gakkhar

IIT Delhi, New Delhi

Highly Charged Ions Based Optical Clocks for Probing Alpha Variation

Palki Gakkhar [1]* and B. K. Mani [1]

[1]palkigakkhar13@gmail.com

[1]Department of Physics, Indian Institute of Technology, Hauz Khas, New Delhi 110016, India

Optical atomic clocks based on dipole-forbidden transitions in trapped atoms or ions have achieved an unprecedented precision, with fractional uncertainties reaching below 10^{-18}. Their exceptional accuracy makes them powerful tools not only for redefining the SI second [1] but also for exploring physics beyond the Standard Model [2] and probing the variations in the fundamental constants [2]. For instance, comparing clock frequencies of systems with different sensitivities to the fine-structure constant α allows for stringent constraints on its possible temporal variation [2]. While current accurate optical clocks such as Sr, Yb, and Al^+ offer excellent stability [1], their clock frequencies are not very sensitive to the variation in α. In contrast, highly charged ions (HCIs) exhibit greater sensitivity due to their compact structure, strong relativistic effects, and large ionization energies [3].

In this study, we explore three thallium-like HCIs, Cf^{17+}, Cm^{15+}, and Bk^{16+}, as potential candidates for next-generation optical clocks. Using Fock-space relativistic coupled-cluster theory [4], we have calculated the excitation energies, transition wavelengths, lifetimes, hyperfine structure constants, and sensitivity coefficients for low lying states in these HCIs. We also analyze the major systematic effects such as electric quadrupole shifts, quadratic Zeeman shifts, and blackbody radiation shifts which contribute to the errors in clock. Our results demonstrate that Cf^{17+}, Cm^{15+}, and Bk^{16+} offer favorable clock transitions that are robust against external perturbations and exhibit strong sensitivity to α variation.

References:

1. A. D. Ludlow, M. M. Boyd, J. Ye, E. Peik and P. O. Schmidt, "Optical atomic clocks", Reviews of Modern Physics **87**, 637 (2015).
2. M. S. Safronova, D. Budker, D. DeMille, D. F. J. Kimball, A. Derevianko and C. W. Clark, "Search for new physics with atoms and molecules", Reviews of Modern Physics **90**, 025008 (2018).
3. M. G. Kozlov, M. S. Safronova, J. R. Crespo López-Urrutia and P. O. Schmidt, "Highly charged ions: Optical clocks and applications in fundamental physics", Reviews of Modern Physics **90**, 045005 (2018).
4. B. K. Mani, S. Chattopadhyay and D. Angom, "RCCPAC: A parallel relativistic coupled-cluster program for closed-shell and one-valence atoms and ions in FORTRAN", Computer Physics Communications **213**, 136-154 (2017).

Panta Sasikanth

IIIT Sri City, Chittor

Numerical Study of Majorana Fermions in SO(3,2) lie group using Non Adiabatic Transition Probability

Panta Sasikanth [1]

PG Scholar, *Dept of CSE, IIIT Sri City, Chittor, India*

redaistarship@gmail.com

Abstract

In our study, we invoked numerical analysis of Majorana Fermions with a fractional quantum Hall system (3/2-FQHS) that leads to the even-denominator fractional quantisation of the Hall resistance which is non-abelian in nature. The symmetrical nature of Dirac States leads to Fermionic Operator $\gamma 1 \rightarrow \pm\ \gamma 2,\ \gamma 2\ \mp\ \gamma 1$ as represented mathematically. So, using numerical integration of the time-dependent Schrödinger equation, we compute the non-adiabatic transition probabilities between instantaneous eigenstates to quantify deviations from adiabatic behavior during parameter quenches or ramps. . We solve the time-dependent Bogoliubov–de Gennes equations using Runge-Kutta and split-operator methods to simulate quantum wells and Non-adiabatic transition probabilities are calculated to capture diabatic effects and topological decoherence.

In conclusion, Map the group generators into the Hamiltonian perturbatively or via coupling constants. To get an insight into the stability of Majorana modes and are affected by symmetry-driven dynamics, highlighting the after effects of quantum information and topologically protected quantum states.

Keywords: Majorana fermions, SO(3,2), non-adiabatic transitions, Lie groups, quantum topology

Pranit Terse

IISER Bhopal

TITLE: High-Sensitivity, Real-Time Magnetometry Using NV Centers in Diamond.

Abstract:

Magnetometry plays a critical role in applications ranging from materials characterization and biomedical diagnostics to navigation and geophysics. Nitrogen-vacancy (NV) centers in diamond have emerged as powerful solid-state quantum sensors for magnetic field detection due to their long coherence times and easy spin-manipulation and readout under ambient conditions. In this work, we present an NV-based magnetometry setup enhanced by lock-in detection and PI-feedback control which allows real-time detection of magnetic fields with high sensitivity and a wide dynamic range. By tracking shifts of the two magnetic sublevels simultaneously, we eliminate thermal drifts, improving long-term stability. Additionally, balanced photodetection is used to reject common-mode noise from laser intensity fluctuations, significantly enhancing the signal-to-noise ratio. We also integrate different optical and magnetic enhancements to improve both field concentration near the sensor and the fluorescence collection efficiency over traditional designs. Combining all these optimization techniques, we achieve a high field-detection sensitivity of $87\, pT/\sqrt{Hz}$. Our closed-loop feedback also results in over 110x enhancement in the dynamic range (from $3.5\ \mu T\ to\ 400\ \mu T$) with a fast response time of $\approx 50\mu s$. Our results demonstrate the effectiveness of NV-based sensors for real-time, high-bandwidth precision sensing applications.

Rakiba Rahaman

Aliah University, Kolkata

Surface Plasmon Polariton Mediated Dual Bandpass Filter in an Electromagnetically Induced Transparency Medium

Rakiba Rahaman[1], Jayanta Kumar Saha[2], Md. Mabud Hossain[3]

Department of Physics, Aliah University, IIA/27, New Town, Kolkata 700 160, India

Email:[1]rakibarahaman27@gmail.com, [2]jksaha.phys@aliah.ac.in,[3]mhossain.phys@aliah.ac.in

Surface plasmon polaritons are the surface electromagnetic waves that propagate along the metal-dielectric interface when a TM-polarized light interacts with the freely oscillating charge at the metal surface **[1]**. It is evanescent in nature, decay very fast away from the interface. Due to their highly confined nature, SPPs are widely used in the field of nanophotonics, biosensors, etc **[2]**. In the present work, we consider a three-layer medium with air as the top layer, metal as the second layer and an atomic medium as the bottom layer. Here, the atomic medium provides the necessary conditions to achieve resonance (momentum conservation) under the electromagnetically induced transparency (EIT) protocol **[3,4]**. We have considered a four-level inverted Y-type atom-laser coupled system **[5]**. In order to obtain the optical coherence term related to the susceptibility of the atomic medium, we solve the optical Bloch equations (OBEs) for the four-level system under weak probe approximation, followed by the calculation of the reflection and transmission coefficients for the multilayered medium using Fresnel's equations. Using these equations, we have theoretically investigated the optical response of SPPs under the effect of a pump and a control beam. A high probe transmission peak is observed at particular value of pump Rabi frequency. For a fixed value of high control Rabi frequency, if the value of pump Rabi frequency increases gradually, then a second window appears where we get another transmission peak. With further increment of pump Rabi frequency, the height of the second peak increases continuously and eventually matches the second peak. However, the amplitude of the transmission peak saturates, as the pump Rabi frequency crosses a critical value. At this optimized value of pump and control Rabi frequencies, the system acts like a dual bandpass optical filter. The response of SPPs in presence of magnetic fields shows a shift in the transmission peak at lower value of magnetic field. As the field increases, a third peak also appear near the resonance line (zero probe detuning). Altogether, this model generates a completely new response of the SPP medium which could be beneficial for future technology in optical communication and quantum sensing.

Keywords: Surface plasmon polaritons (SPPs), Electromagnetically induced transparency (EIT), Inverted-Y type system, Bandpass filter.

RR acknowledges MDFC of Govt. of W.B. for providing financial support through the SVMCM fellowship.

References:

1. H. Raether. Surface plasmons on smooth surfaces. Springer Berlin Heidelberg, 1988.
2. I. Abdulhalim, M. Zourob, and A. Lakhtaki, Electromagnetics, **28(3)**, (2008).
3. K. J. Boller, A. Imamoglu, and S. E. Harris, Physical Review Letter **64**, 1107 (1991)
4. C. Du, Q. Jing, Z. Hu, Physical Review A **91**, 013817, (2015).
5. J. Li, R. Yu, L. Si and X. Yang, Journal of Physics B: Atomic Molecular and Optical Physics **43,** 065502**, (**2010).

Rishabh Pal

IIT Tirupati, Andhra Pradesh

Design and modelling of a compact, vibration insensitive and thermally resilient optical cavity for next-generation portable optical atomic clocks

Rishabh Pal[1], Himanshu Miriyala[1], and Arijit Sharma[1,2,*]
[1]Department of Physics, Indian Institute of Technology Tirupati, Yerpedu-517619, A.P., India
[2]Center for Atomic, Molecular, and Optical Sciences and Technologies, Indian Institute of Technology Tirupati, Yerpedu-517619, A. P., India
*Corresponding author: arijit@iittp.ac.in

Transportable all-optical atomic clocks represent the next-generation devices for precision time keeping, ushering a new era in encompassing a wide myriad of PNT (Position Navigation and Timing) applications in the civil and strategic sectors. Their performance relies on ultra-stable, narrow-linewidth lasers, frequency stabilized to a compact portable optical cavity. Among various designs, the cubic spacer based ultra-stable cavity is particularly well suited for transportable applications due to its low sensitivity to vibrations, owing to its symmetric geometry and robust mounting structure [1,2]. While longer cavities offer lower fundamental thermal noise floor, one needs to strike a balance between transportability and size. In this aspect, the 10 cm dual-axis cubic cavity offers a lower fundamental thermal noise floor in comparison to smaller counterparts, while still retaining a reasonable SWaP (Size, Weight and Power) for terrestrial and aerial PNT applications. Its dual-axis design also enables multi-wavelength laser stabilization, making it a promising candidate for future transportable clock applications.

This work presents a detailed study of the 10 cm dual bore cubic cavity using Finite Element Analysis (FEA) to evaluate its mechanical and thermal stability. We analyze the impact of various geometric factors, mounting forces, and machining imperfections, while also modelling thermal effects such as conduction, radiation, and mirror heating within a vacuum chamber and thermally shielded environment. Our findings provide design insights for developing robust dual-axis optical reference cavities, advancing the deployment of portable atomic clocks for next-generation applications in PNT, geodesy, VLBI, and deep space missions.

[1] S. Webster, P. Gill, "Force-insensitive optical cavity", *Opt. Lett.,* vol. 36(18), pp. 3572-4 (2011).
[2] E. Wiens, S. Schiller, "Simulation of force-insensitive optical cavities in cubic spacers", *Appl. Phys. B,* vol. 124, pp. 140 (2018).

Roshin G Vallatt

IISER Bhopal

Investigation of Dynamical Decoupling Sequences in NV Ensembles

Roshin G Vallatt[1], *Phani Kumar Peddibhotla*[1]
[1]*Department of Physics, Indian Institute of Science Education and Research Bhopal, India*
Email: roshinvallatt@iiserb.ac.in

Nitrogen vacancy (NV) centers in diamond are powerful platforms for nanoscale magnetometry, but their sensitivity is often limited by decoherence arising from dipolar interactions with nearby paramagnetic impurities. Dynamical decoupling techniques are therefore essential for preserving quantum coherence and extending spin dephasing times.This study investigates the implementation of WAHUHA and PulsePol sequences in NV ensembles to enhance T_2^* and suppress decoherence. While WAHUHA acts as a dynamical decoupling sequence to mitigate NV–NV dipolar interactions, PulsePol enables polarization transfer from NV centers to surrounding spin baths, which can indirectly improve coherence by reducing bath-induced fluctuations. Initial measurements revealed Rabi decay due to microwave inhomogeneity from the wire-based setup, motivating efforts toward improved antenna design. Integrating a Halbach array into the current experimental setup will generate a stable and homogeneous bias magnetic field, which is essential for uniform spin control across the NV ensemble. Coherence benchmarking will be performed using Ramsey and Hahn echo sequences. Future work will focus on implementing and comparing both WAHUHA and PulsePol protocols, and evaluating their effectiveness in enhancing T_2^* and enabling robust DC magnetometry in NV ensembles.

Samim Akhtar

Aliah University, Kolkata

Optical Manipulation of Atomic Coherent Signal Using Vector Vortex Beam for Quantum Information Science

Samim Akhtar[1,*], Jayanta K. Saha[1], Md Mabud Hossain[1]

[1]Department of Physics, Aliah University, II A/27, New Town, Kolkata-700160, India

E-mail: *samimakhtar1910@gmail.com

Over the past few decades, the observation of laser-induced coherent optical phenomena such as electromagnetically induced transparency (EIT) and absorption (EIA) using traditional Gaussian-shaped laser beams has been gained an increased research interest in the fields of quantum and nonlinear optics [1,2,3]. In recent decade, the optical manipulation of the atomic coherent signals (EIT and EIA) using structured light has played a pivotal role in the fields of quantum information science and technology due to the inherent additional degrees of freedom [4,5]. In this work, we have experimentally investigated the atomic coherent signals in rubidium vapor cell using vector vortex beam (VVB) as a structured light having different orders of orbital angular momentum (OAM). We have performed a pump-probe laser spectroscopy experiment, where the pump beam corresponds to the VVB and the probe beam to a Gaussian or non-vortex beam (NVB). The effect of VVB-assisted spin-orbit coupling (SOC) mode on the atomic coherent signals (both EIT and EIA) in multi-level Λ-type and V-type schemes of ^{85}Rb-D$_2$ hyperfine line is reported. It is found that the subluminal (slow light) and superluminal (fast light) propagation of the probe NVB can be efficiently controlled by adjusting the SOC mode of pump VVB. Furthermore, we have studied how the spatial polarization rotation of VVB-assisted SOC mode influences the EIT signal in a five-level Λ-type scheme of ^{85}Rb-D$_2$ hyperfine line. Interestingly, the sinusoidal modulation of the EIT amplitude *w.r.t.* spatial polarization is noted for each OAM. Following this key observation, we have intuitively proposed a hybrid qubit algorithm. It is also found that a primitive pump-probe experimental setup can be used to demonstrate or design a hybrid quantum logic gate circuit by utilizing the spatial 'polarization' of the probe NVB and 'EIT amplitude' of the pump VVB as the control and target qubits, respectively. In brief, the experimental results concerning the OAM-dependent hybrid quantum circuit may find potential applications in quantum information science and technology.

Keywords: Laser spectroscopy, electromagnetically induced transparency (EIT) and absorption (EIA), vector vortex beam (VVB), orbital angular momentum (OAM), spin-orbit coupling (SOC), hybrid quantum logic gate circuit.

References :

[1] K. J. Boller, A. Imamoglu, and S. E. Harris, *Physical Review Letters*, **66(20)**, 2593 (1991).
[2] A. Lezama, S. Barreiro, and A. M. Akulshin, *Physical Review A*, **59(6)**, 4732 (1999).
[3] M. O. Scully, and M. S. Zubairy. *Quantum optics*. Cambridge University Press (1997).
[4] N. Radwell, T. W. Clark, B. Piccirillo, S. M. Barnett, and S. Franke-Arnold, *Physical Review Letters*, **114(12)**, 123603 (2015).
[5] F. Cardano, E. Karimi, S. Slussarenko, L. Marrucci, C. D. Lisio, and E. Santamato, *Applied Optics*, **51(10)**:C1–C6 (2012).

Samit Kumar Hazra

IIT Guwahati, Assam

Arbitrary vector beam generation in quantum dots via a four-wave mixing process

Samit Kumar Hazra,[1,*] P. K. Pathak,[2] and Tarak Nath Dey[1]

[1] *Department of Physics, Indian Institute of Technology Guwahati, Guwahati 781039, Assam, India*
[2] *Indian Institute of Technology Mandi, Mandi 175005, Himachal Pradesh, India*

[*] *samit176121009@iitg.ac.in*

Abstract: We propose an arbitrary vector beam (VB) generation scheme in a thin disk-shaped quantum dot (QD) medium considering phonon interaction. The QD biexciton system exhibits the interplay between first- and third-order nonlinear susceptibility between two orthogonal circular polarization transitions. Three QD transitions are coupled with one applied weak and two strong control orbital angular momentum (OAM) carrying fields. Therefore, the applied field experiences absorption, and a new field with the desired OAM is generated via four-wave mixing (FWM). These two orthogonal field superpositions produce VB at the QD medium end. We also demonstrate the polarization rotation of a VB by changing only the relative control field phase. Additionally, we analyze the effect of temperature on the VB generation.

References

1. S. K. Hazra, P. K. Pathak, and T. N. Dey, Arbitrary vector beam generation in semiconductor quantum dots, Physical Review. B 111, (2025).

Sankar Davuluri

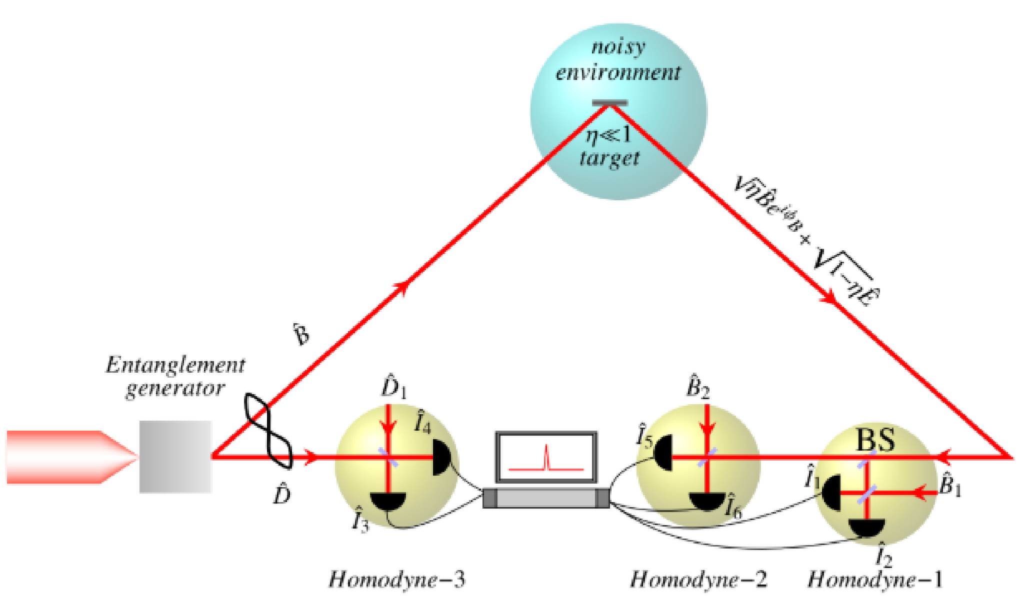
BITS Pilani, Hyderabad

Quantum Lidar

Sankar Davuluri

Birla Institute of Technology and Science, Pilani, Hyderabad Campus, Jawahar Nagar, Kapra Mandal, Medchal District, Telangana 500078, India.
sankar@hyderabad.bits-pilani.ac.in

Quantum illumination (QI) is implemented by a joint measurement between the idler field and the signal field reflected from the low-reflectivity stationary target in a noisy environment. The joint measurement is possible only with prior knowledge of the target's location, which is unknown in many cases. We shall describe a technique to overcomes this limitation by using optical entanglement and quantum cross-correlated homodyne measurement. This technique offers the following additional advantages in comparison with QI implementation through joint measurement: (1) quantum storage and prior knowledge about the stationary target's distance are not required, (2) it adds ranging capability, (3) it adds anti-stealth mechanism to suppress the low-reflectivity of the target. We consider the environment as a stray laser which could be a decoy, jamming field, a probe field from another ranging application, or a field used to mask the actual probe. Thus, the environment considered in this Letter is suitable for ranging applications like lidar.



Quantum lidar schematics. $\hat{B}$ and $\hat{B}$ are the destruction operator of entangled probe and idler fields, respectively. $\hat{E}\hat{D}_i(i = 1,2,3)$ and η are the destruction operator for environment, destruction operator for the reference field, reflectivity. in the homodyne, respectively. Fluctuation in homodye-3 measurement is correlated with the fluctuation in homodyne-2 and homodyne-1

Sankar De

Saha Institute of Nuclear Physics, Kolkata

Correlated vortex generation in coherent medium

Priyabrata Seth*,#,1, Dipankar Bhattacharyya†, Nawaz Sarif Mallick*,#, and Sankar De*,#,2

* Saha Institute of Nuclear Physics, 1/AF, Bidhannagar, Kolkata 700064, India.
# Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai - 400094, India.
† Santipur College, Santipur, Nadia, West Bengal 741404, India.

Optical vortices are optical beams characterized by a helical phase structure around their axis, possessing unique properties associated with orbital angular momentum (OAM) and phase singularities. Their significance is growing in both quantum communication and quantum computation due to their ability to encode and process information in higher-dimensional state spaces, expanding beyond traditional binary qubit systems [1].

We have experimentally observed the correlated vortex generation [2] in the presence of a coherent medium. This new field has been generated from an old field applied to the coherent atoms. The uniqueness of this generation is that the new field replicates the helical phase front, carrying the same amount of OAM.

Coherent atoms are generated with a spatially separated ring-shaped (annular) beam. Then those atoms are again exposed under the influence of another beam with photons carrying $+4\hbar$ of OAM, positioned at the center of the ring. According to our experimental condition, we have separated two interaction regions, leading to a spatial evolution of the coherence. This spatial evolution of coherent atoms is verified through Ramsey interferometry, confirming the phase coherence dynamics in the system. This spatial evolution is highly sensitive to the magnetic field environment, which determines the frequency of the oscillation of this coherence in the dark region (in between the outer ring beam and the central beam).

This coherent generation is a third-order nonlinear process that requires both high optical power and a higher atomic number density. To achieve the necessary conditions, we used a standard vapor cell, which was heated to increase the atomic density and enhance the interaction strength.

We have used the well-known tilted lens detection method [3] to verify the generation and transfer of the OAM of the generated light. Figure 1(a) shows the tilted lens detection image. Four dark lines and right tilt of the image implies that the orbital momentum per photon is $+4\hbar$. Figure 1(b) and (c) shows the generated vortex profile in presence and absence of coherent atoms respectively.

We also did the intensity correlation measurements between the generated beam and the applied beam by means of two identical photo detectors. We have analyzed the sensitivity of the generation against the phase of initial coherence.

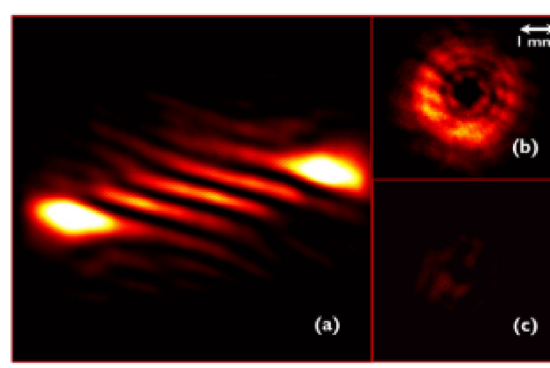


Fig. 1. Detection image obtained using tilted lens configuration. Measured intensity profile of the generated beam in (b) presence and (c) absence of coherent atom.

We thank the Department of Atomic Energy (DAE), Science and Engineering Research Board (SERB) and I-HUB Quantum Technology Foundation for financial support.

References

[1] Y. Shen, X. Wang, Z. Xie, C. Min, X. Fu, Q. Liu, M. Gong & X. Yuan, **Light: Science & Applications 8**, 90 (2019)

[2] P. Seth, D. Bhattacharyya, N. S. Mallick & S. De, Accepted in **Optics Letters**.

[3] P. Vaity, J. Banerji, & R.P. Singh, **Physics Letters A 377**, 1154-1156 (2013)

[1] E-mail: sethpriyabrata@gmail.com
[2] E-mail: sankar.de@saha.ac.in

Sankar De

Saha Institute of Nuclear Physics, Kolkata

Non-adiabatic resonant transient response in electromagnetically induced transparency of hot rubidium atoms with a buffer gas background

Priyabrata Seth[*,#,1], **Dipankar Bhattacharyya**[†], **Nawaz Sarif Mallick**[*,#], **and Sankar De**[*,#2]

[*] Saha Institute of Nuclear Physics, 1/AF, Bidhannagar, Kolkata 700064, India.
[#] Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai - 400094, India.
[†] Santipur College, Santipur, Nadia, West Bengal 741404, India.

The transient absorption of a weak probe beam under electromagnetically induced transparency (EIT) conditions has been extensively studied over the past several decades in both the adiabatic [1] and non-adiabatic regimes [2]. Our focus in this work is on the non-adiabatic regime.

We present the experimental observation [3] of transient dynamics in the weak probe coherence under electromagnetically induced transparency (EIT) in hot Rb atoms with a buffer gas. By rapidly modulating the control beam in a non-adiabatic manner, we investigate the resulting temporal evolution of probe transparency. Following the sudden turn-on of the control beam, the system undergoes multiple dynamical processes before reaching steady-state transparency. Figure 1(a) shows the typical time traces of the probe transmission along with a simulated version in Fig. 1(b). For the simulation, we have numerically solved the time dependent density matrix elements for a Λ system, incorporating the buffer gas effects phenomenologically into these equations. We systematically decode each of these processes across distinct temporal regions, revealing two-photon damped Rabi oscillations, Raman gain, and direct dark state rotation during the evolution.

In region I, the probe beam alone drives the atoms, increasing the probe transparency due to the depopulation of the probe ground state. The accompanying decaying oscillations arise from Larmor precession of the atomic coherence in the absence of the control beam.

Region II shows a sudden overshoot in probe transparency on a few μs timescale, arising from two processes: (A) direct transfer of population to the dark state and (B) Raman gain. The direct transfer was confirmed by a separate experiment where the control beam was switched on earlier, driving population directly to the dark state following probe switching. Raman gain, verified through two-photon Rabi oscillations, involves population transfer from the control ground state to the excited state, creating population inversion between the excited and probe ground states.

To extract these oscillations from the transmission spectrum, we have fitted the rising section (CD) and some portion of the falling section (DE) with asymmetric double-sigmoidal function defined as,

$$f(t) = f_0 + \frac{A}{[1+e^{-(t-t_{mid1})/\tau_1}] \times [1+e^{(t-t_{mid2})/\tau_2}]} \quad (1)$$

[1]E-mail: sethpriyabrata@gmail.com
[2]E-mail: sankar.de@saha.ac.in

Here, τ_1 and τ_2 are the time scales of rising and falling edges respectively.

In region III, probe transparency decreases due to incoherent population transfer to the uncoupled probe ground state, verified by supportive measurements. After reaching a local minimum, the system attains steady-state transparency in region IV, where the atoms are optically pumped into the dark state. This dark state population follows a Lorentzian profile with two-photon detuning, matching the EIT linewidth.

When the control beam is switched off, dark state atoms refill the probe and control ground states, reducing transparency at a rate proportional to probe intensity. Simultaneously, probe-induced optical pumping transfers atoms to the control ground state, counteracting refilling. The interplay of these effects creates a dip in transparency (point B), followed by gradual recovery (region I).

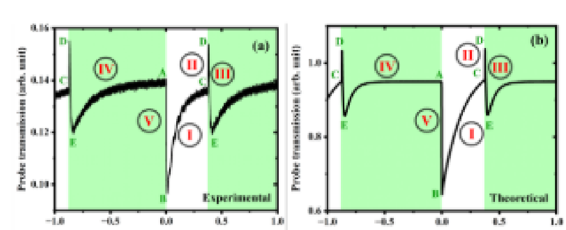


Fig. 1. (a) Experimental and (b) simulated probe transmission spectrum. Control beam on-time has been marked with green region.

We thank the Department of Atomic Energy (DAE), Science and Engineering Research Board (SERB) and I-HUB Quantum Technology Foundation for financial support.

References

[1] S.E. Harris, and Z.-F. Luo, Phys. Rev. A. **52**, R928 (1995).

[2] H.X. Chen, A.V. Durrant, J.P. Marangos, and J.A. Vaccaro, Phys. Rev. A, **58**, 1545 (1998).

[3] P. Seth, N. S. Mallick, S. De and D. Bhattacharyya, **AVS Quantum Sci. 7 (3)**: 033201 (2025).

Shashank Kumar

Bhupendra Narayan Mandal University, Bihar

Gate-Based Quantum Computing for Event Classification in Collider Data

Shashank Kumar*

*Bhupendra Narayan Mandal University, Madhepura,India

Abstract

Quantum computing could open up new ways to analyze data in high-energy physics. In this work, we explore how quantum algorithms can be used to tell apart signal events from background events in collider experiments. We start by reviewing common classical methods such as boosted decision trees, deep neural networks, and graph neural networks. Then, we describe a general quantum approach where event features are turned into quantum states and processed by special quantum circuits. These circuits are trained using a mix of quantum and classical computing. We explain how this method could offer advantages by using the larger space of quantum states and by speeding up certain calculations. We also estimate the number of qubits and gate operations needed for realistic tasks, and discuss challenges such as preparing the quantum states, training difficulties, and noise. Finally, we compare the possible performance of quantum and classical methods, and share our outlook on the future of quantum-enhanced event classification in particle physics.

Sonali Gupta

TIFR, Mumbai

Nitrogen-Vacancy Centers in Diamond

Sonali Gupta*[1], Sanjeev Kumar Maurya[2], Lokesh C Tribedi[2], Sushil Mujumdar[1]

[1]*Nano-optics and Mesoscopic Optics Laboratory, Tata Institute of Fundamental Research, Mumbai, 400005, India*

[2]*Accelerator Based Atomic Physics Laboratory, Tata Institute of Fundamental Research, Mumbai, 400005, India*

*sonali.gupta@tifr.res.in

Single-photon sources are essential for emerging quantum technologies in communication, sensing, and computing. Among various platforms, nitrogen-vacancy (NV) centers in diamond are highly promising due to their photostability, operation at room temperature, and long spin coherence times. In our work, NV centers were created in artificially grown diamond using ion implantation of N^{2+} ions ions at a dose of 10^{12} ions/cm^2, followed by annealing at 1200 K. These centers were characterized using a home-built confocal microscopy setup. Photoluminescence measurements confirmed the presence of the NV^- zero-phonon line at 637 nm and a broadband phonon sideband extending up to 800 nm. Time-resolved fluorescence studies showed a typical lifetime of ~12 ns for both bulk and nanodiamond samples. To verify single-photon emission, we performed second-order correlation $\boldsymbol{g^2}(\boldsymbol{\tau})$ measurements using a portable setup assembled in our lab. After scanning multiple regions of the sample with the confocal microscope, we successfully identified emission sites with $\boldsymbol{g^2}(0)$ value below 0.5, confirming true single-photon behaviour. We also conducted Optically Detected Magnetic Resonance (ODMR) measurements to probe the NV center's spin structure. The NV center has a triplet ground state $|g\rangle$, triplet excited state $|e\rangle$, and a metastable singlet state $|s\rangle$. Zero-field splitting divides the triplet levels into $m_S = \pm1$ and $m_S = 0$, with a 2.87 GHz separation in the ground state. Optical transitions between $|g\rangle$ and $|e\rangle$ preserve spin, but spin-orbit coupling allows non-radiative decay from $|e,m_S=\pm1\rangle$ to $|g,m_S=0\rangle$ via $|s\rangle$. This leads to reduced fluorescence when the system is in $m_S=\pm1$. Upon microwave excitation at 2.87 GHz, we observed a fluorescence dip, confirming spin-state mixing.

Our results establish a robust NV center platform with verified single-photon emission and spin control, paving the way for integrated diamond-based quantum devices.

Sourav Banerjee

CARE, IIT Delhi

Rydberg Atomic Radio Frequency Sensor-based Quantum Radar

Sourav Banerjee, Neel Kanth Kundu
Centre for Applied Research in Electronics (CARE), IIT Delhi
crz248112@care.iitd.ac.in, neelkanth@iitd.ac.in

Abstract

Rydberg atom-based radio frequency (RF) sensors have emerged as a promising solution for electric field sensing, offering advantages such as ultra-high sensitivity, weak field detection, compact form factor, and wideband operation. These sensors leverage the quantum properties of highly excited Rydberg states to enable optical readout of RF signals via electromagnetically induced transparency (EIT).

In this work, we present a quantum radar system model that employs a Rydberg atomic RF sensor as the receiver. Unlike conventional radar systems that rely on dipole antennas and electronic detection, the proposed radar uses laser-based optical readout for echo signal detection. This configuration corresponds to a Type-2 quantum radar, where the transmitter is classical, and the receiver utilizes quantum sensing.

We derive the signal-to-noise ratio (SNR) for the Rydberg quantum radar and compare it with that of a classical radar system. Simulation results demonstrate that the Rydberg-based radar achieves a significantly higher SNR and lower root mean square error (RMSE) in target velocity estimation. These results highlight the potential of Rydberg atom-based receivers in enhancing radar performance and advancing quantum-enhanced sensing technologies.

Sumit Kumar

Royal Holloway University of London, UK

Superfluid Helium in Cavity Optomechanics: From Phononic Crystals to Analogue Gravity and Gravitational Sensing

Sumit Kumar[a,b], Sean Hibbitt[a], Matthew Kenworthy[a], Thomas Speake[a], Carla Martinez Izquierdo[a], Xavier Rojas[a]

a) *Department of Physics, Royal Holloway University of London, Egham, Surrey, TW20 0EX, U.K.*
b) *Department of Physics, IIT (ISM) Dhanbad, Jharkhand, India*

Cavity optomechanics [1] explores the interaction between light and mechanical motion at the quantum level, enabling precision sensing, control of quantum states, and novel tests of fundamental physics. A unique class of mechanical resonators emerges when sound waves propagate in quantum fluids such as superfluid helium, where the absence of viscosity and extremely low dissipation offer a pristine platform for quantum experiments. In this context, we investigate superfluid helium as a versatile medium for optomechanics and fundamental physics. First, we developed a **sonic crystal composed of superfluid helium** [2], where periodic structuring leads to bandgaps for first sound modes. This structure allows tailoring the phononic density of states and opens pathways for engineered dissipation and topological phononic transport. Second, we utilized **superfluid helium as a platform for analogue cosmology** [3], where the collective hydrodynamic excitations mimic aspects of quantum field theory in curved spacetime. By engineering spatial inhomogeneities and dynamical backgrounds, we can emulate cosmological phenomena such as particle creation, horizon analogues, and metric expansion, offering insights into early-universe physics. Finally, we proposed and developed a proof-of-concept experiment for **gravitational wave detection using superfluid helium** [4], leveraging the extreme sensitivity of its acoustic modes to spacetime strain. With high-Q third sound resonances and coupling to superconducting microwave cavities, such a platform presents a promising candidate for compact, cryogenic, and quantum-enhanced gravitational sensors. Together, these projects highlight the versatility of superfluid helium in optomechanics—not only as a mechanical resonator with exceptional coherence but also as a medium for probing analogues of fundamental phenomena in gravity and cosmology.

[1] Aspelmeyer, Markus, Tobias J. Kippenberg, and Florian Marquardt. "Cavity optomechanics." *Reviews of Modern Physics* 86.4 (2014): 1391-1452.

[2] Spence, S., et al. "Superfluid optomechanics with phononic nanostructures." *Physical Review Applied* 15.3 (2021): 034090.

[3] Jacquet, Maxime J., Silke Weinfurtner, and Friedrich König. "The next generation of analogue gravity experiments." *Philosophical Transactions of the Royal Society A* 378.2177 (2020): 20190239.

[4] Singh, S., et al. "Detecting continuous gravitational waves with superfluid 4He." *New Journal of Physics* 19.7 (2017): 073023.

Taj Kumar

Banaras Hindu University, Varanasi

Enhanced phase sensitivity in DSU(1,1) interferometer via photon recycling

Taj Kumar, Aviral Kumar Pandey, Anand Kumar, Devendra Kumar Mishra*
Department of Physics,
Institute of Science, Banaras Hindu University,
Varanasi 221005, India
**kndmishra@gmail.com*

ABSTRACT

In the SU(1,1) interferometer, proposed by Yurke [1], beam splitters are replaced by nonlinear elements like optical parametric amplifiers (OPA) to achieve the sensitivity up to the Heisenberg limit [2]. Non-Gaussian operations, like photon addition or subtraction, can further improve its phase sensitivity and robustness against photon loss but at a high implementation cost. To address this issue, Wei Ye *et. al* [3] introduced the displacement-assisted SU(1,1) (DSU(1,1)) interferometer, using a displacement operator with displacement strength $|\gamma|$.

In this work, we propose a novel approach to enhance the phase sensitivity of the DSU(1,1) interferometer through photon recycling [4]. We begin with a DSU(1,1) interferometer having a vacuum state at port "a" and a squeezed vacuum state (with squeezing parameter r) at port "b". We consider a phase shift Φ, experienced in the arm "b". This setup is modified by re-injecting the output mode "a" into the input mode after a phase shift θ, and photon loss is characterized by $\sqrt{1-T}$, where T is the transmission coefficient of a fictitious beam splitter.

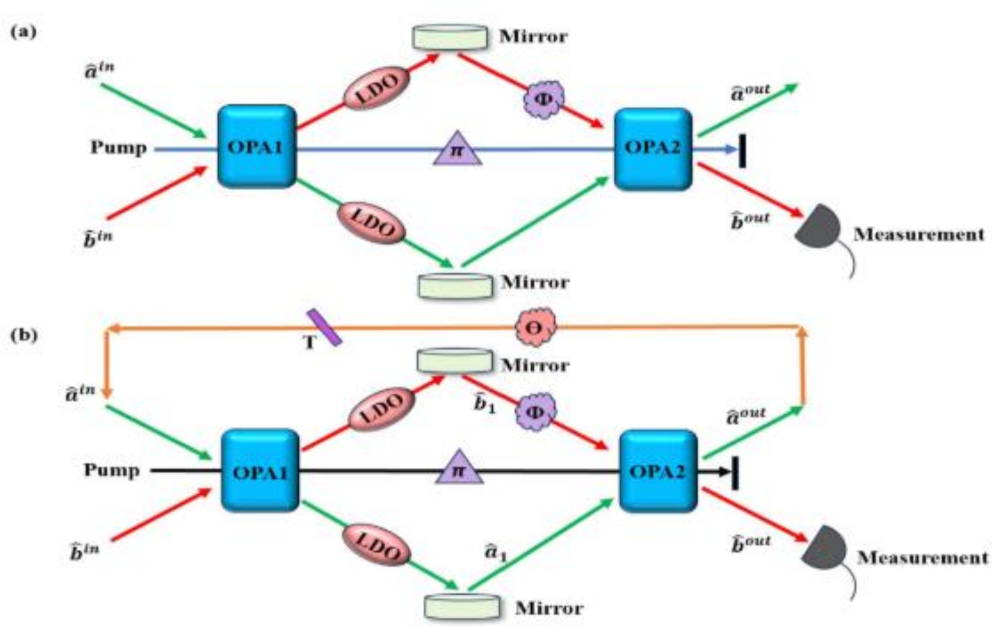


Fig.1. Scheme for phase estimation with photon recycling technique: (a) Schematic diagram of a DSU(1,1) interferometer with the output beam "a" disregarded. (b) The modified scheme with the output mode "a", re-injected into the input mode "a" (PR-DSU(1,1) interferometer).

We examined the phase sensitivity of the PR-DSU(1,1) interferometer $\Delta\phi^{\mathrm{PR}}$ under both single-intensity detection (SID) and homodyne detection (HD) schemes. To provide the ultimate theoretical limit, we calculated the quantum Cramér-Rao bound (QCRB), denoted as $\Delta\phi^{\mathrm{PR}}_{QCRB}$. In order to analyze the improvement in performance induced by photon recycling, we have compared the performance of the PR-DSU(1,1) interferometer with the conventional DSU(1,1) interferometer by introducing two enhancement factors, Σ and Ξ, where $\Sigma = \Delta\phi^{\mathrm{Conv.}}/\Delta\phi^{\mathrm{PR.}}$ and $\Xi = \Delta\phi^{\mathrm{Conv.}}_{QCRB}/\Delta\phi^{\mathrm{PR.}}_{QCRB}$ represent the enhancement factors for phase sensitivity and QCRB of PR-DSU(1,1) interferometer relative to

DSU(1,1) interferometer, respectively. In addition, for each detection scheme, we calculated the enhancement factor for phase sensitivity of the PR-DSU(1,1) interferometer relative to SNL, defined as $\Gamma = \Delta\phi_{\mathrm{SNL}} / \Delta\phi^{\mathrm{PR}}$ and compared the results. Similarly, we calculated the enhancement factor for QCRB of the PR-DSU(1,1) interferometer relative to SNL, defined as $\Lambda = \Delta\phi_{\mathrm{SNL}} / \Delta\phi_{QCRB}^{\mathrm{PR}}$.

Our findings show that we can attain the values of Σ and Ξ, greater than unity, which clearly indicates that the PR-DSU(1,1) interferometer can possess phase sensitivity and QCRB beyond those in the case of the conventional DSU(1,1) interferometer. This highlights the significance of photon recycling in enhancing the sensitivity of the interferometer. Next, we plotted Γ as a function of phases ϕ and θ for different values of T, g, $|\gamma|$, and r (under both detection schemes). The values of these enhancement factor exceeding unity indicate that our scheme can achieve phase sensitivity beyond the SNL. Moreover, it increases with an increase in T, g, $|\gamma|$, and r. Comparing the phase sensitivity of the PR-DSU(1,1) interferometer under both SID and HD schemes, we observe that the HD scheme outperforms the SID scheme. The HD scheme also exhibits a broader region of θ and ϕ for enhanced phase sensitivity beyond SNL, further demonstrates its superiority over the SID scheme. Similarly, we have plotted Λ as a function of r for varying values of g and observed that the value of Λ exceeds unity and increases monotonically with increasing g and r. By plotting Λ as a function of T for varying values of $|\gamma|$, we observed a significant improvement due to recycled photons when accompanied by LDO, depending upon the proper choice of g, r, and the amount of photon loss in the feedback arm.

Therefore, our findings show that this modified scheme has phase sensitivity and QCRB beyond the SNL as well as beyond those in the case of a conventional DSU(1,1) interferometer, offering a novel approach to increase phase sensitivity via photon recycling. This work is based on our recent publication [5].

References

[1] Yurke, B., McCall, S. L., \& Klauder, J. R. (1986). SU (2) and SU (1, 1) interferometers. Physical Review A, 33(6), 4033.
[2] Ou, Z. Y., and Xiaoying Li. "Quantum SU (1, 1) interferometers: Basic principles and applications." APL Photonics 5.8 (2020).
[3] Ye, Wei, et al. "Quantum-improved phase estimation with a displacement-assisted SU (1, 1) interferometer." Optics Express 31.25 (2023): 41850-41863.
[4] Li, Dong, et al. "Enhanced phase sensitivity in a Mach-Zehnder interferometer via photon recycling." Optics Express 31.4 (2023): 6499-6513.
[5] Kumar, Taj, et al. "Enhancement in phase sensitivity in displacement-assisted SU (1, 1) interferometer via photon recycling." *APL Quantum* 2.1 (2025).

In Association with

अनुसंधान नेशनल रिसर्च फाउंडेशन
Anusandhan National Research Foundation

इसरो isro

Title Sponsor

DSS
INSPIRED BY TECHNOLOGY

Silver Sponsor

SIMCO GLOBAL | TOPTICA

LABINDIA® INSTRUMENTS AIMING FOR THE BEST

QUANTUM AI GLOBAL

Bronze Sponsor

HORIBA

Tarsons TRUST DELIVERED

YOKOGAWA

New Age Instruments & Materials Pvt. Ltd.

Special Thanks To

METROLOGY SOCIETY OF INDIA MSI

InRaSS

VVDN® TECHNOLOGIES

SENSORS RESEARCH SOCIETY

Organized By

QuERE Centre for Quantum Engineering Research and Education

tcg crest
Inventing Harmonious Future