QFF 2020

Abstract Booklet

13th January - 18th January, 2020

From Bell tests to quantum network links

Harald WEINFURTER
13.01.2020
11:00 am
LMU University of Munich

W. Rosenfeld, D. Burchardt, R. Garthoff, N. Ortegel, M. Rau, K. Redeker, T. van Leent, W. Zhang, C. Becher, M. Bock

An experimental test of Bell's inequality allows ruling out any local-realistic description of nature by measuring correlations between distant systems. While such tests are conceptually simple, there are strict requirements concerning the detection efficiency of the involved measurements, as well as the enforcement of spacelike separation between the measurement events. With the essential requirement of distributing entanglement to distant locations, such experiments also form the basis for future quantum repeaters which will allow scalable quantum networks for large scale quantum communication and distributed quantum computing. Yet, still missing on the road towards a quantum repeater, is to achieve entanglement between quantum memories over long distances.

Here we present a statistically significant, event-ready Bell test based on combining heralded entanglement of atoms separated by 398m with fast and efficient measurements of the atomic spin states closing essential loopholes. We obtain a violation with $S = 2.221 \pm 0.033$ (compared to the maximal value of 2 achievable with models based on local hidden variables) which allows us to refute the hypothesis of local-realism with a significance level of $P < 2.57 \times 10^{-9}$. To overcome significantly longer distances conversion of the strongly absorbed emission wavelength of 780 nm of the Rubidium atoms is necessary. In a second part we present first results on observing atom-photon entanglement between a Rubidium-87 atom and a telecom photon after transmission ofup to 20 km optical fiber (on acoil) with a fidelity of 78%. Installing frequency conversion for the second atom, in the future, will allow to generate atom-atom entanglement on a suburban scale.

Semi-device-independent self-testing

Archan S MAJUMDAR
13.01.20
11:30 am
S N Bose National Centre for Basic Sciences

Nonclassical temporal correlations in systems with finite memory

Costantino BUDRONI
13.01.2020
12:00 pm
University of Vienna and IQOQI Vienna

In quantum mechanics, spatial correlations arising from measurements at separated particles are well studied. This is not the case, however, for the temporal correlations arising from a single quantum system subjected to a sequence of generalized measurements.

If no further constraints are imposed on the system and the measurements, all correlations compatible with the time-ordering constraint (i.e., a nonsignaling condition from the future to the past) are achievable in a classical theory. It is enough that a system has a "memory" of all the inputs and outputs of previous measurements to obtain all such correlations. It is, thus, natural to consider system with finite memory when discussing temporal correlations. In this framework, we derive temporal inequalities able to distinguish classical and quantum systems with the same memory capacity, or to distinguish systems of the same type (classical or quantum) with different memory. This approach is also extended to generalized probability theories beyond quantum mechanics. Finally, we comment on the relation between the violation of temporal inequalities and the accuracy of classical and quantum clocks.

Sharing non-trivial preparation contextuality by arbitrary number of sequential observers

Alok Kumar PAN
13.01.2020
12:30 pm
National Institute of Technology Patna, Ashok Rajpath, Patna, India

Asmita Kumari

In [Phys. Rev. Lett. 114, 250401 (2015)] the sharing of non-locality by multiple observers was demonstrated through the quantum violation of Clauser-Horne-Shimony-Halt inequality. In this

paper [1] we provide a scheme for sharing of non-locality and non-trivial preparation contextuality sequentially through the quantum violation of a family of Bell's inequalities where Alice and Bob perform 2^{n-1} and n numbers of measurements of dichotomic observables respectively. For this, we consider that Alice always performs projective measurement and multiple Bobs sequentially perform unsharp measurement. We show that when Bob's choices of measurement settings are unbiased, maximum two Bobs can sequentially share the non-locality through the violation of our inequalities. Further, we show that the local bound of the aforementioned family of inequalities gets reduced if non-trivial preparation non-contextuality assumptions are further imposed. Then there is a chance to share the non-trivial preparation contextuality for more number of Bobs than that of non-locality. We demonstrate that the non-trivial preparation contextuality can be sequentially shared by arbitrary numbers of Bob for unbiased choices of his measurement settings.

References

[1] Asmita Kumari and A. K. Pan. *Phys. Rev. A* (In press).

Multi-Path and Multi-Particle Interference

Gregor WEIHS
13.01.2020
2:30 pm
Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria

Andreas Buchleitner, Christoph Dittel, Gabriel Dufour, Sebastian Gstir, Robert Keil, Mattia Walschers

Fundamental questions about quantum physics continue to fascinate us and drive us to pursue ever more and deeper theoretical studies and experimental tests. In our work on the complex interference phenomena that occur when many particle and/or many paths are involved we have been focusing on three areas: suppression laws, multi-particle duality, and higher-order interferences. Suppression laws are tools to identify zeroes in multi-particle interference scenarios, i.e. output states that occur with vanishing probability. Through symmetry considerations we were able to find a general law that applies to any number of bosons and fermions and identifies all possible unitaries and all their suppressed output states [1]. These laws can be turned into tools for verifying unitary networks, which are used in Boson sampling. Complementarity and duality on the other hand are fundamental statements about the relation between particle and wave character of a quantum system. While the single-particle case has been solved a long time ago, not much was known about the scenario of multiple interfering particles. In our work [2] we were able to identify duality relations that apply to very general settings and may be helpful in assessing the performance of multi-particle interferometers. Finally, we have made considerable progress in putting bound on the possibility of hypothetical higher-order interference, which is often linked to a violation of Born's rule. In precision multi-path interferometers based on photonic integrated circuits we were able to exclude any deviation by much tighter bounds [3] and are now applying similar techniques to the exclusion of hypercomplex representations of quantum mechanics.

References

[1] C. Dittel, G. Dufour, M. Walschaers, G. Weihs, A. Buchleitner, and R. Keil. Totally Destructive Many-Particle Interference. *Phys. Rev. Lett*,**120**, 240404 (2018) https://doi.org/10.1103/PhysRevLett.120.240404

[2] C. Dittel, G. Dufour, G. Weihs, A. Buchleitner, Wave-particle duality of many-body quantum states, https://arxiv.org/abs/1901.02810

[3] T. Kauten, R. Keil, T. Kaufmann, B. Pressl, Č. Brukner, and G. Weihs Obtaining tight bounds on higher-order interferences with a 5-path interferometer. *New J. Phys.*,**19**, 033017 (2017) https://doi.org/10.1088/1367-2630/aa5d98

Quantum phase synchronization in spin 1 atoms

Saikat GHOSH
13.01.2020
3:00 pm
IIT Kanpur

Near-100% two-photon-like coincidence-visibility dip with classical light and the role of complementarity

Simanraj SADANA
13.01.2020
3:30 pm
Light and Matter Physics Group, Raman Research Institute, Bangalore 560080, India

Debadrita Ghosh, Kaushik Joarder, Anippedi Naga Lakshmi, Barry Sanders and Urbasi Sinha

The Hong-Ou-Mandel effect, where two-photon coincidence visibility dip (TPCVD) can reach upto 100%, is considered as the signature of the quantumness of light. The upper bound of TPCVD for semi-classical theory is 50%. We have shown, both theoretically and experimentally, that, with proper phase control of the signals, classical pulses can mimic a Hong-Ou-Mandel-like dip. We demonstrate a dip of (99.635 ± 0.002)% with classical microwave fields. Quantumness manifests in wave-particle complementarity of the two-photon state. We construct quantum and classical interferometers for the complementarity test and show that while the two-photon state shows complementarity, the classical pulses do not.

Unscrambling Entanglement through a Complex Medium

Suraj GOEL
13.01.2020
3:45 pm
Indian Institute of Technology Delhi, New Delhi, India

Natalia Herrera Valencia, Will McCutcheon, Hugo Defienne and Mehul Malik

We propose a new method of measuring the transmission matrix of a complex medium by exploiting entanglement. Our technique consists of mapping the complex transmission matrix onto a single, maximally entangled state. Using this method, we are able to recover 6-dimensional entanglement after propagation through a 2 meter multi-mode fibre. Interestingly, we recover the entanglement by only performing operations on the photon that did not go through the fibre.

Srtong quantum nonlocality without entanglement

Somshubhro BANDYOPADHYAY
13.01.2020
4:30pm
Bose Institute

Saronath Halder, Manik Banik, Sristy Agrawal

Coherence as witness for quantumness of gravity

Ahana GHOSHAL
13.01.2020
5:00 pm
Harish-Chandra Research Institute

Arun Kumar Pati and Ujjwal Sen

We propose an interferometric set-up that utilizes the concept of quantum coherence to provide quantum signatures of gravity. The gravitational force comes into nontrivial play due to the existence of an extra mass in the set-up that transforms an incoherent state to a coherent state. The implication uses the fact that quantum coherence at a certain site cannot be altered by local actions at a separate site. The ability to transform an incoherent state to a coherent one in the presence of gravitational field provides a signature of quantumness of gravity.

Resource-efficient topological fault-tolerant quantum computation with hybrid entanglement of light

Omkar **SRIKRISHNA**
13.01.2020
5:15 pm
Department of Physics and Astronomy, Seoul National University, 08826 Seoul, Republic of Korea

Yongsiah Teo and Hyunseok Jeong

We propose an all-linear-optical scheme to ballistically generate a cluster state for measurement-based topological fault-tolerant quantum-computation using hybrid-photonic qubits entangled in a continuous-discrete domain. Availability of near-deterministic Bell-state measurements on hybrid qubits is exploited for this. In the presence of photon losses, we show that our scheme leads to a significant enhancement in both tolerable photon-loss rate and resource overheads. We report a photon-loss threshold of $\sim 3.3\times10^{-3}$, which is higher than known schemes. Furthermore, resource overheads to achieve logical error rate of $10^{-6}(10^{-15})$ is estimated to be $\sim 6.8\times10^{5}(1.4\times10^{7})$ which is less by multiple orders of magnitude than reported values.

Optimal Random Access Code and resource for quantum advantage

Som **KANJILAL**
13.01.2020
5:30 pm
Center for Astroparticle Physics and Space Science (CAPSS), Bose Institute, Kolkata-700 091, India

Jebaratnam Chellasamy, Tomasz Patarek and Dipankar Home

Optimum values of the worst case success probability for the 2 ->1 and 3->1 versions of the bipartite qubit state assisted Random Access Code (RAC) protocol have been derived corresponding to a fixed set of decoding operations. Furthermore, towards identifying the resource for quantum advantage, a condition on the shared bipartite Bell diagonal state has been found such that the relevant versions of the RAC protocol can outperform the corresponding classical analogues for all local decoding strategies.

Generation of Sub-MHz Bandwidth Biphotons by Controlled Quantum Interference

Ravikumar **CHINNARASU**
13.01.2020
5:45 pm
Department of Physics, National Tsing Hua University, Hsinchu 30013, Taiwan

Chi-Yang Liu, Yi-Feng Ding, Ite A Yu and Chih-Sung Chuu

Biphotons of narrow bandwidth and long temporal length have potential applications in realizing efficient light-matter interface and quantum communication. However, generation of these photons usually requires atomic ensembles with high optical depth or spontaneous parametric down-conversion with delicate optical cavities. We propose and demonstrate narrowband biphotons with sub-MHz bandwidth using detuned four-wave mixing in low-optical-depth atomic ensemble. The bandwidth of the biphotons is only limited by the ground-state decoherence rate. We also demonstrate the potential of shaping these photons.

Quantum Information Processing by NMR: Interesting results from our Laboratory

Anil **KUMAR**
14.01.20
9:30 am
Department of Physics and NMR Research Centre, Indian Institute of Science, Bangalore-560012

After a brief introduction to Quantum Information Processing by NMR, I will present some of our interesting experimental results. These include (i) Non-destructive discrimination of Bell States (ii) Experimental test of Quantum No-Hiding Theorem, (iii) Multi-Partite Quantum Correlations Revel Frustration in a Quantum Ising Spin System (iv) Use of Genetic Algorithm in NMR QC (v) Quantum simulation of 3-spin Heisenberg XY Hamiltonian in presence of DM interaction: Entanglement preservation using initialization operator (v) An NMR simulation of Mirror inversion propagator of an XY spin Chain. Finally, if time permits, I will describe simulation of some of the above results by using the IBM's quantum Computer (Quantum Experience) in the cloud.

Investigating Quantum Correlations through Nuclear Magnetic Resonance

T S **MAHESH**
14.01.2020
10:00 am
IISER Pune

S-money: virtual tokens for a relativistic economy

Adrian **KENT**
14.01.2020
11:00 am
DAMTP, University of Cambridge

Damian Pitalua-Garcia, David Lowndes, John Rarity

I describe the theory of "S-money" - virtual tokens designed for high value fast transactions on networks with relativistic or other trusted signalling constraints, defined by inputs that in general are made at many network points, some or all of which may be space-like separated. I show that S-money is more flexible than standard quantum or classical money in the sense that it can solve deterministic summoning tasks that they cannot. S-money requires the issuer and user to have networks of agents with classical data storage and communication, but no long term quantum state storage, and is feasible with current technology. I describe recent experimental work towards a proof of concept implementation.

Table-top Testing of the Non-Classicality of Gravity: Assumptions, Implications and Practicalities of a Proposal

Sougato **BOSE**
14.01.2020
11:30 am
Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT.

A lack of empirical evidence has lead to a debate on whether gravity is a quantum entity. Motivated by this, I will present a feasible idea for such a test based on the principle that two objects cannot be entangled without a quantum mediator. I will show that despite the weakness of gravity, the phase evolution induced by the gravitational interaction of two micron size test masses in adjacent matter-wave interferometers can detectably entangle them even when they are placed far apart enough to keep Casimir-Polder forces at bay. A prescription for witnessing this entanglement, which certifies gravity as a quantum coherent mediator, is also provided and can be measured through simple spin correlations. Further, I clarify the assumptions underpinning the above proposal such as our reasonable definition of "classicality", as well as the crucial aspect of the locality of physical interactions. The role of off-shell processes is also highlighted to clarify what the mediators actually are according to the standard theory of quantum gravity. How the experiment sits within relativistic quantum field theory is clarified. Lastly, the practical challenges are noted.

Photons for micro and macro applications

Piotr **KOLENDERSKI**
14.01.2020
12:00 pm
Nicolaus Copernicus University

One-out-of-m spacetime-constrained oblivious transfer

Damián **PITALÚA-GARCÍA**
14.01.2020
12:30 pm
Centre for Quantum Information and Foundations, DAMTP, Centre for Mathematical Sciences, University of Cambridge

In one-out-of-m spacetime-constrained oblivious transfer (SCOT), Alice and Bob agree on m pairwise spacelike separated output spacetime regions $R_0, R_1, \ldots, R_{m-1}$ in close to Minkowski spacetime; Alice inputs a message x_i in the causal past of a spacetime point Q_i of R_i, for $i \in \{0,1,\ldots,m-1\}$; Bob inputs $b \in \{0,1,\ldots,m-1\}$ in the intersection of the causal pasts of $Q_0, Q_1, \ldots, Q_{m-1}$ and outputs x_b in R_b; Alice remains oblivious to b anywhere in spacetime; and Bob is unable to obtain $x_i inR_i and x_j inR_j$ for any pair of different numbers $i, j \in \{0,1,\ldots,m-1\}$. We introduce unconditionally secure one-out-of-m SCOT protocols extending previous one-out-of-two SCOT protocols, for arbitrary $m \geq 2$.

Experimental Studies of Measurement Uncertainty Relations in Neutron Optics

Stephan **SPONAR**
14.01.2020
12:45 pm
Atominstitut, TU Wien, Stadionallee 2, 1020 Vienna, Austria

Yuji Hasegawa

The uncertainty principle is an important tenet and active field of research in quantum physics. Information-theoretic uncertainty relations, formulated using entropies, provide one approach to quantifying the extent to which two non-commuting observables can be jointly measured. Recent theo- retical analysis predicts that general quantum measurements (i.e. positive-operator valued measures) are necessary to saturate certain uncertainty relations and thereby overcome certain limitations of projec- tive measurements. Here, we experimentally test a tight information-theoretic measurement uncertainty relation with neutron spin-1/2 qubits.

Weak value, Modular Value and Potent Value

Arun K. **PATI**
14.01.2020
2:30 pm
Harish-Chandra Research Institute

Magnetometry with color defects in diamond

Kasturi **SAHA**
14.01.2020
3:00 pm
IIT Bombay

Is There a Momentum Transfer in Which-Way Measurement?

Tabish **QURESHI**
14.01.2020
3:30 pm
Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi, India.

The two-slit which-way experiment has divided the scientific community on the question whether the particle receives a momentum kick. We show here that the same experiment can be viewed in two different ways. In one view, the loss of interference arises due to the entanglement of the two paths of the particle with two orthogonal states of the which-way detector. In another view, the loss of interference can be interpreted as arising from random momentum kicks of magnitude $h/2d$ received by the particle, d being the slit separation. There is no momentum transfer between the which-way detector and the particle.

Entanglement and squeezing properties of tripartite continuous variable systems

S. Lakshmi **BALA**
14.01.2020
3:45 pm
Department of Physics, IIT Madras

The extent of entanglement and squeezing properties displayed by subsystems of model tripartite quantum systems comprising atoms interacting with radiation fields are examined. Interesting nonclassical effects are displayed as the systems considered evolve unitarily under nonlinear Hamiltonians. In particular, in both an optomechanical model of a radiation field interacting with a mechanical oscillator and a two-level atom, and in a system comprising a Λ atom interacting with two radiation fields, collapse of entanglement to a non-zero value over a substantial time interval is shown to occur for specific forms of intensity-dependent couplings.

Preparations and weak-field phase control can witness initial correlations

Sai **VINJANAMPATHY**
14.01.2020
4:30 pm
Department of Physics, Indian Institute of Technology Bombay, Powai, Mumbai

Shlok Nahar

The dynamics of a system that is correlated with an environment is almost always non-Markovian. Hence, it is important to characterize such correlations experimentally and witness them in physically realistic settings. One such setting is weak-field phase control where control is sought by the shaping of the phase of weak laser pulses. In this talk, I will discuss how weak-field phase controllability can be combined with quantum preparations to witness initial correlations between the system and the environment. I will also comment on applying this formalism to the quantum regression formula.

Convex combination of quantum channels

Srikanth **RADHAKRISHNA**
14.01.2020
3:45 pm
Poornaprajna Institute of Scientific Research

Quantum Synchronization in Nano-scale Heat Engines

Noufal **JASEEM P**
14.01.2020
5:30 pm
IITB

Michal Hajdusek, Vlatko Vedral, Rosario Fazio, Leong-Chuan Kwek and Sai Vinjanampathy

Owing to the ubiquity of synchronization in the classical world, it is interesting to study its behavior in quantum systems. Though quantum synchronization has been investigated in many systems, a clear connection to quantum technology applications is lacking. We bridge this gap and show that nanoscale heat engines are a natural platform to study quantum synchronization. We demonstrate an intimate relationship between the power of a heat engine and its phase-locking properties, and link the physical phenomenon of synchronization with the emerging field of quantum thermodynamics by establishing quantum synchronization as a mechanism of stable phase coherence.

Anharmonicity can enhance the performance of quantum refrigerators

Shounak **DUTTA**
14.01.2020
5:45 pm
S. N. Bose National Centre for Basic Sciences, Block JD, Sector III, Salt Lake, Kolkata 700 106, India

Sourav Karar, Sibasish Ghosh and Archan S. Majumdar

We explore a thermodynamical effect of anharmonicity present in quantum mechanical oscillators. We show in the context of an analytically solvable model that quartic perturbations to the quantum harmonic oscillator potential lead to the enhancement of performance of quantum refrigerators. A similar nonlinearity driven enhancement of performance is also observed for an analogous spin-qubit model. Our results are illustrated for both the Otto and Stirling quantum refrigeration cycles. Finally, we investigate the energy cost for creating anharmonicity. The robustness of improvement of the coefficient of performance versus the energy cost can be demonstrated for the experimentally realizable Otto refrigerator.

Using symmetries to understand and work with quantum correlations

A. Ravi P. **RAU**
15.01.2020
9:30 am
Louisiana State Univ, Baton Rouge

The use of symmetries has a long and important role throughout physics, but has not been exploited much in quantum information. I will discuss the group SU(4) for two qubits, corresponding algebra of its generators, and the use of its sub-groups for handling states and their correlations such as entanglement and quantum discord, along with similar extensions to the higher SU group symmetries of multiple qubits and of higher-dimensional spins/qudits.

Quantum Random Numbers in Quantum Computer

Yutaka **SHIKANO**
15.01.2020
10:00 am
Quantum Computing Center, Keio University, Japan

Kentaro Tamura

True random number generation cannot be achieved on current computing devices. Since quantum mechanics is expected to have essentially a probabilistic structure, true random number generation schemes are based on quantum mechanics [1]. A cloud quantum computer, which is runs based on quantum mechanics, is similar to a random number generator in that its physical mechanism is inaccessible to the users. In this respect, a cloud quantum computer is a black box. In both devices, the users decide the device condition from the output. A framework to achieve this exists in the field of random number generation in the form of statistical tests for random number generators. In this study, we generated random numbers on the currently available cloud quantum computer and evaluated the condition and stability of its qubits using statistical tests for random number generators. As a result, we observed that the qubits varied in bias and stability. Statistical tests for random number generators may provide a simple indicator of qubit condition and stability, enabling users to decide for themselves which qubits inside a cloud quantum computer to use. [2].

References

[1] M. Herrero-Collantes and J. C. Garcia-Escartin, Rev. Mod. Phys. **89**, 015004 (2017).

[2] K. Tamura and Y. Shikano, arXiv:1906.04410, accepted for CREST Book “Mathematics, Quantum Theory, and Cryptography" published from Springer.

Correlations in quantum networks

Antonio **ACIN**
15.01.2020
11:00 am
ICFO

We discuss the power of current and near-future quantum networks for quantum information processing. We start in the classical regime and review the concept of causal networks, designed to understand when a given cause pattern is able to reproduce some observed correlations. We then move to the quantum case and explain how Bell's theorem can be interpreted as a gap between the correlations observed in a network when using classical or quantum causes. We present methods to characterize classical and quantum correlations in networks.

Broadcasting of Correlations in Quantum World

Indranil **CHAKRABARTY**
15.01.2020
11:30 am
CSTAR IIIT Hyderabad, Gachibowli, Hyderabad

Quantum mechanical properties like entanglement and correlations act as fundamental resources in various quantum information processing tasks. Consequently, generating more resources from a few, typically termed as broadcasting is a task of utmost significance. One such strategy of broadcasting is through the application of different types of cloning machines. In this talk I review broadcasting of quantum resources in bipartite scenario and its impact in quantum information theory.

Continuous Variables Error Correction Out of the Box Using SPDC

Perola **MILMAN**
15.01.2020
12:00 pm
Laboratoire Matériaux et Phénomènes Quantiques, Sorbonne Paris Cité, Université Paris Diderot, CNRS UMR 7162, 75013 Paris, France

N. Fabre, S. Felicetti, A. Ketterer, G. Maltese, M. Amanti, F. Baboux, T. Coudreau, A. Keller, S. Ducci

Encoding quantum information in continuous variables is intrinsically faulty. Nevertheless, this can be addressed using error correction such as that provided the encoding by Gottesman, Kitaev and Preskill in [1]. We show how to experimentally implement this encoding using time-frequency continuous degrees of freedom of photon pairs produced by spontaneous parametric down conversion. Our theoretical model relies on the analogy between operations involving multi-photon states in one mode of the electromagnetic field and single photons occupying many modes. We illustrate our results using an integrated AlGaAs platform, and show how single qubit gates can be experimentally implemented and detected in a circuit like and in a measurement based architecture. [2].

References

[1] D. Gottesman, A. Kitaev, and J. Preskill, Phys. Rev. A **64**, (2001).

[2] N. Fabre *et al.*, https://arxiv.org/abs/1904.01351 (2019).

Simulation and experimental demonstration of single-photon based QKD (B92) protocol

Kaushik **JOARDER**
15.01.2020
12:30 pm
Raman Research Institute, C. V. Raman Avenue, Sadashivanagar, Bengaluru, Karnataka 560080, India

Rishab Chatterjee, Sourav Chatterjee, Barry C. Sanders and Urbasi Sinha

Quantum key distribution (QKD) refers to a family of protocols for generating a private encryption key between two parties. We have developed a practical simulation architecture for QKD protocols while considering experimental imperfections. We have also demonstrated the B92 protocol using an in-lab setup with a heralded single-photon source and evaluated the performance of the simulator with our experimental results. Using an optimization algorithm that considers a theoretical threshold value for the quantum-bit-error-rate (QBER), we have obtained a key rate of 50 KHz experimentally compared to the 70 KHz result from simulation, while ensuring key-symmetry and a QBER of 4.7

A generic scheme for Enhancing Randomness towards maximum amount of Bell-CHSH certified Genuine Randomness

Souradeep **SASMAL**
15.01.2020
12:45 pm
Centre for Astroparticle Physics and Space Science (CAPSS), Bose Institute, Block EN, Sector V, Salt Lake, Kolkata 700 091, India

Surya Narayan Bannerjee and Dipankar Home

The power of local-filtering operations in the context of randomness is revealed by showing that such operations as applied to a range of bipartite-qubit entangled-states can enable significant enhancement of the amount of Bell-CHSH certified Genuine-Randomness(GR) up to the maximum amount(2 bits). This, therefore, circumvents the limitation entailed by the earlier work achieving close to 2 bits of Bell-CHSH certified GR essentially restricted for the maximally-entangled state. While the amount of nonlocality (Bell-CHSH violation) is always increased under local-filtering operations, amount of GR is not necessarily, thereby providing a comprehensive illustration of the quantitative incommensurability of randomness with nonlocality.

"Quantum" photons from a dipole coupled two-level atomic system

Prasanta K. **PANIGRAHI**
15.01.2020
2:30 pm
IISER Kolkata

Mithilesh K. Parit

We demonstrate that light quanta of well-defined characteristics can be generated in a coupled system of three two-level atoms. The quantum nature of light is controlled by the entanglement structure, discord, and monogamy of the system, which leads to sub- and superradiant behavior, as well as sub-Poissonian statistics, at lower temperatures. Two distinct phases with different entanglement characteristics are observed with uniform radiation in one case and the other displaying highly focused and anisotropic radiation in the far-field regime. At higher temperatures, radiance witness is found to exhibit sub- and superradiant behavior of radiation intensity in the absence of entanglement albeit with non-zero quantum discord. This establishes the physical manifestation of quantum discord. It is also observed that the radiation intensity can be a precise estimator of the inter-atomic distance of a coupled system of two-level atomic systems. Our investigation shows, for the first time, the three-body correlation in the form of a 'monogamy score' controlling the sub- and superradiant nature of radiation intensity.

Entanglement and related concepts in glassy quantum systems

Ujjwal **SEN**
15.01.2020
3:00 pm
Harish-Chandra Research Institute, India

Initial Correlations in Photonic Dephasing Dynamics

Anil **SHAJI**
15.01.2020
3:30 pm
School of Physics, IISER Thiruvananthapuram, Maruthamala PO, Vithura, Kerala 695551

We study a versatile system of a pair of photons in which a controlled interaction between the polarization and frequency degrees of freedom of each photon can be engineered. While preparing the two photon state, three types of initial entanglement can be generated, namely, entanglement between the frequency degrees of freedom of the pair, between their polarization degrees of freedom and finally entanglement between the frequency and polarization degrees of freedom of each individual photon. This two photon system can be experimentally implemented [1]. In this system the open quantum dynamics of the polarization states of the two photons can be studied, treating the frequency degrees of freedom as its environment [2]. We obtain a master equation describing the evolution of the polarization qubits corresponding to various choices of correlated and uncorrelated initial states of the environment furnished by the frequency degrees of freedom. We also study the quantum dynamical maps obtained when there is initial entanglement between the polarization and frequency degrees of freedom of each photon.

References

[1] Zhao-Di Liu, Henri Lyyra, Yong-Nan Sun, Bi-Heng Liu, Chuan-Feng Li, Guang-Can Guo, Sabrina Maniscalco, and Jyrki Piilo. Experimental implementation of fully controlled dephasing dynamics and synthetic spectral densities. *Nature Communications*, 9(1):1–7, August 2018.

[2] Elsi-Mari Laine, Heinz-Peter Breuer, Jyrki Piilo, Chuan-Feng Li, and Guang-Can Guo. Nonlocal Memory Effects in the Dynamics of Open Quantum Systems. *Phys. Rev. Lett.*, 108(21):133–5, May 2012.

Duality in entanglement: Polarization and orbital angular momentum of photons

Ravindra Pratap **SINGH**
15.01.2020
4:30 pm
Physical Research Laboratory, Ahmedabad

Nijil Lal, Sarika Mishra, Anju Rani Sharma

We produce degenerate, collinear pair of photons using type-II parametric down conversion process and study duality in entanglement for these quantum indistinguishable photons selecting polarization and orbital angular momentum as two physical variables.

Using the Majorana representation and weak measurements to investigate quantum paradoxes

Yves **CAUDANO**
15.01.2020
5:00 pm
University of Namur

Mathilde Remy, Mirko Cormann

Quantum-enhanced sensing for plasmonic sensors

Ashok **KUMAR**
15.01.2020
5:30 pm
Department of Physics, Indian Institute of Space Science and Technology, Thiruvananthapuram, 695547, India
Homer L. Dodge Department of Physics and Astronomy, The University of Oklahoma, Norman, OK, 73019, USA

Mohammadjavad Dowran, Benjamin Lawrie, Raphael Pooser and Alberto Marino

Enhancing the sensitivity of sensors by using quantum properties of light is one of the long-standing goals of the quantum optics. Such an enhancement will revolutionize the field of metrology through the development of quantum-enhanced sensors. We have interfaced quantum states of light, known as twin beams with the plasmonic sensors. These sensors are widely used in biological and chemical sensing applications, and offer a unique opportunity to bring such an enhancement to real-life devices. We demonstrate that when probing the plasmonic sensor with quantum states, the sensitivity enhances by 56%.

Towards a device-independent witness of tripartite entanglement resource

Devashish **TUPKARY**
15.01.2020
5:45 pm
Undergraduate Programme, Indian Institute of Science, Bangalore 560012, India

Koon Tong Goh, Charles Lim Ci Wen, Valerio Scarani, Ignatius William Primaatmaja and Jean-Daniel Bancal

We attempt to characterize the set of quantum correlations in the triangle network in the device-independent framework. We are able to show the existence of quantum behaviours that cannot be achieved by bipartite no-signalling resources, and therefore by bipartite quantum resources. To obtain a device independent witness to tripartite entanglement, we allow shared randomness between the three parties. We present numerical evidence which suggests that the statement remains true even after allowing shared randomness.

Measurement Based Quantum Heat Engine with Coupled Working Medium

Sibasish **GHOSH**
16.01.2020
9:30 am
The Institute of Mathematical Sciences, Chennai

Arpan Das

We consider measurement based single temperature quantum heat engine without feedback control, introduced recently by Yi, Talkner and Kim [Phys. Rev. E 96, 022108 (2017)]. Taking the working medium of the engine to be a one-dimensional Heisenberg model of two spins, we calculate the efficiency of the engine undergoing a cyclic process. Starting with two spin-1/2 particles,

we investigate the scenario of higher spins also. We show that, for this model of coupled working medium, efficiency can be higher than that of an uncoupled one. However, the relationship between the coupling constant and the efficiency of the engine is rather involved. We find that in the higher spin scenario efficiency can sometimes be negative (this means work has to be done to run the engine cycle) for certain range of coupling constants, in contrast to the aforesaid work of Yi, Talkner and Kim, where they showed that the extracted work is always positive in the absence of coupling. We provide arguments for this negative efficiency in higher spin scenarios. Interestingly, this happens only in the asymmetric scenarios, where the two spins are different. Given these facts, for judiciously chosen conditions, an engine with coupled working medium gives advantage for the efficiency over the uncoupled one.

References

[1] *Entropy* 2019, **21**, 1131; doi:10.3390/e21111131

Thermoelectricity in twisted bilayer graphene

Arindam **GHOSH**
16.01.2020
10:00 am
Indian Institute of Science

Twisted bilayer graphene (TBLG) is a new and versatile platform to realize effects of strong electron-electron interaction as the mis-orientation angle between the graphene lattices profoundly affects the electronic structure of the combined system. While the layers behave independently at large angles (> 5 degrees), new electronic bands emerge when the angle is decreased, including nearly flat dispersion at the magic angle of 1.1 degree that has been shown the harbor superconductivity, magnetism and other many-body phases. In addition of direct electrical transport, thermoeletric properties are also highly sensitive to electronic correlations, and often manifest in departure from the well-established Mott semiclassical framework. Here we present the results of measurement of thermoelectric power in TBLG over a wide range of mis-orientation angles in high quality van der Waals stacks of twisted bilayer graphene. We have shown that thermoelectricity in TBLG at large angles (> 5 degrees) is expectedly determined by independent electronic structures in the two graphene layers [1]. Even at moderate angles (2 – 5 degrees), the thermoelectricity can be described by the semiclassical Mott relation [2]. At low angles (< 2 degree), however, we observed a strong departure from the semi-classical description, which is most pronounced at the half-filling of the underlying Moire lattice, and persists up to temperatures as high as 40 K [3]. In accordance with the strong enhancement in the electronic interactions at half filling, our experiments provide a new route towards probing the novel interaction-driven effects in TBLG.

Towards device-independent randomness amplification

Sherilyn **WRIGHT**
16.01.2020
11:00 am
Cambridge Quantum

Understanding whether truly random processes exist in nature is a topic of fundamental importance, finding applications in areas such as mathematical simulations, statistical sampling or cryptography. In this talk, we compare different approaches for generating random numbers and focus on device-independent randomness amplification (DIRA) based on Bell tests, in which a source of somewhat random numbers is amplified to a perfectly unpredictable source without the need to rely on a model of the processes. After explaining why DIRA is one of the most fundamental building blocks for cryptography, we present the quantum random number generators taking advantage of device-independence currently being developed by Cambridge Quantum Computing (CQC). Based on Bell tests, we explain which trade-off between assumptions and feasibility of implementation we have chosen, and describe the physics behind it.

Understanding the Born rule in weak quantum measurements

Apoorva **PATEL**
16.01.2020
12:00 pm
Centre for High Energy Physics,
Indian Institute of Science,
Bengaluru

P. Kumar, S. Kundu, M. Chand, R. Vijay

Quantum measurements are described as instantaneous projections in textbooks. They can be stretched out in time using weak measurements, whereby one can observe the evolution of a quantum state towards one of the eigenstates of the measured operator. This evolution is a continuous nonlinear stochastic process, generating an ensemble of quantum trajectories. In particular, the Born rule can be interpreted as a fluctuation-dissipation relation. We experimentally observe the entire quantum trajectory distribution for weak measurements of a superconducting transmon qubit in circuit QED architecture, quantify it, and demonstrate that it agrees very well with the predictions of a single-parameter white-noise stochastic process. This characterisation of quantum trajectories is a powerful clue to unraveling the dynamics of quantum measurement, beyond the conventional axiomatic quantum theory. We emphasise the key quantum features of this framework, and their implications.

Quantum Correlations in Quantum Network Scenario

Debasis **SARKAR**
16.01.2020
12:30 am
Department of Applied Mathematics, University of Calcutta, 92, A.P.C. Road, Kolkata-700009, India

Bell's theorem provides us a milestone on our understanding of quantum theory. The nature of quantum correlation allows us to show violation of Bell inequalities. Original picture was with two parties and two outcomes each with two possible observables. But the assumption of source independence was used to reveal nonlocal (apart from standard Bell-CHSH scenario) nature of correlations generated in entanglement swapping experiments. Usually we consider this picture as a quantum network scenario, i.e., more than two parties are connected to each other in a network. The simple quantum network is the Bilocal network. The Bilocal inequality helps us to analyze quantum correlations arising in the bilocal scenario. Recent result of Gisin et. al. provide us the maximal violation of the bilocal inequality that can be achieved by arbitrary two qubit quantum states. In this lecture, we would tried to show such results to a chain shaped network and star shaped network with generalized Bell state measurement. We would also want to discuss the monogamy of nonbilocal correlations by deriving a relation restricting marginals.

Creating maximally entangled and entangling quantum evolutions

Arul **LAKSHMINARAYAN**
16.01.2020
2:30 pm
Department of Physics, Indian Institute of Technology Madras, Chennai 600036

Suhail Ahmed Rather, and S. Aravinda

Maximally entangled bipartite pure states are central to quantum information and are straightforward to construct and characterize. While operator nonlocality and entanglement as a resource has also been studied for some time now [1–3] maximally entangled unitary operators as quantum gates or propagators are surprisingly hard to even construct. Such operators have recently been called "dual unitary" operators and used as building blocks for quantum many-body nonintegrable, but solvable systems [4,5]. They have also been referred to as 1-unitaries and require that the operator remains unitary under the realignment operation [6]. In addition, if it remains unitary under the partial transpose, they are referred to as 2-unitaries and can be used to construct 4-party absolutely maximaly entangled (AME) states, have *maximal entangling power*, and are examples of "perfect-tensors" used in tensor networks and holography [7]. In this talk we outline a strategy that allows for the construction of maximally entangled unitary operators or dual unitaries in any dimension, while we construct an ensemble of 2-unitaries or perfect tensors for qutrits ($d = 3$) and ququads ($d = 4$), which are known to not exist in $d = 2$.

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Protecting quantum correlations in presence of generalised amplitude damping channel: the two-qubit case

Suchetana GOSWAMI
16.01.2020
3:00 pm
S. N. Bose National Centre for Basic Sciences, Block JD, Sector III, Salt Lake, Kolkata 700 098, India

Sibasish Ghosh and Archan S. Majumdar

Here we study the behaviour of quantum correlations such as entanglement and steering in two-qubit systems under the application of the generalised amplitude damping channel and propose some protocols towards preserving them under this type of noise. First, we employ the technique of weak measurement for the purpose of preservation of correlations. We then show how the evolution under the channel action can be seen as an unitary process. We use the technique of weak measurement and most general form of selective positive operator valued measure to achieve preservation of correlations for a significantly large range of parameter values.

Macrorealistic inequalities stronger than the standard Leggett-Garg inequalities

Swati KUMARI
16.01.2020
3:15 pm
Bose Institute, Kolkata, India
National Institute of Technology, Patna, India

Alok Pan

In his celebrated work, Fine showed that for two parties, two-input and two-output only relevant inequality is the CHSH one. The Standard Leggett-Garg inequalities (SLGIs) are considered to the analogous to the CHSH inequalities. In recent times, there is an upsurge of interest for studying the issue of macrorealism and LGIs. Various formulation of LGIs have recently been proposed, for example, Wigner form of LGIs (WLGIs), Clauser-Horne form of LGIs (CHLGIs). In contrast to the CHSH scenario, here we show that for three-time measurement scenario, WLGIs and CHLGIs are inequivalent and both of them are stronger than SLGIs.

Witnessing bipartite entanglement sequentially by multiple observers

Shiladitya **MAL**
16.01.2020
3:30 pm
Harish-Chandra Research Institute, HBNI, Chhatnag Road, Jhunsi, Allahabad 211 019, India

Anindita Bera, Aditi Sende and Ujjwal Sen

We investigate sharing of bipartite entanglement in a scenario where half of an entangled pair is possessed and projectively measured by one observer, called Alice, while the other half is subjected to measurements performed sequentially by multiple observers, called Bobs. We find that for a two-qubit maximally entangled state, no more than twelve Bobs can detect entanglement. Furthermore, we show that for non-maximally entangled shared pure states, the number of Bobs reduces with the amount of initial entanglement, providing a coarse-grained but operational measure of entanglement. We also consider measurement device independent entanglement witness also.

Persistence of quantum violation of macrorealism for large spins even under coarsening of measurement times

Debarshi **DAS**
16.01.2020
3:45 pm
Centre for Astroparticle Physics and Space Science (CAPSS), Bose Institute, Block EN, Sector V, Salt Lake, Kolkata 700091, India

Sumit Mukherjee, Anik Rudra, Shiladitya Mal and Dipankar Home

We investigate quantum violation of macrorealism for multilevel spin systems under coarsening of measurement outcomes together with coarsening of measurement times. Our study reveals that while for a given dimension, the magnitude of quantum violation of macrorealism decreases with the increasing degree of coarsening of measurement times, this effect of coarsening of measurement times can be annulled by increasing the dimension of the spin system so that in the limit of large spin, the quantum violation of macrorealism continues to persist. Thus, classicality for large spins does not emerge from quantum mechanics in spite of the coarsening of measurement times.

Violation of Leggett-Garg Inequality under non-hermitian PT symmetric Hamiltonian evolution

A R **USHA DEVI**
17.01.2020
9:30 am
Bangalore University

H. S. Karthik and Akshtha Shenoy Hejamadi

The twilight zone between quantum and classical descriptions continues to attract atention. In particular, investigations on understanding when does a quantum system, confined to a discrete set of states, stops to be in a superposition of these states and approaches a classical macrorealistic limit attract attention even after eight decades of Schrodinger's cat thought experiment. Leggett-Garg inquality (LGI) is constructed to probe macrorealism. Macrorealistic bounds placed on temporal correlation of observables in LGI are not violated when the system is in a well defined state during time evolution, but can get violated when the system is in a superposition of states. Here we consider the three term LGI arising from qubit dynamics generated by a non-hermitian PT symmetric Hamiltonian, when a sequence of projective measurements are carried out at different time intervals. We show that the three term LGI gets violated up to the algebraic maximum value 3, exceeding the quantum bound 1.5 for temporal correlations in a two level system.

High fidelity measurements in superconducting qubits

Rajamani **VIJAYARAGHAVAN**
17.01.2020
10:00 am
Tata Institute of Fundamental Research, Mumbai

Quantum time and time of arrival

Lorenzo **MACCONE**
17.01.2020
11:00 am
universita' di Pavia

Seth Lloyd, Vittorio Giovannetti, Krzysztof Sacha, Juan Leon

I show how one can give a quantum description of time and time measurements. Our approach requires a minimal extension of standard quantum mechanics. This presentation is based on the following papers:

References

[1] Vittorio Giovannetti, Seth Lloyd, Lorenzo Maccone Quantum Time *Phys. Rev. D*, 47(12):045033, 2015.

[2] Juan Leon, Lorenzo Maccone The Pauli objection *arXiv:1504.04215, Found. Phys.*, 47(12):1597, 2017.

[3] Lorenzo Maccone, Krzysztof Sacha Quantum measurements of time *arXiv:1810.12869*, 2019.

[4] Lorenzo Maccone A fundamental problem in quantizing general relativity *arXiv:1807.01307, Found. Phys.*, 49(12):1394, 2019.

[5] Ekaterina Moreva, Marco Gramegna, Giorgio Brida, Lorenzo Maccone, Marco Genovese Quantum Time: experimental multi-time correlations *Phys. Rev. D*, 96:102005, 2017.

Progress on superconducting multi-qubit system

Xiaobo **ZHU**
17.01.2020
11:30 am
University of Science and Technology of China

In this talk, I will show our recent progress with our collaborators on superconducting multi-qubits system. We designed and fabricated several versions of quantum processor, on which integrated up to t quibts. The typical T1 and T2 time are both longer than 20 micro-seconds. The fidelity of single-bit gate and two-bit CZ gate are calibrated by randomized benchmarking. For the single-bit, the fidelity is measured higher than 99.9 % and for the CZ gate it reaches 99.5 % in the best case. I will also show some of the multi-qubits experiment results: based only on single-qubit gates and controlled-phase gates, we generated and verified the genuine multiparticle entanglement for 12 superconducting qubits, the fidelity is higher than 70 %; [1] strongly correlated quantum walks was demonstrated with a 12-qubit superconducting processor; [2] propagation and localization of collective excitations was observed on a 24-qubit superconducting processor. [3]

References

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[3] Yangsen Ye et.al. Propagation and Localization of Collective Excitations on a 24-Qubit Superconducting Processor *Phys. Rev. Lett.*, 123:050502, July 2019.

The Second Laws for Quantum and Nano-scale Heat Engines

Manabendra Nath **BERA**
17.01.2020
12:00 pm
Indian Institute of Science Education and Research, Mohali, Punjab 140306, India

Mohit Lal Bera and Maciej Lewenstein

The second law in thermodynamics dictates state transformations. However, the formulation of the second law assumes ensembles with a large number of particles and cannot be extended to the ensembles with a finite number of particles or one-shot regime. Further, the particles could be of quantum nature. We consider heat engines that operate in the one-shot regime and introduce generalized engine operations that allow strong quantum correlations and can improve engine efficiency. With a resource theoretic formalism, we show that thermodynamics of quantum heat engines is fundamentally irreversible and it requires many second laws to characterize the state transformations.

Arrival time distributions and spin in quantum mechanics: A Bohmian perspective

Siddhant **DAS**
16.01.2020
12:15 pm
Mathematisches Institut, Ludwig-Maximilians-Universitat Mu¨nchen, Theresienstr. 39, D-80333 Mu¨nchen, Germany

Detlef Dürr

The arrival time statistics of spin-1/2 particles governed by Pauli's equation, and defined by their Bohmian trajectories, show unexpected and very well articulated features. Comparison with other proposed statistics of arrival times that arise from either the usual quantum flux or from semiclassical considerations suggest testing the notable deviations in an arrival time experiment, thereby probing the predictive power of Bohmian trajectories. The suggested experiment, including the preparation of the wave functions, could be done with present-day experimental technology.

Manipulation of entanglement sudden death in an all-optical experimental setup

Ashutosh **SINGH**
17.01.2020
12:30 pm
Raman Research Institute, Bangalore-560080, India

A. R. P. Rau and Urbasi Sinha

We have experimentally demonstrated the phenomenon of asymptotic decay of entanglement and entanglement sudden death (ESD) in the presence of an amplitude damping channel for two different initially entangled states. For the state undergoing ESD, we have proposed a local unitary operation (NOT operation, σ_x) such that ESD can be hastened, delayed, or avoided depending on the time of application of NOT operation in the decoherence process. Here, I will present the latest experimental results on the ESD and its manipulation. In the end, I will briefly touch upon the non-equivalence of entanglement measures for two-qubit pure states.

Weak values from path integrals

Alex **MATZKIN**
17.01.2020
2:30 pm
CNRS/Univ. Cergy-Pontoise

Quantum circuits with classical versus quantum control of causal orders

Cyril BRANCIARD
17.01.2020
3:00 pm
Institut Néel - CNRS, Grenoble (France)

A standard model for quantum computers is that of quantum circuits, where quantum gates are applied to some quantum systems one after the other, in a well-defined order. It has however been realized in the last decade that quantum theory also allows for quantum operations to be applied in some indefinite order: the paradigmatic example being the so-called « quantum switch », where the state of a « control qubit » controls the order of two operations applied on a « target system ». Here we generalize the idea of the quantum switch; we describe and characterize new classes of quantum circuits, with both classical and quantum control of causal orders. This allows us to investigate new types of quantum processes with indefinite causal order and their potential applications, beyond the quantum switch.

None

Surya N. SAHOO
17.01.2020
3:30 pm
Raman Research Institute

Rydberg physics for quantum information processing applications

Khabat HESHAMI
18.01.2020
11:30 am
National Research Council Canada
and University of Ottawa

Rydberg states of atoms and excitons demonstrate strong interaction that can be used to induce interaction between photons or to achieve non-trivial states for quantum simulation of many-body dynamics. In this talk, I will give an overview of Rydberg atoms and excitons and propose implementation of applications such as quantum nonlinear optics, quantum simulation of many-body dynamics, and quantum simulation of small-scale circuits for quantum error correction.

Towards a global quantum network:Distance and Security

Feihu XU
18.01.2020
12:00 pm
University of Science and Technology of China

I will address our recent efforts at USTC towards the construction of a global quantum communication network. I will primarily talk our experiments and progress to address the issues of long-distance quantum communication and implementation security of quantum cryptography.

From quantum information science to deep-space optical communication

Konrad BANASZEK
18.01.2020
12:30 pm
University of Warsaw

Quantum theory of electromagnetic radiation sets fundamental limits on the information capacity of optical communication links. Analysis of quantum mechanical capacity limits, which follow from Holevo's theorem, requires a change of paradigm from identifying noise inherent to measuring quantities well defined in classical systems, such as the amplitude or the phase of an optical field, to optimizing distinguishability of non-orthogonal quantum states. We discuss capacity limits in the context of deep-space optical communication, in particular downlink transfer of data collected by missions beyond the near-Earth region. The current standard for deep-space links is based on the high-order pulse position modulation (PPM) format. Such a format requires high peak-to-average power ratio of the optical signal, which may reduce the overall wall-plug efficiency of the transmitter subsystem. We describe a possible solution to this problem motivated by the quantum mechanical phenomenon of superadditivity of accessible information in classical communication.

Geo-strategic game theory of quantum technology

Peter **ROHDE**
18.01.2020
3:00 pm
University of Technology Sydney

This is a more technical version of my recent TEDx talk Geo-strategic politics in the quantum era", in which I look not at the underlying technology of quantum computing & communication, but how this will impact international diplomacy, policy-making, and economic development. In particular this focuses on the role the quantum internet will play in this, whether quantum technology is likely to be a force for peace or for conflict, and how we can guide it to the former.

The importance of quantum communications in India's Space Programme

R. **UMAMAHESHWARAN**
18.01.2020
4:00 pm
Scientific Secretary, Indian Space Research Organization

Quantum Communication at RRI Bangalore

Urbasi **SINHA**
18.01.2020
5:00 pm
Raman Research Institute, Institute for Quantum Computing, Harish-Chandra Research Institute