Workshop on Entanglement-Assisted Communication Networks

Munich, Germany, March 09 -12, 2021

Program and Booklet of Abstracts

Organizers:

Christian Deppe   Janis Nötzel

Local Organization:

Andrea Cacioppo   Stephen DiAdamo   Roberto Ferrara   Claudia Koch
Uzi Pereg   Robert Schetterer   Christin Wizemann

ENTANGLEMENT-ASSISTED COMMUNICATION NETWORKS

On March 09-12, 2021, the Workshop on Entanglement Assisted Classical Communication Networks (EACN) will take place at the TUM Institute for Communications Engineering. This event is a joint workshop of the Emmy Noether Group "Theoretical Quantum System Design" supported by the Deutsche Forschungsgemeinschaft (DFG) and the Institute for Communications Engineering supported by the German Federal Ministry of Education and Research (BMBF) with the project Q.Link.X.

EACN Workshop Website:
- `https://mcqst.de/news-and-events/eacn-2021/`

EACN Workshop Platform:
- `https://meetanyway.com/events/eacn-2021/space`

Topics of interest

Will quantum communication reshape classical network design? What will be the next technological breakthrough in quantum communication? This interdisciplinary workshop focusses on entanglement as a resource assisting classical communication systems. We welcome participants from academic institutions, research labs and industry. Selected approaches to entanglement-assisted communication will be presented, along with established communication models in classical networking.

Thanks

The organizers acknowledge funding by the DFG via grant NO 1129/2-1 and by the Bundesministerium für Bildung und Forschung via grant 16KIS1005 and thank the MCQST for supporting us.

About this booklet

This booklet contains hyperlinks to help you navigate:

- Clicking the talk title in the schedule will take you to the talk abstract
- Clicking the talk date/time in the abstract will take you to the schedule
- Clicking the name of a chair will open their email address

Workshop Schedule

Tuesday, March 9th

08:45	First Janis then Christian	Introduction by the Convenor
	Session 1: Q.Link.X - Quantum Repeaters. **Chair: Christian Deppe, Technical Chair: Andrea Cacioppo**	
09:00	Dieter Meschede	Q.Link.X - Cooperation and outreach (20m)
09:30	Christoph Becher	Extending links in quantum networks – an overview on the research network Q.Link.X (40m)
10:20	Peter van Loock	Quantum repeaters: protocols, basic elements, and rate analysis (40m)
	Session 2: Q.Link.X - Quantum-Dots, Atoms and Ions. **Chair: Uzi Pereg, Technical Chair: Andrea Cacioppo**	
11:10	Peter Michler	Towards a semiconductor-based quantum repeater - Part 2 (30m)
11:50	Sven Höfling	Towards a semiconductor based quantum repeater - Part 1 (30m)
12:30	Jürgen Eschner	A programmable atom-photon quantum interface (30m)
13:00		Lunch Break
14:00	Harald Weinfurter	Towards a quantum repeater segment over long fiber distances (30m)
14:40	Gerhard Rempe	Optical-fiber/cavity quantum-network nodes (30m)
	Session 3: Q.Link.X - Diamond centers and Theory. **Chair: Roberto Ferrara, Technical Chair: Stephen DiAdamo**	
15:20	David Hunger	Cavity enhancement for efficient diamond-based spin-photon interfaces (30m)
16:00		Coffee Break
16:30	Florian Kaiser	Interfacing solid-state spins and photons for networked quantum technologies (30m)
17:10	Uzi Pereg	Information theoretic perspective on quantum repeaters (30m)
	Session 4: Quantum Repeaters. **Chair: Christian Deppe, Technical Chair: Stephen DiAdamo**	
17:50	Andreas Reiserer	Erbium-doped crystals: A novel platform for QIP (20m)
18:20	Filip Rozpędek	Quantum repeaters based on concatenated bosonic- and discrete-variable quantum codes (20m)
18:50	Johannes Borregaard	One-way quantum repeater based on near-deterministic photon-emitter interfaces (20m)
19:30	Q.Link.X	Platform Meetings: Quantum Dots, Atoms and Ions, Diamond centers, Theory

Wednesday, March 10th

08:45		Welcome
	Session 1: Theory as innovation driver. Chair: Janis Nötzel, Technical Chair: Andrea Cacioppo	
09:00	Alexander Holevo	The information capacity of entanglement-assisted quantum Gaussian measurements (60m)
10:20	Andreas Winter	Zero-error communication via channels -entanglement assistance and beyond (40m)
11:20	Frank Fitzek	Theory that Matters! (40m)
12:20	Holger Boche	Post-Shannon quantum communication and (unexpected) links between computing and information processing (40m)
13:00		Lunch Break
	Session 2: Hightech Product challenges/opportunities/examples. Chair: Janis Nötzel, Technical Chair: Andrea Cacioppo	
14:00	Frank Fitzek	Start Ups: The better research vehicle? (20m)
14:30	Dieter Meschede	Opticlock – quantum technology almost ready for roll-out (20m)
15:00	Riccardo Bassoli	Network coding for efficient vertical handovers - The scientific method in engineering (20m)
15:30	Daniel Khafif	Concepts behind high-tech entrepreneurial activities in the German market (20m)
16:00		Coffee Break
	Session 3: Hightech Product challenges/opportunities/examples. Chair: Janis Nötzel, Technical Chair: Stephen DiAdamo	
16:30	Helmut Grießer	Deployment of QKD with commercial transport equipment (20m)
17:00	Thomas Hühn Julius Schulz-Zander	Theory and practice of WiFi network development (20m)
17:30	Henning Weier	Tools for interdisciplinary training on the topic of quantum physics (20m)
18:00	Dieter Meschede Norbert Pohlmann	Panel Discussions: Call for proposal - Quantum Tokens

Thursday, March 11th

08:45		Welcome
	Session 1: Simulations / Emulation. Chair: Uzi Pereg, Technical Chair: Andrea Cacioppo	
09:00	Rob Knegjens	NetSquid, a discrete-event simulation platform for quantum networks (20m)
09:30	Rod van Meter	QuISP: the Quantum Internet Simulation Package (20m)
10:00	Stephen Di Adamo	QuNetSim: A software framework for quantum networks (20m)
	Session 2: Hardware / Interconnects. Chair: Uzi Pereg, Technical Chair: Andrea Cacioppo	
10:30	Andreas Reiserer	Rare-earth dopants (20m)
11:00	Kai Müller	Generation and detection of single photons (20m)
11:30	Marcus Huber	High-dimensional entanglement for quantum communication (20m)
12:00	Fabian Steinlechner	Towards high-dimensional quantum communication in space (20m)
12:30	Jörg Wrachtrup	Advanced diamond quantum materials for photonic integration (20m)
13:00		Lunch Break
	Session 3: Hardware / Interconnects / Experimental Challanges. Chair: Christian Deppe, Technical Chair: Stephen DiAdamo	
14:00	Elena del Valle	Engineering single and N-photon emission from frequency resolved correlations (20m)
14:30	Frank Deppe	Microwave quantum teleportation (20m)
15:00	Daniel Twitchen Matthew Markham	Scaling and delivering diamond quantum solutions (20m)
15:30		Coffee Break
16:00	Stefanie Barz	Protocols in quantum networks: recent results and experimental challenges (20m)
16:30	Tal Mor	Quantum key distribution network with quantum candies (20m)
17:00	Ferdinand Schmidt-Kaler	Interconnecting nodes of an trapped-ion quantum processor (20m)
18:00	Boulat Bash Frank Fitzek Andreas Reiserer Andreas Winter	Panel Discussion: What do you see as the potential use of quantum effects in the field of communication networks in 5, 10, and 20 years, and what are the current biggest challenges for this use?

Friday, March 12th

08:45		Welcome
	Session 1: Entanglement-Assisted protocols Part 1. Chair: Janis Nötzel, Technical Chair: Andrea Cacioppo	
09:00	Matteo Rosati	Achieving high-data-rate communication on optical quantum channels: a theoretical implementation-oriented perspective (20m)
09:30	Shayan Srinivasa Garani	Designing rate-efficient coded quantum networks (20m)
	Session 2: Networks: status, directions, use cases. Chair: Roberto Ferrara, Technical Chair: Andrea Cacioppo	
10:00	Marco Tomamichel	Open problem for the entanglement-assisted capacity (20m)
10:30	Elham Kashefi	Privacy and security in quantum network (20m)
11:00	Jens Eisert	Entanglement assisted communication networks (20m)
11:30	Wojciech Kozlowski	Network and software architecture for the quantum internet (20m)
12:00	Moritz Kleinert	Hybrid-photonic integrated circuits for classical and quantum communications (20m)
12:30	Felix Wissel	QKD@DT - We are building the security of the future (20m)
13:00		Lunch Break
14:00	Frank Fitzek	Communicaton networks: Quo vadis? (20m)
	Session 3: Quantum Communication. Chair: Roberto Ferrara, Technical Chair: Stephen DiAdamo	
14:30	Matthias Christandl	Fault-tolerant coding for quantum communication (20m)
15:00	Farzin Salek	When are adaptive strategies in asymptotic quantum channel discrimination useful? (20m)
15:30	Zahra Khanian	Quantum state redistribution for ensemble sources (20m)
16:00		Coffee Break
	Session 4: Entanglement-Assisted protocols Part 2. Chair: Janis Nötzel, Technical Chair: Stephen DiAdamo	
16:30	Zheshen Zhang	Entanglement-assisted communication: experiment to surpass the ultimate classical capacity (20m)
17:00	Quntao Zhuang	Entanglement-assisted communication: theory and protocol design (20m)
17:30	Saikat Guha	Infinite-fold enhancement in communications capacity using pre-shared entanglement (20m)
18:00	Boulat Bash	Fundamental limits of entanglement-assisted covert communication over the bosonic channels (20m)
18:30		Panel Discussions and Meetings

CONTENTS

PROTOCOLS IN QUANTUM NETWORKS: RECENT RESULTS AND EXPERIMENTAL CHALLENGES

Stefanie Barz

Thursday, March 11th, 16:00, 20m

In this talk I will discuss applications of quantum networks going beyond quantum key distribution. I will show that quantum networks can be used to perform distributed computing, both classical and quantum. Furthermore, I will present a recent experiment that shows quantum communication in a multipartite network and allows – besides security in the communication – keeping the identities of the participating parties secure. I will conclude with a discussion of experimental challenges in realizing advanced networked quantum protocols.

Speaker

Stefanie Barz is a professor of physics at the University of Stuttgart. Her research focuses on quantum networks, including both the development of integrated photonic hardware and the implementation of advanced secure protocols. She has demonstrated various networked quantum applications, for example secure quantum cloud computing ("blind quantum computing"), multipartite computing in quantum networks as well as multipartite communication protocols.

Stefanie Barz completed her PhD in Vienna in 2012 and afterwards was a Marie Skłodowska-Curie fellow as well as a Millard and Lee Alexander Fellow at the University of Oxford. In 2017 she became a full professor at the University of Stuttgart. She received a number of awards, including the Laudimaxima Award by the University of Vienna, the Loschmidt Prize by the Austrian Chemical-Physical Society, and the Doc.Award by the University of Vienna & City of Vienna.

FUNDAMENTAL LIMITS OF ENTANGLEMENT-ASSISTED COVERT COMMUNICATION OVER THE BOSONIC CHANNELS

Boulat Bash

Friday, March 12th , 18:00, 20m

We study the fundamental limits of quantum-secure covert-communication over the lossy thermal noise bosonic channels, the quantum-mechanical model for many practical channels. We show that entanglement assistance improves the scaling law for covert communication over these channels: instead of $L_{no-EA}\sqrt{n}-r_{no-EA}(n)$, $r_{no-EA}(n) = o(\sqrt{n})$, covert bits that can be reliably transmitted using n modes of the bosonic channels without entanglement assistance, shared entanglement allows the reliable transmission of $L_{EA}\log(n)\sqrt{n} - r_{EA}(n)$, $r_{EA}(n) = o(log(n)\sqrt{n})$, covert bits using n modes. We develop the expressions for covert capacities L_{no-EA} and L_{EA}, as well as bounds for the remainder terms $r_{no-EA}(n)$ and r_{EA}. Finally, we show that our entanglement-assisted optical transceiver architecture captures the scaling gain for covert communication.

Speaker

Boulat Bash is an assistant professor in the Department of Electrical and Computer Engineering, joining the university after working at Raytheon BBN Technologies in Cambridge, Massachusetts, for three and a half years. He earned an undergraduate degree in economics at Dartmouth College, and his MS and PhD degrees in computer science at the University of Massachusetts Amherst. Bash's research is focused on covert communications, which involves not only protecting the content of communications from adversaries, but keeping adversaries from detecting that communication is happening at all. Bash has authored or co-authored 26 journals, conference articles and technical reports and has one patent.

NETWORK CODING
FOR EFFICIENT VERTICAL HANDOVERS
- THE SCIENTIFIC METHOD IN ENGINEERING

Riccardo Bassoli

Wednesday, March 10th, 15:00, 20m

In 2008, the Institute of Electrical and Electronics Engineers (IEEE) published its standard IEEE 802.21 for media-independent handover services. The main scope of this work was to design a technology agnostic mobility platform to perform vertical handovers between heterogeneous networks. What is the impact of contextualising this scientific question in the real engineering world? Actually, the value of the proposed novel architecture/protocol to efficiently perform vertical handovers is not only given by a theoretical analysis and practical tests (via emulation, simulation, testbeds, etc.). In fact, standardisation bodies, industry and market trends also impact on the value of scientific methods and solution in engineering research.

Speaker

Riccardo Bassoli is a senior researcher at the Deutsche Telekom Chair of Communication Networks, Faculty of Electrical and Computer Engineering, Technische Universität Dresden (Germany). He received his B.Sc. and M.Sc. degrees in Telecommunications Engineering from the University of Modena and Reggio Emilia (Italy) in 2008 and 2010 respectively. Next, he received his Ph.D. degree from the 5G Innovation Centre at the University of Surrey (UK), in 2016. He was also a Marie Curie ESR at the Instituto de Telecomunicações (Portugal) and visiting researcher at Airbus Defence and Space (France). Between 2016 and 2019, he was a postdoctoral researcher at the University of Trento (Italy). He is an IEEE and ComSoc member. He is also a member of Glue Technologies for Space Systems Technical Panel of IEEE AESS. He has co-authored the book 'Quantum Communication Networks' (Springer 2021). He investigates the integration between classical and quantum technologies in a unique classical-quantum communication network infrastructure.

EXTENDING LINKS IN QUANTUM NETWORKS – AN OVERVIEW ON THE RESEARCH NETWORK Q.LINK.X

Christoph Becher

Tuesday, March 9th, 09:30, 40m

Quantum networks, i.e. local nodes consisting of stationary quantum bits able to process and store quantum information connected by "flying" qubits suited to transfer this information, are at the heart of concepts for long-range secure quantum communication and distributed quantum computing or quantum sensing. The main obstacle in establishing networks over large distances is the inherent loss of transmission channels, in particular for networks based on an infrastructure of optical fibers. The most feasible and promising route towards long distance quantum communication without sacrificing the physical security based on quantum mechanical concepts is based on quantum repeaters [1] to distribute entangled states to remote communication partners. The German research network "Quantum Links extended – Q.Link.X" investigates a bottom-up approach to realizing basic elements of fiber-based quantum repeaters (QR). The basic elements are QR-segments, i.e. heralded entanglement distribution between two nodes, and QR-cells, i.e. a node comprising two qubits sending out photons entangled with one of the qubits, respectively, and gate operations between the qubits to perform a Bell-state measurement, realizing a "single sequential quantum repeater" scheme [2]. The combination of QR-segments and QR-cells then allows for scaling up the quantum links. Q.Link.X investigates three different hardware platforms to realize these elements, i.e. trapped neutral atoms and ions, semiconductor quantum dots and color centers in diamond. The talk will present the basic concepts and an overview on recent experimental achievements in Q.Link.X.

References

[1] H.-J. Briegel et al., Phys. Rev. Lett. 81, 5932 (1998). DOI: 10.1103/PhysRevLett.81.5932
[2] D. Luong et al., Appl. Phys. B 122, 96 (2016). DOI: 10.1007/s00340-016-6373-4

Speaker

Christoph Becher has been working as a professor at Saarland University since 2005, focusing on quantum optics and quantum technologies. He is involved in numerous national and international research projects. As spokesman of the top-class research consortium Q.Link.X, funded by the German Federal Ministry of Education and Research (BMBF), he is researching, among other things, how the range of secure quantum communication in fiber optic networks can be extended. The consortium of a total of 39 partners throughout Germany is researching so-called quantum repeaters, which - similar to repeaters for classic computer networks communication networks - can increase the range of networks based on quantum technology. A network that operates according to the principles of quantum physics would be provably tap-proof and could network powerful quantum computers in the future. The German Academy of Science and Engineering is the national academy funded by the German federal and state governments and the voice of the technical sciences in Germany and abroad. It advises politicians and society on issues relating to the future of technology science and technology policy and is under the patronage of the Federal President.

POST-SHANNON QUANTUM COMMUNICATION AND (UNEXPECTED) LINKS BETWEEN COMPUTING AND INFORMATION PROCESSING

Holger Boche

Wednesday, March 10th, 12:20, 40m

The talk will first introduce performance requirements and post Shannon communication tasks for future quantum communication networks. Following this, the post Shannon communication tasks "identification of messages" and "secure identification of messages" will be discussed in detail and corresponding capacities will be derived. It turns out that these communication tasks behave quite unexpectedly compared to "Shannon's message transmission" communication tasks. This also applies to "identification of messages" with feedback and entanglement assistance. Subsequently, it will be shown that important capacities are not Turing computable, i.e. they can never be calculated or simulated on digital hardware with performance guarantees.

Continuing with these results, the second part of the talk will examine methods of information processing and physical theories regarding their computability on Turing machines. Some questions of computability and connections to Research Unit B, quantum simulation, and to Research Unit C, quantum computing, will be discussed. A large number of information processing tasks and physical theories will be identified that are not computable on Turing machines, i.e. ones that can never be simulated on a Turing machine with performance guarantees. For some of these problems, "implementations" on "ideal analog computers" are possible. Thus on the level of "abstract machine models" for computation it turns out that for these tasks the "ideal analog computer" is more powerful than the ideal digital computing model of "Turing Machine."

Speaker

Holger Boche joined in 1997 the Heinrich-Hertz-Institut (HHI) für Nachrichtentechnik Berlin, Berlin, Germany. Starting in 2002, he was a Full Professor for mobile communication networks with the Institute for Communications Systems, Technische Universität Berlin. In 2003, he became the Director of the Fraunhofer German-Sino Lab for Mobile Communications, Berlin, Germany, and in 2004, he became the Director of the HHI, Berlin, Germany. Since October 2010, he has been with the Institute of Theoretical Information Technology and a Full Professor with the Technische Universität München (TUM), Munich, Germany. Since 2014, he has been a Member and Honorary Fellow of the TUM Institute for Advanced Study, Munich, Germany, and since 2018, a founding Director of the Center for Quantum Engineering (ZQE), TUM. During the 2004 and 2006 Winter terms, he was a Visiting Professor with the ETH Zurich, Zurich, Switzerland, and during the 2005 Summer term, with KTH Stockholm, Stockholm, Sweden. Among his publications is the recent book Information Theoretic Security and Privacy of Information Systems (Cambridge University Press). He is a Member of IEEE Signal Processing Society SPCOM and SPTM Technical Committee. He was elected a Member of the German Academy of Sciences (Leopoldina) in 2008 and the Berlin Brandenburg Academy of Sciences and Humanities in 2009. He was the recipient of the research award “Technische Kommunikation” from the Alcatel SEL Foundation in October 2003, the “Innovation Award” from the Vodafone Foundation in June 2006, the Gottfried Wilhelm Leibniz Prize from the Deutsche Forschungsgemeinschaft (German Research Foundation) in 2008, and the 2007 IEEE Signal Processing Society Best Paper Award. He was the co-recipient of the 2006 IEEE Signal Processing Society Best Paper Award. He was the General Chair of the Symposium on Information Theoretic Approaches to Security and Privacy at IEEE GlobalSIP 2016.

ONE-WAY QUANTUM REPEATER BASED ON NEAR-DETERMINISTIC PHOTON-EMITTER INTERFACES

Johannes Borregaard

Tuesday, March 9th, 18:50, 20m

In a so-called one-way quantum repeater, quantum information is encoded in an error-correcting code to protect it against loss between the repeater stations. Compared to other repeater architectures, the one-way repeater does not require long-term quantum memories and can have a very high rate approaching the MHz-range over a 1000 km distance. In this talk, I will describe our recent proposal for a one-way repeater which can be constructed with as little as two stationary spin qubit and one quantum emitter per repeater station. This significantly increases the experimental feasibility and represents orders of magnitude decrease in spin-qubit resource compared to previous proposals. I will discuss potential implementations with diamond defect centers and semiconductor quantum dots efficiently coupled to photonic nanostructures and outline how such systems may be integrated into repeater stations.

Speaker

Johannes Borregaard obtained his PhD in theoretical quantum optics from the Niels Bohr Institute, Copenhagen in 2015 under the supervision of Prof. Anders Sørensen. This was followed by a two-year postdoc position (2015-2017) in the group of Prof. Mikhail Lukin at Harvard University, Boston and a three-year postdoc position (2017-2020) at the Centre for the Mathematics of Quantum Theory (QMATH), Copenhagen before joining QuTech in 2020 as an Assistant Professor.

Johannes' focus early on has been to consider quantum technology in realistic settings subject to experimental imperfections. In his research, he tries to bridge the gap between quantum software and hardware working in the intersection of mathematics and physics. As a result, Johannes is working closely together with both experimental teams and quantum information theorists across Europe and the US. This allows to tailor protocols to the best suited hardware, which may consist of atoms, diamond defect centers, quantum dots, superconducting qubits, or squeezed light.

A substantial part of Johannes' research evolves around quantum networks in a broad sense. This includes protocols for long-distance quantum communication and quantum sensor networks for enhanced metrology. An integral part of this is to exploit novel applications of quantum networks whilst outlining protocols for the implementation with specific hardware. In addition, Johannes is also very interested in investigating potential applications of the noisy quantum computing devices that exist today and in the near future.

FAULT-TOLERANT CODING FOR QUANTUM COMMUNICATION

Matthias Christandl

Friday, March 12th , 14:30, 20m

Designing encoding and decoding circuits to reliably send messages over many uses of a noisy channel is a central problem in communication theory. When studying the optimal transmission rates achievable with asymptotically vanishing error it is usually assumed that these circuits can be implemented using noise-free gates. While this assumption is satisfied for classical machines in many scenarios, it is not expected to be satisfied in the near term future for quantum machines where decoherence leads to faults in the quantum gates. As a result, fundamental questions regarding the practical relevance of quantum channel coding remain open. By combining techniques from fault-tolerant quantum computation with techniques from quantum communication, we initiate the study of these questions. We introduce fault-tolerant versions of quantum capacities quantifying the optimal communication rates achievable with asymptotically vanishing total error when the encoding and decoding circuits are affected by gate errors with small probability. Our main results are threshold theorems for the classical and quantum capacity: For every quantum channel T and every $\varepsilon > 0$ there exists a threshold $p(\varepsilon, T)$ for the gate error probability below which rates larger than $C - \varepsilon$ are fault-tolerantly achievable with vanishing overall communication error, where C denotes the usual capacity. Our results are not only relevant in communication over large distances, but also on-chip, where distant parts of a quantum computer might need to communicate under higher levels of noise than affecting the local gates.

Speaker

Matthias Christandl's research is in the area of Quantum Information Theory. It is his aim to improve our understanding of the ultimate limits of computation and communication given by quantum theory. Concrete research results range from new protocols for the communication with single quantum particles (e.g. photons) to a new measure for quantum entanglement.

Matthias Christandl received his PhD from the University of Cambridge in 2006. He then became a Thomas Nevile Research Fellow at Magdalene College Cambridge. In 2008, he joined the faculty of the University of Munich as a Junior-professor; since 2010 he has been assistant professor at ETH Zurich.

ENGINEERING SINGLE AND N-PHOTON EMISSION FROM FREQUENCY RESOLVED CORRELATIONS

Elena del Valle

Thursday, March 11th, 14:00, 20m

Correlations in light resolved both in time and frequency provide valuable information about the level structure and dynamics of an emitting system and its capabilities as a quantum light source. First, I will review a generalization of Glauber's N-photon coherence functions to the frequency domain and present our "sensing method" to compute them and gain important insights [1,2]. Second, I will show how the information that these functions provide, lead to both fundamental understanding and technological applications in the epitome system of Quantum Optics, resonance fluorescence, a single two-level system emitter (qubit) driven by a laser:

In the low driving (Heitler) regime, this system was believed to provide an emission both perfectly antibunched and spectrally narrow (with a subnatural linewidth). We show that, when including measurement, these two properties are not compatible and propose a scheme which interferes the emission with an external laser to reconcile them again [3,4,5].

In the high driving (Mollow) regime, we propose schemes to create, by using a cavity to select and enhance emission from the system at precise frequencies, an N-photon emitter [6,7], possibly heralded, or two-mode squeezing.

References:

[1] Theory of frequency-filtered and time-resolved N-photon correlations, E. del Valle et al., Phys. Rev. Lett. 109, 183601 (2012). DOI: 10.1103/PhysRevLett.109.183601

[2] Frequency-resolved Monte Carlo, J. C. López Carreño et al., Sci. Rep., 8, 6975 (2018). DOI: 10.1038/s41598-018-24975-y

[3] Joint subnatural-linewidth and single-photon emission from resonance fluorescence, J. C. López Carreño et al., Quantum Sci. Technol. 3, 045001 (2018). DOI: 10.1088/2058-9565/aacfbe

[4] Origin of Antibunching in Resonance Fluorescence, L. Hanschke et al. Phys. Rev. Lett. 125, 170402 (2020). DOI: 10.1103/PhysRevLett.125.170402

[5] Conventional and Unconventional Photon Statistics, E. Zubizarreta Casalengua et al., Laser Photonics Rev. 1900279 (2020). DOI: 10.1002/lpor.201900279.

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[7] Filtering multiphoton emission from state-of-the-art cavity quantum electrodynamics, C. Sánchez Muñoz et al., Optica 5, 14 (2018). DOI: 10.1364/OPTICA.5.000014

Speaker

Elena del Valle completed her PhD at the Universidad Autónoma de Madrid (UAM) in 2009, in the field of cavity-QED with quantum dots. Then, she pursued postdoctoral research, first, with a Newton International Fellowship at the University of Southampton, second, with a Humboldt Research Fellowship at the Technische Universität München. She investigated more fundamental quantum optical problems such as the single-atom lasing or frequency-resolved temporal correlations. In 2014, she was awarded a Marie-Curie Fellowship back at the UAM, followed by a Ramón y Cajal tenure track position.

She is now a Senior Lecturer in Quantum Optics at the University of Wolverhampton since 2019.

MICROWAVE QUANTUM TELEPORTATION

Frank Deppe

Thursday, March 11th, 14:30, 20m

We demonstrate the successful realization of unconditional quantum teleportation in the microwave regime over the distance of 42 cm by exploiting two-mode squeezing and analog feedforward. We generate squeezed and feedforward signals in the GHz regime by using superconducting Josephson parametric amplifiers. We realize quantum teleportation of coherent states with fidelities exceeding the no-cloning limit, thus, proving the unconditional security of the protocol. Furthermore, our experiments reveal the influence of the feedforward gain and entanglement strength on the teleportation fidelity in the presence of finite noise and losses. In the end, we demonstrate that quantum microwave communication is feasible over macroscopic distances in the cryogenic environment. Our results enable future implementations of microwave quantum local area networks and distributed quantum computing with superconducting circuits.

We acknowledge support by the German Research Foundation through the Munich Center for Quantum Science and Technology (MCQST), Elite Network of Bavaria through the program ExQM, EU Flagship project QMiCS (Grant No. 820505), and the German Federal Ministry of Education and Research (BMBF) via the project QUARATE (Grant No. 13N15380).

Speaker

Frank Deppe is Junior Group Leader “Superconducting Quantum Circuits” at the Walther-Meißner-Institut (WMI) in Garching near Munich, Germany. In addition, he is private lecturer (“Privatdozent”) at Technische Universität München (TUM) with the official right to supervise Bachelor, Master, and PhD theses. During his PhD studies, he performed experiments on superconducting flux quantum circuits, partly in the group of Kouichi Semba at NTT Basic Research Laboratories in Japan and partly in the group of Rudolf Gross at TUM. As a postdoc, he continued at the WMI, where, together with Dr. Achim Marx, he co-organizes the Superconducting Quantum Circuits Group. After holding a personalized postdoc position within the Collaborative Research Center 631 on “Solid Sate Quantum Information Processing” of the German Research Foundation, he became a permanent scientist at the WMI in 2014. Frank Deppe was/is principal investigator in several national and EU projects. He is associate member of the excellence cluster ‘Nanosystems Initiative Munich’ (NIM). In 2017, he received the German university teaching license (“Habilitation”) and private lecturership (“Privatdozent”) at TUM. Frank’s main areas of expertise are superconducting quantum circuits, ultrastrong light-matter coupling, and propagating quantum microwaves for communication and sensing.

QUNETSIM: A SOFTWARE FRAMEWORK FOR QUANTUM NETWORKS

Stephen DiAdamo

Thursday, March 11th, 10:00, 20m

As quantum internet technologies develop, the need for simulation software and education for quantum internet rises. QuNetSim aims to fill this need. QuNetSim is a Python software framework that can be used to simulate quantum networks up to the network layer. The goal of QuNetSim is to make it easier to investigate and test quantum networking protocols over various quantum network configurations and parameters. The framework incorporates many known quantum network protocols so that users can quickly build simulations and beginners can easily learn to implement their own quantum networking protocols.

Speaker

Stephen DiAdamo is a PhD student in the Theoretical Quantum System Design group at the Technical University of Munich. He received his Bachelor's of Science at the University of Toronto in Computer Science and a Master's of Mathematics at the Technical University of Munich. His research is regarding quantum network design and applications of quantum networks. Such applications include entanglement-assisted communication of classical information and distributed quantum computing. He contributes and manages open-source software projects such as QuNetSim and Interlin-q, which are supported by the Unitary Fund grant. He regularly volunteers as a mentor to students who are interested in quantum information via the Quantum Open Source Foundation. He worked as a research intern as the quantum computing company Riverlane where we worked on distributed quantum computing topics.

ENTANGLEMENT ASSISTED COMMUNICATION NETWORKS

Jens Eisert

Friday, March 12th , 11:00, 20m

Quantum architectures may indeed play a significant role in future classical communication network, but in what precise way seems less clear. In this talk, we will have a look at in what way genuinely multi-partite features may come into play in this endeavour, beyond quantum-assisted point-to-point protocols. We ask how multi-partite routing in quantum networks can be deviced [1]. Along the way, we address the old question of the manipulation of multi-partite entangled states, a question for which we can offer technical progress [2]. Turning to more practical aspects, it has long been suggested that multi-partite schemes and entangled resources may offer advantages in multi-partite cryptographic protocols, but it remains a challenge to pinpoint specific network coding advantages. We will investigate a family of secret sharing protocols in which such an advantage can be proven [3]. If time allows, we will hint at even more practically minded classical simulations of quantum repeater schemes for communication networks [4] and aspects of their verification [5].

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Speaker

Jens Eisert is known for his research in and has made numerous contributions to quantum information science and quantum many-body theory in condensed matter physics. He has made significant contributions on entanglement theory and the study of quantum computational models, as well as quantum optical implementations of protocols in the quantum technologies and the study of complex quantum systems. He is also notable as one of the co-pioneers of quantum game theory with Maciej Lewenstein and PhD advisor Martin Wilkens. He attended high school at the Wilhelm von Humboldt Gymnasium, Ludwigshafen, Germany. He obtained his first degree in physics from the University of Freiburg and his master's degree in mathematics and physics from the University of Connecticut under a Fulbright scholarship. In 2001, he obtained his PhD from University of Potsdam under Martin Wilkens with a thesis entitled Entanglement in Quantum Information Theory. In 2001-2002, he was a Feodor Lynen Fellow at Imperial College London. In 2002-2003, he was a visiting scholar at Caltech. During 2002-2005, he was a junior professor at the University of Potsdam. During the 2005-2008 period he was a lecturer at Imperial College London. In 2008, he became a full professor at the University of Potsdam and in 2011 a full professor at the Free University of Berlin. In 2009-2010, he was a fellow at the Institute for Advanced Study, Berlin.

A PROGRAMMABLE ATOM-PHOTON QUANTUM INTERFACE

Jürgen Eschner

Tuesday, March 9th, 12:30, 30m

We are implementing a comprehensive set of single-atom-single-photon quantum interfaces that enable controlled generation, storage, transmission, conversion, and entanglement of photonic and atomic qubits in quantum networks. Such tools are required, for example, in quantum repeater protocols for reliable intermediate storage and long-range transmission of quantum information. Specifically, we demonstrated a programmable ion-photon interface, employing controlled quantum interaction between a single trapped 40Ca+ ion and single photons [1,2]. Depending on the choice of input and output qubits, the interface protocol serves as an atom-to-photon or photon-to-atom qubit converter, or as a source of entangled atom-photon pair states. The interface lends itself particularly to integrating Ca+ ions with entangled photon pairs from a resonant, narrowband spontaneous parametric down-conversion (SPDC) source [3,4]. We demonstrate high-fidelity transfer of entanglement from an SPDC photon pair to atom-photon pairs, as well as atom-to-photon quantum bit teleportation [5]. We also extend our quantum network toolbox into the telecom regime by quantum frequency conversion of ion-entangled photons [6]. The reverse conversion process from 1550-nm telecom photons to ion-resonant photons at 854 nm is also realized, with high fidelity after 40 km of fiber transmission [7].

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Speaker

The experimental research of Jürgen Eschner and his collaborators is dedicated to the controlled interaction between light and matter in the quantum mechanical regime.

The main goal is to study and experimentally realize the transformation between quantum states of single photons and single atoms. For this purpose, single laser-cooled atoms in atom and ion traps and quantum mechanically entangled photon pairs are used, as well as high Q optical resonators in which light fields are stored and controlled.

COMMUNICATON NETWORKS: QUO VADIS?

Frank Fitzek

Friday, March 12th , 14:00, 20m

This talk will describe the evolution and revolution in communication networks by the example of softwarization and 5G technology. It will explain why the aforementioned (r)evolution was following the needs of industry or consumer market. Based on the current developments the talk also looks into the future, describing the rush for 6G technology and why we better should focus on more promising features and trends in communication networks such as quantum communication, molecular communication, or Post-Shannon.

Speaker

Frank H. P. Fitzek is a Professor and head of the "Deutsche Telekom Chair of Communication Networks" at TU Dresden coordinating the 5G Lab Germany. He is the spokesman of the DFG Cluster of Excellence CeTI.

He received his diploma (Dipl.-Ing.) degree in electrical engineering from the University of Technology – Rheinisch-Westfälische Technische Hochschule (RWTH) – Aachen, Germany, in 1997 and his Ph.D. (Dr.-Ing.) in Electrical Engineering from the Technical University Berlin, Germany in 2002 and became Adjunct Professor at the University of Ferrara, Italy in the same year. In 2003 he joined Aalborg University as Associate Professor and later became Professor.

He co-founded several start-up companies starting with acticom GmbH in Berlin in 1999. He has visited various research institutes including Massachusetts Institute of Technology (MIT), VTT, and Arizona State University. In 2005 he won the YRP award for the work on MIMO MDC and received the Young Elite Researcher Award of Denmark. He was selected to receive the NOKIA Champion Award several times in a row from 2007 to 2011. In 2008 he was awarded the Nokia Achievement Award for his work on cooperative networks. In 2011 he received the SAPERE AUDE research grant from the Danish government and in 2012 he received the Vodafone Innovation prize. In 2015 he was awarded the honorary degree "Doctor Honoris Causa" from Budapest University of Technology and Economics (BUTE).

His current research interests are in the areas of wireless and 5G communication networks, network coding, cloud computing, compressed sensing, cross layer as well as energy efficient protocol design and cooperative networking.

START UPS: THE BETTER RESEARCH VEHICLE?

Frank Fitzek

Wednesday, March 10th, 14:00, 20m

By the example of three Start Ups it is shown that research can be carried out and monetized successfully. The three examples cover robotics, connectivity, and human-machine interaction.

Speaker

Frank H. P. Fitzek is a Professor and head of the "Deutsche Telekom Chair of Communication Networks" at TU Dresden coordinating the 5G Lab Germany. He is the spokesman of the DFG Cluster of Excellence CeTI.

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His current research interests are in the areas of wireless and 5G communication networks, network coding, cloud computing, compressed sensing, cross layer as well as energy efficient protocol design and cooperative networking.

THEORY THAT MATTERS!

Frank Fitzek

Wednesday, March 10th, 11:20, 40m

This talk will motivate the need for contributions in theory and implementation for a given research field. By the example of past research activities the theory that matters approach is highlighted. As it will be explained in the talk, the approach will lead to meaningful research directions as well as leading to dissemination and exploitation potential.

Speaker

Frank H. P. Fitzek is a Professor and head of the "Deutsche Telekom Chair of Communication Networks" at TU Dresden coordinating the 5G Lab Germany. He is the spokesman of the DFG Cluster of Excellence CeTI.

He received his diploma (Dipl.-Ing.) degree in electrical engineering from the University of Technology – Rheinisch-Westfälische Technische Hochschule (RWTH) – Aachen, Germany, in 1997 and his Ph.D. (Dr.-Ing.) in Electrical Engineering from the Technical University Berlin, Germany in 2002 and became Adjunct Professor at the University of Ferrara, Italy in the same year. In 2003 he joined Aalborg University as Associate Professor and later became Professor.

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His current research interests are in the areas of wireless and 5G communication networks, network coding, cloud computing, compressed sensing, cross layer as well as energy efficient protocol design and cooperative networking.

DESIGNING RATE-EFFICIENT CODED QUANTUM NETWORKS

Shayan Srinivasa Garani

Friday, March 12th , 09:30, 20m

Distributed quantum information stored across the nodes of a coded quantum network can help in quantum network recovery from node failures using encoded graph states. This problem is particularly interesting from the context of distributed quantum storage networks since a node loss leads to a mixed state post quantum decoherence, without any classical analogy. In this talk, I will present how rate-optimal quantum network code designs can be done, resilient to a single node failure using only local operations within the neighborhood of the lost node. These ideas can generalize and scale to arbitrary quantum node failures, useful for the design of next generation quantum networks. Discussions will be held on the theoretical and practical feasibility of the proposed ideas.

Speaker

Shayan Srinivasa Garani received his Ph.D. in Electrical and Computer Engineering from Georgia Institute of Technology, Atlanta, M.S. from the University of Florida, Gainesville and B.E. from Mysore University. He has held senior engineering positions within Broadcom Corporation, ST Microelectronics and Western Digital. Prior to joining IISc, Dr. Garani was leading various research activities, managing and directing research and external university research programs within Western Digital. He was the Chairman for signal processing for the IDEMA-ASTC and a co-chair for the overall technological committee.

He is currently the Chair for IEEE Data Storage Technical Committee. His research interests include broad areas of channels engineering for physical data storage, quantum information processing, neural networks and learning systems and music signal processing.

DEPLOYMENT OF QKD WITH COMMERCIAL TRANSPORT EQUIPMENT

Helmut Grießer

Wednesday, March 10th, 16:30, 20m

Future-proofing current fibre networks with quantum key distribution (QKD) is an attractive approach to combat the ever growing breaches of data theft. This talk is about enabling long-term security for high-speed data. We give an overview of the QKD used cases. Furthermore, we compare information theoretic security and long-term security. We report on the real world QKD developments, Enabling long-term security for high-speed data. As an example of a link where QKD is used, we report on the UK regional network (the Cambridge quantum network).

Speaker

Since 2016 Helmut Grießer has been responsible for advancing innovation to enhance the capacity, range, security and agility of optical networks from data center interconnects to long-haul transmission. Prior to that he worked as one of the company's principal engineers.

During his career he has authored or co-authored more than 100 technical publications and is a frequent reviewer of scientific papers. His research activities include digital signal processing, coding and encryption for optical communication systems.

Before joining ADVA, Helmut Grießer held senior positions in research teams for Ericsson, coordinating projects focused on high-speed optical fiber communications and leading fiber communications research. He has also worked as a research engineer for Marconi. He has a master's degree and a PhD in electrical engineering from Ulm University.

INFINITE-FOLD ENHANCEMENT IN COMMUNICATIONS CAPACITY USING PRE-SHARED ENTANGLEMENT

Saikat Guha

Friday, March 12th , 17:30, 20m

Pre-shared entanglement can significantly boost communication rates in the regime of high thermal noise, and a low-brightness transmitter. In this regime, the ratio between the entanglement-assisted capacity and the Holevo capacity, the maximum reliable-communication rate permitted by quantum mechanics without any pre-shared entanglement as a resource, is known to scale as $\log(1/N_S)$, where $N_S \ll 1$ is the mean transmitted photon number per mode. This is especially promising in enabling a large boost to radio-frequency communications in the weak-transmit-power regime, by exploiting pre-shared optical-frequency entanglement, e.g., distributed by the quantum internet. In this paper, we propose a structured design of a quantum transmitter and receiver that leverages continuous-variable pre-shared entanglement from a downconversion source, which can harness this purported infinite-fold capacity enhancement—a problem that has been open for over a decade. Its implication to the breaking of the well-known *square-root law* for covert communications, with entanglement assistance, is discussed.

Speaker

Saikat Guha is an Associate Professor at the University of Arizona, College of Optical Sciences, starting July 2017. Saikat received his Bachelor of Technology degree in Electrical Engineering from Indian Institute of Technology, Kanpur in 1998, and his S.M. and Ph.D. degrees in Electrical Engineering and Computer Science from Massachusetts Institute of Technology in 2004 and 2008, respectively. From 2008 to 2017, he worked for Raytheon BBN Technologies, where in his most recent role as Lead Scientist, he led various sponsored projects funded by DARPA, ONR, NSF, DoE, and ARL, in topics surrounding quantum enhanced photonic information processing. He was one of the founding members of the Quantum Information Processing group at BBN, formed in 2009.

Saikat's research interests are in the quantum limits of optical communications and quantum-secured communications (rate) and optical sensing (resolution)—both in the evaluations of these fundamental limits using tools from quantum information and estimation theory, as well as in the associated circuit synthesis problem, that of trying to piece together familiar classical and non-classical optical building blocks to realize transmitters and receivers needed to attain those limits. He is interested in the design of quantum repeaters for long-distance entanglement distribution. He has also been lately interested in continuous variable photonic quantum computing, and quantum networks.

TOWARDS A SEMICONDUCTOR BASED QUANTUM REPEATER - PART 1

Sven Höfling

Tuesday, March 9th, 11:50, 30m

One of the most promising routes toward long-distance quantum communication is based upon quantum repeaters (QR) that include intermediate stations equipped with quantum memories. Here, we discuss the common efforts of the semiconductor consortium within the BMBF financed network Quantum Link Extended (Q.Link.X) towards the QR. Important pre-conditions for a quantum repeater are high-brightness quantum light sources, long coherent quantum memory times and efficient and high-fidelity quantum optical operations such as entanglement swapping. We will present the state-of-the art obtained in semiconductor technology achieved within the consortium on deterministic fabrication of quantum optical devices and interfaces, including tunable devices. High efficiency single photon sources with high indistinguishability has been obtained. Furthermore, recent progress towards a QR cell and QR segment at 900 nm will be presented as well as compete coherent control of a single quantum dot spin at 1,55 μm wavelengths. We will also demonstrate swapping of entangled states between pairs of photons emitted by a single dot. Furthermore, we will report on the on-chip integration of a quantum dot (QD) microlens with a 3D-printed micro-objective in combination with a single-mode on-chip fiber coupler. The efforts to provide the relevant quantum photonic hardware emitting directly in the telecom C-Band (around 1.55 μm) will also be presented.

Speaker

Sven Höfling studied applied physics at the Coburg University of Applied Sciences. In 2002, he graduated with a diploma thesis on GaN-based LEDs, conducted at the Fraunhofer Institute for Applied Solid State Physics inFreiburg. Sven Höfling then moved to the Department of Technical Physics at the University of Würzburg. There he completed his doctorate with a thesis on "Monomodig emitting GaAs/AlGaAs quantum cascade lasers" and took over the leadership of the Optoelectronic Materials and Devices working groups. During his scientific activity, he succeeded in producing highly regarded papers on future photonic devices such as polariton lasers, single photon sources, quantum dot lasers, solar cells or quantum memories. In October 2013, he took up a professorship at the University of St. Andrews in Scotland. After his professorship in Scotland, Höfling received an appointment to the Chair of Technical Physics at the University of Würzburg as successor to Prof. Forchel and heads the Gottfried Landwehr Laboratory for Nanotechnology. For his work on the electrically driven polariton laser, the German Physical Society awarded him the Walter Schottky Prize in 2014.

THE INFORMATION CAPACITY OF ENTANGLEMENT-ASSISTED QUANTUM GAUSSIAN MEASUREMENTS

Alexander Holevo

Wednesday, March 10th, 09:00, 60m

The talk is devoted to investigation of the entropy reduction and entanglement-assisted classical capacity (maximal information gain) of continuous variable quantum measurements. These quantities are computed explicitly for multimode Gaussian measurement channels of type 1 (generalized heterodyning) and type 2 (generalized homodyning). For this we establish a fundamental property of the entropy reduction of a measurement: under a restriction on the second moments of the input state it is maximized by a Gaussian state (providing an analytical expression for the maximum). In the case of one mode, the gain of entanglement assistance is investigated in detail.

Speaker

Alexander Holevo is a Soviet and Russian mathematician, one of the pioneers of quantum information science. He has been a member of Steklov Mathematical Institute, Moscow, since 1969. He graduated from Moscow Institute of Physics and Technology in 1966, defended a PhD Thesis in 1969 and a Doctor of Science Thesis in 1975. Since 1986 he is a Professor (Moscow State University and Moscow Institute of Physics and Technology). He made substantial contributions in the mathematical foundations of quantum theory, quantum statistics and quantum information theory. In 1973 he obtained an upper bound for the amount of classical information that can be extracted from an ensemble of quantum states by quantum measurements (this result is known as Holevo's theorem). He developed the mathematical theory of quantum communication channels, the noncommutative theory of statistical decisions, he proved coding theorems in quantum information theory and revealed the structure of quantum Markov semigroups and measurement processes. He is the author of about one-hundred and seventy published works, including five monographs.

THEORY AND PRACTICE OF WIFI NETWORK DEVELOPMENT

Thomas Hühn and Julius Schulz-Zander

Wednesday, March 10th, 17:00, 20m

Systems Research in Wireless IEEE 8021.11 networks challenged years of wireless modelling work. Significant research results based on wireless channel and mac80211 modells did not hold in real WiFi networks. In this talk we present the Dev-Ops challenges in real productive wireless networks and the experimental effort needed to validate and analyse its systems performance. The example of mac802.11 rate control algorithms and its assumptions from theory are presented and compared to more robust resource allocation approaches. The importance of randomisation for robust resource allocation in wireless systems is is highlighted by concrete example, to provide an API for potential applications of randomized quantum protocols. The practical applicability to entangled quantum networks will be discussed.

In this talk, we motivate the benefits of integrating systems research as early as possible, to validate theoretical results in testbed and network experiments.

Speakers

The main research areas of the communication technology department at Nordhausen University of Applied Sciences, which is headed by Prof. Dr.-Ing. Thomas Hühn, lies in the practical resource allocation of transmission power and transmission rates in wireless WLAN networks. Prof. Hühn did his doctorate on efficient algorithms for resource allocation in application-oriented WLAN-based radio networks and acquired and managed various national and international research projects. As an active partner in national (SupraCoNeX - BMBF, Verdele FACTS - BMWi) and European (MONROE - Horizon2020) research projects, Prof. Hühn has a sound technical knowledge of network experiments for the validation and performance evaluation of algorithms for resource allocation and wireless software-defined networks concepts in WLAN-based radio networks appropriated.

Julius Schulz-Zander is a Senior Researcher and head of the Intelligent Network Architectures research group at the Fraunhofer Heinrich Hertz Institute (HHI) in Berlin, Germany. At TU Berlin he is appointed to teach the graduate-level course "Network Protocols and Architectures", that explains the architecture of the Internet and the basics of every communication within it, since several years. Before that, he was a postdoctoral researcher and PhD student in Prof. Anja Feldmann's Internet Network Architectures (INET) research group at TU Berlin and Deutsche Telekom Laboratories (T-Labs). He received a Doctoral degree with distinction "summa cum laude" and Diploma degree in Computer Science from Technische Universität Berlin, Germany, in 2016 and 2011, respectively. He was associated as a short term scholar in Prof. Nick McKeown's research group at Stanford University and a visiting researcher in Prof. Doug Leith's research group at Hamilton Institute at Maynooth University, Ireland. He is currently involved in several national research projects on applying AI/ML concepts on communication networks such as SupraCoNeX, KICK, and FabOS. He also led the BMWi flagship project IC4F - Industrial Communications for Factories. His research interests range from wireless access technologies, softwarization and virtualization of computer networking to autonomous networks. Furtermore, he is also curious how entanglement assisted communication networks will shape future generations of wireless communication networks.

HIGH-DIMENSIONAL ENTANGLEMENT FOR QUANTUM COMMUNICATION

Marcus Huber

Thursday, March 11th, 11:30, 20m

Entanglement unlocks many applications in quantum communication, such as the highest possible level of security in quantum key distribution. As photons are inevitably lost or decohered over longer distances, it seems obvious that using the full spectrum of photonic degrees of freedom is desirable. In addition to more encodable bits per photon, entanglement in high dimensions also yields a surprising resistance to noise. This comes at the expense of more complicated measurements that in themselves can contribute to the overall noise in the data, leading to an interesting optimisation. In this talk I will discuss the origin of noise resistance and how it can be practically realised in different photonic implementations using entangled photons.

Speaker

Marcus Huber is a Group Leader at IQOQI Vienna, where he is leading a research group in the intersection of Quantum Information and Quantum Thermodynamics. He is also working at the interface between quantum information theory and experimental implementations, especially in quantum photonics. His group consists of around 15 postdocs and PhD students with different backgrounds and expertise, creating a vibrant and friendly atmosphere united in a common passion for science.

CAVITY ENHANCEMENT FOR EFFICIENT DIAMOND-BASED SPIN-PHOTON INTERFACES

David Hunger

Tuesday, March 9th, 15:20, 30m

Color centers in diamond provide a promising combination of properties for the realization of large-scale quantum networks. In particular, NV centers stand out due to their long electron spin coherence of up to seconds, their potential to harness individual 13C nuclear spins as even longer-lived multi-qubit memory register, and the availability of Fourier-limited spin-selective cycling transitions which enable single-shot readout. A key remaining challenge is to improve on the efficient extraction of coherent photons to enable spin-photon and spin-spin entanglement at higher rates.

In this talk I will summarize the recent progress on using microcavities to enhance the emission from color centers in diamond and compare approaches used for NV and SiV centers in diamond.

Speaker

David Hunger received his PhD in 2010 working on ultracold atoms and Bose Einstein condensates coupled to micromechanical oscillators. In parallel, he developed fiber-based high-finesse optical microcavities, a cavity platform that has become a widespread tool for cavity QED, spectroscopy and sensing. As a group leader with Nobel laureate Ted Hänsch, he used these cavities to demonstrate a scanning cavity microscope, cavity-enhanced Raman hyperspectral imaging, and fluorescence enhancement of various solid-state quantum emitters. In June 2016 he accepted a W3 Professor position at the faculty of Physics of the KIT.

INTERFACING SOLID-STATE SPINS AND PHOTONS FOR NETWORKED QUANTUM TECHNOLOGIES

Florian Kaiser

Tuesday, March 9th, 16:30, 30m

Further, solid-state systems promise scalability as they lend themselves to on-chip integration into nanophotonic resonators to boost the efficiency of the aforementioned interfaces [2, 3]. One of the grand challenges toward this goal is to identify suitable systems that show only little to no deterioration of spin-optical properties after integration into nanostructures. This presentation starts with a brief summary on spin-photon interfaces based on diamond color centers and their limitations toward scalable networks. In the second part, we will introduce systems that promise scalability and integration due to their weak interaction with the local environment. In particular, this presentation focusses on silicon vacancy centers in semiconductor silicon carbide, for which we have recently shown spin-optical stabilities that are on-par with diamond defects [4]. We show a high-fidelity interface in which a single spin controls the properties of two-photon states with more than 90% fidelity [5]. Additionally, we show that the system can be integrated into nanophotonic waveguides with almost no degradation of the spin-optical quantum properties. Those results represent a milestone toward CMOS compatible integration of optically-active solid-state spins into nanophotonic devices [6, 7]. In combination with recently demonstrated control over nuclear spin qubits [5, 8], this technology holds great promises toward the development of networked quantum technologies.

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Speaker

Florian Kaiser received the Ph.D. degree in physics from the University Nice Sophia Antipolis, Nice, France, in 2012, where he worked in the “Quantum Information with Light and Matter” Group of Dr. S. Tanzilli on the development of various photonic entanglement sources, and the realization of an entanglement-enabled delayed-choice experiment. He continued his work in 2013 in Nice and developed a teleportation experiment with long coherence time photons. In 2014, he joined the German Electron-Synchrotron facility (DESY) in the framework of the European XFEL Project. His responsibilities included project management, laser development, and engineering, as well as beamline installation. His work received the award in 2013 by both the European Physical Society with the QEOD Thesis Prize in the category of “Applied Aspects” and by the Medal of the University Nice Sophia Antipolis.

PRIVACY AND SECURITY IN QUANTUM NETWORK

Elham Kashefi

Friday, March 12th , 10:30, 20m

Multi-Party Quantum Computation, involves distrustful parties wishing to perform a joint computation without leaking information. This functionality has attracted a lot of attention as a potential killer-app for quantum networks through its ability to preserve privacy and integrity of the highly valuable computations that quantum computers would enable us to obtain. In this talk I present the latest progress towards bringing MPQC protocol to the actual real world. We improve on almost all known efficiency metrics and introduce new functionalities that may be of independent interest for designing future protocols.

Speaker

Elham Kashefi is Professor of Quantum Computing at the School of Informatics, University of Edinburgh, and Directeur de recherche au CNRS at LIP6 Sorbonne Universite. She co-founded the fields of quantum cloud computing and quantum computing verification, and has pioneered a trans-disciplinary interaction of hybrid quantum-classical solutions from theoretical investigation all the way to actual experimental and industrial commercialisation (Co-Founder of VeriQloud Ltd). She has been awarded several UK, EU and US grants and fellowships for her works in developing applications for quantum computing and communication. She served as the Associate Director of the NQIT Hub before being elected to lead the software activities within the quantum computing and simulation hub

CONCEPTS BEHIND HIGH-TECH ENTREPRENEURIAL ACTIVITIES IN THE GERMAN MARKET

Daniel Khafif

Wednesday, March 10th, 15:30, 20m

The first flights of Brothers Wright or Konrad Zuse's Z3: Any historic entrepreneurial start had – and has – many obstacles to solve – and as often, upcoming obstacles are not predictable. What is predictable though, if we look back in history, is, that science drives economy – but sometimes it's as well the economists driving science.

Thus, growth is a result of interdisciplinary network: Industry, government, Research - especially nowadays, when ROI forms part of the strategy budget and investors need fast results. History shows that both, an operation network but as well a public interest are needed, in any era, let it be an aristocracy or democracy, that does not matter. Because research means progress. What counts, is connected co-work of economic and scientific power. Pioneer mentality is the the lowest common denominator of politics, economy and science.

During my keynote I will let you dive deeper into the world and history of incorporating potential market perspectives and go-to-market strategies on the road from research to industry, especially focusing Germany, but as well the USA, the UK and more countries.

Speaker

Daniel Khafif has been working as a copywriter, content director, storyteller and journalist for over 20 years. He lectures communication at ISM.de and speaks and writes fluent Spanish and English besides his native German. His focus is on technical, interdisciplinary and intercultural communication, especially for mobility, IT, aerospace, architecture, tourism.

As a copywriter for the automotive company Suzuki, he won the Golden IF Award in 2008. Afterwards he was editorial director for Airbus/EADS and worked in many creative agencies for text (print/online), storytelling and content.

QUANTUM STATE REDISTRIBUTION FOR ENSEMBLE SOURCES

Zahra Khanian

Friday, March 12th , 15:30, 20m

We consider a generalization of the quantum state redistribution task, where pure multipartite states from an ensemble source are distributed among an encoder, a decoder and a reference system. The encoder, Alice, has access to two quantum systems: system A which she compresses and sends to the decoder, Bob, and the side information system C which she wants to keep at her site. Bob has access to quantum side information in a system B, and wants to decode the compressed information in such a way to preserve the correlations with the reference system on average.

As figures of merit, we consider both block error (which is the usual one in source coding) and per-copy error (which is more akin to rate-distortion theory), and find the optimal compression rate for the second criterion, and achievable and converse bounds for the first. The latter almost match in general, up to an asymptotic error and an unbounded auxiliary system; for so-called irreducible sources they are provably the same.

Speaker

Zahra Khanian received her MSc in Electrical Engineering from Sharif University of Technology in Iran. She joined the Quantum Information group at Universitat Autonoma de Barcelona led by ICREA Professor Dr. Andreas Winter, and carried out her PhD studies in Quantum Optics between Prof. Winter's group and the Quantum Optic Theory group at ICFO led by ICREA Professor at ICFO Dr. Maciej Lewenstein. Dr. Khanian's thesis entitled "From Quantum Source Compression to Quantum Thermodynamics" was supervised by Professors Winter and Lewenstein. Since 2020, she is at the Technical University of Munich in Prof. König's group.

HYBRID-PHOTONIC INTEGRATED CIRCUITS FOR CLASSICAL AND QUANTUM COMMUNICATIONS

Moritz Kleinert

Friday, March 12th , 12:00, 20m

Hybrid photonic integration offers a way of realizing versatile components for a broad array of applications, especially in optical communications. This talk will discuss the current progress on hybrid photonic integrated circuits for quantum communications developed at Fraunhofer HHI as well as similarities and differences with similar components for classical communications. On this basis, possible pathways towards combined classical and quantum photonic integrated circuits for all-optical networks are proposed.

Speaker

Moritz Kleinert is a researcher in the Photonic Components Department at the Fraunhofer Heinrich Hertz Institute (HHI). He develops photonic components and integrated circuits based on InP/polymer/graphene/SiN material systems for telecom/datacom, sensing, analytical, and medical applications according to customer needs and specifications.

The HHI technology platforms PolyBoard and SiNiX allow for rapid prototyping, short iteration cycles and low upfront development effort and cost. His expertise includes simulation, CAD, technology development, device manufacturing, characterization and qualification.

NETSQUID,
A DISCRETE-EVENT SIMULATION PLATFORM
FOR QUANTUM NETWORKS

Rob Knegjens

Thursday, March 11th, 09:00, 20m

In order to bring quantum networks into the real world, we would like to determine the requirements of quantum network protocols including the underlying quantum hardware. Since sufficiently detailed architecture proposals are generally too complex for mathematical analysis, it is natural to employ numerical simulation. Here, we introduce NetSquid, a generic discrete-event based platform for simulating all aspects of quantum networks and modular quantum computing systems, ranging from the physical layer hardware and the control plane all the way to the application level. We study several use cases to showcase the power of NetSquid. First, we perform a detailed physical layer simulation of repeater chains using processing nodes based on NV centres in diamond, as well as repeaters based on atomic ensembles. Second, we study the control plane of a recently introduced quantum switch beyond the analytically known regime. Use of the novel discrete-event paradigm for simulating networks allows the study of time-dependent noise in an entirely modular simulation, predicting the combined performance of physical hardware and control. Finally, we showcase Netsquid's ability to investigate large networks by simulating entanglement distribution over a chain of up to one thousand nodes using simplified physical models in less than three seconds.

Speaker

Rob Knegjens began studying electrical engineering and computer science at the University of Canterbury in New Zealand. A strong interest in theoretical physics led him to change his major after two years. After graduating with an honours degree (2006, first class) he was awarded the Rutherford memorial scholarship to continue his studies abroad. He chose to do so at Utrecht University in the Netherlands, completing a masters degree in theoretical physics (2009, cum laude). Rob continued as a PhD researcher (2010-2014) in theoretical particle physics at the Nikhef institute in Amsterdam on the topic of matter-antimatter symmetry violating interactions at the Large Hadron Collider at CERN.

Aside from physics, Rob has a passion for creating software. During his PhD he and a colleague, Damien George, co-created the Paperscape map project: an online interactive visualization of the 1 million+ articles on the arXiv. After his PhD Rob worked as a postdoc at the TU Munich, where he continued his research on the phenomenology of quark flavour-changing processes. From there he made a career switch to industry, joining Shell as a geophysicist in 2015. Missing a research aspect to his work, he switched jobs to the Intelligent Autonomous Systems (IAS) department of TNO in 2016, where he has worked on multi-agent systems and discovered a fascination for quantum technology.

Rob joined QuTech in 2017 when he and colleague Julio Oliveira were tasked with developing a quantum network discrete event simulator for the theoretical groups of David Elkouss and Stephanie Wehner. Rob brought to QuTech a multi-disciplinary background in software development, Monte Carlo simulations and theoretical physics. The resulting simulator, NetSquid, is being widely used within the QINC division of QuTech, as well as in European projects such as the Quantum Internet Alliance. A beta release was made publicly available in 2020. Rob leads NetSquid's development team.

NETWORK AND SOFTWARE ARCHITECTURE FOR THE QUANTUM INTERNET

Wojciech Kozlowski

Friday, March 12th , 11:30, 20m

The quantum technology revolution brings with it the promise of a quantum internet. A new — quantum — network stack will be needed to account for the fundamentally new properties of quantum entanglement. The first realisations of quantum networks are imminent and research interest in quantum network protocols has started growing. I will present a proposal for a quantum network architecture with a particular focus on the network layer responsible for end-to-end entanglement connectivity and a software architecture based on a programmable quantum data plane.

Speaker

Wojciech Kozlowski is a postdoctoral researcher at QuTech at the Delft University of Technology. His work is focused on developing the network and software architecture for quantum networks. He is part of Stephanie Wehner's group which places him within the Quantum Internet Division at QuTech and the Quantum Internet Alliance funded by the European Unions Quantum Flagship program.

He did his MSci and PhD in quantum physics, but after graduating from Oxford he worked as a software engineer for two years in the network software team at Metaswitch. This has placed him in the unusual position of having experience in both computer networking and quantum physics which is how he ended up at QuTech. Through his brief stint in industry he has also acquired an interest in purely classical topics such as software-defined networking and programming languages like Rust.

OPTICLOCK – QUANTUM TECHNOLOGY ALMOST READY FOR ROLL-OUT

Dieter Meschede

Wednesday, March 10th, 14:30, 20m

Late in 2016 a small number of pilot projects were initiated by the BMBF in order to boost interest in quantum technology both in the scientific community and the society. Opticlock was one of the 3 projects selected in an unusual procedure by the scientific community itself. Opticlock had proposed to take a single ion clock from an exuberant scientific laboratory set-up to a system ready for roll-out from the laboratory. The opticlock is now up and running continuously and living up to the expected specifications. I will review the scientific status and try to give some insight how a combination of six larger and smaller firms, two public research institutes, and two universities achieved a promising result.

Speaker

Dieter Meschede studied physics at the University of Cologne, graduating in 1979, and received his doctorate in 1984 from the Ludwig Maximilian University of Munich (radiation interaction of Rydberg atoms, realization of a one-atom maser), where he also completed his habilitation in 1989. As a post-doctoral researcher, he was Lecturer at Yale University from 1984 to 1986, where he became Assistant Professor in 1986. From 1988 to 1990 he was Senior Scientist at the Max Planck Institute for Quantum Optics in Garching. In 1990 he became a full professor of physics at Leibniz University in Hanover and in 1994 at Rheinische Friedrich-Wilhelms University in Bonn. In 1999/2000 he chaired the physics department there, and from 2008 to 2012 he was a member of the Senate.

He teaches at the Institute of Applied Physics at the University of Bonn, where he helped establish the Bonn International Graduate School in Physics and Astronomy in 2001. He is also group leader of the Quantum Technology Group at the University of Bonn, and he was coordinator of the European Commission's Nanostructure Fabrication by Controlled Deposition of Atoms (NanoFab) program in 1998-2003. In 2007 he chaired the program committee of the International Quantum Electronics Conference (IQEC) and in 2009 he chaired the European Quantum Electronics Conference (EQEC). In 2010, he was the spokesperson of the collaborative project Quantum Communication of the German Federal Ministry of Education and Research. From 2018 to April 1, 2020, he was president of the German Physical Society and is currently its vice president.

He has been working on questions of atomic, molecular, and quantum physics for about thirty years. One of the greatest successes of his research group is the so-called "conveyor belt of light" that moves and sorts individual atoms with the help of laser beams, which could allow atoms to be used as a computational device for a quantum computer. Another important area of his research is atomic lithography, which can be used to structure material surfaces with sub-micrometer accuracy using atomic beams - a method of nanotechnology.

He is the editor of the last three editions of the textbook "Gerthsen Physics" and author of the textbook "Optics, Light and Lasers" and since 2012 he is the main editor of the journal Applied Physics B - Optics and Lasers, which plays a central role in applied physics. He has been a full member of the Academia Europaea since 2012, and an associate member of the German Academy of Science and Engineering (acatech) since 2021.

From 2005 to 2018, he was scientific director of the Physics Center Bad Honnef of the DPG, on whose scientific council he had been since 1998.

Q.LINK.X - COOPERATION AND OUTREACH

Dieter Meschede

Tuesday, March 9th, 09:00, 20m

Quantum technology is expected to produce significant impact on several branches of future information technology relevant for the society, including e.g. secure communication links. Simple point to point quantum links have become commercially available already some time ago. Only advanced concepts such as quantum networks, however, promise to make use of the full advantage of quantum technology, while the expertise on these concepts remains to date largely confined to the academic world and is furthermore distributed over numerous laboratories. Therefore, beyond the challenges posed by purely scientific and technological questions there are challenges to be met by the scientific community, the commercial world, and the society – rendering efficient concepts of cooperation and outreach important. I will give reflections on this issue from the perspective of the academic world.

Speaker

Dieter Meschede studied physics at the University of Cologne, graduating in 1979, and received his doctorate in 1984 from the Ludwig Maximilian University of Munich (radiation interaction of Rydberg atoms, realization of a one-atom maser), where he also completed his habilitation in 1989. As a post-doctoral researcher, he was Lecturer at Yale University from 1984 to 1986, where he became Assistant Professor in 1986. From 1988 to 1990 he was Senior Scientist at the Max Planck Institute for Quantum Optics in Garching. In 1990 he became a full professor of physics at Leibniz University in Hanover and in 1994 at Rheinische Friedrich-Wilhelms University in Bonn. In 1999/2000 he chaired the physics department there, and from 2008 to 2012 he was a member of the Senate.

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He is the editor of the last three editions of the textbook "Gerthsen Physics" and author of the textbook "Optics, Light and Lasers" and since 2012 he is the main editor of the journal Applied Physics B - Optics and Lasers, which plays a central role in applied physics. He has been a full member of the Academia Europaea since 2012, and an associate member of the German Academy of Science and Engineering (acatech) since 2021.

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TOWARDS A SEMICONDUCTOR-BASED QUANTUM REPEATER - PART 2

Peter Michler

Tuesday, March 9th, 11:10, 30m

One of the most promising routes toward long-distance quantum communication is based upon quantum repeaters (QR) that include intermediate stations equipped with quantum memories. Here, we discuss the common efforts of the semiconductor consortium within the BMBF financed network Quantum Link Extended (Q.Link.X) towards the QR. Important pre-conditions for a quantum repeater are high-brightness quantum light sources, long coherent quantum memory times and efficient and high-fidelity quantum optical operations such as entanglement swapping. We will present the state-of-the art obtained in semiconductor technology achieved within the consortium on deterministic fabrication of quantum optical devices and interfaces, including tunable devices. High efficiency single photon sources with high indistinguishability has been obtained. Furthermore, recent progress towards a QR cell and QR segment at 900 nm will be presented as well as compete coherent control of a single quantum dot spin at 1,55 μm wavelengths. We will also demonstrate swapping of entangled states between pairs of photons emitted by a single dot. Furthermore, we will report on the on-chip integration of a quantum dot (QD) microlens with a 3D-printed micro-objective in combination with a single-mode on-chip fiber coupler. The efforts to provide the relevant quantum photonic hardware emitting directly in the telecom C-Band (around 1.55 μm) will also be presented.

Speaker

Peter Michler got his Physics Diploma and his PhD degree from the University of Stuttgart in 1990 and 1994, respectively. He worked as post-doc at the Max-Planck Institute for Solid State Research in Stuttgart from 1994 to 1995. From 1995 to 1999, he was a research group leader at the University of Bremen and from 1999 until 2000 he spent a one year research stay at the University of California, Santa Barbara. In 2001, he performed his Habilitation at the University of Bremen and he became a professor in 2003 at the University of Stuttgart. Since May 2006, he is the head of the Institute for Semiconductor Optics and Functional Interfaces at the University of Stuttgart, concentrating research on quantum dots, quantum optics, non-classical light sources and semiconductor lasers.

QUANTUM KEY DISTRIBUTION NETWORK WITH QUANTUM CANDIES

Tal Mor

Thursday, March 11th, 16:30, 20m

In 1996 Biham Huttner and Mor presented a quantum key distribution (QKD) network relying on centers connected via teleportation lines. The Biham-Huttner-Mor protocol, i.e., the case of a network with just one center, was later on found to be very useful also for designing the first measurement-device-independent QKD (MDI-QKD).

Very recently, in a conference proceedings (TPNC'2020), we presented a surprisingly simple and intuitive model, which we name "Jacobs' quantum candies" to demonstrate the Bennett-Brassard 1984 (BB84) protocol for QKD, a model using only green and red candies, filled with either chocolate or vanilla cream. We also greatly extended Jacobs' quantum candies to enable entanglement-based protocols.

Here I'll show that our quantum candies are sufficient for presenting Biham-Huttner-Mor QKD network hence also MDI-QKD.

Speaker

Tal Mor is professor of computer science at the Technion - Israel Institute of Technology. His prime goal of research is the investigation of new models of computation and information processing, as manifested in the rapidly evolving area of quantum information, computation and cryptography. This field is usually called "Quantum Information Processing (QIP)". First, he is highly interested in finding and developing new applications iri this area, and in particular "near-future" ones. Second, as the usage of the full power of quantum information processing is sometimes far beyond current technology, He focus his research on analyzing the power of more "restricted models" or "limited models" - namely, models in which various practical considerations are taken into account, and "semi-quantum" models in which the allowed states or operations are restricted in some respects. Third (and closely related to the above two), he study the complex relationship between theoretical QIP achievements, proposed models for the physical realization of quantum information units (quantum bits, quantum trits, etc.), and the actual experimental implementations of these models. His goal here is to bridge the gap between QIP achievements and experimental implementations by creating more appropriate models and by suggesting novel experiments.

GENERATION AND DETECTION OF SINGLE PHOTONS

Kai Müller

Thursday, March 11th, 11:00, 20m

Single photons are key ingredients for many applications in quantum technologies. In this talk, I will discuss the dynamics of generating single photons using semiconductor quantum dots and recent progress in the development of highly-efficient superconducting single photon detectors. Due to their excellent optical properties, such as fast emission rates and nearly transform-limited linewidth, semiconductor quantum dots are promising as single-photon sources. Here, the fundamental limits of the single-photon purity and photon indistinguishability for resonantly driven two-level systems and three-level ladder systems will be discussed, as well as the origin of antibunching under weak cw excitation. Superconducting single photon detectors have established themselves as the most promising system for the detection of single photons in the visible and near-infrared wavelength spectrum. However, understanding their operation in detail is crucial for further improving their performance metrics and integration into quantum photonic integrated circuits.

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Speaker

Kai Müller studied Physics at TUM. After completing a PhD in Physics at TUM in 2013 he spent two years as a postdoctoral researcher at Stanford University, funded by a Feodor-Lynen fellowship from the Alexander von Humboldt foundation. After returning to Germany he established a junior research group at the Walter Schottky Institut of TUM, funded by the highly-competitive “Quantum Futur” program from the German ministry of education and research (BMBF). Since May 2017, he is one of the twenty members of the “Young Academy” of the Bavarian Academy of Sciences and Humanities. In April 2019 he was appointed as a Rudolf Mößbauer Tenure Track Professor in the Department of Electrical and Computer Engineering of TUM.

INFORMATION THEORETIC PERSPECTIVE ON QUANTUM REPEATERS

Uzi Pereg

Tuesday, March 9th, 17:10, 30m

We consider communication over a quantum broadcast channel with cooperation between the receivers. Through this setting, we provide an information-theoretic perspective on quantum repeaters. First, we observe that entanglement resources alone do not increase the achievable communication rates. By comparison with the recent results by https://doi.org/10.1038/s41467-020-15240-w, this observation reveals a violation of the BC-MAC duality between the broadcast channel with two receivers and the multiple-access channel with two transmitters. The next form of cooperation addressed is classical conferencing, where Receiver 1 can send classical messages to Receiver 2. We provide a regularized characterization of the classical capacity region and establish a single-letter formula for the special class of Hadamard broadcast channels. Given both classical conferencing and entanglement resources, Receiver 1 can teleport a quantum state to Receiver 2. This setting is intimately related to quantum repeaters, as the sender, Receiver 1, and Receiver 2 can be viewed as the transmitter, the repeater, and the destination receiver, respectively. When Receiver 1's sole purpose is to help the transmission to Receiver 2, the model reduces to the quantum primitive relay channel. We derive lower and upper bounds for each setting; and conclude with observations on the tradeoff between repeater-aided and repeaterless communication, and the bottleneck flow behavior of quantum repeaters.

Speaker

Uzi Pereg is a post-doctoral researcher in the Institute of Communication Engineering in the Technical University of Munich (TUM). He was awarded the Ph.D. degree at the Viterbi Faculty of Electrical Engineering, Technion - Israel Institute of Technology, Haifa, Israel, in 2019. Uzi received the B.Sc (summa cum laude) degree in Electrical Engineering from Azrieli College of Engineering, Jerusalem, Israel, in 2011, and the M.Sc. degree from Technion, Haifa, Israel, in 2015. His research interests are in the areas of quantum communications, information theory and coding theory. Uzi is a recipient of the Pearl Award for outstanding research work in the field of communications, the KLA-Tencor Award for an excellent conference paper, the Viterbi Scholarship of the Technion, and the CHE Scholarship for outstanding postdoctoral fellows in quantum science and technology.

ERBIUM-DOPED CRYSTALS: A NOVEL PLATFORM FOR QIP

Andreas Reiserer

Tuesday, March 9th, 17:50, 20m

In spite of decade-long research into different physical systems, the demonstration of a scalable platform for quantum information processing remains an outstanding challenge. In this context, we investigate the use of erbium-doped silicon [1] and silicate [2,3] crystals. This novel experimental platform offers unique potential to overcome the main bottlenecks of other quantum hardware: First, erbium dopants can exhibit second-long coherence in a temperature range that is accessible with 4He cryocoolers [4]. Second, the optical transition of erbium is the narrowest spectral feature ever measured in a solid. Thus, frequency multiplexed addressing of individual dopants [5] gives access to an unprecedented qubit density as long as spin-spin interactions can be suppressed by dynamical decoupling [3]. Finally, erbium is the only emitter for which lifetime-limited optical coherence in the telecommunications frequency window has been demonstrated [2]. Here, loss in optical fibers is minimal, which is a prerequisite for global quantum networks. In addition, operating below the bandgap energy of silicon allows for complex nanophotonic circuits with low loss that can be fabricated by standard processes of the semiconductor industry. Our approach may thus enable the realization of scalable distributed quantum information processing based on well-established technology.

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Speaker

Andreas Reiserer conducts research in the Otto Hahn Group Quantum Networks at the Max Planck Institute of Quantum Optics. The group "Quantum Networks" investigates new quantum systems. The focus is on single rare earth ions in optical resonators. These ions have extraordinary coherence properties unmatched by any other system, and their control is compatible with existing microfabrication processes and optical technologies. This opens unique opportunities to realize large quantum networks.

RARE-EARTH DOPANTS

Andreas Reiserer

Thursday, March 11th, 10:30, 20m

Distributed quantum networks [1] will allow users to perform tasks and to interact in ways which are not possible with present-day technology. Their implementation is a key challenge for quantum science and requires the development of stationary quantum nodes that can send and receive as well as store and process quantum information locally. The nodes are connected by quantum channels for flying information carriers, i.e., photons. These channels serve both to directly exchange quantum information between nodes and to distribute entanglement over the whole network. In order to scale such networks to many particles and long distances, an efficient interface between the nodes and the channels is required. While early work has focused on atoms trapped in vacuum [2], solid state systems may offer advantages with respect to scalability. This talk will therefore introduce rare-earth doped crystals as an emerging hardware platform for quantum network nodes [3]. Such crystals can serve as efficient quantum memories [4] with exceptional coherence times, with the current record of 6 h achieved in Eu:YSO [5]. Furthermore, ensemble memories can maintain a high bandwidth and multiplexing capacity, and store entanglement between photons [6]. Recent approaches have demonstrated the spectroscopy and multiplexed control of individual dopants by integrating them into optical resonators [7–9]. This may allow for the implementation of local deterministic quantum gate operations and thus pave the way for a realization of the seminal quantum repeater protocol [10] in order to scale quantum networks to global distances.

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Speaker

Andreas Reiserer conducts research in the Otto Hahn Group Quantum Networks at the Max Planck Institute of Quantum Optics. The group “Quantum Networks" investigates new quantum systems. The focus is on single rare earth ions in optical resonators. These ions have extraordinary coherence properties unmatched by any other system, and their control is compatible with existing microfabrication processes and optical technologies. This opens unique opportunities to realize large quantum networks.

OPTICAL-FIBER/CAVITY QUANTUM-NETWORK NODES

Gerhard Rempe

Tuesday, March 9th, 14:40, 30m

Quantum-optical systems consisting of modular and individually programmable information-pro-cessing modules [Daiss et al., Science 371, 614 (2021)] will be essential tools of an advanced quantum backbone for long-distance quantum communication and distributed quantum computation. Incorporating optical fiber technology has additional advantages such as miniaturization that increases photon confinement and, moreover, allows for novel optical architectures. Against this backdrop, the talk reports on recent achievements including a passive heralded quantum memory for photonic qubits, an ideal quantum-network end node [Brekenfeld et al., Nature Physics 16, 647 (2020)], and a nondestructive photonic qubit detector, a promising quantum-network middle node that has the potential to speed up a plethora of quantum communication protocols, e.g., entanglement distribution and teleportation as required for a quantum repeater [Niemietz et al., Nature (in press)].

Speaker

Gerhard Rempe is a German physicist, director at the Max Planck Institute of Quantum Optics and honorary professor at the Technical University of Munich. He has performed pioneering experiments in atomic and molecular physics, quantum optics, and quantum information processing.

Gerhard Rempe studied mathematics and physics at the Universities of Essen and Munich from 1976 to 1982. He has been a member of the Catholic student fraternity KDStV Tuiskonia Munich since 1983. In 1986, he received his doctorate from the University of Munich under Herbert Walther with the dissertation Investigation of the Interaction of Rydberg Atoms with Radiation. In the same year, he received his first offer of a permanent position as a lecturer at the Free University of Amsterdam in the Netherlands. Rempe remained in Munich, however, and habilitated in 1990 with a paper entitled Quantum Effects in the Single-Atom Maser. He was then Lecturer from 1990 to 1991 and Robert Andrews Millikan Fellow from 1990 to 1992 at the California Institute of Technology in Pasadena, California. In 1992, he accepted an appointment as Professor of Experimental Physics at the University of Konstanz. In 1999, he was appointed Scientific Member of the Max Planck Society and Director at the Max Planck Institute of Quantum Optics, as well as Honorary Professor at the Technical University of Munich.

Gerhard Rempe is considered a pioneer in the research field of cavity quantum electrodynamics. He was the first to observe how a single atom repeatedly emits and absorbs a single particle of light. Early experiments he performed with microwave photons in superconducting cavities. He later extended his interest to optical photons between highly reflective mirrors.[3] His experiments laid the foundation for the development of quantum nonlinear optics, in which a single particle, atom or photon, causes an effect that cannot be caused by many particles.

ACHIEVING HIGH-DATA-RATE COMMUNICATION ON OPTICAL QUANTUM CHANNELS: A THEORETICAL IMPLEMENTATION-ORIENTED PERSPECTIVE

Matteo Rosati

Friday, March 12th , 09:00, 20m

Quantum information science is shifting from theory to practice. In communication, key theoretical results of the past have shown that long-distance communication on optical quantum channels, such as optical fiber and free space, can attain the channel capacity by using simple coherent-state alphabets. Unfortunately, the receiver end is where quantum mechanics plays a crucial role, requiring the implementation of joint quantum measurements on multiple signals, which proves challenging with current technology.

Speaker

Matteo Rosati has been awarded a Marie Skłodowska Curie Fellowship to study machine-learning-aided decoders realizable with current technology for classical communication on quantum Gaussian channels. He is a postdoctoral researcher at the Group of Quantum Information at UAB, working with Profs. Andreas Winter and John Calsamiglia on Quantum Communication and Resource Theories, Quantum Statistical Inference and Quantum Machine Learning. In 2017 he obtained a PhD in Physics from Scuola Normale Superiore, Pisa, defending a thesis titled "Decoding Protocols for Classical Communication on Quantum Channels", under the supervision of Prof. Vittorio Giovannetti. He graduated in Theoretical Physics at Università La Sapienza, Rome, with a thesis on the modeling of Disordered and Complex Systems under the supervision of Prof. Giorgio Parisi.

QUANTUM REPEATERS BASED ON CONCATENATED BOSONIC- AND DISCRETE-VARIABLE QUANTUM CODES

Filip Rozpędek

Tuesday, March 9th, 18:20, 20m

We propose a novel architecture of quantum-error-correction-based quantum repeaters that combines the techniques used in discrete and continuous-variable quantum information. Specifically, we propose to encode the transmitted qubits in a concatenated code consisting of two levels. On the first level we use a continuous-variable GKP code which encodes the qubit in a single bosonic mode. On the second level we use a small discrete-variable code, encoding a logical qubit in as few as four or seven physical qubits. Such an architecture introduces two major novelties which allow us to make efficient use of resources. Firstly, our architecture makes use of two types of quantum repeaters: the simpler GKP repeaters that need to only be able to store and correct errors on a single GKP qubit and more powerful but more costly multi-qubit repeaters that additionally can correct errors on the higher level. We find that the combination of using the two types of repeaters enables us to achieve performance needed in practical scenarios with a significantly reduced cost with respect to an architecture based solely on multi-qubit repeaters. Secondly, the use of continuous-variable GKP code on the lower level has the advantage of providing us with the information about the success probability of the specific GKP correction round. This analog information, unique to bosonic codes, provides significant boost in performance when used to correct second level errors in the multi-qubit repeaters.

Speaker

Filip Rozpędek's interests are mostly in the field of quantum communication. He investigate the methods in which one can efficiently generate entanglement and secret-key over large distances. Practical schemes for remote entanglement generation over a quantum network will be based on multiplexing which we have analysed in van Dam et al., Quantum Sci. Technol. 2 034002 (2017). For quantum networks with long distance links, direct transmission of photons through the fibre suffers great losses and needs to be aided by the so-called quantum repeaters, which he has investigated in Rozpędek et al., arXiv preprint arXiv:1705.00043 (2017). The final ingredient of a quantum repeater is entanglement distillation, which is often a necessary tool for preserving high fidelity of the long distance entangled links. In his recent work he investigates numerically the optimality of existing distillation schemes for experimentally relevant quantum states. In the past he has also worked on foundations of quantum mechanics, specifically on the quantum uncertainty principle. In Rozpędek et al., New J. Phys. 19 023038 (2017) he investigated the question whether all uncertainty in the entropic formulation of this principle is really intrinsic to the measurement process.

WHEN ARE ADAPTIVE STRATEGIES IN ASYMPTOTIC QUANTUM CHANNEL DISCRIMINATION USEFUL?

Farzin Salek

Friday, March 12th , 15:00, 20m

We present a broad investigation of asymptotic binary hypothesis testing, when each hypothesis represents asymptotically many independent instances of a quantum channel, and the tests are based on using the unknown channel and observing its output. Unlike the familiar setting of quantum states as hypotheses, there is a fundamental distinction between adaptive and non-adaptive strategies with respect to the channel uses, and we introduce a number of further variants of the discrimination tasks by imposing different restrictions on the test strategies. The following results are obtained: (1) The first separation between adaptive and non-adaptive symmetric hypothesis testing exponents for quantum channels, which we derive from a general lower bound on the error probability for non-adaptive strategies; the concrete example we analyze is a pair of entanglement-breaking channels. (2) We prove that for classical-quantum channels, adaptive and non-adaptive strategies lead to the same error exponents both in the symmetric (Chernoff) and asymmetric (Hoeffding, Stein) settings. (3) We prove, in some sense generalizing the previous statement, that for general channels adaptive strategies restricted to classical feed-forward and product state channel inputs are not superior in the asymptotic limit to non-adaptive product state strategies. (4) As an application of our findings, we address the discrimination power of quantum channels and show that adaptive strategies with classical feedback and no quantum memory at the input do not increase the discrimination power of entanglement-breaking channel beyond non-adaptive tensor product input strategies.

`https://arxiv.org/abs/2011.06569`

Speaker

Farzin Salek has held appointments at the Research Center for Quantum Computing (CQC), Peng Cheng Laboratory, Shenzhen, China, Centre for Quantum Software and Information (QSI) at University of Technology Sydney (UTS), Sydney, Australia and Department of Information and Communication Technologies in Pompeu Fabra University, Barcelona, Spain. He is currently working at the Technical University of Munich in the group of Robert König. His research interests include quantum and classical information theory, quantum computing and quantum machine learning.

INTERCONNECTING NODES
OF AN TRAPPED-ION QUANTUM PROCESSOR

Ferdinand Schmidt-Kaler

Thursday, March 11th, 17:00, 20m

Quantum processor architectures are limited in scalability. While we see clear plans that will lead us to fully controlled 50, up to 100 ion qubits, it may be hard to scale up further. However, scalability above this limits may be reached when processor nodes of that type are interconnected, such that quantum entanglement is built up and qubits are exchanged between nodes. I discuss different options and sketch experimental studies for networks between trapped-ion processor nodes.

Speaker

Ferdinand Schmidt-Kaler habilitated at the University of Innsbruck with work on quantum information processing with stored ions and then followed an appointment at the University of Ulm, where he expanded the Institute for Quantum Information Processing. His research interests range from laser cooling and laser traps for atoms and ions to high-resolution spectroscopy and quantum information engineering with atoms, ions, electrons, and solids. Schmidt-Kaler has received several awards for his outstanding research in the fields of precision spectroscopy on hydrogen, cavity quantum electrodynamics, and quantum information processing with single ions. He is currently head of the QUANTUM research group and a member of the Helmholtz Institute at the University of Mainz.

TOWARDS HIGH-DIMENSIONAL QUANTUM COMMUNICATION IN SPACE

Fabian Steinlechner

Thursday, March 11th, 12:00, 20m

Entanglement is a key resource in quantum information processing and its distribution between distant parties is a key challenge in quantum communications. In this presentation, I will review ongoing technology developments for efficient generation and manipulation of photonic entanglement in various degrees of freedom, as well as ongoing engineering challenges in the development and integration of field-ready quantum communication systems in fiber networks, long-distance free-space and, ultimately, satellite links.

Speaker

Fabian Steinlechner is a quantum physicist at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF. The Quantum Communication Technologies group at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF conducts applied research in the field of quantum communication and photonic quantum information processing. Working in close collaboration with partners in academia and industry they aim to bridge the gap between fundamental quantum research and real-world applications. Their research focuses on novel quantum light sources for applications in quantum communication and sensing, efficient processing and detection schemes for high-dimensional quantum information, as well as scalable methods for the transmission of quantum states over long distances. A central goal is to incorporate photonic quantum technologies in robust, field-deployable hardware systems that are suitable for integration in future quantum networks, long-distance atmospheric free-space links, and ultimately satellite-based quantum key distribution sytems.

OPEN PROBLEM FOR THE ENTANGLEMENT-ASSISTED CAPACITY

Marco Tomamichel

Friday, March 12th , 10:00, 20m

Arguably the most fundamental communication task involving entanglement is entanglement-assisted classical communication. It is thought to be well understood, at least since Bennet et al.'s work establishing its single-letter capacity formula. Nonetheless, in this talk I will present some progress and an open problem concerning the second-order asymptotics of this problem, showing that it still retains some secrets.

Speaker

Marco Tomamichel received an M.Sc. in Electrical Engineering and Information Technology from ETH Zurich in 2007 and then followed his interest in quantum information to graduate with a Ph.D. in Physics at the Institute of Theoretical Physics also at ETH in 2012. His love of travel in addition to the global attractiveness of the Centre for Quantum Technologies at NUS then first brought him to the National University of Singapore for a postdoc stint. Before commencing his current position, he has also been a Research Fellow at the University of Sydney and an Associate Professor at the University of Technology Sydney.

His research interests lie in the intersection of information theory, cryptography and quantum mechanics. His main focus is on the mathematical foundations of quantum information theory, for example the study of entropy and other information measures, as well as theoretical questions that arise in quantum communication and cryptography when the available resources are limited. He currently serves as Associate Editor for the IEEE Transactions on Information Theory.

SCALING AND DELIVERING DIAMOND QUANTUM SOLUTIONS

Daniel Twitchen and Matthew Markham (Element Six)

Thursday, March 11th, 15:00, 20m

A brief review of diamond technology for quantum applications summarizing some of the current research areas. Presentation will also briefly discuss the needs to develop an ecosystem of solutions and how road mapping can be a useful tool to get alignment to deliver on scale.

Speaker

Daniel Twitchen has 25 years' experience developing CVD diamond synthesis for optical, thermal, electrochemical and sensing applications. He has led or contributed to multiple new product introductions as well as figuring as inventor on more than 50 related patents and co-author on 150 academic papers. His academic career started in Oxford working on defects in wide bandgap materials before moving to Element Six (E6) in its CVD team. Prior to his current role, he led E6's CVD commercial business for four years, with five years spent in the US helping to establish E6's facility and team in Silicon Valley. He has led E6's Quantum Program since 2007 with notable milestones, including: - In 2012, Harvard reported isotopically engineered CVD single crystal achieved spin coherence times of seconds at room temperature - Alongside Delft University of Technology in 2015, Element Six material enabled the first successful loophole-free Bell's inequality test, proving for the first time that 'spooky action at a distance' is real. This also marked a significant technology step toward a quantum-secure enabled network - In 2018, Imperial College London utilised engineered single crystal material in the development of the world's first continuous-wave, room-temperature, solid-state MASER (microwave amplification by stimulated emission of radiation) - Lockheed Martin's 2019 Dark Ice program delivered a DNV-enabled magnetometer that measured the direction and strength of nearly imperceptible magnetic field anomalies, opening up diamond-based quantum devices in GPS-denied navigation applications

QUANTUM REPEATERS: PROTOCOLS, BASIC ELEMENTS, AND RATE ANALYSIS

Peter van Loock

Tuesday, March 9th, 10:20, 40m

Direct quantum communication through optical fibers is hard to realize on a large, global scale, because either the quantum states' arrival probability or their fidelity decay exponentially with distance. We give an overview of protocols and basic elements to circumvent this complication with the focus on memory-based quantum repeaters and their quantitative assessment.

Speaker

Peter van Loock is a professor in theoretical quantum optics and quantum information at the Institute of Physics of Mainz University. His research interests include protocols for processing quantum information on a small scale and for communicating quantum information on a large scale, with current or near-future, optical technology. He has contributed to the fields of continuous-variable and linear-optics quantum information processing as well as hybrid quantum information processing combining discrete and continuous approaches. In 2002, he received his Ph.D. degree from the University of Wales, UK. From 2002 to 2004 and from 2004 to 2007, he was a postdoc at the University of Erlangen-Nuernberg, Germany, and a visiting associate professor at the National Institute of Informatics in Tokyo, Japan, respectively. From 2007 to 2012, before moving to Mainz, he was an Emmy Noether junior research group leader at Erlangen-Nuernberg University and at the Max Planck Institute for the Science of Light in Erlangen, Germany.

QUISP: THE QUANTUM INTERNET SIMULATION PACKAGE

Rodney van Meter

Thursday, March 11th, 09:30, 20m

Simulating a Quantum Internet is a challenging task: of course, the number of network nodes can reach the thousands; non-Pauli errors such as loss and relaxation are important physical processes to model; advancing generations of quantum repeaters may create and use entangled states of hundreds of qubits; and distributed control protocols and software must be modeled accurately. Our Quantum Internet Simulation Package aims to scale to simulate a complete Quantum Internet on all these fronts. I will review the progress and current state of our open source software and discuss how others can be involved.

Speaker

Rodney Van Meter is the Vice Center Chair of the Keio Quantum Computing Center. At KQCC, his research centers on hybrid quantum-classical optimization and machine learning algorithms for use on noisy intermediate-scale quantum devices, and on methods for analyzing the performance and fidelity of such machines.

Rodney Van Meter received a B.S. in engineering and applied science from the California Institute of Technology in 1986, an M.S. in computer engineering from the University of Southern California in 1991, and a Ph.D. in computer science from Keio University in 2006. His current research centers on quantum computer architecture and quantum networking. Other research interests include storage systems, networking, and post-Moore's Law computer architecture.

He is a Professor of Environment and Information Studies at Keio University's Shonan Fujisawa Campus. He is the Vice Dean of the Graduate School of Media and Governance, and the Vice Center Chair of the Keio Quantum Computing Center. Dr. Van Meter is a member of AAAS, ACM and IEEE.

TOWARDS A QUANTUM REPEATER SEGMENT OVER LONG FIBER DISTANCES

Harald Weinfurter

Tuesday, March 9th, 14:00, 30m

Entanglement between stationary quantum memories and photonic channels is the essential resource for future quantum networks. Together with entanglement distillation it will enable for efficient distribution of quantum states. Here we report on the generation and observation of entanglement between a Rb-87 atom and a photon at telecom wavelength over 20 km optical fiber. To overcome the strong absorption of spontaneously emitted photons from Rb we use polarization-preserving quantum frequency conversion transforming the wavelength of the photon entangled with the atomic spin state from 780 nm to the telecom S-band at 1522 nm. We give an update on the prospects for the next step, i.e., to the observation of entanglement between two distant atomic quantum memories.

Speaker

Harald Weinfurter is an Austrian physicist and university lecturer who works experimentally on fundamentals of quantum mechanics and quantum optics.

Weinfurter studied technical physics at the Vienna University of Technology from 1978, where he received his diploma in 1983 and his PhD in 1987, and habilitated at the University of Innsbruck in 1996 (Quantum Interferometry). From 1988 to 1991 he was at the Hahn-Meitner Institute in Berlin and from 1991 a university assistant in Innsbruck, where he was in the group of Anton Zeilinger. From 1996 to 1999 he was an APART Research Fellow of the Austrian Academy of Sciences. He has been a professor of quantum optics at Ludwig Maximilian University in Munich since 1999.

Weinfurter's work has included quantum entanglement and quantum cryptography, where he is known for a record with Christian Kurtsiefer in the transmission of a tap-proof message over 23.4 km between Zugspitze and Karwendel in 2002.

In 1996, he received the Fritz Kohlrausch Prize and the Start Prize, and in 2003, with Christian Kurtsiefer, the Philip Morris Research Prize. In 2004 he was one of the recipients of the Descartes Prize for the IST-QuComm project, and in 2014 he received the Copernicus Award. Since 2010 Weinfurter has been a "Fellow" at the Max Planck Institute of Quantum Optics, Garching.

TOOLS FOR INTERDISCIPLINARY TRAINING ON THE TOPIC OF QUANTUM PHYSICS

Henning Weier

Wednesday, March 10th, 17:30, 20m

In this talk, we will give an introduction to the Entanglement Demonstrator (quED) and available add-ons for the instrument. The quED is designed for educational purposes, fits on any lab desk, and can be set up in minutes. The easy-to-use system helps to explain the complex phenomena of quantum mechanics through the demonstration of several different quantum experiments. During this webinar, you will also get a brief overview of the quNV (quantum sensing) and the Quantenkoffer (their versatile quantum science kit) which complete qutools' educational portfolio.

Qutools GmbH provides tools for quantum research and educational outreach. Founded in 2005, qutools' aim is to enable the better understanding of quantum physics on one hand and to advance technology through this understanding on the other hand. That is why qutools focuses on innovation while addressing the needs in the lab, making it possible to concentrate on the didactics, not on the measurement tools.

Speaker

In 2005 Henning Weier started together with Prof. Dr. Christian Kurtsiefer and Prof. Dr. Harald Weinfurter from the quantum physics lab at Ludwig-Maximilians-University in Munich started the company qutools. They wanted to provide "tools" for "quantum physics" – so they named the company qutools.

Having started with developing receiver modules for quantum cryptography, our expertise increases with every challenge that we take on and the ensuing innovation that we uncover. That is how the demonstrator for quantum entanglement quED was born and later transformed into a complete setup for student laboratories, courses and lectures. A similar application suitable for pupils and high-school students and designed primarily for education purposes is the Quantenkoffer.

This initial device already included a time-to-digital converter to correlate two APD signals, so it did not take long until the quTAU came to life, measuring timestamps with a resolution of $<$100ps and calculating coincidences and correlations. This has finally evolved into our newest baby, quTAG, which is faster and more precise.

ZERO-ERROR COMMUNICATION VIA CHANNELS - ENTANGLEMENT ASSISTANCE AND BEYOND

Andreas Winter

Wednesday, March 10th, 10:20, 40m

We put Shannon's theory of zero-error communication via (classical) channels into a broader perspective by allowing the sending and receiving parties to share additional resources. Indeed, while Shannon already considered the case of instantaneous feedback, work by various authors over the past years has shown that entanglement or more abstractly nonlocal correlations can enhance both one-shot and asymptotic zero-error capacities. The talk will survey the known results on this quantum and nonlocal advantage, focusing especially on upper bounds. Among them the most important is the Lovász number and its refinement by Schrijver, which continue to be upper bounds on the entanglement-assisted zero-error capacity. Haemers' rank bound on the other hand is broken by entanglement-assisted zero-error codes.

Speaker

Andreas Winter was born in Altötting, a small rural town near Munich, known also as the Heart of Bavaria. After developing an infatuation with science early on, and in particular with mathematics, he decided to study this subject in Konstanz and Berlin. He graduated in 1997 from the Freie Universität Berlin, and went on to obtain a doctorate in mathematics from the Universität Bielefeld in 1999, with the late Rudolf Ahlswede. In 2001 he joined the quantum information group in Bristol as a postdoc, became Lecturer in Applied Mathematics there in 2003, and Professor of the Physics of Information in 2006. In 2012 he left Bristol after 11 years, to move to the Universität Autònoma de Barcelona as ICREA Research Professor, where he is now part of the quantum information group.

QKD@DT - WE ARE BUILDING THE SECURITY OF THE FUTURE

Felix Wissel

Friday, March 12th , 12:30, 20m

Quantum computers enable attacks on established key exchange methods, which form the basis for all digital communication. Quantum key distribution is based on physical laws of nature and, if implemented correctly, also provides security against currently unknown quantum algorithms. We show how Deutsche Telekom is dealing with the threat scenario, what developments we expect in the coming years and provide an insight into the architecture of the planned QKD platform.

Speaker

Felix Wissel holds a PhD in Theoretical Physics. He is in the engineering department of Deutsche Telekom Technik GmbH which he joined in 2014 as senior expert for network concepts and architectures. Before, he was in-house consultant at T-Systems International GmbH and as such is with DT since 2011. He participated in international projects for ESA and EU (e.g. IDEALIST) and now focuses on IP-optical integration, SDN solutions and latest developments in transport technologies and security. As such, he is heavily involved in quantum cryptography within the framework of the Quantum Flagship (CiViQ) and works on deploying a QKD platform for Deutsche Telekom. He is interested in mathematics, topology and network design challenges.

ADVANCED DIAMOND QUANTUM MATERIALS FOR PHOTONIC INTEGRATION

Jörg Wrachtrup

Thursday, March 11th, 12:30, 20m

Color centers in nanofabricated diamond devices have demonstrated highly-efficient spin-photon interfaces, which have a direct impact on long-distance quantum communication and distributed quantum computing [1]. Key towards system scalability is reproducible engineering of advanced diamond quantum materials for photonic integration.In my talk I will summarize the challenges for cavity quantum electrodynamics with optically active spins in diamond, with a particular focus on material and fabrication.

References

[1] M.K. Bhaskar et al. Nature 580, 60 (2020). DOI: 10.1038/s41586-020-2103-5

Speaker

Jörg Wrachtrup is director of the 3rd Institute of Physics and the Centre for Applied Quantum Technology at Stuttgart University. He is an appointed Max Planck Fellow at the Max Planck Institute for Solid State Research in Stuttgart. Wrachtrup is a pioneer in solid state quantum physics. Already in his PhD thesis, he carried out the first electron spin resonance experiments on single electron spins.[1] The work was done in close collaboration with M. Orrit at the CNRS Bordeaux. To achieve the required sensitivity and selectivity, optical excitation of single molecules was combined with spin resonance techniques. This optically detected magnetic resonance is based on spin dependent optical selection rules. An important part of the early work was coherent control. As a result the first coherent experiments on single electron spins and nuclear spins in solids were accomplished. While working at the Chemnitz University of Technology, he headed a research team that has, for the first time, detected the optical as well as spin signal of a single dopant atom in a solid. The particular dopant, was a nitrogen atom joined by a vacancy, the nitrogen-vacancy center (N-V) in diamond.[2] This pioneering work has created standards for numerous follow-up studies of individual N-V centers aiming at manipulations of individual electron and nuclear spins in solids (quantum computer). In contrast to the earlier studies on single molecules the target spin state in these system is a ground state. This facilitates quantum control as spin relaxation and coherence times turned out to be exceptionally long, even under ambient conditions. In addition the defect center proved to be unconditionally photostable, in contrast to most other single quantum emitters. This discovery is the basis for numerous applications of defects in diamond as single photon source, quantum register and in magnetometry. Wrachtrup has made several pioneering contribution to solid state quantum physics. Most notably this is demonstration of nanoscale quantum sensing of magnetic fields using single defects. His group accomplished spin Hamiltonian engineering to measure electric fields as well as temperature using single defect centers. The first entanglement between single electron and nuclear spins in solids as well as single shot quantum state readout was accomplished by his group. Nanoscale quantum sensors also proved to be capable to detects single electron spins as well as measure nuclear magnetic resonance signals with unprecedented sensitivity and spatial resolution.

ENTANGLEMENT-ASSISTED COMMUNICATION: EXPERIMENT TO SURPASS THE ULTIMATE CLASSICAL CAPACITY

Zheshen Zhang

Friday, March 12th , 16:30, 20m

The seminal work by Bennett, Shor, Smolin, and Thapliyal showed that pre-shared entanglement between communication parties can be harnessed to increase the rate of reliable classical communication over noisy and lossy channels, known as entanglement-assisted communication (EACOMM). Despite the advances of quantum technology in the last a few decades, EACOMM surpassing the ultimate classical channel capacity has never been experimentally demonstrated. We report the construction of an efficient entangled-photon source and a nontraditional quantum phase-conjugate receiver to realize EACOMM over a lossy and noisy bosonic channel. We show that EACOMM beats the classical capacity of the channel, quantified by the Holevo-Schumacher-Westmoreland formula, by up to 14.6% even though the initial entanglement is completely destroyed by loss and noise. As a practical performance benchmark, a classical communication protocol without entanglement assistance is implemented over the same bosonic channel, showing that EACOMM reduces the bit-error rate by up to 69%. Our work opens a route to provable quantum advantages in a wide range of quantum information processing tasks.

Speaker

Zheshen Zhang is an Assistant Professor in the Department of Materials Science and Engineering and the James C. Wyant College of Optical Sciences at the University of Arizona. He received the B.S. degree in Electrical Engineering from Shanghai Jiao Tong University in 2006 and the Ph.D. degree in Electrical and Computer Engineering from the Georgia Institute of Technology in 2011. During his Ph.D. studies, Zhang split his time between Georgia Tech's main campus in Atlanta and its Lorraine campus in Metz, France. Prior to joining the University of Arizona in 2017, Dr. Zhang was a Research Scientist at MIT.

Dr. Zhang's research encompasses a broad swath of the experimental and theoretical aspects of quantum information science. Dr. Zhang studies unique quantum phenomena such as entanglement and leverage these quantum phenomena in quantum-optics and nanophotonic platforms to implement devices and systems for quantum communications, quantum sensing, and quantum computing. Dr. Zhang's research gives rise to novel applications in diverse fields ranging from non-invasive sensing to telecommunications with provable security.

ENTANGLEMENT-ASSISTED COMMUNICATION: THEORY AND PROTOCOL DESIGN

Quntao Zhuang

Friday, March 12th , 17:00, 20m

Entanglement offers substantial advantages in quantum information processing, but loss and noise hinder its application in practical scenarios. Although it has been well known for decades that the classical communication capacity of lossy and noisy bosonic channels can be significantly enhanced by entanglement, no practical encoding and decoding schemes are available to realize any entanglement-enabled advantage.

In this talk, we will present the theory and protocol design of entanglement-assisted classical communication. Our first result is a capacity theorem of entanglement-assisted classical communication for multiple-access channels (MAC), where we show that the capacity region enjoys a similar advantage to the known single-sender case. Then we provide structured encoding and decoding schemes for to achieve entanglement advantage in both the single-sender case and the MAC case. The protocol design has recently led to the first experimental demonstration of entanglement-assisted communication surpassing the ultimate classical capacity. We also discuss how the absence of a shared phase reference will affect the entanglement advantage.

References

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Speaker

Quntao Zhuang is an assistant professor in the Department of Electrical and Computer Engineering and the College of Optical Sciences. He joined the department after finishing a position as a postdoctoral fellow at the University of California, Berkeley. He earned his PhD in physics from the Massachusetts Institute of Technology in 2018. Quntao is broadly interested in quantum information processing and quantum optics.