FM 33: Quantum Networks: Concepts & Applications

Time: Tuesday 14:00–16:00 Location: 1015

Invited Talk FM 33.1 Tue 14:00 1015

Quantum Networking, fully connected and international — •Rupert Ursin — Institute for Quantum Optics and Quantum Information - Vienna, Austrian Academy of Sciences, Austria

Quantum communication is most advanced under the quantum technologies discussed in the scientific literature, such as quantum computing and quantum sensing. One challenge of Quantum Key Distribution (QKD) is how to spread that intrinsic point-to-point protocol to the public users in a scalable manner. I will present a proof-of-principle experiment spreading the quantum information to four users in a novel network architecture which enables scalable quantum communication based on polarisation-entangled photon pairs at telecommunications wavelength [1]. Our scheme uses frequency multiplexing to share 6 two-photon entangled states between each pair of clients in a mesh-like network topology using only one fiber per client.

Furthermore I will present our efforts to use a satellite to distribute quantum information also on an international scale [2]. The mission of the Chinese Academy of Sciences into space will be described and the experiment we did with the Chinese satellite will be presented in my talk.

[1] S. Wengerowsky, et al., Nature, 564(7735), (2018).
[2] SS.-K. Liao et al., Phys. Rev. Lett., 120:030501, (2018).

FM 33.2 Tue 14:30 1015

Free-space channels: entanglement distribution and teleportation — •Martin Bohmann[1,2], Kevin Hofmann[1], Andrii A. Semenov[1,3], Jan Sperling[4], and Werner Vogel[1] — [1]Universität Rostock, Rostock, Germany — [2]QSTAR, INO-CNR, and LENS, Firenze, Italy — [3]Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine — [4]University of Paderborn, Paderborn, Germany

Global quantum communication based on atmospheric free-space channels is a rapidly developing and growing research area. In this contribution, we address the question of how fluctuating losses in such channels affect continuous-variable entanglement distribution and quantum state teleportation. We perform a rigorous analysis of the quantum states after passing through the turbulent atmosphere and study Gaussian and non-Gaussian entanglement. We identify optimal strategies for the transmission of entangled states, and we show that atmospheric channels differ essentially from constant-loss scenarios. Eventually, we propose strategies for the successful quantum-state teleportation through free-space channels.

FM 33.3 Tue 14:45 1015

Tolerances of Photon Pair Sources for Satellite-Based Quantum Communication — •Rana Sebak[1,2] and Fabian Oliver Steinlechner[1] — [1]Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Albert-Einstein-Straße 7, 07745 Jena — [2]Friedrich-Schiller University Jena, Abbe School of Photonics, Albert-Einstein-Str. 5, 07745 Jena, Germany

Satellite-based quantum communication is considered to be one possible way to guarantee unconditional security for communication, by using quantum information protocols enabling quantum key distribution (QKD). High-performance entangled photon-pair sources are the bottleneck for such applications. The efficiency of the photon-pair sources depends critically on their alignment.

The goal of this work is to achieve a robust entangled photon-pair source suitable for harsh environments as present in space. The angular and lateral tolerances of the collection optics were calculated for different pump and collection parameters with various brightness efficiencies. Additionally, they are evaluated experimentally in a type-II phase matched ppKTP crystal pumped at 405 nm. Moreover, different crystal lengths have been investigated while keeping all other parameters constant. We present results on the corresponding spectral power densities.

FM 33.4 Tue 15:00 1015

Quantum network routing and local complementation — Frederik Hahn, •Anna Pappa, and Eisert Jens — Dahlem Center for Complex Quantum Systems, Freie University Berlin

Quantum communication between distant parties is based on suitable instances of shared entanglement. For efficiency reasons, in an anticipated quantum network beyond point-to-point communication, it is preferable that many parties can communicate simultaneously over the underlying infrastructure; however, bottlenecks in the network may cause delays. Sharing of multi-partite entangled states between parties offers a solution, allowing for parallel quantum communication. Specifically for the two-pair problem, the butterfly network provides the first instance of such an advantage in a bottleneck scenario. The underlying method differs from standard repeater network approaches in that it uses a graph state instead of maximally entangled pairs to achieve long-distance simultaneous communication. We will demonstrate how graph theoretic tools, and specifically local complementation, help decrease the number of required measurements compared to usual methods applied in repeater schemes. We will examine other examples of network architectures, where deploying local complementation techniques provides an advantage. We will finally consider the problem of extracting graph states for quantum communication via local Clifford operations and Pauli measurements, and discuss that while the general problem is known to be NP-complete, interestingly, for specific classes of structured resources, polynomial time algorithms can be identified.

FM 33.5 Tue 15:15 1015

Quantum Shannon theory with superpositions of trajectories — Giulio Chiribella[1,2] and •Hlér Kristjánsson[2] — [1]Department of Computer Science, The University of Hong Kong, Hong Kong — [2]Department of Computer Science, University of Oxford, Oxford, United Kingdom

Shannon's theory of information was built on the assumption that the information carriers were classical systems. Its quantum counterpart, quantum Shannon theory, explores the new possibilities arising when the information carriers are quantum systems. Traditionally, quantum Shannon theory has focussed on scenarios where the internal state of the information carriers is quantum, while their trajectory is classical. Here we propose a second level of quantisation where both the information and its propagation in spacetime is treated quantum mechanically. The framework is illustrated with a number of examples, showcasing some of the counterintuitive phenomena taking place when information travels simultaneously through multiple transmission lines [1].

[1] G. Chiribella and H. Kristjánsson, *Proc. R. Soc. A* **475**, 20180903 (2019).

FM 33.6 Tue 15:30 1015

Single- and multiphoton interference using time-multiplexed network — •Syamsundar De[1], Thomas Nitsche[1], Evan Meyer-Scott[1], Johannes Tiedau[1], Aurél Gábris[2,3], Sonja Barkhofen[1], Jan Sperling[1], Benjamin Brecht[1], Igor Jex[2], and Christine Silberhorn[1] — [1]Integrated Quantum Optics, University of Paderborn, Warburger Strasse 100, 33098 Paderborn, Germany — [2]Department of Physics, Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Břehová 7, 115 19 Praha 1 - Staré Město, Czech Republic — [3]Department of Quantum Optics and Quantum Information, Wigner Research Centre for Physics, Budapest, Konkoly-Thege M. U. 29-33, H-1121 Budapest, Hungary

Time-multiplexed networks constitute a versatile platform to extract benefits from the optical coherence linked to their high flexibility and reconfigurability as well as excellent efficiency and stability. Such time-multiplexing schemes show great potentials for fundamental studies as well as applications in quantum technology. Examples include quantum-walk, boson sampling, generation of large-scale cluster states, measurement-based quantum computing, to name only a few. In this study, we exploit our well-established fiber optical-loop design for time-multiplexing to synthesize the modal structure of the photon wave-packets and to test the quantum-classical nature of the involved optical states. We utilize single- and multiphoton quantum interference in the time-multiplexed network to recover both the modal structure and the quantum-classical nature of pulsed light.

FM 33.7 Tue 15:45 1015

Interaction-free discrimination of quantum channels — •Markus Hasenöhrl and Michael M. Wolf — Technische Universität München, Munich, Germany

Interaction-free measurement, as proposed by Elizur and Vaidman in their famous bomb-tester experiment is a way to employ the counterintuitive laws of quantum mechanics to obtain information about an object, without influencing it in an essential way. For example, finding out if there is an ultra-sensitive bomb in a given black box, without causing the bomb to explode. In my talk, I will show how to reinterpret the bomb-tester experiment as a quantum channel discrimination problem and create a framework that generalizes the notion of interaction-free to arbitrary quantum channels. Furthermore, we explore the implications of this new model. We arrive at two major conclusions: the first one being that we can always find out, whether or not there is an object in a given black box, without influencing the object. This is true, even if we have no prior knowledge which object it might be. The second finding then is that it is impossible to find out, which object is present in the black box, without influencing it. Together these results yield a complete characterization of what is possible and impossible to achieve with interaction-free measurements.