MON 1: QIP Implementations: Photons I

Time: Monday 14:15–16:00 Location: ZHG001

MON 1.1 Mon 14:15 ZHG001

Boosted fusions for photonic quantum computation — •Nico Hauser[1], Matthias Bayerbach[1], Simone D'Aurelio[1], Raphael Weber[2], Matteo Santandrea[2], Shreya P. Kumar[2], Ish Dhand[2], and Stefanie Barz[1] — [1]Universität Stuttgart, Institut für funktionelle Materie und Quantentechnologien — [2]QC Design GmbH, Ulm

Entangling two-photon measurements, called fusions, are a fundamental requirement for photonic fusion-based quantum computation. One way of implementing such a fusion is a linear-optical Bell-state measurement. However, conventional linear-optical Bell-state measurements are limited to an overall success probability of 50%. This constraint significantly reduces the scalability of fusion-based quantum computation, where reliable fusions are needed. Here, we present a boosted fusion that surpasses this 50% success probability limit by using an entangled ancillary photon pair along with a fibre-based 4x4 multimode interferometer. By simulating fusion networks with boosted fusions, we show a significant increase in the performance of fusion-based quantum computation. We find that using boosted fusions significantly increases the robustness of fusion-based schemes to photon loss, which is one of the most prominent errors in photonic quantum technologies.

MON 1.2 Mon 14:30 ZHG001

Integrated resonant squeezer for GBS — •Jonas Sichler, Christine Silberhorn, Philip Mues, Werner Ridder, and Simone Atzeni — IQO, Universität Paderborn, Deutschland

Single-spectral-mode single-mode squeezed states are a key resource for Gaussian boson sampling (GBS) and other large-scale photonic networks. We investigate an integrated, resonator-enhanced, type-0 parametric down-conversion source in titanium-indiffused lithium niobate waveguides. By tuning the pump pulse length and tailoring the cavity geometry and mirror reflectivities correlations are suppressed and single-modeness can be achieved. The phase-matching center is set by the periodic poling and custom dielectric coatings define the cavity finesse. Achieving full single-modeness still requires external filtering in order to reject the neighboring cavity modes separated by the GHz-scale free spectral range, a demanding yet tractable task, which can be achieved, for example, with the use of filter cavities. Simulations incorporating realistic fabrication tolerances confirm that this multidimensional optimization delivers the desired joint-spectral amplitude. The resulting chip-scale Ti:LiNbO3 source provides a practical, low-loss building block for deployment in large quantum photonic networks, for example as the workhorse of GBS.

MON 1.3 Mon 14:45 ZHG001

Enhanced phase sensitivity in displacement-assisted SU(1,1) interferometer with photon recycling — Taj Kumar, Aviral Kumar Pandey, Anand Kumar, and •Devendra Kumar Mishra — Department of Physics, Institute of Science, Banaras Hindu University, Varanasi-221005, Uttar Pradesh, India

In this work, we propose a novel method to improve the phase sensitivity of the displacement-assisted SU(1,1) (DSU(1,1)) interferometer (with displacement strength γ) via photon recycling. We consider vacuum and squeezed vacuum (with squeezing parameter r) states as inputs, with a phase shift ϕ in one of the arms. This setup is modified by re-injecting the one output mode into the input mode after a phase shift θ, and the photon loss, characterized by $\sqrt{1-\mathrm{T}}$, where T is the transmission coefficient of a fictitious beam splitter. We determined the phase sensitivity of the photon recycled DSU(1,1) (PR-DSU(1,1)) interferometer under the single-intensity and homodyne detection schemes along with the quantum Cramér-Rao bound (QCRB). Then, we compared its performance with the conventional DSU(1,1) interferometer and found that the PR-DSU(1,1) interferometer can achieve improved phase sensitivity and a lower QCRB compared to the latter. Moreover, for both detection schemes, we observed the improvement in the phase sensitivity and QCRB of the PR-DSU(1,1) interferometer relative to the SNL, which further increases with an increase in T, g, $|\gamma|$, and r. Therefore, our work offers a novel approach to increase phase sensitivity via photon recycling. This work is based on our recent publication [APL Quantum 2, 016127 (2025)].

MON 1.4 Mon 15:00 ZHG001

Low-noise cascaded frequency conversion of 637.2 nm light to the telecommunication C-band in a single-waveguide device — Fabrice von Chamier, Joscha Hanel, Chris Müller, Wanrong Li, •Roger Kögler, and Oliver Benson — Humboldt-Universität zu Berlin, Institut für Physik, Newtonstraße 15, 12489, Berlin, Germany

Quantum devices and optical states often operate at disparate frequencies, making frequency conversion essential for connecting nodes in quantum networks. Here, we demonstrate a two-stage frequency conversion using an integrated device, successfully converting 637.2 nm photons emitted by nitrogen-vacancy centers in diamond into telecom wavelengths. Our system achieves low internal (external) noise spectral densities of 2.4 ± 0.8 (16 ± 5) cps/GHz, owing to the cascaded architecture, which mitigates excess noise typically introduced by spontaneous parametric down-conversion from the strong pump field.

The device is based on a periodically poled lithium niobate waveguide featuring two distinct poling sections. Remarkably, it also exhibits a phase-matched interaction between thermally generated photons and the pump field, which we investigate in detail. Additionally, we demonstrate tunable frequency conversion across the C-band by thermally controlling the phase-matching conditions of each stage. This enables wavelength targeting in the range of 1559.0 nm to 1564.9 nm, with external (internal) conversion efficiencies reaching $3.0 \pm 0.1\%$ ($20.5 \pm 0.8\%$).

MON 1.5 Mon 15:15 ZHG001

Phase stabilization of high-bandwidth squeezed and entangled states over 1km distributed optical fiber — •Sophie Verclas[1], Benedict Tohermes[1], and Roman Schnabel[2] — [1]Institut für Quantenphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Institut für Quantenphysik & Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Quantum Key Distribution (QKD) is a technology for secure communication between two parties, using the principles of quantum mechanics. Our continuous-variable QKD experiment implements a fiber-based scheme, connecting two laboratories in two separated buildings (building A and B). We set up an EPR entanglement source in building A, consisting of two squeeze lasers and overlapped their outputs at a 50/50 beamsplitter to generate two-mode squeezed states. They are shared between A and B via a 1km optical fiber. In both buildings, the states are measured with self built balanced homodyne detectors. Due to the entanglement, the results are random but also correlated and can be used to generate a secret key. Attacks on the channel and on devices in building B reduce the entanglement strength and can thus be quantified. A major challenge in this setup is the phase stabilization and synchronization between the two buildings. Here, I will introduce the experiment, discuss the problem of phase noise and our approach to a control scheme for its compensation. As a first result, I will show measurements for the phase lock of distributed squeezed states, which is an important first step towards stabilized entanglement.

MON 1.6 Mon 15:30 ZHG001

Optical Protocol for Generating non-Gaussian state in C-band. — •Elnaz Bazzazi, Roger Alfredo Kögler, Leon Reichgardt, Marco Schmidt, and Oliver Benson — Department of Physics, Humboldt University Berlin, Berlin, Germany

Non-Gaussian states play a crucial role in fault-tolerant quantum computing, where the encoded information is protected from decoherence processes [1]. Certain classes of non-Gaussian states, however, coherent state superpositions known as cat states, pose challenges in generation due to the complexity of breeding protocols and limitations in their output states [2,3]. In this study, we explore the state engineering of squeezed coherent state superpositions (SCSS) through a catalysis protocol [4].

In this scheme, a beam splitter operation applied to two input states: a vacuum squeezed state and an m-photon Fock state, followed by photon number resolving detection in one of the output arms. Simulations results demonstrate the potential of this protocol to generate high-amplitude squeezed cat states with realistic quantum resources. We also outline an experimental implementation, and present the current progress. This research contributes to advances in quantum state engineering methods, crucial for the generation of resource states for fault-tolerant quantum computing.

[1] D. S. Schlegel et al., Phys. Rev. A 106, 022431 (2022).
[2] K. Takase et al., Phys. Rev. A 103, 013710 (2021).
[3] M. Endo et al., Opt. Express 31, 12865 (2023).
[4] R. J. Birrittella et al., J. Opt. Soc. Am. B 35, 1514 (2018).

MON 1.7 Mon 15:45 ZHG001

Topology-Optimized Integrated Photonics for Quantum Experiments — •Shiang-Yu Huang[1], Shreya Kumar[1], Jeldrik Huster[1], Yannick Augenstein[2], Carsten Rockstuhl[2,3], and Stefanie Barz[1,4] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany — [2]Institute of Theoretical Solid State Physics, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [3]Institute of Nanotechnology, Karlsruhe Institute of Technology, 76021 Karlsruhe, Germany — [4]Center for Integrated Quantum Science and Technology (IQST), University of Stuttgart, 70569 Stuttgart, Germany

Interference of single photons plays a central role in photonic quantum technologies as it is an essential process for creating and manipulating desired quantum states in linear optical systems. By incorporating integrated photonics, multiphoton interference can take place within on-chip interferometers featuring a minimal footprint. Furthermore, such devices can be miniaturized even further by applying inverse design methods, showing a promising path for innovating conventional integrated systems for photonic quantum technologies. Here we demonstrate the inverse-designed interferometers developed using topology optimization with an ultracompact footprint. We showcase their capabilities for quantum experiments through multiphoton interference. We also inversely design on-chip couplers to facilitate high-efficiency interconnection with an exceptionally small footprint. These topology-optimized components have great potential for building up high integration density integrated circuits for photonic quantum technologies.