Q 12: Quantum Optics (Miscellaneous) II

Time: Monday 16:30–18:00 Location: Q-H14

Q 12.1 Mon 16:30 Q-H14

Two-Mode Photon-Number Correlations Created by Measurement-Induced Nonlinearity — •Jan Philipp Höpker, Maximilian Protte, Christof Eigner, Christine Silberhorn, Polina Sharapova, Jan Sperling, Torsten Meier, and Tim Bartley — Department of Physics, Paderborn University, Warburger Str. 100, 33098 Paderborn, Germany

In quantum optics, a measurement can be used as a tool to manipulate a quantum state. Photon subtraction, implemented with a partial detection of a quantum state, is a pertinent example for this nonlinear manipulation. Furthermore, single-photon measurements (a particle-like phenomenon) can be directly combined with the interference of two quantum states (a wave-like phenomenon), yielding interesting features in both phase space and the photon-number basis. In this work, we explore theoretically and experimentally complex correlations in the photon numbers of two-mode quantum states using this scheme. For this, we use integrated beam-splitter networks based on titanium in-diffused lithium niobate waveguides and superconducting single-photon detectors.

Q 12.2 Mon 16:45 Q-H14

Compensating decoherence of squeezed light in cavity-enhanced quantum metrology — •Mikhail Korobko[1], Jan Südbeck[1], Sebastian Steinlechner[2], and Roman Schnabel[1] — [1]Institut für Laserphysik und Zentrum für Optische Quantentechnologien, Universität Hamburg — [2]Maastricht University, Netherlands

Quantum states of light are commonly used to enhance detection in modern sensors. For instance, quantum squeezed light allows to reach high sensitivity without using significant optical power, and thus it finds application in various metrological devices, from biological sensing to gravitational-wave detection. At the same time, quantum states are very fragile, and even a small amount of decoherence significantly impacts them. For example, decoherence due to optical loss limits the benefit from using squeezed light to enhance the sensitivity of cavity-enhanced sensors, such as gravitational-wave detectors. We propose a new approach that allows to compensate a significant part of quantum decoherence, thus increasing the sensitivity beyond the previously established decoherence-induced quantum limit. To achieve this, we use an optimally tuned quantum squeezer placed directly inside the detector cavity. We present the first experimental combination of intra-cavity and externally injected squeezing used to enhance the sensitivity. We use intra-cavity squeezing to demonstrate for the first time quantum enhancement to the sensitivity that is not affected by the increase in optical loss. Finally, we derive the new decoherence-induced quantum limit. Our approach will add the new level of flexibility to the design of quantum sensors.

Q 12.3 Mon 17:00 Q-H14

Characterization of Cryogenic Integrated Spontaneous Parametric Down-Conversion — •Nina Amelie Lange[1], Jan Philipp Höpker[1], Raimund Ricken[2], Viktor Quiring[2], Christof Eigner[2], Christine Silberhorn[2], and Tim J. Bartley[1] — [1]Mesoscopic Quantum Optics, Department of Physics, Paderborn University, Warburger Str. 100, 33098 Paderborn, Germany — [2]Integrated Quantum Optics, Department of Physics, Paderborn University, Warburger Str. 100, 33098 Paderborn, Germany

We show for the first time that spontaneous parametric down-conversion (SPDC) in nonlinear waveguides remains functional when operated at cryogenic temperatures. With this proof-of-principle experiment, we demonstrate that SPDC, a standard technology for the generation of nonclassical light under ambient conditions, is fully compatible with integrated components that require cryogenic operating conditions, such as superconducting detectors. We characterize our SPDC source at room temperature and under cryogenic conditions at 4.7 K. We measure the spectral properties, including the marginal spectra of the signal and idler photons and the joint spectral intensity. Our experimental results show very good agreement with theory, based on the temperature-dependent dispersion of the waveguide. Furthermore, we investigate the source performance metrics, which do not show a significant change compared to our results at room temperature. Although we change the operation temperature by nearly two orders of magnitude, our SPDC source remains fully operational.

Q 12.4 Mon 17:15 Q-H14

A stepwise approach to the BSV description — •Dennis Scharwald and Polina Sharapova — Paderborn University, Department of Physics, Warburger Str. 100, D-33098 Paderborn, Germany

The bright squeezed vacuum state of light (BSV) is a macroscopic state generated by unseeded parametric down-conversion (PDC). Its large photon number and strong correlations between the signal and idler photons make it an interesting candidate for applications and theoretical investigations. One of the prominent theoretical frameworks for the BSV description is the “regular” Schmidt-mode theory, which describes the BSV in terms of Schmidt modes. This provides a fully analytical description but fails to explain the broadening of the itensity spectrum with increasing gain [1]. Another purely numerical approach involves the solution of integro-differential equations in order to obtain the output state of the PDC section [2]. This approach is in good agreement with the experiment even with increasing gain.

In our work, we combine both approaches by splitting the PDC section into small segments which are connected via the input/output relations for the plane-wave operators. As a result, we can observe the evolution of the Schmidt-modes as they propagate through a nonlinear crystal, as well as the broadening in the intensity spectrum which matches the prediction of the integro-differential equation method and the experimental results.

[1] P. Sharapova *et al.*, Phys. Rev. A **91**, 043816 (2015)
[2] P. R. Sharapova *et al.*, Phys. Rev. Research **2**, 013371 (2020)

Q 12.5 Mon 17:30 Q-H14

Microwave Stimulated Raman Adiabatic Passage in the Electronic Ground State of the NV Center — •Florian Böhm[1], Niko Nikolay[1], Sascha Neinert[1], Christoph E. Nebel[2], and Oliver Benson[1] — [1]Institut für Physik IRIS Adlershof, Humboldt-Universität zu Berlin, Germany — [2]Nanomaterials Research Institute, Kanazawa University, Japan

The nitrogen-vacancy (NV) center in diamond features an electronic qutrit ground state with long coherence times even at room temperature, which can conveniently be manipulated by microwave pulses and read-out optically [1]. The NV center is well-known for offering a broad range of quantum applications, which stimulates a great interest in developing new, or adapting known control schemes.

Here we present the well-known concept of stimulated Raman transitions [2], which can be used to excite transitions between two states not directly coupled to a radiation field, applied to the NV center's triplet ground state. Depending on the two-photon microwave pulse sequence, either stimulated Raman transitions (SRT) or stimulated Raman adiabatic passage (STIRAP) could successfully be implemented in the NV center [3]. We show, that both schemes can successfully drive the dipole-forbidden $m_s = -1 \leftrightarrow m_s = +1$ transition. Furthermore we compare both mechanisms on their robustness and success of spin-swap, as well as their experimental challenges.

[1] Doherty, Marcus, et al., Physics Reports 528.1 (2013): 1-45
[2] Sola, Ignacio, et al., Adv. Mol. Opt. Phys., 67 (2018): 151-256.
[3] Böhm, Florian, et al., Phys. Rev. B, 104.3 (2021): 035201

Q 12.6 Mon 17:45 Q-H14

Fabrication of periodically poled LNOI for efficient non-linear optical processes — •Laura Bollmers[1], Peter Mackwitz[2], Laura Padberg[1], Marcello Massaro[1], Gerhard Berth[2], Christof Eigner[1], and Christine Silberhorn[1] — [1]Paderborn University, Integrated Quantum Optics, Institute of Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098 Paderborn, Germany — [2]Paderborn University, Nanostructure Optoelectronics, Warburger Str. 100, 33098 Paderborn, Germany

Miniaturization of optical circuits has been a vivid field of both, research and development for several decades. Within the last years, this progress has reached the realms of integrated optics and quantum photonics. Here, LNOI has become one of the most promising materials, as it combines the excellent properties of lithium niobate with small feature sizes. In order to fully exploit the possibilities of the material platform, dispersion engineered processes can be tailored by means of quasi-phase matching, which is based on periodic poling of the crystal. For periodically poled LNOI samples, novel processes need to be developed, which makes LNOI technology challenging and demanding. On our first step we focused on the fabrication of finger electrodes for periodic poling and investigated and optimized the respective design parameters. We tested different timing schemes for periodic domain inversion to optimize switching kinetics. We demonstrate that poling lengths up to 7.5 mm are possible and show first nonlinear optical conversion analysis.