Q 58: Quantum Optics with Photons I

Time: Thursday 14:30–16:30 Location: F442

Q 58.1 Thu 14:30 F442

Improving the Phase Sensitivity of SU(1, 1) **Interferometers by Phase Matching Compensation** — •Dennis Scharwald and Polina Sharapova — Paderborn University, Department of Physics, Warburger Str. 100, D-33098 Paderborn, Germany

Improving the phase sensitivity of interferometers is a central challenge in quantum optics. Using coherent light, the lower limit for the sensitivity is given by the shot noise limit (SNL), while the quantum mechanical lower bound for this sensitivity is given by the Heisenberg limit. One way of surpassing the shot noise limit is using SU(1, 1) interferometers, which consist of two PDC sections. Between these sections pump, signal and idler photons experience some relative phase shift. [1] In our work, we extend the approach of integro-differential equations for the description of the PDC process derived in Ref. [2] to a certain kind of configuration where the PDC radiation generated by a single crystal is focussed back into a PDC section after experiencing the phase shift. We show numerically that using this setup, the phase sensitivity of the interferometer can be improved below the shot noise limit easier than using an SU(1, 1) interferometer without such kind of compensation.

[1] M. Manceau *et al.*, New J. Phys. **19**, 013014 (2017)
[2] P. R. Sharapova *et al.*, Phys. Rev. Research **2**, 013371 (2020)

Q 58.2 Thu 14:45 F442

Quantum characterization of superconducting detectors — •Timon Schapeler and Tim J. Bartley — Institute for Photonic Quantum Systems, Paderborn University, Germany

Single-photon detectors, especially based on superconductivity are indispensable for most quantum applications, which makes characterizing them necessary to ensure proper operation. We show a characterization of superconducting nanowire single-photon detector arrays using quantum detector tomography. We quantify the photon-number-resolving ability through the purity of the detection outcomes. Additionally, we investigate the spectral response of a detector for possible spectroscopic applications.

Q 58.3 Thu 15:00 F442

Optical quantum tomography in the time domain — •Emanuel Hubenschmid[1], Thiago Guedes[2], and Guido Burkard[1] — [1]Universität Konstanz, 78467 Konstanz, Deutschland — [2]Forschungszentrum Jülich, 52428 Jülich, Deutschland

Electro-optic sampling presents a powerful tool to sample the waveform of a mid-infrared pulse in the time domain by measuring the effect a nonlinear interaction of the sampled mid-infrared pulse has on an ultrabroadband near-infrared pulse. Recent experiments applied this technique to sample the electric field fluctuation of the squeezed vacuum [Nature 541, 376 (2017)] on a sub-cycle scale. However, a full quantum tomography scheme in the time domain is still missing. Here we present a theoretical description of a possible electro-optic-based quantum tomography scheme with sub-cycle resolution. By combining novel theoretical tools to describe the interaction of the sampled pulse and an ultrabroadband near-infrared pump pulse in the nonlinear crystal [Phys. Rev. D 105, 056023 (2022)] and of quantum tomography with continuous wave-driven electro-optic sampling [Phys. Rev. A 106, 043713 (2022)], we calculate the probability distribution of our tomography schemes signal depending on the time delay between the sample and near-infrared pulse. Furthermore, we analyze the noise of the signal and describe how to reduce the contribution due to the broadness of the pump pulse. Combining these results, we describe how to reconstruct an arbitrary quantum state and its waveform, without any post-processing in the frequency domain and thereby paving the way towards quantum tomography in the time domain.

Q 58.4 Thu 15:15 F442

Measurement of two-point spectral correlation functions of pulsed quantum states of light — •Abhinandan Bhattacharjee, Patrick Folge, Laura Serino, Benjamin Brecht, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Straße 100, 33098 Paderborn, Germany

Coherence theory is an established research area for characterizing statistical randomness in an optical field. Typically, coherence is quantified through a two-point correlation function. This is routinely measured in spatial and temporal domains. One can also consider spectral coherence, however, the measurement of spectral two-point correlation function becomes challenging because interferometric techniques generally require high-intensity input fields and reconstruction algorithms do not work well for arbitrary spectral shapes.

Recently, the emergence of the quantum pulse gate (QPG), a frequency up-conversion process, has enabled the projection of an input field onto any desired spectral mode with high fidelity, including in the single photon regime. This device therefore overcomes the challenges of measuring spectral coherence. We propose an interferometric scheme that uses a QPG to project a classical or quantum state of light field onto a superposition of two spectral bins and obtains the two-point correlation function by measuring the intensity of the up-converted field as a function of the bin separation. In the context of parametric down-conversion, the spectral coherence measurement of only one of the arms certifies the spectral entanglement between two outputs.

Q 58.5 Thu 15:30 F442

Bi-photon correlation time measurements with a two-colour broadband SU(1,1) interferometer — •Franz Roeder, Michael Stefszky, René Pollmann, Kai Hong Luo, Matteo Santandrea, Victor Quiring, Raimund Ricken, Christof Eigner, Benjamin Brecht, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098 Paderborn, Germany

SU(1,1) interferometers have lately been used for several applications such as achieving super-sensitivity for quantum metrology or enabling spectroscopy and imaging with undetected photons. So far, most of the developed interferometers are based on parametric down-conversion (PDC) from bulk crystals, limiting the brightness of the sources as well as integrability. Furthermore, only spectral or temporal interferograms have been investigated so far.

Here, we demonstrate spectral and temporal interferometry using a SU(1,1) interferometer based on ultra-broadband, non-degenerate dispersion-engineered parametric down-conversion in nonlinear waveguides. These PDC sources exhibit strong frequency correlations and, simultaneously, sub-100 fs photon-photon correlation times. Measuring spectral and temporal interferograms simultaneously allows us to extract the ultra-short biphoton correlation time of our source, a task that has been challenging until now. Knowledge about this quantity is essential for further applications such as entangled two-photon absorption.

Q 58.6 Thu 15:45 F442

Terahertz sensing with undetected photons — •Mirco Kutas[1,2], Björn Haase[1,2], Jens Klier[1], Georg von Freymann[1,2], and Daniel Molter[1] — [1]Fraunhofer Institute for Industrial Mathematicutes ITWM, Fraunhofer-Platz 1, 67663 Kaiserslarn — [2]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern (TUK), 67663 Kaiserslautern

Today, terahertz applications are widely used in industry as well as scientific research. Although the used components have undergone a tremendous development in recent decades, detection of terahertz radiation is still subject of current investigation. By using a quantum-optical measurement concept, we demonstrate a novel approach to detect phase-sensitive terahertz information. With this concept, it is possible to transfer the terahertz photon properties after interaction with a sample to visible photons. As a result, detection can be realized by easily accessible and highly developed silicon-based detectors without the need of cooling or expensive equipment. We report on the demonstration of quantum sensing and spectroscopy in the terahertz frequency range by only detecting visible light.

Q 58.7 Thu 16:00 F442

Remote Imaging in a Three Atom System — •Manuel Bojer[1], Jörg Evers[2], and Joachim von Zanthier[1] — [1]Quantum Optics and Quantum Information, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 1, 91058 Erlangen, Germany — [2]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

We study a system consisting of three identical two-level atoms where two atoms are assumed to be close to each other such that they interact via the dipole-dipole interaction while the third atom is located at a distance $d \gg \lambda$, with λ the atomic transition wavelength. Although the distant third atom does not directly interact with the collective two-atom subsystem, it can be used to alter the total system's spontaneous emission properties via measurement-induced entanglement. We present a detection scheme for which Glauber's third-order photon correlation function displays an oscillatory behavior in time, with a frequency determined by the coherent coupling parameter of the dipole-dipole interaction between the first two atoms. This parameter crucially depends on the two-atom separation allowing to resolve the distance between the two adjacent atoms with sub-Abbe resolution.

Q 58.8 Thu 16:15 F442

Phase-quadrature quantum imaging with undetected light — •Björn Haase[1,2], Joshua Hennig[1,2], Mirco Kutas[1,2], Erik Waller[1], Julian Hering[2], Georg von Freymann[1,2], and Daniel Molter[1] — [1]Fraunhofer Institute for Industrial Mathematics ITWM, Fraunhofer-Platz 1, 67663 Kaiserslautern — [2]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern (TUK), 67663 Kaiserslautern

The use of nonlinear interferometers allows sensing with undetected photons. The corresponding experiments base on biphotons that are generated by spontaneous parametric down-conversion. They enable the transfer of spectral properties from one spectral range that is usually hard to investigate to photons from another spectral region easier to observe. By detecting these signal photons, the interaction of a sample with the idler light can be investigated. So far, the sample's information in terms of both phase and transmittance is received by measuring the corresponding interferogram, which is achieved by multiple recordings with phase changes in between. On this conference, I will present an alternative phase-quadrature approach with a nonlinear interferometer used for imaging with undetected light in the NIR range. With this development, in which we use wave plates and a polarizing beam splitter, we are able to obtain both the phase and visibility with one single image acquisition without the requirement to change optical paths or phases. Thus, with the reduced measurement duration it becomes possible to observe dynamic processes like the drying of an isopropanol film with this kind of nonlinear interferometer.