Q 65: Quantum Information (Miscellaneous)

Time: Friday 10:30–12:15 Location: Q-H12

Q 65.1 Fri 10:30 Q-H12

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

SU(1,1) interferometers have been investigated intensively lately for applications such as spectroscopy or imaging with undetected photons. These interferometers are mostly utilising engineered broadband non-degenerate PDC sources as active elements to achieve broad spectral coverage. Being pumped with a narrow bandwidth CW laser, these PDC sources exhibit strong frequency correlations and simultaneous correlation times between the photons down to below 100 fs. In general, such short correlation times are hard to measure. Nevertheless, knowledge about this quantity is essential for further applications such as entangled two-photon absorption.

In this contribution, we show that the fringing pattern, measured in terms of single photon numbers and coincidence counts, of a SU(1,1) interferometer is directly connected to the correlation time.

We will present measurements from an interferometer consisting of a broadband integrated Type-II PDC source operating at wavelengths of 830 nm and 1370 nm. We are able to deduce the correlation time of the bi-photons within the interferometer and discuss its significance for applications.

Q 65.2 Fri 10:45 Q-H12

Engineering of Kerr squeezing of light — •Nikolay A. Kalinin[1,2], Arseny A. Sorokin[1,2], Thomas Dirmeier[2,3], Elena A. Anashkina[1,4], Gerd Leuchs[1,2,3], and Alexey Andrianov[1] — [1]Institute of Applied Physics, RAS, Nizhny Novgorod, Russia — [2]Max Planck Institute for the Science of Light, Erlangen, Germany — [3]Department of Physics, Friedrich-Alexander-University Erlangen-Nürnberg, Germany — [4]Advanced School of General and Applied Physics, Lobachevsky State University of Nizhny Novgorod, Russia

We report on a new experimental study and a modified set-up, allowing for reliably generating 5dB of two-mode Kerr squeezing. Manipulating the two-mode squeezed state using standard linear optic unitary transformations, we also demonstrate the enhancement of the sensitivity of an interferometer. In addition, we are studying different glasses with higher Kerr effect coefficient [A.A. Sorokin et al., Photonics 8, 226 (2021)]. Squeezing coherent states of light using the optical Kerr effect requires no phase matching condition. The effect is observable, if the incoming coherent light is intense enough, the interaction is long enough and losses are small enough. Therefore, experimental studies concentrated on optical waveguides, such as fibers of several meter length, using pulses in the soliton domain to enhance the overall effect. The Kerr nonlinear phase shift results in an elliptical distribution in phase space, tilted with respect to amplitude quadrature. Squeezing cannot be seen in intensity detection directly out of the waveguide, so that demonstrating sensitivity enhancement of an interferometer is challenging. (RFBR 19-29-11032; Megagrant 075-15-2021-633)

Q 65.3 Fri 11:00 Q-H12

Sensing with few photons: beating the Standard Quantum Limit in lossy SU(1,1) interferometers — •Matteo Santandrea, Kai Hong Luo, Michael Stefszky, Jan Sperling, Harald Herrmann, Benjamin Brecht, and Christine Silberhorn — Paderborn University, Department of Physics, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburgerstr. 100, D-33098 Paderborn, Germany

SU(1,1) interferometers have been shown to be able to beat the Standard Quantum Limit (SQL), since their uncertainty in phase estimation scales as $\sim 1/\langle n\rangle$, in the limit of $\langle n\rangle \gg 1$, where $\langle n\rangle$ indicates the mean photon number inside the interferometer. However, in recent years, these systems have been used more and more often in the low photon number regime ($\langle n\rangle \ll 1$) for spectroscopy and microscopy applications, where the scaling properties are not considered. In this regime, it is not obvious whether they can beat the SQL or in which cases - in particular when losses inside and outside the interferometer are considered.

In this contribution, we investigate lossy SU(1,1) interferometers in the low photon number regime. We show that concidence measurement can drastically help in beating the SQL and that it is still possible to beat the SQL even in the presence of moderate losses inside the setup.

The results of this work are fundamental in understanding the behaviour of SU(1,1) interferometers in the low photon number regime and provides the foundations for improved low-photon-number interferometric schemes.

Q 65.4 Fri 11:15 Q-H12

Engineering Organic Molecules with Long-Lived Quantum Coherence — •Burak Gurlek[1], Vahid Sandoghdar[1], and Diego Martin-Cano[2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Departamento de Físíca Teórica de la Materia Condensada and Condensed Matter Physics Center, Universidad Autónoma de Madrid, Madrid, Spain

Some organic molecules in the solid state offer remarkable coherent properties at liquid helium temperatures and flexibility in their chemical synthesis [1]. However, the excited state associated with the strong Fourier-limited zero-phonon lines of these systems decay within nanoseconds, posing a challenge for practical applications in quantum technologies. In this theoretical work, we propose a new molecular system with quantum coherences up to millisecond time scales. Here, we exploit the inherent optomechanical character of organic molecules in a solid organic crystal [2]. The proposed scheme consists of a single organic molecule in a host matrix with a structured phononic environment. By suppressing phononic decay channels, we realize and exploit long optomechanical coherence times up to milliseconds for storing and retrieving information. We show that the resulting long-lived vibrational states facilitate reaching the strong optomechanical regime at the single photon level. The proposed system shows the promise of organic molecules for achieving unexplored optomechanical phenomena and long-lived quantum memories. References: [1] C. Toninelli et al., Nat. Mater. 20, 1615-1628 (2021). [2] B. Gurlek et al., Phys. Rev. Lett. 127, 123603 (2021).

Q 65.5 Fri 11:30 Q-H12

Quantum interference and spectral properties of single photons generated from a single $^{40}Ca^+$ ion — •Matthias Kreis, Jelena Ritter, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken

Generation of single photons by Raman scattering is a way of realizing an atom-photon quantum interface [1]. For quantum communication applications, well-controlled temporal and spectral properties are important, for example for the indistinguishability of photons from different senders.

We record spectra of single photons generated on the 393 nm ($P_{3/2} \rightarrow S_{1/2}$) and 854 nm ($P_{3/2} \rightarrow D_{5/2}$) transitions of a single trapped $^{40}Ca^+$ ion, using frequency stabilized Fabry-Perot cavities as single-photon spectrometers. The temporal single-photon wave packets are recorded simultaneously.

We report comprehensively on the observed properties, including the time-bandwidth product, in dependence of the excitation parameters. We demonstrate the generation of photons narrower than the natural linewidth of the $P_{3/2}$ state. We further discuss quantum interference effects in absorption and emission leading to an enhancement and suppression of the emission into certain frequency modes. For all cases, measured spectra are compared to model calculations extended from the theory in [2] and [3].

[1] C. Kurz et al., Phys. Rev. A **93**, 062348 (2016).
[2] P. Müller et al., Phys. Rev. A **96**, 023861 (2017).
[3] S. Zhu et al., Phys. Rev. A **52**, 4791 (1995)

Q 65.6 Fri 11:45 Q-H12

Optimal control design of preparation pulses for higher contrast imaging — •Amanda Nicotina and Steffen Glaser — Technische Universität München, Munich, Germany

Magnetic Resonance Imaging (MRI) is an imaging technique that has gained a lot of attention in the medical community for its ability to visualize the internal body in a non-invasive manner. This visualization is achieved based on the contrast originating from intrinsic tissue properties, such as relaxation times (T1 and T2). This contrast can be emphasized via additional acquisition parameters (for example, flip angles/RF pulses), the standard acquisition strategies being T1 and T2 weighting. However, these do not always generate the optimal contrast. This work proposes a more tailored approach, where we present how to find an optimal sequence of flip angles based on optimal control theory for the contrast between specific tissues. In addition, it allows for robust control pulses even when introducing B0- and B1-inhomogeneities. More precisely, we employ the Pontryagin Maximum Principle to numerically find optimal solutions to the underlying Bloch equations implementing the GRadient Ascent Pulse Engineering (GRAPE) algorithm. In particular, we focus on the theoretical and experimental limits of the optimizations.

Q 65.7 Fri 12:00 Q-H12

Incompatibility of energy conservation and fluctuation theorems for quantum work — •Karen Hovhannisyan[1] and Alberto Imparato[2] — [1]University of Potsdam, Institute of Physics and Astronomy, 14476 Potsdam, Germany — [2]Aarhus University, Department of Physics and Astronomy, Ny Munkegade 120, 8000 Aarhus, Denmark

Characterizing the fluctuations of work in coherent quantum systems is a notoriously elusive problem. Aiming to reveal the ultimate source of this elusiveness, we demand of a work measurement the sheer minimum and check if those demands can be met at all. We require (A) energy conservation for arbitrary initial states of the system and (B) the Jarzynski equality for thermal initial states. By energy conservation we mean that the average work must be equal to the difference of initial and final average energies, and that untouched systems must exchange deterministically zero work. Requirement B encapsulates the second law of thermodynamics and the quantum–classical correspondence principle. We prove that work measurement schemes that do not depend on the system's initial state satisfy B if and only if they coincide with the famous two-point measurement scheme, thereby establishing that state-independent schemes cannot simultaneously satisfy A and B. Expanding the scope to the realm of state-dependent schemes allows for more compatibility between A and B. However, merely requiring the state-dependence to be continuous still effectively excludes the possibility of coexistence of A and B.