# Q 51: Quantum Optics IV

Time: Thursday 14:00–16:00 Location: f342

Q 51.1 Thu 14:00 f342

**Lindbladian approximation beyond the ultra weak coupling assumption** — •Tobias Becker, Ling-Na Wu, Daniel Vorberg, and André Eckardt — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden

Markovian master equations of Lindblad form for the description of open quantum systems have not only the advantage that they guarantee a completely positive trace preserving (CPT) evolution. They are also the starting point for efficient stochastic quantum trajectory simulations. For thermal environments, such Lindblad-type master equations are commonly derived by starting from the Redfield-equation obtained within Born-Markov approximation and by applying additionally also a rotating-wave (or secular) approximation. However, the latter requires ultra weak system-bath coupling, which is small compared to the level splitting in the system, a condition which is hard to achieve in large systems that approach a continuous spectrum in the thermodynamic limit. Here, we describe an alternative approximation to the Redfield equation, which also leads to a master equation of Lindblad form. This approximation does not require ultra weak system bath coupling, but rather sufficiently large temperatures. It, thus, works in regimes, where the secular approximation breaks down. We test our results using the example of an extended Hubbard chain coupled to two baths of different temperature.

Q 51.2 Thu 14:15 f342

**Master equation for multilevel interference in a superradiant medium** — •Aleksei Konovalov, Andreas Buchheit, and Giovanna Morigi — Universität des Saarlandes, Saarbrücken, Germany

We derive a master equation for a superradiant medium which includes multilevel interference between the individual scatterers. The derivation relies on the Born-Markov approximation and implements the coarse graining formalism. The master equation fulfils the Lindblad form, the dynamics it predicts shows that the scattering properties are affected by the interplay between single-atom multilevel interference, multi-atom interference between identical transitions, and multi-atom interference between different electronic transitions with parallel dipoles. This formalism is then applied to determine the excitation spectrum of two atoms using the parameters of the Hydrogen transitions $2S_{1/2} \rightarrow 4P_{1/2}$ and $2S_{1/2} \rightarrow 4P_{3/2}$. The distortion of the signal due to the interplay of multilevel and multi-atom interference is discussed as a function of the interatomic distance. These results are relevant for the realization of atomic clocks using cold atomic ensembles.

Q 51.3 Thu 14:30 f342

**Dynamical detection of dipole-dipole interactions in dilute atomic gases** — •Benedikt Ames, Edoardo Carnio, Vyacheslav Shatokhin, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

Recent experiments have identified signatures of the dipole-dipole interaction in extremely dilute, thermal atomic vapors via fluorescence signals excited by ultrashort, phase-modulated laser pulses [1]. The nonlinear spectroscopic technique allows to extract spectral features stemming from collective effects from an intense single-scattering background, down to the lowest experimentally accessible densities of $\sim 10^7\,\mathrm{cm}^{-3}$.

To provide quantitative, analytical expressions for the fluorescence signals, we use an open quantum system treatment which was previously employed to investigate coherent backscattering of light by cold atoms [2]. By adapting it to time-dependent driving, we obtain a model which is non-perturbative in the atom-laser interaction and admits a series expansion with respect to the weak inter-atomic coupling as mediated by the exchange of (transverse) photons. In terms of those single- and double-scattering contributions to the scattering series which survive the average over random atomic configurations, we interpret the lineshapes and relative strength of single- and double-quantum coherence signals.

[1] L. Bruder et al., Phys. Chem. Chem. Phys. **21**, 2276–2282 (2019)
[2] V. Shatokhin, C. Müller, A. Buchleitner, Phys. Rev. A **73**, 063813 (2006)

Q 51.4 Thu 14:45 f342

**Quantum illumination for remote target detection** — •Giacomo Sorelli[1,2], Nicolas Treps[2], Frédéric Grosshans[3], Claude Fabre[2], and Fabrice Boust[1] — [1]Département ElectroMagnétisme et Radar, Onera - Paliseau - France — [2]Laboratoire Kastler Brossel, Sorbonne Université, CNRS, ENS-Université PSL, Collège de France - Paris - France — [3]LIP6, Sorbonne Université, CNRS - Paris - France

Entanglement revealed to be a fundamental resource to provide sensing performance beyond those allowed by classical physics. It is therefore natural to explore its potential to improve radar technology. The first attempt in this direction is represented by quantum illumination [1]: an entanglement-based protocol to detect a low-reflectivity target immersed in high thermal background. The most astonishing characteristic of this protocol is that, under specific energy constraints, it provides a quantum advantage, even though noise and losses completely destroy the initial entanglement.

In this talk we will review the continuous variable version [2] of the quantum illumination protocol. In particular, by using figures of merit typical of the classical radar literature, we will evaluate its performances in realistic radar and lidar scenarios. We will show that the regime where the standard quantum illumination protocol provide an advantage over classical radar is of little use in such realistic settings and discuss how one could overcome this limitation.

[1] S. Lloyd, Science 321, 5895, 1463-1465 (2008)
[2] Tan et al., Phys. Rev. Lett. 101, 253601 (2008)

Q 51.5 Thu 15:00 f342

**Optimizing spontaneous parametric down-conversion sources for boson sampling** — •Reinier van der Meer[1], Jelmer J. Renema[1], Benjamin Brecht[2], Christine Silberhorn[2], and Pepijn W. H. Pinkse[1] — [1]University of Twente, Enschede, The Netherlands — [2]Paderborn University, Paderborn, Germany

The next milestone in photonic quantum information processing is to demonstrate an optical experiment at which the quantum device outperforms any classical computer. This can be achieved by sending single photons through a passive linear-optical network. However, this requires the generation of many identical single photons, which is challenging to realize. Spectral impurity reduces the visibility of quantum interference of the photons, which can be mitigated by filtering at the cost of optical losses. Unfortunately, these losses are also detrimental to quantum interference.

We recently demonstrated how to analyze the role of imperfections in multiphoton interference experiments [1]. We now apply these results to the problem of constructing single-photon sources. In this work we show that an optimum exists where we can outperform a classical computer, using off-the-shelf parametric down-conversion photon sources. These results show that demonstrating a quantum advantage using photonics is difficult, but possible.

[1] J.J. Renema et al., arXiv: 1809.01953 (2018)

Q 51.6 Thu 15:15 f342

**Correlated photon-pair emission from a cw-pumped Fabry-Perot microcavity** — •Thorsten F. Langerfeld, Felix Rönchen, Hendrik M. Meyer, and Michael Köhl — Physikalisches Institut, Universität Bonn, Wegelerstraße 8, D-53115 Bonn, Germany

The generation of correlated photons is an important milestone in fundamental test of quantum mechanics and in the quest to interconnect remote quantum systems with the goal of creating quantum networks. For the latter, a tunable photon pair source, which can be tailored to the physical properties of the network nodes is desirable. For that purpose, we study a dispersion-compensated high-finesse optical Fabry-Perot microcavity under high-intensity cw pumping. The Kerr non-linearity in the optical coatings causes a spontaneous four-wave mixing process, triggered by vacuum fluctuations of the unoccupied cavity modes. Thus time-correlated photon pairs are emitted, which are shifted in frequency by $\pm 1$ free spectral range relative to the pump frequency. The ease of the experimental setup and the principal tunability of the wavelengths and bandwidths of the created photon pair make the scheme an attractive candidate for a photon-pair source with application in hybrid quantum systems in which wavelength has to be bridged between dissimilar systems. Furthermore, by filling the cavity with a synthetic silicon oil the optical non-linearity is extended over the entire cavity length which increased the pair correlation rate by a factor of more than $10^3$ and improved the coincidence to accidental ratio by a factor of 1.7.

Q 51.7 Thu 15:30 f342

**Quantum Feedback, self-stimulation and Fock State Generation** — •Melanie Engelkemeier[1], Ish Dhand[2], Evan Meyer-Scott[1], Jan Sperling[1], Sonja Barkhofen[1], Benjamin Brecht[1], Martin Plenio[2], and Christine Silberhorn[1] — [1]Universität Paderborn, Integrierte Quantenoptik, Warburger Str. 100, D-33098 Paderborn — [2]Universität Ulm, Institut für Theoretische Physik, Helmholtzstraße 16, D-89081 Ulm

The generation of higher-order Fock states is important for several physical applications, such as fundamental studies of physics and quantum metrology. Usually, the means of choice to generate heralded higher-order Fock states is a dispersion-engineered parametric down conversion (PDC) process. These processes feature a high overall brightness, however the probability to generate specific higher-order Fock states decreases with increasing state size; large states are generated only at low rates. To overcome this challenge, we utilize a time-multiplexed quantum feedback, which introduces self-stimulation in the PDC process. This leads to a successive build up of higher order Fock states due to a coherent addition of photons. Therefore, within this setup, it is possible to generate higher-order Fock states with higher rates compared to a single PDC source. In this talk, we report on the current status of this project.

Q 51.8 Thu 15:45 f342

**Second Harmonic Generation at Cryogenic Temperatures in Lithium Niobate Waveguides** — •Nina Amelie Lange[1], Moritz Bartnick[1], Jan Philipp Höpker[1], Frederik Thiele[1], Raimund Ricken[2], Viktor Quiring[2], Christof Eigner[2], Harald Herrmann[2], Christine Silberhorn[2], and Tim Bartley[1] — [1]Mesoskopische Quantenoptik, Department Physik, Universität Paderborn, Warburger Straße 100, 33098 Paderborn, Germany — [2]Integrierte Quantenoptik, Department Physik, Universität Paderborn, Warburger Straße 100, 33098 Paderborn, Germany

Waveguides in lithium niobate have shown extensive functionality in quantum photonics. Their high second-order nonlinearity and electro-optic properties make them ideal for nonlinear processes and active manipulation of quantum optical states. These properties are well-known under ambient conditions; however, to be compatible with other photonic technologies such as single photon emitters and superconducting detectors, optimisation at cryogenic temperatures is required. We demonstrate second harmonic generation (SHG) down to a temperature of 4K, using a robust fibre-pigtailing procedure, a narrowband tuneable pump laser and a closed-cycle cryostat. We analyse the role of the temperature change on the phasematched wavelength, and investigate various dynamics across different timescales, which indicate the appearance of pyroelectric fields.