Q 70: Quantum Optics and Control II

Time: Friday 11:00–13:00 Location: P 3

Invited Talk Q 70.1 Fri 11:00 P 3

Totally destructive many-body interference beyond bosons and fermions — •Gabriel Dufour and Andreas Buchleitner — Physikalisches Institut & EUCOR Center for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg

The suppression of coincidence events in the Hong-Ou-Mandel experiment is a striking example of totally destructive many-body interference of two bosons. Similar effects have been described for greater numbers of bosons or fermions in larger interferometers. Here, we describe suppressions of certain particle configurations at the output of a Fourier interferometer when the many-body state on input has a specific symmetry under particle exchange, which need not be bosonic or fermionic.

Q 70.2 Fri 11:30 P 3

How to Break Symmetries to Get Quantum Systems under Control — •Thomas Schulte-Herbrüggen[1], Emanuel Malvetti[1], and Gunther Dirr[2] — [1]Technical University of Munich (TUM), School of Natural Sciences — [2]University of Würzburg, Institute of Mathematics

In quantum engineering one wants to know "what one can do" with a given controlled dynamical system when starting with given initial conditions. The degree to which such a system can be controlled (accessed), observed, tomogaphied, or Kalman-filtered is readily judged by symmetries. To wit, those symmetries shared by the dynamic generators and the observables or filters.

We give constructive guidelines how to break symmetries to bring quantum systems under control, or observation, or Kalman-filtering. They are part of an overarching frame for quantum systems theory. [For a tutorial overview, see Proc. IEEE-CDC **63** (2024), p5231-5247.]

Q 70.3 Fri 11:45 P 3

Nonlinear excitations in laser driven two level systems — •Deniz Adigüzel, Miriam Gerharz, and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The extreme narrow linewidths of Mössbauer nuclei transitions render precision spectroscopy possible but subsequently make it also very challenging to achieve nonlinear excitations. Recent experiments at X-ray free electron lasers allow one to access new excitation regimes. This makes the study of nonlinearly excited nuclear systems particularly relevant. The interaction in question is a laser driven two level system which can be studied by solving the Maxwell-Bloch equations coupled with the propagation equation. As this system consists of a coupled partial differential equation, the analytical solution is in general not always obtainable. To overcome this problem, we implemented the method of lines to investigate light propagation beyond low excitations numerically. Here we report on the nonlinear timeshifts in the minima of the coherently scattered light and transitions around population inversion. Subsequently a signature was proposed in order to quantify the degree of excitation.

Q 70.4 Fri 12:00 P 3

Enhancing Stimulated Raman Scattering Using Kerr Squeezing — •Nikolay Kalinin[1], Kilian Scheffter[1,2], Seungwon Moon[1], Hannah Gallop[3], Mehdi Alizadeh[3], Adrian F. Pegoraro[4], Hanieh Fattahi[1,2], Alexey V. Andrianov[5], Albert Stolow[3], Luis L. Sánchez-Soto[1,6,7], and Gerd Leuchs[1,2,3] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Physik Department, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany — [3]Department of Physics, University of Ottawa, Ottawa, Canada — [4]Metrology Research Centre, National Research Council Canada, Ottawa, Canada — [5]Nizhny Novgorod, Russia — [6]Departamento de Óptica, Facultad de Física, Universidad Complutense, Madrid, Spain — [7]Institute for Quantum Studies, Chapman University, Orange, CA, USA

Squeezed light states provide a way to improve signal-to-noise ratio (SNR) in various measurements when classical methods face a limit. In state-of-the-art stimulated Raman scattering (SRS) experiments, such a limit is photodamage of biological samples. Recently, several groups demonstrated SRS with nonclassical light, where a $\chi^{(2)}$ nonlinearity was employed to produce squeezing. In this work, we explore an alternative approach based on Kerr ($\chi^{(3)}$) nonlinearity to enhance SRS. Our setup is relatively simple and robust, while also providing a perfect spatial mode for the Raman interaction. By injecting Kerr-squeezed light at 1.5 μm as the pump for the SRS in quartz, we achieve 3.0 dB of SNR improvement, a value on par with other known results.

Q 70.5 Fri 12:15 P 3

Pulse Engineering via Projection of Response Functions at Infinite Nonlinear Order — •Lia Kley[1,2] and Ludwig Mathey[1,2,3] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]Institut für Quantenphysik, Universität Hamburg, 22761 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany

High-fidelity control of quantum systems requires methods that are both flexible and practical. We introduce a new method for optimal control that iteratively refines control parameters by evaluating the response of the fidelity to the applied control operators. It aims to implement target operations reliably with high fidelity, while extending established optimal-control techniques by providing access to the parameter update without the need for hyperparameter tuning, enhancing both practicality and applicability. To illustrate its potential, we discuss its application to a multi-qubit gate optimization task, comparing the method to existing approaches and highlighting improvements in usability and convergence relative to conventional strategies.

Q 70.6 Fri 12:30 P 3

Towards coherent dipole-dipole coupling of molecular dimers — •Dinesh Reddy[1,2], Ashley Shin[1], Tim Hebenstreit[1,2], Siwei Luo[1,2], Mikhail Kalinin[3], Alexander Oshchepkov[3], Jan Renger[1], Tobias Utikal[1], Konstantin Amsharov[3], Vahid Sandoghdar[1,2], and Stephan Götzinger[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Department of Physics, Friedrich Alexander University Erlangen-Nuremberg, Erlangen, Germany — [3]Department of Organic Chemistry, Martin-Luther-University Halle-Wittenberg, Halle(Saale), Germany

Coherent coupling between two quantum emitters via their optical near-field gives rise to the formation of sub- and superradiant entangled states. It can be experimentally challenging to optically confirm such coupling, as it typically requires emitters to be separated by only a few nanometers. We adopt a bottom-up synthetic approach, leveraging precise molecular engineering to tune the inter-emitter distance using tailored organic linkers. Our study focuses on single-molecule spectroscopy of dibenzanthanthrene (DBATT) that has shown to have high quantum yield and lifetime-limited linewidths at cryogenic temperatures (<2.2K). By functionalizing DBATT with various linker groups, we construct isolated monomers with linkers as well as dimers. We utilize a tunable narrow-band CW laser to obtain near lifetime-limited fluorescence excitation spectra as well as emission spectra with high spectral resolution to distinguish the effects of chemical functionalization from strong coupling. Additionally, we report autocorrelation and inhomogeneous broadening of all DBATT species.

Q 70.7 Fri 12:45 P 3

Storing images in hot atomic vapors — •Denis Uhland and Ilja Gerhardt — light & matter group, Institute for Solid State Physics, Leibniz University Hannover

The ability to reliably store and retrieve photons lies at the heart of emerging quantum technologies. A suitable medium for the storage and retrieval of photons are hot atomic vapors, which offer a possible way for room-temperature optical quantum memories. Previous works have demonstrated the storage and retrieval on the single photon level [1] and of images from a laser illuminated mask [2] in hot atomic vapors via electromagnetically induces transparency (EIT). Here, we show coherently storage and retrieval of two-dimensional images by exploiting the memory capabilities of the hot atomic vapor. Such image-preserving quantum memories overcome the idealized single-modal treatment of a collective excitation in an atomic ensemble. This combines the quantum storage of light with the unique sensing properties of a hot atomic vapor cell.

[1] L. Esguerra et al., Phys. Rev. A (2023) 107, 042607 [2] M. Shuker et al., Phys. Rev. Lett. 100, 223601