Q 33: Quantum Information (Concepts and Methods) III

Time: Tuesday 14:00–16:00 Location: K 1.019

Group Report Q 33.1 Tue 14:00 K 1.019

Quantum imaging with incoherent X-rays — •Joachim von Zanthier — for the Quantum Imaging Collaboration: Department Physik, Universität Erlangen-Nürnberg, 91058 Erlangen; Department Physik, Universität Hamburg, 22761 Hamburg; Center for Free-Electron Laser Science, 22761 Hamburg; The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg; Deutsches Elektronen-Synchrotron DESY, 22607 Hamburg

For more than 100 years, coherent diffraction of X-rays has been used to determine the structure of crystals and molecules. For this approach incoherence due to wavefront distortions or incoherent fluorescence emission - often the predominant scattering mechanism - is usually considered detrimental. Here we show that methods from quantum imaging, i.e., exploiting higher order intensity correlations, can be used to reconstruct and image the full 1D, 2D and even 3D arrangement of incoherently scattering objects [1-4]. Incoherent diffraction imaging allows for a significantly higher resolution compared to conventional coherent diffractive imaging techniques. We discuss a number of properties that are conceptually superior and point out that current free-electron lasers are ideally suited for the implementation of the approach [3]. We also present a first experimental demonstration in the soft X-ray domain, where we use higher-order intensity correlations to achieve higher fidelities and potentially a sub-Abbe resolution [4]. [1] S. Oppel et al., PRL 109, 233603 (2012). [2] A. Classen et al., PRL 117, 253601 (2016). [3] A. Classen et al., PRL 119, 053401 (2017). [4] R. Schneider et al., Nature Phys., published online October 30, 2017.

Q 33.2 Tue 14:30 K 1.019

Universality of weak values and its application to an efficient alignment method for interferometers — Jan Dziewior[1,2], Lukas Knips[1,2], Demitry Farfurnik[3], •Katharina Senkalla[1,2], Nimrod Benshalom[3], Jonathan Efroni[3], Jasmin Meinecke[1,2], Shimshon Bar-Ad[3], Harald Weinfurter[1,2], and Lev Vaidman[3] — [1]Max-Planck-Institute for Quantum Optics, Garching 85748 — [2]Department for Physics, Ludwig-Maximilians-University, Munich 80797 — [3]Raymond and Beverly Sackler School of Physics and Astronomy, Tel-Aviv University, Tel-Aviv 69978

Weak values characterize the weak interactions of pre- and postselected quantum systems, in particular they provide a simple and universal description for different measurement pointers and observables. We demonstrate this universality by considering a photon in an interferometer with weak local interactions in one of its arms coupling to different degrees of freedom (DOF), like position $\hat{x}$, momentum $\hat{p}$, and polarization of the photon. We show theoretically and experimentally that different interactions in the same arm will all modify the pointer DOF in an universal way.

By considering misalignments of an interferometer as such a coupling to $\hat{x}$ and $\hat{p}$ we can provide an easy and efficient alignment method. We use the fact, that the centroid of the interference pattern is modified according to the weak value, which mainly depends on the phase, the relative intensity and the overlap of the two arms. Analyzing a single 2π phase scan taken by a single position sensing detector yields all necessary alignment parameters.

Q 33.3 Tue 14:45 K 1.019

Amplified measurement of a mode function's rotation — •Sabrina Hartmann, Joachim Fischbach, and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm

We present a complete quantum optical description of a Mach-Zehnder interferometer, including a Dove prism, which is rotated by a small angle compared to the plane of incidence [1]. The Dove prism changes polarization and rotates the mode function in one arm of the interferometer. Subsequently, by post-selecting photons at the output via polarization we identify an amplification of the mode function's rotation. This has been explained by the weak value formalism. We show, however, that this explanation is limited to a certain set of parameters. Furthermore, we evaluate the interferometric setup for several non-classical states and hence, determine conditions to obtain the above mentioned effect. The amplification of the mode function's rotation can also be observed in the second order correlation function.

[1] O.S. Magaña-Loaiza et al., *Physica Scripta*, **92**, 023001 (2016).

Q 33.4 Tue 15:00 K 1.019

Binary Homodyne Detection of Quadrature Squeezing over Satellite Links — •Christian R. Müller[1,2], Kaushik P. Seshadreesan[3,1,2], Gerd Leuchs[1,2,4], and Christoph Marquardt[1,2] — [1]Max-Planck-Institut für die Physik des Lichts, Erlangen, Deutschland — [2]Department Physik, Friedrich-Alexander-Universität Erlangen Nürnberg (FAU), Erlangen, Deutschland — [3]College of Optical Sciences, University of ArizonaTucson (AZ) USA — [4]Department of Physics and Max Planck Centre for Extreme and Quantum Photonics, University of Ottawa, Ottawa (ON), Canada

Optical satellite links are a promising candidate to overcome the distance limits of fiber-based quantum key distribution protocols [1]. Moreover, the vast distances and the varying gravitational potential renders optical satellite links an exciting testbed for probing the laws of physics at the interface between quantum mechanics and general relativity.

Quadrature squeezing is a nonlinear effect based on quantum correlations between photons in the optical signal. We demonstrate the feasibility of squeezing detection in a realistic scenario of an optical satellite link. Furthermore, we show that efficient squeezing detection is even feasible in the extreme case of a homodyne detector with merely one bit of resolution - a situation commonly found in long-haul optical communications. Our results pave the way for a timely and cost-efficient realization of fundamental tests of physics.

[1] K. Günthner et al., Optica (4)6 pp.611-616 (2017).

Q 33.5 Tue 15:15 K 1.019

Ergotropy and daemonic gain for multipartite systems — •Fabian Bernards[1], Otfried Gühne[1], Matthias Kleinmann[1], and Mauro Paternostro[2] — [1]Universität Siegen, Siegen, Germany — [2]Queen's University Belfast, United Kingdom

The emerging field of quantum thermodynamics tries to establish connections between thermodynamics and quantum mechanics. This connection brings up questions like 'How is the maximal extractable work from a quantum system related to its inherent classical and nonclassical correlations?' or 'Can entanglement help us to develop better work extraction protocols?'. The maximal amount of extractable work from a system when maximizing over all possible unitary time evolutions is called ergotropy. If the system is correlated to an ancilla, the maximal amount of extractable work can on average be increased by performing measurements on the ancilla before extracting the work from the system. This increased amount of extractable work is then called daemonic ergotropy and the average gain from performing optimal measurements on the ancilla is the daemonic gain. In [G. Francica et al., NPJ Quantum Information 3,12 (2017)] a connection was established between the daemonic gain and measures of correlations in the system such as concurrence. Additionally, numerical results were presented for the two-qubit case. In our contribution, we are going to present applications of the concepts above on higher-dimensional and multi-partite systems.

Q 33.6 Tue 15:30 K 1.019

Exponentially many monogamy and correlation constraints for multipartite states — •Christopher Eltschka[1], Felix Huber[2], Otfried Gühne[2], and Jens Siewert[3,4] — [1]Universität Regensburg, Regensburg, Germany — [2]Universität Siegen, Siegen, Germany — [3]Universidad del País Vasco UPV/EHU, Bilbao, Spain — [4]IKERBASQUE Basque Foundation for Science, Bilbao, Spain

By generalizing the universal state inversion map, we obtain local unitary invariants of degree 2 for arbitrary finite-dimensional multipartite quantum states, for which we systematically derive a set of independent equalities constraining the correlations in the system. The number of those equalities is exponential in the number of parties of the multipartite state.

The derived constraints represent linear inequalities for the linear entropies of the subsystems. For pure quantum states they turn into monogamy relations that constrain the distribution of entanglement among the subsystems of the global state.

Surprisingly, our method of derivation, which is based on the theory of entanglement — the universal state inverter was originally in-

troduced in order to generalize the two-qubit concurrence to higher-dimensional bipartite systems — turns out to be directly linked to the generalized shadow inequalities proved by Rains [1].

[1] E. M. Rains, IEEE Trans. Inf. Theory **46**, 54 (2000)

Q 33.7 Tue 15:45 K 1.019

Even and odd components of correlations in multi-qubit systems — •Nikolai Wyderka, Felix Huber, and Otfried Gühne — Naturwissenschaftlich Technische Fakultät, Universität Siegen, Walter-Flex-Str. 3, D-57068 Siegen, Germany

In multi-particle quantum systems correlations can arise between different sets of particles. A possible strategy is to divide the global correlations into two components, depending on the question whether they affect an odd or an even number of particles. For pure multi-qubit states we prove that these two components are inextricably interwoven and often one type of correlations completely determines the other. As an application, we prove that all pure qubit states with an odd number of qubits are uniquely determined among all mixed states by the odd component of the correlations. In addition, our approach leads to invariants under the time evolution with Hamiltonians containing only odd correlations and can simplify entanglement detection.