Q 10: Quantum Optics II

Time: Monday 14:30–16:30 Location: f442

Q 10.1 Mon 14:30 f442

Topological classification of one-dimensional symmetric quantum walks — •Christopher Cedzich[1], Tobias Geib[1], Francisco Alberto Grünbaum[2], Christoph Stahl[1], Luis Velazquez[3], Albert Werner[4], and Reinhard Werner[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany — [2]Department of Mathematics, University of California, Berkeley CA 94720 — [3]Departamento de Matematica Aplicada & IUMA, Universidad de Zaragoza, Maria de Luna 3, 50018 Zaragoza, Spain — [4]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany

We study symmetry protected topological phases for one-dimensional quantum walks. Topological phases play an important role in the classification of quantum matter. An analogous phase classification of quantum walks encounters the problem that walks are given by a unitary operator rather than a Hamiltonian. As a consequence, walks allow local perturbations which cannot be continuously contracted to the identity without violating unitarity, symmetry or a gap condition. This leads to an additional invariant in the homotopy classification which is, however, not invariant under local but not contractible perturbations.

(See also the related talk by T. Geib)

Q 10.2 Mon 14:45 f442

Decoupling and invariants of one-dimensional symmetric quantum walks — Christopher Cedzich[1], •Tobias Geib[1], Francisco Alberto Grünbaum[2], Christoph Stahl[1], Luis Velazquez[3], Albert Werner[4], and Reinhard Werner[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover — [2]Department of Mathematics, University of California, Berkeley CA 94720 — [3]Departamento de Matemática Aplicada & IUMA, Universidad de Zaragoza, María de Luna 3, 50018 Zaragoza, Spain — [4]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin

We study one-dimensional quantum walks satisfying a set of discrete symmetries and a gap condition. For most of the usual symmetry types, a classification can be built on decoupling, i.e., an arbitrary walk can be deformed continuously and while respecting symmetry and gap conditions into one consisting of two non-interacting half chains. The additional eigenvalues appearing after such decoupling are the basis of the classification. One symmetry type (namely DIII in the Cartan classification) does not seem to allow decoupling in general. For this type an alternative approach presented in a related talk by C. Cedzich can be applied.

Q 10.3 Mon 15:00 f442

Measuring topological invariants in photonic quantum walks — •Thomas Nitsche[1], Fabian Elster[1], Sonja Barkhofen[1], Aurél Gábris[2], Igor Jex[2], and Christine Silberhorn[1] — [1]Universität Paderborn, Integrierte Quantenoptik, Warburger Str. 100, D-33098 Paderborn — [2]Department of Physics, Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Brehova 7, 11519 Praha, Czech Republic

Concepts such as topological insulators have sparked interest in the investigation of topological material properties. Here, we present the simulation of topological phenomena in a discrete-time quantum walk experiment.

In our implementation of a photonic quantum walk system, we are able to dynamically control the quantum-coin, making it feasible to implement a split-step quantum walk protocol simulating the interfacing of bulks with different topological properties.

Being able to read-out the external as well as the internal state of the walker, we measure reflection amplitudes directly corresponding to topological invariants. We show that by tuning the coin operation, we alter topological phases in our model system.

Q 10.4 Mon 15:15 f442

Multipath correlation interference with a thermal source and quantum logic simulations: a fundamental effect in quantum optics — •Johannes Seiler and Vincenzo Tamma — Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm, D-89069 Ulm, Germany

We theoretically demonstrate [1] a novel fundamental effect in quantum optics: the emergence of multipath correlation interference with a thermal source and its ability to simulate the operation of a quantum logic gate known as controlled-NOT gate. In particular, 100%-visibility correlations typical of any Bell state are demonstrated by performing polarization correlation measurements in the fluctuation of the number of photons at the interferometer output. The physics of multiboson interference at the very heart of this proposal can be readily used to simulate on-demand higher-order entanglement correlations in higher-dimension bosonic networks.

[1] V. Tamma, J. Seiler, arXiv:1503.07369 (2015)

Q 10.5 Mon 15:30 f442

Lichtstreuung an Ionenkristallen: Sichtbarkeit der Young'schen Interferenzstreifen — •Sebastian Wolf[1], Julian Wechs[2], Joachim von Zanthier[2] und Ferdinand Schmidt-Kaler[1] — [1]QUANTUM, Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Staudtstr. 1, 91058 Erlangen, Germany

Das Young'sche Doppelspaltexperiment ist ein grundlegendes Experiment der Quantenmechanik. Bei Vorliegen eines Interferenzmusters sind die dazu beitragenden Lichtfelder zueinandner kohärent. Es wurden Kalzium-Ionenkristalle beleuchtet und das gestreute Licht im Fernfeld beobachtet [1]. Den Grad der Kohärenz der gestreuten Lichtfelder untersuchen wir, indem wir den Kontrast des Interferenzmusters bestimmen [2]. Dabei steigt mit der Intensität des anregenden Lasers der Anteil der inelastischen Streuung und der Kontrast sinkt. Andererseits verändern sich bei erhöhter Laserintensität auch die Laserkühlparameter und damit die Ionentemperatur, was ebenfalls zu einem reduzierten Kontrast führt. Durch ein gepulstes Kühl- und Nachweisverfahren gelingt es uns, beide Effekte voneinander zu trennen. Wir haben ebenfalls Interferenzmuster von Kristallen mit drei und vier Ionen gemessen. Durch Anpassen der Fallenspannungen lässt sich ein äquidistanter Vier-Ionen-Kristall erzeugen. Das gemessene Muster stimmt hier sehr gut mit der Verteilung eines kohärent beleuchteten Gitters überein.

[1] Eichmann et al., PRL 70 2359 (1993).
[2] S. Wolf et al., arXiv:1511.08697 (2015).

Q 10.6 Mon 15:45 f442

Programming quantum interference in 10^3 channels in multiple-scattering materials — •Tom A.W. Wolterink, Ravitej Uppu, Georgios Ctistis, Willem L. Vos, Klaus-J. Boller, and Pepijn W.H. Pinkse — MESA+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands

We demonstrate quantum interference in multiple-scattering materials. Starting with on the order of 10^3 coupled channels we create the equivalent of a 2×2 linear optical circuit with programmable correlations by adaptive phase modulation of incident wavefronts. This results in fully programmable Hong-Ou-Mandel interference, showing bunching as well as antibunching of output photons. Our results establish multiple-scattering materials as a platform for adaptive high-dimensional quantum interference experiments, as required, e.g., for boson sampling. Moreover, since multiple-scattering materials are excellent physical unclonable functions for use as optical keys in quantum-secure authentication, our results show the feasibility of including optical keys in other quantum-information protocols.

Q 10.7 Mon 16:00 f442

The $3D$ inverse optoacoustic source problem on the beam axis — •O. Melchert, J. Stritzel, M. Wollweber, M. Rahlves, and B. Roth — Hannover Centre for Optical Technologies, Leibniz Universität Hannover, Hannover, Germany

Today, optoacoustics is widely used in the life sciences, e.g. for imaging of biological tissue. A yet unsolved problem is to determine optical properties from the experimental signals. While the *direct* problem of absorption of light in biological media consists of solving the optoacoustic wave equation for an initial pressure distribution $p_0(\mathbf{r})$, the mathematically challenging *inverse* problem requires the reconstruction of $p_0(\mathbf{r})$ from a proper set of observed signals.

For the particular case of a Gaussian transverse beam profile, the signal $p(z, \tau, \mathbf{r}_\perp = 0)$ at a point z along the beam axis (i.e. $\mathbf{r}_\perp = 0$), at the (retarded) time τ, is given by an integral equation, linear in the initial pressure profile $p_0(\tau)$ on the boundary of the absorbing medium. This integral equation can be interpreted as a Volterra equation of the second kind with known kernel, where $p(z, \tau, \mathbf{r}_\perp)$ is given and $p_0(\tau)$ is an unknown function to be solved for. For this integral equation, technically feasible inversion schemes exist. We study the inversion of *synthetic* signals that correspond to different initial pressure distributions, compare the inversion in the far-field to an approximate method based on the solution of a simple differential equation and consider the effect of noise on the quality of the reconstructed profile.

Q 10.8 Mon 16:15 f442

Mirror-like effect in correlated atoms — •Qurrat-ul-Ain Gulfam[1] and Zbigniew Ficek[2] — [1]Department of Physics, Jazan University, Jazan, Saudi Arabia — [2]The National Center for Mathematics and Physics, KACST, Riyadh, Saudi Arabia

Reflection of light off correlated two-level identical atoms has been investigated. To ensure a one-dimensional emission from the system, normally the atoms have to be coupled with external media [1]. Contrarily, here, we have considered a real 3-dimensional dipole dipole interaction among free space atoms. The directionality in the collective spontaneous emission is induced by the vacuum-mediated interaction based effects. Clear evidence of mirror-like effect in a one-dimensional cavity can be observed in atomic position configurations as simple as a 3-atom linear chain. We first consider the transient behavior when an initial excitation is contained in the system and later also study the steady state evolution of a weakly-driven system. Correlations among the atoms strongly affect the angular distribution of the first order correlation function detected in the far-field. This way suitable directions for enhanced(reduced) reflectivity are determined [2].

[1] D. E. Chang, et al, Phys. Rev. Lett., **110**, 113606 (2013).
[2] V. E. Lembessis, et al, Phys. Rev. A., **92**, 023850 (2015).