Q 6: Quantum Effects: Light Scattering and Propagation

Time: Monday 10:30–13:00 Location: SCH A01

Q 6.1 Mon 10:30 SCH A01

Multiple scattering of photons on disordered atomic samples: localization vs. nonlinearity — •Ralf Blattmann, Felix Eckert, Jochen Zimmermann, Vyacheslav Shatokhin, Thomas Wellens, and Andreas Buchleitner — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3 , 79104 Freiburg

When single photons are multiply scattered inside a disordered cloud of cold atoms, interference between different scattering paths manifests themselves in weak and strong localization effects such as coherent backscattering and – in the most extreme case – even a complete suppression of classical diffusion. At higher laser intensities, however, nonlinear and inelastic multi-photon scattering events must be taken into account, and compete with the coherent transport effects mentioned above. First, we show – by means of diagrammatic scattering theory – that the coherent backscattering peak is reduced, or even inverted, for classical light propagating in a nonlinear disordered medium, and generalize these results to the regime of strong localization. In addition to the nonlinearity, we then address inelastic scattering resulting from the interaction of atoms with the quantized radiation field. In particular, we will analyze scattering of intense laser light by two atoms with degenerate energy levels. Finally, we consider coherent propagation of one and two photons in a one-dimensional disordered chain of two-level atoms, where – in contrast to 3D – recurrent scattering cannot be neglected.

Q 6.2 Mon 11:00 SCH A01

Highly resonant spin noise spectroscopy at the D_2 rubidium transition — •Hauke Horn[1], Ernst Rasel[2], Luis Santos[3], Michael Oestreich[1], and Jens Hübner[1] — [1]Institute for Solid State Physics, Leibniz University Hannover, Appelstr. 2, 30167 Hannover, Germany — [2]Institut für Quantenoptik, Leibniz University Hannover, Welfengarten 1, 30167 Hannover, Germany — [3]Institute for Theoretical Physics, Leibniz University Hannover, Appelstr. 2, 30167 Hannover, Germany

We measure the fluctuating magnetization noise of an ensemble of non-interacting rubidium atoms with high sensitivity Faraday rotation spectroscopy. This measurement technique called spin noise spectroscopy allows us to probe the equilibrium spin dynamics of our sample. In spin noise spectroscopy, a magnetic field is applied in Voigt geometry to modulate the occurring spin noise with the Larmor frequency $\omega_L = g_I \mu_B B/\hbar$ with atom g–factor g_I, Bohr magneton μ_B and magnetic field B. Usually, the laser is widely detuned from optical resonances to avoid unwanted excitation effects (as e.g. carrier heating in semiconductors).

Here, we probe the Faraday rotation noise under resonant and nonresonant conditions in terms of non-linear magneto–optics. We tune the laser ±10 GHz around the Rb D_2-transition and see a clear signature of coherent couplings of the participating electronic levels and explain it fully by extended Bloch equations including all D_2 hyperfine states as well as homogeneous and inhomogeneous processes like pressure broadening of the resonances and diffusion of the atoms.

Q 6.3 Mon 11:15 SCH A01

Creation of Strongly Correlated States for Photons using Rydberg Interactions — Johannes Otterbach[1], Alexey V. Gorskov[2], •Thomas Pohl[3], Mikhail D. Lukin[4], and Michael Fleischhauer[1] — [1]Fachbereich Physik & Forschungszentrum OPTIMAS, TU Kaiserslautern — [2]Physics Department, California Institute of Technology, Pasadena, CA, USA — [3]Max-Planck-Institut für Physik komplexer Systeme, Dresden — [4]Physics Department, Harvard University, Cambridge, MA, USA

Due to their strong long-range interaction and high level of controllability Rydberg-atoms are especially well suited for applications in quantum-information [1]. We study the interaction of single- or few-photon pulses in a coherently driven ensemble of Rydberg atoms exhibiting a ladder-like linkage pattern. Under conditions of electromagnetically induced transparency the photons form quasi-particles, so-called dark-state polaritons [2]. We investigate the effect of the strong Rydberg interactions on the polaritons. In particular we discuss two-particle correlations which are shown to decay very quickly to zero within the so-called blockade radius if the lower transition is close to resonance. Away from resonance temporary two-polariton bound states are formed. On length scales large compared to the blockade radius the Rydberg polaritons experience a repulsive interaction. Finally we discuss the formation of strongly correlated many-photon states.

[1] M. Saffman et al., Rev. Mod. Phys. 82, 2313 (2010).
[2] M. Fleischhauer et al., Rev. Mod. Phys. 77, 633 (2005).

Q 6.4 Mon 11:30 SCH A01

Suppression of stimulated Brillouin scattering in a photonic crystal fiber with periodically-varied core diameter — •Birgit Stiller[1], Michaël Delqué[1], Min Won Lee[1], Alexandre Kudlinski[2], Hervé Maillotte[1], and Thibaut Sylvestre[1] — [1]Institut FEMTO-ST, Université de Franche-Comté, 25030 Besançon, France — [2]Université Lille 1, IRCICA, Laboratoire PhLAM, 59655 Villeneuve d'Ascq, France

Suppression of stimulated Brillouin scattering (SBS) in optical fibers is of particular interest for telecommunication and fiber laser applications. For this purpose we designed a photonic crystal fiber with periodically varying size of the air-hole-structure by 7% while keeping a low attenuation coefficient. We experimentally demonstrate 7 dB improvement in SBS suppression compared to a homogenous fiber. The fiber under test was characterized by using Brillouin echoes distributed sensing technique where the periodic variation of the Brillouin frequency shift is demonstrated. Additionally guided acoustic wave Brillouin scattering was investigated in this fiber and compared to numerical simulations of a full-vectorial finite element method based on the scanning electron microscope image of the fiber cross section.

Q 6.5 Mon 11:45 SCH A01

Photon-Phonon Interaction in Hollow-Core Photonic Crystal Fibers — •Wenjia Zhong, Bettina Heim, Dominique Elser, Christoph Marquardt, and Gerd Leuchs — MPI für die Physik des Lichts, Erlangen, Germany

In hollow-core photonic crystal fibers (HCPCF) light travels in the central air core surrounded by a photonic-bandgap structure.

We performed quantum-noise-limited measurements in a HCPCF and observed polarization noise at sideband frequencies in the MHz range when using a pulsed laser. The observation shows that although the light has small overlap with the silica material, there exists excess polarization noise.

The agreement of the experimental findings with finite element method simulations of the acoustic vibrational modes of the HCPCF shows that the polarization noise is induced by thermally excited acoustic vibrations of the photonic crystal structure of the HCPCF.

Q 6.6 Mon 12:00 SCH A01

Wavefield Back-Propagation in High-Resolution X-ray Holography with a Movable Field of View — •Erik Guehrs[1], Christian Günther[2], Bastian Pfau[1], Torbjörn Rander[1], Stefan Schaffert[1], William Schlotter[3], and Stefan Eisebitt[1] — [1]TU-Berlin — [2]Helmholtz-Zentrum Berlin — [3]Centre for Free-Electron Laser Science, Universität Hamburg

Mask-based Fourier transform holography (FTH) is used to record images of biological objects with 2.2 nm X-ray wavelength. The holography mask and the object are separated from each other allowing us to move the field of view of the sample. Due to the separation of the holography mask and the sample on different X-ray support membranes, a gap between both windows of several 10s of microns typically exists which can be due to misalignment or dust or is desired to protect the sample from direct contact. The depth of field, thus limits the gap size for which sharp images of the sample can be reconstructed using a 2D Fourier Transform of the hologram. In this contribution, we systematically investigate the imaging and reconstruction conditions for mask-sample separations up to 400 μm. We demonstrate the feasibility to combine FTH and wavefield backpropagation to obtain a focused image even for large separations and discuss the limitations of our approach which are mainly associated with Fresnel illumination. In particular for high-resolution imaging with soft X-rays and the associated small fields of view below 2 μm, our approach is crucial in order to obtain diffraction limited resolution combined with experimental ease regarding the scanning setup.

Q 6.7 Mon 12:15 SCH A01

Collective multi-mode effects in quantum optics — •Bojan Skerlak[1,2], Matthias Liertzer[3], Stefan Rotter[3], and Hakan Türeci[1,2] — [1]Department of Electrical Engineering, Princeton University, USA — [2]Institute for Quantum Electronics, ETH Zürich, Switzerland — [3]Institute for Theoretical Physics, TU Vienna, Austria

Controlling the photon emission of quantum systems is at the heart of a number of fields ranging from quantum information processing to single-molecule spectroscopy. A way to tune the spontaneous emission rate and directionality of a quantum emitter is to place it in a suitably designed photonic structure. Much of the earlier work has focused here on the resonant coupling of the emitter to a single, carefully chosen mode of this photonic structure with favorable emission properties, while the coupling to the rest of the modes of the photonic environment is regarded as a parasitic influence. This approach results in stringent requirements on the spectral and spatial overlap of the emitter and the resonant mode in question. Here we investigate the opposite approach: coupling an emitter to a large number of modes of a cavity. In particular, we show how this multi-mode coupling can be engineered to lead via interference to a robust collective enhancement of directionality which is more pronounced than that of each mode.

Q 6.8 Mon 12:30 SCH A01

Single-Slit Focusing and its Representations — •Emerson Sadurni[1], William Case[2], and Wolfgang Schleich[1] — [1]Institut fuer Quantenphysik, Ulm Universitaet, Albert-Einstein Allee 11 89081 Ulm - Germany — [2]Department of Physics, Grinnell College, P.O. Box 805, Grinnell, Iowa 50112

We have found that under free Schroedinger propagation a real-valued square wave packet shrinks rather than expands for very short times. The amplitude is enhanced by an approximate factor of 1.8. This is also the case when a two dimensional electromagnetic wave of constant phase hits a single slit and focuses around the optical axis in the near-field region. We give several descriptions of the problem, covering its many aspects from different (but equivalent) points of view: Wigner functions, fractality, suitable focusing measures et cetera.

Q 6.9 Mon 12:45 SCH A01

Optical control of the relativistic x-ray resonance fluorescence spectrum — •Octavian Postavaru[1,2], Zoltán Harman[1,2], and Christoph H. Keitel[1] — [1]Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]ExtreMe Matter Institute EMMI, Planckstrasse 1, 64291 Darmstadt, Germany

Resonance fluorescence of laser-driven highly charged ions is studied in the relativistic regime by solving the time-dependent master equation in a multi-level model [1]. Our ab initio approach based on the Dirac equation allows for investigating highly relativistic ions, and, consequently, provides a sensitive means to test correlated relativistic dynamics, bound-state quantum electrodynamic phenomena and nuclear effects by applying coherent light with x-ray frequencies. Atomic dipole or multipole moments may be determined to unprecedented accuracy by measuring the fluorescence spectrum narrowed by quantum interference due to an additional optical driving.

[1] O. Postavaru, Z. Harman, C. H. Keitel, arxiv.org/abs/1011.6416