Q 54: Poster 3

Time: Thursday 16:30–19:00 Location: Poster.I+II

Q 54.1 Thu 16:30 Poster.I+II

Effect of Medium Acidity and Photostability of 3-(4-Dimethylamino-phenyl)-1-(2,5-dimethyl-thiophen-3-yl)-propenone DDTP): A New Green Emitting Laser Dye — •Khalid Alamry, Abdullah Asiri, Salman Khan, Samy El-Daly, and Mahmoud Hussein — Chemistry Department, Faculty of Science, King Abdulaziz University, P.O. Box 80203, Jeddah 21589, Saudi Arabia

On the line of a previous work on the spectral properties of some of heteroaryl chalcone, the effect of medium acidity and photoreactivity of 3-(4-dimethylamino-phenyl)-1-(2,5-dimethyl-thiophen-3-yl)-propenone (DDTP) has been investigated in dimethylformamide and in chloromethane solvents such as methylenechloride, chloroform and carbon tetrachloride. The dye solution (ca. 5*10*4 mol*L*1 in DMF) gives a good laser emission in the range 470*560 nm with emission maximum at 515 nm upon pumping by nitrogen laser (λex*337.1 nm). The laser parameters such as gain coefficient (α), emission cross section (σe) and half life energy (E1/2) at maximum laser emissionare also determined.

Q 54.2 Thu 16:30 Poster.I+II

Hybrid quantum repeater with encoding — •Nadja Kolb Bernardes[1,2] and Peter van Loock[1,2] — [1]OQI Group, MPL, Erlangen, Germany — [2]Institute of Theoritical Physics I, Uni. Erlangen-Nuremberg, Erlangen, Germany

In the context of the quantum repeater, practical limitations as finite memory decoherence times and imperfect two-qubit operations will constraint the final-state fidelity and the key generation rate of the protocol. By aiming to improve the hybrid quantum repeater [1,2] against these limitations, we present an encoded scheme using Calderbank-Shor-Steane codes [3]. For the case of repetition codes, we propose an explicit implementation of the quantum error correction protocol. Moreover, we analyze the entangled-pair distribution rate for the hybrid quantum repeater with encoding and we clearly identify a triple trade-off between the efficiency of the codes, the memory decoherence time, and the local gate errors. Finally, we show that in the presence of reasonable imperfections our system can achieve rates of roughly 620 Hz per memory for 20 km repeater spacing, a final distance of 1280 km, and final fidelity of about 0.95.

[1] P. van Loock et al., Phys. Rev. Lett. 96, 240501 (2006).
[2] P. van Loock et al., Phys. Rev. A 78, 062319 (2008).
[3] N. K. Bernardes and P. van Loock, arXiv:1105.3566 (2010).

Q 54.3 Thu 16:30 Poster.I+II

Quantitative Benchmarking of Quantum Error Correction Codes for Amplitude Damping — •Ricardo Wickert[1,2] and Peter van Loock[1,2] — [1]Optical Quantum Information Theory Group, Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Institute of Theoretical Physics I, Universität Erlangen-Nürnberg, Erlangen, Germany

The ability to transmit quantum states of light in a coherent and error-free fashion is a fundamental requirement for the successful implementation of quantum communication protocols. When comparing error-correction strategies, the importance of quantitative benchmarks becomes apparent: various measures can be employed which can, under certain circumstances, give rise to different relative orderings between codes. Here we discuss the connection of entanglement-based quantities with worst-case and codeword fidelities, with a particular attention to codes designed to protect both discrete-variable (single-photon states) and continuous-variable (coherent-state superpositions) quantum information carriers against amplitude damping (photon-loss) errors.

Q 54.4 Thu 16:30 Poster.I+II

High-fidelity entanglement purification using chains of atoms and optical cavities — •Denis Gonta[1,2] and Peter van Loock[1,2] — [1]Institut of Optik, Information und Photonik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstrasse 7, 91058 Erlangen — [2]Optical Quantum Information Theory Group, Max Planck Institute for the Science of Light, Günther-Scharowsky-Str. 1, Bau 26, D-91058 Erlangen

In our previous work [1], we proposed a practical scheme to purify dynamically a bipartite entangled state using short chains of atoms coupled to high-finesse optical cavities. In contrast to conventional entanglement purification protocols, we avoid CNOT gates and thus reduce complicated pulse sequences and superfluous qubit operations. In this paper, we significantly improve the output fidelity of remotely entangled atoms by introducing one additional entanglement mechanism in each of the repeater nodes and by optimizing the laser pulses required to control the entire scheme. The latter entanglement mechanism exploits again the cavity-QED dynamics and requires only one extra high-finesse cavity in each node of the repeater. Our improved distillation scheme together with entanglement distribution and swapping, opens an attractive route towards efficient and experimentally feasible quantum repeaters for long-distance quantum communication.

[1] D. Gonta and P. van Loock, Phys. Rev. A 84, 042303 (2011).

Q 54.5 Thu 16:30 Poster.I+II

Long distance QKD enhanced by quantum repeaters with linear optics. — •Silvestre Abruzzo, Hermann Kampermann, and Dagmar Bruss — Heinrich-Heine-Universität Düsseldorf, Institut für Theoretische Physik III, Düsseldorf, Germany

In this work we analyze and characterize a generic quantum repeater[1] architecture based on dual-rail entanglement, heralding and entanglement swapping with linear optics and quantum memories. We calculate the asymptotic secret key rate and we show its dependency on the experimental parameters describing the proposed quantum repeater. This will permit us to bound and to estimate the requirements on the imperfections of the experimental set-up.

[1] H. J. Briegel et al., Phys. Rev. Lett. 81, 5932-5935 (1998).

Q 54.6 Thu 16:30 Poster.I+II

Free Space Quantum Communication using Continuous Polarization Variables — •Bettina Heim[1,2], Christian Peuntinger[1,2], Fabian Sproll[1], Christoffer Wittmann[1,2], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]MPI for the Science of Light, Günther-Scharowsky-Str. 1 / Bld. 24, Erlangen — [2]Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, Staudtstraße 7 / B2, 91058 Erlangen, Germany

We present our experimental work on quantum communication using an atmospheric channel of 1.6 km in an urban environment. In our prepare-and-measure setup, we encode information into continuous polarization states. The signal states are measured using homodyne detection with the help of a local oscillator (LO). Both, signal and LO, are sent through the free-space quantum channel, polarization multiplexed and occupying the same spatial mode. This leads to an excellent detection interference and an auto-compensation of the phase fluctuations introduced by the channel. Additionally, the LO automatically acts as a spatial and spectral filter, which allows for unrestrained daylight operation. As low losses are a crucial point for quantum communication protocols, we have developed an active beam stabilization in order to increase the overall channel transmission. Currently, we are working on the implementation of protocols for Continuous Variable (CV) Quantum Key Distribution with different modulation schemes. Furthermore, the transmission of squeezed and EPR-entangled states is in preparation.

Q 54.7 Thu 16:30 Poster.I+II

Concepts for a portable squeezed light source for use in quantum communication — •Christian Peuntinger[1,2], Stefan Berg-Johansen[1,2], Christian Gabriel[1,2], Bettina Heim[1,2], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max-Planck-Institut für die Physik des Lichts, Günther-Scharowsky-Str. 1 / Bau 24, 91058 Erlangen, Deutschland — [2]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Staudtstrasse 7 / B2, 91058 Erlangen, Deutschland

We present experimental investigations of two portable squeezed light sources, one of which is meant to be implemented in a 1.6 km free-space quantum communication experiment. The first design is an asymmetric Sagnac interferometer with a fiber acting as the nonlinear medium [1]. This setup generates amplitude squeezed states which can be easily detected. The second design is a single-pass fiber setup which squeezes the polarization field variables. It has been shown that this scheme is

capable of generating high amounts of squeezing [2]. The advantages and disadvantages of both schemes are discussed in detail. A special focus is laid on the obtainable amount of squeezing in each system as well as their mechanical stability and the ease of detection of the quantum state of light by the receiver.

[1] J. Heersink et al. Phys. Rev. A, **68** (1), 013815 (2003)
[2] R. Dong et al. Opt. Lett., **33**, 116-118 (2008)

Q 54.8 Thu 16:30 Poster.I+II

Investigating the feasibility of a practical Trojan-horse attack on a commercial quantum cryptosystem — •Nitin Jain[1,2], Elena Anisimova[3], Christoffer Wittmann[1,2], Christoph Marquardt[1,2], Vadim Makarov[3], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Institut fuer Optik, Information und Photonik, University of Erlangen-Nuremberg, Germany — [3]Department of Electronics and Telecommunications, Norwegian University of Science and Technology, Trondheim, Norway

An optical component inside a quantum key distribution (QKD) system may be probed via the quantum channel by sending in sufficiently intense light and analyzing the back-reflected light. This forms the basis of a Trojan-horse attack. We experimentally review the feasibility of such an attack on a commercially available QKD system from ID Quantique. The objective is to read Bob's phase modulator (to acquire knowledge of his basis choice) without alerting him; this breaches the Scarani-Acin-Ribordy-Gisin protocol. Using optical time domain reflectometry, we prepared optical maps of Bob's module at three different wavelengths: 806, 1310 and 1550 nm. With the intensity of Eve's input light chosen so as to obtain a requisite back-reflection level (5-10 photons per pulse), we find a strong afterpulsing ensues in Bob's detectors. This would cause a high QBER that would stop the QKD exchange, so we are now exploring the longer wavelength (1630-2000 nm) regime, where we conjecture a weaker afterpulsing would allow us to craft and execute a successful attack.

Q 54.9 Thu 16:30 Poster.I+II

Quantum key distribution on Hannover Campus — •Jörg Duhme[1], Torsten Franz[1], Reinhard F. Werner[1], Vitus Händchen[2], Tobias Eberle[2], and Roman Schnabel[2] — [1]Leibniz Universität Hannover, Institut für Theoretische Physik, AG Quanteninformation — [2]Albert Einstein Institut, Quantum Interferometry

We report on the progress of the implementation of an entanglement-based quantum key distribution on Hannover campus using squeezed gaussian states (continuous variables). This poster focuses on the theoretical aspects of the project. Experimental data has been compared with the theoretical simulation of the experimental setup. We especially discuss effects of the homodyne detection and postprocessing in use on the measurement outcome.

Q 54.10 Thu 16:30 Poster.I+II

Cavity QED quantum interface — •Bernardo Casabone[1], Andreas Stute[1], Tracy Northup[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck — [2]Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, Innsbruck

While trapped ions are suitable candidates as qubits at quantum nodes, photons are ideal candidates as flying qubits to transfer quantum states between remote locations. Optical cavities provides a coherent and highly-efficient interface between ion and photon. Such an interface could be used as a quantum-memory-readout device, mapping the quantum state of a single ion to a single photon.

A system consisting of a single trapped $^{40}Ca^{+}$ ion coupled to the mode of a high-finesse optical resonator is used. Intra-cavity photons are generated in a vacuum-stimulated Raman process between two atomic states driven by a laser and the cavity vacuum field. Single photons are generated on the $4P_{3/2} \leftrightarrow 3D_{5/2}$ transition, in which all Zeeman states are resolved in agreement with theoretical simulations. A laser on the narrow $4S_{1/2} \leftrightarrow 3D_{5/2}$ transition permits the addressing of individual Zeeman states. Coherent state manipulation on this transitions enables the initial preparation of any quantum state.

We present the results of mapping a initial quantum state of the trapped $^{40}Ca^{+}$ ion to a polarization superposition of a single photon, via a bichromatic excitation of two vacuum-stimulated Raman transitions.

Q 54.11 Thu 16:30 Poster.I+II

SPDC-basierte Einzelphotonenquellen für Anwendungen in der Quanteninformation — •Sabine Euler[1,2], Tobias Diehl[1] und Thomas Walther[1,2] — [1]Institut für Angewandte Physik, TU Darmstadt, Schlossgartenstr. 7 D-64289 Darmstadt — [2]CASED, Mornewegstr. 32, D-64293 Darmstadt

Durch parametrische Abwärtskonversion (SPDC) in periodisch gepoltem Kalium-Titanyl-Phosphat (PPKTP) werden in einem temperaturstabilisierten, cw gepumpten Typ-II-Prozess degenerierte Photonenpaare bei 808 nm erzeugt. Der Hong-Ou-Mandel-Kontrast liegt bei 95%, es werden etwa 3x10^4 Photonenpaare pro mW und nm detektiert.

Die Photonenquelle bildet die Grundlage für zwei verschiedene Anwendungen: In einem ersten Experiment wird ein QKD-Setup entsprechend dem BB84-Protokoll implementiert, die Einzelphotonenquelle wird für das Sender-Modul verwendet. Die Photonenpräparation erfolgt dabei durch die Verwendung von Strahlteilerwürfeln rein passiv. Ziel des zweiten Experimentes ist es, durch Rückkopplung eines der SPDC-Photonen in den Kristall in einem stimulierten Prozess zwei identische Photonen zu erzeugen, die anschließend an einem polarisierenden Strahlteiler ausgekoppelt und nachgewiesen werden können. Der aktuelle Stand beider Experimente wird präsentiert.

Q 54.12 Thu 16:30 Poster.I+II

Photoleitfähigkeit und Lasereffizienz von Yb:YAG Keramiken verschiedener Korngrößen im Vergleich mit Einkristallen — •Ulrike Wolters[1], Susanne T. Fredrich-Thornton[1], Luo Dewei[2], Jian Zhang[2], Klaus Petermann[1] und Günter Huber[1] — [1]Institut für Laser-Physik, Universität Hamburg — [2]Temasek Laboratories, Nanyang Technological University, Singapur

Vergleichende Studien haben gezeigt, dass trotz sehr ähnlicher spektroskopischer Eigenschaften hochdotierte Yb:YAG-Einkristalle eine geringere Lasereffizienz aufweisen als entsprechende Yb:YAG-Keramiken. Untersuchungen zu den Effizienzeinbußen in hochdotierten Yb:YAG-Lasermaterialien belegen, dass bei Einstrahlung von 940 nm Pumplicht eine Photoleitfähigkeit generiert wird. Dies deutet auf die Erzeugung freier Ladungsträger durch einen Upconversion-Prozess hin. Es wurden unterschiedlich hohe Photoströme in keramischem und einkristallinem Material gemessen, wofür Korngrenzen in den keramischen Proben verantwortlich gemacht werden. Die systematische Untersuchung von Keramiken mit verschiedenen Korngrößen soll in Verknüpfung mit der Lasereffizienz der untersuchten Proben Rückschlüsse auf die beobachteten Verlustprozesse im Laserbetrieb ermöglichen.

Q 54.13 Thu 16:30 Poster.I+II

Stickstoff-gekühlter Ytterbium-Faserverstärker bei 1015 nm — •Ruth Steinborn[1,2], Thomas Diehl[1,2], Andreas Koglbauer[1,2], Daniel Kolbe[1,2], Matthias Sattler[1,2], Matthias Stappel[1,2] und Jochen Walz[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz, Deutschland — [2]Helmholtz-Institut Mainz, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Deutschland

Ytterbium-Faserlaser/verstärker sind eine bewährte, vielseitige und zuverlässige Laser-Quelle im Wellenlängenbereich von 1050 nm bis 1100 nm. Für kürzere Wellenlängen steigt der Absorptionsquerschnitt an und beschränkt den Laserbetrieb.

Bei Kühlung zu kryogenen Temperaturen ändert sich die thermische Besetzung der Stark-aufgespaltenen Laserniveaus $^2F_{7/2}$ und $^2F_{5/2}$. Damit lässt sich die Absorption im Bereich von 1000 nm bis 1050 nm deutlich reduzieren.

Dieser Effekt wird ausgenutzt um einen Faserverstärker bei 1015 nm aufzubauen. Dazu soll ein, von einem TA (tapered amplifier) vorverstärkter, Diodenlaser von einem auf 77 K gekühlten und bei 976 nm gepumpten Ytterbium-Faserverstärker verstärkt werden.

Es soll der Einfluss unterschiedlicher Faserlängen und Pumpkonfigurationen untersucht werden. Der aktuelle Stand des Experiments sowie erste Ergebnisse werden präsentiert.

Q 54.14 Thu 16:30 Poster.I+II

Kristallzüchtung und spektroskopische Untersuchungen von Ce:$CaSc_2O_4$ — •Matthias Fechner, Fabian Reichert, Klaus Petermann und Günter Huber — Institut für Laser-Physik, Universität Hamburg

Mit der Absicht einen durchstimmbaren Festkörperlaser im sichtbaren Spektralbereich zu realisieren, wurde Ce:$CaSc_2O_4$ untersucht. Dieses orthorhombische System ist neben den Granaten eines der wenigen oxidischen Wirtsmaterialen, bei denen der 5d-4f-Übergang des Ce^{3+}-Ions im grüngelben Spektralbereich fluoresziert [1]. In diesem Beitrag werden die Kristallzüchtung des Materials sowie die spektroskopischen

Untersuchungen der Einkristalle behandelt. Mit temperaturabhängigen Lebensdauermessungen konnte beispielweise gezeigt werden, dass bei Raumtemperatur keine nichtstrahlenden Prozesse die Quanteneffizienz verringern. Während bei allen bisher untersuchten Cer dotierten Granaten aufgrund von Absorption aus angeregten Zuständen kein Laserbetrieb im sichtbaren Spektralbereich möglich ist [2,3], konnte mit Ce^{3+}:$CaSc_2O_4$ erstmals Verstärkung durch stimulierte Emission im sichtbaren Spektralbereich für ein Cer dotiertes Material nachgewiesen werden.

[1] Y. Shimomura, *et al.*, J. Electrochem. Soc. **154**, 234 (2007).
[2] D. S. Hamilton, *et al.*, Phys. Rev. B **39**, 8807 (1989).
[3] J. K. Lawson, *et al.*, Phys. Rev. B **47**, 14003 (1993).

Q 54.15 Thu 16:30 Poster.I+II

Power scaling of an all-solid-state laser source for trapping lithium — •Andrea Bergschneider, Ulrich Eismann, Frédéric Chevy, and Christophe Salomon — Laboratoire Kastler Brossel, CNRS UMR 8552, UPMC, Ecole Normale Supérieure, 24 rue Lhomond, 75231 Paris, France

We recently presented an all-solid-state laser source emitting 670 mW of narrowband 671-nm light, frequency-locked to the lithium D-line transitions for laser cooling applications [1]. It consists of a solid-state Nd:YVO_4 ring laser emitting light of 1342 nm wavelength, which is subsequently frequency-doubled in an enhancement cavity using periodically-polarized potassium titanyl phosphate (ppKTP). Meanwhile, a power of about 800 mW has been achieved.

Here, we focus on the challenge of increasing the output power into the multi-Watt range. The key issue is the minimization of unavoidable detrimental thermal effects in the Nd:YVO_4 and the nonlinear crystal. We discuss in detail the theoretical optimization of the spatial overlap between pump beam and cavity mode while keeping a TEM_{00}-mode [2]. We experimentally alter the pump beam wavelength and size as well as the crystal doping and length and compare to theoretical results. We also investigate intra-cavity second harmonic generation.

[1] U. Eismann et al., arXiv:1103.5841 (2011)
[2] Y. F. Chen et al., IEEE J. Quantum Electron. **33**, 1424 (1997)

Q 54.16 Thu 16:30 Poster.I+II

Untersuchung von holographischen Verstärkungsgittern in Nd:YAG — •Roland Ullmann[1], Robert Elsner[1], Axel Heuer[1], Ralf Menzel[1] und Martin Ostermeyer[1,2] — [1]Universität Potsdam, Institut für Physik und Astronomie, Karl-Liebknecht-Str. 24-25, 14476 Potsdam — [2]IBL Innovative Berlin Laser GmbH, Am Schlangengraben 16, 13597 Berlin

Moderne LIDAR-Verfahren benötigen gepulste Lasersysteme mit einer hohen Schuß-zu-Schuß Frequenzstabilität. Diese wird typischerweise durch elektronische Regelverfahren wie ramp and fire oder Pound-Drever-Hall erzielt. Durch die Kopplung eines frequenzstabilen Dauerstrichlasers an einen gepulsten Ringoszillator über dynamische Verstärkungsgitter lässt sich ein passives Stabilisierungsschema realisieren. Darüber hinaus dient das Verstärkungsgitter gleichzeitig als passive Güteschaltung [1] sowie als phasenkonjugierendes Element [2].

Zur Charakterisierung des Verstärkungsgitters wurden erste Experimente durchgeführt und anschließend die Ergebnisse mit einem eigens entwickelten numerischen Modell verglichen.

[1] Damzen et al, Opt. Lett. 20, 1704 (1995)
[2] Sillard et al, Opt. Lett. 23, 1093-1095 (1998)

Q 54.17 Thu 16:30 Poster.I+II

Aufbau eines ECDL-basierten Sensors für die Konzentrationsmessung von Gasen — •Timothy Quincey, Thorsten Führer und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, AG Laser und Quantenoptik, Schlossgartenstr. 7, D-64289 Darmstadt

Laserdioden mit externem Resonator (ECDL) sind heute in vielen Bereichen im Einsatz - unter anderem in der Sensorik und in der Spektroskopie.

Eine aktive Stabilisierung aus Eigenentwicklung ermöglicht große modensprungfreie Durchstimmbereiche und gewährleistet den stabilen Betrieb eines solchen ECDL-Systems. Auf Basis von Polarisationsspektroskopie wird ein Fehlersignal erzeugt, welches das Längenverhältnis zwischen dem externen Resonator und dem internen Resonator der Laserdiode darstellt.

Vorgestellt wird ein neuartiges Konzept für einen Sensor, wobei das Fehlersignal der aktiven Stabilisierung für die Gasdetektion verwendet wird. Durch das Scannen über einen ausgewählten Wellenlängenbereich werden Absorptionslinien der Gasatome wegen der optischen Längenänderung aufgrund der Dispersion im Fehlersignal sichtbar.

Aufbauend auf vorherigen theoretischen Betrachtungen ist es möglich aus dem Dispersionssignal die Teilchenzahldichte und damit die Konzentration der Atome in der Zelle zu bestimmen.

Erste Messungen wurden mit einer Rb-Gaszelle bei Raumtemperatur durchgeführt. Der verwendete Aufbau und die bisherigen Ergebnisse werden präsentiert und diskutiert.

Q 54.18 Thu 16:30 Poster.I+II

Efficient frequency doubling of laser light at 738 nm — •Thomas Collath[1], Michael Johanning[1], Ladislav Bohaty[2], Petra Becker[2], and Christof Wunderlich[1] — [1]Universität Siegen, Naturwissenschaftlich-Technische Fakultät, Dept. Physik, 57068 Siegen — [2]Universität zu Köln, Institut für Kristallographie, 50939 Köln

For laser cooling and detection of ytterbium ions stored in a Paul trap, continuous-wave laser light with a wavelength of 369 nm is required. This light is generated with a titanium-sapphire laser at 738 nm and a frequency doubler. Two nonlinear optical crystals, bismuth triborate (BiB_3O_6) and β-barium borate (β-BaB_2O_4), are used for second-harmonic generation. A ring resonator in symmetric bow-tie configuration is used to achieve higher power densities. The parameters characterizing the resonator (focus diameter, optical length, reflectivity of the incoupling mirror) are optimally adjusted for each of the two nonlinear crystals and the results are compared.

Q 54.19 Thu 16:30 Poster.I+II

VUV generation in a hollow core fiber — •Andreas Koglbauer[1,2], Thomas Diehl[1,2], Daniel Kolbe[1,2], Matthias Sattler[1,2], Matthias Stappel[1,2], Ruth Steinborn[1,2], and Jochen Walz[1,2] — [1]Johannes Gutenberg-Universität, D-55099 Mainz — [2]Helmholtz-Institut Mainz, D-55128 Mainz

Non-degenerate four-wave mixing (FWM) in metal vapors is a well-established method for the generation of cw vacuum ultraviolet (VUV) radiation, such as Lyman-α-light (121.56 nm), the cooling transition in (anti-)hydrogen. Utilizing resonances of the nonlinear medium (mercury) enabled the highest mixing-efficiencies so far [1]. Nevertheless the achievable output power is in the nW regime.

Using focused beams, the interaction region is in the order of the confocal parameter ($\sim$1 mm). One possibility to further enhance the efficiency is to elongate this region. This can be accomplished by confining the light in a vapor filled hollow core fiber, which can have a length of several cm.

We present a study of possible phase-matching scenarios with the associated VUV efficiencies, considering dispersion and losses due to the medium as well as the fiber. The phase-matching temperature is smaller, compared to the mixing with focused beams. This allows for the FWM between Hg isotopes, promising a gain of more than three orders of magnitude in the nonlinear susceptibility. Generation of Hg vapor within the fiber is demonstrated via absorption spectroscopy on the $6^1S - 6^3P$ transition in Hg transverse through the fiber.

[1] Can. J. Phys. 89(1), 25-28 (2011)

Q 54.20 Thu 16:30 Poster.I+II

Numerical Investigation of Frequency Stable Coupling of Laser Oscillators via Gain Gratings — •Robert Elsner[1], Roland Ullmann[1], Axel Heuer[1], Ralf Menzel[1], and Martin Ostermeyer[1,2] — [1]University of Potsdam, Institute for Physics and Astronomy, Karl-Liebknecht-Str. 24/25, 14476 Potsdam, Germany — [2]IB Laser, Am Schlangengraben 16, 13597 Berlin, Germany

Pulsed laser sources with a high shot-to-shot frequency stability are required for advanced LIDAR techniques. Frequency stable operation of such laser sources is commonly achieved using active stabilization schemes. Unfortunately, the performance of these active schemes is inherently limited by the bandwidth of the controller. Therefore, it would be advantageous for mobile applications if the components for active stabilization could be discarded. Gain gratings in saturable gain media offer the potential to realize such a passive stabilization scheme in self-Q-switched loop resonators [1,2]. The spectral and spatial selectivity of the gain grating in combination with a cw seed ensures single-frequency operation and high shot-to-shot stability. This passive coupling scheme is investigated numerically. Existing numerical models are extended to two spatial dimensions and selected results are presented.

[1] Damzen et al. Opt. Lett. 20, 1704(1995)
[2] Sillard et al. J. Quantum Electron, IEEE J. of 34, 465-472(1998)

Q 54.21 Thu 16:30 Poster.I+II

Intracavity absorption spectroscopy with a Nd-doped ZBLAN fiber laser in the spectral range from 1.32 to 1.35 μm — •Johannes Röhl, Svetlana Kuznetsova, Peter Fjodorow, Ortwin Hellmig, Benjamin Löhden, Klaus Sengstock, and Valery Baev — Institut für Laserphysik, Universität Hamburg, Germany

Emission spectrum of Nd^{3+}- doped silica fiber lasers is very sensitive to intracavity absorption. Up to now absorption measurements have been performed in the spectral ranges 0.9 - 0.945 μm ($^4F_{3/2} \rightarrow {}^4I_{9/2}$) and 1.075 - 1.14 μm ($^4F_{3/2} \rightarrow {}^4I_{11/2}$) [1]. The laser emission at another strong transition, $^4F_{3/2} \rightarrow {}^4I_{13/2}$ around 1.33 μm could not be excited in silica glass, because of strong excited state absorption. In order to achieve laser emission in this spectral range we use a Nd-doped ZBLAN glass fiber where the influence of excited state absorption is sufficiently reduced. The selected ZBLAN fiber is doped with 1000 ppm of Nd and pumped by a laser diode at $\lambda_p = 808$ nm. The fiber length is 50 cm, the cut-off wavelength $\lambda_c = 1.05$ μm and the core/cladding diameters are 5/125 μm. In the emission spectra of the laser, ranging from 1.32 to 1.35 μm, we have observed a strong atmospheric absorption dominated by water vapor lines. The sensitivity of this fiber laser to intracavity absorption corresponds to the effective absorption path length of several kilometers. Absorption spectra of various other molecules such as HF, CH_4, OH and NO can be detected in this spectral range as well.

[1] J. Hünkemeier et al., Optics Communications 176, 417 (2000).

Q 54.22 Thu 16:30 Poster.I+II

Stimulierte Raman-Streuung in einem mikrofluidischen Kanal mittels integrierter Wellenleiter — •Claudia Hoffmann[1], Matthias Pospiech[1], Moritz Emons[1], Günter Rinke[2] und Uwe Morgner[1,3] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Deutschland — [2]Karlsruher Institut für Technologie, Institut für Mikroverfahrenstechnik, Eggenstein-Leopoldshafen, Deutschland — [3]Centre for Quantum Engineering and Space-Time Research (Quest), Hannover, Deutschland

Die Verwendung mikrostrukturierter Komponenten in der Verfahrenstechnik ermöglicht Transport, Mischung und Analyse von Substanzen auf kleinstem Raum und von sehr geringen Mengen. Für die Kontrolle und Optimierung solcher Komponenten ist ein genaues Wissen über die innerhalb ablaufenden Reaktionsprozesse erforderlich.

In unserem Experiment verwenden wir stimulierte Raman-Streuung (SRS), um Flüssigkeiten in einem Mikrokanal in einem Quarzglassubstrat zu unterscheiden. Das Anregungslicht wird dazu mittels Wellenleitern zum Kanal hin und wieder weggeführt. Die für SRS erforderlichen Anregungswellenlängen werden durch einen NOPA bereitgestellt, der durch ein faserbasiertes Verstärkersystem mit einer Repetitionsrate von 1 MHz gepumpt wird, sowie direkt vom verstärkten Lasersystem. Verglichen wurden Aceton und Methanol, wobei ein Bereich von 970 cm-1 bis 1120 cm-1 angeregt wurde. In diesem Bereich weist Methanol eine starke Resonanz auf, Aceton aber nur eine schwache. Erwartungsgemäß konnte in Methanol ein deutlich stärkeres Signal erzeugt werden.

Q 54.23 Thu 16:30 Poster.I+II

Ein Brillouin-LIDAR zur Messung von Temperaturprofilen des Ozeans: Optimierung des ESFADOF-Pumpprozesses — •Vincenzo Talluto, Andreas Rudolf, Carl Böhmer und Thomas Walther — Institut für Angewandte Physik, AG Laser- und Quantenoptik, Technische Universität Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt

Faraday **A**nomalous **D**ispersion **O**ptical **F**ilter (FADOF) sind besonders schmalbandige, abstimmbare, atomare Kantenfilter, welche Transmissionsänderungen von nahezu 100 % innerhalb eines Frequenzbereichs von einem GHz und weniger ermöglichen. Sie sind in der Lage, minimale Frequenzverschiebungen des Eingangssignals in große Intensitätsänderungen des Ausgangsignals zu Überführen.

Ein **E**xcited **S**tate FADOF (ESFADOF) soll als Detektor des von uns entwickelten Brillouin-LIDARs eingesetzt werden. Das System ist für den Einsatz an Bord eines Helikopters gedacht und wird die berührungslose Messung von Temperaturprofilen des Ozeans ermöglichen.

Hierzu muss der ESFADOF Frequenzverschiebungen der temperaturabhängigen Brillouin-Streuung von ± 7-8 GHz auflösen. Um die Absorptionsverluste im Wasser zu minimieren, wird ein atomarer Übergang bei 543 nm zwischen zwei angeregten Zuständen in Rubidum genutzt. Das Rubidium muss daher bei 780 nm optisch gepumpt werden. Wir zeigen, dass durch Optimierung dieses Pumpprozesses die Filtercharakteristik gezielt gestaltet werden kann. Insbesondere lassen sich die Transmissionskanten mit hoher Genauigkeit symmetrisieren. Die maximale Transmission beträgt dabei 72 % ± 0,2 %.

Q 54.24 Thu 16:30 Poster.I+II

Diffraction Unlimited Imaging of NV Centers in Diamond — •Pascal Heller, Andreas Häussler, and Fedor Jelezko — Institut für Quantenoptik, Universität Ulm, Albert-Einstein-Allee 11, 89081 Ulm - Germany

Near pairs or chains of multiple Nitrogen-Vacancy (NV) color centers in diamond are interesting candidates for a multi qubit system in solid state. The coupling of such NVs is due to dipole dipole interaction and therefore is limited by these short-range forces to about 50 nm. Resolving and measuring the properties of such near NV, an imaging method far more powerful than conventional far-field-microscopy is needed. We use the nonlinear effect of Ground State Depletion (GSD) to overcome the diffraction limit by more than one order of magnitude. So far a spatial resolution below 20 nm perpendicular to the optical axis has been achieved. Further improvement will lead to superresolved 3D images, enabling high precision qubit engineering.

Q 54.25 Thu 16:30 Poster.I+II

Intensity measurement of strong laser beams using multiphoton Thomson scattering — Omri Har-Shemesh, •Felix Mackenroth, and Antonino Di Piazza — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, Heidelberg, Germany

The development of strong laser pulses (intensity $I > 10^{20}\,\mathrm{W/cm^2}$) is of both theoretical and practical interest. Intensities as high as $2 \times 10^{22}\,\mathrm{W/cm^2}$ have already been reported [1], and are expected to increase even more in the near future.

The precise measurement of the intensity of such strong laser pulses is very challenging. The equipment involved in intensity measurements for lower-intensity lasers cannot withstand such strong fields, and the tight focus of these latter pulses introduces further complications.

In this work we propose a new method for measuring the intensity of strong laser fields. Our method exploits the well-known fact that when ultra-relativistic electrons are accelerated they emit radiation primarily in a narrow-cone around the direction of their instantaneous velocity [2]. By allowing ultra-relativistic electrons to propagate through a strong laser field, and by measuring the spectrum of the radiation emitted, it is shown that the value of the peak laser intensity can be inferred.

References

[1] V. Yanovsky *et al.*, Opt. Express **16**, 2109 (2008)
[2] J.D. Jackson, *Classical Electrodynamics*, 3rd edition, Chapter 14.

Q 54.26 Thu 16:30 Poster.I+II

Interferometric locking link between tunable cw lasers and frequency combs — •Erik Benkler[1], Felix Rohde[2], and Harald R. Telle[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig — [2]Cosingno, Imagine Optic Spain S.L.,Mediterranean Technology Park av. Canal Olimpic s/n 08860 Castelldefels (Barcelona)

We present a novel transfer interferometer acting as versatile and robust optical frequency locking link between a tunable single frequency laser and an optical frequency comb. In contrast to conventional locking schemes which employ merely one single line, the signal-to-noise ratio is much superior here since substantial parts of the comb, i. e. many lines, contribute to the error signal. The set point of the control loop can be arbitrarily chosen. Thus, assuming a stabilized frequency comb (e. g via self-referencing and external standard) the frequency of the cw laser can be continuously tuned over thousands of subsequent comb lines while the frequency stability of the comb is transferred to a high degree. Fluctuations and drift effects of the transfer interferometer itself are widely eliminated with the help of a fast common mode rejection circuit. Experimental results will be presented for a tunable extended-cavity 1.5 μm laser diode linked to an Er-fiber based frequency comb.

Q 54.27 Thu 16:30 Poster.I+II

Performance of the Advanced Ligo laser — •Patrick Oppermann[1], Christina Bogan[1], Jan Hendrik Pöld[1], Patrick Kwee[1,2], Benno Willke[1], and Karsten Danzmann[1] — [1]Albert-Einstein-Institut Hannover — [2]MIT, Cambrige, USA

Most high precission measurements require a very stable and robust light source. The gravitational wave detector Advanced LIGO has very

strict requirements according to the frequency and power stability as well as with the spatial beam profile of the injected continuous wave 200W Nd:YAG laser. Therefore a combined active and passive stabilization scheme is essentialy. In order to achieve a TEM00 mode content of more than 99.5% a bow-tie shaped cavity is used which also supress beam pointing and power noise at radio frequencies. For the frequency stabilization the laser system is stabilized to a high finesse reference cavity. The laser system is power stabilized to a relative power noise of 2*10e-8/sqrt(HZ) and provides an additional input to achieve a relative power noise of 2*10e-9/sqrt(Hz) at the interferometer input.

In this contribution the concepts and results of the stabilization of the Advanced LIGO laser will be presented. Particular attention is paid to the requirements of AdvLIGO, and how they can be fullfilled within the current power stabilization. A second key aspect is the complex structure of the frequency stabilization including an AOM in douple-pass configuration allowing for frequency shifts.

Q 54.28 Thu 16:30 Poster.I+II

Comprehensive study on Virtually Imaged Phased Arrays - experiment, theory and optical simulation — •Karsten Sperlich, Stephan Reiss, and Heinrich Stolz — Institut für Physik, Universität Rostock

Virtually Imaged Phased Arrays (VIPAs) are highly dispersive elements that can be used for spectroscopy. Their advantage in Brillouin spectroscopy is the very high dispersion, much higher than a grating's dispersion, and the low intensity loss compared to other multiple-beam interferometer, like Fabry-Pérot- or Lummer-Gehrcke interferometer. In this paper we shortly explain the basic principle of VIPAs and present Brillouin scattering measurements performed with a standard VIPA-setup together with the setup itself. Furthermore we show our ray tracing simulation using FRED and compare the achieved results, the experimental data as well as the theory, published by Xiao et al. [1], together in a Mathematica framework. Due to the framework it is very fast and easy to change all relevant parameters of the whole setup and get the results from theory instantly while the FRED simulation is closer to the experimental data, but takes several minutes computing time. [1] Xiao, S. Weiner, A.M. Lin, C., "A Dispersion Law for Virtually Imaged Phased-Array Spectral Dispersers Based on Paraxial Wave Theory", IEEE JOURNAL OF QUANTUM ELECTRONICS, VOL. 40, NO. 4, APRIL 2004

Q 54.29 Thu 16:30 Poster.I+II

Laser feedback System for X-ray pump-probe experiments — •Dennis Goeries, Benjamin Dicke, Edgar Weckert, and Alke Meents — Deutsches Elektronen Synchrotron (Desy) - Hasylab, Notkestrasse 85, D-22607 Hamburg, Germany

The research in organic light emitting devices (OLEDs) is becoming more and more important nowadays. We plan to determine the excited state structures of different metal-organic compounds with time-resolved microcrystallography. Here the sample is probed by an X-ray a few microns in size only. This also requires the excitation of a much smaller volume than in conventional time-resolved experiments. This introduces less heat to the system and therefore allows higher repetition rates of the laser system.

A challenge for such kind of experiments is to provide a spatial and temporal overlap of both, the small laser and X-ray beam, over several hours with deviations below two microns. On this background we developed a PID controlled optical feedback system. It consists of two piezo actuator-driven mirrors (full stroke 23*m) and two position detecting devices (lateral effect sensors or cameras) with a high resolution. This system is divided into two loops, the first one for the positional and the second one for the angular stability. The second loop requires an additional lens focusing the light onto the detector and is highly dependent from the first loop, which defines a point source.Therefore a written complex algorithm ensures a smooth interplay between both loops. This configuration is built at beamline P11 at Petra III and we present results on the meeting.

Q 54.30 Thu 16:30 Poster.I+II

Laser-induced front side etching using self-regenerating adsorber layer (SAL-LIFE) of fused silica — •Pierre Lorenz, Martin Ehrhardt, and Klaus Zimmer — Leibniz-Institut of Surface Modification, Permoserstr. 15, 04318 Leipzig, Germany

Laser-induced front side etching (LIFE) is a method for laser etching of transparent materials using absorber layers. Within this study the continuous etching of fused silica with self-regenerating adsorber layers is presented using nanosecond KrF excimer laser radiation (λ = 248 nm, Δt_p = 25 ns). The sample was positioned in a vacuum chamber which was loaded by toluene gas and the gas phase induced the self-regenerating adsorber layer on the sample surface. The laser beam was focused onto the sample surface through the gas. The laser fluence, the number of pulses, the repetition rate as well as the partial pressure of toluene was varied. The laser fluence was altered up to 5 J/cm^2 and the surface was processed with different pulse numbers up to 1000 pulses at different repetition rates from 1 to 100 Hz. The treated fused silica was analysed with microscopic (white light interferometry, scanning electron microscopy (SEM)) and spectroscopic methods (X-ray photoelectron spectroscopy (XPS), energy dispersive X-ray spectroscopy (EDX)). The results disclose that the SAL-LIFE method allows nm-precision structuring of fused silica with low surface roughness over a large etching depth range from nm to a few hundred μm as well as a large lateral etching region from sub-μm to a few cm.

Q 54.31 Thu 16:30 Poster.I+II

Einstufiges fs-Faserverstärkersystem mit 1 MHz Repetitionsrate und 80 μJ Pulsenergie — •Bernhard Kreipe[1], Marcel Schultze[1], Moritz Emons[1], Mathias Hoffmann[1] und Uwe Morgner[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [2]Centre for Quantum Engineering and Space-Time Research (QUEST),Welfengarten 1, 30167 Hannover

Wir präsentieren ein kompaktes einstufiges Faserverstärkersystem, das bei 1 MHz Repetitionsrate und 100 W mittlerer Ausgangsleistung komprimierte Pulse mit 80 μJ Pulsenergie und 700 fs Pulsdauer liefert.

Als Seedquelle dient ein Chirped-Pulse-Oscillator mit zwei Yb:KYW Kristallen, der bei einer Zentralwellenlänge von 1045 nm Pulse mit 5 W mittlerer Leistung und 1 MHz Repetitionsrate mittels Cavity-Dumping erzeugt [1]. Diese werden mit einem Chirped-Volume-Bragg-Grating gestreckt und in einer 80 cm langen Rod-Type Faser auf 100 W hochverstärkt. Die Kompression mit einem Gitterkompressor liefert Pulse mit 80 μJ Pulsenergie und 700 fs Pulsdauer, woraus Spitzenleistungen im 100 MW-Bereich resultieren. Dieses System wird als Laserquelle für einen Pulsed-Laser-Deposition Aufbau zur Erzeugung von Random-Lasing Strukturen eingesetzt.

[1] Palmer et al.: „12 MW peak power from a two-crystal Yb:KYW chirped-pulse oscillator with cavity-dumping". Opt. Express **18** 19095 (2010)

Q 54.32 Thu 16:30 Poster.I+II

Acceleration of non-relativistic electrons at a dielectric grating structure — •John Breuer and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Garching bei München, Germany

Using the laser *electric field* for particle acceleration has been proposed about 30 years ago [1]. First experimental results have recently been obtained [2]. The key advantages are not only high accelerating gradients and therefore future smaller sized accelerators, but also the precise temporal control of the electron motion via the laser fields. The concept of sub-wavelength fused-silica transmission gratings, which provide spatial harmonics that propagate synchronously with electrons passing parallel by the grating surface, has been proposed [3]. We are following this approach for non-relativistic (27 keV) electrons in order to prove the efficacy of light-field based acceleration and steering of electrons, analogous to today's microwave accelerators. From numerical simulations we expect an accelerating gradient of up to 60 MeV/m and an energy gain of about 300 eV for electrons passing 100 nm away from the grating. We will present the experimental setup, the current status and detail possible applications.

[1] R. Palmer, Particle Accelerators, 11, 81-90 (1980)
[2] T. Plettner, R. L. Byer et al., PRL, 95, 134801 (2005)
[3] T. Plettner, R. L. Byer et al., PRSTAB, 9, 111301 (2006)

Q 54.33 Thu 16:30 Poster.I+II

Ultrafast electron emission from sharp tungsten tips using few-cycle infrared pulses — •Michael Förster, Sebastian Thomas, Markus Schenk, Michael Krüger, Lothar Maisenbacher, and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching bei München, Germany

Strong-field photoemission from metal nanotips triggered by few-cycle Ti:Sa pulses shows pronounced similarity to the well-studied case of gases irradiated with high-power lasers. In particular, evidence for the recollision of electrons with the surface of a tungsten tip has been found [1], which hints at the possibility of electron recombination with

the metal and corresponding high harmonic generation (HHG).

Using longer wavelengths offers the possibility to access a new parameter range that is in principle similar to that leading to HHG in gas systems, but comes at the difficulty that no known laser medium supports few-cycle pulses around 2 μm directly. Here we show first results of photoemission measurements using two different light sources, one of them relying on parametric amplification and broadband difference-frequency generation [2]. We compare our findings to established results in the solid state and the gas phase.

[1] M.Krüger, M.Schenk, P.Hommelhoff, *Nature* **475**, 79 (2011).
[2] C.Homann, M.Bradler, M.Förster, P.Hommelhoff, E.Riedle, submitted for publication.

Q 54.34 Thu 16:30 Poster.I+II

Progress in metering the absolute phase — •Tim Rathje[1], A.Max Sayler[1], Max Möller[1], Daniel Adolph[1], Dominik Hoff[1], Walter Möller[1], Gero Stiebenz[2], and Gerhard G. Paulus[1] — [1]Institut für Optik und Quantenelektronik and Helmholtz-Institut Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]APE GmbH, Plauener Str. 163-165, 13053 Berlin, Germany

We report on progress in metering the absolute phase of few-cycle laser pulses. The respective phasemeter (PM) is based on measuring the asymmetry of photoelectrons emitted in opposite directions. A prescision of 80 mrad is achived for every single shot in real-time. At the same time an accurate measurement of the pulse duration is obtained. So far this technique was restricted to sub-8 fs laser pulses. By combining the PM with polarization gating we extend the measurement range of the PM up to a pulse length of 12 fs. Together with a fast electronic real-time circuit, the PM also allows for improvement of the carrier-envelope phase stabilization of few-cycle laser pulse systems by 25 % as compared to commercial f-2f interferometric stabilization systems. This electronic circuit delivers the asymmetry parameter in less than 20 μs with 100 % duty cycle. A parallel use of a PM with phase-sensitive experiments and tagging each measurement with the absolute phase opens the door to phase-senstive measurements without a phase-stabilized laser system (phase-tagging).

Q 54.35 Thu 16:30 Poster.I+II

Towards nonlinear optical microscopy with few-cycle laser pulses — •Wan Hui[1], Stefan Gomes da Costa[1], Hilton B. de Aguiar[1], Gabriel Tempea[2], and Andreas Volkmer[1] — [1]3. Institute of Physics, University of Stuttgart, Stuttgart 70550, Germany — [2]FEMTOLASERS Produktions GmbH, Fernkorngasse 10, 1100 Wien, Austria

With the advent of high-dispersion mirrors, the delivery of tightly focused laser pulses with sub-20-fs pulse durations became feasible with compact and user-friendly compressors. For tightly focused sub-10-fs pulses in the visible and near infrared region, typically active pulse-shaping techniques are employed. Here, we report on pushing the limits of purely passive dispersion management in nonlinear optical microscopy with few-cycle pulses. 6.4-fs pulses from a Ti:Sapphire oscillator were coupled into an inverted microscope. Ultra-broadband dispersive mirrors covering the full laser spectrum pre-compensate the dispersion of high-N.A. objectives, resulting in pulse durations of 9.8 fs at the focus. The pulse duration at the sample was limited by the properties of the microscope's dichroic filter. We have designed a filter that supports the full bandwidth of the laser and introduces negligible dispersion. Its implementation is expected to enable pulse durations closely approaching the sub-7-fs bandwidth limit at the focus.

Q 54.36 Thu 16:30 Poster.I+II

An optimized Ultrafast Electron Diffraction setup to reach a high spatial and temporal resolution — •Silvio Morgenstern, Christian Gerbig, Vanessa Sporleder, Cristian Sarpe, Matthias Wollenhaupt, and Thomas Baumert — Universität Kassel, Institut für Physik und Center of Interdisciplinary Nanostructure Science and Technology (CINSaT), D-34132 Kassel, Germany

Ultrafast Electron Diffraction (UED) has lately become one of the most promising techniques to directly provide insights into fundamental dynamics in solids at the microscopic level and on the pico- to subpicosecond timescale [1].
In this contribution we present an optimized compact and self-referencing UED-setup to reach a high spatial and temporal resolution. Additionally we present first results in time-resolved diffraction experiments.

[1] M. Chergui & A. H. Zewail, Chem. Phys. Chem. **10**, 28 (2009)

Q 54.37 Thu 16:30 Poster.I+II

Full characterization of ultrashort electron pulses — •Vanessa Sporleder, Christian Gerbig, Silvio Morgenstern, Cristian Sarpe, Matthias Wollenhaupt, and Thomas Baumert — Universität Kassel, Institut für Physik und Center of Interdisciplinary Nanostructure Science and Technology (CINSaT), D-34132 Kassel, Germany

We use grating enhanced ponderomotive scattering [1] to in situ characterize ultrashort electron pulses obtained from our femtosecond transmission electron diffractometer [2,3]. The temporal and spatial electron pulse shape is reconstructed employing our particle tracer algorithm taking the complete setup geometry into account. In addition to space charge density effects on the electron pulse duration, the influence of the spatio-temporal source profile is studied to achieve shortest electron pulses at highest coherence.

[1] C. T. Hebeisen *et al.*, Opt. Express **16**, 3334 (2008)
[2] M. Chergui & A. H. Zewail, Chem. Phys. Chem. **10**, 28 (2009)
[3] G. Sciaini & R. J. D. Miller, Rep. Prog. Phys **74**, 096101 (2011)

Q 54.38 Thu 16:30 Poster.I+II

Gepulste-Laser-Deposition von ZnO: Random Lasing und Strukturanalyse der Schichten mit RHEED — •Mathias Hoffmann[1], Stefan Schrameyer[2], Mark Gyamfi[2], Detlev Ristau[2] und Uwe Morgner[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland — [2]Laser Zentrum Hannover, Hannover, Deutschland

Mit Hilfe der gepulsten Laserdeposition (engl.: Pulsed Laser Deposition - PLD) können eine Vielzahl von Materialien als Schichten bzw. Schichtstrukturen deponiert werden. Bei unserem System wird der Materialabtrag mit einem hochrepetierenden fs-IR-Laser durchgeführt. Deponiert wird Zinkoxid (ZnO) auf amorphen Substraten. Angeordnet als stark streuendes Medium (z.B. in Form von Nanopartikeln) ist ZnO bekannt für seine Eigenschaft als 'Random Laser'. Einen Einblick in die Struktur der hergestellten Schichten ermöglicht neben der Rasterelektronenmikroskopie (SEM) das RHEED-Verfahren. Dieses Verfahren kann im Gegensatz zum SEM bereits während des Herstellungsprozesses Informationen über das Strukturwachstum liefern. In diesem Beitrag werden aktuelle Ergebnisse mit Bezug auf die Eigenschaften des Random Lasings von ZnO und der Struktur in Abhängigkeit der Substrattemperatur und des Hintergrundgases vorgestellt.

Q 54.39 Thu 16:30 Poster.I+II

Compression and control of ultra short laser pulses applying Phase Resolved Interferometric Spectral Modulation (PRISM) — •Tillmann Kalas, Hendrike Braun, Jens Köhler, Matthias Wollenhaupt, and Thomas Baumert — University of Kassel, Institute of Physics and CINSaT, D-34132 Kassel, Germany

We present experimental results on spectral domain pulse shaper based ultra short laser pulse compression and control. Experiments involving ultra short laser pulses rely on proper compression techniques to compensate dispersion and phase distortions accumulated on the optical path to the interaction volume. On our home build precision pulse shaper [1] we implement the novel pulse compression technique *PRISM* (Phase Resolved Interferometric Spectral Modulation) [2]. One advantage of the *PRISM*-method is that it does not need any parametrization of the spectral phase function. Furthermore, unlike the *MIIPS*-technique (Multiphoton Intrapulse Interference Phase Scan) in which the spectrally dispersed second harmonic spectrum is measured, *PRISM* only requires a measurement of the integrated nonlinear signal. We present applications of *PRISM* to pulse compression in a commercial microscope and a vacuum champer, exploiting nonlinear signals like two photon induced photodiode current and multiphoton ionization (MPI) of Xe. We additionally show that *PRISM* can also be used for the optimization of user-defined contrasts in the spectrum of second harmonic generated radiation (SHG).

[1] J. Köhler *et al.*: Opt. Express, **19**(12), 11638(2011)
[2] T. Wu *et al.*: Opt. Express, **19**(14), 12961(2011)

Q 54.40 Thu 16:30 Poster.I+II

Controlling ionization mechanisms in high band gap dielectrics via tailored femtosecond laser pulses. — •Thomas Winkler, Cristian Sarpe, Jens Köhler, Matthias Wollenhaupt, and Thomas Baumert — University of Kassel, Institute of Physics and CINSaT, D-34132 Kassel, Germany

Tailored ultrashort laser pulses provide a great potential to control laser induced ionization being the primary step in the ablation pro-

cess of dielectric materials. In our previous work we have shown that shaped pulses enhance the precision in material processing of transparent dielectrics. For instance pulses generated by cubic spectral phase modulation allow to create structures with sizes one order of magnitude below the diffraction limit by controlling the interplay between multiphoton and avalanche ionization [1]. Here we extrend our previous work [2] with simulations to study the dynamics of the free electron plasma in a thin water jet induced by both bandwidth limited and shaped laser pulses. These simulations, based on numerically solving the rate equation [3] in a refined form [4] for the time dependent free electron density, allow to investigate the dynamics for different temporal pulse shapes. Comparing the simulation results with the experimental data on phase shifts from laser-induced electron density obtained by a precise spectral interference technique we find very good agreement between these two approaches.

[1] L. Englert *et al.*, Appl. Phys. A, **92**, 749 (2008), [2] C. Sarpe *et al.*, APL , **88**, 261109 (2006), [3] P. K. Kennedy *et al.*, IEEE JQE., **31**, 2241 (1995), [4] J. Noack, A. Vogel, IEEE JQE, **35**, 1156 (1999)

Q 54.41 Thu 16:30 Poster.I+II

THz-Erzeugung durch optische Gleichrichtung in $LiNbO_3$ mit ultrakurzen Femtosekundenlaserpulsen — •Martin Richter[1], Maksim Kunitski[1], Mark Thomson[2], Arno Vredenborg[1], Jian Wu[1], Hartmut G. Roskos[2] und Reinhard Dörner[1] — [1]Institut für Kernphysik, Goethe Universität Frankfurt — [2]Physikalisches Institut, Goethe Universität Frankfurt

Die Manipulation von Elektronen durch starke THz-Felder kann zur Untersuchung von Ionisationsprozessen in Atomen und Molekülen verwendet werden. Vor kurzem wurde eine effiziente THz-Erzeugungsmethode vorgeschlagen, die auf optischer Gleichrichtung von Femtosekundenlaserpulsen in $LiNbO_3$ Kristallen basiert [1]. Allerdings wurde festgestellt, dass das üblicherweise verwendete Pulse-Front-Tilt Schema mit einer einzelnen Linse als abbildendes Element ineffizient ist, wenn ultrakurze Femtosekundenlaserpulse (<100 fs) als Pumpstrahl verwendet werden. Zur Entwicklung eines effizienteren THz-Aufbaus wurde ein Raytracingcode geschrieben, der eine Simulation der Abbildungsfehler ermöglicht. Anhand dieser Simulation und nachfolgender Experimente wurden verschiedene THz-Erzeugungsschemen verglichen.

[1] J. Hebling et al., Opt. Express 21, 1161 (2002)

Q 54.42 Thu 16:30 Poster.I+II

Tip-based electron source for femtosecond electron diffraction — •Jan-Paul Stein, Johannes Hoffrogge, Markus Schenk, Michael Krüger, Peter Baum, and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching bei München

Illumination of a sharp tungsten tip with femtosecond laser pulses leads to the emission of ultrashort, high brightness electron pulses that are ideally suited for ultrafast electron diffraction (UED) experiments [1]. The tip's small virtual source size (∼5 nm) results in a large transverse coherence length of the electron pulse and therefore better spatial resolution as compared to a conventional flat cathode design. The enhanced electric field at the tip apex (2 GV/m) is about two orders of magnitude larger than the maximum electric field applicable in a plate capacitor based setup (20 MV/m). This reduces the influence of the initial energy distribution on the pulse duration at the target and improves the timing jitter. Simulations show that a setup with a sharp tip as the cathode in combination with two anodes yields an electron pulse duration of about 50 fs at the sample. The electron energy is 30 keV and the gun to sample distance is 3 cm. We implemented the two anode setup with the tip experimentally. We will present the experimental characteristics of the emitted electron beam both in static field emission and in laser triggered emission.

[1] P. Hommelhoff, C. Kealhofer et al., Ultramicroscopy **109**, 423-429 (2009)

Q 54.43 Thu 16:30 Poster.I+II

Broadband degenerate four-wave mixing of optical vortex beams — Peter Hansinger[1], •Georgi Maleshkov[2], Dragomir N. Neshev[3], Alexander Dreischuh[1,2], and Gerhard G. Paulus[1,4] — [1]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Department of Quantum Electronics, Sofia University, 5 James Bourchier Blvd., Sofia-1164, Bulgaria — [3]Nonlinear Physics Centre, Research School of Physics and Engineering, Australian National University, Canberra, Australia — [4]Helmholtz-Institute Jena, Helmholtzweg 4, 07743 Jena, Germany

Optical vortices, also known as screw dislocations, are singular points within the phase of a light beam. The phase varies by a multiple m of 2π over the angular coordinate ϕ, and is therefore undefined in the center and the intensity becomes zero at this point. m is called the topological charge and corresponds to photon angular momentum, and as such is a conserved quantity. Such donut beams have become useful e.g. in optical micromanipulation as so-called optical tweezers.

We have performed experiments where vortex beams with different topological charges are interacting via degenerate four-wave mixing in a nonlinear Kerr medium. The vortices are imprinted on ultrashort laser pulses of different central wavelengths, so that both spectral broadening and topological charge mixing occurs. This leads to sum- and difference- topological charges in the spectral satellites. The cascaded mixing process is observed up to third order. Broadband simulations in the spectral domain confirm the experimental findings.

Q 54.44 Thu 16:30 Poster.I+II

Remote entanglement of distant single atoms — •Andreas Reiserer, Stephan Ritter, Christian Nölleke, Carolin Hahn, Andreas Neuzner, Manuel Uphoff, Martin Mücke, Eden Figueroa, Jörg Bochmann, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Entanglement of remote particles is a key resource for quantum communication and distributed quantum computing. In our experiments, two single atoms are trapped in high-finesse optical cavities in independent laboratories and entangled via the exchange of a single photon. For this purpose, we first demonstrate that a single atom in an optical cavity can work as an efficient quantum memory for single photons generated by another independent setup with similar parameters. This is then used to transfer quantum information from one atom to the other and to generate and store maximally entangled states between the two atoms.

Q 54.45 Thu 16:30 Poster.I+II

Design considerations for an optical microfibre fabrication machine — •Christian Lützler, Marcel Spurny, Wolfgang Alt, and Dieter Meschede — Institut für Angewandte Physik, Universität Bonn

Due to their high light confinement and strong evanescent field, optical microfibres are ideal for nonlinear optics, surface spectroscopy and interferometric sensing. The shape of both waist and tapered sections determines the optical properties of the microfibre, in particular surface intensity, adiabaticity and number of guided modes. A heat-and-pull apparatus is used to produce microfibres from standard diameter fibres. Applications which are sensitive to the exact shape of the optical fibres, e.g. interferometric sensing, showed that the microfibres obtained from a previous pulling machine [1] do not fully meet the expectations in terms of mode guidance, shape accuracy and reproducibility.

Our poster shows both requirements on the mechanics of a microfibre fabrication machine and indicates critical points during fabrication process. Possible reasons for the discrepancy between obtained and desired shape of the optical microfibres are illustrated. These are, among others, the inertia of the employed translation stages and the influence of the hydrogen-oxygen burner which is used as a heat source. The new fibre pulling machine, which is built under these design considerations at the University of Bonn, is presented.

[1] F. Warken, A. Rauschenbeutel und T. Bartholomäus, "Fiber pulling profits from precise positioning", Photonics Spectra 42, 3, 73 (2008).

Q 54.46 Thu 16:30 Poster.I+II

Bandbreitenreduzierung der stimulilerten Brillouin Streuung für ultrahochauflösende Spektroskopie von optischen Signalen — •Stefan Preussler, Andrzej Wiatrek, Kambiz Jamshidi und Thomas Schneider — Institut für Hochfrequenztechnik, Hochschule für Telekommunikation Leipzig

Die Messung von optischen Signalen im Frequenzbereich ist in den Bereichen Wissenschaft und Technik von großer Bedeutung. Zum Beispiel können in optischen Kommunikations- und Übertragungssystemen einzelne WDM-Kanäle betrachtet werden. Außerdem ist die hochauflösende Darstellung des Spektrums von Millimeter- oder Terahertz-Wellen durch optische Methoden essenziell für verschiedenste Anwendungen. Die Auflösung der Spektren ist bei herkömmlichen gitterbasierten optischen Spektrumanalysatoren stark begrenzt. Spektrale Komponenten

unterhalb von 1.25 GHz können nicht korrekt dargestellt werden. Im Bereich der optischen Kommunkationstechnik wird der nichtlineare Effekt der stimulierten Brillouin Streuung verwendet um Spektren mit einer wesentlich höheren Auflösung von 20 MHz zu messen.

In diesem Beitrag zeigen wir die Verringerung der natürlichen Brillouin Bandbreite und damit die Erhöhung der Auflösung. Durch die Überlagerung des Brillouin Gewinns mit zwei Verlusten wird die Brillouin Bandbreite auf 3.4 MHz reduziert und zur ultrahochauflösenden Messung des Spektrums eines mit 5 MHz modulierten optischen Signals verwendet.

Q 54.47 Thu 16:30 Poster.I+II

Entanglement of two single atoms over a distance of 20m — •Norbert Ortegel[1], Michael Krug[1], Julian Hofmann[1], Kai Redeker[1], Lea Gérard[1], Wenjamin Rosenfeld[1,2], Markus Weber[1], and Harald Weinfurter[1,2] — [1]Department für Physik, LMU München, Schellingstraße 4, 80799 München — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching

Atom pairs entangled over long distances can serve as basic elements in quantum communication schemes e.g. the quantum repeater. They can also be used to carry out fundamental tests of quantum mechanics such loophole free tests of Bells inequality. Recently, we generated entanglement between two single Rb87 atoms that are located in independent optical dipole traps 20 meters apart.

In our case entanglement between the atoms is obtained via the entanglement swapping protocol. In this contribution we present details on the tools and methods used to perform such an experiment. It starts by creating entanglement between the electronic spin state of each atom and the polarization state of a photon. The photons are then brought together via an actively stabilized fiber link without loss of coherence. A Bell-state projection of the two-photon state by two-photon interference at a fiber beamsplitter yields an entangled atom pair. In order to preserve the entanglement the atomic spin state is stabilized by actively compensating external magnetic fields. Finally, a state-readout of the atoms reveals the non-classical correlations that prove their entanglement.

Q 54.48 Thu 16:30 Poster.I+II

Highly efficient sub-microsecond Zeeman-state readout of Rb87 via state-selective ionization — •Kai Redeker[1], Norbert Ortegel[1], Lea Gérard[1], Michael Krug[1], Julian Hofmann[1], Florian Henkel[1], Wenjamin Rosenfeld[1,2], Markus Weber[1], and Harald Weinfurter[1,2] — [1]Department für Physik, LMU München, Schellingstraße 4, 80799 München — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching

Future applications in quantum information technology such as quantum repeaters and atomic quantum computers heavily rely on the capability to read out qubits fast and efficiently. Here we present a readout scheme for a qubit encoded in Zeeman-states of a single Rb87 atom that fulfills these requirements. It is based on a state-selective photo-ionization of the atom and subsequent detection of the ionization fragments.

The readout starts by mapping a selected superpostion of two Zeeman-states onto a superpostion of two hyperfine levels using a STIRAP transfer sequence. The atom is then hyperfine-state selectively ionized and the produced electron and ion are collected using two opposing channel-electron mulitpliers (CEM's). The whole process takes less than 1 microsecond and the overall efficiency of the CEM's to detect at least one of the ionization fragments was found to be above 99%.We show data on the speed and precision of the photo-ionization process, measurements of the absolute detection efficiencies of the CEM's as well as progress towards integrating the CEM's into a single atom trap setup.

Q 54.49 Thu 16:30 Poster.I+II

Experimental investigation of thermal and mechanical properties of a subwavelength-diameter silica fiber — •Christian Wuttke and Arno Rauschenbeutel — VCQ, TU Wien – Atominstitut, Stadionallee 2, A-1020 Wien

Subwavelength-diamter optical fibers have proven to be a powerful tool for coupling light and matter. Furthermore, thanks to their evanescent field, they can be used as coupling devices for optical cavities like, e.g., whispering-gallery-mode microresonators. For many of these applications, the mechanical and thermal properties of the subwavelength-diameter fiber are of relevance. However, these properties are not easily calculated. As an example, the transverse dimension of the subwavelength-diameter fiber is comparable to the thermal wavelength. Thus, the thermal radiation differs from the classical blackbody spectrum. For this reason, we carry out experimental investigations using a Fabry-Pérot type optical resonator. It is based on a tapered optical fiber (TOF), equipped with two fiber Bragg gratings which enclose a subwavelength-diameter waist. Since the TOF is inside the resonator volume, this enables us to measure changes of the subwavelength-diameter fiber properties with high precision. We present the current status of the experiments.

We gratefully acknowledge financial support by the Volkswagen Foundation and the ESF.

Q 54.50 Thu 16:30 Poster.I+II

Nanofiber-based optical spectroscopy on emitter-doped crystals — •David Papencordt, Ariane Stiebeiner, Moritz Numrich, Ruth Garcia-Fernandez, and Arno Rauschenbeutel — VCQ, TU Wien – Atominstitut, Stadionallee 2, 1020 Wien, Austria

The use of optical nanofibers as an exceedingly sensitive tool for spectroscopy has proven to exhibit numerous advantages [1,2]. We present our results on nanofiber-based spectroscopic measurements on dye-doped organic crystals. We deposit the crystals on the nanofiber waist of a tapered optical fiber and excite them via the nanofiber, while the emitted fluorescence light is coupled into the guided mode of the fiber. Thus, crystal growth and guest-host interactions in the crystal can be studied spectroscopically. The measurements are performed under cryogenic conditions, allowing us to better resolve the spectral information. By measuring the statistical fine structure of the emitter-molecules doping the crystal, we take an important step towards nanofiber-based single molecule spectroscopy.

We gratefully acknowledge financial support by the Volkswagen Foundation, the ESF, and the EC (STREP "CHIMONO").

[1] F. Warken et al., Opt. Express, **15**, 11952 (2007)
[2] A. Stiebeiner et al., Opt. Express, **17**, 21704 (2009)

Q 54.51 Thu 16:30 Poster.I+II

Controlling the radiative properties of molecules in a microresonator — •Andreas M. Kern[1], Alexey Chizhik[2], and Alfred J. Meixner[1] — [1]Institut für Physikalische und Theoretische Chemie, Universität Tübingen — [2]Drittes Physikalisches Institut, Universität Göttingen

The enhancement of light in an optical resonator leads to stronger absorption by a molecule located therein. This, however, has been shown to be only one of two effects on the light-molecule interaction. The increased density of optical states also leads to a shorter radiative lifetime and thus enhanced emission. Here, we present our work on the control of the optical properties of single molecules in optical microresonators formed by two silver mirrors placed only half a wavelength apart. Using higher-order laser modes as illumination, the geometric orientation of the molecules can be probed and proves to have a large effect on the coupling of the molecule to the resonator modes. Influencing the photonic landscape around the molecule, one also gains insight into the nonradiative, lossy processes and thus the system's quantum yield. Using pulsed excitation, we obtain additional information on the dynamics of an emitter's decay path. This versatile measurement approach allows the detailed study of fluorescence, luminescence and FRET processes.

Q 54.52 Thu 16:30 Poster.I+II

Stability of nonlocal solitary waves in random nonlinear media — •Fabian Maucher[1,2], Wieslaw Krolikowski[2], and Stefan Skupin[1,3] — [1]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [2]Laser Physics Centre, Research School of Physics and Engineering, Australian National University, Canberra, ACT 0200, Australia — [3]Friedrich Schiller University, Institute of Condensed Matter Theory and Optics, 07743 Jena, Germany

Nonlocal nonlinearities are common to diverse physical settings, such as beam propagation in media where certain transport processes like heat or charge transfer, or diffusion and/or drift of atoms are responsible for the nonlinearity. It also occurs in systems involving long-range interaction of atoms or molecules, e.g., nematic liquid crystals or Bose-Einstein condensates with long-range interatomic interaction. Here, we consider solitary waves subject to random perturbations, where the randomness acts on the source of the underlying physical process leading to nonlocality. We use both numerical simulations and analytical methods to show that stability of bright solitons in presence of random perturbations can be dramatically enhanced if the nonlocality-induced correlation length becomes comparable to the extent of the

wave packet. In the regime of weakly correlated disorder, a simplified mean-field approach allows to estimate the life-time of solitary wave-packets.

Q 54.53 Thu 16:30 Poster.I+II

Müller Matrices of an arbitrarily oriented polarizer in three dimensions — •Tobias Kolb[1,2], Vanessa Chille[1,2], Jan Korger[1,2], Christoffer Wittmann[1,2], Andrea Aiello[1,2], Peter Banzer[1,2], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Guenther-Scharowsky-Str. 1, 91058 Erlangen, Germany — [2]Institute for Optics, Information and Photonics, University Erlangen-Nuremberg, Staudtstr. 7/B2, 91058 Erlangen, Germany

Motivated by a recently predicted phenomenon, the geometric spin Hall effect of light (gSHEL) at polarizing interfaces [1], we investigate the action of a real polarizer. In this work, we study a commercial polymer film polarizer and compare our experimental findings with a well-known projecting polarizer model [2].

To this end, we rotate and tilt our polarizer around the horizontal and vertical axes and measure the Müller Matrix for a multitude of configurations. The Müller Matrix describes, how a sample effects the state of polarization of a light beam transmitted across it.

We specifically adapt the polarizer model to the case of absorbing polarizers. We show that this modified model is in good agreement with our experimental data.

Finally we present a setup designed to measure the position of a light beam transmitted across a tilted polarizer. This setup allows a direct measurement of the gSHEL using our

[1] J.Korger, et. al., Appl Phys B, 427–432 (2011); [2] Y. Fainman, J. Shamir, Appl Optics 23, 3188 (1984)

Q 54.54 Thu 16:30 Poster.I+II

Investigation of a Single Chiral Nano-Structure — •Paweł Woźniak[1,2], Sarah Fritsch[1,2], Peter Banzer[1,2], Katja Höflich[1], Silke Christiansen[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Günther-Scharowsky-Str. 1, D-91058 Erlangen, Germany — [2]Institute of Optics, Information and Photonics, University Erlangen-Nuremberg, Staudtstr. 7/B2, D-91052 Erlangen, Germany

Metamaterials built from chiral meta-atoms have attracted increasing interest in the last years. For instance, such materials can be used as broadband waveplates which sense the handedness of the impinging light beam. In our studies, we experimentally investigate the optical properties of single nano-scaled helices using different types of tightly focused polarization tailored light beams. The single three dimensional nanostructures are fabricated on an ITO-on-glass substrate using electron-beam-induced deposition (EBID) [1]. They consist of a composite material of gold nano-crystals (2-7 nm) embedded into a carbonaceous matrix. They are designed such that they have a diameter of only 50-200 nm with up to five helix pitches resulting in a resonant behavior in the visible wavelength range. We present first experimental results of our measurements on single nano-helices performed in transmission and reflection.

[1] K. Höflich et al., Adv. Mater. 23, 2657-2661 (2011)

Q 54.55 Thu 16:30 Poster.I+II

Towards highly efficient whispering gallery supported THz detection — •Florian Sedlmeir[1,2], Dmitry V. Strekalov[3], Sebastian Bauerschmidt[1,2], Sascha Preu[2], Stefan Malzer[2], Gottfried H. Döhler[1], Harald G. L. Schwefel[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institut für die Physik des Lichts, Erlangen, Deutschland — [2]Universität Erlangen-Nürnberg, Erlangen, Deutschland — [3]Jet Propulsion Laboratory, Pasadena, CA, United States

Efficient detection of weak terahertz signals is a very challenging task. Here we present a new concept and first experimental results of measuring weak terahertz signals using a triply-resonant, phase-matched whispering gallery mode resonator (WGMR). The idea is based on sum-frequency generation in a highly nonlinear $\chi^{(2)}$-material ($LiTaO_3$). There, a THz signal and a near infrared pump beam is converted into a near infrared idler beam, which can easily be detected. In order to increase the conversion efficiency the crystal is shaped with a diamond turning machine into a WGMR, where long interactions lengths are possible.

We will present efficient coupling of near infrared light into high quality (Q) modes with $Q \sim 10^8$, as well as sufficient $Q \sim 200$ in the THz domain. Due to the extremely high refractive index $n_{\mathrm{THz}} \sim 6$, highly efficient coupling into the WGMR in the THz domain is challenging and novel methods ranging from high index waveguides to grating enhanced evanescent coupling will be discussed. First steps towards measuring the near infrared sidebands will be presented.

Q 54.56 Thu 16:30 Poster.I+II

Coupling color centers in diamond to optical fiber microcavities — Hanno Kaupp[1,2], Matthias Mader[1,2], •Louis Costa[1,2], Christian Deutsch[3], Jakob Reichel[3], Theodor W. Hänsch[1,2], and David Hunger[1,2] — [1]Ludwig-Maximilians-Universität München, Deutschland — [2]Max-Planck-Institut für Quantenoptik, Garching, Deutschland — [3]Laboratoire Kastler Brossel, E.N.S., Paris, Frankreich

Optical fibers with machined and coated end facets can serve as high reflectivity mirrors to build low loss optical resonators with free space access [1]. These microcavities feature a very small mode volume on the order of a few tens of cubic wavelengths and a very large Finesse of up to 10^5, corresponding to quality factors of several millions. Thus, the Purcell factor, being proportional to the ratio of quality factor and mode volume, can be as high as 10^3, which can dramatically enhance the emission rate of an emitter inside the cavity.

We want to use the microcavities to couple solid state based emitters such as color centers in diamond to the cavity mode and raise the emission efficiency. First steps towards studying the interaction with nitrogen-vacancy centers in diamond will be presented.

[1] D. Hunger, New Journal of Physics 12, 065038 (2010)

Q 54.57 Thu 16:30 Poster.I+II

Towards Cavity Nanoscopy — •Matthias Mader[1,2], Hanno Kaupp[1,2], Louis Costa[1,2], Christian Deutsch[1,2], Jakob Reichel[3], Theodor W. Hänsch[1,2], and David Hunger[1,2] — [1]Ludwig-Maximilians-Universität, München, Deutschland — [2]Max-Planck-Institut für Quantenoptik, Garching, Deutschland — [3]Laboratoire Kastler Brossel, E.N.S. Paris, Frankreich

The sensitivity for observing nano-objects with conventional microscopy is limited by their small cross section. Exploiting multiple interactions of light with nanoscale objects inside an optical resonator increases the sensitivity for detecting nano-particles. To realize high spatial resolutions under these conditions, microscopic mode cross sections within the cavity are required. These requirements are fulfilled by fiber-based Fabry-Pérot type cavities. This type of optical resonator provides a high finesse, a small mode volume and easy free-space access. The cavity is made of a laser-machined and high-reflective coated end facet of a single mode optical fiber and a plane macroscopic mirror.

Scanning the plane mirror under the fiber enables spatial resolved detection and spectroscopy of single nanoparticles on top of this mirror.

This opens the possibility for highly sensitive spatially resolved spectroscopy of a wide variety of nano-objects.

We report first results of experiments on absorption spectroscopy and cavity nanoscopy with gold nanoparticles.

Q 54.58 Thu 16:30 Poster.I+II

Nanodiamonds for biological application — •Anna Ermakova[1], Boris Naydenov[1], Fedor Jelezko[1], Rolf Reuter[2], Jörg Wrachtrup[2], Goutam Pramanik[3], and Tanja Weil[3] — [1]Institute for Quantum Optics, University Ulm, Germany — [2]3. Physical Institute, University Stuttgart, Germany — [3]Institute of Organic Chemistry III, University Ulm, Germany

Diamond is good material for biological and medical application, since it is highly biocompatible diamond and its surface can be functionalized and covered with active molecules. This very interesting for nanodiamonds which have large specific surface area the are small enough in order to move inside the cell. At the same time small diamond nanoparticles (2-10 nm) have been shown to be non-toxic for a variety of cells, compared to different dyes. Moreover, diamond contains a variety of photostable defects. Where the nitrogen-vacancy center [NV] is the most promising one. Nanodiamonds containg NV allow the detection of small magnetic field with high spatial resolution and sensitivity.

In this work we present motional dynamics of nanodiamonds coated with a novel peptide-polymer hybrid poly(ethylene oxide) (cBSA-PEO) marked with Rhodamine in the solution. The successful coating of nanodiamond with cBSA-PEO has been confirmed by emission from NV centers. The higher colloidal stability of this nanodiamonds in the solution with high ionic strength was determined by fluorescence correlation spectroscopy.

Q 54.59 Thu 16:30 Poster.I+II

Generation of a close to full solid angle dipole wave — •Marianne Bader[1,2], Andrea Golla[1,2], Benoît Chalopin[1,3], Irina Harder[1], Klaus Mantel[1], Robert Maiwald[1,2], Norbert Lindlein[2], Markus Sondermann[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, Erlangen, Germany — [3]Laboratoire Collisions Agrégats Réactivité, Université Paul Sabatier, Toulouse, France

Efficient photon-atom interaction is essential for quantum communication protocols. We aspire to a coupling strength close to unity for interfacing the free-space light field with a single trapped Ytterbium ion. To this end we trap the ion in the focal point of a deep parabolic mirror allowing illumination from nearly the complete solid angle [1]. The mirror converts a properly shaped incident plane wave into an inwards running dipole wave matching the dipole properties of the atomic transition [2]. Absorption experiments require additional temporal shaping of the incident light [2,3].

We present spatial and temporal pulse shaping at the cooling wavelengths of Yb^+ and Yb^{2+} (370nm and 252nm, respectively) as well as results of an aberration correction of the parabolic mirror. Furthermore, we define a measure for the quality of our experimental achievements. From that, we envision absorption efficiencies beyond 80%.

[1] R. Maiwald et. al., Nature Physics 5, 551 (2009)
[2] M. Sondermann et. al., Applied Physics B, 89, 489 (2007)
[3] M. Stobinska et. al., EPL 86, 14007 (2009)

Q 54.60 Thu 16:30 Poster.I+II

Setup for dissipative Optomechanics in a signal recycled Michelson-Sagnac Interferometer — •Ramon Moghadas Nia[1], Andreas Sawadsky[1], Henning Kaufer[1], André Xuereb[1,2], Klemens Hammerer[1,2], and Roman Schnabel[1] — [1]Institut für Gravitationsphysik, Leibniz Universität Hannover and Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstraße 38, D-30167 Hannover, Germany — [2]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, D-30167 Hannover, Germany

Conventional optomechanical experiments couple mechanical oscillators with an optical cavity mode in a dispersive manner. The result of this is that the cavity resonance frequency experiences a shift depending on the displacement of the mechanical oscillator. Here we illustrate an experimental setup which enables optomechanical coupling, tunable between either a dispersive or a solely dissipative domain. In the dissipative case, the dependence of the cavity linewidth on the mechanical displacement is dominating the dispersive coupling. We use a silicon nitride micro-mechanical membrane with high-Q as a mirror inside a signal-recycled Michelson-Sagnac interferometer. This composition can lead to strongly enhanced cooling in the non-sideband-resolved regime. In the case of a pre-cooled cryogenic setup, one can expect ground state cooling of the membrane*s fundamental oscillation mode. This system is also appropriate for highly sensitive position measurements.

Q 54.61 Thu 16:30 Poster.I+II

Interaction of a single atom with an optomechanical resonator — •Juan Mauricio Torres and Marc Bienert — Theoretische Physik, Universität des Saarlandes, D-66041 Saarbrücken, Germany

We study the dynamics of a Fabry-Perot cavity with a pendular end mirror coupled to an atomic dipole. The system is driven by an external laser and dissipates due to cavity losses and atomic fluorescence. We focus on the good cavity limit where the fluorescence can be suppressed by quantum interference between the cavity and atomic degree of freedom. For this case we analyze the spectrum of the scattered light which is dominated by features due to the mechanical interaction with the movable mirror. We discuss how to extract information about the motional state of the mirror and the possibilities of interfacing the atomic with the mechanical degree of freedom.

Q 54.62 Thu 16:30 Poster.I+II

A Non-Gaussian master equation for the optomechanical strong coupling regime — •Niels Lörch and Klemens Hammerer — Leibniz Universität Hannover, 30167 Hannover, Germany

We study the dynamics of an optomechanical system consisting of a driven optical cavity that is coupled to a mechanical oscillator via radiation pressure force. It is well known that in such systems the classical nonlinear dynamics can give rise to self-induced oscillations. More recently the strong coupling regime, in which the optomechanical coupling g can exceed the cavity decay rate κ, is starting to become experimentally available. We derive a master equation for this regime as an expansion in g/ω_M, where ω_M denotes the frequency of the mechanical oscillator.

Q 54.63 Thu 16:30 Poster.I+II

Quantum light generated by atomic arrays — •Hessam Habibian[1,2], Sergey Grishkevich[2], Stefano Zippilli[1,2,3], and Giovanna Morigi[1,2] — [1]Universitat Autónoma de Barcelona, Spain — [2]Universität des Saarlandes, Germany — [3]Universitá degli Studi di Salerno, Italy

Atom-photon interactions by a periodic atomic array is studied, when the scattering cross-section is increased either by an optical fiber or a cavity resonator. In the latter case, we consider a setup in which the atoms are driven by a laser and identify the conditions, under which the light at the cavity output exhibits nonclassical features. When the atoms form a periodic array confined, for instance, in a multimode hollow fiber [1,2], they can constitute a quantum nonlinear medium leading to the formation of spatial patterns of the propagating light. The coherence properties of the emitted light are determined and characterized for experimentally accessible parameters.

[1] D. Chang, V. Gritsev, G. Morigi, V. Vuletic, M. Lukin, and E. Demler, Nature Phys. 4, 884 (2008).
[2] M. Bajcsy, S. Hofferberth, V. Balic, T. Peyronel, M. Hafezi, A. S. Zibrov, V. Vuletic, and M. D. Lukin, Phys. Rev. Lett. 102, 203902 (2009).

Q 54.64 Thu 16:30 Poster.I+II

Semi-classical correlation functions in cavity QED — •James Alves de Souza[1,2], Haytham Chibani[1], Markus Koch[1], Christian Sames[1], Tatjana Wilk[1], Celso Jorge Villas-Boas[2], and Gerhard Rempe[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany — [2]Departamento de Fisica, Universidade Federal de São Carlos, Via Washington Luis km 235, São Carlos, SP 13565-905, Brazil

In a recent experiment, we have studied the quantum dynamics of a strongly coupled atom-cavity system by evaluating time-dependent second- and third-order correlation functions of the photons emitted from the cavity [1]. A new coherent dynamical process named super Rabi oscillation has been observed, which reflects the coherent exchange of energy between the driving laser and the atom-cavity system. For low driving strengths, it is well explained by the Rabi oscillations between the ground state and the first excited dressed states of the system. For higher driving, systematic deviations from this two-level model are found due to the population of higher excited dressed states. Here, we address the question if this deviation can also be explained by semi-classical models of light-matter interaction. To this end, we introduce the idea of semi-classical trajectories. Similarly to a quantum trajectory the semi-classical evolution of the system is interrupted by sudden quantum jumps when a photon is spontaneously emitted by the atom. This enables us to investigate the effect of the atomic emissions on a classical field. [1] M. Koch et al, Phys. Rev. Lett. 107, 023601 (2011).

Q 54.65 Thu 16:30 Poster.I+II

Kinetic approach to quantum radiation reaction — •Norman Neitz and Antonino Di Piazza — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg

Nonlinear quantum electrodynamical effects gained more and more attention over the last years due to the increasing intensity of modern laser systems and the availability of high energetic electron beams. Although the laser intensities might not be sufficiently high to allow pair creation, especially the collision of laser pulses with ultra-relativistic electrons will lead to processes that include multi-photon emissions whose influences are significant for the dynamic of the electrons in the laser field. Therefore we study the evolution of distribution functions for a system of an intense laser field and a counterpropagating electron beam. We treat the problem in the well-known framework of strong-field QED [1] and formulate cascade equations in the kinetic approach [2]. We restrict ourselves to the impact of pure radiation effects and thus exclude the possibility of pair creation. We show analytically that the classical limit coincides with the result of the Landau-Lifshitz equation [3] and perform numerically simulations for different field strengths and electron momenta.

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[2] V. N. Baier, V. M. Katkov and V. M. Strakhovenko, "Electromag-

netic processes at high energies in oriented single crystals" (World Scientific, Singapore, 1998).
[3] L. D. Landau and E. M. Lifshitz, "The Classical Theory of Fields" (Elsevier, Oxford, 1975)

Q 54.66 Thu 16:30 Poster.I+II

Trapping states of the electromagnetic field. — •Melanie Rolles, Christian Arenz, and Giovanna Morigi — Universität des Saarlandes

The dynamics of the electromagnetic field of a high-finesse resonator, which is pumped by a beam of "two-level" atoms, can exhibit trapping states when the strong coupling regime holds [1,2]. Trapping states are fixed points of the dynamics, which occur for well defined interaction times, and can exhibit marked non-classical features [2,3]. In this work we study the existence of trapping states of two-modes of a high-finesse microwave resonator, which are pumped by a beam of multilevel atoms. In particular, we analyze the conditions on the atomic configurations, on the coupling and on the interaction times which can lead to the creation of stable, entangled states of the cavity field modes.
[1] John J. Slosser, P. Meystre and Samuel L. Braunstein, Phys. Rev. Lett. 63, 934 (1989).
[2] P. Filipowicz, J. Javanainen and P. Meystre, J. Opt. Soc, 3, 906 (1986).
[3] M. Weidinger, B. T. H. Varcoe, R. Heerlein, and H. Walther, Phys. Rev. Lett. 82, 3795 (1999).

Q 54.67 Thu 16:30 Poster.I+II

Noise effects on Landau-Zener transitions in Bose-Einstein condensates — •Matthias Kraft, Stephan Burkhardt, and Sandro Wimberger — Institute for Theoretical Physics and HGSFP, University Heidelberg

Quantum transport phenomena in Bose-Einstein condensates (BEC) loaded into spatially periodic lattices is an active area of current research. For the Wannier-Stark system, which can be realized with a tilted optical lattice, the Landau-Zener model provides a fruitful approach to describe interband transitions of the atoms in the condensate. Nevertheless to gain a good understanding of the dynamics of any real system the implementation of noise into the model is crucial. We therefore extend the simple Landau-Zener model to incorporate typical sources of noise. This is done to investigate the interband transition dynamics of the atoms in the BEC when a "noisy" optical lattice is considered. The possibility to use noise to control the transition probability is discussed.

Q 54.68 Thu 16:30 Poster.I+II

Auf dem Weg zu Lasing Without Inversion in Quecksilber bei einer Wellenlänge von 253,7 nm bzw. 185 nm — •Benjamin Rein und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, AG Laser und Quantenoptik, Schlossgartenstr. 7, D-64289 Darmstadt

Das Erreichen der Besetzungsinversion im Verstärkungsmedium eines Lasers ist die fundamentale Voraussetzung für die Dominanz der stimulierten Emission und somit das Einsetzen der Lasertätigkeit. Dieses Prinzip schränkt jedoch die Entwicklung von cw-Lasern im VUV-Wellenlängenbereich und darunter drastisch ein, da die für eine Besetzungsinversion nötige Pumpleistung mit der 4ten Potenz der Frequenz der Laserstrahlung ansteigt und technisch nicht mehr erreichbar wird.

Lasing Without Inversion macht es jedoch möglich, ähnlich wie bei EIT, durch die kohärente Anregung von atomaren Übergängen und deren destruktive Interferenz die Absorption auf dem Laserübergang zu unterdrücken. Somit genügen schon wenige angeregte Atome, um Lasertätigkeit zu erzielen.

Es wird die experimentelle Realisierung des LWI Experimentes in Quecksilber vorgestellt, sowie erste Ergebnisse zum 435,8 nm Lasersystem präsentiert. Diese Wellenlänge wird durch eine hoch effiziente Frequenzverdopplung mittels eines KNbO3-Kristalls in einem temperaturstabilisierten Resonator erzeugt. Die Fundamentale wird von einer Laserdiode im ECDL-Aufbau bereitgestellt. Ein spezielles Locking-Verfahren erlaubt dabei einen weiten modensprungfreien Abstimmbereich um die Zielwellenlänge einfach zu erreichen.

Q 54.69 Thu 16:30 Poster.I+II

Optimized waveguide arrays for multiple walker continuous-time quantum walks with integrated photon-pair creation — •Fabian Katzschmann[1], Andreas Schreiber[1,3], Aurél Gábris[2], Craig Hamilton[2], Igor Jex[2], and Christine Silberhorn[1,3] — [1]Integrated Quantum Optics, Applied Physics, University of Paderborn, 33098 Paderborn, Germany — [2]Department of Physics, Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Brehová 7, Prague 11519, Czech Republic — [3]MPI for the Science of Light, IQO Group, Erlangen, Germany

Quantum walks enable the simulation of coherent procedures in nature, like the energy transport in photosynthesis, and they provide a platform for the realization of quantum algorithms and quantum computing schemes.

For this purpose we consider a multiple walker continuous-time quantum walk in periodically poled $LiNbO_3$ waveguide arrays. In this process a pump field is coupled into a waveguide of the array to drive a PDC process generating photon-pairs, which subsequently perform a continuous-time quantum walk in our waveguide array. The phase matching conditions can be engineered through the periodic poling of the $LiNbO_3$ crystal and tuned by the temperature of the device to switch from degenerate photon pairs to non-degenerate.

We report on the characterization and optimization of periodically poled $LiNbO_3$ waveguide arrays used to implement an all optical multiple walker continuous-time quantum walk and present our current experimental results.

Q 54.70 Thu 16:30 Poster.I+II

Manipulation of nuclear linewidths by coherent control and cooperative effects — •Sumanta Das, Adriana Pálffy, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Coherent manipulation of electronic states in atomic and molecular systems have led to several fascinating applications in varied branches of physics. Coherent control techniques for nuclear states can be of tremendous advantage, in particular for metrology and quantum computation given the reduced sensitivity of nuclei system to the environment due to screening by the atomic electrons. However extremely narrow linewidths make it difficult to probe nuclei directly by means of atomic spectroscopic techniques. Here we investigate possibilities to manipulate the linewidths of nuclei. One direction involves the hyperfine coupling between the nuclear and electronic degrees of freedom to effect the absorption-emission spectra for the nuclear transitions by coherent driving the corresponding electronic transitions [1]. Another direction is related to collective phenomena such as super- and subradiance [2] in a dense sample of nuclei to modify the linewidth of the nuclear transition.
[1] O. Kocharovskaya, R. Kolesov and Y. Rostovtsev, Phys. Rev. Lett. **82**, 3593 (1999).
[2] R. H. Dicke, Phys. Rev. B **89**, 472 (1953).

Q 54.71 Thu 16:30 Poster.I+II

Non-monotonic signatures of many-particle indistinguishability — •Malte C. Tichy[1,2], Young-Sik Ra[3], Hyang-Tag Lim[3], Osung Kwon[3], Florian Mintert[1,4], Yoon-Ho Kim[3], and Andreas Buchleitner[1] — [1]Physikalisches Institut der Albert-Ludwigs-Universität, D-79104 Freiburg — [2]Lundbeck Foundation Theoretical Center for Quantum System Research, Department of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus, Denmark — [3]Department of Physics, Pohang University of Science and Technology (POSTECH), Pohang, 790-784, Korea — [4]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität, D-79104 Freiburg

Many-particle interference effects, which constitute a building block for applications in quantum technologies, require the precise understanding and faithful manipulation of the mutual indistinguishability of the interfering particles. We study theoretically and experimentally the transition between many distinguishable and indistinguishable particles in scattering setups that exhibit many-particle interference. A theoretical exact few-particle study is confirmed by a four-photon Hong-Ou-Mandel type interference experiment, while a complementary semiclassical approach allows an approximate description of the behavior in the limit of many particles. Surprisingly, interference signals are non-monotonic in the inter-particle distinguishability in the vast majority of possible setups, which is explained by the competition of many-particle interference terms of various degrees.

Q 54.72 Thu 16:30 Poster.I+II

Validity of the quantum regression formula for resonance fluorescence in a photonic crystal — •Geesche Boedecker and Carsten Henkel — Universität Potsdam

In many theoretical treatments of open quantum systems, the Markov

assumption is made, i.e., quanta emitted by the system disappear rapidly in the bath. A photonic crystal provides a structured photon continuum where this is not justified, due to strong backscattering and the formation of band gaps. We evaluate within the second-order Born approximation the spectrum of resonance fluorescence. Predictions from the quantum regression theorem are compared with Kubo's formula (linear response theory) that does not make use of the Markov approximation.

Q 54.73 Thu 16:30 Poster.I+II

Spatial correlations of biphotons generated by parametric down conversion pumped with different transversal laser modes — •Dirk Puhlmann[1], Dietmar Korn[2], Axel Heuer[1], and Ralf Menzel[1] — [1]Universität Potsdam, Photonik, Karl-Liebknecht-Strasse 24/25, 14476 Potsdam-Golm — [2]Institut für Photonik und Quantenelektronik Karlsruher Institut für Technologie (KIT), Engesserstr. 5, D-76131 Karlsruhe

Biphotons can be used for a variety of applications in metrology, imaging or in quantum mechanics. In this Poster we present investigations of the transversal correlations of biphotons generated from type II parametric down conversion (PDC). To enhance the spatial correlations the diameter of the pump beam can be increased and small apertures in the experimental setup should be avoided [1]. To investigate the spatial correlations, two different types of laser sources, a pico second laser and a cw laser, and different transversal laser modes were applied to pump the PDC process. Higher TEM modes were generated by a spatial light modulator. The results of the measurements are reported.

[1] Ostermeyer M., Puhlmann D., Korn D., J. Opt. Soc. Am. B 26, 2347-2356 (2010)

Q 54.74 Thu 16:30 Poster.I+II

Spin-light entanglement in an optical cavity — •Hessam Habibian[1,2], Stefano Zippilli[1,2,3], and Giovanna Morigi[1,2] — [1]Universitat Autónoma de Barcelona, Spain — [2]Universität des Saarlandes, Germany — [3]Universitá degli Studi di Salerno, Italy

Photonic interfaces count on several successful implementations that make use of atomic ensembles [1]. The combination of atomic ensembles and optical resonators can provide further resources for quantum networks [2]. Here we study a system consisting of a periodic atomic array where the atoms couple with the mode of a high-finesse optical resonator and are driven by a laser. When the von-Laue condition is not satisfied, coherent scattering into the cavity mode is suppressed, and photons are pumped via inelastic scattering processes [3]. In this regime, the collective spin-wave modes and the cavity mode are effectively coupled in the low excitation limit. In this contribution we discuss how this coupling can be used in order to generate entanglement between the spin modes and the cavity mode.

[1] K. Hammerer, A.S. Sørensen, E.S. Polzik, Rev. Mod. Phys. 82, 041 (2010).

[2] I. Leroux, M.H. Schleier-Smith, V. Vuletic, Phys. Rev. Lett. 81, 021804 (2010); J.B. Brask, L. Jiang, A.V. Gorshkov, V. Vuletic, A.S. Sorensen, M.D. Lukin, Phys. Rev. A 81, 020303(R) (2010).

[3] H. Habibian, S. Zippilli, G. Morigi, Phys. Rev. A 84, 033829 (2011).

Q 54.75 Thu 16:30 Poster.I+II

Asymptotic Long-Time Properties of Decoherence and Quantum Darwinism — •Nenad Balaneskovic[1], Gernot Alber[1], and Jaroslav Novotny[1,2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Darmstadt, Germany — [2]Department of Physics, FNSPE, Czech Technical University in Prague, 115 19 Praha 1 - Stare Mesto, Czech Republic

Decoherence plays a crucial role in understanding the mechanism of emergence of the classical world from quantum mechanics and offers numerous interesting applications in the course of quantum information processing as well as other areas of quantum information science, ranging from error correction to storage of information. Different decoherence models provide several perspectives on the destruction of entanglement and shed new light on einselection of preferred pointer states of open systems due to their interaction with environments [1].

In this contribution we discuss characteristic properties of decoherence and quantum Darwinism based on qubit-models of open systems [2] which interact with their respective environment by iterated and randomly applied controlled-NOT-type operations. The asymptotic dynamics of the resulting quantum Markov chain is determined analytically [3]. From this asymptotic dynamics characteristic features of quantum Darwinism including its connection to decoherence-induced loss of entanglement of open quantum systems can be investigated.

[1] W. H. Zurek, Nature Physics 5, 181-188 (2009). [2] W. H. Zurek, Phys. Rev. A 71, 052105 (2005). [3] Novotny, J., Alber, G., Jex, I., Phys. Rev. Lett. 107, 090501 (2011).

Q 54.76 Thu 16:30 Poster.I+II

Dynamics of two spins coupled to spin chain environment — •Pierre Wendenbaum[1,2], Bruno Taketani[2], Endre Kajari[2], Giovanna Morigi[2], and Dragi Karevski[1] — [1]Institut Jean Lamour, dpt P2M, Nancy Université-CNRS, France — [2]Theoretische Physik, Universiät des Saarlandes, Saarbrücken, Germany

We study the dynamics of two spin-$\frac{1}{2}$ systems, which are coupled to a Ising spin chain but do not interact directly with one another. As shown in [1], the interaction between the distant spins, mediated by the chain, may give rise to quantum correlations in the systems of interest. We investigate these scenarios by considering the Ising chain, in the thermodynamic limit, as a commom environment to which both spins are coupled. We derive the Heisenberg-Langevin equations of motion for the spins degrees of freedom and discuss their predictions for several limiting cases.

[1] L.Campos Venuti, S.M Giampaolo, F. Illuminati and P. Zanardi, Phys. Rev. A 76, 052328 (2007).

Q 54.77 Thu 16:30 Poster.I+II

Quantum interference and entanglement of photons which do not overlap in time — Ralph Wiegner[1], Christoph Thiel[1], •Johannes Hölzl[1], Joachim von Zanthier[1], and Girish Agarwal[2] — [1]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Erlangen — [2]Department of Physics, Oklahoma State University, Stillwater, USA

Since the celebrated work of Hong-Ou-Mandel [1] the interference of two independent photons at a beam splitter has been studied in various experiments. To observe the interference the photons have to be identical in their spectral, spatial and polarization modes and measured within their coherence time. However, the temporal overlap of photons at a beam splitter is not a fundamental requirement for the observation of two-photon interferences. Here we discuss a different interferometer where the photons are scattered from two independent single photon sources and registered by two detectors in the far field [2]. It is shown that two-photon interferences occur in this setup even though the time delay between the photons may be larger than the transit time of the photons from the sources towards the detectors. This is equivalent to the statement that two-photon interferences can be observed even though the photons exist at different intervals of time. Since the two-photon signal violates Bell's inequalities this implies that entanglement among two photons may arise even though the photons do not overlap in time.

[1] C. K. Hong, Z. Y. Ou, L. Mandel, PRL 59, 2044 (1987). [2] R. Wiegner et al., Opt. Lett. 36, 1512 (2011).

Q 54.78 Thu 16:30 Poster.I+II

Enhancement of block-block entanglement due to localized impurities in the 1D Fermi-Hubbard model — Tobias Brünner[1,2], Erich Runge[2], •Vivian França[1], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs Universität, Freiburg, Germany — [2]Technische Universität Ilmenau, Fachgebiet Theoretische Physik I, Ilmenau, Germany

While the study of entanglement in many-body interacting systems is important for a deeper understanding of the fundamental properties of entanglement in solids, the impact of naturally occurring impurities on the entanglement is an essential issue for the development of quantum information processors. We investigate the block-block entanglement of the 1D Fermi-Hubbard model in the presence of localized impurities. The block-block entanglement is defined as the entanglement between two specific blocks of sites in the chain. We find that, despite the presence of inhomogeneities, on average the block-block entanglement still obeys the area law with a logarithmic correction predicted by Calabrese-Cardy for homogeneous systems. In addition, for specific block positions, we find that entanglement is considerably enhanced by the impurities. This is in strong contrast to what has been observed for single-site entanglement, where inhomogeneities always destroy entanglement, and, therefore, suggests that the block-block entanglement is more robust against inhomogeneities.

Q 54.79 Thu 16:30 Poster.I+II

Characterization of a SPDC biphoton source pumped with

high power cw-laser — •Henning Kurzke, Michael Seefeldt, Axel Heuer, and Ralf Menzel — Universität Potsdam, Institut für Physik und Astronomie, Photonik, Karl-Liebknecht-Str. 24-25, Haus 28, 14476 Potsdam

Today, entangled photons (biphotons) are mostly generated via Spontaneous Parametric Down-Conversion (SPDC). Biphoton rates up to the μW range were reported [1]. These biphotons are applied in a wide range of science and technology. The applications range from fundamental experiments proving basic concepts of quantum mechanics up to quantum spectroscopy and cryptography. Nevertheless, the weak intensity of such biphoton sources prevent further applications. Therefore we tried to increase the biphoton rate by using high cw-pump power up to 10 W. The 4 mm long NLO crystal consists of MgO doped Lithium Niobate (PPLN) with 5 periodically poled gratings. Each grating had a individual grating period. Results, characterizing the SPDC light, will reported.

[1] A. Jechow, A. Heuer, R. Menzel, Opt. Express, Vol. 16(17), 2008

Q 54.80 Thu 16:30 Poster.I+II

Entanglement Benchmarked Transport — •Dominik Hörndlein, Vivian França, and Andreas Buchleitner — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg im Breisgau, Germany

Quantum transport phenomena in interacting many particle systems can be studied to unprecedented detail with the use of experimentally engineered Hubbard-type hamiltonians. Further on entanglement measures have shown to be sensitive indicators of phase transitions. Such different phases can be associated with very different transport properties, as evident, e.g. for the Anderson and the Mott transition. Therefore, in a numerical study of the Fermi-Hubbard model, we investigate the direct relation between transport and the entanglement properties of the many particle system.

Q 54.81 Thu 16:30 Poster.I+II

The Hong-Ou-Mandel effect in the context of few-photon scattering — •Paolo Longo[1] and Kurt Busch[2] — [1]Institut für Theoretische Festkörperphysik, Karlsruher Institut für Technologie (KIT), 76128 Karlsruhe, Germany — [2]Humboldt-Universität zu Berlin, Institut für Physik, AG Theoretische Optik, Newtonstr. 15, 12489 Berlin, and Max-Born-Institut, Max–Born–Str. 2A, 12489 Berlin, Germany

The Hong-Ou-Mandel effect [1] states that two photons impinging on a perfect beamsplitter from different ports leave the device "together" in either one of the two output ports.

Interestingly, the problem of two photons propagating from different ends in a waveguide towards a scatterer, e.g. an artificial atom, is intimately related to the Hong-Ou-Mandel effect. We numerically investigate the scattering problem in a time-dependent wavefunction formalism [2]. Depending on the realization of the scatterer and its properties, we specifically calculate the joint probability of finding both photons on either side of the waveguide after scattering and how this can be used as a probe to identify effective photon-photon interactions mediated by the scatterer. Dissipation and dephasing is taken into account with the help of a quantum jump approach.

[1] C. K. Hong, Z. Y. Ou, and L. Mandel, Phys. Rev. Lett. **59**, 2044 (1987)

[2] P. Longo, P. Schmitteckert, and K. Busch, J. Opt. A: Pure Appl. Opt. **11**, 114009 (2009); Phys. Rev. Lett. **104**, 023602 (2010); Phys. Rev. A **83**, 063828 (2011)

Q 54.82 Thu 16:30 Poster.I+II

Photon transport in one–dimensional systems coupled to three–level quantum impurities — •Christoph Martens[1], Paolo Longo[1], and Kurt Busch[2,3] — [1]Institut für Theoretische Festkörperphysik and DFG–Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany — [2]Humboldt Universität zu Berlin, Institut für Physik, AG Theoretische Optik, Newtonstr. 15, 12489 Berlin, Germany — [3]Max-Born-Institut, Max-Born-Str. 2A, 12489 Berlin, Germany

Recent studies on the dynamics of photon transport in waveguiding systems in the presence of a quantum impurity show interesting transport properties [1-4], for instance, *strong effective photon–photon interactions* [1,4], *interaction–induced radiation trapping* [2] and *electromagnetically induced transparency* [3,4]. In this contribution, we present our recent results on such systems with the quantum impurity modeled as a single undriven or driven three–level system. By monitoring the time evolution of few–photon pulses we investigate the transmission characteristics in position and momentum space. Furthermore, we analyze the conditions under which *long time occupation* of the excited states of the three–level system or even the excitation of an *atom–photon bound state* can occur.

[1] J. T. Shen and S. Fan, Phys. Rev. Lett. **98,** 153003 (2007)

[2] P. Longo *et al.*, J. Opt. A: Pure Appl. Opt. **11,** 114009 (2009); Phys. Rev. Lett. **104,** 023602 (2010); Phys. Rev. A **83,** 063828 (2011)

[3] D. Witthaut *et al.*, New Journal of Physics **12,** 043052 (2010)

[4] D. Roy, Phys. Rev. Lett. **106,** 053601 (2011)

Q 54.83 Thu 16:30 Poster.I+II

Multiplexed image storage by EIT in a doped solid — •Nina Rentzsch, Georg Heinze, Daniel Schraft, and Thomas Halfmann — Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstraße 6, 64289 Darmstadt

The concept of stored light in atomic coherences, driven by electromagnetically induced transparency (EIT) is a promising technique for coherent storage and processing of optical data. Typically, EIT is implemented with single light pulses, which carry single-bit information. However, realistic applications require the storage of much larger amounts of data. Hence, the storage of 2D light patterns (images) by EIT attracted interest in recent years.

To further increase the storage capacity, we apply frequency- and angle-resolved multiplexing to simultaneously store more than one image by EIT in a rare-earth-ion doped solid. The inhomogeneous linewidth of the medium (Pr^{3+}:Y_2SiO_5) is in the range of GHz, while the optical transition linewidths are kHz. This enables addressing of different ensembles of Pr^{3+} ions by frequency multiplexing – hence multiplexed data storage by EIT. In addition, we demonstrate EIT multiplexing also by a variation of the angle between the driving laser pulses. Due to phase matching conditions, we can hereby separately address specific ensembles of ions. We experimentally demonstrate, that both multiplexing approaches permit independent, selective storage and readout of more than one image by EIT in a doped solid. Moreover, we demonstrate combination of frequency and angle-multiplexing to further increase the storage capacity in the EIT-driven solid medium.

Q 54.84 Thu 16:30 Poster.I+II

Light scattering by two atoms in a high finesse resonator — •Rick Dannert, Marc Bienert, and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, D-66041 Saarbrücken, Germany

We investigate the excitation spectra of two atoms which are tightly trapped in individual potentials inside a cavity. The cavity is driven by an external laser from the side. The excitation spectra are analyzed as a function of positions of the atoms in the single mode standing wave, and assuming they are two different species, as a function of their detuning. Interference effects are identified, which may lead to the appearence of collective dark resonances.

Q 54.85 Thu 16:30 Poster.I+II

A critical review of theories for quantum friction — •Gregor Pieplow, Harald R. Haakh, and Carsten Henkel — Universität Potsdam

Quantum friction is a force mediated by the electromagnetic field at $T = 0$, that opposes the relative motion of two objects. Typical systems consist of charges, neutral particles, or dielectric bodies moving with constant velocity above or through a medium. The mere existence and the precise expression for such friction forces have been the topic of discussions since the 1970s. We present a common theoretical framework based on linear response theory of the media in question. This requires the study of response functions, such as reflection coefficients and Green's tensors, and of the action of the Lorentz group on the multipole moments of the moving particle and on the fields above (or in) the medium. Our approach recovers formalisms used by other authors and provides a classification of previous treatments. In particular, we can narrow down the origin of differences between authors, to the description of electromagnetic field modes in the material. This also provides an interpretation of quantum friction in analogy to Cerenkov radiation and the dynamical Casimir effect.

Q 54.86 Thu 16:30 Poster.I+II

Full Counting Statistics in one-dimensional waveguiding systems — •Matthias Moeferdt[1], Peter Schmitteckert[2], and

Kurt Busch[3,4] — [1]Institut für Theoretische Festkörperphysik, Karlsruher Institut für Technologie (KIT), 76131 Karlsruhe, Germany — [2]Institut für Nanotechnologie, Karlsruher Institut für Technologie (KIT), 76344 Eggenstein-Leopoldshafen, Germany — [3]Humboldt-Universität zu Berlin, Institut für Physik, AG Theoretische Optik, Newtonstr. 15, 12489 Berlin — [4]Max-Born-Institut, Max-Born-Str. 2A, 12489 Berlin, Germany

We present an approach to calculate the Full Counting Statistics (FCS) for one–dimensional waveguiding systems. FCS is the full probability distribution of quantum transport. It is obtained by adding a counting field to the physical Hamiltonian which allows us to calculate a Moment Generating Function.

While this concept is widely used in the studies of fermionic systems, it is rarely applied to bosons, although it originated in the field of quantum optics. We implement a waveguide as a coupled resonator optical waveguide (CROW) with a side–coupled impurity. Transmittance and reflectance are calculated for a variety of different impurities and initial pulses. Furthermore, we study occupation numbers of specific sites and higher order correlations.

Q 54.87 Thu 16:30 Poster.I+II

Apparatus to study collective scattering in cavity quantum electrodynamics — •Markus P. Baden[1], Kyle J. Arnold[1,2], and Murray D. Barrett[1,2] — [1]Centre for Quantum Technologies, 117543 Singapore — [2]Department of Physics, National University of Singapore, 117543 Singapore

We report our progress in the study of collective scattering effects with ultracold atoms coupled to a high-finesse optical resonator. In order to observe collective scattering from the side into the resonator, we trap up to 10^4 rubidium atoms in a deep two-dimensional optical lattice with a lattice spacing of the wavelength of the scattered light. In this setup, all atoms are coupled identically to the resonator and light scattered into the resonator by individual atoms interferes constructively. In addition, high trapping frequencies with respect to the resonator linewidth allow us to study cavity cooling.

Q 54.88 Thu 16:30 Poster.I+II

Periodic orbit bunches in open billiard systems — •Thai Hien Tran, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

For chaotic systems Gutzwillers periodic orbit theory has proven successful in the domain between quantum and classical mechanics. Its pivotal formula, the Gutzwiller trace formula, expresses the quantum density of states in terms of all classical periodic orbits. With the symbolic dynamics, all periodic orbits can be found in principle. However, the number of orbits increases exponentially with their symbolic length. Here, we present a systematic way for open billiard systems to group orbits with near-degenerate actions in bunches. The Gutzwiller trace formula can be applied with only one representative per bunch instead of the full set of periodic orbits. The number of bunches increases algebraically, so that calculations can be extended to longer orbits.

Q 54.89 Thu 16:30 Poster.I+II

The Quantum Free-Electron Laser and the Jaynes-Cummings model — Rainer Endrich[1], •Enno Giese[1], Paul Preiss[1,2], Roland Sauerbrey[2], Wolfgang P. Schleich[1], and M. Suhail Zubairy[3] — [1]Institut für Quantenphysik, Univeristät Ulm, 89069 Ulm, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, 01314 Dresden, Germany — [3]Institute for Quantum Studies, Texas A&M University, College Station, TX 77843-4242, USA

Free-electron lasers (FELs) are a class of coherent light sources in focus of today's research. Many areas of science benefit from their unique properties, such as coherence or widely ranged tunability. The predictions from classical theory match the experimental results extremely well. So the usual classical approach is sufficient to understand FELs' principles of operation.

Recently the question has been raised whether it is possible to operate FELs in a regime, where quantum effects are of importance and cannot be neglected. The electron's recoil due to the scattering with a light wave has to be included in such a regime.

Unfortunately, a general quantum description of FELs leads to a model for which the time evolution cannot be solved analytically. Hence, we will face this problem by two approaches: We find a regime in which the FEL can be described as an effective two-level system ala Jaynes-Cummings model and the interaction takes place between two intervals in momentum space. The other approach is fourth-order perturbation theory in the photon number, where we see that mainly one-photon transitions occur in the quantum regime.

Q 54.90 Thu 16:30 Poster.I+II

Optimally focusing wave packets of a free particle — •Christoph Tempel, Karl Vogel, Lev Plimak, and Wolfgang P. Schleich — Institute of Quantum Physics, Ulm University

Appropriately prepared real-valued one-dimensional wave packets can focus [1,2] during a short period of time before they spread – even in the absence of any force. We consider a family of measures of width to describe this effect quantitatively and determine the *optimally focusing wave packet* for each member of this family numerically. Furthermore, we examine the properties and time evolution of these wave packets.

[1] I. Bialynicki-Birula et. al., *Phys. Rev. Lett.* **89** 060404, 2002.
[2] K. Vogel et. al., *Chem. Phys.* **375** 133, 2010.

Q 54.91 Thu 16:30 Poster.I+II

Ersatz für Ar^+ Laser basierend auf einem Yb-Faserverstärker — •Tobias Beck und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, Laser und Quantenoptik, Schlossgartenstraße 7, 64289 Darmstadt

Vorgestellt wird eine Laserquelle, die zur Kühlung relativistischer Ionen am experimentellen Speicherring der GSI eingesetzt werden soll. Die Ausgangsleistung des Faserverstärkers beträgt bis zu 12 W bei 1029 nm. Die so erzeugte Strahlung kann spektral bis zu 26 GHz in 5 ms modensprungfrei abgestimmt werden. Bei einer Scanrate von 1 kHz kann stabil bis zu 4 GHz weit gescannt werden. Die Linienbreite beträgt etwa 100 kHz. Anschließend wird durch Frequenzverdopplung in einem Überhöhungsresonator mit einem LBO-Kristall die Zielwellenlänge von 514 nm erreicht. Die Konversionseffizienz beträgt bei einer IR-Leistung von 2, 5 W über 30 %. Das System wird mit Hilfe eines Offset-Locks auf eine externe Referenz absolut in seiner Frequenz stabilisiert.

Q 54.92 Thu 16:30 Poster.I+II

Ein Brillouin-LIDAR zur Messung von Temperaturprofilen des Ozeans: Entwicklungsstand des gepulsten Faserverstärkers — •Robert Schulz, Andreas Rudolf und Thomas Walther — Institut für Angewandte Physik, AG Laser und Quantenoptik, Technische Universität Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt

Im Rahmen des Brillouin-LIDAR-Projekts wird aktuell ein portables Fernerkundungssystem zur berührungslosen Messung von Profilen der Wassertemperatur des Ozeans entwickelt. Als Indikator wird spontane Brillouin-Streuung genutzt, die zu einer temperaturabhängigen Frequenzverschiebung des rückgestreuten Lichts führt.

Für die aktive Erzeugung des Streulichts bauen wir ein robustes, rein festkörperbasiertes Lasersystem auf. Konkret handelt es sich um einen gepulsten, Ytterbium-dotierten Faserverstärker. Die Seed-Strahlung wird von einem ECDL bei einer Wellenlänge von 1086,6 nm bereitgestellt. Mittels elektro-optischer Modulatoren werden fourier-limitierte Pulse mit einer Länge von 10 ns erzeugt. Die Wiederholrate beträgt bis zu 5 kHz. Nach dreistufiger Verstärkung ins mJ-Regime erfolgt effiziente Frequenzverdopplung in den grünen Spektralbereich.

Limitiert ist die Pulsenergie durch das Auftreten von stimulierter Brillouin-Streuung (SBS) in den Verstärkerfasern. Geeignete Maßnahmen zur Erhöhung der SBS-Schwelle wurden getroffen. Im Vortrag wird die Charakterisierung der gesamten Strahlquelle vorgestellt.