Q 15: Poster 1: Quanteninformation, Quanteneffekte, Laserentwicklung, Laseranwendungen, Ultrakurze Pulse, Photonik

Time: Monday 16:30–19:30 Location: P1

Q 15.1 Mon 16:30 P1

Characterization of THz generation by ionizing two-color pulses — •Christian Koehler[1], Eduardo Cabrera[1], Ihar Babushkin[2], Joachim Herrmann[3], and Stefan Skupin[1,4] — [1]Max-Planck-Institute for the Physics of Complex Systems, Dresden, Germany — [2]Weierstraß-Institut für Angewandte Analysis und Stochastik, Berlin, Germany — [3]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Berlin, Germany — [4]Friedrich-Schiller-University, Institute of Condensed Matter Theory and Solid State Optics, Jena, Germany

We present a theoretical and numerical investigation of the mechanisms responsible for the THz generation by ionizing two-color laser pulses. In that setup, a laser pulse containing a fundamental and its second harmonic frequency is focused into a gas, where the generated electrons are accelerated by the laser field and thus build up a current. That current in turn partly radiates in the THz range. To elucidate the underlying processes, numerical simulations using Forward Maxwell as well as Finite Difference Time Domain schemes are used and supported by analytical calculations. We explain how angularly resolved THz spectra depend on laser pump frequencies, phase relation between fundamental and second harmonic, and the plasma geometry.

Q 15.2 Mon 16:30 P1

Hochfrequenz-Lasersysteme für die Quelle polarisierter Elektronen am Darmstädter S-DALINAC — •Martin Espig, Joachim Enders, Janina Lindemann, Markus Roth, Fabian Schneider, Markus Wagner, Antje Weber und Benjamin Zwicker — Institut für Kernphysik, Darmstadt, Deutschland

Am Darmstädter supraleitenden Elektronenlinearbeschleuniger S-DALINAC können nun durch Bestrahlung einer Strained-superlattice-GaAs-Photokathode mit zirkularpolarisiertem Laserlicht polarisierte Elektronen für Experimente erzeugt werden. Um den erzeugten Elektronenstrahl an die Hochfrequenzbeschleunigung anzupassen, soll der Laser der Photoelektronenquelle mit einer Repetitionsrate von 3 GHz bei Pulslängen im Bereich weniger ps gepulst werden. Wir berichten über Untersuchungen an Diodenlasersystemen, u.a. VCSEL-Systemen für die künftige Verwendung an der polarisierten Quelle.

Gefördert durch die DFG im Rahmen des SFB 634.

Q 15.3 Mon 16:30 P1

Characterization of the laser-induced enhanced absorbance due to etching with LESAL — •Martin Erhardt and Klaus Zimmer — Permoser Str. 15

High-quality etching of transparent materials for applications in micro- and nano-structuring as well as in precision engineering is still a challenge for current laser processing techniques. Laser Etching at a Surface-Adsorbed Layer (LESAL) is an advanced laser processing method applying a gaseous absorber at the backside of the processed sample. Material processing with the LESAL method is particularly characterized by a low etching rate (< 1 nm/pulse) and a very low surface roughness of down to 0.4 nm rms. In previous studies LESAL was investigated in terms of the influence of different laser parameters like fluence, wavelength, pulse duration, and pulse number on the etching rate and the achieved surface qualities. This work is addressed to study the laser-induced alterations of LESAL-processed fused silica surfaces by means by investigating the optical properties. For this purpose depth-resolved transmission measurements were done in the UV/Vis wavelength range of laser-etched areas. The results were correlated with the used laser parameters. The obtained results are of basic interest to reveal the etching mechanism, to clarify the role of the near-surface modification at LESAL and to provide input data for simulations of the LESAL process.

Q 15.4 Mon 16:30 P1

Laser generated x-ray beams from a table-top source — •Michael Schnell[1], Christian Peth[2], Björn Landgraf[1,3], Tobias Thiele[2], Thomas Königstein[2], Timur Kudyakov[2], Alexander Sävert[1], Maria Reuter[1], Bernhard Hidding[2], Monika Toncian[2], Toma Toncian[2], Matle Kaluza[1,3], Georg Pretzler[2], Oswald Willi[2], and Christian Spielmann[1,3] — [1]Institut für Optik und Quantenelektronik, Friedrich-Schiller Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Institut für Laser- und Plasmaphysik, Heinrich-Heine Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf, Germany — [3]Helmholtzinstitut Jena, Helmholtzweg 4, 07743 Jena, Germany

The use of ultra intense laser pulses to excite plasma waves with a relativistic phase velocity is a possible route to the development of compact particle accelerators. Quasimonoenergetic electron beams with energies from 0.1 to 1 GeV have been reliably generated. In addition these compact particle accelerators are sources of intense x-rays with peak brilliances comparable to "3rd generation" synchrotrons.

In this poster we present measured x-ray betatron spectra recorded in Düsseldorf and Jena with maximum emission at serveral keV. The spectra were taken in single photon counting mode and are in good agreement with theoretical simulations. Furthermore we used the "knife-edge" technique for an estimation of the betatron source size.

Q 15.5 Mon 16:30 P1

Multimodaler Aufbau zur Kombination von OCT und CARS mit einem Ultrakurzpuls-Titan:Saphir-Laser — •Claudia Hoffmann[1], Bernd Hofer[2,3], Sara Rey[3,4], Angelika Unterhuber[2,3], Wolfgang Drexler[2,3] und Uwe Morgner[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland — [2]Medizinische Universität Wien, Zentrum für medizinische Physik und Biomedizintechnik, AKH Wien, Österreich — [3]Biomedical Imaging Group, School of Optometry and Vision Sciences, Cardiff University, Cardiff, UK — [4]School of Biosciences, Cardiff University, UK

Optische Kohärenz-Tomographie (OCT) ist ein nichtinvasives interferometrisches Bildgebungsverfahren, mit dem in vivo hoch aufgelöste Tiefenschnitte von Mikrostrukturen erstellt werden können. Bei der kohärenten Anti-Stokes Raman Streuung (CARS) handelt es sich um eine nichtlineare spektroskopische Technik, die auf Grund eines Vierwellen-Mischprozesses molekulare Informationen zugänglich macht.

Um die Funktionalität optischer Kohärenz-Tomographie in Hinblick auf die Detektion des molekularen Fingerabdrucks einer Probe zu erweitern, wurde ein multimodaler Aufbau entwickelt. Bei diesem wird ein Ultrakurzpuls-Titan:Saphir-Laser verwendet, um in Kombination mit einem spektralen Pulsformer hoch aufgelöste OCT-Aufnahmen und die Erzeugung eines CARS-Signals zu ermöglichen.

Wir präsentieren Messungen verschiedener Proben mit diesem multimodalen Setup.

Q 15.6 Mon 16:30 P1

Kinetic description of laser-induced dielectric breakdown of insulators — •Nils Brouwer[1], Oliver Brenk[1], Helena Krutsch[2], Dieter H. H. Hoffmann[2], and Bärbel Rethfeld[1] — [1]Technische Universität Kaiserslautern, Deutschland — [2]Technische Universität Darmstadt, Deutschland

Ultrashort laser pulses of high intensity are of increasing importance in material processing and fundamental research. A proper understanding of the involved microscopic processes in condensed matter induced by laser irradiation is needed for enhanced controllability and to avoid damage to lenses. Transparent dielectrics may become opaque when being irradiated with intense laser beams, due to the creation of free electrons. We use the Boltzmann equation for a kinetic modelling of the microscopic collision processes determining the materials' response. In order to investigate the change of optical parameters, like the dielectric function and the reflectivity, we extended a former model [1] by a dynamic calculation of the internal laser field. The contributions of impact ionization and strong electric field ionization to the total free electron density are calculated for fused silica. We trace dielectric breakdown initiated by the increasing free electron density. In addition, we calculate the energy transfer to the lattice obtaining a damage threshold for lattice melting.

[1] A. Kaiser, B. Rethfeld, M. Vicanek and G. Simon, *Phys. Rev. B* **61**, 11437 (2000)

Q 15.7 Mon 16:30 P1

Preparation of free-standing single and few-layer Graphene for Ultrafast Electron Diffraction experiments — •Silvio Morgenstern, Christian Gerbig, Cristian Sarpe, Matthias Wollenhaupt, and Thomas Baumert — University of Kassel, Institute of Physics and Center of Interdisciplinary Nanostructure Science and Technology (CINSaT), D-34132 Kassel, Germany

Graphene is a recently discovered material with unique properties arising from its 2D crystal lattice [1]. The preparation and characterization of single- and few-layer graphene (SLG/FLG) with various methods on different substrates [1,2] as well as free-standing membrans [3] is a highly active field of research. The investigation of structural dynamics in graphene after ultrashort laser excitation should bring new insights in its mechanical and optical properties.
In this contribution we present first results on the preparation of free-standing SLG/FLG and the direct observation of optically induced lattice heating in these material using Ultrafast Electron Diffraction [4]. In addition, we show improvements and a new approach of our setup, leading to an enhanced spatial and temporal resolution.

[1] A. K. Geim & K. S. Novoselov, Nature Materials **6**, 183 (2007)
[2] S. Park & R. S. Rouff, Nature Nanotechnology **4**, 217 (2009)
[3] J. C. Meyer *et al.*, Appl. Phys. Lett. **92**, 123110 (2008)
[4] M. Chergui & A. H. Zewail, Chem. Phys. Chem. **10**, 28 (2009)

Q 15.8 Mon 16:30 P1

Spectroscopy and coherent control of colloidal semiconductor nanocrystals by phase-shaped femtosecond laserpulses — •Roland Wilcken, Martin Ruge, Matthias Wollenhaupt, and Thomas Baumert — University of Kassel, Institute for Physics and CINSaT, Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

The interaction of a quantum system with the electric field of an ultrashort, shaped laser pulse is one of the key aspect in coherent control. Semiconductor nanocrystals - or quantum dots (QDs) - are often considered as artificial atoms with discrete energy levels but obeying bulk semiconductor properties like confined lattice vibrations as well. Several control schemes are well established for atomic and molecular transitions [1]. The aim is the adaption of control strategies based on experiences gained on atoms and molecules. The synthesis of QDs consisting of different semiconductors, e.g. PbS or CdX (X = S, Se, Te), is done by chemical hot-injection methods with the ability to tailor the size, shape and structure. In this way the optical properties can be tuned over a wide range by changing the quantum confinement. The ligand-stabilized QDs, dispersed in hexane, are used for experiments at room temperature. In a pump-probe setup collinear double pulse sequences are applied, generated by a high resolution polarization pulse shaper. The transmitted light intensity as well as the photoluminescence are detected. First results on the excitation dynamics and the related vibrational features in the nanocrystals are shown. The photoluminescence signal for a variety of different pulse shapes is measured.
[1] M. Wollenhaupt et al., Annu. Rev. Phys. Chem., 56, 25-56 (2005)

Q 15.9 Mon 16:30 P1

High Power THz Generation in a Thin Lithium Niobate Slab using a Non-Collinear Cherenkov-Type Geometry — •Ulrich Arthur Fromme, Benjamin Ewers, Maik Scheller, Sangam Chatterjee, and Martin Koch — Department of Physics and Material Sciences Center, Philipps-Universität Marburg, Renthof 5, D 35032 Marburg

In the field of non-linear terahertz (THz) spectroscopy, there is a growing demand for THz emitters strong enough to induce significant non-linear effects. But since the optically gated THz antennas usually used to generate THz pulses already saturate at moderate laser intensities, they cannot convert extremely high pump energies efficiently. Another method to achieve strong THz emission is optical rectification, a $\chi^{(2)}$ process which generates strong THz radiation at high laser pump powers. In this work, lithium niobate ($LiNbO_3$) is used to convert intense pulses of infrared light into THz waves. A simple thin slab of bulk $LiNbO_3$ is illuminated with the light of a regenerative Ti:Sapphire amplifier system in a non-collinear Cherenkov-type geometry. To overcome the total reflection of the THz waves at the $LiNbO_3$-air interface, a silicon prism is contacted to the crystals surface. Using an additional diffractive grating to tilt the lasers wave front allows for phase matching between the optical and the THz pulses in the utilized geometry. Thus, conversion efficiencies up to 10^{-4} and peak electric fields strengths of $50\frac{kV}{cm}$ are obtained at pump pulse energies of $450\mu J$. We investigate the effect of changing the tilt angle of the wave on the generated THz amplitude and spectrum.

Q 15.10 Mon 16:30 P1

Erzeugung von Nanostrukturen durch 2-Photonen-Polymerisation mit einem sub-10-fs-MHz-NOPA — •Moritz Emons[1], Guido Palmer[1], Marcel Schultze[1], Kotaro Obata[2], Boris Chichkov[2] und Uwe Morgner[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [2]Laser Zentrum Hannover, Hollerithallee 8, 30419 Hannover

Wir präsentieren die ersten Ergebnisse von Nanostrukturierung mittels Zwei-Photonen-Polymerisation (2PP) durch die Verwendung eines nicht-kollinearen parametrischen Verstärkers (NOPA), welcher Pulse mit Dauern von weniger als 10 fs erzeugt. Die realisierbaren Nanostrukturen können weit unter den Beugungsbegrenzungen aus der klassischen Optik liegen, was im wesentlichen dadurch gegeben ist, dass die verwendete Strahlquelle mit ihren besonderen zeitlichen und energetischen Eigenschaften zur Verfügung steht. Das 2PP-Verfahren ermöglicht eine weitgehend flexible räumliche Gestaltung der Energiedeposition im Material, wodurch eine dreidimensionale Strukturierung im Volumen ermöglicht wird, die gezielt auf die Erfordernisse technischer und biomedizinischer Fragestellungen angepasst werden kann. Anhand dieses Posters sollen die erzielten Ergebnisse mit denen anderer Lasersysteme verglichen werden.

Q 15.11 Mon 16:30 P1

A high repetition rate High Harmonic Generation source for coherent XUV microscopy and electron spectroscopy — •Jürgen Schmidt[1], Christian Späth[1], Michael Hofstetter[2], Soo Hoon Chew[1], Alexander Guggenmos[2], Mihael Kranjec[1], and Ulf Kleineberg[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität München, 85748 Garching, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Laser driven high harmonic sources have established as versatile instruments for fundamental research in the EUV, XUV and SXR wavelength range. Due to their outstanding properties like coherence, the possibility of locking them to the driving laser pulse and of generating sub-fs pulses, they are inevitable for ultrafast pump-probe experiments and improved applications such as the lens-less coherent diffraction imaging XUV microscopy. In our setup we seeded, to our knowledge for the first time, a HHG gas source with a 10 kHz repetition rate Ti:Sa laser system with pulses of 5 fs duration and 0.2 mJ energy. Having high rep rates in the harmonics is very desirable regarding integration time e.g. for scanning microscopic schemes or often even indispensible for detector types which barely can handle multi-hit events, e.g. delay-line detectors. Experiments and applications relying on those detectors/schemes could only poorly performed so far with today's available HHG sources at repetition rates below 1 kHz. We characterized the harmonic output of our system by means of a XUV flat field spectrometer and tested its potential and limits with respect to harmonic selectivity, energy-range/cut-off tunability and conversion efficiency.

Q 15.12 Mon 16:30 P1

Interferometrische Vermessung von Laser-erzeugten Plasmen zur Elektronenbeschleunigung — •Maria Reuter, Alexander Sävert, Ajay Kawshik Arunachalam, Michael Schnell, Maria Nicolai, Christina Widmann, Björn Landgraf, Oliver Jäckel, Christian Spielmann, Gerhard G. Paulus und Malte C. Kaluza — Institut für Optik und Quantenelektronik, Jena

Laser-erzeugte Plasmen stellen aufgrund der mit ihrer Hilfe erzeugbaren immensen elektrischen Felder eine mögliche Alternative für konventionelle Beschleunigersysteme dar. Um die Parameter der erzeugten Teilchenstrahlung so genau wie möglich kontrollieren zu können, ist eine genaue Beobachtung der bei der Beschleunigung auftretenden Prozesse notwendig. Eine Möglichkeit stellt die Verwendung eines kurzen, synchronisierten optischen Probestrahls dar. Am JETI-Lasersystem des IOQ wurde ein solcher Probestrahl aufgebaut. Mithilfe von Interferometrie konnte u.a. die zeitliche Entwicklung der Plasmadichte bestimmt werden. Dabei wird über die Phase des Probestrahls die Brechungsindexverteilung entlang seines Weges durch das Plasma aufgenommen. Die Interferogramme können anschließend bezüglich ihrer Phaseninformation ausgewertet werden, um die Elektronendichteverteilung des Plasmas zu erhalten. Im Rahmen eines Experiments zur Elektronenbeschleunigung am JETI-Laser wurden relativistische Elektronenpulse erzeugt und in einem Spektrometer detektiert. Gleichzeitig wurde die Plasmadichte interferometrisch bestimmt. Über den Vergleich der Energiespektren mit den Interferogrammen können Informationen über den Beschleunigungsprozess gewonnen werden.

Q 15.13 Mon 16:30 P1

Einfluss der experimentellen Parameter auf die Stabili-

tät der Laser-Wakefield-Beschleunigung von Elektronen — •Maria Nicolai, Christina Widmann, Alexander Sävert, Michael Schnell, Maria Reuter, Oliver Jäckel, Christian Spielmann, Gerhard G. Paulus und Malte C. Kaluza — Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität, 07743 Jena

In den letzten Jahren wurden wichtige Fortschritte im Bereich der Laser-Wakefield-Beschleunigung erzielt. Durch die starken elektrischen Felder, die eine durch einen intensiven Laserpuls erzeugte Plasmawelle zur Verfügung stellen kann, können Elektronen auf relativ kurzen Distanzen auf relativistische Energien beschleunigt werden. So konnten Elektronenpulse innerhalb von wenigen Millimetern auf Energien im GeV-Bereich beschleunigt werden. Die Stabilität, gerade im Hinblick auf Energie, Bandbreite und Richtung, muss aber noch verbessert werden, um die laserbeschleunigten Elektronen für Anwendungen interessant zu machen. Da der Beschleunigungsprozess oft nichtlinear von den Anfangsbedingungen abhängt, haben wir mit den JETI-Laser-System am IOQ in Jena Untersuchungen durchgeführt, wie sich die Eigenschaften der Elektronenpulse in Abhängigkeit von den experimentellen Parametern ändern. Die Einflüsse der Elektronendichte, der Laserenergie, der Pulsdauer und der Pulsfrontverkippung auf die Elektronenenergie, die Richtungsstabilität und die Reproduzierbarkeit werden präsentiert.

Q 15.14 Mon 16:30 P1

Time Resolved Electron Diffraction of a Charge Density Wave — •Eichberger Maximilian[1], Schäfer Hanjo[1], Krumova Marina[1], Beyer Markus[1], Demsar Jure[1], Moriena Gustavo[2], Sciaini German[2], and Miller Dwayne[2] — [1]Universität Konstanz, Germany — [2]University of Toronto, Canada

We employed femtosecond electron diffraction (FED) and all-optical pump probe experiments on the 2D charge density wave (CDW) system 1T-TaS_2, studying the order parameter relaxation therein. The data suggest an optically induced suppression of the CDW within ~250 fs, followed by a purely electronic relaxation which is faster than ~100 fs. The order parameter of the CDW however, recovers on a timescale of several picoseconds which can be directly assessed by the FED data and also indirectly by the undertaken all-optical pump probe experiments.

Q 15.15 Mon 16:30 P1

Broadband polarization control and preservation for scanning near-field optical microscopy — •Christoph Zeh[1], Ron Spittel[2], Sonja Unger[2], Jörg Opitz[1], Bernd Köhler[1], Johannes Kirchhof[2], Hartmut Bartelt[2], and Lukas M. Eng[3] — [1]Fraunhofer Institut für Zerstörungsfreie Prüfverfahren IZFP, Institutsteil Dresden, Maria-Reiche-Str. 2, 01109, Dresden — [2]Institut für Photonische Technologien, Albert-Einstein-Str. 9, 07745 Jena, Deutschland — [3]Institut für Angewandte Photophysik, Technische Universität Dresden, 01062 Dresden, Deutschland

To achieve high throughput with apertureless fiber probes for scanning near-field optical microscopy (SNOM) radial polarized, non-fundamental fiber modes can be used. A radial polarized fiber mode can be converted efficiently into a propagating surface plasmon mode on the metal coating of the probe, leading to a highly focused spot at the tip apex. Since for our index-tailored fiber (ITF) the first higher order modes have well separated effective indices, mode coupling due to external stress (e.g. bending, twist) is suppressed. This allows for transmitting radial and other complex states of polarization through the fiber for SNOM and many other applications. Here, we show how we can control the state of polarization of non-fundamental modes in an ITF by selective mode excitation using mechanical long period gratings. A mayor advantage of the ITF is its broad wavelength range of 1000 nm to 1600 nm. We will show first results of translating this behavior from infrared to visible wavelength.

Q 15.16 Mon 16:30 P1

Finite element modeling of high-Q microcavities — •Dominik Floess[1], Tobias Grossmann[1,2], Mario Hauser[1], Saskia Becker[1], Torsten Beck[1], Timo Mappes[2], and Heinz Kalt[1] — [1]Institut für Angewandte Physik, Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany — [2]Institut für Mikrostrukturtechnik, Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany

We report on simulations of high-Q microcavities using the JCMresonance-module of the software JCMsuite, which is based on the time-harmonic finite element method. The simulations enable optimization of the device performance by studying geometry variations and allow for understanding of measured mode spectra by visualization of the spatial distribution of whispering gallery modes (WGMs) and their corresponding Q factors.

The eigenfrequencies are computed by solving Maxwell's equations on a finite number of elements using an adaptive refinement technique of the mesh. Due to the radial symmetry of the resonator, the eigenvalue problem is effectively two dimensional. In contrast to many numerical methods carried out in the time domain, this method efficiently allows for the exact analysis of Q factors, eigenfrequencies and field distributions.

First results show the analysis of the modestructure and Q factors of high-Q conical polymeric microcavities, a promising photonic structure for label-free molecule detection. The simulation results predict Q factors above 100 million in the visible sprectral region.

Q 15.17 Mon 16:30 P1

Accurate generation of polarization-shaped femtosecond laser pulses with zeptosecond precision — Jens Köhler, Tim Bayer, Cristian Sarpe, •Tom Bolze, Matthias Wollenhaupt, and Thomas Baumert — Universität Kassel, Institut für Physik und CINSaT, Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

Femtosecond laser pulse shaping is the key technology in quantum control. In particular, polarization-shaped pulses are of current interest, because they exploit the vectorial aspects of light-matter interaction, i.e. they are well-suited for 3D coherent control. We demonstrate realization of *accurately* generated polarization-shaped pulses delivering full control over the polarization state in the interaction region of a vacuum chamber employing photoelectron imaging spectroscopy [1]. Currently, we extend the application of our polarization-shaping capabilities to the generation of "designer" free-electron wave packets characterized by 3D tomographic reconstruction [2]. In addition, we have investigated the *precision* achievable in the generation of a pulse pair by making use of phase- and amplitude modulation of femtosecond laser pulses. To this end, we study the interference signal of two temporally delayed pulses as well as ultrafast switching of photoelectron spectra via Photon-Locking by temporal phase discontinuities [3]. Our results show, that the pulse-to-pulse delay and the relative temporal phase can be controlled with *zeptosecond precision*.

[1] M. Wollenhaupt et al., Applied Physics B, 95(2), 245–259, (2009)
[2] M. Wollenhaupt et al., Applied Physics B, 95(4), 647–651, (2009)
[3] M. Wollenhaupt et al., Phys. Rev. A, 73(6), 063409, (2006)

Q 15.18 Mon 16:30 P1

Adhering and coupling emitter-doped organic crystals to optical nanofibers — •David Papencordt, Ariane Stiebeiner, Nils Konken, Ruth Garcia-Fernandez, and Arno Rauschenbeutel — Technische Universität Wien - Atominstitut, Stadionallee 2, 1020 Wien, Austria

Optical nanofibers have proven to be an extremly sensitive tool for spectroscopy of particles near or on the fiber surface [1, 2]. Here, we present our results on adhering emitter-doped organic crystals to the nanofiber waist of a tapered optical fiber. The emitted fluorescence light is coupled into the guided mode of the fiber, allowing us to spectroscopically study crystal growth and guest-host interactions in the crystals. Additional information can be obtained by performing such measurements under cryogenic conditions. In particular, it should be possible to realize nanofiber-based spectrosopy at the single molecule level.

We gratefully acknowledge financial support by the Volkswagen Foundation (Lichtenberg Professorship), the ESF (European Young Investigator Award), and the EC (STREP "CHIMONO").

[1] F. Warken et al., Optics Express, Vol. 15, 19, 11952-11958 (2007)
[2] A. Stiebeiner et al., Optics Express, Vol. 17, 24, 21704-21711 (2009)

Q 15.19 Mon 16:30 P1

Phase behaviour of electro-optic liquid crystals-oil blends — •Kirstin Bornhorst, Martin Blasl, and Florenta Costache — Fraunhofer Institut for Photonic Microsystems, Maria-Reiche-Str. 2, 01109 Dresden, Germany

New blends with high electro-optic (EO) constants are created by mixing the thermotropic liquid crystals 4-cyano-4*-n-alkylbiphenyle (nCB) with immersion oils. EO effect in blends occurs in their nematic as well as their isotropic phases. We study the optical, thermal and morphological changes of the new blends in view of possible applications for dynamic EO waveguides and compare them to pure nCBs.

The phase transition behaviour of pure *n*-CBs (n = 4-7) and nCB-oil blends was analysed as a function of oil concentration by DSC and their corresponding changes in morphology with polarized optical microscopy. For all blends we observed that the nematic-isotrop transition temperature, T_{NI}, as well as the crystalline-nematic transition temperature, T_{CN}, shift largely toward lower temperatures with increasing oil concentration. For instance, T_{NI} in the 5CB-oil blend was found to be 17 °C lower than that of pure 5CB. Additionally, we observed significant texture changes in the blends.
The isotropic phase for 5CB- and 6CB-oil blends occurs at room temperature. Interestingly, the nematic phase of 5CB-oil blend exists over a much wider temperature range as compared to that of pure 5CB. We will show that this can considerably help the temperature stabilization requirements of the EO waveguide device.

Q 15.20 Mon 16:30 P1

Enhanced single photon emissions from nitrogen-vacancy centers in diamond — •Moritz Eyer[1], Helmut Fedder[1], Merle Becker[1], Robert Rossbach[2], Daniel Richter[2], Michael Jetter[2], Peter Michler[2], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart — [2]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart

Nitrogen-Vacancy (NV) centers in nano diamonds or bulk diamonds are a promising source for single photon emissions, which is stable even at room temperature. This opens the door to a great field of applications such as quantum computing, nano sensing and optical imaging below the diffraction limit. Our goal is to increase the photon yield of these emissions by using specially created structures of the diamond material and its surroundings. The resonant coupling to plasmonic structures and micro layer cavities are promising proposals in order to both increase the excitation rate and decrease the lifetime of the excited NV centers and to enhance the emitted field without losing their character as a quantum mechanic single photon process.

The necessary measurements are realized by using Fluorescence Lifetime Imaging Microscopy (FLIM) and antibunching measurements attached to a confocal microscope. Enhanced single phtoton emission from NV centers holds promise for applications in quantum cryptography, nondeterministic quantum computation based on indistinguishable photons, as well as entanglement generation of distant NV spin qubits.

Q 15.21 Mon 16:30 P1

Direct evaluation of the spatio-temporal coherence properties of free electron laser pulses at FLASH — •Sebastian Roling[1], Michael Wöstmann[1], Rolf Mitzner[2], Björn Siemer[1], Kai Tiedtke[3], and Helmut Zacharias[1] — [1]Westfälische Wilhelms-Universität Münster, Wilhelm Klemm Str. 10, 48149 Münster — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, A.-Einstein-Str. 15, 12489 Berlin — [3]Deutsches Elektronen-Synchrotron, DESY, Notkestraße 85, 22607 Hamburg

The spatio-temporal behaviour of the mutual coherence of soft x-ray free electron laser pulses at FLASH is measured at 32 nm, 25.8 nm, 24 nm, 19 nm, 13 nm, 8 nm and 8 nm as third harmonic of 24 nm wavelength setting. Two time-delayed partial beams are directly interfered on a CCD camera. Both pulses are derived from the same optical source by wavefront beam splitting at a sharp mirror edge in a beam splitter and delay unit (autocorrelator). The delay of one partial beam reveals a coherence time of about 6 fs at 24 nm and 2.9 fs at 8 nm. A decrease of coherence time with decreasing wavelength scaling with $\lambda^{2/3}$ is found, in agreement with FEL theory. The spatial coherence was measured by increasing the overlap angle between the two partial beams, which increases the distance Δx_d between the interfering points of the beam. With increasing Δx_d the visibility shows a Gaussian-like decrease, as expected. A transverse coherence length of 2.3 mm (rms) at the entrance of the autocorrelator is observed, where the beam size is 2.5 mm (rms).

Q 15.22 Mon 16:30 P1

Fabrication and characterization of low-loss waveguides in lithium niobate — •Benjamin Weigand[1], Andreas Lenhard[1], Mareike Stolze[2], Felix Rübel[2], Sandra Wolff[3], Johannes L'huillier[2], and Christoph Becher[1] — [1]Universität des Saarlandes, FR 7.2 Experimentalphysik, Campus E2.6, 66123 Saarbrücken — [2]Photonik-Zentrum Kaiserslautern e.V., Kohlenhofstr. 10, 67663 Kaiserslautern — [3]Nano+Bio Center, Erwin-Schrödinger-Str. Geb. 13, 67663 Kaiserslautern

Waveguides in $LiNbO_3$ find widespread applications in the fields of optical data transmission and quantum communication. In recent years ridge waveguide structures have attracted increasing interest as they offer significant advantages: the high refractive index contrast of ridge waveguides leads to both, strong mode confinement and mode overlap and thus to enhanced interaction of guided light fields. Furthermore, transmission losses are kept to a minimum. Our approach for fabrication of ridge waveguides is based on ultra-short laser pulse ablation, reactive ion etching or combinations of both methods. We compare waveguides produced with the different techniques and report on experimental investigations of transmission losses. We develop numerical models for designing waveguides with maximum mode overlap and minimum transmission losses and compare their predictions with the experimental results. Possible applications for the waveguide structures investigated here are experiments towards frequency conversion of single photons into the telecom band.

Q 15.23 Mon 16:30 P1

Cold atom cavity quantum electrodynamics experiments with ultra-high Q whispering-gallery-mode bottle microresonators — •Danny O'Shea, Christian Junge, Sebastian Nickel, Christian Hauswald, Konstantin Friebe, and Arno Rauschenbeutel — Technische Universität Wien - Atominstitut, Stadionallee 2, 1020 Wien, Austria

We describe an apparatus to deliver cold rubidium atoms to a nanofiber-coupled whispering-gallery-mode bottle microresonator using an atomic fountain. We actively stabilize the frequency of the ultra-high Q resonator mode (Q>100 million) to less than 10% of its linewidth. Moreover, the resonator-nanofiber separation is actively stabilized to a fraction of the resonant wavelength. This represents an important advancement for cavity quantum electrodynamic experiments with monolithic microresonators. On the cold atom side, we show that our atomic fountain creates a moving molasses for cold rubidium atoms with a temperature of 5–10 μK. The turning point of the parabolic trajectory of the atoms can be precisely controlled using an acousto-optic modulator driven by a digital synthesizer. Finally, our progress toward coupling atoms to a mode of the bottle resonator is presented.

Financial support by the DFG, the Volkswagen Foundation, and the ESF is gratefully acknowledged.

Q 15.24 Mon 16:30 P1

Full active stabilization of an evanescently coupled ultra-high Q whispering-gallery-mode microresonator-nanofiber system — •Christian Junge, Danny O'Shea, Sebastian Nickel, Konstantin Friebe, and Arno Rauschenbeutel — Technische Universität Wien - Atominstitut, Stadionallee 2, 1020 Wien, Austria

We have experimentally solved the issue of operating an ultra-high Q whispering-gallery-mode microresonator under highly stable and reproducible conditions concerning both its resonance frequency and the evanescent in- and out-coupling of light by means of an optical nanofiber. For this purpose, we have implemented a double Pound-Drever-Hall scheme that allows us to derive two unambiguous error signals. Using these signals, we actively stabilize the resonator frequency to an external reference while, simultaneously, the resonator-nanofiber gap and thus the evanescent in- and out-coupling of light is actively stabilized to a fixed value. We characterize the performance of our method and demonstrate that it also works under ultra-high vacuum conditions. These results are highly relevant for the use of whispering-gallery-mode bottle microresonators in cavity quantum electrodynamics experiments.

Financial support by the DFG, the Volkswagen Foundation, and the ESF is gratefully acknowledged.

Q 15.25 Mon 16:30 P1

Single optical microfibre interferometer — •Konstantin Karapetyan, Wolfgang Alt, Fabian Bruse, and Dieter Meschede — Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, 53115, Bonn, Germany

Over the last seven years, optical microfibres (OMF) with a diameter on the order of 100...1000 nm operating in the strong guiding regime have been investigated and applied in various fields of physics and photonics, including evanescent field spectroscopy, atom trapping and nonlinear optics. In this work we present a single OMF interferometer—a monolithic single-fibre device for dispersive sensing. It uses the down-taper of an OMF as a beam splitter and the up-taper as a beam recombiner, as in a Mach-Zehnder interferometer. The two arms are realized here by two different transverse modes guided in the waist of the OMF. Details of the design, manufacturing and testing of this device as well as our first results on dispersive sensing of liquids, molecules and atoms are presented.

Q 15.26 Mon 16:30 P1

Point-by-point Inscription of Bragg Gratings in Coated Standard Telecommunication Fibers Using Infrared Femtosecond Laser Pulses — Jörg Burgmeier[1], Günter Flachenecker[2], •Markus Thiel[1], and Wolfgang Schade[1,2] — [1]Institut für Energieforschung und Physikalische Technologien der TU Clausthal, EnergieCampus, Am Stollen 19 , 38640 Goslar — [2]Fraunhofer Heinrich Hertz Institute, Fibre Optical Sensor Systems, EnergieCampus, Am Stollen 19, 38640 Goslar

Writing of fibre Bragg gratings (FBG) in non-photosensitized single mode fibres by femtosecond laser pulses has attracted significant interest in the recent past. The core and the cladding of a standard telecommunication fibre consist of fused silica, which is transparent in the near infrared spectral region. The interaction between laser pulses and the material is taking place by multiphoton absorption. In the interaction area a change of the refractive index takes place. A grating is created by periodical modification of the refractive index in the fibre. Generally the coating of the fibre has to be removed for this fabrication technique. In our approach the use of a tightly focussing objective lens in combination with a transparent polymer coating allows the inscription of FBGs without removing the coating. Due to the presence of a protecting polymer, the robustness of the resulting device could be improved, which is of great importance for various applications. A prototype of a FBG sensor system for monitoring stress being effective on power cables will be presented, too.

Q 15.27 Mon 16:30 P1

Development of low-loss silicon rib waveguides with 4 microns height — •Harald Richter[1], René Eisermann[1], Mirko Fraschke[1], Lars Zimmermann[1,2], Katrin Schulz[1], Marco Lisker[1], Wolfgang Höppner[1], Jürgen Drews[1], Georg Winzer[2], and Bernd Tillack[1,2] — [1]IHP Frankfurt, Im Technologiepark 25, 15236 Frankfurt (Oder) — [2]Technische Universität Berlin, HFT 4, Einsteinufer 25

There has been an increased interest in silicon as a material for use in integrated optoelectronics. Silicon-on-insulator (SOI) waveguides are very promising for realization of photonic integrated circuits. The transport of light by a waveguide is one main reason for light intensity loss. The minimization of propagation loss is the main goal in waveguide fabrication process development. Silicon roughness, critical dimension stability and side wall slope angles determine the silicon waveguide quality essentially. The present work is focused on the development of a manufacturing process for silicon rib waveguides with 4 microns height. Different hard mask layer stacks for the deep silicon etch process were tested and optimized. Experiments have shown the mask opening step is significant for high-quality silicon waveguides. For the following silicon dry etch process an HBr/SF6 chemistry was chosen for fabrication of rib waveguide with sidewall slope angles between 89° and 90° and minimal sidewall roughness. Propagation loss values less than 0.3 dB/cm verify the technological manufacturing process quality.

Q 15.28 Mon 16:30 P1

Processing of Small Integrated Optical Spectrometer Devices with Femtosecond Laser Pulses — •Markus Thiel[1], Günter Flachenecker[2], Jörg Burgmeier[1], and Wolfgang Schade[1,2] — [1]Institut für Energieforschung und Physikalische Technologien der TU Clausthal, EnergieCampus, Am Stollen 19 , 38640 Goslar — [2]Fraunhofer Heinrich Hertz Institute, Fibre Optical Sensor Systems, EnergieCampus, Am Stollen 19, 38640 Goslar

Compact miniature spectrometers have, due to their advantage of size and cost-efficiency, increasing significants in networks based on fibre optics like telecommunication or dispersed optical sensor systems. Here we show first results of a spectrometer, which is processed directly into glass with femtosecond laser pulses. The design is a spatial heterodyne spectrometer, based on an array of Mach-Zehnder interferometers.[1] Fundamental parameters for processing waveguide structures are discussed and future applications for sensor networks are outlined. The design of the spectrometer is compared with conventional arrayed waveguide gratings.

References:

M. Florjanczyk, P. Cheben, S. Janz, A. Scott, B. Solheim, D. Xu, OPTICS EXPRESS, 15, 18176 (2007)

Q 15.29 Mon 16:30 P1

Tailoring the Single Photon Emission from Nitrogen-Vacancy Centres using Metallic Structures — •Merle Becker[1], Daniel Dregely[2], Helmut Fedder[1], Fedor Jelezko[1], Harald Giessen[2], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart, 70550 Stuttgart — [2]4. Physikalisches Institut, Universität Stuttgart, 70550 Stuttgart

The nitrogen-vacancy (NV) centre is a promising single photon source in the solid state. Control over NV centre emission properties as well as surface plasmon propagation is important for many quantum applications including quantum repeaters and single photon transistors. This implies efficient coupling of the NV centre to guided modes of the electrical field. One possible approach is to concentrate optical fields at the NV centre location. These strong fields can be obtained by metallic antenna structures. We investigate field enhancement and increased decay rate of the NV centre, both being indications of strong electrical fields, for different metallic antenna structures.

Q 15.30 Mon 16:30 P1

Phase-preserving amplitude regeneration of quadrature-amplitude-modulated signals — •Tobias Röthlingshöfer[1,2,3], Georgy Onishchukov[2,3], Bernhard Schmauss[3,4], and Gerd Leuchs[1,2,3] — [1]Institute of Optics, Information and Photonics, University Erlangen — [2]Max Planck Institute for the Science of Light — [3]Erlangen Graduate School in Advanced Optical Technologies (SAOT) — [4]Chair for Microwave Engineering, University Erlangen

Quadrature amplitude modulation (QAM), a combination of amplitude and phase-shift keying, has often been suggested to increase the spectral efficiency in optical communication systems.

Its main problem is a higher sensitivity to amplitude and phase noise. Amplitude noise can be converted into nonlinear phase noise in the transmission fiber due to the Gordon-Mollenauer effect which is usually the major limiting factor for phase-encoded transmission. As the regeneration of the signal phase is complex, phase-preserving amplitude regeneration can be used to reduce amplitude fluctuations, which are the origin of nonlinear phase noise. Such phase-preserving amplitude regeneration of signals with phase-shift keying has been demonstrated using a nonlinear amplifying loop mirror (NALM). Due to its periodic behavior of the power transfer characteristic, this regenerator type is a promising candidate for multilevel phase-preserving amplitude regeneration as well.

A comparison of different NALM modifications and their performance for phase-preserving amplitude regeneration of QAM formats is presented.

Q 15.31 Mon 16:30 P1

Digital plasmonics — Bergin Gjonaj[1], •Jochen Aulbach[1], Patrick M. Johnson[1], Allard P. Mosk[2], Laurens Kuipers[1], and Ad Lagendijk[1] — [1]FOM Institute for Atomic and Molecular Physics AMOLF, Science Park 113, 1098 XG Amsterdam, The Netherlands — [2]Complex Photonic Systems, MESA+ Institute, University of Twente, Post Office Box 217, NL-7500 AE Enschede, The Netherlands

We control the wavefronts of Surface Plasmon Polaritons (SPP) on nanohole arrays using a digital spatial light modulator. Optimizing the plasmonic phases via feedback we focus SPPs at a freely pre-chosen point on the surface of the array with high resolution. Digital addressing of SPPs without mechanical motion will enable novel interdisciplinary applications of advanced plasmonic devices in cell microscopy, optical data storage and sensing.

Q 15.32 Mon 16:30 P1

Taper design for high Q factors in hybrid photonic wire slot microcavities — •Clemens Schriever, Christian Bohley, and Jörg Schilling — Zentrum für Innovationskompetenz SiLi-nano, Martin-Luther-Universität Halle Wittenberg

An outstanding property of photonic crystals is their ability to confine light in a small volume. Microcavities with huge quality factors (Q-factors) can be created in such a way enabling a strong light matter interaction. These cavities were commonly produced by introducing defects into planar 2D photonic crystals by removing or shifting single pores. Recently, there is a growing interest in 1D photonic crystal microcavities realized by etching periodic pore chains into photonic wires. Here, possible designs of slotted photonic wire microcavities are numerically investigated, which allow intensive light matter interac-

tion. In contrast to solid microcavities, here the microcavity consists of a slot etched into the waveguide at the cavity position. The slot can be locally infiltrated and offers the possibility to be used as a device for sensing or nonlinear optical applications or as an optical nano probe. The Q factor of the device can be enhanced by a proper design of a tapering region between the mirrors and the cavity. These tapers can be designed to match the electric field distribution of the cavity mode to the field of the evanescent Bloch mode in the mirror, thus reducing scattering losses. We have adapted the design concept for solid cavities and modified it for the case of an infiltrated hybrid slot photonic waveguide. For a linear taper of pore position and radius, this leads to a Q factor of about 35000.

Q 15.33 Mon 16:30 P1

Towards magnetic levitation in opto-mechanics — •Jonas Schmöle — Quantum Optics, Quantum Nanophysics, Quantum Information; Faculty of Physics, University of Vienna, Austria

Diamagnetic suspension allows the creation of freely levitating objects, which might serve as high quality mechanical oscillators. We explore the feasibility of magnetic levitation in combination with cavity optomechanics and we discuss possible experimental challenges.

Q 15.34 Mon 16:30 P1

Lichtstreuung an einem atomaren Dipol in einem optomechanischen Resonator — •Daniel Breyer, Giovanna Morigi und Marc Bienert — Theoretische Quantenphysik, Universität des Saarlandes, 66041 Saarbrücken

Wir untersuchen die elementare Wechselwirkung in einem optomechanischen System, welches aus einem optischen Resonator besteht, der über den Strahlungsdruck mit einem mechanischen Oszillator wechselwirkt und dessen elektromagnetisches Feld an einen Dipolübergang eines Atoms koppelt. Die Schwerpunktsposition des Atoms ist fest vorgegeben, während die Bewegung des mechanischen Oszillators, des elektrischen Feldes und des elektronischen Freiheitsgrades quantenmechanisch behandelt wird. Die Form des Hamiltonoperators für das gekoppelte System wird mit Hilfe des Lagrange- und Hamiltonformalismus ausgehend von den klassischen Bewegungsleichungen abgeleitet.

Mit Hilfe der gefundenen Wechselwirkungsterme wird die Streuung einzelner Photonen eines Lasers untersucht, der das Atom treibt. Wir beschränken uns auf den Fall, in dem die Breite des Wellenpaketes des mechanischen Oszillators viel kleiner ist als die Dimension des optischen Resonators, und nur eine Mode des elektromagnetischen Feldes relevant ist. Wir konzentrieren uns auf Streuprozesse, die den Zustand des mechanischen Resonators verändern, und untersuchen verschiedene Wechselwirkungsmechanismen. Anhand der Ergebnisse geben wir einen Ausblick, wie die Manipulation oder die Charakterisierung des Bewegungszustands des mechanischen Oszillators erreicht werden kann.

Q 15.35 Mon 16:30 P1

A table-top demonstration of radiation pressure — •Dilek Demir, Garrett D. Cole, and Markus Aspelmeyer — Fakultät Physik, Universität Wien, Boltzmanngasse 5, A-1090 Wien, AUSTRIA

The observation of the momentum transfer of light, i.e. radiation pressure, goes back to the seminal experiments by Lebedew and by Nichols and Hull in the early 20th century. Up to now, all experimental demonstrations of this effect rely on a well-shielded experimental environment that is operated in vacuum. In this presentation we describe a simple table-top experiment that illustrates the momentum transfer between light and a suspended mechanical mirror under ambient conditions. Our work is enabled by the development of millimeter-sized cantilevers of high reflectivity ($> 99.98\%$), very low spring constant (< 0.001 N/m) and very low levels of optical absorption (< 100 ppm). Using these devices in an optical lever arrangement we unambiguously demonstrate radiation pressure effects while operating in air, at room temperature and with only modest(< 10 mW) laser power.

Q 15.36 Mon 16:30 P1

Light-induced entanglement between vibrational modes in nanostructures — •Michael Schmidt[1], Max Ludwig[1], and Florian Marquardt[1,2] — [1]Institut für Theoretische Physik, Universität Erlangen-Nürnberg, Staudtstrasse 7, D-91058 Erlangen, Germany — [2]Max Planck Institute for the Science of Light, Günter-Scharowsky-Strasse 1/Bau 24, D-91058 Erlangen, Germany

Novel photonic crystal structures with localized vibrational modes (optomechanical crystals) can be used to strongly couple a trapped light field to its mechanical degrees of freedom. Such structures are a versatile example of an optomechanical system. Recent experiments aim towards the quantum ground state of the vibrational modes. In our theoretical work, we show that entanglement between distinct vibrational modes can be achieved by intensity modulation of the driving laser.

Q 15.37 Mon 16:30 P1

Effects of ultrastrong light-mechanics coupling — •Andreas Kronwald[1], Max Ludwig[1], and Florian Marquardt[1,2] — [1]Institut für Theoretische Physik, Universität Erlangen-Nürnberg, Staudtstrasse 7, D-91058 Erlangen, Germany — [2]Max Planck Institute for the Science of Light, Günter-Scharowsky-Strasse 1/Bau 24, D-91058 Erlangen, Germany

A generic optomechanical system consists of a mechanical degree of freedom coupled to a laser-driven photonic mode. Recent experiments aim towards the quantum regime of mechanical motion. In addition, there is a trend towards strongly enhanced light-mechanics coupling. Here we show first theoretical predictions for the ultrastrong coupling regime, where single photons in the cavity are able to strongly affect the mechanical system.

Q 15.38 Mon 16:30 P1

Dipole force driven mechanical oscillation of a silica nanofiber — •Christian Wuttke, Christian Wagner, and Arno Rauschenbeutel — Technische Universität Wien - Atominstitut, Stadionallee 2, A-1020 Wien

We present experimental results on the excitation of mechanical modes in an optical nanofiber by light-induced dipole forces. The nanofiber has a diameter of 500 nm and is realized as the waist of a tapered optical fiber, fabricated from a standard optical glass fiber in a heat-and-pull process. By sending near infrared light through such a nanofiber, a strong evanescent field builds up in its vicinity.

When a second nanofiber is inserted into this evanescent field, the coupling results in an optical dipole force between the fibers. By periodically modulating the intensity of the light, we excite a mechanical oscillation of the fibers. This oscillation can then be detected by the change of the light field coupling caused by the oscillation. Using this method, we observe mechanical resonances at frequencies of several hundred kHz. We examine the dependence of the mechanical quality factors of the resonances on the pressure of the gas atmosphere surrounding the fibers and find values exceeding 10^5 for pressures up to the mbar range. This shows that silica nanofibers are interesting devices for quantum optomechanics applications.

Financial support by the ESF (EURYI Award) and the Volkswagen Foundation (Lichtenberg Professorship) is gratefully acknowledged.

Q 15.39 Mon 16:30 P1

One- and Two-Photon Scattering in a Disordered 1D Quantum System — •Jochen Zimmermann, Thomas Wellens, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79108 Freiburg

We present our findings on the scattering of one and two photons in a 1D system of two level atoms with binary disorder. For the single-photon case, the scattering matrix is mapped onto the corresponding transfer matrix [1]. Anderson localization and recurrent phases are observed numerically as well as analytically, using a selfconsistent equation for the phase relation.

On the other hand, localization of two photons is still an open problem. Our special interest lies in the role of inelastic scattering events, which occur each time both photons meet at the same atom. We present first perturbative results for the scattering amplitudes of two photons by two atoms and discuss their implication for the construction of a two photon transfer matrix approach.

[1] C. J. Lambert and M. F. Thorpe. Random T-matrix approach to one-dimensional localization. Phys. Rev. B, 27(2):715-726, Jan 1983

Q 15.40 Mon 16:30 P1

Faserverstärker basierter Ersatz für einen Ar^+-Laser — •Benjamin Rein, Tobias Beck und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, Laser und Quantenoptik, Schloßgartenstraße 7, D-64289 Darmstadt

Es wird ein schmalbandiges und weit abstimmbares Lasersystem vorgestellt, dass bei einer Wellenlänge von 514,5 nm emittiert und als Ersatz für Ar^+-Laser eingesetzt werden kann. Die spektralen Eigenschaften des Lasersystems werden durch die Seedquelle vorgegeben, welche als External Cavity Diode Laser realisiert wurde. Die eingesetzte, leistungsstarke Laserdiode emittiert bei 1029 nm und kann durch ein auf Polarisationsspektroskopie basierendes Locking-Verfahren auch ohne AR-Beschichtung modensprungfrei über einen Bereich von 26 GHz mit hohen Scanfrequenzen von bis zu 400 Hz abgestimmt werden. Die Seedstrahlung wird durch eine Yb-dotierte, polarisationserhaltende Faser auf bis zu 10 W verstärkt, um in einer anschließenden Intracavity-Frequenzverdopplung die Zielwellenlänge zu erreichen.

Q 15.41 Mon 16:30 P1

Diodengepumpte Femtosekunden-Laser geschriebene Kanal-Wellenleiterlaser in Yb:YAG-Kristallen — •Thomas Calmano, Jörg Siebenmorgen, Klaus Petermann und Günter Huber — Universität Hamburg, Institut für Laser-Physik, Hamburg

Durch die Fokussierung von fs-Laserpulsen in dielektrische Medien kann aufgrund nichtlinearer Absorptionsprozesse eine Volumenstrukturierung im μm Bereich erfolgen. In Yb:YAG Kristallen führt eine Zerstörung der kristallinen Struktur im Fokus des fs-Lasers aufgrund des elasto-optischen Effektes zu einer lokalen spannungsinduzierten Erhöhung des Brechungsindexes in der Umgebung des modifizierten Bereiches. Dieser Effekt wurde genutzt um Wellenleiter in Yb:YAG zu schreiben. Durch Verfahren des Kristalls unter dem Fokus der Probe wurden Spurpaare geschrieben, zwischen denen Wellenleitung möglich ist. Die Rückkopplung aufgrund der Fresnel Reflexion an den Endflächen der Wellenleiter von ca. 9% in den Wellenleiter ist ausreichend, um Laseroszillation zu ermöglichen. Dies entspricht einem Auskoppelgrad von 99%. Als Pumpquelle für die Laserexperimente diente eine Single-Mode Laserdiode mit einer Ausgangsleistung von 300 mW bei einer Wellenlänge von 940 nm. Mit dem Yb:YAG Wellenleiterlaser konnte eine maximale Ausgangsleistung von 43 mW und ein differentieller Wirkungsgrad von $\eta_s = 51\%$ bezüglich einfallender Pumpleistung erreicht werden. Die Schwellpumpleistung betrug 183 mW. Ein Vergleich mit Experimenten bei denen ein Ti:Saphir Laser als Pumpquelle verwendet wurde zeigt, dass der Wellenleiterlaser für beide Pumpquellen nahezu dasselbe Verhalten im Bereich nahe der Laserschwelle zeigt.

Q 15.42 Mon 16:30 P1

Er^{3+}-Doped YVO_4 Laser Emitting around 1.6 μm — Christian Brandt, •Francesca Moglia, Klaus Petermann, and Günter Huber — Institut of Laser-Physics, Luruper Chaussee 149, 22761 Hamburg, Germany

Resonantly inband pumped Er^{3+}-doped solid-state lasers offer the opportunity for efficient operation around 1.6 μm wavelength. These lasers in the eye-safe region are interesting for medical applications, telecommunication, and remote sensing. In particular for remote measurements of CO_2 using the DIAL (Differential Absorption Lidar) technique an efficient laser is needed at appropriate absorption bands of the CO_2 molecule at 1579 nm or 1603 nm.

Resonantly inband pumping an Er(1.1 at.%):YVO_4 crystal by a fiber laser at 1536 nm results in a maximum slope efficiency with respect to the absorbed pump power of 57.9%. For the maximum pump power of about 8 W a maximum laser output power of 2.3 W was achieved. Depending on the output coupler transmission the free running laser oscillated between 1603 and 1608 nm. By using a birefringent filter the laser wavelength could be tuned from 1578.8 to 1582.3 nm and from 1601.4 to 1607.8 nm, covering two suitable wavelengths for CO_2 DIAL application. Between these tuning bands the laser also oscillated at 1594 nm.

Q 15.43 Mon 16:30 P1

Ein universeller, VCSEL-geseedeter ns-Ti:Sa Laser mit (fourierlimitierten Pulsen und) großer spektraler Abdeckung — •Suleiman Amiri, Simon Metzendorf, Thorsten Führer, Alexander Bertz und Thomas Walther — Technische Universität Darmstadt, Institut für Angewandte Physik, Schlossgartenstr. 7 64289 Darmstadt

Ein Titan:Saphir-Laser wird durch einen frequenzverdoppelten Nd:YAG-Laser gepulst betrieben und emittiert im Wellenlängenbereich von 670 nm bis 1100 nm, wobei das Maximum bei 780 nm liegt. Um Pulse nahe am Fourierlimit zu erzeugen, wird der Ti:Saphir-Laser durch einen schmalbandigen Halbleiterlaser geseedet, wobei die Stabilisierung des Resonators auf die Seedwellenlänge über Polarisations-Spektroskopie nach Hänsch-Couillaud erfolgt. Der Resonator ist in einer Dreieckskonfiguration aufgebaut und ermöglicht eine kurze Buildup-Zeit von 21 ns bei einem FSR von 1GHz. Dies ermöglicht es durch SFG und DFG ein Spektrum von 190nm bis 6000nm zu erschließen. In einem weiteren Schritt soll das Injection-Seeding durch eine MEMS-VCSEL-Diode realisiert werden, welcher bei einer Zentrallwellenlänge von 850 nm über 20 nm modensprungfrei abstimmbar ist.

Q 15.44 Mon 16:30 P1

Effiziente Pr^{3+}:YLF-Laser im Dauerstrich-Betrieb bei den Wellenlängen 522,6 nm, 545,9 nm, 607,2 nm und 639,5 nm — •Teoman Gün, Philip Metz und Günter Huber — Universität Hamburg, Institut für Laser-Physik

Seit der Entwicklung von InGaN-Laserdioden (LD) im blauen Spektralbereich gehören Praseodym-dotierte $LiYF_4$ (YLF)-Kristalle zu den effizientesten Festkörperlasermaterialien im sichtbaren Spektralbereich. In diesem Beitrag werden die aktuellsten Ergebnisse zu LDn-gepumpten Pr^{3+}-Lasern vorgestellt. Dabei konnten, ausgehend von Pr^{3+}:YLF-Kristallen mit einer Dotierungskonzentration von 0,5 at.% und einer Länge von 2,9 mm, im sichtbaren Spektralbereich maximale Ausgangsleistungen von bis zu 938 mW bei einem differentiellen Wirkungsgrad von 63,6 % erreicht werden. Für die Laserexperimente im Dauerstrichbetrieb wurden einfach gefaltete Resonatoren aufgebaut und der Pr^{3+}:YLF-Laserkristall über zwei LDn mit je 1 W Ausgangsleistung beidseitig gepumpt. Zum Fokussieren des Pumpstrahls wurden zwei Linsen mit je 40 mm Brennweite genutzt um einen möglichst guten Überlapp zwischen Pump- und Lasermode zu realisieren. Bei einer absorbierten Pumpleistung von etwa 1,5 W konnten maximale Laserausgangsleistungen von 773 mW bei 522,6 nm, 384 mW bei 545,9 nm, 418 mW bei 607,2 nm und 938 mW bei 639,5 nm generiert werden. Die dabei erreichten maximalen differentiellen Wirkungsgrade für die entsprechenden Wellenlängen betrugen 61,5 %, 52,1 %, 32,0 % und 63,6 %. Die Beugungsmaßzahl des Laserübergangs bei 522,6 nm wurde zu $M_x^2 \approx M_y^2 \approx 1{,}1$ bestimmt.

Q 15.45 Mon 16:30 P1

mode interaction in ZnO random lasers — •Janos Sartor, Daniel Schneider, Felix Eilers, Dirk Silber, Claus Klingshirn, and Heinz Kalt — Institut für Angewandte Physik, Karlsruhe Institute of Technology (KIT) 76128 Karlsruhe (Germany)

Random lasing is a phenomenon found in strongly scattering materials that provide sufficient optical gain. Optically pumped ZnO powder with a mean grain size in the order of the wavelength is such a system and provides excellent conditions to examine random lasing activity. In this system optical modes with different degrees of localization can be observed. Our work concentrates on the characterization of single random lasing modes and their interactions. In samples of reduced size the strong fluctuations typical for random lasers can be suppressed and almost stable emission from single modes can be observed. However at higher excitation densities additional modes appear influencing the formerly stable modes. Once multiple modes begin to lase at the same time, fluctuations of spectral mode positions are observed. This behavior can be explained by carrier density fluctuations caused by spatially overlapping modes.

Q 15.46 Mon 16:30 P1

Aktive Regelung und Kontrolle der Linienbreite eines ECDLs — •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) ermöglichen große Durchstimmbereiche und weisen niedrige spektrale Linienbreiten auf. Für viele Bereiche, beispielsweise in der Sensorik oder der Präzisionsspektroskopie, sind ECDLs daher unverzichtbar. Es wird ein aktives Stabilisierungsverfahren präsentiert, das neben dem Erreichen großer modensprungfreier Durchstimmbereiche die Möglichkeit bietet, die Linienbreite des ECDLs zu minimieren und während des Abstimmens sowie im Betrieb bei einer fixen Wellenlänge konstant zu halten. Darüber hinaus lässt sich die Linienbreite innerhalb gewisser Schranken beliebig einstellen. Das Verfahren nutzt den Polarisationszustand des ECDLs als Fehlersignal für einen geschlossenen Regelkreis, der die Resonanz des Gesamtsystems aufrecht erhält.

Basierend auf der Technik der selbst-heterodynen Detektion werden Messungen präsentiert, die eine Aufschlüsselung der Linienbreite in verschiedene Rauschtypen ermöglichen. Der Einfluss des Stabilisierungsverfahrens auf den jeweiligen Typus wird diskutiert.

Q 15.47 Mon 16:30 P1

Effect of detuning in Fourier domain mode locked lasers on the performance of optical coherence tomography — •Lars Kirsten, Julia Walther, Peter Cimalla, Sven Meissner, Mirko

Mehner, and Edmund Koch — Dresden University of Technology, Faculty of Medicine Carl Gustav Carus, Clinical Sensoring and Monitoring, Fetscherstraße 74, 01307 Dresden, Germany

Optical coherence tomography (OCT) is an interferometric imaging technique, generally used in medical diagnostics, providing cross-sectional and volumetric images of tissue with a spatial resolution of a few micrometers [1]. Broadband wavelength sweeps are required for swept source Fourier domain OCT to detect the interference spectrum time encodedly. For achieving high repetition rates, Fourier domain mode locked (FDML) lasers [2] have been introduced. In contrast to conventional ring lasers, a long single mode fiber (km) is additionally inserted in the ring resonator yielding a relatively long round trip time (μs). Synchronously to the round trip, a Fabry-Perot filter is tuned periodically over the wavelength range of the amplifier in the ring laser. The presented FDML laser provides wavelength sweeps in the 1300 nm range with repetition rates of 50 kHz and 123 kHz. The laser performance is significantly affected by detuning the sweep frequency of the Fabry-Perot filter against the optical round trip frequency. The influence of detuning on OCT performance, especially on the SNR, is demonstrated.

[1] D. Huang et al. Science 254, 1178-1181 (1991)
[2] R. Huber et al. Optics Express 14, 3225-3237 (2006)

Q 15.48 Mon 16:30 P1

Induzierte spontane Lasertätigkeit in Quecksilber durch Zweiphotonenanregung
— •Daniel Kolbe, Andreas Koglbauer, Ruth Steinborn und Jochen Walz — Institut für Physik, Johannes Gutenberg-Universität Mainz und Helmholtz-Institut Mainz, D-55099 Mainz

Die geringe Anregungswahrscheinlichkeit bei einer Zweiphotonenresonanz stellt eine Herausforderung dar, diesen Prozess als Pumpmechanismus zum Laserbetrieb zu nutzen. Die nötigen Pumpintensitäten werden meist nur durch gepulste Quellen erreicht. Hier wird von spontaner Lasertätigkeit auf dem 7^1S–6^1S Übergang in Quecksilber mit kontinuierlichen Pumplasern berichtet. Durch die Wahl der Verstimmung zum intermediärem 6^3P Niveau kann die Zweiphotonenanregung stark erhöht werden und die Laserschwelle kann bereits bei wenigen 100 mW Pumpleistung überwunden werden. Durch Veränderung der Leistungen kann isotopenselektive Lasertätigkeit beobachtet werden.

Q 15.49 Mon 16:30 P1

Dauerstrich optisch parametrischer Oszillator zur Erzeugung von Terahertzstrahlung und Kombination mit einem Photomischer zur kohärenten Detektion*
— •Jens Kiessling, Rosita Sowade, Karsten Buse und Ingo Breunig — Physikalisches Institut, Universität Bonn, Wegelerstr. 8, 53115 Bonn

Wir stellen einen durchstimmbaren optisch parametrischen Oszillator vor, der auf periodisch gepoltem Lithiumniobat basiert und kontinuierliche Terahertzstrahlung um 1,4 THz mittels eines kaskadierten optisch parametrischen Prozesses erzeugt. Die Leistung der Terahertz-Strahlung liegt im Mikrowatt-Bereich. In Kombination mit einem Photomischer wird die Terahertzstrahlung kohärent nachgewiesen, was die simultane Bestimmung von Amplituden- und Phaseninformationen des Terahertzlichts ermöglicht.

* Wir danken der Deutschen Forschungsgemeinschaft (FOR 557) und der Deutschen Telekom AG für finanzielle Unterstützung.

Q 15.50 Mon 16:30 P1

Unequal spacing of attosecond pulse trains from relativistic surface high harmonic generation
— •Jana Bierbach[1], Christian Rödel[1,4], Michael Behmke[2], Daniel an der Brügge[3], Martin Heyer[1], Matthias Kübel[1], Monika Toncian[2], Dirk Hemmers[2], Oliver Jäckel[1,4], Toma Toncian[2], Oswald Willi[2], Alexander Pukhov[3], Georg Pretzler[2], and Gerhard Paulus[1,4] — [1]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena — [2]Institut für Laser- und Plasmaphysik, Heinrich-Heine Universität Düsseldorf — [3]Institut für Theoretische Physik, Heinrich-Heine Universität Düsseldorf — [4]Helmholtz-Institut Jena

The interaction of an intense ultrashort laser pulse with a solid density plasma leads to the emission of XUV attosecond pulses within each laser cycle. The process is very sensitive to the laser pulse contrast and the plasma scale length. We observe a strong influence of pre-plasma conditions on the spectral fine structure of high harmonic spectra. The modifications were realized by an adjustable contrast enhancement using different plasma mirror targets. While in the case of high contrast sharp harmonic lines are obtained, an intermediate contrast leads to a strongly modulated spectrum. These modulations can be explained by an unequal pulse spacing in the attosecond pulse train due to a positive linear chirp caused by the cycle averaged motion of the electron plasma surface. A simple analytical model can describe this temporal denting effect and is in good agreement with Particle-In-Cell simulations and the experiment.

Q 15.51 Mon 16:30 P1

Efficiency of surface high harmonic radiation generated with a table-top terawatt laser
— •Silvio Fuchs[1,3], Christian Rödel[1,3], Michael Behmke[2], Erich Eckner[1,3], Jana Bierbach[1,3], Wolfgang Ziegler[1,3], Oliver Jäckel[1,3], Georg Pretzler[2], and Gerhard Paulus[1,3] — [1]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena — [2]Institut für Laser- und Plasmaphysik, Heinrich-Heine Universität Düsseldorf — [3]Helmholtz-Institut Jena

High harmonic radiation generated on solid surfaces is a promising source of intense XUV radiation. When terawatt laser pulses are focused with high temporal contrast on a glass target to relativistic intensities of 10^{19} W/cm^2, the plasma-vacuum boundary and the electrons therein quiver due to the oscillating electric field of the driving laser pulse. The generated plasma oscillations cause two different generation mechanisms of surface high harmonics that contribute to the observed high harmonic spectra. We determined the efficiency of single high harmonic lines from laser-solid interaction as a function of the incident laser energy for the first time. The 17^{th} harmonic, assigned to the CWE mechanism, has a pulse energy of $\approx 1 - 10\ \mu J$. Relativistic surface harmonics (ROM) contain 100 nJ and 20 nJ for the 21^{st} and 25^{th} harmonic respectively. The conversion efficiency for CWE harmonics is 10^{-5}. The relativistic harmonics have a conversion efficiency of 10^{-7} (21^{st}) to 10^{-8}(25^{th}). A comparison with efficiencies that are obtained using Particle-In-Cell simulations shows good agreement for our experimental parameters.

Q 15.52 Mon 16:30 P1

Gekoppelte Ringresonatoren mit Tapered Amplifier und miniaturisiertem SHG Resonator zur effizienten Frequenzverdopplung auf 488 nm
— •Danilo Skoczowsky, Andreas Jechow, Axel Heuer und Ralf Menzel — Universität Potsdam, Institut für Physik und Astronomie, Photonik, Karl-Liebknecht-Straße 24-25, Haus 28, 14476 Potsdam

Die effiziente Erzeugung von sichtbarer Laserstrahlung ist für viele Anwendungen von hohem Interesse. Neben der direkten Erzeugung beispielsweise mit Laserdioden ist die Frequenzverdopplung von infraroter Laserstrahlung nach wie vor eine gängige Technik. Wird die Intensität der Grundwelle mit Hilfe eines Resonators überhöht, so kann der Verdopplungsprozess deutlich effizienter gestaltet werden. Diese Technik erfordert jedoch eine Stabilisierung der Frequenz des Pumplasers mit der Resonanzfrequenz des hochvergüteten Resonators oder umgekehrt. Vorgestellt wird ein neues, passives Kopplungskonzept basierend auf einem Tapered Amplifier in einer ringförmigen Resonatoranordnung, an den ein zweiter, miniaturisierter Ringresonator gekoppelt ist. Dieser ist hochvergütet ausgeführt und enthält einen periodisch gepolten, nichtlinearen Kristall zur Frequenzverdopplung. Beide Resonatoren sind ohne eine aktive Regelung rein optisch gekoppelt. Es konnten bisher über 300 mW blaues Licht bei 488 nm generiert werden. Das blaue Licht ist nahezu beugungsbegrenzt und hat eine Bandbreite von 50 MHz. Die Emission ist zeitlich stabil mit Fluktuationen $< 1\%$.

Q 15.53 Mon 16:30 P1

Thomson backscattering on laser-accelerated relativistic electron sheets
— •Stephan Kuschel[1,2], Christian Rödel[1,2], Athena Paz[1,2], Oliver Jäckel[1,2], Malte Kaluza[1,2], and Gerhard Paulus[1,2] — [1]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena — [2]Helmholtz-Institut Jena

High-intensity femtosecond laser pulses open the way to ultra-short particle sources with relativistic energies. When a short laser pulse interacts with a counter-propagating electron bunch, the Thomson backscattering frequency is Doppler upshifted by $4\gamma^2$ times the laser frequency. Since both the electron bunch and the optical pulse have a duration in the femtosecond domain, the scattered radiation is a promising ultra-short XUV source. An all-optical compact particle and photon source was set up for this purpose using a 30-fs 40-TW laser. An electron bunch with MeV electron temperature was created by focusing the TW pulses on a thin metal foil after enhancing the pulse contrast by means of a plasma mirror. A temporally delayed probe pulse was focused on the counter-propagating electron bunch. The

XUV emission recorded with an XUV spectrometer showed a clear dependence on the delay. The yield of the XUV radiation and its spectral shape are in agreement with theoretical predictions. The XUV signal which is attributed to Thomson backscattering gives rise to an electron temperature of about 1-3 MeV which is consistent with former experimental findings and theoretical predictions.

Q 15.54 Mon 16:30 P1

Continuous wave Lyman-α (121.56 nm) generation by four-wave mixing in mercury — •Matthias Sattler, Daniel Kolbe, Andreas Koglbauer, Thomas Diehl, Matthias Stappel, Anna Beczkowiak, and Jochen Walz — Institut für Physik, Johannes Gutenberg-Universität Mainz und Helmholtz Institut Mainz, D-55099 Mainz

For future precision experiments on antihydrogen, laser cooling of the magnetically trapped atoms down to milliKelvin range is essential. We present the generation of Lyman-α light on the cooling transition at 121.56 nm wavelength by sum frequency four-wave mixing (FWM) in mercury vapor using solid-state laser systems. The current status of projects for power enhancement and stability improvement is presented. This includes the design of powerful fundamental laser systems like a 30 W Yb:YAG fiber amplifier (1091 nm) and a Yb:Lu_2O_3 disk laser (1015 nm). Additionally FWM in a three color enhancement cavity and a hollow core fiber is investigated.

Q 15.55 Mon 16:30 P1

Frequency-Quadrupled 285nm Diode Laser System for Photoionization of Mg using LBO as a Second Harmonic Generation Crystal — •Stephan Duewel, Martin Enderlein, Thomas Huber, Johannes Stroehle, Christian Schneider, and Tobias Schaetz — MPI für Quantenoptik

Trapped Mg ions have shown to be a good candidate for quantum simulations[1,2]. Ionization using electron bombardment has turned out to be disadvantageous causing long time degradation of trapping conditions. In our current setup, Mg ions are produced out of a thermal atomic beam by a photoionization laser system generating several mW of 285nm single mode laser light via one SHG resonator from a dye laser at 570nm. However, dye lasers and their optical pumps are expensive and work intensive to maintain and operate. An alternative is frequencyquadrupling of a diode laser at 1140nm, previously realized using periodically poled LiNbO3 in the first SHG cavity[3]. We report on an all solid state frequency-quadrupling system pumped by a diode laser at 1140nm, using an LBO crystal for SHG in the first resonator. Despite its low non-linear coefficient of only 0.82pm/V, we are currently able to achieve 9.5mW at 570nm from a pump power of 70mW and optimize the system for a doubling efficiency of 20% of the first SHG at a pump power of 100mW. This should provide on the order of 0.5mW at 280nm, sufficient for efficient photoionization.

[1] A. Friedenauer et al., Nat. Phys. 4, 757-761 (2008)
[2] H. Schmitz et al., Phys. Rev. Lett. 103, 090504 (2009)
[3] D. Nigg, Master's thesis, Universität Innsbruck (2009)

Q 15.56 Mon 16:30 P1

Intracavity absorption spectroscopy with an Er^{3+}-doped fiber ring laser — •Peter Fjodorow, Luis Leal, Benjamin Löhden, Klaus Sengstock, and Valeri Baev — Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Laser intracavity absorption spectroscopy is a very effective way to enhance the sensitivity of absorption measurements. With this technique, a sample of narrow-line absorption is placed into the cavity of a broadband laser, e.g. a fiber laser. The laser light passes through the absorber many times, and the absorption signal appears in the output spectrum, as in a multipass cell. The highest sensitivity is achieved with a cw laser, and it is limited by nonlinear mode coupling. e.g. by the spatial inhomogeneity of the laser gain and by stimulated Brillouin scattering. We report here on an experimental setup for sensitive absorption measurements based on a broadband Er^{3+}-doped fiber unidirectional ring laser. In this laser the complete elimination of the spatial gain inhomogeneity, reduction of stimulated Brillouin scattering in the fiber and decrease of spectral noise has been demonstrated. The sensitivity achieved with this laser is approximately one order of magnitude higher compared to the linear laser configuration with similar parameters [1] and corresponds to the effective absorption path length of over 500 km. This system can be used for the detection of trace gases and for environmental or medical applications.

[1] B. Löhden, S. Kuznetsova, K. Sengstock, V. M. Baev, A. Goldman, S. Cheskis, and B. Pálsdóttir, Appl. Phys. B, DOI 10.1007/s00340-010-3995-9 (2010).

Q 15.57 Mon 16:30 P1

Aufbau eines Integrated-Cavity-Output-Spektrometers im mittleren Infrarot — •Lars Czerwinski, Kathrin Heinrich, Marcus Sowa und Peter Hering — Institut für Lasermedizin, Universitätsklinikum Düsseldorf, Universitätsstr. 1, 40225Düsseldorf

Die Integrated-Cavity-Output-Spektroskopie (ICOS) ist eine Weiterentwicklung der Absorptionspektroskpie, die mit Hilfe eines optischen Resonators die Wechselwirkungsstrecke zwischen Laserlicht und absorbierendem Medium verlängert, um die Nachweisgrenze zu verbessern. Das Spektrometer wurde neu aufgebaut und soll dem hochempfindlichen Nachweis von Stickstoffmonoxid (NO) dienen. NO besitzt eine bedeutende medizinische Relevanz bei der Regulation des Blutdrucks, bei der Kommunikation von Nervenzellen, bei der Zerstörung von Krankheitserregern und anderen physiologischen Prozessen. Das hier vorgestellte Spektrometer wird mittels eines Quantenkaskadenlasers (QCL) betrieben, der mit einem Peltier-Element gekühlt wird und bei einer Wellenlänge von 5,3 μm emittiert. Die Verwendung eines QCL ermöglicht die Realisierung eines kompakten Systems mit technisch minimalen Aufwand für die Spurengasanalytik. Das Spektrometer erreicht bei einer Allan-Varianz-Messung eine minimale rauschäquivalente Absorption von $8{,}4 \cdot 10^{-7}\,\mathrm{cm}^{-1}$ bei einer Integrationszeit von 270 Sekunden. Dies entspricht einer rauschäquivalenten Konzentration von 355,9 ppb ^{14}NO.

Im Rahmen eines Posters sollen der Aufbau des Spektrometers und erste Ergebnisse präsentiert werden.

Q 15.58 Mon 16:30 P1

Flow measurements by the phase-resolved Doppler OCT and the signal power decrease in Spectral Domain OCT — •Julia Walther and Edmund Koch — Clinical Sensoring and Monitoring, Faculty of Medicine Carl Gustav Carus, Dresden University of Technology, Fetscherstr. 74, 01307 Dresden, Germany

Optical Coherence Tomography (OCT) is a non-invasive, contactless imaging modality in medical diagnosis and biomedical research providing cross-sectional images of internal structures of highly scattering samples with micrometer resolution. Spectral Domain OCT (SD OCT), based on the spectrometer analysis of the interference signal, is gaining considerable interest due to its high sensitivity and high image acquisition speed. Nowadays, SD OCT structural imaging is extended with functional studies for the determination of physiology and functional impairment of diseases. The phase-resolved Doppler method is based on the linear relation of the phase difference of adjacent interference signals and the axial sample velocity and is often used to measure blood flow velocities in small vessels. Unfortunately, this technique can be inflamed due to high sample velocities during the integration time resulting in a signal power decrease of the backscattering signal. We propose to take advantage of the signal damping for the quantification of high flow velocities at which the standard Doppler OCT does not work any longer. Furthermore, a combination of the established Doppler OCT and the numerically simulated signal damping due to obliquely moved scatterers is presented for an in vitro 1% Intralipid flow phantom study.

Q 15.59 Mon 16:30 P1

High-resolution Optical Nanospectrometers for Medical Applications using Substrate Conformal Imprint Lithography as Novel 3D Fabrication Technique — •Alla Albrecht, Xiaolin Wang, Hanh H. Mai, Timo Schotzko, Imran Memon, Martin Bartels, and Hartmut Hillmer — Institute of Nanostructure Technologies and Analytics, University of Kassel, 34132 Kassel, Germany

Optical spectroscopy has become one of the most prevalent characterization methods used in a wide array of field applications such as medical health-care. The most important challenge facing the construction of spectrometers is their miniaturization and integration into mobile devices. This pocket-size spectrometry will enable a long-time self-monitoring of the user's state of health in a non-invasive way.

Due to the fact that the miniaturization of grating-based spectrometers has reached its limits, they need to be replaced by novel approaches, e.g. by Fabry-Pérot (FP) based spectrometers combined with Nanoimprint Technology. We have successfully implemented a new methodology of fabricating miniaturized spectrometers (Nanospectrometers) with 3D filter-arrays of different cavity heights with high vertical resolution by only one single process step. For a detection of a broad spectral range, multiple DBRs (Distributed Bragg Reflectors) with different physical heights are obligatory. The novel

Substrate Conformal Imprint Lithography (SCIL) affords to print on those cascade structured surfaces. Nanospectrometers, as fabricated at the INA, are low in cost, very robust and show a very high optical resolution ($\lambda/\Delta\lambda$) up to 500 and thus, having a great potential for the commercial market.

Q 15.60 Mon 16:30 P1

Novel Technology for Highly Sensitive Gas Sensors — •Sven Blom, Mahamoud Ahmad, Jyoti Shrestha, Nico Storch, Usman Masud, Sandra Schink, Basim Kudhair, and Hartmut Hillmer — Institute of Nanostructure Technologies and Analytics, University of Kassel, 34132 Kassel, Germany

Modern industrial and medical applications require precise sensing of substances, e.g. pollutants or biomarkers. Commercially available sensors are very cost intensive and due to their size hard to handle or to implement. Moreover, size-reduced sensors do not reach the required sensitivity. A novel technology sensor system, developed at the INA, has the potential to combine miniaturization, high sensitivity and a low cost production.

The concept of our optical system is the reaction of a semiconductor laser to slight variation of its resonator parameters. For a very high sensitivity a two mode laser-system is used, in which both modes are brought into an artificial intensity equilibrium. One of the two modes is tuned to a characteristic absorption line of the substance to be analyzed. Even an extremely small amount of molecules introduced into the resonator results in an intensity difference which is coevally correlated to the gas concentration.

Conventional gas sensors require a photomultiplier. In contrast, our system measures the mode competition by means of "relative intensity noise" (RIN). This electrical evaluation also enables the miniaturization of our system. Due to this and the possibility to tailor this sensor for individual substances, the application field becomes very broad.

Q 15.61 Mon 16:30 P1

Laser-induced front side etching of fused silica with KrF excimer laser using thin metal layers — •Pierre Lorenz and Klaus Zimmer — Leibniz-Institut für Oberflächenmodifizierung e. V., Permoserstraße 15, 04318 Leipzig, Germany

Laser-induced front side etching is a method for laser etching of transparent materials using thin absorber layers. This approach is a straight forward advancement of the backside etching techniques. Within this study the etching of fused silica with different thin metal layers as absorbers is presented using nanosecond KrF excimer laser radiation (λ = 248 nm, 25 ns pulses, 10 Hz). The laser fluence, the number of pulses, the absorber material, as well as the layer thickness were varied. As metallic absorber materials chrome, aluminium, silver, titanium, as well as molybdenum were used with different layer thicknesses from 2 nm to 250 nm. Furthermore, the laser fluence was altered from below the metal ablation threshold up to 10 J/cm^2 and the surface was processed with different pulse numbers up to 10 pulses. 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)). An etching depth up to 500 nm with well-defined etching regions can be achieved.

Q 15.62 Mon 16:30 P1

Carrier-envelope phase stabilized 9.3 fs, 0.54 mJ pulses at 1.8 μm — Ding Wang[1], •Canhua Xu[1], Liwei Song[1], Chuang Li[1], Chuanmei Zhang[1], Yansui Huang[1], Xiaowei Chen[1,2], Yuxin Leng[1], Ruxin Li[1], and Zhizhan Xu[1] — [1]State Key Laboratory of High Field Laser Physics, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Shanghai 201800, China — [2]Laboratoire d'Optique Appliquee, ENSTA ParisTech, Ecole Polytechnique, CNRS, 91761 Palaiseau Cedex, France

Generation of 0.54 mJ, 9.3 fs pulses at 1.8 μm with a controlled waveform comprised of $\tilde{1}$.5 optical cycles is demonstrated. The 1.27 mJ, 40 fs seed pulses from a passive carrier-envelope-phase (CEP) stabilized optical parametric amplifier are spectrally broadened in an argon-filled hollow-core fiber, subsequently compressed through linear propagation in a glass plate in the anomalous dispersion regime. The reservation of the pulse CEP stabilization is also demonstrated, with the drift error of the compressed pulses of 0.516rad (rms), comparable to the incident pulses.

Q 15.63 Mon 16:30 P1

New Beamline for applied High Harmonics Spectroscopy — •Jochen Vieker, Hatem Dachraoui, Martin Michelswirth, Tobias Milde, and Ulrich Heinzmann — Molecular and Surface Physics, University of Bielefeld

Spectroscopy of High Harmonic Generation (HHG) on laserfield-aligned molecules using femtosecond lightsources has become popular over the last years, due to its ability of probing molecular dynamics. A new beamline with a pulsed gas jet HHG-target, followed by a toroidal mirror based spectrometer was recently put into operation. The beam is generated by a 50Hz Ti:Sa lasersystem (804nm), producing 50fs, 15mJ pulses.

Q 15.64 Mon 16:30 P1

Untersuchungen zur spektralen Emissionscharakteristik von PLD deponierten laseraktiven Materialien — •Mathias Hoffmann[1], Stefan Schrameyer[2], Mark Gyamfi[1], Holger Blaschke[2], Detlev Ristau[2] und Uwe Morgner[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [2]Laser Zentrum Hannover, Hollerithallee 8, 30419 Hannover

Mit Hilfe der gepulsten Laserdeposition (engl.: Pulsed Laser Deposition - PLD) können eine Vielzahl von Materialien als Schichten bzw. Schichtstrukturen deponiert werden. Als laseraktives Material wurden die Materialien Nd:YAG und Nd:Glas verwendet und auf hochwertigen Quarzglassubstraten deponiert. In diesem Beitrag werden aktuelle Ergebnisse und der Projektstand der PLD vorgestellt. Darüber hinaus wurden als wesentlicher Bestandteil der Charakterisierung die spektralen Emissionseigenschaften der Proben untersucht. Dabei deuten die Resultate der Fluoreszenzmessungen auf eine nichtlineare Frequenzkonversion der generierten Emissionen im Schichtmaterial hin.

Q 15.65 Mon 16:30 P1

Ultrashort laser pulse characterization based on a pulse shaping device — •Stefanie Züllighoven, Jens Köhler, Tillmann Kalas, Cristian Sarpe, Matthias Wollenhaupt, and Thomas Baumert — University of Kassel, Institute of Physics and Center of Interdisciplinary Nanostructure Science and Technology (CINSaT), Heinrich-Plett-Str. 40, D- 34132 Kassel, Germany

Femtosecond (fs) laser pulse shaping is a key technology often used in the fields of fs spectroscopy and ultrafast laser control. In order to characterize ultrashort laser pulses typically autoccorrelation (AC), crosscorrelation (CC) and spectrogram based techniques are employed. A common feature of all these pulse measurement methods is the use of an interferometric setup. In this contribution we present our scheme to combine these two approaches. Our pulse shaper consists of a standard 4f-zero dispersion compressor setup and a double layer liquid crystal spatial light modulator allowing for independent spectral phase and amplitude modulation. This device provides the possibility to simultaneously generate complex-shaped laser pulses and to mimic the interferometer needed for their characterization [1].

We present results on measurements and simulations of collinear AC as well as CC traces and their spectrally resolved counterparts, i.e. FROG and X-FROG spectrograms. In addition, we utilize Fourier techniques to extract the non-collinear information of the collinear measurements [2].

[1] A. Galler and T. Feurer, Appl. Phys. B 90, 427 (2008)
[2] I. Amat-Roldan *et al.*, Optics Express 12, 1169 (2004)

Q 15.66 Mon 16:30 P1

New kind of single-shot pulse length measurement of intense few-cycle laser pulses — •T. Rathje[1], A. M. Sayler[1], W. Müller[1], C. Kürbis[1], K. Rühle[1], G. Stibenz[2], and G. 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

Intense few-cycle (4–8 fs) laser pulses at 790 nm are now being used in a wide variety of application, including the production of attosecond extrem-ultraviolet (XUV) pulses. Since these experiments are sensitive to the electric field of the laser light, the characterization of the waveform is critical for the understanding and control of these interactions. We present a new technique to determine the pulse length by using a stereographic laser-induced above-threshold ionization (ATI) measurement of Xe, i.e. the same technique that provides precise, real-time, every-single-shot carrier-envelope phase measurement of ultrashort laser pulses. By comparing the left and right electron time-of-flight signals in the stereographic ATI apparatus we can calculate the asymmetry of the lasers electric field in real-time for every individual laser shot. This asymmetry increases when the pulse length decreases and vice versa. The corresponding relationship allows us to determine the temporal waveform of every single pulse in a kHz pulse train within the Gaussian pulse approximation. For calibration we used a few-cycle spectral phase interferometer for direct electric-field reconstruction (SPIDER). Our measurements roughly agree with calculations done using quantitative rescattering theory (QRS).

Q 15.67 Mon 16:30 P1

Single-shot carrier-envelope phase tagged non-sequential double ionization of argon in intense 4-fs laser fields — •A. M. Sayler[1], T. Rathje[1], W. Müller[1], K. Rühle[1], G. G. Paulus[1], Nora G. Johnson[2,3], O. Herrwerth[2], A. Wirth[2], S. De[3], I. Ben-Itzhak[3], M. Lezius[2], B. Bergues[2], A. Senftleben[4], C. D. Schröter[4], R. Moshammer[4], J. Ullrich[4], K. J. Betsch[5], R. R. Jones[5], and M. Kling[2,3] — [1]Institut für Optik und Quantenelektronik and Helmholtz Institut Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching 85748, Germany — [3]Kansas State University, Manhattan, KS 66506, USA — [4]Max-Planck-Institut für Kernphysik, Heidelberg, 69117, Germany — [5]University of Virginia, Charlottesville, VA 22904, USA

Single-shot carrier envelope phase (CEP) tagging has been utilized in a cold-target recoil-ion momentum spectroscopy (COLTRIMS) measurement of ultra-short laser-induced non-sequential double ionization (NSDI) of argon. This novel technique facilitates an unprecedented level of stability, longevity, and precision in the determination of CEP dependence and, in general, shows great promise for utilization in a wide variety of CEP sensitive measurements. Here we find that the yield of Ar^{2+} in 4 fs laser fields at 750 nm and an intensity of 1.6×10^{14} W/cm^2 shows a strong CEP dependence which compares with recent theoretical predictions employing quantitative rescattering (QRS) theory. Additionally, the Ar^{2+} momentum, along the laser polarization axis, is strongly influenced by the CEP.

Q 15.68 Mon 16:30 P1

Precision measurement of carrier-envelope phase dependent ATI spectra for the noble gases using phase-tagging technique — •Dominik Hoff, Stefan Fasold, Tim Rathje, Walter Müller, Klaus Rühle, A. M. Sayler, and G. G. Paulus — Institut für Optik und Quantenelektronik and Helmholtz Institut Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Presented are the carrier-envelope phase (CEP) and energy dependent ATI spectra for Xenon, Argon, and Neon. This data was obtained using a phase tagging technique which is based on a novel, robust, real-time, every-single-shot technique for determining the carrier-envelope phase via a stereographic ATI setup. The CEP is calculated and output within $\sim$20 μs of the laser interaction and this information is then used to tag ATI data of several noble gases to investigate their dependence on the relative CEP. Additionally the relative phase was kept constant for all targets, thus the relationship between the ATI phase dependencies is revealed. This phase measurement also enables the tagging of any other event-mode experiment run in parallel with the phase determination to get a relative dependence of these experiments from the corresponding CEP of the pulse.

Q 15.69 Mon 16:30 P1

Pulsformer für Pulsspektren mit 1,5 Oktaven von VIS bis NIR — •Anne Harth[1,2], Marcel Schultze[1,2], Stefan Rausch[1,2] und Uwe Morgner[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany — [2]QUEST: Centre for Quantum Engineering and Space-Time Research, Hannover, Germany

Die zeitliche Pulsformung im fs-Bereich erfordert die Manipulation der spektralen Phase eines Pulsspektrums und somit einen Fourierwechsel vom Zeit- in den Frequenzraum. Dies wird üblicherweise durch einen 4f-Aufbau realisiert, in dessen Fokus ein LC-Display steht. Entsprechende Pulsformer werden bereits in vielen Gebieten verwendet, wie der kohärenten Kontrolle chemischer Prozesse (coherent control), der Erzeugung fourierlimitierter Pulse oder auch der Pulscharakterisierung (MIIPS).

Wir präsentieren einen Pulsformer für ein 1,5 Oktaven breites Spektrum (450 nm - 1,1 μm) basierend auf einem breitbandigen LC-Display und zwei hochbrechende Prismen zur Frequenzaufspaltung.

Q 15.70 Mon 16:30 P1

Frequency comb stabilization with zero phase slip frequency for high repetition rate carrier envelope sensitive experiments — •Matthias Hensen, Christian Strüber, and Walter Pfeiffer — Fakultät für Physik, Universität Bielefeld, Universitätsstr. 25, 33615 Bielefeld, Germany

In the regime of few-cycle laser pulses light-matter interaction becomes sensitive to the absolute phase of the electric field. The stabilization and control of this carrier envelope phase (CEP) made it for example possible to extend the time-resolution in laser spectroscopy to the attosecond regime. Most present experiments rely on amplified pulses and thus it suffices to stabilize the frequency comb modulo a constant phase slip frequency, commonly chosen as one quarter of the oscillator repetition rate. However, this limits the applicability of CEP stabilized lasers in experiments using directly the high repetition rate oscillator pulses. To overcome this limitation we have built a f-2f interferometer in which the fundamental-arm is shifted in frequency by an acousto-optic modulator. Using a commercial phase locking control electronics this allows stabilizing the CEP at zero phase slip frequency. Long term CEP stabilization of <7 fs laser pulses with a rms phase noise of 130 mrad is achieved for closed-loop operation.

Q 15.71 Mon 16:30 P1

Monochromatizing a Femtosecond High-Order Harmonic VUV Photon Source with Reflective Off-Axis Zone Plates — •Mateusz Ibek[1], Torsten Leitner[1], Alexander Firsov[2], Alexei Erko[2], and Philippe Wernet[1] — [1]Institute for Methods and Instrumentation for Synchrotron Radiation Research, Helmholtz-Zentrum Berlin — [2]Institute for Nanometer Optics and Technology, Helmholtz-Zentrum Berlin

Conventional grazing incidence grating monochromators pose major disadvantages to monochromatizing femtosecond pulses in the vacuum ultraviolet (VUV) photon energy range. Their transmission efficiency is very low and they increase the pulse duration considerably. Additionally, the efficiency further decreases with every optical element added to a given setup. Using the laser-based high-harmonic generation (HHG) setup at HZB/BESSYII we have characterized the properties of off-axis reflection zone plates (RZP) for simultaneously monochromatizing and focusing a femtosecond VUV photon source. Our setup generates 50 fs pulses and here we used photon energies between 15 and 30 eV. Three RZPs, each designed for a specific harmonic were etched on a gold coated plane substrate. Here we present the proof of principle of such a system, its spectral resolution and focal characteristics among others. The results show clearly that the RZPs besides being cheaper and easier to manufacture have a higher efficiency and good energy resolution. Furthermore, we demonstrate how with these RZPs one can easily trade in dispersion (spectral resolution) versus pulse broadening online to adapt these parameters.

Q 15.72 Mon 16:30 P1

Optical vortex supercontinuum and topological charge transfer — •Peter Hansinger[1,2], Alexander Dreischuh[1,3], Georgi Maleshkov[3], and Gerhard Georg Paulus[1,2] — [1]Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Helmholtz-Institut Jena, Helmholtzweg 4, 07743 Jena, Germany — [3]Department of Quantum Electronics, Sofia University, 5 James Bourchier Blvd., Sofia-1164, Bulgaria

Optical vortices, also known as screw dislocations, are singular points within the phase of a light beam. The phase varies by a multiple of 2π over the angular coordinate ϕ, and is therefore undefined in the center and the intensity becomes zero at this point. Such donut beams have become useful e.g. in optical micromanipulation as so-called optical tweezers. Particularly interesting is the generation of optical vortices in broadband coherent continua, such as ultrashort pulses.

To date, most experiments aimed to generate a broad spectral distribution first (e.g. in photonic crystal fibers) and subsequently impose the phase singularity onto the generated white-light beam. Only recently, supercontinuum has been generated directly with an optical vortex beam in calcium fluoride glass.

We have conducted measurements with an optical vortex beam in Argon gas, which serves as a nonlinear Kerr medium. During propagation, inhomogeneities in the beam profile initiate filamentation and supercontinuum generation. Despite strong background beam modulation, the vortex phase is preserved in a broad spectral range.

Q 15.73 Mon 16:30 P1

Low-threshold conical microcavity dye lasers — •Saskia Becker[1], Tobias Grossmann[1,2], Mario Hauser[1], Dominik Floess[1], Torsten Beck[1], Timo Mappes[2], and Heinz Kalt[1] — [1]Institut für Angewandte Physik, Karlsruhe Institute of Technology

(KIT),76128 Karlsruhe, Germany — [2]Institut für Mikrostrukturtechnik, Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany

We report on utilizing high-Q polymeric conical microresonators for the development of low-threshold lasers operating in the visible spectral region. This type of laser is promising for the development of highly integrated photonic circuits or lab-on-chip systems.

The microcavities are made of low loss, thermoplastic polymer poly(methyl methacrylate) (PMMA), directly processed on a silicon substrate and possess cavity Q factors above two million in the 1300 nm wavelength region. By integrating a large oscillator strength gain material, e.g. the dye molecule rhodamine 6G, into the polymeric host matrix, laser thresholds as low as 3 nJ per pulse are observed under quasi-stationary pumping conditions. By varying the dye concentration, laser emission wavelengths can be spectrally tuned. This effect can be explained using a standard model of a dye lasing in a Fabry-Perot cavity.

Q 15.74 Mon 16:30 P1

Toroid microcavity based frequency combs for optical telecommunication — •Marcel Dornbusch[1], Florian Bach[2], Mario Hauser[1], Jörg Pfeifle[2], Torsten Beck[1], Tobias Grossmann[1], Christian Koos[2], and Heinz Kalt[1] — [1]Institute of Applied Physics, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]Institute of Photonics and Quantum Electronics, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Optical frequency comb generation has been demonstrated using various high-Q whispering gallery mode microcavities made of different nonlinear media. Such combs can be used as integrated light sources for ultra-high speed optical data transmission based on modulation of each individual frequency line. This application requires a comb with a multitude of equally strong, equidistant lines spaced apart 100 GHz or less.

A simulation to investigate the required resonator properties is presented. It is based on the nonlinear Schrödinger equation. The model parameters such as the effective mode area and the nonlinearity parameter are computed numerically with the help of a finite element mode solver.

Additionally, we investigate the fabrication process of glass toroid microcavities on a silicon chip setting value on the specifications of size, quality factor and mode area obtained in the simulation.

Q 15.75 Mon 16:30 P1

Photonic Phase Gate via an Exchange of Fermionic Spin Waves in a Spin Chain — •Johannes Otterbach[1], Alexey V. Gorskov[2], Eugene Demler[3], Michael Flesichhauer[1], and Mikhail D. Lukin[3] — [1]Fachbereich Physik & Forschungszentrum OPTIMAS, TU Kaiserslautern — [2]Physics Department, California Institute of Technology, Pasadena, CA, USA — [3]Physics Department, Harvard University, Cambridge, MA, USA

We propose a new protocol for implementing the two-qubit photonic phase gate. In our approach [1], the phase is acquired by mapping two single photons into atomic excitations with fermionic character and exchanging their positions. This scheme provides a robust phase shift in thus the relative acquired phase is exactly π, independent of any fine tuning of parameters. The fermionic excitations are realized as spin waves in a spin chain, while photon storage techniques provide the interface between the photons and the spin waves. Experimental systems suitable for implementing the gate and possible imperfections are discussed.

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Q 15.76 Mon 16:30 P1

Radiative corrections in strong field QED in intense laser fields — •Sebastian Meuren and Antonino Di Piazza — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg

We investigate radiative corrections to electron states in a background plane-wave laser field [1]. At the tree level, electrons are described by Volkov states, which are solutions of the Dirac equation in a plane-wave field. However, the interaction of the electron with its own electromagnetic field leads to “radiative” modifications of the states [2,3]. We investigate these quantum corrections by solving the Dirac-Schwinger equation perturbatively in a constant-crossed field and in a linearly-polarized plane wave field. To this end we present a new derivation of the mass operator entering the Dirac-Schwinger equation for a constant-crossed field. Finally, experimental possibilities of measuring these radiative corrections are discussed.

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Q 15.77 Mon 16:30 P1

Robustness of trapping states in microwave cavity QED. — •Christian Arenz and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes

Trapping states are fixed points of the dynamics of the mode of a high-Q resonator coupled with a beam of atoms [2, 3]. Such states are found in the strong coupling regime and for well defined interaction times. In [1] it was shown that, when the atoms are prepared in a coherent superposition of ground and excited state, the corresponding trapping state can be a "Schrödinger-cat" state of the cavity field, provided that the atomic velocity is appropriately selected.
We study both analytically and numerically the stability of trapping states for different initial states of the driving atoms, as a function of the velocity distribution of the atoms, of their arrival rate, and of the photon storage time in the cavity field. Furthermore we determine the fidelity of preparing these states for experimentally accessible parameters [2, 3].

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[3] J.M. Raimond, M. Brune, S. Haroche, Rev. Mod. Phys. 73, 565 (2001).

Q 15.78 Mon 16:30 P1

An optical cavity with a strongly focused mode — •Kadir Durak, Syed Abdullah Aljunid, Brenda Chng, Gleb Maslennikov, and Christian Kurtsiefer — Centre for Quantum Technologies / Dept. of Physics, National University of Singapore

Electrical field enhancement with optical cavities is a common method to observe strong coupling between atoms and photons for efficient quantum interfaces. Commonly, free-space cavities for such experiments have paraxial field modes, but additional field enhancement can be accpomplished by placing the atoms in focused cavity modes [1]. We investigate an anaclastic cavity lens configuration [2], which provides strong coupling with a moderate finesse cavity and allow for efficient matching to Gaussian modes outside the cavity[3]. We report on our progress for mode characterization and alignment of such a nearly-critical resonator.

[1] S.E. Morrin, C.C. Yu, T.W. Mossberg, Phys. Rev. Lett. **73** 1489 (1994).
[2] Ibn Sahl, On burning mirrors and lenses. Baghdad (984).
[3] S.A. Aljunid et al., arXiv:1006.2191v1 / J. Mod. Opt. (2010)

Q 15.79 Mon 16:30 P1

Theoretical aspects of the QFEL — •Rainer Endrich[1], Enno Giese[1], Matthias Knobl[1], Paul Preiss[1,2], Roland Sauerbrey[2], and Wolfgang P. Schleich[1] — [1]Institut für Quantenphysik, Universität Ulm, 89069 Ulm, Germany — [2]Forschungszentrum Dresden-Rossendrof, 01314 Dresden, Germany

Free-Electron Lasers (FEL) provide coherent and widely tunable radiation of high brilliance. Most theoretical descriptions are based on classical physics in agreement with experimental results. However, in the near future an FEL working in the quantum regime is within reach at the Research Center Dresden-Rossendorf. Some theoretical progress has been made so far to understand quantum effects which are usually suppressed in the classical regime and therefore ignored. This includes two-level photon transitions, significant recoil effects, phase diffusion and much more. Based on our earlier work, we take a closer look at the density matrix of the joint system of laser field and electron beam. In this way we will analyze the behavior of both systems and, in particular, the photon statistics of the field and the microbunching of the electrons with the corresponding reduced density matrices.

Q 15.80 Mon 16:30 P1

Storing the collective positronium atoms with laser field — •Ni Cui, Mihai Macovei, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Different from ordinary atoms, positronium(Ps) atoms in the ground states are unstable, and annihilate by γ emission. Populating the excited states of Ps atoms is an efficient way to increase the annihilation lifetime with resonant excitation by laser field [1]. If the inter-particle intervals among Ps atoms is small on a scale given by the relevant transition wavelength, collective effects have large influence on the annihilation probabilities in an assembly of Ps atoms. The numerical results show that, both superradiance and subradiance phenomena are present in the cooperative spontaneous evolutions of two-state (1S-2P) Ps atoms with initially suitable preparation by optical pumping. Then, for the collective three-state (1S-2P-3D) Ps atoms excited by resonant laser field, we find that the Ps atoms could be stored in the upper state with an extended lifetime by a factor much longer than independent Ps atoms.

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Q 15.81 Mon 16:30 P1

Plasmon-mediated interaction and level shifts of atoms: a Green's function approach — •David Dzsotjan[1,2] and Michael Fleischhauer[1] — [1]TU Kaiserslautern, Kaiserslautern, Germany — [2]RMKI-KFKI, Budapest, Hungary

We investigate the long-range coupling of individual atoms placed close to metallic nanowires. Putting the emitter close to the surface of a thin wire, a strong Purcell effect can be observed due to the extremely small transverse mode area of the surface plasmon modes: the emitter will decay into guided surface plasmon modes of the wire with a rate exceeding that of free space by a large factor. Placing a pair of emitters along the wire, we observe a strong, wire- mediated long-range interaction between the emitters. As a result, super- and subradiance can occur over distances large compared to the resonant wavelength. The states with enhanced or suppressed decay rate are the symmetric or anti-symmetric Dicke states. Besides the modification of decay rates, dipole-dipole shifts emerge due to the wire-mediated interaction, which we calculate explicitly. Coupling more atoms to a wire network with a nontrivial coupling topology leads to interesting entangled subradiant states of the system.

Q 15.82 Mon 16:30 P1

Time-Continuous Measurements and Non-Markovian Open Quantum Systems — •Sven Krönke and Walter T. Strunz — Institut für Theoretische Physik, TU Dresden, Zellescher Weg 17, 01069 Dresden

Both Markovian and non-Markovian open quantum systems can be described by means of Monte Carlo methods: The reduced density operator of the open system can be obtained by averaging over many solutions of a stochastic Schrödinger equation. In the Markovian case, where the environment has no memory at all, it is moreover possible to really generate those solutions in an experiment by time-continuously monitoring the environment (e.g. by homo-/heterodyne detection). This offers the possibility to non-demolition measurements: By observing many identical copies of the system and averaging over the measurement outcomes, the influence of the measurements on the open system dynamics is removed.

This contribution deals with the question whether or not it is feasible to find such measurement schemes even in the non-Markovian regime, where the coupling between the system and its environment is not necessarily small and the environment has a finite memory.

Q 15.83 Mon 16:30 P1

Dynamical cooling of a single-reservoir open quantum system via optimal control — •Rebecca Schmidt, Jürgen T. Stockburger, and Joachim Ankerhold — Institut für Theoretische Physik, Universität Ulm, Albert Einstein-Allee 11, 89069 Ulm

The coherent optimal control of noisy and open quantum systems is critical in tailored-matter such as quantum information processing. We investigate this type of control problem using the exact description of the dynamics of open quantum systems given by stochastic Liouville-von Neumann equations [1], and generalizing Krotov's iterative algorithm. We apply this formalism to an harmonic oszillator coupled to an ohmic bath. Performing optimal control on this system, allows us to cool translational motion with a single thermal reservoir and without involving internal degrees of freedom [2].

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[2] Schmidt, R., Negretti, A., Ankerhold, J., Calarco, T. and Stockburger, J.T., arXiv:1010.0940 (2010)

Q 15.84 Mon 16:30 P1

Entanglement of motion with optimal control — •Thomas Stefan Häberle and Matthias Freyberger — Institut für Quantenphysik, Universität Ulm, 89069 Ulm

We discuss two compact particles in a harmonic trap which interact via pointlike collisions. The interaction can be modelled by a δ-potential in the relative coordinate of the particles. Each collision will dynamically entangle the motion of the particles by a certain amount. Therefore, the time evolution of entanglement will show a step-like behaviour. Our aim is to optimize the corresponding von-Neumann-entropy at an arbitrarily fixed time by dynamically varying the trap frequency. Hence we apply a special form of Krotov's method for optimal control problems which guarantees monotone convergence even for non-linear functionals.

Q 15.85 Mon 16:30 P1

Bose-Einstein Condensation and QND Measurements in a Crossed Optical Cavity — •Ralf Kohlhaas[1], Thomas Vanderbruggen[1], Simon Bernon[1], Andrea Bertoldi[1], Philipp Bouyer[1], Arnaud Landragin[2], and Alain Aspect[1] — [1]Laboratoire Charles-Fabry de l'Institut d'Optique, CNRS and Univ. Paris-Sud, Campus Polytechnique, RD 128, F-91127 Palaiseau, FRANCE — [2]LNE-SYRTE, Observatoire de Paris, CNRS, UPMC, 61 avenue de l'Observatoire, 75014 Paris, FRANCE

The atomic shot noise level is a limit for the sensitivity of atom interferometers and can be overcome with the use of non-classical atomic states such as spin squeezed states. In this context, we investigate the generation of such states by quantum non-demolition measurements in a high-finesse optical cavity. Recent progress in the all-optical trapping and evaporation in a crossed optical cavity and a first characterization of the non destructive heterodyne detection scheme is reported.

Q 15.86 Mon 16:30 P1

Entanglement Control via Magnetic Fields in Solid Systems — •Vivian França and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität, Hermann-Herder-Str. 3, Freiburg, Germany

Entanglement, one of the most intriguing characteristics of Quantum Mechanics, is considered an important key in Quantum Information Theory. Among several possible systems, solids are good candidates for the development of devices for quantum information processes. While in condensed matter physics the Hubbard model has been largely used for describing properties of many-body systems, only recently entanglement studies have been performed in the one-dimensional Hubbard model. In homogeneous systems many interesting properties were analised, however previous investigations showed that the inhomogeneities present in real-life systems in general destroy the degree of entanglement in the system [1]. Here we use Density Functional Theory techniques for investigating the impact of spin imbalanced population and external magnetic fields onto the entanglement of inhomogeneous systems. In particular two inhomogeneous systems are investigated: chains with disordered impurities and harmonically confined chains, which can simulate for example cold atoms in optical lattices. Our preliminary results for the confined chains show that, although the degree of entanglement for the homogeneous case can not be recovered, it is possible to increase the entanglement degree by a factor of as much as 5 via the application of magnetic fields.

[1] V. V. França and K. Capelle, Phys. Rev. Lett. 100, 070403 (2008).

Q 15.87 Mon 16:30 P1

Photosynthesis and quantum mechanical transport processes — •Dominic Wörner and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Recent experimental results on quantum effects in photosynthetic units motivate the study of quantum mechanical transport processes, in particular also under the influence of decoherence. Here, we present results on such transport models. In particular, we focus on the evolution of correlations throughout the transport and on possible implementations of biologically relevant transport configurations in light scattering setups accessible in the lab.

Q 15.88 Mon 16:30 P1

Self-focusing and defocusing of twisted light in non-linear media. — •Anita Thakur[1,2] and Jamal Berakdar[2] — [1]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle(Saale) — [2]Institut für Physik, Martin-Luther Universität Halle-Wittenberg, Heinrich Damerow Str.4, 06120 Halle(Saale), Germany.

We study the self-focusing and defocusing of a light beam carrying angular momentum (called twisted light) propagating in a non-linear medium. We derive a differential equation for the beam width parameter f as a function of the propagation distance, angular frequency, beam waist and intensity of the beam. The method is based on the Wentzel-Kramers-Brillouin and the paraxial approximations. Analytical expressions for f are obtained, analyzed and illustrated for typical experimental situations.

Q 15.89 Mon 16:30 P1

Atom-Photon Entanglement in Cavity QED with a Single Calcium Ion — •Bernardo Casabone[1], Andreas Stute[1], Birgit Brandstätter[1], Diana Habicher[1], Johannes Ghetta[1], Andrew McClung[1], Tracy Northup[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25/4, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, Otto-Hittmair-Platz 1, 6020 Innsbruck, Austria

A cavity QED system for atom-photon entanglement enables efficient collection of entangled photons; such a system could be used in a quantum network to remotely entangle atoms. Here, our progress toward entanglement in an optical cavity with a calcium ion is discussed.

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. We have previously implemented a single-photon source on the $4P_{1/2} \leftrightarrow 3D_{3/2}$ transition; we now generate single photons on the $4P_{3/2} \leftrightarrow 3D_{5/2}$ transition. All Zeeman states are resolved in agreement with theoretical simulations. A laser on the narrow $4S_{1/2} \leftrightarrow 3D_{5/2}$ transition permits detection of individual Zeeman states. Coherent state manipulation on this transition enables characterization of an entangled atom-photon state.

We discuss our ion-photon entanglement scheme, including simultaneously driving two vacuum-stimulated Raman transitions.

Q 15.90 Mon 16:30 P1

Classical and quantum radiation reaction effects in intense laser fields — •Omri Har-Shemesh, Antonino Di Piazza, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg (Germany)

A fundamental problem in classical electrodynamics (CED) is the so-called "radiation reaction" problem: classically, when a charged particle (an electron, for definiteness) is accelerated by an external field, it emits radiation and this emission changes the motion of the electron. In the realm of CED, the so-called Landau-Lifshitz (LL) describes the motion of an electron by including the effects of radiation reaction and it has not yet been tested experimentally. We explore a new regime of parameters in which, as predicted by the LL equation, the influence of radiation reaction on the electromagnetic spectra emitted by the electron is substantial [1]. What is the quantum analog of radiation reaction? In [2] we have answered this question and we have investigated the quantum radiation dominated regime, in which quantum recoil and radiation reaction effects both dominate the dynamics of the electron.

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Q 15.91 Mon 16:30 P1

Imaging, Addressing and State Detection of Two Ions in an Optical Cavity — •Diana Habicher[1], Andreas Stute[1], Bernardo Casabone[1], Birgit Brandstätter[1], Johannes Ghetta[1], Andrew McClung[1], Tracy Northup[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck,Technikerstraße 25, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, 6020 Innsbruck, Austria

Entangling two atoms via the mode of an optical cavity is a major goal of cavity quantum electrodynamics. Recent progress towards this goal is presented.

In the experiment, two $^{40}Ca^+$ ions are stored in a linear ion trap and coupled to the same mode of a high-finesse optical resonator. In order to evaluate the quantum state of the ions, one must implement state tomography, which requires both state detection and single-ion (addressed) rotations. For the necessary state detection, fluorescence detection methods have been implemented, using both a CCD camera and a PMT. To apply the rotations, a custom objective for a 729nm laser has been installed and single-ion addressing has been characterized. Finally, two possible methods to achieve entanglement are discussed.

Q 15.92 Mon 16:30 P1

Zeta States in Phase Space — •Cornelia Feiler and Wolfgang P. Schleich — Institute for Quantum Physics, Ulm University

In 1859 Bernhard Riemann mentioned in his seminal paper "Ueber die Anzahl der Primzahlen unter einer gegeben Grösse" [1], the by now famous conjecture: *all non-trivial zeros of the zeta function have real part one-half* without giving a proof for it. Although the Riemann hypothesis was studied by many famous mathematicians and lately was attacked by physicists, no rigorous proof exists today.

Our approach towards the Riemann zeta function takes advantage of the time evolution of two interacting quantum systems followed by a joint measurement. The states which reproduce the zeta function in the different parts of the complex plane inherit the properties of the different representations [2] of the zeta function. To understand their behavior we investigate the Wigner functions of these so-called zeta states.

[1] B. Riemann. Monatsbericht der Berliner Akademie, 1859.
[2] E. C. Titchmarsh. *The Theory of the Riemann Zeta-Function*. Oxford, Charlendon Press, 1967.