Q 3: Ultrashort Laser Pulses

Time: Monday 10:30–12:45 Location: K 0.023

Q 3.1 Mon 10:30 K 0.023

Noncollinear third harmonic generation in MgO — •Dennis Mayer, Axel Heuer, and Markus Gühr — Institut für Physik und Astronomie, Universität Potsdam

In a recent study You et al. observed that harmonic generation in MgO is sensitive to the crystal structure and that the polarization dependent efficiency exhibits additional features in the strong field regime [1]. In contribution to this study we report the observation of intensity- and polarization-dependent far field patterns in the perturbative third harmonic generation in MgO. Using 400fs pulses from an Yb-based laser we observed a transition from collinear to different non-collinear emissions depending on the pump-pulse polarization at intensities of 10^{11} W/cm^2. The emission is locked to the Mg-O direction inside the crystal for linear polarization and occurs in a cone for circular polarization. Since this transition is irreversible for a given polarization and does not occur for pulse durations below 100fs, we attribute this effect to stress-induced damage inside the crystal.

[1] Y.S. You et al., Nature Physics AOP (2016)

Q 3.2 Mon 10:45 K 0.023

Quasi-phase matched high harmonic generation in spatially structured Al plasmas — •Michael Wöstmann and Helmut Zacharias — Westfälische-Wilhelms Universität Münster, Physikalisches Institut, Wilhelm-Klemm-Straße 10, 48149 Münster

A route is presented in order to realize quasi-phase-matching of high-order harmonic generation in laser produced plasmas. This requires the spatial modulation of the plasma. A simple stack of thin target material (ca. 0.5 mm) and spacers is used in order to induce the modulation. The exact dimensions are derived by measuring the coherence lengths in unmodulated plasmas and the beam profile with respect to the focal position of the harmonic generating beam. The geometric phase advance of the fundamental radiation through its focus is found to be the governing parameter for resetting the phase of the emitted harmonic radiation between two slices of plasma. Applying four separated plasma plumes, an enhancement factor of 170 is observed for the 25th harmonic in relation to the maximal harmonic intensity generated in an unmodulated plasma of the same composition. The principle is expected to work even better at higher harmonic orders.

Q 3.3 Mon 11:00 K 0.023

2 μm doubly resonant paramatric oscillator pumped by a thin disk ultrashort laser — •Christian Markus Dietrich, Ihar Babushkin, Laura Rust, José Andrade, and Uwe Morgner — Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany

Ultrafast light sources with a wavelength around two micrometers are interesting for several experiments like high harmonic generation and investigation of Brunel harmonics [1]. We want to present a doubly resonant optical parametric oscillator (DROPO) for intracavity experiments. Our system is pumped by a home built kerr lens mode locked Yb:YAG thin disk laser with a repetition rate of 34 MHz. The DROPO is operating in a bowtie configuration and uses a BBO as the nonlinear medium. An additional focus point inside the cavity is suitable for further experiments. The wavelength can be rapidly adjusted between the degeneracy point up to 1900 nm + 2300 nm by cavity length tuning alone.

[1] Babushkin, Brée, Dietrich, Demircan, Morgner & Husakou, J. Mod. Opt. Vol. 64 , Iss. 10-11, 2017

Q 3.4 Mon 11:15 K 0.023

Sub-10-fs visible pulses at 1MHz repetition rate from an optical-parametric amplifier — •Sven Kleinert[1], Ayhan Tajalli[1], Bernhard Kreipe[1], David Zuber[1], José R. C. Andrade[1], and Uwe Morgner[1,2,3] — [1]Institute of Quantum Optics, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover, Germany — [3]Hannoversches Zentrum für Optische Technologien, Leibniz Universiät Hannover, Nienburger Straße 17, 30167 Hannover, Germany

We present a compact optical-parametric amplification system (OPA) operating in the visible spectral range, delivering pulses with a Fourier-limited pulse duration below 10fs at a repetition rate of 1MHz. To this end, the output of a mode-locked chirped-pulse oscillator with cavity dumping is amplified in a single-stage rod-type fiber chirped-pulse amplifier delivering up to 40W of average power. These pulses enable the generation of energetic pump radiation for the OPA in the blue range, as well as a broadband supercontinuum seed in the visible spectral range. The OPA delivers more than 600nJ of pulse energy featuring a highly applicable source for different areas of strong-field studies where a high repetition rate is beneficial.

Q 3.5 Mon 11:30 K 0.023

Attosecond electron bunch creation in optical traveling waves via ponderomotive scattering — •Norbert Schönenberger, Martin Kozák, Timo Eckstein, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

Many atomic, molecular and other condensed matter structures have not been fully studied yet at ultrafast timescales because adequate probing methods, like XUV, ultrafast electron diffraction and microscopy, are only now becoming available. Here, we report on the ponderomotive interaction of electrons with optical traveling waves and the ultrashort electron bunch trains generated after this interaction [1]. Such bunch trains could be the basis of such a probing method. In the interaction, the travelling waves are created by the superposition of two laser pulses at different frequencies intersecting at specific angles to ensure phase matching with the electrons. This technique allows for a strong energy modulation of the free electrons of 2.2 GeV/m. Even higher gradients could be achievable, as the ponderomotive force is only limited by the available laser power. Subsequent dispersive propagation of the electrons in free space causes ballistic microbunching on the sub cycle timescale. This bunching is detected via a second ponderomotive interaction at the temporal focus. Spectrograms recorded in this setup in conjunction with numerical simulations are used to determine that pulse trains of 300 as pulses are formed.

[1] Kozák, M., Eckstein, T., Schönenberger, N. & Hommelhoff, P., Nat. Phys. (2017), DOI: 10.1038/NPHYS4282.

Q 3.6 Mon 11:45 K 0.023

Strong-field-driven dispersive waves in gas-filled hollow-core fibres — •David Novoa[1], Felix Köttig[1], Francesco Tani[1], Marco Cassataro[1], Mehmet C. Günendi[1], John C. Travers[2], and Philip St.J. Russell[1] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Heriot-Watt University, Edinburgh, United Kingdom

The nonlinear parametric process of dispersive wave (DW) emission in gas-filled hollow-core photonic crystal fibres has been largely exploited as a means to efficiently generate tunable ultrafast radiation in the ultraviolet region, with a multitude of applications. The emission of DWs occurs in the normal dispersion regime of the fibre via nonlinear transfer of energy from a self-compressed soliton spectrally located in the anomalous dispersion region, a process that relies crucially on phase matching to be efficient. However, this picture becomes richer when the self-compression dynamics of the pump pulse is taken into account. In particular, peak intensity levels high enough to partially ionize the filling gas can be attained owing to the high damage threshold of these fibres, opening access to in-fibre strong-field dynamics. Thus, it was recently predicted that, in the strong-field regime, the additional transient anomalous dispersion introduced by gas ionization may enable resonant excitation of DWs in the mid-infrared, a forbidden process in the absence of free electrons. Here we report the experimental observation of such strong-field-driven mid-infrared DWs, embedded in a 4.7-octave-wide spectrum that uniquely reaches simultaneously to the vacuum ultraviolet, with 1.7 W of total average power.

Q 3.7 Mon 12:00 K 0.023

Long-Lived Index Changes Induced by Femtosecond Ionization in Ar-Filled Hollow-Core PCF — •Johannes R. Köhler, Francesco Tani, Barbara M. Trabold, Felix Köttig, Mallika I. Suresh, and Philip St.J. Russell — Max-Planck-Institut für die Physik des Lichts, Erlangen, Deutschland

Gas-filled hollow-core photonic crystal fibre (HC-PCF) is finding important applications in ultrafast nonlinear optics, for example for pulse compression down to single cycles and for generation of broadband tunable radiation in the deep and vacuum ultraviolet. Scaling these novel light sources to MHz repetition rates is enabled by exploiting the large damage threshold in HC-PCFs that guide light by anti-resonant reflection (ARR) in the cladding. At the same time, they offer small core diameters, making it possible to access strongly nonlinear effects such as gas ionisation, using femtosecond pulses with energies of only a few μJ. When a plasma forms, each pulse causes a transient refractive index change that, if sufficiently long-lived, may affect the propagation of subsequent pulses. Here we investigate the effects of ionization, caused by self-compressed femtosecond pulses, on the temporal refractive index evolution in an argon-filled ARR-PCF. To this end we focus CW probe light transversely through the fiber cladding into the core and follow its transient phase-shifts over time using a fibre-based Mach-Zehnder interferometer. The results reveal long-lived ionisation-induced refractive index changes decaying over $\sim$25 μs and indicate that interactions among pulses, so far disregarded in HC-PCFs, will occur at repetition rates as low as 40 kHz.

Q 3.8 Mon 12:15 K 0.023

Micro-sized synthesis of customized 3D GRadient INdex elements by femtosecond laser lithography — Neus Oliver, •Alejandro Jurado, and Cornelia Denz — Institut für Angewandte Physik (WWU Universität) Münster, Germany

Increasing interest in micro-scale optics has led to the development of novel miniaturization techniques, among which laser lithography stands out as a powerful approach. Laser lithography allows the design and synthesis of arbitrary geometries to act as lenses, waveguides or diffractive components. Advances in this field have been focused, not only on improving the spatial resolution, but also on tuning the optical properties of the structures, such as the refractive index (RI). Specifically, elements with a spatial variation of the local RI can be obtained (GRadient INdex). The dependence of the attained RI with the exposure parameters in various polymers has been addressed, enabling the realization of 2D and multilayered GRIN structures. In this work, hybrid polymer Ormocomp is used to fabricate GRIN micro-structures via femtosecond laser lithography based on two-photon polymerization (TPP). We characterize the RI of our samples with phase maps obtained through interferometry and Fourier analysis methods. As calibration, the relation between laser power and the RI is studied. With our procedure, 3D GRIN distributions down to tens of micrometers can be achieved. We complement our results with ray tracing simulations for optimization of GRIN design. Our approach represents a comprehensive and versatile strategy for the tailored fabrication of 3D GRIN micro-optical systems, in which the downscaling is foreseen.

Q 3.9 Mon 12:30 K 0.023

Real time Dynamics of Femtosecond Soliton Molecules — •Georg Herink[1], Felix Kurtz[2], Claus Ropers[2] und Daniel Solli[3] — [1]Universität Bayreuth, Bayreuth, Deutschland — [2]Universität Göttingen, Göttingen, Deutschland — [3]UCLA, Los Angeles, USA

Femtosecond lasers feature bound states of ultrashort pulses, known as Soliton molecules. The rapid internal motion of such bound states can be resolved in real-time based on the time-stretch dispersive Fourier transformation. We present the initial binding of soliton molecules and resolve several classes of bound state dynamics, ranging from highly regular to stochastic trajectories. The underlying mechanisms are discussed and implications for novel states of laser operation are highlighted.