A 24: Laser Development and Applications (Spectroscopy) (with Q)

Time: Wednesday 14:30–16:30 Location: P 5

A 24.1 Wed 14:30 P 5

A pulsed single-mode Ti:sapphire laser for high-resolution resonance ionization spectroscopy — •Dominik Studer[1], Tobias Kron[1], Sebastian Raeder[2], Volker Sonnenschein[3], Pascal Naubereit[1], and Klaus Wendt[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz — [2]GSI Darmstadt — [3]Department of Quantum Engineering, Nagoya University

Resonance ionization spectroscopy (RIS) is a well-established technique for both atomic and nuclear research. Through the stepwise excitation and ionization of an atom individual transitions can be probed, allowing the extraction of fundamental parameters, such as isotope shifts and nuclear moments, provided an adequately narrow experimental linewidth is realized. Due to their high reliability and stability, pulsed Ti:sapphire lasers as designed at JGU Mainz are used at on-line laser ion sources worldwide. The standard design features a Z-shaped standing wave cavity, pumped by a frequency-doubled Nd:YAG laser with a repetition rate of 10 kHz. The output power reaches up to 4 W with pulse lengths of 40 ns. Frequency selection is achieved by a combination of a Lyot-Filter and a thin Etalon, resulting in a spectral linewidth of ≈5 GHz. Operation on a single longitudinal mode can be achieved using a ring cavity design featuring an additional air-spaced etalon, resulting in ≈50 MHz linewidth. Compared to the previously used technique of injection-locking, this design implies an unseeded single-mode operation, greatly reducing the complexity of the system. Moreover the wavelength range is not constrained by a master laser, allowing easy set-up and scanning operation.

A 24.2 Wed 14:45 P 5

Quantum metamaterials as an active lasing medium: Effects of disorder — •Martin Koppenhöfer[1,2], Michael Marthaler[2], and Gerd Schön[2] — [1]University of Basel, Basel, Switzerland — [2]Karlsruhe Institute of Technology, Karlsruhe, Germany

A metamaterial formed by artificial atoms, e.g., superconducting circuits or quantum dots, can serve as an active lasing medium when coupled to a microwave resonator. For these artificial atoms, in contrast to real atoms, variations in their parameters cannot be avoided. We examine the influence of disorder on such a multiatom lasing setup. We find that the lasing process evolves into a self-organized stationary state that is quite robust against disorder. The reason is that photons created by those atoms which are in or close to resonance with the resonator stimulate the emission also of more detuned atoms. Not only the number of photons grows with the number of atoms but also the width of the resonance as a function of the detuning. Similar properties are found for other types of disorder such as variations in the individual coupling. We present relations on how the allowed disorder scales with the number of atoms and confirm it by a numerical analysis. We also provide estimates for the sample-to-sample variations to be expected for setups with moderate numbers of atoms.

A 24.3 Wed 15:00 P 5

Laser System Technology for Quantum Optics Experiments in Space — •Kai Lampmann[1], Moritz Mihm[1], André Wenzlawski[1], Ortwin Hellmig[6], Markus Krutzik[2], Achim Peters[2], Patrick Windpassinger[1], and The MAIUS Team[1,2,3,4,5] — [1]Institut für Physik, JGU Mainz — [2]Institut für Physik, HU Berlin — [3]FBH, Berlin — [4]IQO, LU Hannover — [5]ZARM, Bremen — [6]ILP, UHH Hamburg

Numerous applications of quantum optics demand for operating experiments in extreme environments. Leaving the lab poses strict requirements to the experimental systems, especially the laser systems, in terms of miniaturization, power consumption, and mechanical and thermal stability. We follow a hybrid approach to build laser systems that can overcome these issues.

Optical bench systems using a set of specially designed freespace optics based on glass ceramics are combined with fiberintegrated components like splitters, modulators or resonators. Our systems fulfill all different functions such as laser frequency stabilization, switching and distribution of laser light.

Successful sounding rocket missions show that our systems can overcome the extreme loads of a rocket launch and that we are able to bring laser systems into space.

Our work is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economic Affairs and Energy (BMWi) under grant numbers 50 WP 1433 and 50 WM 1345, 1646.

A 24.4 Wed 15:15 P 5

Dy^{3+}:Lu_2O_3 as a promising gain material for mid-infrared lasers — •Alexander M. Heuer[1,2], Patrick von Brunn[1,2], and Christian Kränkel[1,2] — [1]Institut für Laser-Physik, Universität Hamburg — [2]The Hamburg Centre for Ultrafast Imaging

The cubic sesquioxide Lu_2O_3 is a suitable host material for mid-infrared laser applications due to its high thermal conductivity and low phonon energy. We report on the first growth from the melt and spectroscopic analysis of monocrystalline Dy^{3+}:Lu_2O_3 in the mid-infrared spectral range. Absorption and emission cross-sections in the wavelength range between 2 μm and 3.8 μm were determined. Gain cross-sections in the same wavelength region were derived and point towards possible laser action at 3256 nm and 3388 nm. The most suitable pump wavelengths for in-band pumping directly into the emitting multiplet were found to be 2713 nm and 2776 nm. This allows for pumping by an erbium-based mid-infrared laser. From the emission cross-sections the lifetime of the emitting $^6H_{13/2}$ multiplet has been calculated to be in the order of 20 ms. Corresponding measurements are in progress. Compared to the values reported for the mid-infrared laser material Dy:ZBLAN the cross-sections of Dy^{3+} in Lu_2O_3 are about 50 % higher. This reveals that Dy^{3+}:Lu_2O_3 is a promising candidate for the first mid-infrared oxide host material based on the Dy^{3+}-ion.

A 24.5 Wed 15:30 P 5

Low drift cw-seeded high-repetition-rate optical parametric amplifier for fingerprint coherent Raman spectroscopy — •Joachim Krauth[1], Tobias Steinle[1], Bowen Liu[2], Moritz Floess[1], Heiko Linnenbank[1], Andy Steinmann[1], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart — [2]Ultrafast Laser Laboratory, Tianjin University

We introduce a broadly tunable robust source for fingerprint (170 - 1620 cm^{-1}) Raman spectroscopy. A cw thulium-doped fiber laser, gap-free tunable from 1770 - 2030 nm, seeds an OPA, which is pumped by a 7-W, 450-fs Yb:KGW bulk mode-locked oscillator with 41 MHz repetition rate. The OPA is designed in double-pass configuration for power scaling and delivers a signal output power of around 1 W over most of the tuning range. The output radiation of the OPA signal is frequency doubled in a PPLN crystal and generates 0.7 - 1.3-ps-long narrowband pump pulses for the subsequent Raman spectroscopy that are tunable between 885 and 1015 nm with >80 mW average power. The Stokes beam is delivered by a part of the oscillator output, which is sent through an etalon to create pulses with 1.7 ps duration. We demonstrate a stimulated Raman gain measurement of toluene in the fingerprint spectral range. Here we use an acousto-optic modulator to modulate the pump pulse, while the Stokes intensity is detected using a single silicon photodiode, which is connected to a high-frequency lock-in amplifier. Our system combines the simplicity and the robustness of an OPA with the ultra-low intensity noise of a solid-state oscillator. Furthermore, the cw seeding intrinsically ensures low spectral drift.

A 24.6 Wed 15:45 P 5

Spatial Nonuniformity and Photochemical Doping in exfoliated WS2 Monolayers — •Ioannis Paradisanos — N. Plastira 100, Heraklion, Crete, Greece

Monolayers of transition metal dichalcogenides (TMDs) are promising new materials for future 2D nanoelectronic systems. With their tunable direct gap in the visible range of the optical spectrum and high surface-to-volume ratio, these 2D semiconducting systems are ideal for field-effect transistors, photovoltaics, light-emitting diodes, single-atom storage, molecule sensing and quantum-state metamaterials.

Here we report on the extraordinary photoluminescence (PL) and Raman properties, not only of the physical but also of intentionally created via femtosecond laser ablation, boundaries of mechanically exfoliated WS2 monolayers. In particular, it is shown that the edges of such monolayers exhibit significant Raman shifts as well as remarkably increased PL efficiency compared to their respective central area with the emission channels being of different origin. Moreover, by exploiting the interaction of UV nanosecond pulses with WS2 monolayers in

rich Cl2 environment, a fine control of the crystal*s carrier density can be achieved. This is confirmed by micro-PL measurements at 78K that show significant energy shifts of the neutral and charged exciton*s emission. At the same time, micro-Raman experiments reveal systematic shifts of the -doping sensitive- A1* vibrational mode.

We envisage that these novel findings could find diverse applications in the development of TMDs-based optoelectronic devices.

A 24.7 Wed 16:00 P 5

Mid-IR laser-based FTIR imaging using a broadband fs laser source at 73 MHz repetition rate — •Florian Mörz, Rostyslav Semenyshyn, Tobias Steinle, Frank Neubrech, Andy Steinmann, and Harald Giessen — 4^{th} Physics Institute and Research Center SCOPE, University of Stuttgart, 70550 Stuttgart,Germany

We demonstrate FTIR imaging of sub-wavelength layers of C60 and Pentacene at 7 μm using a broadband laser source. Imaging has been conducted by using aperture sizes as small as 10 x 10 μm with a 36x microscope objective. A 100 x 100 μm image of the molecule layers has been measured. A signal-to-noise ratio that exceeds common FTIR light sources, such as globars or synchrotrons, due to a several orders of magnitude higher brilliance has been observed. The applied laser source is based on the ffOPO system presented in [1, 2]. Here, a commercially available Yb:CALGO laser, providing 98 fs pulses at 73 MHz repetition rate, is used as a pump oscillator. The post-amplified ffOPO system converts the pump light to the 1.4 - 4 μm wavelength range. By difference frequency generation between signal and idler in $AgGaSe_2$ up to 1 mW average power at 7 μm with 446 nm (93 cm^{-1}) bandwidth ($1/e^2$) is generated. The system exhibits superior long term stability over several hours. In conclusion, this laser based FTIR setup enables applications such as single nano-antenna measurements or protein sensing based on surface-enhanced infrared absorption (SEIRA).

[1] F. Moerz et al., Opt. Exp. **23**, 23960 (2015)
[2] T. Steinle et al., Opt. Lett. **41**, 4863 (2016)

A 24.8 Wed 16:15 P 5

Towards Precision Infrared Spectroscopy on Small Molecules — •Arthur Fast[1], John E. Furneaux[2], and Samuel A. Meek[1] — [1]Max Planck Institute for Biophysical Chemistry, Germany — [2]University of Oklahoma, USA

Our goal is a high resolution measurement of the two-photon $v = 2 \leftarrow v = 0$ vibrational transitions in the hydroxyl (OH) radical with a relative accuracy of 10^{-14}. These transitions can be used for a test of a possible time variation of the electron-proton mass ratio. The core of this endeavor is a laser beam in the mid infrared region at 2.9 μm with a narrow optical linewidth below 1 kHz. This is the idler wavelength of an optical parametric oscillator (OPO) pumped at 1064 nm by a Nd:YAG laser. The same laser is also frequency-doubled and locked to a molecular iodine transition at 532 nm. By doing this, the Nd:YAG laser obtains a high short term stability, around 10^{-14} at the one-second timescale. To transfer this stability to the idler wavelength of the OPO at 2.9 μm we make use of an optical frequency comb. The frequency comb is stabilized to the Nd:YAG laser, and the OPO is stabilized to the frequency comb by controlling its cavity length with a piezo mirror. The frequency comb is also used to compare the measured absolute frequencies of the various lasers to a GPS-linked radio frequency reference. In this way, we obtain a long-term stability and absolute accuracy for our spectroscopic measurements.