Q 16: Laser Developments and Applications

Time: Monday 14:00–15:45 Location: S SR 211 Maschb.

Q 16.1 Mon 14:00 S SR 211 Maschb.

Theory of transient x-ray lasing in the small signal regime

— •Chunhai Lyu, Stefano M. Cavaletto, Zoltán Harman, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Transient lasing processes are conventionally modeled by the Maxwell–Bloch equations which can not be solved analytically in the general case even for a one-dimensional model. Thus, numerical simulation of these equations is the main method to analyze the properties of the output lasers [1]. Here, we present a formal solution of the one-dimensional Maxwell–Bloch theory in the small-signal regime where the laser intensity is well below the saturation intensity. For the case of x-ray lasers pumped by an x-ray free-electron laser, direct integration of the formal solution reproduces the behaviors obtained from numerical simulations. Furthermore, in this regime, the dynamics of the polarization field in the gain medium follows the strength of the laser field adiabatically. This allows us to derive an approximate analytical solution for the time-dependent laser field, which is shown to be characterized by a Gaussian-like profile, with the duration and spectrum width determined by the population-inversion lifetime, the gain coefficient and the decoherence rate. Our results would be beneficial for the experimental design of a specific x-ray laser, i.e., by facilitating the determination of the laser parameters.

[1] C. Lyu, S. M. Cavaletto, C. H. Keitel, and Z. Harman, arXiv:1801.02503 (2018).

Q 16.2 Mon 14:15 S SR 211 Maschb.

Transform Limited Pulse Amplification in an Ytterbium Doped Photonic Crystal Fibre

— •Sebastian Hepp, Daniel Kiefer, and Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, Laser- und Quantenoptik, Schlossgartenstr. 7, 64289 Darmstadt

For precision experiments in the heavy ion storage ring ESR at GSI and in the future heavy ion synchrotron SIS100 at FAIR in Darmstadt, beams of high brilliance are desirable. A crucial element to achieving this is reducing the momentum spread of the relativistic ions, which has been successfully accomplished at GSI using conventional laser cooling [1]. White light laser cooling has proven to be an even more efficient method for not only cooling but also suppressing intra beam scattering leading to a reduced particle loss [2].

For this purpose, we have implemented a laser system providing transform limited pulses with variable length at 257.5 nm. A continuous wave MOPA system with subsequent acousto-optical and electro-optical modulation generates pulses at 1030 nm with variable length from 70 ps up to 740 ps. Three consecutive fibre amplifiers are used to increase the pulse energy to a suitable level for efficient fourth harmonic generation. As self phase modulation limits our system, one of the fibre amplifiers has been replaced by a photonic crystal fibre with larger mode field diameter. The current status of the system is presented.

[1] D. Winters et al, Phys. Scr. T166 (2015), 014048.
[2] S. N. Atutov et al, Phys. Rev. Lett. 80 (1998), 2129-2132.

Q 16.3 Mon 14:30 S SR 211 Maschb.

Bright light source at 2.128 μm using optical-parametric oscillation

— •M. Schröder, C. Darsow-Fromm, R. Schnabel, and S. Steinlechner — Institut für Laserphysik und Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

In recent years, gravitational-wave detection has further proven its potential with the emergence of multi-messenger astronomy following the observation of a binary neutron star coalescence in August 2017. Subsequently, a lot of effort has been put into enhancing detector sensitivity to further increase the event horizon.

Current detectors are mainly limited by coating thermal noise, hence ensuing the investigation of testmass materials suitable for cryogenic operation. Crystalline silicon has been considered as a substrate material for the longest time due to its high mechanical quality factor and thermal conductivity, while the latest research of coating technologies has shown promising mechanical loss results with amorphous silicon thin films. Both, however, restrict the possible operating laser wavelength to above 2 μm.

Our experiment encompasses the creation of a bright light source at 2.128 μm by optically pumping a periodically poled KTP crystal at 1064 nm using optical-parametric down-conversion. The generated light is wavelength-doubled and retains the excellent amplitude and phase noise properties of the pump beam.

In this talk we will present first results on the way to a comprehensive solution for nonclassical interferometry at 2.128 μm.

Q 16.4 Mon 14:45 S SR 211 Maschb.

Extended-cavity diode laser at 633 nm stabilized to iodine using Noise-Immune Cavity-Enhanced Optical Heterodyne Molecular Spectroscopy (NICE-OHMS)

— •Florian Krause, Uwe Sterr, and Erik Benkler — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Helium-neon lasers at 633 nm are still widely-used for interferometry and metrology. Iodine-stabilized helium-neon lasers are used as frequency standards for calibration with uncertainty 2.1×10^{-11} and instabilities of 1.1×10^{-11} at 1 s. However, the technical know-how for building and maintaining helium-neon laser is dying out. An attractive alternative to these gas lasers are diode laser systems stabilized to molecular references.

Here we present a 633 nm diode laser system stabilized to Doppler-free hyperfine components of the iodine P(33) 6-3 transition. We employ the NICE-OHMS technique with an external cavity containing a 10 cm long Brewster windowed iodine cell. This system has achieved a frequency instability of 3.4×10^{-12} at 1 s, which is lower than the instability of PTB's iodine-stabilized helium-neon lasers (4.1×10^{-12} at 1 s).

Q 16.5 Mon 15:00 S SR 211 Maschb.

Towards an XUV frequency comb for precision spectroscopy of trapped highly charged ions

— •Jan-Hendrik Oelmann, Janko Nauta, Alexander Ackermann, Julian Stark, Steffen Kühn, Thomas Pfeifer, and José Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Highly charged ions (HCI) with only few tightly bound electrons have many interesting properties for probing fundamental physics and developing new frequency standards [1]. To perform high resolution spectroscopy of cold HCI in the extreme ultraviolet (XUV), we are developing a high-harmonic generation based XUV frequency comb [2]. To reach the required peak intensity levels ($\approx 10^{13}\,\mathrm{W/cm^2}$) at MHz repetition rates, laser pulses are first amplified to high power and then resonantly overlapped in a femtosecond enhancement cavity [3]. Recent progress and first results of intra-cavity multiphoton experiments are presented.

[1] M.S. Safronova et al., Phys. Rev. Lett. 113, 030801 (2014).
[2] G. Porat et al., Nat. Photon, 12, 387 - 391 (2018).
[3] J. Nauta et al., Nucl. Instrum. Meth. B 408, 285 (2017).

Q 16.6 Mon 15:15 S SR 211 Maschb.

Novel Quantum Physical ^{39}Ar Dating of Alpine Glacier Ice, Ocean- and Lake Water with Small Sample Sizes

— •Maximilian Schmidt[1,2], Zhongyi Feng[2], Lisa Ringena[2], Arne Kersting[1], Julian Robertz[2], Sven Ebser[2], Werner Aeschbach[1], and Markus K. Oberthaler[2] — [1]Institute of Environmental Physics Heidelberg — [2]Kirchhoff-Institute for Phyics Heidelberg

The cosmogenic radioisotope ^{39}Ar ($t_{1/2} = 269$ a) offers the possibility for radiometric dating in a time span of 50 -1000 years and thus is capable of studying dynamics of aquatic and glacial systems of the last millennium. So far its natural isotopic abundance of $^{39}\mathrm{Ar/Ar} = 8 \cdot 10^{-16}$ and long lifetime required sample sizes of about 1000L. The utilization of quantum optical techniques widely used in atomic physics solves the problem by reducing sample volume requirements by three orders of magnitude. The problem of the very low isotopic abundance is resolved by resonant multi-photon scattering of ^{39}Ar in an atom trap. This technique named Argon Trap Trace Analysis (ArTTA) is the door opener for new geophysical research fields that were excluded from radio-argon dating so far due to large sample size requirements. Here we present our most recent results covering multi-tracer dating studies with ocean- and lake water and glacier ice using sample sizes of about 10-20 L of water and 5-10 kg of ice respectively corresponding to 0.5-20 mL_{STP} argon. The significant sample size reduction makes standard sampling techniques like Niskin bottles for aquatic systems and drill core sampling for glacial systems feasible.

Q 16.7 Mon 15:30 S SR 211 Maschb.

Counting magnetotactic bacteria with a combination of microfluidics and optically pumped magnetometers — •Tino Fremberg, Volkmar Schultze, Florian Wittkämper, Mark Kielpinski, and Ronny Stolz — Leibniz Institute of Photonic Technology, Albert-Einstein-Strasse 9, D-07745 Jena, Germany

Magnetotactic bacteria (MTB) are aquatic bacteria with the ability to grow single domain magnets, so called magnetosomes, inside their bodies. They contribute significantly to the microbiotic biomass of our planet and are involved in environmental cycles of iron, sulfur, nitrogen and carbon. After death the MTB remain magnetic, so they can be used as markers for archeogeomagnetics and archeology. In order to learn more about their abundance and distribution on planet Earth, we want to examine water samples via automated single detection by means of microfluidics (MF) and optically pumped magnetometers (OPM). As the MTB's magnetic moment is very small (10-15 Am^2) and the resulting magnetic field drops with third power of distance, a detector with a small size in close proximity to the MTB is required.

Currently, a new vapor cell design is under examination with regard to fabrication and sensitivity. It features a tube with 100 μm outer diameter to transport the MTBs directly through the alkali vapor and shall enable measuring within a distance of 50 - 100 μm from the MTB.