Q 30: Laser Development: Solid State and Semiconductor Lasers

Time: Tuesday 14:30–16:30 Location: K/HS2

Q 30.1 Tue 14:30 K/HS2

An all-solid-state, high power, tunable cw laser system for quantum optics applications — •Simon Mieth and Thomas Halfmann — Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstraße 6, 64289 Darmstadt, Germany

We present a compact, tunable all-solid-state laser system based on an optical parametric oscillator (OPO), pumped by a fiber laser, extended by intra-cavity sum frequency generation (SFG) and frequency stabilization, to provide intense radiation in the visible spectral regime [1]. We apply the system for coherent, optical data storage in rare-earth doped solids, driven at a wavelength of 606 nm - which otherwise is only accessible by dye lasers or larger setups involving frequency mixing of two phase-locked lasers. The setup is based on a commercially available cw OPO system for mid-infrared output. The SFG and OPO processes are driven on a single periodically-poled lithium niobate crystal. Variation of the poling periods on the crystal allows for coarse wavelength tuning in a range between 605 and 616 nm. Pump wavelength tuning achieves a single-longitudinal mode tuning range of around 20 GHz. The robust, combined SFG-OPO approach is also applicable to other wavelength regimes. The system provides more than 1W output power over the full spectral range. A Pound-Drever-Hall frequency stabilization reduces the laser linewidth to the regime of 100 kHz (FWHM).

[1] S. Mieth, A. Henderson, and T. Halfmann, *Tunable, continuous-wave optical parametric oscillator with more than 1W output power in the orange visible spectrum*, Opt. Expr. 22, 11182 (2014)

Q 30.2 Tue 14:45 K/HS2

High finesse thin-disk laser for adiabatic alignment of molecules — •Bastian Deppe[1,2,3,4], Günter Huber[1,2,3], Jochen Küpper[2,3,4], and Christian Kränkel[1,3] — [1]Institut für Laser-Physik, Universität Hamburg — [2]Department of Physics, University of Hamburg — [3]Centre for Ultrafast Imaging, University of Hamburg — [4]Center for Free-Electron Laser Science, DESY, Hamburg

We are setting up a diode pumped cw thin-disk laser with a high intracavity power. This setup will provide the necessary field strengths for x-ray diffraction experiments of adiabatically aligned molecules at arbitrary repetition rates. The alignment requires an intracavity cw power of more than 150 kW in a focus of $\omega_0 = 25\ \mu$m. For low pump power and low output-coupling transmission, any additional resonator losses are detrimental for achieving a high intracavity power. Thus, we have to rely on gain materials with low intrinsic losses. For this purpose the laser performance of several Yb:YAG and Yb:Lu_2O_3 disks was analyzed at different output-coupling transmission rates below 0.5%. The calculated resonator roundtrip losses are lower than 0.03% with both gain materials. With Yb:YAG we obtained an intracavity power of 135 kW for a diode pump power of 54 W in a 6 cm short linear resonator. We will report about further power scaling experiments with an equivalent in-vacuum setup. In laser experiments under vacuum conditions we decrease the temperatures of the laser-disk below -50°C. In these experiments an increased output power stability and lower losses were demonstrated.

Q 30.3 Tue 15:00 K/HS2

Spectroscopy and Laser Operation of Nd,Mg:$SrAl_{12}O_{19}$ — •Liang Gong[1], Daniel-Timo Marzahl[1], Thomas Calmano[1,2], Fabian Reichert[3], Christian Kränkel[1,2], and Günter Huber[1,2] — [1]Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Center for Free-Electron Laser Science, Luruper Chaussee 149, 22761 Hamburg, Germany

The host material $SrAl_{12}O_{19}$ (SRA) exhibits excellent thermo-mechanical properties which makes it interesting for high power laser application. The trivalent Nd^{3+} is a well-known rare earth ion with transitions around 1μm. In our laboratory Nd,Mg:SRA crystals with various doping concentrations were grown by the Czochralski method. Spectroscopic data show that the two strongest transitions from the emitting $^4F_{3/2}$-multiplets of Nd,Mg:SRA crystals are centered at 900 nm and 1050 nm. These transitions exhibit emission cross sections of $4.6\cdot10^{-20}$ cm^2 and $2.0\cdot10^{-20}$ cm^2 in σ polarization, respectively. The highest absorption cross section in the spectral range between 750 nm and 920 nm is $3.6\cdot10^{-20}$ cm^2 at 798 nm. In this contribution we report about laser emission at 900 nm with 62% slope efficiency and 0.79 W maximum output power. Moreover, laser operation at 1050 nm with 55% slope efficiency and 1.6 W maximum output power is achieved.

Q 30.4 Tue 15:15 K/HS2

Efficient Yb:$CaGdAlO_4$bulk and waveguide lasers — •Kore Hasse[1], Bastian Deppe[1,2,3], Thomas Calmano[1,2], and Christian Kränkel[1,2] — [1]Institut für Laser-Physik, Universität Hamburg — [2]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg — [3]Center for Free-Electron Laser Science, DESY, Hamburg

Femtosecond-laser-writing of waveguides in crystalline materials allows for compact efficient waveguide lasers in continuous wave operation. Furthermore these kinds of lasers could be suitable to generate high repetition rates and ultra-short pulses in modelocked operation.
The crystalline laser material Yb:$CaGdAlO_4$ is known for its broad emission spectrum. Therefore it is an established material for the generation of ultra-short pulses in modelocking experiments.
Here we report on our research towards a modelocked Yb:$CaGdAlO_4$ waveguide laser. We performed crystal growth, spectroscopy and laser experiments in bulk and waveguide geometry. In the bulk laser experiments slope efficiencies of up to 75% were obtained. Furthermore we fabricated waveguides by fs-laser-inscription in this material. By pumping with an optically pumped semiconductor laser at 980 nm we demonstrated, to the best of our knowledge, the first fs-laser written waveguide-laser in Yb:$CaGdAlO_4$. We achieved a slope efficiency of 32% with a maximum output power of 1.3 W at a laser wavelength of 1055 nm. Further investigations regarding improved fs-laser-writing and laser parameters will be presented at the conference.

Q 30.5 Tue 15:30 K/HS2

Circularly curved waveguide lasers inscribed into Yb:YAG by direct fs-laser writing — •Thomas Calmano[1,2], Lukas Terkowski[1], Sven H. Waeselmann[1], Christian Kränkel[1,2], and Günter Huber[1,2] — [1]Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg

In this contribution we report about curved waveguide lasers, which are suitable as basic components for complex active optical devices. The waveguides consist of segments of circles with an arc length of about 15 mm and radii of curvature between 30 mm and 80 mm. The waveguiding structures were inscribed by direct fs-laser writing. This technique allows for the inscription of waveguides in three dimensions into a wide range of dielectric materials including various laser crystals. In this work we utilized ytterbium doped $Y_3Al_5O_{12}$ (Yb:YAG) for the fs-laser inscription. Yb:YAG offers excellent thermomechanical properties and a large gain due to high peak emission cross sections. Furthermore, the low quantum defect enables highly efficient lasers. Thus, nearly 80% slope efficiency and more than 5 W of output power could be demonstrated with Yb:YAG waveguide lasers in the past. With the circularly curved waveguides presented in this work more than 40% slope efficiency for radii between 60 mm and 80 mm and more than 1.5 W of output power were achieved. However, the maximum output power and slope efficiency decreased to approximately 0.9 W and 25%, respectively, for the waveguides with smaller radii.

Q 30.6 Tue 15:45 K/HS2

Modellierung von Eu^{3+}-kodotiertem Dy^{3+}:$LiLuF_4$ und Dy^{3+}:$LiYF_4$: Spektroskopie und Dauerstrichlaser — •Philip Werner Metz[1], Giacomo Bolognesi[2,3,4], Daniela Parisi[5], Daniel-Timo Marzahl[1], Mauro Tonelli[4,5], Christian Kränkel[1,6] und Günter Huber[1,6] — [1]Institut für Laser-Physik, Universität Hamburg, Deutschland — [2]INRIM, Istituto Nazionale di Ricerca Metrologica, Italy — [3]Politecnico di Torino, Italy — [4]Dipartimento di Fisica, Università di Pisa, Italy — [5]NEST, Istituto Nanoscienze-CNR, Italy — [6]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Deutschland

Dy^{3+}-Laser eignen sich aufgrund ihrer Emission im Gelben unter anderem zum Treiben des $^1S_0 \rightarrow {}^3P_0$ Übergangs bei 578 nm in hochpräzisen Yb-Atomuhren. Allerdings ist in Fluoriden wie Dy^{3+}:$LiLuF_4$ und Dy^{3+}:$LiYF_4$ im Gegensatz zu z.B. Dy^{3+}:YAG die Lebensdauer des unteren Laserniveaus zu lang, um sie als reine Vierniveausysteme zu betrachten. Die Folgen sind instabiler Laserbetrieb und tendenziell ins Langwellige verschobene Laseremission. Eu^{3+}-Kodotierung verkürzt diese Lebensdauer um etwa eine Größenordnung und ermöglicht stabilen Dauerstrichbetrieb bei Wellenlängen wie sie für reine Vierniveaulaser erwartet werden. Auf diese Weise wurden bisher bis zu 40 mW Ausgangsleistung bei 578 nm erzielt. Die Ergebnisse dieser Laserexperimente stehen in guter Übereinstimmung mit einer Modellierung des Lasers unter Berücksichtigung der Besetzungsakkumulation im unteren Laserniveau.

Q 30.7 Tue 16:00 K/HS2

Ein regenerativer Zweifarben-Ti:Sa Verstärker für ein Triplett-Solvatationsdynamik Experiment — •Vincenzo Talluto[1], Lukas Mader[1], Thomas Walther[1] und Thomas Blochowicz[2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt — [2]Institut für Festkörperphysik, Technische Universität Darmstadt, Hochschulstr. 8, 64289 Darmstadt

Die Triplett-Solvatationsdynamik (TSD) ist eine optische Methode, mit der die molekulare Reorientierungsdynamik in unterkühlten Flüssigkeiten nahe des Glasübergangs untersucht werden kann. Der Flüssigkeit wird dazu ein Farbstoff beigemischt, welcher mit einem UV-Laserpuls angeregt wird. Ein Teil der Farbstoffmoleküle geht über in einen langlebigen Triplettzustand. Über den zeitlichen Verlauf der Phosphoreszenzwellenlänge kann die Relaxation der Solvatationshülle in einem Zeitbereich von 1ms bis 1s verfolgt werden. Durch eine Zwei-Photonen Anregung soll der erfassbare Dynamikbereich zu kurzen Zeiten hin erweitert werden. Hierzu wurde ein regenerativer Ti:Sa-Verstärker aufgebaut, welcher simultan Pulse aus zwei schmalbandigen Diodenlasern verstärkt. Die benötigten Wellenlängen von 940nm und 960nm liegen dabei weit vom Verstärkungsmaximum von Ti:Saphir entfernt. Das Verhältnis der Pulsenergien bei beiden Wellenlängen lässt sich beliebig über die Seedleistungen variieren. Die erreichte Pulsenergie beträgt maximal 4mJ. Über eine effiziente Frequenzverdreifachung können bis zu 1mJ bei 320nm erzeugt werden. Wir präsentieren das Lasersystem und den aktuellen Stand des Experiments.

Q 30.8 Tue 16:15 K/HS2

Micro-integrated diode laser modules for high precision quantum sensors in space — •Anja Kohfeldt[1], Christian Kürbis[1], Erdenetsetseg Luvsandamdin[1], Max Schiemangk[1,2], Andreas Wicht[1,2], Götz Erbert[1], Achim Peters[1,2], and Günther Tränkle[1] — [1]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany — [2]Humboldt-Universität zu Berlin, Institut für Physik, Newtonstr. 15, 12489 Berlin, Germany

We report on the development of a very robust, energy-efficient, semiconductor based laser platform for the deployment of cold atom based quantum sensors in space. This platform is suitable for Master Oscillator Power Amplifier (MOPA) and Extended Cavity Diode Laser (ECDL) modules. The modules have a footprint not larger than $80 \times 25\,mm^2$ and make use of either already space qualified or space qualifiable components and integration technologies. In addition an electrical interface for RF modulation of the injection currents is provided.

Designed for rubidium and potassium spectroscopy at 780 nm and 767 nm we present MOPA systems achieving an optical output power > 1 W and an intrinsic linewidth of < 50 kHz and ECDL systems with < 2 kHz at 30 mW.

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