# Q 28: Laser Development I

Time: Wednesday 11:00–13:00 Location: a310

Q 28.1 Wed 11:00 a310

**Nd:Sapphire Ridge Waveguide Laser** — •Sven H. Waeselmann[1], Sebastian Heinrich[1], Christian E. Rüter[2], Detlef Kip[2], Christian Kränkel[1,3], and Günter Huber[1,3] — [1]Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Faculty of Electrical Engineering, Helmut Schmidt Universität, 22043 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Sapphire is well known for its outstanding thermo-mechanical properties among the common laser host crystals. It is thus a highly desirable host material for rare-earth (RE) doping. Unfortunately, RE:sapphire cannot be grown in the thermal equilibrium. We performed off-equilibrium growth of Nd:Sapphire films via pulsed laser deposition (PLD). With doping concentrations of 1 at.% Nd, PLD films of 2.6 $\mu$m thickness proved to function as planar waveguide lasers. In order to obtain two-dimensional confinement, we applied diamond dicing to the thin films to prepare ridge waveguides. At 2.5 W of incident pump power at a wavelength of 833 nm we obtained a maximum of 116 mW of cw output at 1093 nm with a slope efficiency of 5% in a 47 $\mu$m wide ridge waveguide with a length of 8 mm.

Q 28.2 Wed 11:15 a310

**Kontinuierliches UV-Lasersystem bei 254 nm durch Frequenzvervierfachung eines Flüssigstickstoff-gekühlten Faserverstärkers bei 1015 nm** — •Ruth Steinborn, Patrick Bachor, Thomas Diehl, Sascha Rau, Matthias Stappel und Jochen Walz — Johannes Gutenberg-Universität und Helmholtz-Institut Mainz, D-55099 Mainz

Durch Kühlung von Ytterbium-dotierten Glasfasern auf kryogene Temperaturen lässt sich die Absorption in der Faser im Wellenlängenbereich von 1000 nm bis 1050 nm deutlich reduzieren. Dieser Effekt wird ausgenutzt, um einen Faserverstärker bei 1015 nm zu betreiben. Dazu wird von einem Diodenlasersystem erzeugtes Licht in einer auf 77 K gekühlten Ytterbium-Faser verstärkt. Dieses System erreicht zuverlässig und polarisationsstabil Ausgangsleistungen von über 10 W. Die experimentellen Ergebnisse sowie Vergleiche mit Simulationen des Verstärkers bei unterschiedlichen Temperaturen werden vorgestellt.

Das verstärkte Licht wird in zwei Stufen auf die Wellenlänge 254 nm frequenzvervierfacht, welche dem $6^1S_0 \rightarrow 6^3P_1$-Übergang in Quecksilber entspricht. Die erste Frequenzverdopplung mit einem periodisch gepolten Lithiumniobat-Kristall (PPLN) erreicht im Einfachdurchgang eine Ausgangsleistung von 2 W. Das so erzeugte grüne Licht wurde in einem Überhöhungsresonator mit verschiedenen Cäsium-Lithiumborat-Kristallen (CLBO) frequenzverdoppelt, wobei ein starker Einfluss der Kristallqualität auf die erzeugte UV-Leistung beobachtet wurde. Mit einem der Kristalle kann eine stabile Ausgangsleistung von bis zu 500 mW bei 254 nm erzeugt werden.

Q 28.3 Wed 11:30 a310

**Oscillator-pumped femtosecond laser source with nearly gap free tuning range from 1.4 to 12 $\mu$m** — •Florian Mörz, Tobias Steinle, Andy Steinmann, and Harald Giessen — 4th Physics Institute and Research Center SCOPE, University of Stuttgart, 70550 Stuttgart,Germany

We present a femtosecond laser source that provides infrared radiation between 1.4 and 12 $\mu$m. The setup consists of a multi-Watt mid-infrared optical parametric master oscillator power amplifier (MOPA) that is tunable from 1370 nm to 4120 nm, and a difference frequency generation (DFG) stage, in which the MOPA signal and idler are mixed. The MOPA generates up to 4.3 W average output power at 1370 nm, corresponding to a photon conversion efficiency of 78 %. Nearly Fourier-limited pulses and excellent power stability are observed. The DFG setup provides radiation of up to 50 mW average output power at 6 $\mu$m and several mW up to 12 $\mu$m at a passive long term stability of $< 1$ % RMS. This MOPA DFG setup is pumped by a single Yb:KGW femtosecond oscillator with 8 W average pump power.

Q 28.4 Wed 11:45 a310

**High-repetition rate, high-power femtosecond difference frequency generation behind an OPO for the mid-infrared fingerprint region** — •Joachim Krauth, Tobias Steinle, Andy Steinmann, and Harald Giessen — 4th Physics Institute and Research Center SCoPE

We demonstrate a high power, femtosecond optical parametric oscillator (OPO) based on periodically poled lithium niobate crystal used for pumping a subsequent difference frequency generation (DFG) setup based on an $AgGaSe_2$ crystal. The linear cavity OPO generates up to 1.33 W (signal) and 1.63 W (idler) output power while it is synchronously pumped by a Yb:KGW oscillator that provides up to 7 W output power with 440 fs pulses at 41 MHz repetition rate at 1033 nm. The generated signal and idler are mixed in the DFG setup to generate as much as 150 mW in the mid-infrared (mid-IR) fingerprint region, with a tuning range between 4.9 and 7.3 $\mu$m. This stable, high power setup is useful for various applications including mid-IR spectroscopy. A complete characterization of the OPO and DFG stage along with power scaling, stability and mid-IR DFG spectral measurements will be presented.

Q 28.5 Wed 12:00 a310

**Thin-film filter wavelength-stabilized, grating combined high-brightness direct diode laser** — •Matthias Haas, Simon Nagel, Simon Rauch, Markus Ginter, Rolf Beisswanger, Alexander Killi, and Hagen Zimer — TRUMPF Laser GmbH, Schramberg, Germany

Direct diode lasers are of great interest in many fields of today's industrial laser material processing. During the past decade low-brightness multi-kW direct diode lasers have successfully replaced flash lamp pumped rod lasers in laser metal processing applications such as surface treatment, brazing and welding. The striking advantage of such lasers compared to optically pumped solid state lasers consists of higher compactness and enhanced electrical-to-optical conversion efficiency of up to 50%. Quite recently high-brightness external cavity dense wavelength beam combined diode lasers have come of age which are able to serve all kinds of high-brilliance laser applications as for instance flat-sheet metal cutting or remote welding. In our talk we report on dense wavelength beam combining (DWBC) of ten horizontally stacked broad-area laser diode bars by using a novel multi-laser cavity approach based on a thin-film filter (TFF) as a dispersive optical element. The wavelength-stabilized output of the TFF cavity is beam combined upon a transmission grating in Littrow configuration. Hereby a cylindrical telescope is used for dispersion matching between the TFF and the combiner grating. We demonstrate a direct diode laser with an output power of 500 W from a 100-$\mu$m, 0.1-NA fiber and discuss limitations of beam quality preservation using this DWBC architecture.

Q 28.6 Wed 12:15 a310

**Passiv harmonisch-modengekoppelter Yb:CALGO-Laser** — •Hauke Bensch[1] und Uwe Morgner[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, D-30167 — [2]Laser Zentrum Hannover, Hollerithallee 8, D-30419 Hannover

Um hohe Pulsenergien zu erreichen werden normalerweise Laseroszillatoren verlängert, wodurch bei gleicher mittlerer Leistung die Pulsenergie ansteigt. Durch diese Verlängerung der Resonatoren sinkt jedoch die Repetitionsrate des Systems. Um die höheren Pulsenergien bei langen Resonatoren mit höheren Repetitionsraten nutzen zu können, bietet die harmonische Modenkopplung eine mögliche Lösung. Dieser Lösungsansatz wird an einem SESAM-modengekoppelten Yb:CALGO-Oszillator präsentiert, dessen solitärer Multipulsbetrieb passiv so gesteuert werden kann, dass der Laserbetrieb sich auf das genaue Vielfache der fundamentalen Repetitionsrate stabilisiert. Um diese Phasenstabilität zu verdeutlichen, wird der harmonisch gelockte Multipulsbetriebs anhand des Radiofrequenzspektrum mit einer schnellen Photodiode untersucht, wozu zum einen die resonatorinterne Leistung und zum anderen die Gesamtdispersion des Systems variiert wird. Anhand dieser Messungen ist ersichtlich, dass beim harmonisch-modengekoppelten Multipulsbetrieb die fundamentale Repetitionsrate komplett unterdrückt werden kann, während dies bei einem einfachen Multipulsbetrieb nicht zu beobachten ist. Somit vereint der präsentierte SESAM-modengekoppelte Yb:CALGO Oszillator die Vorteile höherer Pulsenergie bei gleichzeitig höheren Repetitionsraten.

Q 28.7 Wed 12:30 a310

**Development of a cavity dumped 4-crystal oscillator based**

**on Yb:CALGO** — •Jana Kampmann[1], Bernhard Kreipe[1], and Uwe Morgner[1,2] — [1]Institute für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [2]Centre for Quantum Engineering and Space-Time Research

The possibiltiy to scale the output parameters of oscillators by using multiple gain media is explored and different approaches on a modular setup were tested. In this scheme, the total pump power that is needed to scale the pulse energy can be enhanced without accumulating too much heat in a single crystal. Operating the system with cavity-dumping enables high outcoupling ratios, whereas the reduced repetition rate will lead to even higher pulse energies. Due to beneficial properties like a high thermal conductivity and a large bandwith, Yb:CALGO is choosen as gain material.

Q 28.8 Wed 12:45 a310

**Polarization effects in bulk and waveguide lasers in cubic $Pr^{3+}$:$KY_3F_{10}$** — •Dominik Brüske[1], Thomas Calmano[1,2], Philip Werner Metz[1], Christian Kränkel[1,2], Daniel-Timo Marzahl[1], 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, Luruper Chaussee 149, 22761 Hamburg, Germany

Due to the cubic structure of rare earth doped $KY_3F_{10}$ no polarization dependence in the spectroscopic characteristics is expected. However, since each doping ion is surrounded by eight fluorine ions in $C_{4V}$ symmetry a predominant local symmetry axis is provided, resulting in polarization dependent spectroscopic characteristics despite the cubic structure. With a suitable doping ion, this effect allows for switching of the laser wavelength by simply changing the pump light polarization. Utilizing $Pr^{3+}$:KYF, we achieved wavelength switching between 610 nm in the orange and 645 nm in the red in bulk and fs-laser written waveguide lasers.