CSC-RUB PhD Project Proposal

Title: High-power solid-state laser modelocking at 3 µm wavelength

Sector of research: PhD

Degree awarded: Laser Physics and Engineering

Keywords: Laser Physics, High Power lasers, Laser materials, Modelocking, Ultrafast Lasers

Supervisor of PhD project: Prof. Dr. Clara Saraceno, Photonics and Ultrafast Laser Science, Faculty of Electrical Engineering and Information Technology, e-mail: clara.saraceno@rub.de

Research focus of supervisor: Our research focuses on advancing ultrafast laser technology, explore new areas of coherent light generation using nonlinear optics, and apply our uniquely tailored ultrafast sources to better understand chemical, biological, and physical processes. Our core expertise is in the development of high-average power and high-repetition rate femtosecond modelocked oscillators based on the thin-disk geometry, where we demonstrate record-holding systems. In addition to developing cutting-edge laser sources, we are pioneers in the use of these high-average power lasers to generate high-power Terahertz pulsed radiation and we apply these unique THz sources in imaging and spectroscopy.

5 Key Publications in the last 5 years:

“Moving towards high-power thin-disk lasers in the 2-µm wavelength range” S. Tomilov, M. Hoffmann, Y. Wang, C. J. Saraceno - Journal of Physics: Photonics, Volume 3, Number 2, 2021 (invited paper)

“High-power modelocked thin-disk oscillators as potential technology for high-rate material processing” Y. Wang, S. Tomilov and C. J. Saraceno - Advanced Optical Technologies, vol. 10, no. 4-5, 2021 (invited review)


Second Supervisor of PhD project Prof. Dr. Poul Petersen, Chemistry Faculty (TBD)

Summary of research plan:

Background: Ultrafast lasers in the mid-infrared region (2–5 µm) are an intense topic in laser research owing to their many applications, for example fast material processing of polymers, enhanced nonlinear conversion from the XUV to the THz region, and vibrational absorption spectroscopy. Among these exciting areas, high-average power, ultrafast 3 µm laser sources have big potential for THz generation and water science, which are at the focus of the research of the proposed host institution. The use of longer wavelength drivers improves the conversion efficiency of THz generation in modern schemes and directly provides complimentary spectroscopy possibilities.

Study objective: Most ultrafast 3 µm lasers are low average power, complex and expensive parametric amplifiers. A much more compelling route is to generate powerful ultrashort pulses directly with laser gain media emitting at 3 µm, in power-scalable laser geometries. In this respect, bulk and thin-disk lasers (TDL) geometries are promising, as they can directly
provide high average power and high repetition rate modelocking, without complex multi-
stage amplifiers, an area where the host group has large expertise. However, so far, no ultrafast bulk or TDL in this wavelength have been demonstrated, making this an area with large potential. The main objective of this project is therefore to achieve mode locking of solid-state laser using gain materials emitting in the 3 μm wavelength region first in the bulk geometry and then in the thin-disk geometry to achieve tens of watts of average power, and apply this source for THz generation.

**Expected Results:** If we achieve the main objective as described above we will significantly advance the field of ultrafast laser science and several high-ranked publications can be expected. In fact, modelocking of solid-state lasers in this wavelength range has been a long-sought goal from the community, but was prevented by a lack of expertise in the finer details of modelocking mechanisms – an expertise the host group has. We expect a first demonstration and a power scaling experiment to result in a minimum of two high-impact publications (Impact Factor of >10). Last but not least, the resulting THz source will additionally generate its own sets of high-impact results with comparable impact factor.

**Methods:** The study will be started with Erbium-doped sesquioxide (Er:Lu2O3) and some novel mixed (Er:(Lu,Sc)2O3) ceramics, which offer a good compromise between thermal conductivity, phonon energy, and gain bandwidth for high power ultrafast 3 μm laser. We will first focus our attention on Kerr-lens mode locking, to achieve shortest pulse width. All characterization tools required for measuring the performance of the laser is available through our ERC project which aims to do modelocking at a slightly shorter wavelength – but can be used for this wavelength too.

**Candidate Requirements:** The candidate should hold a degree in Physics, Electrical Engineering or equivalent, and ideally have experience with laser physics. Excellent English language skills and the desire to work in an international team are crucial. A proactive attitude, self-organized work and team spirit are particularly valued skill for the candidate. You hold an A-grade (“very good”) qualifying degree at either the level of Master or Diploma to enter the iGSS’s Track I or an A-Grade (3 yr. or, preferably, 4 yr.) Bachelor to enter the iGSS’s Track II.

**Motivation for CSC application** (max 250 words): The host group is an internationally renowned group for ultrafast laser development, and the candidate would be part of a world-leading team in the area of the topic proposed, which will provide him extremely valuable methods on ultrashort pulse generation, characterization and nonlinear optics – both experimental and simulations. This will certainly bring the candidate visibility and know-how. The planned publications will also form the candidate in scientific writing and the scientific publishing process. The state-of-the-art laser labs of the host group are equipped with most modern characterization tools for ultrashort pulses and modelocking – since all equipment was purchased in the last 5 years with generous starting grants. In this context, the candidate has a unique position to publish a large number of publications of high quality. I strongly encourage my group members to attend international conferences, which will also enhance the candidate’s visibility to the international community. Last but not least, the group’s unique link to RESOLV makes this project already ready for applications in spectroscopy and other multidisciplinary fields of physics and chemistry. In this respect, the candidate’s enrolment in the iGSS program of RESOLV will have additional benefits:

- You will be embedded in a high-profile research environment.
- You are integrated in the International Faculty Solvation Science and will gain international work experience during a 2 – 3 months internship abroad.
- You will benefit from personal development possibilities, the entrepreneurial attitude within RESOLV and a broad spectrum of lectures as well as transferable skills courses.
- You will develop your science communication skills by presenting your research to the public.
- You are provided with funding for visiting international conferences.