2023 Helmholtz – OCPC – Programme

for the involvement of postdocs in bilateral collaboration projects

PART A

Title of the project:

High-power sources for ultrafast, infrared strong-field science

Helmholtz Centre, division:

GSI, division HI Jena, work site: DESY Hamburg

Project leader:

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Research Group:

DESY / GSI Young Investigator Group for High-power Laser Development

GSI-OCPC Programme Coordinator:

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Description of the project:

The mid-infrared (mIR) spectral region offers a great variety of scientific, medical, chemical and environmental sensing applications as it covers characteristic dipole transitions of molecular vibrations, phonons and magnons. Furthermore, frequency down-conversion of energetic near-infrared (nIR) lasers enables the generation of powerful light pulses with a high pulse-to-photon energy ratio. Subsequently, field-sensitive effects prevail over multi-photon events in intense light-matter interactions. The consequent strong biasing of matter can, for instance, lead to phase-transitions in so-called quantum materials.[1] Due to their property of undergoing macroscopic changes through only small stimulations, they are of utmost interest in modern time-resolved spectroscopy as performed, for example, at FLASH, DESY's free electron laser facility in Hamburg, Germany.[2]

Due to the risk of damage and slow relaxation times, solid-state materials are typically excited by ultrashort pulses with a few μJ of pulse energies and 100 kHz – 1 MHz repetition rates. In this way, nonlinear effects are accessible and high data rates are possible. Whereas the target laser parameters are readily accessible in the visible and nIR spectral regions, it is challenging to generate multi-μJ mid-infrared pulses at up to MHz rates, especially at central wavelengths longer than 5 μm. By means of single-stage down-conversion of an ultrafast Yb:YAG nIR laser, conversion efficiencies of only a few percent have been reached for Watt-level mIR generation,[3] i.e. for a 10 μJ MHz pulse train at 10 μm wavelength, a 1 μm driver of at least 300 W average power would be required.

For maximizing the mid-infrared pulse energies, cascaded frequency down-conversion presents an attractive alternative. In particular, degenerate optical parametric oscillators

(OPOs) are capable of reversing the second harmonic generation process and can efficiently split one nIR photon into two mIR ones.[4] However, synchronously pumped OPOs typically run at tens to hundreds of MHz repetition rates as the optical feedback paths become otherwise tens or hundreds of meters long. Nevertheless, we target to implement a 1 MHz, high energy mid-IR OPO due our experience in laser synchronization[5] and building long optical delay lines for spectral broadening applications[6] as well as due to outstanding interest in the mid-infrared sources.
The successful candidate for the postdoctoral stipend will take a leading role in the development of degenerate OPOs and associated frequency down-conversion schemes. This primarily includes experimental work in DESY's modern and well-equipped laser laboratories. In addition, supporting numerical simulations and advising of graduate level students would be desired.

[1]D.N. Basov et. al., "Towards properties on demand in quantum materials", Nature Materials 16, 1077 (2017).
[2]M. Beye and S. Klumpp, "FLASH2020+ conceptual design report," Tech. rep. DESY (2020).
[3]M. Seidel et al., "Multi-watt, multi-octave, mid-infrared femtosecond source," Sci. Adv. 4, eaaq1526 (2018).
[4]A. Marandi et al., "Cascaded half-harmonic generation of femtosecond frequency combs in the mid-infrared", Optica 3,324 (2016).
[5]S. Schulz et al., "Femtosecond all-optical synchronization of an X-ray free-electron laser", Nat. Commun. 6, 5938 (2015).
[6]M. Seidel, et al., "Factor 30 Pulse Compression by Hybrid Multipass Multiplate Spectral Broadening", Ultrafast Science 2, 9754919 (2022).

Description of existing or sought Chinese collaboration partner institute (max. half page)**:**

Required qualification of the postdoc:

- PhD in optics, physics or electrical engineering
- Experience with high-power, ultrafast lasers and nonlinear frequency conversion
- Additional skills in laser synchronization and nonlinear pulse propagation simulations as well as international work experience are a plus
- Very good oral and written English skills