Generation and Applications of High-Energy Few-Cycle Mid-IR Pulses

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Femtosecond mid-IR lasers in the 3—8 μm wavelength range hold great promise for numerous areas of the AMO research. There are several broad application scopes for each of the currently achievable pulse energy and repetition rate ranges. Microjoule-level sources are required for 2D mid-IR spectroscopy permitting access to ultrafast structural dynamics of molecules through bond-specific vibrational coupling. (Sub-)millijoule mid-IR pulses are required in strong-field molecular techniques to prevent premature photo-dissociation of large(r) molecules. Multimillijoule mid-IR driver, as a consequence of a λ^2 scaling of the ponderomotive energy, are critical in the generation of coherent and incoherent secondary radiation in the X-ray and THz domains. Such high-energy driver pulses are also proving indispensable in femtosecond filamentation because of the unique opportunity to initiate plasma-chemical reactions with hot electrons emitted through long-wave optical field ionization.

The talk reviews the current status of the intense mid-IR laser research at TU Vienna aimed at solving the scalability challenges of secondary sources and their laser pump systems. We identify the limits of the current laser technology of 1-μm pump lasers based on Nd:YAG picosecond amplifiers and Yb:CaF_2 femtosecond chirped-pulse amplifiers (CPA). Whereas the use of such 1-μm pump lasers enables broadband parametric amplification at wavelengths up to 4.2 μm using state-of-the-art KTA crystals, shifting the pump wavelength to 2.1 μm opens the way to extend the range of efficient parametric amplification deeper into the mid-IR. We demonstrate a prototype parametric amplifier, based on a ZGP crystal pumped by femtosecond pulses at 2.1 μm, which operates at the central wavelength of 6 μm and supports a single-cycle pulse bandwidth. Finally, we report on our efforts to develop a dedicated 2.1-μm pump laser for mid-IR parametric amplification and present a multi-millijoule 0.5-ps kHz-repetition-rate CPA system based on a cw-pumped Ho:YAG regenerative amplifier.