Multi-mJ SWIR OPCPA pumped and seeded with 1.2 ps Yb:YAG laser

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Few-cycle short-wavelength infrared (SWIR) pulses are in demand for research in strong field physics and nonlinear optics, efficient generation of attosecond X-ray pulses and THz radiation. At the same time, broadband SWIR-MIR pulses, covering many important molecular vibrations, are useful for remote sensing and LIDAR. Lasers with multi-mJ femtosecond pulses at a wavelength of 2 µm are needed to pump Mid-IR parametric amplifiers based on non-oxide crystals (ZGP, $CdSiP_2$, OP-GaAs) to go beyond 4 µm. Optical parametric chirped pulse amplification (OPCPA) has been successfully applied to generate multi-mJ SWIR pulses. One possible implementation of the SWIR OPCPA is based on the use of a small portion of the pump laser energy to generate a supercontinuum (SC) up to 2.5 µm, which is amplified in one or more OPCPA stages. We demonstrate a non-collinear amplification of white-light supercontinuum seed pulses in three degenerate OPCPA (DOPA) stages based on bismuth triborate (BiBO) crystals up to 2.2 mJ in the wavelength range of 1.9 – 2.3 µm.

The experimental setup of the three-stage SWIR OPCPA is shown in Fig. 1. The pump source for both SC and OPCPA is a homemade two-stage double-pass Yb:YAG chirped pulse amplifier with a grating compressor that provides transform-limited ~1.2 ps pulses with an output energy of up to 20 mJ at a repetition rate of 100 Hz [1]. SC seed pulses were generated in a YAG crystal 15 mm long [2] and stretched to 550 fs in 30 mm long ZnSe plate. Amplification of broadband seed pulses was carried out in a three-stage noncollinear OPCPA based on BiBO crystals (type-I, phase matching angle θ = 8°) AR-coated in the range of 1750 – 2500 nm. The sizes of BiBO crystals in three OPCPA stages are 4×4×6 mm^3 for OPA 1, 10×10×4 mm^3 for OPA 2 and 15×15×4 mm^3 for OPA 3, respectively. After amplification, the pulses were compressed in a Suprasil 300 glass plate of 55 mm long.

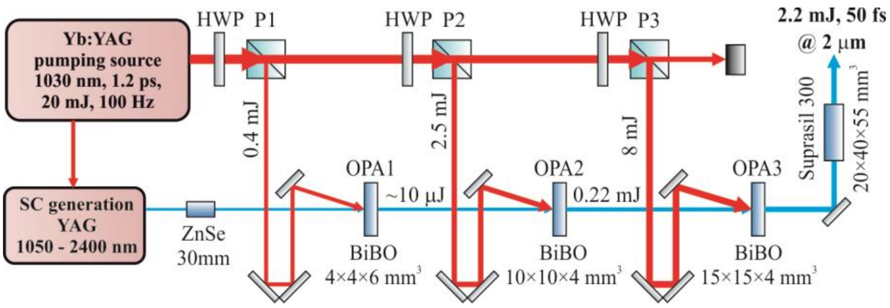

Fig. 1 Experimental layout of SC amplification in three OPCPA stages based on BiBO crystals: P1, P2, P3 –polarizing cubes, HWP – half wave plate, ZnSe– zinc selenide plate.

In the first OPCPA stage, the best conversion efficiency of ~3% with maximum signal energy of >10 µJ was observed at a pump intensity of 60 GW/cm^2. In the second OPCPA stage, pump-to-signal conversion efficiency of 10% was achieved at a pump intensity of 40 GW/cm^2. After two OPCPA stages, the signal amplified to 220 µJ. Finally, in the third OPCPA stage achieved a record conversion efficiency of 30% and output pulses with energies greater than 2 mJ at a center wavelength of 2.05 µm, supporting a transform-limited pulse width of ~30 fs. An even higher output energy can be obtained by using the maximum pump energy in BiBO crystals with a larger aperture. After three OPCPA staged, the pulses were compressed from 480 fs to 50 fs in a glass plate.

Thus, we have developed SWIR OPCPA with output pulses of 40 GW peak power in the 1.9 – 2.3 µm wavelength range. This is sufficient for filamentation in gas cells filled by N_2 or H_2 and a significant expansion of the spectrum to wavelengths beyond 3 µm due to the excitation of rotational stimulated Raman scattering.

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References

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