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High Average Power Nonlinear Pulse Compression in a Gas-filled Multi-pass Cell at 2 µm Wavelength

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Ultrafast lasers sources in the short-wavelength infrared region (SWIR, 1.5 µm to 3.0 µm wavelength) are of great interest for manifold direct applications, as well as for nonlinear frequency conversion techniques addressing terahertz, mid-infrared or even soft to hard X-ray spectral regions [1-3]. Especially, the so called “water window” spectral region which expands from around 280 eV–530 eV is of utmost interest in high-resolution imaging or SXR-spectroscopy of biological specimen [4]. These and other applications emphasize the demand for scalable, high-flux, table-top coherent soft X-ray sources which can be obtained via high-order harmonic generation (HHG) from SWIR driving lasers. One concept that can provide ultrafast high-average power SWIR pulses is optical parametric chirped-pulse amplification (OPCPA) [5]. Another concept aimed at high-power ultrashort pulse generation in the SWIR is based on thulium-doped fiber chirped-pulse amplification systems (Tm:FCPA). These lasers deliver multi-GW peak powers, multi-100 W average output power with pulses as short as sub-100 fs [6]. Nevertheless, a subsequent pulse shortening according to the above discussion is typically desired.

Traditionally, this is done in waveguides such as noble gas-filled capillaries [7]. Besides fiber-based post-compression schemes, multi-pass cells (MPC) have emerged as an attractive approach for nonlinear post-compression, showing excellent preservation of the input beam quality and high throughput efficiency [8-9]. Until now, MPCs have been rarely demonstrated in the SWIR wavelength regime, especially at high average power levels of several tens of Watt.

We report on the first nonlinear pulse post compression of the output from a Tm:FCPA using a gas-filled Herriott-type MPC. The driving laser system delivers 138 fs pulses (FWHM) and 65 W of average output power at a repetition rate of 300 kHz, centered at a wavelength of 1940 nm. The MPC is filled with krypton gas at 3 bar of pressure and the throughput is as high as 80%. After the beam propagation through the cell, fused silica is employed to post compress the spectrally broadened pulses to a FWHM duration of 35 fs, with an estimated peak power of several GW. For analyzing the post compressed output pulses in detail, we employed an in-house built SHG-FROG device. The corresponding results are depicted in Fig.1. At 300 kHz repetition rate, a record compressed average power of 51 W is demonstrated, which is the highest to date from any SWIR MPC-based nonlinear pulse post compression experiments.

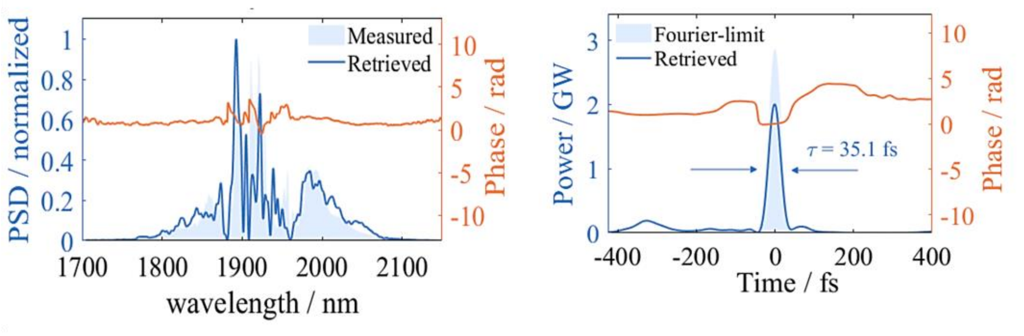

Fig. 1 FROG measurement of the post compressed MPC output.
Left plot, measured and retrieved spectrum. Right plot, retrieved pulse and corresponding Fourier-limit.

This result shows the scalability and enormous potential of the MPC technology in the 2 µm wavelength region, where nonlinear pulse compression at high average power is challenging due to the unfavorable existence of water vapor absorptions [10]. The experiment presented in this contribution is an important development step towards highly application relevant laser-driven nonlinear frequency conversion experiments and further performance enhancement towards mJ-energy, few-cycle laser sources at 2 µm wavelength with >100 W average power.

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