Highly stable, few-cycle, 2.2-μm optical parametric chirped pulse amplifier

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Synopsis: We demonstrate a 10-GW peak power, 3-optical-cycle, CEP-stabilized, 2.2-μm OPCPA with 1-kHz repetition rate. Implementation of superfluorescence suppression techniques enables rms energy and intensity fluctuations of only 1.5% and 0.8%, respectively.

Since the prediction of high-yield soft X-ray photon generation through high harmonic generation (HHG) with long-wavelength drive pulses [1, 2], the development of high-power, few-cycle, carrier-envelope phase- (CEP-) stabilized sources in the mid-IR has attracted great attention. Ultra-broadband optical parametric chirped pulse amplification (OPCPA) is one of the promising techniques to meet the requirement for the driving source.

In this paper, we report on the development of a 2.2-μm OPCPA which generates 10-GW, 3-optical-cycle pulses (230 μJ, 23 fs) at 1 kHz. Several design features are implemented in our setup to suppress superfluorescence (SF), which is a critical issue for high-power mid-IR OPCPA systems [3, 4]. Especially, we carefully avoided loss in the stretching and introduced additional chirp between pre-amplification stages and power amplification stage to achieve high conversion efficiency, broad signal spectrum, and low SF simultaneously. SF suppression is evidenced by an unprecedented clean spectrum and low energy fluctuation. The current results suggest that this OPCPA design can be scaled to the multi-mJ energy level without SF taking over the signal, which will allow absorption-limited HHG in the water window.

Fig. 1 shows the amplified spectrum (a) and the corresponding interferometric autocorrelation trace (b) of the OPCPA system. The pulse is compressed nearly to its transform limit, i.e., 23 fs, or 3 cycles in FWHM. The CEP stability is characterized using an *f*-to-3*f* spectral interferometer and Fig. 1(c) shows that the rms phase fluctuation is ~150 mrad over 10 s, where the residual phase excursion at time = ~2 s is attributed to the amplitude–phase noise coupling in the *f*-to-3*f* interferometer while any significant drift is not observed during 10 s.

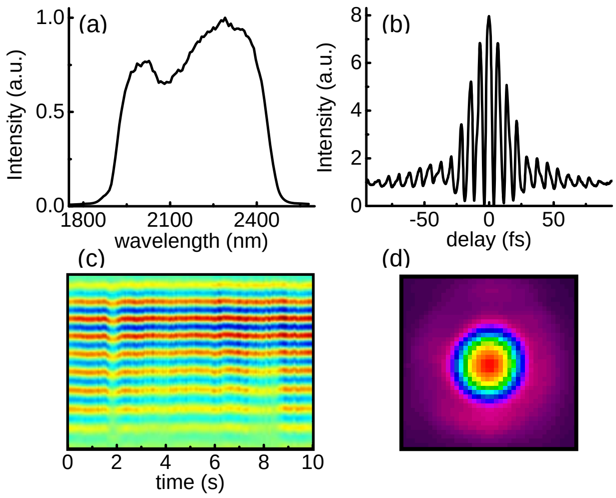

Fig. 1. (a) Amplified spectrum, measuring 500-nm FWHM in bandwidth. (b) IAC of the compressed pulse, measuring 23 fs (3 cycles). (c) *f*-*3f* spectral interferogram, measuring 150 mrad rms in CEP fluctuation. (d) Pyrolelectric CCD image of the output beam.

The SF level is estimated by measuring the energy fluctuation and the intensity fluctuation, followed by statistical analysis and is about 8%. With slightly less saturation in the power amplification stage, 170 μJ signal energy with SF reduced to 2%is obtained.

References

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