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Octave-Spanning Supercontinuum Generation for an Er-doped Fiber Laser Frequency Comb at a 1 GHz Repetition Rate

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Abstract: We report a 1GHz Er-doped femtosecond fiber laser system that provides 2nJ pulses at ~100fs durations and generates octave-spanning supercontinuum generation from 1µm–2.4µm in a highly nonlinear fiber that is suitable for 1f-2f stabilization of the frequency comb.

OCIS codes: (140.3280) Laser amplifiers; (140.3500) Lasers, erbium; (320.7090) Ultrafast lasers

High repetition rate optical frequency combs have long garnered particularly strong interest in the fields of frequency metrology [1], optical arbitrary waveform generation [2], and high speed A/D conversion [3]. Recent advances in pump sources have led to the development of lasers operating at GHz repetition rates, thus opening more applications such as the generation of astrocombs for space exploration [4, 5]. These laser sources can further be amplified and compressed enabling octave-spanning supercontinuum generation allowing for stabilization of such frequency combs. This paper reports on the development of a 1GHz Er-doped femtosecond fiber laser and high-power amplifier system providing 2nJ pulses at ~100fs durations, which is suitable for generating supercontinuum spanning an entire octave from 1µm – 2.4µm.

The current configuration of the system is depicted in Figure 1. A 1GHz fundamentally mode-locked erbium fiber laser generating ~2pJ pulses with transform-limited durations of ~500fs was developed to seed the amplifier. The laser’s linear cavity is made up of ~83mm of 80dB/m Er-doped anomalous dispersion gain fiber, butt-coupled to a 5% dielectric-coated output coupler on one end, collimated and focused onto a SBR (23% modulation depth) on the other end. A single 980nm laser diode pumps the cavity, providing ~200mW of coupled power into the gain fiber. Approximately 1mW of the oscillator output is coupled into a pre-amplifier designed to provide ~17dB gain. The pre-amplifier, which is pumped with a single 980nm laser diode outputting 500mW, amplifies the pulse train up to ~65mW. The next stage of the amplification process is comprised of a Raman fiber laser, capable of outputting up to 10W of power at 1480nm, pumping a section of 110dB/m Er-doped gain fiber. The gain fiber’s high absorption ensures that only a short length is needed to extract most of the pump, thus minimizing the amount of nonlinear phase shift accumulated during the amplification process. An optimized gain fiber length of ~1.5m was determined using a cut-back procedure maximizing the conversion of pump to signal power, yielding pulses with energies greater than 2nJ. A plot of the amplifier’s performance at various pump powers is shown in Figure 2(b).

To generate octave-spanning supercontinuum, the amplified pulses need to be compressed to sub-100fs durations. The compression component of the system is entirely based on spectral generation during amplification in the normal dispersion gain fiber, and is therefore accomplished through the optimization of pre- and post-chirp fiber lengths. An appropriate length of SMF pre-chirp fiber anomalously chirps the pulse train so that the pulses...
recompress to their transform limit near the end of the gain fiber. The output spectrum shown in Figure 3(a) is a result of ~1.2m of pre-chirp fiber. The nearly symmetric structure in the spectrum indicates that SPM dominates the spectral broadening process, which is to be expected in a normal dispersion medium. The spectrum out of the amplifier is broadened to a FWHM of ~25nm, which is a five-fold increase over the spectrum directly out of the oscillator. A ~1m length of SMF post-chirp fiber is used to compensate for chirp resulting from the spectral broadening process. The pulses can be compressed down to ~100fs with only slight pedestals.

Figure 2: (a)RF spectrum of the 1GHz laser output. (b)Output performance of the amplifier for different pump powers

The ~2nJ, ~100fs pulses are sent into a ~11cm piece of UV-exposed small-core silica HNLF from OFS to generate supercontinuum. Figure 3(b) shows the generated supercontinuum, which spans over an octave from 1µm – 2.4µm. In addition, the concentrated power around 1µm and 2µm should ease measures for frequency comb stabilization.

Figure 3: (a) Comparison of the optical spectrum of the laser (black curve) and amplifier (red curve) output. (b) Octave-spanning supercontinuum spectrum (blue curve) generated with ~2nJ, ~100fs pulses using a UV-exposed HNLF.

In conclusion, we have developed a 1 GHz Er-doped femtosecond fiber laser. The amplified sub-100fs pulse with 2nJ pulse energy from a high-power Er-fiber amplifier enables supercontinuum generation spanning an entire octave from 1µm – 2.4µm, which is suitable for 1f-2f stabilizing the frequency comb.

References