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Multi-GHz repetition rate femtosecond electro-optic frequency comb based on one single phase modulator and non-linear processes

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Abstract. We report on a multi-GHz repetition rate, femtosecond fiber laser operating in the burst mode, achieved by nonlinearly shaping and amplifying a phase-only modulated electro-optic comb at 1.03 µm. The system delivers an average power of 1.2 W with pulses compressible down to sub 100 fs.

1 Introduction

Ultrashort laser pulse generation at GHz repetition rate has attracted more and more attention in recent years. With tens or hundreds of times higher repetition rate than conventional mode-locked lasers, GHz lasers are advantageous for various applications, such as high-efficiency laser ablation [1], real-time spectroscopy [2], high-speed optical transmission systems [3] and so on. Electro-optic (EO) frequency combs emerging in recent years, represent a unique way of generating ultrashort pulses at widely tunable multi-GHz repetition rates free of mode locking. Ultrafast EO combs are usually composed of a continuous-wave (CW) seed laser, a few phase modulators to broaden the spectrum, an intensity modulator to carve pulses and various radio-frequency (RF) electronics. Simplifying their modulation to only one phase modulator could greatly reduce the complexity and cost. In this contribution, using an EO comb comprising a single phase modulator associated to non-linear propagation and amplification, we demonstrate a burst-mode, multi-GHz-repetition-rate femtosecond fiber laser system.

2 Experimental setup

Fig. 1(left) shows the experimental setup for the fiber laser system seeded by a phase-only modulated EO comb. The EO comb consists of a continuous-wave (CW) single-frequency diode laser at 1030 nm and an EO phase modulator driven by a RF signal at 17.5 GHz. The sinusoidal modulation of the laser phase broadens the seed laser's spectrum with comb lines evenly spaced by 17.5 GHz and, at the same time, introduces quasi-linear up and down chirps. The quasi-linear down chirp is then compensated in a long single mode fiber leading to the compression of the modulated photons associated with the down chirp, while the photons modulated with the opposite chirp acquire an additional chirp further extending their temporal span, resulting in a significant pedestal and a poor pulse contrast.

The low contrast ~2 ps pulse train is further gated to produce bursts of pulses (60 kHz burst repetition rate, 50 ns burst duration), linearly amplified and finally nonlinearly filtered by a Mamyshev regenerator.

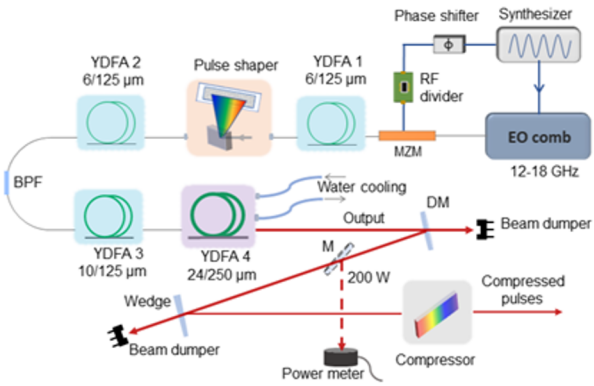

Fig. 1. Experimental setup for the laser system. AOM: acousto-optic modulator; AMP: amplifier.

2 Results and discussion

Fig.2 shows the measured spectrum of the initial EO comb, as well as the spectra after nonlinear broadening and spectral filtering by the Mamyshev regenerator. The filtered spectrum is ~1 nm wide (FWHM) centered at

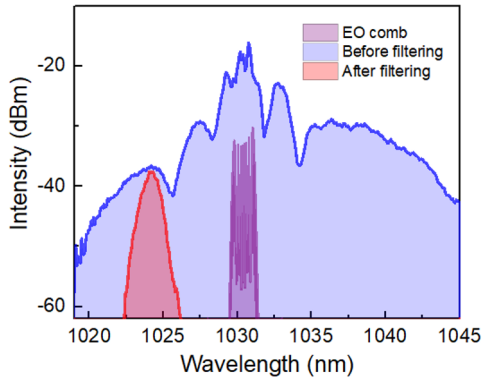

Fig. 2. Initial spectrum of the EO comb and spectra before and after filtering in the Mamyshev regenerator.

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1024 nm, corresponding to a clean pulse of 1.7 ps after chirp compensation. The clean pulses are then linearly amplified and injected to a 10-µm-core Yb-fiber for further nonlinear amplification up to 1.2 W [4]. The output pulses from the last fiber amplifier are finally

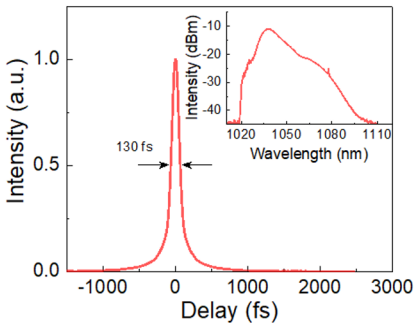

Fig. 3. Autocorrelation trace of the output pulses and output spectrum

compressed by a grating pair and characterized by autocorrelation (AC). The measured AC trace has a FWHM duration of 130 fs, as shown in Fig. 3, indicating a sub-100 fs pulse duration. The measured output spectrum has a 10 dB bandwidth of 32 nm, as displayed in the inset of Fig. 3. The spectral profile shows a shifted center wavelength to 1040 nm and a tail extending to longer wavelengths, due to broadening by self-phase modulation and the evolving gain spectrum along the active fiber.

3 Conclusion

In conclusion, we have demonstrated sub 100 fs all-fiber laser at 17.5 GHz repetition rate operating in burst-mode. It is based on nonlinearly shaping and amplifying a phase-only modulated EO comb. The system simplifies conventional ultrafast EO combs, while providing femtosecond pulses with enhanced energy in burst mode and the potential for further power/energy scaling.

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