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Synchronized and tunable femtosecond laser source from CW laser

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Ultrafast fiber-based laser sources are key tools for a large variety of applications in scientific research, medicine, and industry [1]. Fiber oscillators are generally based on mode-locking (ML). Another way to obtain short optical pulses from a CW laser is based on the electro-optic pulse gating approach. This technique allows one to generate pulses down to tens of picoseconds and the repetition rate can be tuned from a few MHz up to a few GHz and synchronization with an external signal with a peak-to-peak timing jitter below 1ps. By using commercially available fibered components and ytterbium-doped fibers, it is straightforward to generate Watt-level optical power around 1.0 µm. With this optical power level and tens of picosecond pulse durations, it is possible to reach the sub-picosecond regime thanks to self-phase modulation (SPM) in long optical fibers. The optical spectrum can be broadened up to a few nm using polarization maintaining (PM) single-mode fiber operating in the normal dispersion regime. Then ultra-short pulses can be retrieved using standard compression techniques. The experimental setup is shown in Figure 1. A 100 mW CW DFB laser diode operating at 1031.6 nm is spliced to a fiber-pigtailed MZM (20 GHz BW) driven by a homemade high-speed pulse generator (45ps FWHM electrical pulses). The pulse repetition rate is controlled by an external RF synthesizer and we operate the laser from 10 MHz to 100 MHz. The intensity modulator is actively bias controlled in order to maximize the Extinction Ratio (ER) between the optical pulses and the CW background (> 30 dB). The optical pulse train obtained at the MZM output is amplified up to 2 W of average power and injected in 150 m of PM980 fiber. Simulations were used as a guide to determine the optimal fiber length in our system, indicating that 150m is sufficient to obtain significant spectral broadening (10nm at -10 dB) [2].

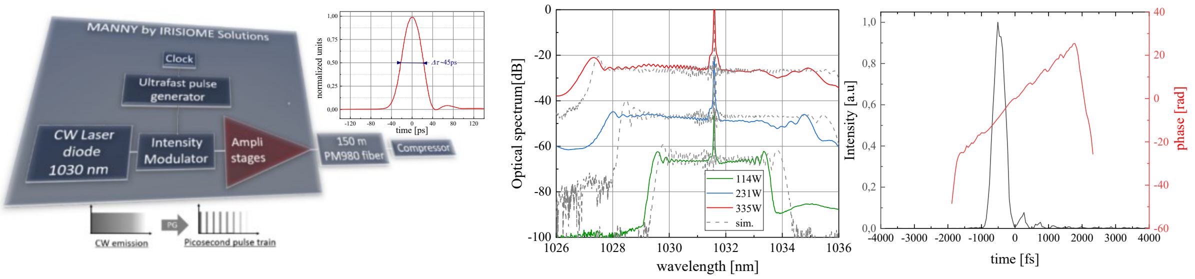

Fig. 1. (Left) Experimental setup for the laser system and measured optical pulse. (Middle) Simulated and measured spectra with different input powers level. (Right) FROG trace of the output pulses and (intensity and phase) at 10MHz repetition rate.

Experimentally, we observe the onset of Stimulated Raman Scattering (SRS) (not considered in the simulations). However, despite the onset of SRS, the spectrum continues to broaden. A saturation of the spectral broadening occurs when the second order Stokes appears [3]. We compressed the output pulses using a homemade grating compressor (1750 l/mm) and measured the compressed pulses (30 nJ) with a single-shot FROG, the FWHM pulse duration is 377 fs (368 fs transform limited pulse). The temporal profile is clean, despite small post-pulses inherited from the ps pulse of the output of the amplifier. Indeed, the initial post pulses has created several post pulses during the nonlinear propagation. However, most of the energy, about 94%, is contained in the main pulse. The retrieved pulse durations are almost the same for the different repetition rates when the injected power is tuned at the input of the nonlinear fiber to obtain same spectral broadening. Usually, the compressor must be reoptimized when changing the laser output power since the chirp and spectral broadening vary with the peak power [4]. Therefore, it is possible to obtain the shortest pulse duration without changing the compressor length, while modifying the pulse repetition rate to realize unprecedented agility. The power tuning is not critical and can support up to 10% of variation with negligible impact on the pulse duration and shape. We have demonstrated an agile and simple alternative to mode-locked lasers. With this experiment we open new avenues in non-mode-locked femtosecond sources for application requiring agility and simple synchronization with low timing jitter. This paves the way to use this technology for instance in micromachining or other applications where high repetition rates are beneficial [5].

References

[1] U. Keller, Appl. Phys. B, **100**, 15-28 (2010).
[2] S. Pierrot and F. Salin, Opt. Express, **21**, 20484-20496 (2013).
[3] A.M. Weiner, J. P. Heritage and R. H. J. Stolen, Opt. Soc. Am. B, **5**, 364-372 (1988).
[4] J.P. Heritage, A.M. Weiner, R.J. Hawkins and O.E. Martinez, Optics Communications, **67**, 367-372 (1988).
[5] W. Renard, C. Chan, A. Dubrouil, J. Lhermite, G. Santarelli and R. Royon, Laser Phys. Lett. **19**, 075105 (2022)