Demonstration of supercontinuum and frequency shifted solitons pumped at 1.56 µm as seed sources for Tm-doped fiber amplifiers

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Stable, low noise and coherent light sources operating in near- and mid-infrared regime draw much attention recently due to their potential scientific, medical and industry applications. Nonlinear effects that occur in microstructured silica fibers, e.g. soliton self-frequency shift (SSFS) [1] or supercontinuum (SC) generation [2] can be exploited to build such sources as an alternative to lasers based on conventional gain media, e.g. Ho- or Tm-doped fibers combined with different mode-locking techniques. Nowadays, the possibility of using dispersion-engineered fibers with their structure consisting of numerous air-holes in the cladding gives the opportunity to control the nonlinearities in such fibers which makes it a powerful tool for nonlinear optics. Since both SSFS and SC were already used as seed sources for Tm-doped amplifiers [1,3] (as an alternative to a Tm-doped mode-locked laser), the aim of the presented work is to directly compare their performance in terms of power, noise, coherence and stability.

In our experiment (Fig. 1(a)), an Er-doped fiber laser operating at 1.56 µm, emitting 50 fs pulses at 125 MHz repetition rate was used as a pump source. The laser beam was coupled into two nonlinear fibers – an all-normal dispersion (ANDi) fiber generating SC and anomalous dispersion fiber fiber that generated tunable solitons in the range up to 2 µm. The noise dynamics of the pulses emitted at the outputs of both fibers were then analyzed by measuring degree of coherence, shot-to-shot noise (by means of dispersive Fourier transform) and relative intensity noise (the last presented in Fig. 1(b)). The obtained results indicate high coherence level as well as good noise properties for both nonlinear fibers, yet with slightly better performance for the SSFS. Both types of sources were used as seeds for an all-fiber Tm-doped fiber amplifier, leading to 88 fs pulses with average power of 365 mW for the SSFS and 92 fs pulses with average power of 360 mW for the SC. What is more, the emission wavelength of the soliton could have been adjusted and the pulses of a duration 80 fs and optical power 400 mW could have been achieved. Adding a low shot-to-shot noise confirmed with DFT, high coherence and low RIN, we show that Raman-shifted solitons are excellent seed sources for Tm-doped fiber amplifiers, outperforming ANDi-SC. This work was financed by Foundation for Polish Science (First TEAM/2017-4/39).

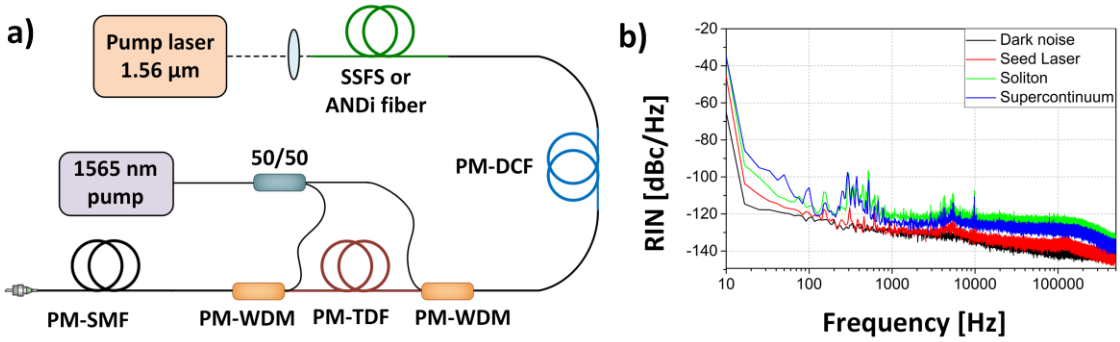

Fig. 1 Schematic of the experimental setup (ANDi – all-normal dispersion fiber, SSFS – soliton self-frequency shift fiber, PM-DCF – polarization maintaining dispersion compensating fiber, PM-WDM – PM wavelength division multiplexer, PM-TDF – PM thulium-doped fiber, PM-SMF – PM single-mode fiber (a). Relative intensity noise of the soliton and supercontinuum and the seed laser comparison (b).

References

[1] G. Soboń, T. Martynkien, D. Tomaszewska, K. Tarnowski, P. Mergo, and J. Sotor, "All-in-fiber amplification and compression of coherent frequency-shifted solitons tunable in the 1800–2000 nm range," Photon. Res. **6**, 368-372 (2018).
[2] K. Tarnowski, T. Martynkien, P. Mergo, J. Sotor, and G. Soboń, "Compact all-fiber source of coherent linearly polarized octave-spanning supercontinuum based on normal dispersion silica fiber", Sci. Rep. **9**, 12313 (2019).
[3] A. Rampur, Y. Stepanenko, G. Stępniewski, T. Kardaś, D. Dobrakowski, D.-M. Spangenberg, T. Feurer, A. Heidt, and M. Klimczak, "Ultra low-noise coherent supercontinuum amplification and compression below 100 fs in an all-fiber polarization-maintaining thulium fiber amplifier," Opt. Express **27**, 35041-35051 (2019).