Generation of 12 nJ Pulse Energy by a Thulium-doped Fiber Mamyshev Oscillator

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As a dynamic field in ultrafast fiber oscillators, Mamyshev oscillators proved pulse energy scaling capabilities, in particular in ytterbium- and erbium-based systems. Up to 190 nJ of pulse energy and compressed pulse durations below 50 fs have been achieved by using standard single mode step-index fibers in the spectral range of 1 µm [1,2].

Transferring this unique oscillator concept towards the near mid-infrared wavelength range was achieved in our group owing to the integration of passive normal dispersive fiber for dispersion-management and nonlinear spectral broadening, alongside with anomalous dispersive core-pumped gain fibers. This approach generated up to 6.4 nJ pulse energy with a compressed pulse duration of 156 fs [3]. However, these parameters remained only in the range of the best previously reported ultrafast thulium-doped fiber oscillators. The main limitation of the Mamyshev oscillator was excessive amplified spontaneous emission (ASE) in the short wavelength band of thulium around 1850 nm, which led to parasitic lasing and in turn to a destabilization of the mode-locked pulse train by gain competition.

Here, we address this limitation by a tailored red-shifted gain spectrum in one of the oscillator arms: Replacing one of the core-pumped gain fibers with a highly thulium-doped double-clad fiber resulted in a signal-to-ASE ratio of 22 dB owing to the re-absorption inside the fiber, which was an improvement by over an order of magnitude. The significant reduction of ASE allowed to generate up to 128 mW average power at a repetition rate of 10.25 MHz. Corresponding to the average power, 12 nJ of pulse energy were calculated at the output. In agreement to these high-energy pulses, the optical spectrum was governed by characteristic modulations owing to self-phase modulation and spanned about 60 nm, as presented in Figure 1a. The emitted up-chirped pulses could still be compressed to 154 fs, which is only 16 % above the transform limited pulse duration, as shown in Figure 1b.

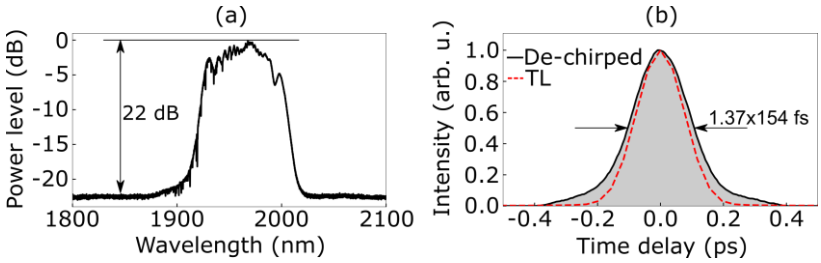

Fig. 1 Pulse characteristic in the spectral and temporal domain: a) Optical output spectrum and b) autocorrelation after compression and the corresponding transform limited pulse (TL).

To best of our knowledge, this is the highest reported pulse energy of an ultrafast thulium-doped fiber oscillator to date. Future improvements will include the replacement of the first arm by a passive normal dispersive arm, which makes the setup more compact and convenient to operate.

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