Development of a ~0.1 ps pulse, Er-fiber laser amplifier tunable in the 1560-1700 nm range

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Abstract: We report on a ~0.1 ps, 50 MHz repetition rate Er-fiber laser amplifier delivering Raman shifted, ~2 nJ solitary pulses in the wavelength range of 1560-1700 nm for nonlinear microscopy and atmospheric laser radar applications.

Pulsed sub-ps fiber coupled [1] or optical fiber lasers [2] play an increasingly important role in nonlinear microscopy. Fiber lasers utilizing single mode (SM) fiber components [2] are cheaper, more compact and exhibit low sensitivity for environmental disturbances such as air fluctuations or vibrations. However, they have several drawbacks, including high sensitivity to temperature changes due to stress induced birefringence in SM fiber components and their limited tunability compared to Ti:Sapphire laser oscillators [1]. The former problem can be solved by using more complex, more expensive polarization maintaining (PM) fiber technology while the latter one can be improved by applying Raman-induced frequency shift in properly tailored optical fiber configurations [3]. The aim of our current work is to replace a fixed repetition rate, femtosecond pulse Ti-sapphire laser [1] by a frequency doubled Er-fiber laser amplifier system, which can provide optical pulses at around 780 nm in two-photon NAD(P)H fluorescence lifetime imaging (FLIM) experiments [4]. Our additional goal is to develop a sub-ps fiber amplifier system operating in the 1.7 micron range that is able to penetrate deeper layers of tissues for 3-photon excitation of fluorophores [5], which allows imaging of skin tumor (especially melanoma) biopsies at a lower risk of tissue damage induced by laser absorption in melanin. The pulsed fiber laser system operating at around 1.7 micron is also a promising candidate for atmospheric laser radar applications, where it should be operated in "burst" mode as opposed to single-pulse mode for better detectability.

A significant difference between Yb-fiber (operating at around 1030 nm) [2] and Er-fiber laser systems is that in the former case the optical fibers used typically have normal dispersion, while in Er-fiber laser systems the fibers have typically anomalous dispersion (negative GDD) at around 1560 nm. In our experiments we used an ELMO oscillator manufactured by MenloSystems GmbH (Germany) and a commercial EDFA 100S Er-fiber amplifier manufactured by Thorlabs Inc. (N.J, USA). By using optical fibers with different dispersion properties spliced in front of and behind the Er-fiber amplifier, and by optimizing the amplification of the fiber amplifier, we could produce amplified soliton laser pulses at around 1560 nm with a typical pulse duration of ~100 fs before a second-harmonic generation (SHG) unit converting our laser pulses to 780 nm. The block diagram of the optimized experimental setup for second harmonic generation SHG is shown in Figure 1.

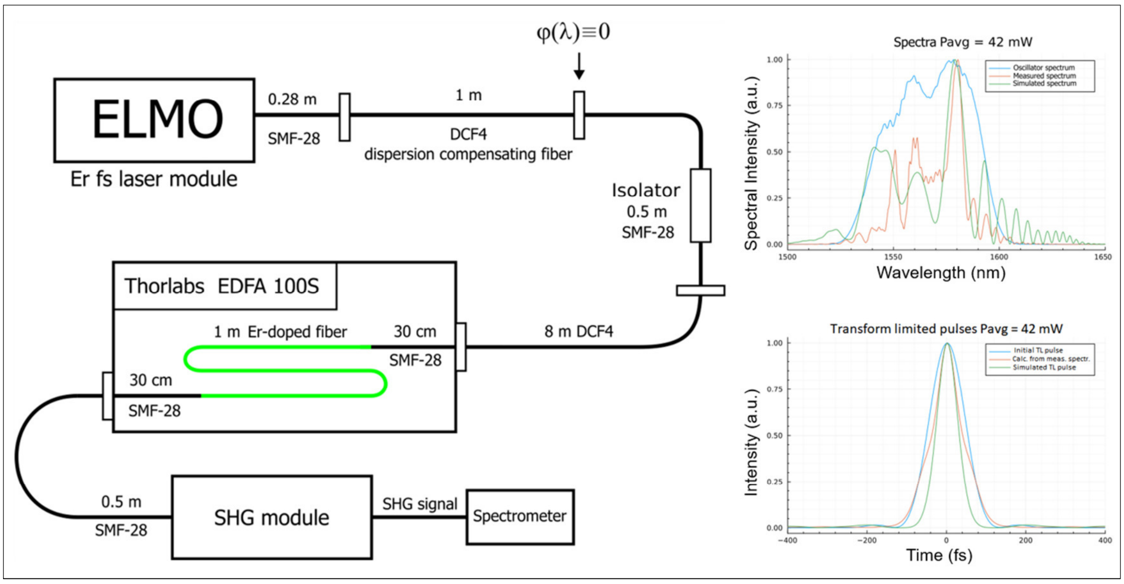

Fig. 1. Left: Block diagram of the Er-fiber amplifier system optimized for SHG when using DCF4 dispersion-compensating fibers and SMF-28 anomalous dispersion optical fibers. Right up: spectrum of the Er-oscillator measured at the input of the Er-fiber amplifier (blue), measured spectrum of soliton pulses with energy of ~0.84 nJ arriving at the SHG unit (red), and corresponding result of numerical simulation (green). Right down: temporal shapes corresponding to spectra depicted above, assuming transform-limited laser pulses.