2 microns all-fiber picosecond pulse source with gigahertz repetition rate

Adrien Billat[1], Steevy Cordette[1] and Camille-Sophie Brès[1]
1. Photonic Systems Laboratory, Ecole Polytechnique Fédérale de Lausanne (EPFL), CH-1015, Lausanne, Switzerland

Pulsed lasers operating in the 2 µm spectral region are now widely used in material processing [1], remote sensing [2] or for nonlinear frequency conversion deeper in the mid-IR where sub-ns pulse durations and high peak powers are required. Driven by these demands, substantial progress has recently been made in the improvement of thulium-doped lasers and amplifiers. Even if modelocked thulium-doped fibre (TDF) lasers are the widespread solution to address these needs, their cavity length generally prevents output repetition rates to be higher than a few tens of MHz. With the advent of optical communications in the 2 µm band and other important applications such as frequency comb metrology, a gigahertz repetition rate fibre source near 2 µm is a desired component. Here, we describe an all-fibre pulsed source based on parametric conversion followed by thulium amplification able to deliver picosecond long pulses at gigahertz repetition rates. Additionally, the pulse duration and rate can be easily tuned and the central wavelength can be freely selected in the range 1930-1980 nm. A maximum power of 1.2 W peak and 115 mW average is obtained at 1960 nm.

The physical principle is similar to the parametric converter followed by a TDF described in [3] and the setup schematic is shown in Fig. 1a. However here a 1566 nm pump laser is first modulated into a sinc-shaped pulse train through two intensity modulators [4] before being amplified and mixed with a continuous O-band signal. The pulsed pump and signal are launched in the highly nonlinear fibre (HNLF) where four-wave mixing gives rise to a pulsed idler located around 1950 nm. The repetition rate ν is set by the first modulator. The output of the HNLF is then directly coupled to 11.5 m of TDF where the pump power is further transferred toward the idler while strongly attenuating the signal.

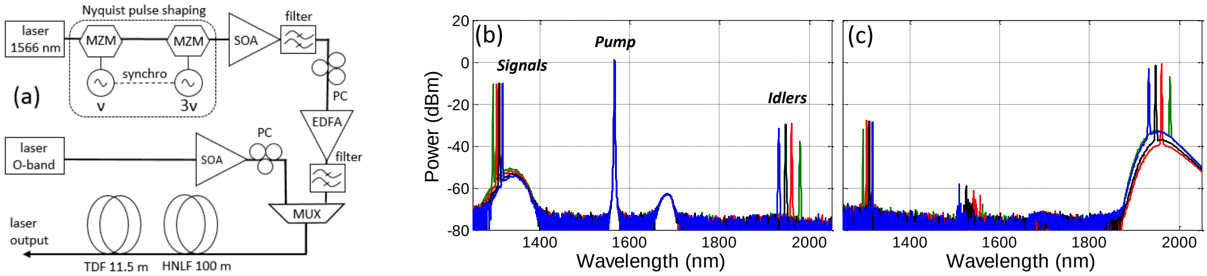

Fig. 1 (a) Experimental setup. MZM: Mach-Zehnder modulator, SOA: semiconductor optical amplifier, PC: polarization controller, EDFA: erbium-doped fiber amplifier, MUX: wavelength multiplexer. (b) Spectra for 4 signals after HNLF (c) Spectra for the same signals after TDF (OSA res: 1 nm). Attenuator used before OSA, attenuation function was taken into account for power computations.

After the HNLF (Fig. 1b) pulsed ilders are generated with good conversion efficiency close to -15 dB, taking into account the duty cycle. After the TDF (Fig. 1c), idlers undergo strong amplification (29 dB) whereas the pump and the signal are partly or totally absorbed. As a result the output of the TDF can directly be considered as a narrow linewidth pulsed source and wavelength tuning requires no additional filtering in the 2um band. Four waveforms of the pulses recorded at the TDF output with an InGaAs 22 GHz photodiode when ν is set at 2 and 3 GHz, and when the idler central wavelength is set at 1961 and 1932 nm, are shown in Fig. 2a-d, respectively. More than 20 dB of optical signal to noise ratio is maintained leading to good quality pulses. Pulse durations of 40 ps are measured at 2 GHz and 3 GHz, which indicates a nonlinear pulse compression in the first case and that the cut-off frequency of the detector is probably exceeded in the second case (pump pulses are 1/9ν long). As the pulse duration decreases, polarization effects are detected, leading to slight pulse distortions.

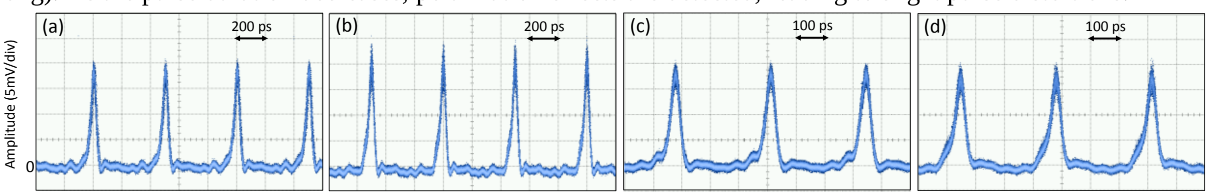

Fig. 2 Pulsed idlers waveforms (a) 2 GHz rate at 1961 nm. (b) 2 GHz rate at 1932 nm. (c) 3 GHz rate at 1961 nm. (b) 3 GHz rate at 1932 nm.

In summary, we presented an all fibre picosecond pulsed source capable of GHz repetition rate in the 2 µm band. Further increase in repetition rate can be achieved by reducing HNLF length and increasing pump peak power.

References

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