

# Optical frequency comb covering the 3.5-5 $\mu\text{m}$ range for Fourier transform spectroscopy

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Spectroscopic systems based on optical frequency comb technology deliver high speed, excellent accuracy and quantum-noise limited sensitivity [1]. The popular solution to get a broadband comb source in the mid-infrared range is to use a nonlinear optical process like difference frequency generation (DFG). DFG involves the interaction of two input waves (pump and signal waves) in a highly nonlinear material resulting in the generation of a third wave (idler) with a frequency that is the difference between two input wave frequencies [2].

The heart of the whole system (Fig. 1(a)) is a polarization-maintaining (PM), mode-locked fiber laser with an ytterbium-doped active fiber. The pulses were then amplified in the gain-managed nonlinear fiber amplifier [3]. The characteristics of amplified pulses are: a central wavelength of 1078 nm with 67 nm width, pulse duration of 51 fs and average power of 2.85 W. After amplification, the pulses were divided into two parts – pump and signal. In the signal arm, a nonlinear process called soliton self-frequency shift (SSFS) in highly nonlinear fiber (HNLF) was used to redshift the wavelength of the pulse. There was a delay line in the pump arm to match the optical paths in both arms perfectly. Once the two arms were combined, the pulses were focused on a periodically poled lithium niobate (PPLN) crystal where the differential frequency generation occurred. The generated spectra for different polling periods are pictured in Fig. 1(b).

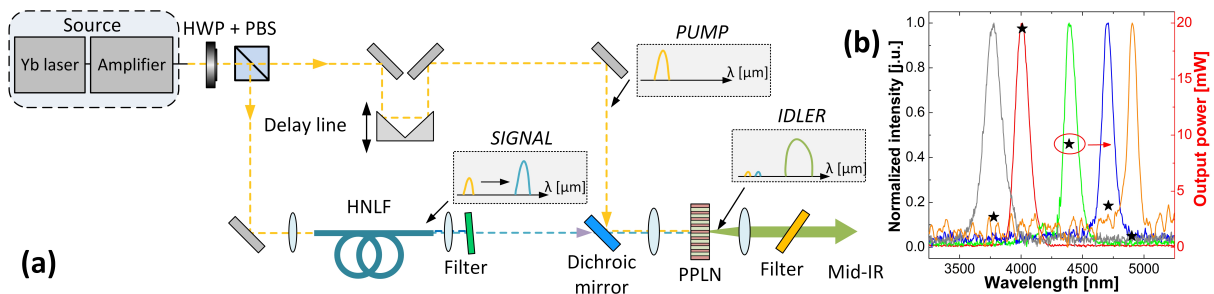


Fig. 1: (a) The setup for difference frequency generation (HWP – half-wave plate; PBS – polarizing beam splitter, HNLF – highly nonlinear fiber). (b) The optical spectra of the frequency comb in the mid-IR generated through the DFG process for different polling periods of the crystal, together with the average output power (black stars).

The presented system allows obtaining a spectrum in the range of 3.5-5  $\mu\text{m}$  with a maximum average power of 19.5 mW for the central wavelength of 4010 nm. The generated mid-IR optical frequency comb source is inherently  $f_{\text{ceo}}$ -free and can be used in laser-based gas sensors requiring stable carrier-envelope offset. The research was funded by the Polish Ministry of Education and Science (DG2018 006648).

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