# Compact, stabilized, fiber-based mid-infrared frequency comb tunable from 6.5 to 9 µm for Fourier Transform Spectroscopy

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Optical frequency combs emerge as ideal sources for molecular spectroscopy, due to their broad spectral coverage, wavelength-tunability and compatibility with enhancement cavities [1]. The broad spectrum of frequency combs enables targeting of entire molecular bands of multiple molecules simultaneously, which is impossible using classical systems based on single-frequency lasers. The development of robust and field-deployable gas detection platforms relies on the development of compact, environmentally stable combs in the mid-infrared (MIR). Here, we present a compact and robust all-fiber MIR comb which emits tunable radiation in the range between 6.5 µm and 9 µm with an average output power up to 5 mW at 125 MHz repetition frequency. The all-in-fiber construction of the source along with active stabilization techniques results in long-term stability and robustness.

The setup of the comb is depicted in Fig. 1. The MIR radiation is obtained via difference frequency generation (DFG) of the output of a 125 MHz repetition rate Er-doped fiber laser (1560 nm) with Raman-shifted solitons generated from the same source in a highly nonlinear fiber (at ~1950 nm). As a result of nonlinear mixing of both beams in an GaP crystal, a coherent idler tunable from 6.5 – 9 µm is generated. We applied a feedback loop to stabilize the output power by stabilizing the temporal overlap between two pulses interacting in the crystal. The used seed oscillator is equipped with a piezoelectric transducer, which enables locking to an external RF reference. The entire system fits in a 19-inch rack-compatible box with 435x350 mm size and 120 mm height, shown in Fig. 1, with a separate module with the nonlinear crystal (100x130 mm size). The overall robustness and long-term stability of the constructed source paves the way to out-of-lab applications, e.g. in environmental multispecies monitoring. The primary motivation for our study is the application in MIR Fourier-transform spectroscopy (FTS), for high-resolution measurements and line position retrieval. We performed Fourier transform spectroscopy of $N_2O$ at 7.8 µm [2]. We retrieved line center frequencies of the $\nu_1$ fundamental band and the $\nu_1 + \nu_2 - \nu_2$ hot band of $^{14}N_2{}^{16}O$ with the precision of 100 kHz, which is an order of magnitude improved compared to previous FTIR based measurements.

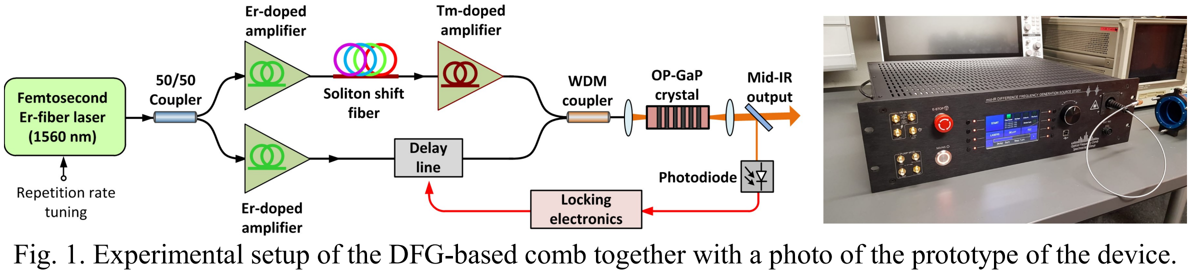


Fig. 1. Experimental setup of the DFG-based comb together with a photo of the prototype of the device.

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[1] A. Schliesser, N. Picque, and T. W. Hänsch, *Nat. Photonics* 6, 440-449 (2012).
[2] A. Hjältén, M. Germann, K. Krzempek, A. Hudzikowski, A. Głuszek, D. Tomaszewska, G. Soboń, A. Foltynowicz, *J. Quant. Spectrosc. Radiat. Transf.* 271, 107734 (2021).