# Spatially-multiplexed tunable dual-comb optical parametric oscillator at 250 MHz

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**Abstract:** We demonstrate a spatially-multiplexed dual-comb 250-MHz OPO from a single linear cavity. The adjustable repetition-rate difference is 4.1 kHz. Each idler comb has >200-mW average power at 3.5 µm with 30 nm bandwidth. The OPO is wavelength-tunable from 1.36 µm to 1.7 µm and 2.9 µm to 4.17 µm. © 2022 The Author(s)

Dual optical frequency combs in the mid-IR are valuable tools for spectroscopic measurements in the so-called molecular fingerprint region [1]. Among the many technologies for mid-IR generation, optical parametric oscillators (OPOs) pumped by solid-state lasers (SSLs) are compelling due to their flexible pulse parameters and a wide center wavelength tuning range enabled by the parametric process. Additionally, spectroscopic measurement signal-to-noise ratio is sensitive to intensity noise, where ultrafast OPOs are advantageous [2]. Yet, most dual-comb OPOs are complex systems including at least three different cavities [3]. Here, we demonstrate a single-cavity dual-comb OPO synchronously and collinearly pumped by a single-cavity dual-comb Yb:YAG laser with a similar architecture to the one presented in [4]. While the design of our previous bidirectional OPO limited us to 125 Hz repetition rate difference $\Delta f_{rep}$ and a fixed wavelength at a low repetition rate of $f_{rep}$=80 MHz [2], the new OPO presented here is spatially multiplexed in a linear cavity with the help of a new intra-cavity biprism scheme [4]. Moreover, we use picosecond pulses at a repetition rate of $f_{rep}$=250 MHz, which supports high-spectral resolution together with a high repetition rate difference of 4.1 kHz. This enables a simple, broadly tunable, and high-power-per-comb-line source that can serve as a tool for dual-comb spectroscopy at high signal-to-noise ratio.

The schematic of our dual-comb OPO cavity is illustrated in Fig. 1(a). Both the pump and the OPO are designed such that the two combs take a similar path through the cavity sharing all the optical elements, and thus most noise sources added by the cavity are expected to be correlated.

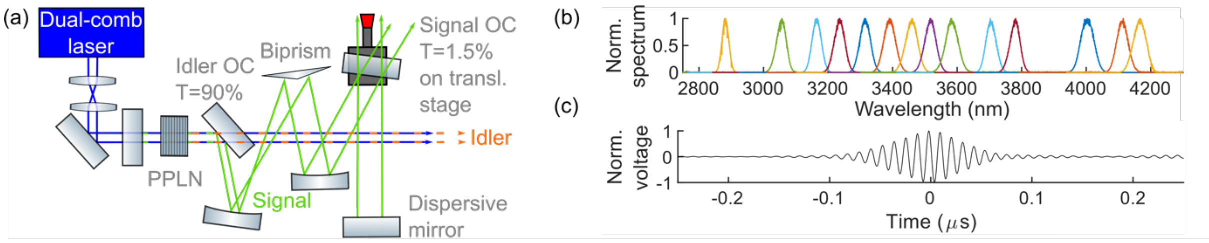


Fig. 1. (a) Schematic of the linear OPO cavity. Note, that for clarity the two combs are shown horizontally separated. In the laboratory, they are vertically multiplexed. (b) Tunable optical spectra of the idler combs measured with a Thorlabs OSA205. (c) Typical interferogram of the two signal beams in the time domain.

Up to 1.6 W of average power per comb at a center wavelength of 1031 nm, and a FWHM optical bandwidth of 1.7 nm (pump 1) and 1.8 nm (pump 2) is directed to the common pump focusing lens. The OPO uses a periodically poled lithium niobate (PPLN) crystal which is 4-mm-long, 5 mol. % MgO doped, and has a fan-out grating with periods ranging from 24.8 µm to 31.2 µm (HC Photonics). The residual pump and idler combs are transmitted via the idler output coupler (OC). The biprism introduces a cavity length difference for the two signal combs such that the OPO can run at high and tunable repetition rate differences. The synchronicity of the signal cavity with the pump is obtained by scanning the OPO cavity length with a translation stage. Dispersive mirrors are used to reduce the OPO sensitivity to cavity length fluctuations.

The OPO delivers idler average powers of 200 mW (idler 1) and 220 mW (idler 2), and total combined signal powers of 360 mW (signal 1) and 370 mW (signal 2) at an idler wavelength of 2.9 µm and signal wavelength of 1.6 µm after their respective OC. Due to the relatively narrow bandwidth and high repetition rate, the OPO idler has a power per comb line of about 60 µW. The broad tuning range of the idler from 2.9 µm to 4.17 µm is shown in Figure 1(b). Figure 1(c) shows a typical interferogram from the beating of the two signal combs upon combination at a non-polarizing beam splitter, illustrating the dual-comb nature of the source.

## 5. References:

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