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► **To cite this version:**

Q. Clément, E. Lucas, J.M. Melkonian, J.B. Dherbecourt, M. Raybaut, et al.. Nested Cavity Optical Parametric Oscillator Emitting at $8 \mu\text{m}$ Pumped by a Pulsed Single-Frequency $2 \mu\text{m}$ Fiber Laser. 6th EPS-QEOD Europhoton Conference, Aug 2014, NEUCHATEL, Switzerland. hal-01082818

HAL Id: hal-01082818

<https://hal.science/hal-01082818>

Submitted on 14 Nov 2014

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Nested Cavity Optical Parametric Oscillator Emitting at 8 μm Pumped by a Pulsed Single-Frequency 2 μm Fiber Laser

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Optical coherent sources with a narrow spectral linewidth and a broad tunability are of primary interest for chemical species detection by optical spectrometry. Optical parametric oscillators (OPOs) fulfill all these requirements and are especially broadly tunable with respect to lasers. The so-called molecular fingerprint spectral region between 7 and 14 μm is a spectral range of interest as many hazardous species and explosives are found with non-overlapping rovibrational lines. However, to the best of our knowledge, there has never been any demonstration of a single-frequency OPO directly emitting in the 7-14 μm range.

For the first time, we report on a nested cavity optical parametric oscillator (NesCOPO) [1] emitting around 8 μm . This device is a doubly resonant OPO in which the signal and idler cavities have different physical lengths. Each cavity length can be controlled independently by moving a different mirror mounted on a piezoelectric actuator. This way, overlapping of the signal and idler cavity frequency modes can be adjusted to yield tunable single-frequency emission: it is the optical equivalent of the Vernier effect. For instance, detection of CH_4 , CO_2 , H_2O was successfully obtained at ONERA with a single NesCOPO operating near 2 μm , while a NesCOPO pumped by a 1064 nm fiber laser was developed for detection of methane and organic compounds in the 3-5 μm range [2]. Our aim is to apply this concept in the 8-12 μm range.

Here, the NesCOPO is made with a Type II ZnGeP_2 (ZGP) crystal cut at $\theta = 64^\circ$, chosen owing to its high nonlinear coefficient $d_{\text{eff}} = 75 \text{ pm/V}$. The length of the crystal is 5 mm, a trade-off between efficiency, walk-off and condition for single-frequency operation. The device is pumped with a home-made single-frequency fiber laser emitting at 2051 nm with a repetition rate of 20 kHz and a pulse duration of 270 ns [3]. Its waist in the ZGP crystal is of 90 μm . The experimental setup is displayed in Fig. 1a. The oscillation threshold is measured at a peak power $P_{\text{th}} = 74 \text{ W}$ ($J_{\text{th}} = 0.16 \text{ J/cm}^2$) at the entrance of the crystal and a pump depletion of 43% is reported at 8 μm (Fig. 1b). Thermal effects due to pump and idler absorption that disturb the stability of the cavities have been identified, a well-known effect in the ZGP [4]. Nevertheless we measure up to $P_i = 55 \text{ mW}$ of idler radiation at 8 μm for an average pump power of 1.1 W. Preliminary tuning has been done from 7.9 to 8.3 μm without losing oscillation.

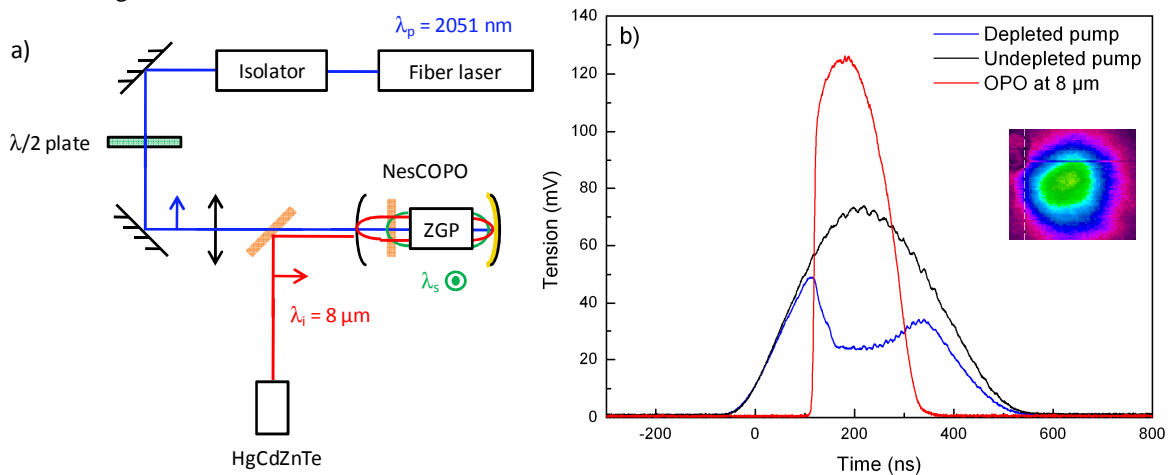


Fig 1. a) Setup of the ZGP NesCOPO experiment. b) Temporal profiles of the pump and the idler wave collected onto a HgCdZnTe detector. Inset: spatial profile of the idler observed with a Pyrocam III camera.

Our next objective is to analyze the spectrum to confirm the single-frequency emission and to tune the wavelength. More experimental details and preliminary results with other crystals will be presented.

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