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Parametric Sources for Chemicals and Gas Sensing

Abstract: We present our activities on the development of tunable optical parametric sources for gas sensing. In particular, we introduce the nested cavity OPO, and rapidly tunable OPOs based on aperiodic quasi-phase matching.

1. Introduction

Multispecies gas detection, quantification, and localization in the atmosphere has become a growing concern for a great variety of applications from environmental and air quality monitoring, to warfare agents detection for defense, through industrial security. For these purposes laser absorption spectroscopy in the mid-infrared from 1.5 μm to 14 μm is an extremely valuable tool due to the presence of atmospheric transmission windows as well as intense and well separated absorption lines of the species of interest.

There is consequently a significant need for broadly tunable laser sources in the mid-infrared exhibiting high spectral purity, narrow linewidth, as well as compactness and robustness for field campaign deployment. Various optical sources (solid state lasers, fiber lasers, semiconductor lasers or optical parametric devices) have demonstrated their capability to cover the spectral range of interest; nonetheless, delivering a narrow linewidth radiation with high wavelength agility remains challenging.

2. Gas sensing with narrow-linewidth nested cavity OPO

In this talk, we will present our most recent developments on novel optical parametric sources and their integration in gas sensing instruments. In particular, we have introduced the nested cavity optical parametric oscillator (NesCOPO) scheme that enables to deliver a single frequency tunable emission with a much simpler and more compact device than usual narrow-linewidth OPOs. The NesCOPO device was successfully demonstrated in the microsecond to nanosecond regime and in spectral ranges from short- to long-wave infrared. Its high potential was demonstrated for multiple-gas sensing, either for point measurements or standoff gas detection using lidar instruments [1]. For long range applications, the compact NesCOPO is implemented in a master oscillator power-amplifier (MOPA) architecture. For local sensing, activities are carried out to develop compact quartz-enhanced photoacoustic spectroscopy sensors.

The presentation will especially focus on our latest development on high energy infrared emitters (mJ level) for long range (km) differential absorption LIDAR (DIAL) applications. These developments either address the 1.6 μm – 2 μm range for the detection of greenhouse gases (CO_2 , CH_4 , and H_2O), and the 8.0 μm – 12 μm region for the detection of toxic agents. Emitters' performances, LIDAR instrument capabilities, as well as experimental demonstration results will be discussed during the presentation.

3. Rapidly tunable picosecond OPO based on aperiodic quasi-phase matching

For time-resolved spectroscopy applications the picosecond regime is of high interest. In the mid-infrared, this type of picosecond tunable emission can be provided by synchronously-pumped optical parametric oscillators (SPOPOs). In this context we have developed a specific approach that takes advantage of the SPOPO synchronism condition by combining broad band parametric gain, provided by an aperiodically poled lithium niobate (APPLN) nonlinear crystal, with an intracavity fast spectral filter, in order to rapidly tune the emission wavelength within the parametric gain bandwidth. This spectral filtering is realized by dispersion tuning with a chirped volume Bragg grating [2].

4. References

[1] Godard, M. Raybaut, M. Lefebvre, "Nested Cavity Optical Parametric Oscillators—A Tunable Frequency Synthesizer for Gas Sensing", *Encyclopedia of Analytical Chemistry* (2017)

[2] D. Descloux, G. Walter, E. Cadiou, J.-B. Dherbecourt, G. Gorju, J.-M. Melkonian, M. Raybaut, C. Drag, and A. Godard, "Wide and fast dispersion tuning of a picosecond OPO based on aperiodic quasi-phase matching using an axially chirped volume Bragg grating", *Opt. Lett.* 41, 4060–4063 (2016).

Information Page

1) Title

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4) Topic and session organizer

SC3 Focus Session entitled "Advanced Photonic Technologies for Spectroscopic Applications" / Weidong Chen, Vincenzo Spagnolo, and Ulrike Willer.

5) Oral (invited presentation)