Mid-Infrared Sensors using Periodically Poled $LiNbO_3$ for Trace Gas Detection

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The development and applications of solid state gas sensors based on diode-pumped mid-infrared difference frequency generation (DFG) in periodically poled lithium niobate (PPLN) will be discussed. The quasi-phase matching properties of PPLN can be readily engineered for DFG in the 2-5 μm region when pumped with commercially available diode, solid-state, or fiber lasers. This, along with its large optical nonlinearity and good optical quality, makes PPLN an ideal nonlinear mixing material for DFG applications targeted at species like CO, N_2O, CO_2, SO_2, H_2CO, HCl, and CH_4. Detection limits of better than 10 ppb have been realized for several trace gases in air.

To date, our choice of laser pump sources was motivated primarily by their capability of reliable single frequency, low-noise operation over extended periods of time. One of the pump sources is a diode pumped ring Nd-YAG laser with 750 mW output power at 1064.5 nm. The other pump source can be a 100 mW GaAlAs Fabry-Perot diode laser available at wavelengths from 790 to 865 nm [1]. Although these laser diodes operate single frequency over certain spectral ranges, convenient continuously tunable single frequency operation can only be achieved with such laser diodes when operated in an external cavity configuration. However, this comes at the expense of reduced output power of ~20 mW. The beams of the two pump lasers are combined by a dichroic beamsplitter and focused into a anti-reflection coated PPLN crystal. The crystal has typically 1.5 mm wide strips with domain grating periods ranging from 22 to 23 μm in 0.1 μm steps. Typical idler powers of several μW were measured in the 3 to 5 μm DFG region with a Peltier-cooled HgCdTe infrared detector. The instrument employs no cryogenic or high voltage components, measures 30x30x60 cm, weighs 25 kg, and is controlled by a laptop computer. Spectroscopic absorption measurements could be performed using either open path measurements or by extraction to a compact multipass gas cell. The DFG spectrometer was used for real time measurements of CO, N_2O, and CO_2 in open air. We demonstrated the feasibility of a relative measurement of the $^{13}C/^{12}C$ and the $^{18}O/^{17}O/^{16}O$ isotopic ratios in atmospheric CO_2. CH_4, H_2CO, and SO_2 were measured in a cell at reduced pressures [2]. The development of PPLN waveguide chips and the use of fiber beam delivery and amplifiers will lead to important advances in the design of compact, alignment free gas sensors.

References:

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