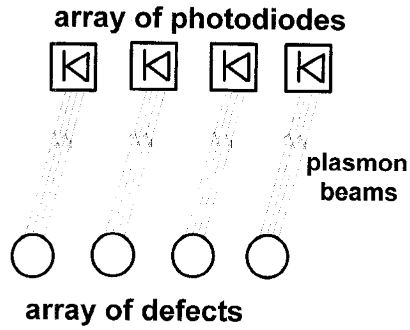


CTuP52 Fig. 3 Novel multi-channel plasmon sensor device.

sized surface plasmon sensor. The density of packaging of such pairs in a multi-channel array is limited by the diffraction of plasmon beams. Our study of plasmon diffraction shows that a density of one sensor pair per 30 μm^2 is achievable.

1. B. Liedberg, C. Nylander, I. Lundstr, Sensors and Actuators **4,** 299 (1983).
2. M. W. Foster, D. J. Ferrel, R. A. Lieberman, SPIE **2293,** 122 (1994).
3. I. I. Smolyaninov, D. L. Mazzoni, C. C. Davis, Phys. Rev. Lett. **77,** 3877 (1996).

CTuP53

Mid-infrared laser-based sensors for trace gas detection

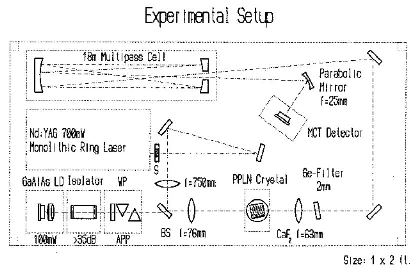
Y. Mine, K. P. Petrov, R. F. Curl, F. K. Tittel, Th. Töpfer,* *Rice Quantum Institute, Rice University, Houston, Texas 77251-1892; E-mail: miney@owlnet.rice.edu*

The development of compact room temperature operating gas sensors has been motivated by the need for monitors of environmentally important trace gases and by the need for monitors for studying global atmospheric chemistry. Direct optical absorption in the infrared is a particularly convenient method, since the vibrational fundamental transitions of many trace gas molecules are located in the mid-infrared part of the electromagnetic spectrum. Difference frequency generation (DFG) in periodically poled $LiNbO_3$ (PPLN) crystals pumped by a diode-pumped monolithic Nd:YAG ring laser ($\lambda = 1.0645$ μm) and tunable solitary laser diodes are attractive mid-infrared spectroscopic sources, offering wavelength selectivity, high sensitivity, frequency stability, compact size, and low cost.[1,2]

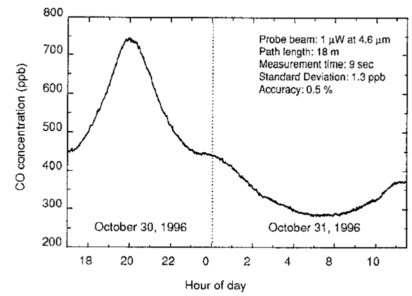
Several gas species detectable by this mid-infrared DFG-based sensor are listed in Table 1 along with the required wavelengths and PPLN grating periods. The absorption lines were chosen to be free from water interference, and to be at diode wavelengths covered by commercial diode lasers. Concentrations detectable with 1% accuracy are estimated from the results obtained with the CO sensor described below.

The schematic diagram of the mid-infrared DFG sensor is shown in Fig. 1. The output beams of a 100-mW single-frequency GaAlAs diode laser at 865 nm and a 700-mW diode-pumped monolithic ring Nd:YAG laser at 1064.5 nm are mixed in a 19-mm-long PPLN crystal generating 5 μW infrared output power at 4.6 μm. By modulating the diode current with a triangular waveform, the idler frequency can be tuned continuously over 30 GHz. The infrared beam probes air inside a compact 30-cm-long commercial Herriot cell with 18-m effective path length and 35% throughput at 4.6 μm. The beam passing through the cell is focused onto a thermoelectrically cooled HgCdTe detector with 1×1 mm active area. The detected signal is amplified by a low-noise, DC-coupled preamplifier. This allows measurement of IR power without the use of a chopper. The sensor including power supplies and electronics is contained in a $1 \times 1 \times 2$ ft enclosure.

Data acquisition and processing are performed on a laptop computer equipped with a PCMCIA 16-bit analog-to-digital converter and running a LabVIEW program. Data processing includes averaging, filtering, and calculating the concentration from a fit to a Lorentzian line profile. Depending on the number of scans averaged, the measurement update interval varies from 1 to 30 s.



CTuP53 Fig. 1 Schematic diagram of a CO sensor. S: mechanical shutter, WP: half wave plate, APP: anamorphic prism pair, BS: beam splitter.



CTuP53 Fig. 2 Typical concentration record of CO in room air.

As the first demonstration of such a gas sensor, we measured the CO concentration in laboratory air. The CO concentration was monitored over 17 hours with a precision of better than 2 ppb, and verified, with use of commercial 1 ppm and 9 ppm CO in air reference mixtures. The peak near 20:00 was presumably due to higher emission by traffic on a nearby highway during the rush hour between 16:00 and 18:00, which reached the location of the sensor in our laboratory approximately two hours later.

This work was supported in part by the National Aeronautics and Space Administration, the Texas Advanced Technology Program, and the Robert A. Welch Foundation.

Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität, Max-Wien-Platz 1, D-07743 Jena, Germany; E-mail: toepfer@pinet.uni-jena.de

1. K. P. Petrov, L. Goldberg, W. K. Burns, R. F. Curl, F. K. Tittel, Opt. Lett. **21,** 86 (1996).
2. A. Balakrishman, S. Sanders, S. DeMars, J. Webjorn, D. W. Nam, R. J. Lang, D. G. Mehuys, R. G. Waarts, D. F. Welch, Opt. Lett. **21,** 952 (1996).

CTuP53 Table 1 Gas species accessible by mid-infrared DFG based sensors with use of a PPLN crystal. A laser diode in the 800 to 875 nm spectral region and a 1.06 μm Nd:YAG laser are assumed to be used as a pump and a signal source, respectively

Gas species	Absorption line (μm)	Diode wavelength (nm)	Grating period (μm)	Concentration detectable with 1% accuracy (@ pressure)
CH_4	3.29	804	22.1	500 ppb (1 atm)
HCl	3.40	817	22.0	1 ppb (1 atm)
H_2CO	3.56	819	22.6	2 ppm (0.1 atm)
HBr	3.78	830	22.9	500 ppb (0.1 atm)
N_2O	4.53	861	23.3	50 ppb (1 atm)
CO	4.61	865	22.8	100 ppb (1 atm)
OCS	4.87	873	23.0	50 ppb (1 atm)

Medical and Biological Applications

CTuP54

A simple and ultrabright optical source for airway gas monitoring

David A. King, Richard J. Pittaro, *Hewlett-Packard Laboratories, 3500 Deer Creek Rd., Palo Alto, California 94304*

Over the past several years we have been investigating the use of Raman scattering to monitor anesthetic agents and respiratory gases in an operating room environment. A Raman-based approach allows convenient, simultaneous, and real-time quantification of the components of a complex gas mixture. However, in practice the very weak scattering cross section requires a minimum cw laser power between 1 W and 10 W. We have developed a diode-pumped power-buildup cavity in which we use the high intensity beam in the cavity to generate Raman scattering. Through a major