Diode and quantum cascade laser based spectroscopic sources for trace gas detection.

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The design issues and development of gas sensors based on diode and quantum cascade lasers in the mid-infrared spectroscopic fingerprint region will be reported. Recent advances in photonic technologies and spectroscopic detection schemes have been employed in various sensor platforms to achieve minimum detectable coefficients of 10^{-9} cm^{-1} in real world applications.

These sensors are based on absorption spectroscopy of near-infrared vibrational overtone and combination bands from 1 to 3 µm and of fundamental bands in the 3 to 25 µm spectral region. In this talk we report the development of portable gas sensors based on three different types of device architectures. If the anticipated concentration levels of a desired trace gas are sufficiently large and if this species exhibits near-IR resolved rotational-vibrational transitions that are free of interfering species (such as CO_2 and H_2O), then sensors based on distributed feedback (DFB) diode lasers are ideally suited. If, however, trace gas detection at ppb and ppt levels is required for a specific application, it is convenient to select a sensor architecture suitable for the mid-IR based on difference-frequency generation (DFG) in a nonlinear optical material such as periodically poled lithium niobate pumped by two near-IR diode lasers [1] or on quantum cascade-DFB lasers [2] in the 3 to 5 µm and 4 to 19 µm spectral region, respectively. Each of these three sensor designs can be used with different detection schemes that are selected to achieve minimum detectable absorbances ranging from 10^{-9} to 10^{-6} cm^{-1}, depending on the applications driven sensing scenario. Balanced detection, wavelength modulation, and cavity enhanced spectroscopy and combinations thereof are used to realize enhanced trace gas detection sensitivities at the sub-ppb level. In the case of the two types of diode laser based gas sensors, we have used robust fiber pigtailed telecommunications DFB diode lasers and, when appropriate, Yb and Er/Yb fiber amplifiers to boost their power and to provide fibered beam delivery. The QC-DFB based gas sensors have been operated either cw or pulsed, cooled to liquid nitrogen and room temperatures, respectively. Details of the critical spectroscopic parameters for the three spectroscopic devices will be reported, specifically their available power, linewidth, and wavelength tunability.

Chemical and environmental sensing applications that were investigated recently included NH_3 detection using vibrational overtone spectroscopy at 1.53µm (6528.8 cm^{-1}), fundamental ro-vibrational spectroscopy at 3.035 µm (3295.4 cm^{-1}) and at 10.04 µm (997 cm^{-1}), respectively in the laboratory and at the NASA Johnson Space Center on a bioreactor developed for water reprocessing; formaldehyde concentration measurements in ambient air at three different environmental monitoring sites in the Houston area and volcanic emission studies at the Masaya volcano in Nicaragua with a multi-species DFG based gas sensor.

References:

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