Quantum Cascade Lasers for Chemical, Environmental and Biomedical Analysis

Frank. K. Tittel, Anatoliy Kosterev, Robert F. Curl

Rice Quantum Institute, Rice University, Houston, TX 77251-1892

Claire Gmachl and Federico Capasso

Bell Laboratories, Lucent Technologies, 600 Mountain Avenue, Murray Hill, NJ 07974

Novel pulsed and cw quantum cascade distributed feedback (QC-DFB) lasers operating in the 4.3 to 24 micron spectral range with cw power levels of >100 mW are now available for the detection and quantification of trace gases in ambient air by means of sensitive absorption spectroscopy. Recent advances in photonic technologies and spectroscopic detection schemes have been employed in various sensor platforms to achieve minimum detectable absorption coefficients of 10^{-9} cm^{-1} in real world applications.

The gas sensor architecture depends on the concentration levels of a desired trace gas species. A number of gases such as CH_4, N_2O, NO, CO, NH_3, C_2H_5OH, and H_2O have been detected and quantified to date in ambient air and other gas mixtures with sensitivity of several parts per billion by volume. Detection of biomedically produced nitric oxide (NO) is of particular importance because of its critical role in human physiology. NO in human breath samples was detected by its fundamental absorption at 5.2 μm (1921.6 cm^{-1}) with a CES technique. Application of CRS yielded a single ringdown event sensitivity to absorption of $2 \cdot 10^{-8}$ cm^{-1}. Recently also ammonia detection at 10.04 μm (997 cm^{-1}) was carried out at the NASA Johnson Space Center, Houston, on a bioreactor being developed for water reprocessing in future spacecraft habitats.