Off-Axis Integrated Cavity Output Spectroscopy for Nitric Oxide Detection in Human Breath using a Quantum Cascade Laser

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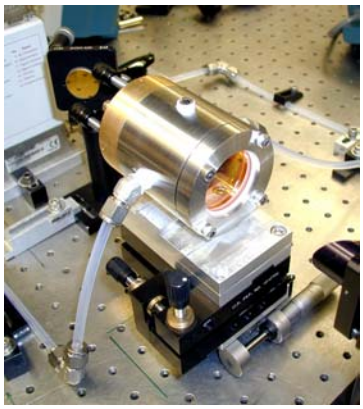
Abstract: Integrated Cavity Output Spectroscopy technique for Nitric Oxide detection in human breath based on a compact high-finesse optical cavity, consisting of two ultra-low loss concave mirrors, spaced 5 cm apart has been implemented. A tunable CW QC-Laser operating at 5.2 μm is used. To date a detection sensitivity of 15 ppb has been demonstrated.

OCIS codes: (140.5960) Semiconductor lasers; (280.3420) Laser sensors; (300.6320) Spectroscopy, high resolution

Human breath analysis is a promising and rapidly developing technique for non-invasive real time medical diagnostics of different diseases. A number of trace gases, which were found in exhaled air at ultra-low (parts per billion by volume – ppb) concentrations can be considered as disease markers. For example, elevated concentrations of nitric oxide (NO) were found to be related to asthma [1]. Laser absorption spectroscopy in mid-IR region combined with long optical path cell provides the required sensitivity for breath diagnostics. A new generation of semiconductor lasers, quantum cascade lasers (QCL) opens the way to realize a compact gas sensor that is compatible with a clinical setting. An effective optical pathlength exceeding several hundred meters can be achieved in a gas cell of just a few cm in physical length by using ultra low-loss dielectric mirrors. The mirrors form an optical cavity, and the intracavity absorption can be measured either through a change of the cavity ringdown time (CRDS) [2] or using an integrated cavity output spectroscopy (ICOS) technique [3,4].
In this work we investigated the feasibility of an off-axis ICOS approach with a short cavity. The cavity was formed by two concave ultra-loss mirrors (2 inch in diameter, 1 m radius of curvature) separated by 5 cm and is depicted in Fig.1.



The optimum NO detection sensitivity at 1920.7 cm^{-1} realized to date is 15 ppb.

[1] B. Gaston, J. M. Drazen, J. Loscalso, J. S Stamler, "The Biology of Nitrogen Oxide in the Airways", American Journal of Respiratory and Critical Care Medicine **149**, 538-551 (1994).
[2] A.A. Kosterev, F. K. Tittel, "Chemical Sensors Based on Quantum Cascade Lasers", IEEE J. Quantum. Electron. **38**, 582-591 (2002).
[3] J. B. Paul, L. Larson, J.G. Anderson, "Ultrasensitive absorption spectroscopy with a high-finesse optical cavity and off-axis alignment", Appl. Opt. **40**, 4904-4910 (2001).
[4] D.S. Baer, J. B. Paul, M. Gupta, A. O'Keefe, "Sensitive absorption measurements in near-infrared region using off-axis integrated-cavity-output spectroscopy", Appl. Phys. B **75**, 261-265 (2002).