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

Yury A. Bakhirkin, Anatoliy A. Kosterev, Robert F. Curl, Mark G. Allen* and Frank K. Tittel

Rice Quantum Institute, Rice University, 6100 S. Main St., Houston, TX 77251-1892
Phone: (713) 348 2757, Fax: (713) 348 5686, e-mail: yubakh@rice.edu
*Physical Sciences Inc., Andover, MA 01810

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.

©2003 Optical Society of America
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.