Development of compact quantum cascade laser based trace gas sensors

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Abstract. Development of a compact, tunable absorption spectroscopy based platform suitable for real-time quantification and monitoring of trace gas species at ppb levels will be reported. Chemical sensing was performed for two specific target gases (CO and COS) using pulsed quantum cascade lasers and utilizing DSP based system control, data acquisition, and processing.

Trace gas detection at ppb (part per billion) to sub-ppb concentration levels is essential in such diverse areas as atmospheric chemistry, environmental monitoring, chemical analysis, industrial process control, and medical applications. This work reports details of a DSP controlled thermo-electrically cooled, distributed feedback quantum cascade (QC-DFB) laser based sensor for trace gas detection as in [1,2]. The sensor architecture was evaluated for two target gases: CO and COS. Issues pertaining to deployment of spectroscopic sensors in real world applications are:

1. Sensitivity
2. Room temperature operation
3. Rapid response times
4. Size, weight and power consumption
5. Reliability and ease of use

The architecture of a sensor using a QC-DFB laser is based on spectrometer designs described in [2]. To address the need for fast real-time data acquisition, the system to be reported here incorporates high-speed data acquisition and processing electronics built around the recently introduced Texas Instruments TMS320F2812 digital signal processing (DSP) technology capable of high precision sampling and data analysis at relatively high rates, while simultaneously providing robust control functions for the system.

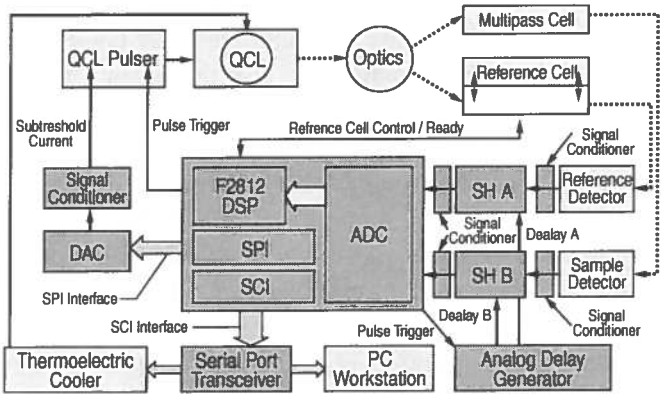

Fig. 1. Electronic block diagram.

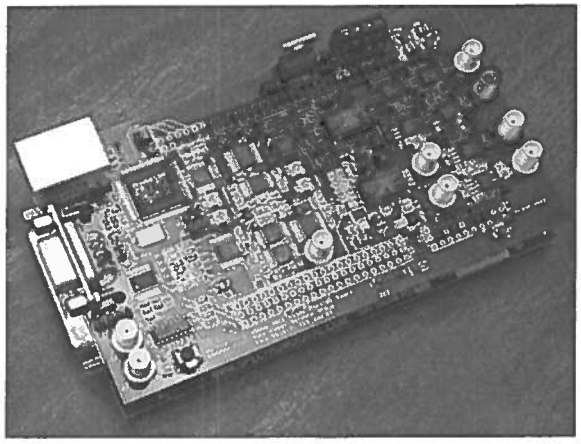

Fig. 2. DSP controller board for pulsed QC laser based gas analyzer.

A mid-infrared QC-DFB laser mounted on a Peltier cooler inside a sealed housing is excited with ~ 15–25 ns current pulses at repetition rates up to 1 MHz. A beam splitter located outside the laser housing generates a reference beam employed for both laser wavelength stabilization and power normalization. The signal beam enters a multipass gas cell for sensitivity enhancement. The exiting signal and reference beams are directed onto photovoltaic HgCdZnTe detectors. Each pulse is controllable in amplitude and length by digital to analog converter outputs. Several other system characteristics useful for feedback control may be monitored simultaneously (such as temperature, pressure) using one of 16 analog inputs.

The resulting output signal from the detector is digitized, accumulated, and autonomously processed by the DSP to yield a concentration for a specific target gas. Results may be continuously logged into a database via standard UART serial or standard 10/100BaseT Ethernet access, which also provides the ability for remote chemical sensing and analysis of trace gas species.

References

[1] A. A. Kosterev and F. K. Tittel, *IEEE JQE Special Issue on QC Lasers* **38**, 582–591 (2002).

[2] C. Roller, A. A. Kosterev, F. K. Tittel, K. Uehara, C. Gmachl, and D. L. Sivco, *Optics Letters* **28**, 2052–2054 (2003).