Title: DEVELOPMENT OF ALL-SOLID-STATE SENSORS FOR MEASUREMENT OF NITRIC OXIDE AND AMMONIA CONCENTRATIONS BY OPTICAL ABSORPTION IN PARTICLE-LADEN COMBUSTION EXHAUST STREAMS

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Abstract

An all-solid-state continuous-wave (cw) laser system for ultraviolet absorption measurements of the nitric oxide (NO) molecule has been developed and demonstrated. For the NO sensor, 250 nW of tunable cw ultraviolet radiation is produced by sum-frequency-mixing of 532-nm radiation from a diode-pumped Nd:YAG laser and tunable 395-nm radiation from an external cavity diode laser (ECDL). The sum-frequency-mixing process occurs in a beta-barium borate (BBO) crystal. The nitric oxide absorption measurements are performed by tuning the ECDL and scanning the sum-frequency-mixed radiation over strong nitric oxide absorption lines near 226 nm. The demonstrated detection limit for the system is less than 1 ppm of NO for a 1-meter absorption path length in clean flows.

A series of NO absorption measurements were performed in the exhaust of a co-fired combustion facility. The conventional co-fired boiler burner facility is a 30 kW (100,000 Btu/hr)

downward-fired furnace with a steel shell encasing ceramic insulation. The combustion facility was modified so that optical absorption measurements can be performed in the exhaust stream. The exhaust is routed from the coal combustor laboratory to an adjoining laboratory where the sensor systems are located. The exhaust tube is fitted with a window assembly for the NO measurements.

Nitric oxide concentrations in the exhaust stream were measured successfully in the combustor exhaust stream even under conditions of significant laser beam attenuation. The diode-laser-based sensor measurements showed good agreement with the results from physical probe sampling of the combustion exhaust. The diode-laser-based ultraviolet absorption measurements were successful even when the beam was severely attenuated by particulate in the exhaust stream and window fouling. Even under conditions where the laser beam intensity was attenuated to approximately 1% of its initial value, high quality, fully resolved NO spectra were still recorded. Single-laser-sweep measurements were demonstrated with an effective time resolution of 100 msec, limited by the scan rate of our mechanically tuned ECDL system. We have recently purchased a new 395-nm ECDL with a significantly increased mode-hop-free tuning range that can be scanned at rates up to 200 Hz. Future measurements will thus have greatly improved time resolution and sensitivity levels.

We are also in the process of developing a mid-infrared diode-laser-based sensor for the measurement of ammonia concentrations. The NH_3 sensor is based on difference frequency mixing of the output of a 550 mW, 1064-nm laser system and a 785-nm ECDL system in a periodically poled lithium niobate (PPLN) crystal. This sensor is quite similar to the mid-infrared CO sensor that we have developed and are currently testing in our laboratory. For the NH_3 sensor, we will be able to use the same 1064-nm laser source and the same InSb detectors. We will also modify our data analysis code by incorporating a computer model of NH_3 absorption. This model will be developed using data from the HITRAN computer code and will be tested using calibrated mixtures of ammonia and buffer gases.

Papers and Presentations

1. R. P. Lucht, T. N. Anderson, S. Priyadarsan, S. Arumugam, R. Barron-Jimenez, J. A. Caton, and Kalyan Annamalai, "Diode-Laser-Based Sensor Measurements of Nitric Oxide in Particulate-Laden Combustion Exhaust Streams," Proceedings of the Twentieth Annual International Pittsburgh Coal Conference, Pittsburgh, Pennsylvania, September 15-19, 2003; paper in preparation for submission to *Energy and Fuels*.