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

Author(s): Robert P. Lucht
Purdue University
School of Mechanical Engineering, 585 Purdue Mall
West Lafayette, IN 47907-2088
Lucht@purdue.edu (Email)
(765) 494-5623 (Phone)
(765) 494-0539 (Fax)

Jerald A. Caton
Texas A&M University
Department of Mechanical Engineering
3123 TAMU
College Station, TX 77843-3123
jcaton@tamu.edu (Email)
(979) 845-4705 (Phone)
(979) 845-3081 (Fax)

Kalyan Annamalai
Texas A&M University
Department of Mechanical Engineering
3123 TAMU
College Station, TX 77843-3123
kannamalai@tamu.edu (Email)
(979) 845-2562 (Phone)
(979) 862-2418 (Fax)

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.

Measurements will be 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. Previously, coals and coal:FB blends have been used in the burner for determining the combustion and NO_x emission performance. The facility has been

modified for reburn experiments with a premixed propane burner in order to produce hot furnace gases simulating the products of coal combustion. Ammonia is injected into the premixed propane fuel stream and burnt in the primary zone to simulate NO_x emitted from coal fire plant. Measurements of nitric oxide concentration in the exhaust stream will be performed after modification of facility for laser based NO_x diagnostics. The percentage reduction for nitric oxide emissions due to the reburning process will be quantified. The reburn approach is also used in order to reduce the particulate loading.

The combustion facility is in the process of being modified so that optical absorption measurements can be performed in the exhaust stream. The exhaust will be routed from the present coal combustor laboratory to an adjoining laboratory where the sensor systems are located. The exhaust tube is being fitted with a window assembly for initial NO measurements. The detection limit and accuracy of the NO sensor in the exhaust stream will be characterized, and the effect of particulate loading on the ultraviolet absorption measurements will be assessed.

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 have purchased the required ECDL and PPLN crystal and will demonstrate the NH_3 sensor later this summer. 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.