Laser Sensor for Combustion-Generated CO

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Motivation

Carbon monoxide is a particularly important target species as it is a toxic pollutant and product of the incomplete combustion of hydrocarbon fuels. Tunable diode laser absorption spectroscopy (TDLAS), known for its ability to provide non-intrusive, gas-specific, time-resolved *in situ* measurements, is adopted as a robust measure for monitoring gas composition and temperatures in harsh combustion environments. In this research we seek to develop extended near-IR absorption sensors for CO monitoring in combustion exhaust gases using transitions in the first-overtone band near 2.3micron.

Overview

Tunable diode laser absorption spectroscopy of CO was first studied in the controlled laboratory environments of a heated cell and a laboratory combustion exhaust rig (see Fig. 1), and then used for measurements in the economizer region of a commercial coal-fired power plant.

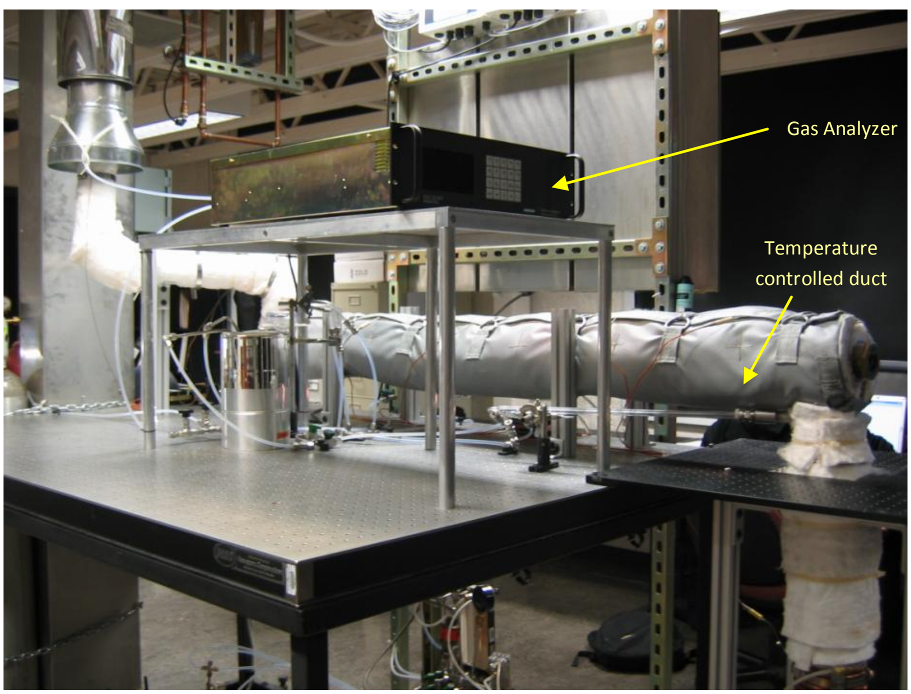

Figure 1: Stanford's constant temperature combustion exhaust duct facility

The design of the CO sensor consists of four major steps:

1. Spectral simulation and line selection: The absorption spectrum is calculated for 100ppm CO, 10% H_2O, 10% CO_2, and the balance air as a function of temperature up to 1500 F (~1100 K). This spectral simulation finds no significant interference from CO_2, but does find significant interference from H_2O. From these

calculations, two candidate transitions (R(10) and R(11) of the first overtone vibrational band) are selected to minimize the H_2O interference (Fig. 2).

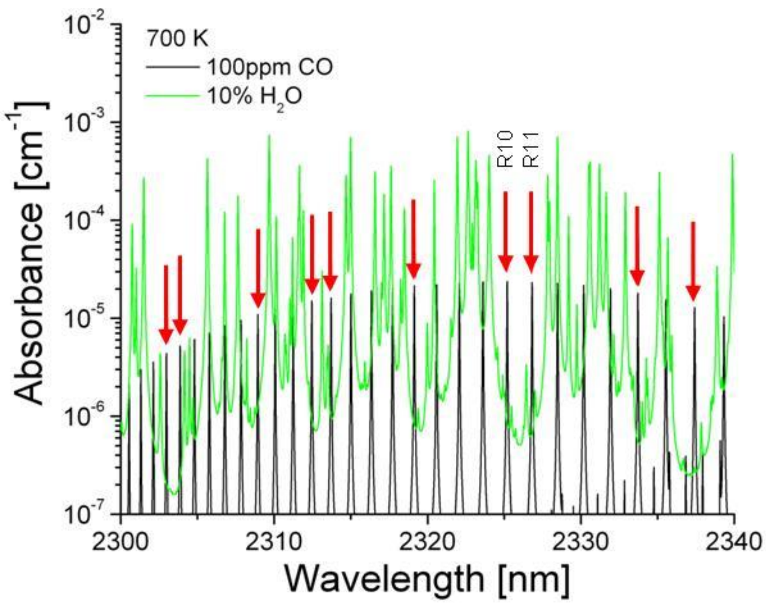

Figure 2: Absorbance per cm of pathlength for 100ppm CO and 10% H_2O at 800 F (700 K) in atmospheric pressure gas simulated from HITRAN. Transitions for CO sensing with the potential to avoid H_2O interference are marked with red arrows; transitions R(10) and R(11) are especially promising. (Simulation calculation from HITRAN)

2. Database validation: The spectral database is measured in the laboratory as a function of temperature up to 1100K for CO and for H_2O (Fig. 3). Such spectroscopic parameters obtained are crucial for accurate measurement at elevated temperatures.

3. Prototype sensor constructed and tested in controlled laboratory environments: Absorption measurements are conducted with direct absorption and with 1f-normalized wavelength-modulation spectroscopy with 2f detection (WMS-2f/1f) to evaluate the sensitivity using both measurement schemes (Fig. 3). The ppm sensitivity of WMS-2f/1f is selected for the sensor strategy.

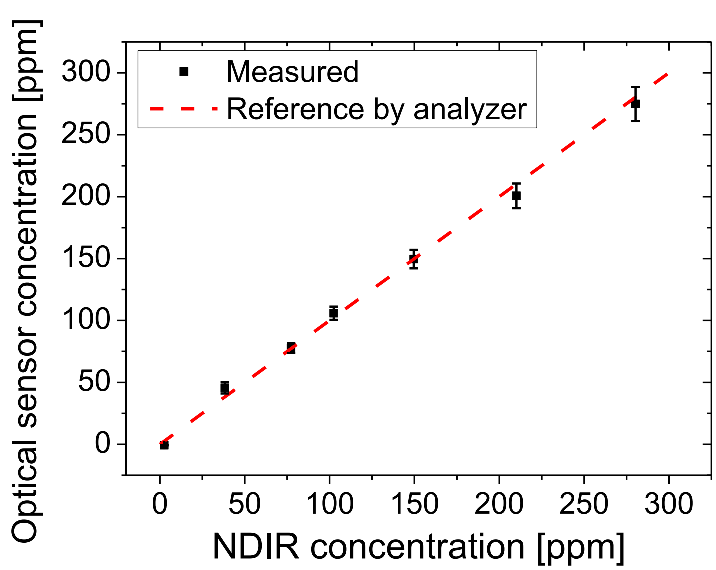

Figure 3: Concentrations measured by 2f/1f optical sensor versus NDIR measurement in sampled combustion gas with pathlength L=1.79m.

4. Second generation prototype sensor constructed and tested in industrial environments: The sensor was demonstrated for real-time *in situ* measurement of CO in the exhaust of the economizer of a 300MW unit of a 1.2GW pulverized-coal-fired power utility (EPRI member facility, see Fig. 4). WMS-2f/1f strategy is employed considering the low absorption level, as well as its immunity to beam steering, dust and soot obstruction. Plans are underway for continued testing of this sensor for real-time CO concentration in combustion exhaust gas with high time-resolution for an extended period of time (hours).

Figure 4: Photo of pulverized coal fired power plant where NO sensor was tested.

Next Steps

A new fiber-coupled DFB laser at 2.3micron has been purchased and tested for the next generation sensor. The laser emits a beam that is >5 times stronger than the laser used before, and the fiber-coupling configuration would simplify the system and ease optical alignment. Other modifications of the sensor system, including enhanced cooling, increased collection angle, etc., are under way to further improve the sensor performance.

References

1. Chao, X.; Jeffries, J.B.; Hanson, R.K. "Absorption sensor for CO in combustion gases using 2.3µm tunable diode lasers", Measurement Science and Technology, 20 (2009) 115201 (9pp).