Mid-IR Sensing of Nitric Oxide in Coal-Fired Power Plants

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Motivation

Nitric oxide (NO) is an important atmospheric constituent of the oxides of nitrogen (NOx), and the majority of this pollutant is formed from the combustion of fossil fuels. NO contributes to ground-level ozone, acid rain, and a variety of adverse human health effects, which has led to increasingly stringent regulatory mandates on the emission of NOx. As a result, the electric-power industry has a growing need to develop reliable control systems to suppress the release of NOx effluent from combustion-driven generation of electricity. Traditional extractive sampling methods suffer from long response time and have the potential for secondary chemistry in the sampling probes. There is thus strong motivation for developing sensors for *in situ* monitoring of NO in combustion exhaust streams.

Overview

A new mid-infrared absorption sensor for *in situ* detection of nitric oxide in combustion exhaust gases has been developed and demonstrated for temperatures up to 700K. A novel external-cavity quantum-cascade diode laser, which can be wavelength-tuned over the R-branch of the fundamental absorption band near 5.2μm, was utilized, enabling critical evaluation of the interference absorption by H_2O in combustion exhaust gases (Fig. 1). NO absorption lines that lie within the gap between water vapor transitions, e.g. R(10.5) pair near 1912cm^{-1} and R(15.5) pair near 1926cm^{-1} were selected as candidate transitions for NO sensing in combustion exhaust.

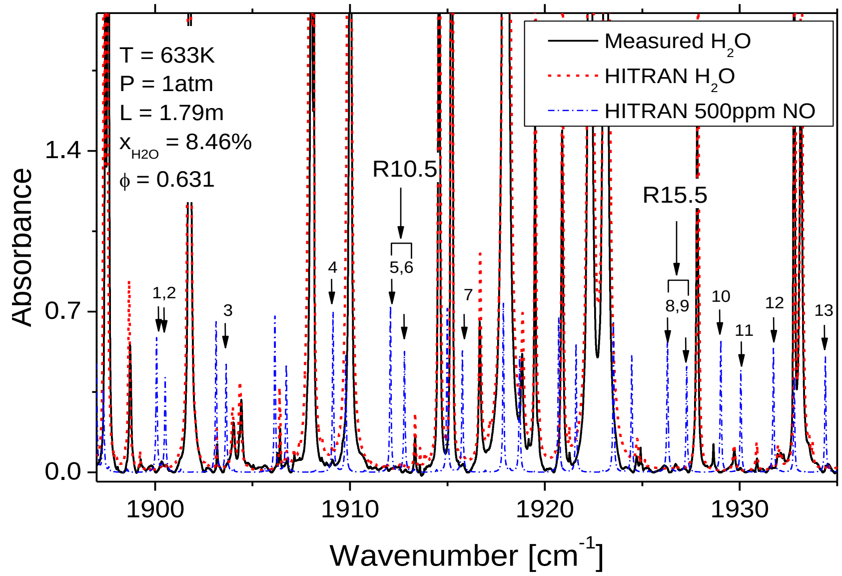

Figure 1: Solid line shows the H_2O absorption measured at 633K (680F) in the effluent of a fuel lean C_2H_4/air flame. Dashed red line shows the H_2O absorption simulated from HITRAN and the dashed blue line shows the positions of the NO transitions and the absorption predicted by HITRAN for 500ppm of NO. Arrows show potential transitions and selected windows in the water vapor spectra for NO detection. (Measurement rig shown in "Laser sensor for combustion-generated CO")

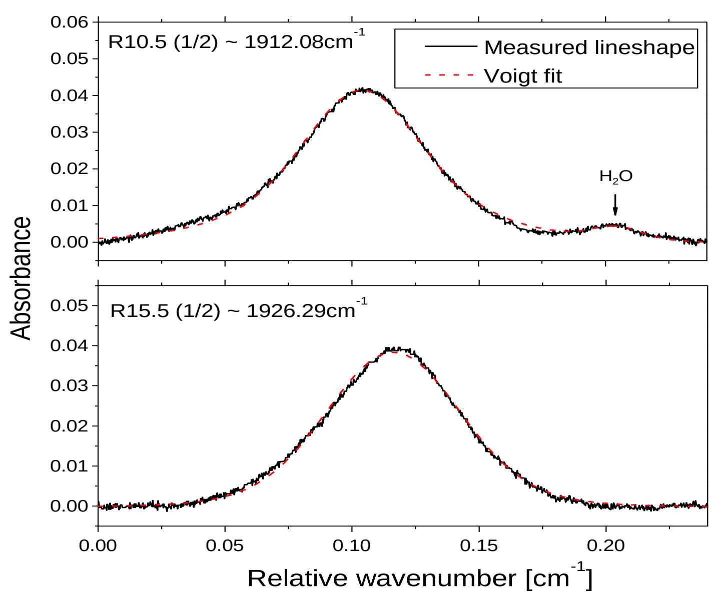

Figure 2: Measured direct-absorption NO lineshapes in combustion exhaust for fuel-lean C_2H_4/O_2/Ar flame with 22ppm of added NO at 1 atm, 600K, L = 1.79m.

The grating scan of the external-cavity laser provided broad wavelength tuning for a complete single-scan survey spectrum (Fig. 1) in a time of under five seconds. The absorption SNR was improved with faster scanning over shorter wavelength ranges by driving the external-cavity length with a piezoelectric element on the cavity mirror (Fig. 2). Such a scan range was sufficient for direct-absorption scans of a single NO transition. With this strategy and the interference-free transitions selected previously, NO was first measured in hot combustion exhaust environment provided by a laboratory combustion exhaust duct. An example single-sweep lineshape of R10.5 (1/2) and R15.5 (1/2) lines is shown in Fig. 2.

The sensor was subsequently tested for real-time measurements of NO across a 3m path in the exhaust of a pulverized-coal-fired power plant (Fig. 3), including capture of a 30% transient change in NO concentration at the economizer exit that occurred during the shutdown and recovery of the SNCR NOx control system (Fig. 4). The sensor shows excellent promise for monitoring NO in practical combustion exhausts of coal-fired power plants at temperatures up to at least 700K.

Figure 3: Photo of pulverized coal fired power plant where NO sensor was tested.

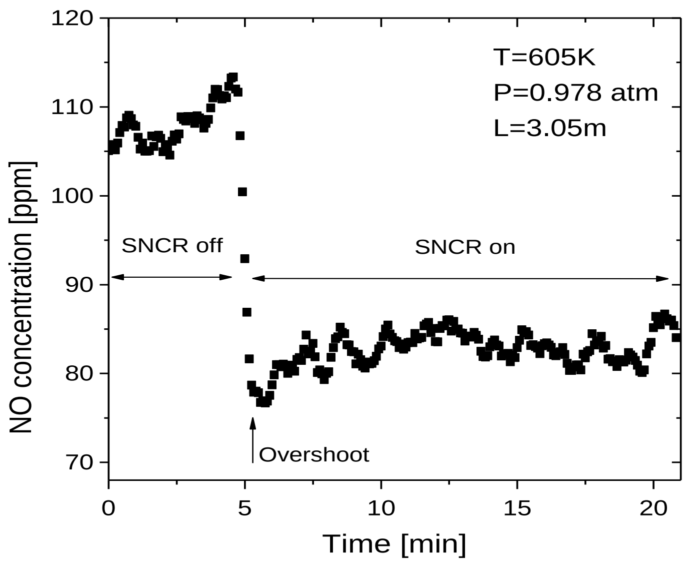

Figure 4: Optical measurement of NO concentration during the failure and recovery of SNCR NOx control system.

Next Steps

Investigation of WMS strategy for NO sensing using quantum-cascade lasers is underway. Other modifications of the sensor engineering, including enhanced cooling, increased collection angle, etc., are being investigated to further improve the sensor performance.

References

1. Chao, X.; Jeffries, J.B.; Hanson, R.K. "*In situ* absorption sensor for NO in combustion gases with a 5.2µm quantum-cascade laser ", accepted for oral presentation in 33rd Combustion Symposium, 2010.