PROJECT facts

U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

Advanced Research

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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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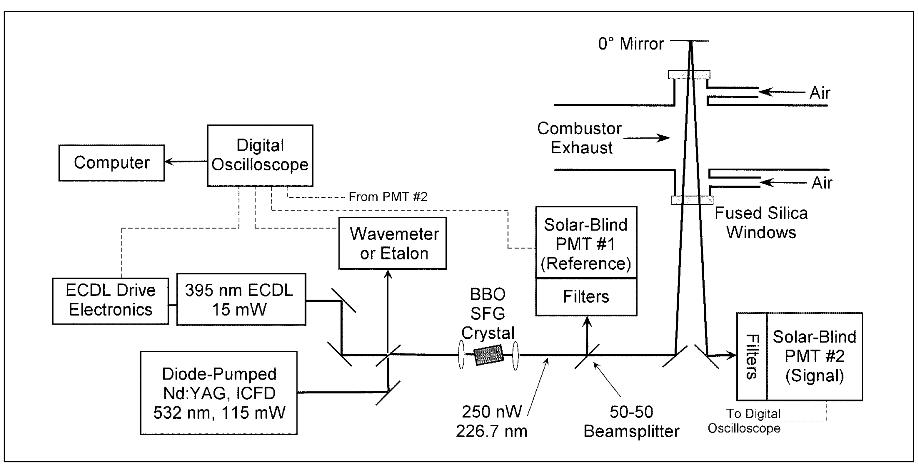
Description

The objective of the research is the development and demonstration of new optical absorption sensors for the measurement of nitric oxide and ammonia in coal combustor exhaust streams. The development of these diode-laser-based systems will significantly enhance the sensor capabilities for practical combustion systems. In both cases, frequency conversion techniques are employed to enable the use of well-developed lasers that emit in the visible and/or near-infrared. In the case of NO, sum-frequency-mixing (SFM) is used to produce laser radiation at 226.7 nm in the ultraviolet region of the spectrum, and in the case of NH_3 difference-frequency-mixing will be used to generate 3.00 mm laser radiation in the mid-infrared. In both cases the frequency conversion allows us to access very strong fundamental absorption bands of the molecule, greatly increasing the sensitivity of the absorption measurements.

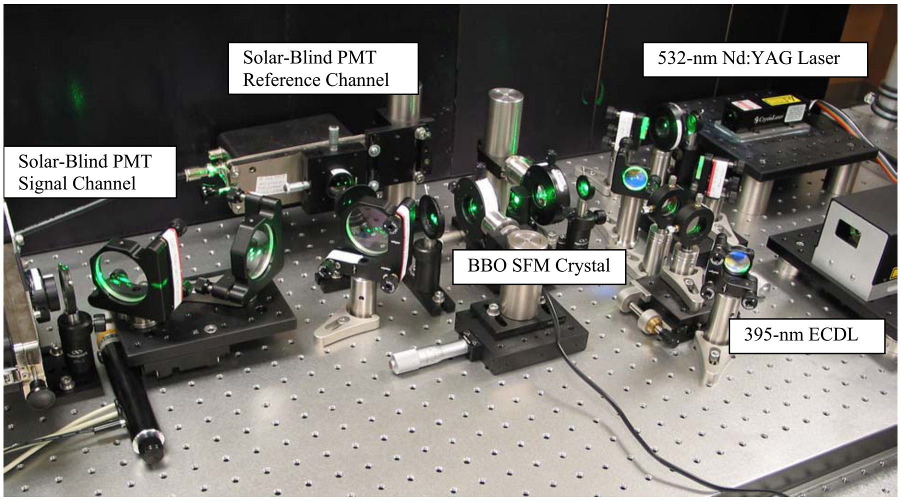
The optical sensors that we are developing for path-averaged absorption measurements are extremely sensitive and selective for particular chemical species, and they do not require calibration other than a measurement of optical path length. The NO measurements, for example, are inherently much less susceptible to interference from other species and much less dependent on system calibration factors than traditional physical sampling



Schematic Diagram of the NO Ultraviolet Absorption Sensor techniques. The optical sensor systems that we have developed can be miniaturized significantly and have modest power requirements due to the inherent efficiency of diode lasers. The simplicity, generality, and relatively low cost of the sum-frequency-mixing-based sensor strategy will enable the development of absorption sensors throughout the entire ultraviolet spectrum. In the mid-infrared spectral region, we use difference-frequency-mixing techniques to produce laser radiation tuned to strong fundamental vibrational transitions of species such as NH_3. These frequency-mixing techniques open up a wide range of new possibilities for sensing and control of chemically reacting flow processes.

Accomplishments

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 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 nitric oxide sensor has been used for measurements in the exhaust of a coal-fired laboratory combustion facility. The Texas A&M University boiler burner facility is a 30 kW (100,000 Btu/hr) downward-fired furnace with a steel shell encasing ceramic insulation. Measurements of nitric oxide concentration in the exhaust stream were performed after modification of the facility for laser based NO_x diagnostics. 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. Single-laser-sweep measurements were demonstrated with an effective time resolution of 100 msec, limited at this time by the scan rate of our mechanically tuned ECDL system. Future planned modifications will lead to even faster response times at sensitivity levels at or below 1 ppm.



NO Ultraviolet Absorption Sensor in Operation.

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$200,000

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WEBSITES

www.netl.doe.gov/coal