PROJECT facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Advanced Research

09/2005

Mercury/Mercury Chloride Detection

Description

Mercury is viewed as both a health hazard and environmental hazard. As such, the reduction of vapor-phase mercury emissions from coal-fired power-plants is of immediate and practical concern. The efficiency of Hg removal depends strongly on the distribution of Hg compounds in the power-plant flue gas: $HgCl_2$ (the most abundant form of oxidized Hg emitted by most coal-fired boilers) and other forms of oxidized Hg can be efficiently removed by filtration or particle injection, while elemental Hg (Hg^0) is much more difficult to collect. The relative abundance of elemental and oxidized mercury depends on the fuel stock and combustion conditions. Accurate measurements of Hg^0 and $HgCl_2$ are essential to modeling the fate and transport of Hg and to evaluating and optimizing the effectiveness of possible Hg control technologies. To meet this need, Sandia researchers are developing new laser-induced-fluorescence (LIF) capabilities for short-range, sensitive detection of gaseous Hg^0 and $HgCl_2$. This effort has three main tasks:

1) development, optimization, and quantification of a resonance-fluorescence detection scheme for Hg^0 and pulsed photofragment emission detection scheme for $HgCl_2$;

2) development of a compact, broadly tunable, fiber-based, ultraviolet (UV) laser system to make the above approach (and other UV sensors) practical outside the laboratory;

3) construction of a breadboard $Hg^0/HgCl_2$ sensor to demonstrate detection of these species in the exhaust of a coal-fired, pilot-scale combustor.

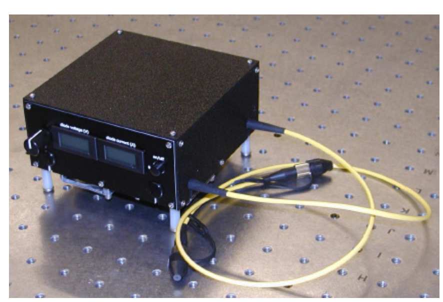
Fiber Laser Sources for Sensor Applications

In a fiber amplifier, a single-mode optical fiber is doped with a rare-earth ion that can be pumped with a laser diode to achieve a population inversion. The fiber can be used to amplify a weak seed signal or can be configured as a laser. Use of an optical fiber offers several advantages over a bulk crystal or glass host, including:

1) Both the pump and seed light are confined within the fiber, providing long interaction lengths (meters) and consequently high efficiency.

2) The intrinsically high beam quality characteristic of a single-mode fiber is insensitive to thermal or mechanical perturbations and optical power level.

3) The availability of fiber-coupled components makes packaging relatively simple and low cost; the fiber pigtails can be fused, resulting in a rugged, hermetically sealed, alignment-free optical system.



Fiber laser source

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PROJECT DURATION

October 2003 –
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PROJECT COST

$1,800,000

CUSTOMER SERVICE

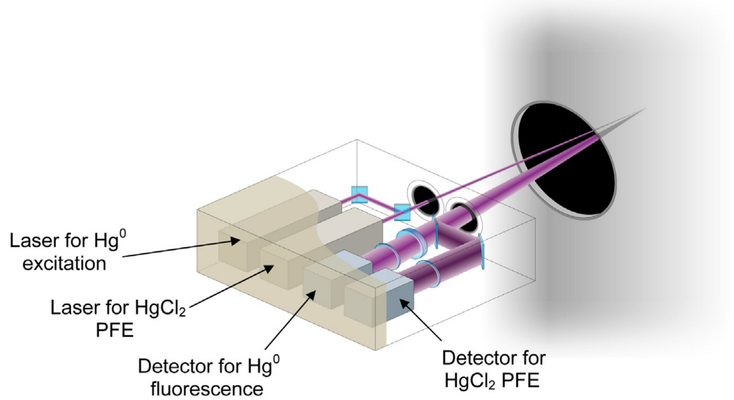
1-800-553-7681

WEBSITE

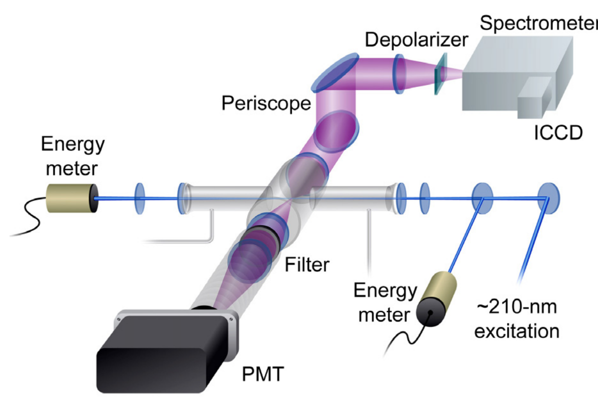
www.netl.doe.gov

Accomplishments

This project's initial goal was to assess the feasibility of $HgCl_2$ detection with photofragment emission (PFE) using a fiber-amplifier as a laser excitation source. The characteristics of the fiber amplifier, the spectroscopic signature of the PFE technique, and the detection optics/electronics were evaluated to determine the sensitivity of this measurement approach. We have examined the dependencies of the $HgCl_2$ PFE signal on laser pulse energy and the concentrations of the dominant collisional species. In parallel to the efforts assessing the measurement technique, we have constructed a high-power pulsed near-IR fiber amplifier and have frequency-converted the output wavelength to the deep-ultraviolet (213 nm). Assuming typical flue gas concentrations (74% N_2, 12% CO_2, 8% H_2O, and 6% O_2) at 200ºC, we estimate a sub-parts-per-billion (ppb) detection limit for a 1-mm^3 probe volume and a 5-minute signal-integration time. This estimate of the detection limit assumes a 10-kHz, 100 µJ/pulse, ~210-nm excitation source. The predicted performance of $HgCl_2$ PFE with this laser approaches that of current wet-chemical monitoring techniques, with the significant advantages of providing real-time analysis with a non-invasive approach.



Sensor schematic for in situ detection



Schematic of laboratory detection system

Future Work

The current focus of the project is to develop and evaluate the filtered resonance fluorescence approach for detection of Hg^0. The performance of a novel filtering scheme will be investigated, quantifying both the transmission of the mercury fluorescence and suppression of laser scatter by the filter. Meanwhile, we will develop a fiber-based UV laser with the requisite optical characteristics to implement this detection method. The LIF detection approaches for $HgCl_2$ and Hg^0 will then be combined to demonstrate real-time speciating measurement of mercury emissions.