the ENERGY lab

PROJECT FACTS

Advanced Research

Micro-Structured Sapphire Fiber Sensors for Simultaneous Measurements of High Temperature and Dynamic Gas Pressure in Harsh Environments

Description

Securing a sustainable energy economy by developing affordable and clean energy from coal and other fossil fuels is a central element to mission of The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL). To further this mission, NETL funds research and development of novel sensor technologies that can function under the extreme operating conditions often found in advanced power systems.

The use of optical fibers has made a significant impact on sensing technology in harsh environments. Optical fibers are ideal for applications that require high-temperature and -pressure measurements because they are more sensitive to the parameters being measured. An optical fiber sensing system is composed of a light source, an optical waveguide (the optical fiber), a sensing element or transducer, and a detector. The transducer modulates some parameter of the light traveling inside the optical fiber (e.g., intensity, wavelength, polarization, or phase) and the system measures the changes in the optical signal received at the detector.

Under the Advanced Research program at NETL, a multidisciplinary research team led by Missouri University of Science and Technology, with members from University of Cincinnati, is working to solve challenges in the design, fabrication, integration, and application of sensing technologies in harsh environments. The focus of this 3-year project is to conduct fundamental and applied research leading to the successful development and demonstration of robust, multiplexed, micro-structured sensors that use single-crystal sapphire fibers. At the core of the technology are hybrid extrinsic/intrinsic Fabry-Perot interferometer (HEIFPI) sensors directly micro-machined on a sapphire fiber using an ultrafast laser. This hair-thin, cylindrical filament made of single-crystal sapphire (glass) is able to transmit light by confining it within regions of different optical indices of refraction. These sensors can be deployed into the hot zones of advanced power and fuel systems (inside a coal gasifier or gas turbine system) to simultaneously measure high temperature (up to 1600 °C) and dynamic gas pressure.

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AmerenUE Corporate

PERIOD OF PERFORMANCE

10/01/2009-09/30/2012

COST

Total Project Value
$1,131,799

DOE/Non-DOE Share
$896,838/ $234,961

Goals

The primary goal of this program is to develop and demonstrate multiplexed, micro-structured, single-crystal sapphire fiber sensors for temperature and gas pressure measurement in harsh environments. The project has three main objectives: (1) to incorporate sapphire fibers into sensors that will be fully operational at high temperatures in a simulated harsh environment; (2) to develop and demonstrate novel sensors to simultaneously measure temperature and gas pressure in harsh environments; and (3) to develop and demonstrate novel sapphire fiber cladding and excitation techniques to assure high signal integrity and sensor robustness.

Technological Approach

Single-crystal sapphire fiber-based sensors for in situ measurement of temperature and dynamic pressure in harsh environments will be developed in two phases. During Phase I, researchers will determine concept viability using micro-machined sapphire fiber HEIFPI sensors for measurements of high temperature and dynamic gas pressure. During Phase II, researchers will optimize, characterize, and demonstrate key functions of the proposed technology for concurrent measurement of temperature and dynamic gas pressure in a laboratory-based simulated high-temperature, high-pressure harsh environment. Upon successful technology demonstration in laboratory tests, the team will collaborate with engineers from AmerenUE Corporate to create a test plan to package, install, and test the sensors and measurement system at AmerenUE Corporate test facilities.

Benefits

The sapphire sensors developed in this project will help produce affordable, clean energy from coal and other fossil fuels and contribute to a sustainable energy economy. Advanced process controls facilitated by robust optical fiber sensors will contribute to high efficiency, high reliability, and high environmental performance of existing and future advanced power and fuel systems. Specifically, these sensors will permit gasification plants to produce power from various fuels cleanly and efficiently, supporting the DOE's goals to increase the availability of power from domestic fuels and decrease the negative environmental effects of power production.

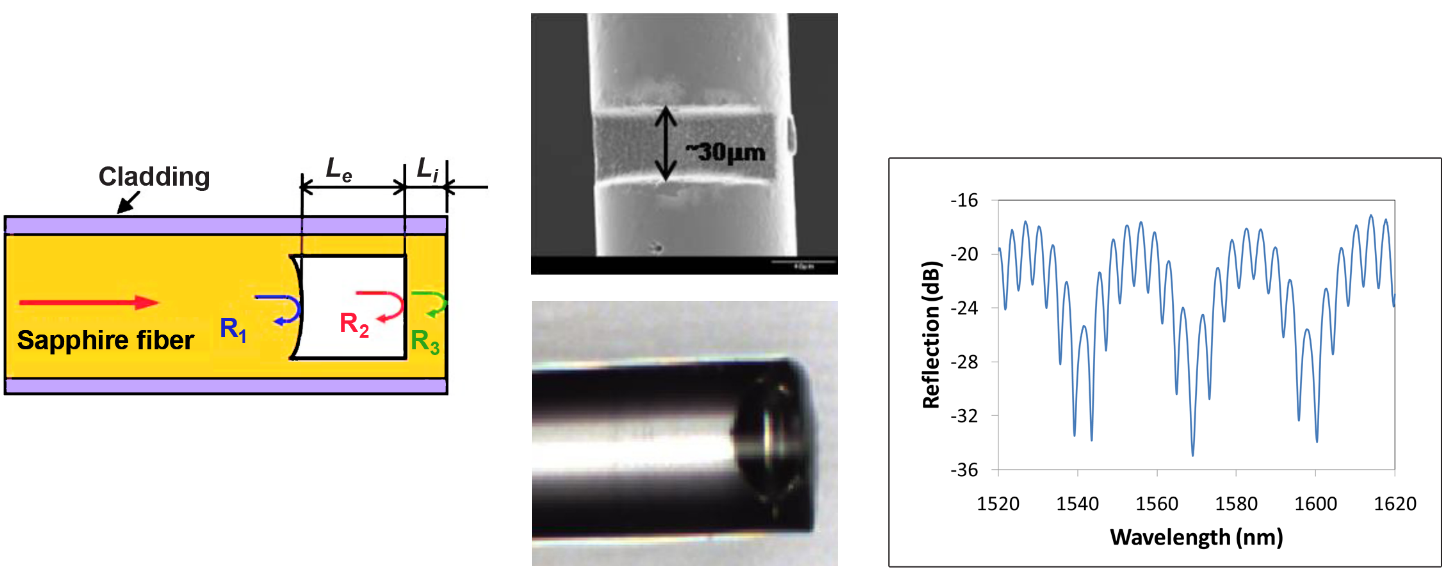

Figure 1. The sapphire sensor is designed with double layer cladding to protect the sapphire fiber in a harsh environment. A micro-machined sensor element, the micro-inline HEIFPI, will allow the sapphire sensors to simultaneously measure high temperature and dynamic gas pressure within the gasifier and the gas turbine.