Established The rr( ) cos(2 ) and ( ) cos 2 ( ) Single J. Huang, T. Wang, L. Hua, J. Fan, H. Xiao, M. Luo, H. Jiang, R. Yang, X. Tang, A. Burnett, X. Lan, H. Xiao, J. Dong, dd U f e f t U f e ft U f e f t

Concept & Approach: The approach to this project is to develop a well-known optical fiber interferometric sensor mechanism, the Fabry-Perot interferometer (FPI), in the coaxial cable (CC), referred to as a CC-FPI sensor (3). The CC-FPI sensors, as illustrated below, operate in radio frequency (RF) domain which allows choices of low-cost commercial components and instruments for sensor signal processing.

Introduction: The development of cleaner coal-based power plants has necessitated real-time monitoring of process conditions and equipment physical states. The realization of such monitoring capability will rely largely on the development of harsh environment sensors that are currently nonexistent. In recent years, various fiber optic sensors (FOS) have been under development and found many successful applications in harsh environments due to their unique advantages including compactness, high resolution, immunity to electromagnetic interference, remote operability, multiplexing capability, and thermal and chemical stabilities [1]. However, they are fragile, requiring very bulky, costly, and sophisticated packaging, and have a small dynamic due to their limited reversibility deformability. Coaxial cables may overcome the fragility issue and the signal generation and transmission mechanisms are governed by the same electromagnetic principles as in FOS.

Research Progress: 1. Established facilities for metal-ceramic coaxial cable FPI (MCCC-FPI) sensor fabrication and test

Objectives & Deliverables: To develop a new metal-ceramic coaxial cable (MCCC) Fabry-Perot interferometer (FPI) sensor and demonstrate its ability for real-time, distributed monitoring of temperatures up to 1000°C. The project has the following four specific technical objectives: (i) to identify and optimize metal and ceramic materials with desired electrical and dielectric properties as well as thermochromical stability, (ii) to construct the MCCC-FPI sensors and test the sensor stability in high temperature gas environments relevant to fossil energy power system, (iii) to develop the instrumentation for signal processing and algorithmic integration for sensing systems, and (iv) to demonstrate the MCCC-FPI sensor for real-time distributed temperature measurement and evaluate its performance in terms of sensitivity, spatial resolution, stability, and response speed that are important to practical applications.

Assuming the amplitude reflection coefficients of the two reflectors are the same, the two reflected waves (U1 and U2) are given as:

\[ U_1 = T_1 F \frac{\cos (2 \pi f t + \theta_1)}{c} \]
\[ U_2 = T_2 F \frac{\cos (2 \pi f t + \theta_2)}{c} \]

where \( T_1, T_2 \) are the intensity reflection coefficient of the reflector; \( f \) is the frequency of the EM wave; \( a \) is the propagation loss coefficient; \( z \) denotes the cable axial direction; \( r \) is the time delay between the two reflected wave; \( d \) is the distance between the two reflectors; \( c \) is the relative permittivity of the inner dielectric material of the cable; and \( c \) is the speed of light in vacuum. The interference signal (I) is the summation of the two reflected waves, expressed as:

\[ I = U_1 U_2 \]

The CC-FPI measures temperature by monitoring the interferogram shift from a reference defined at an arbitrary temperature (Tg) because d and c are functions of temperature:

\[ d_T = \frac{d_{T_0}}{a} + \frac{b}{a} (T - T_0) \]
\[ c_T = c_{T_0} \frac{T}{T_0} \]

The interference signal thus becomes a function of temperature and monitoring the interferometric spectrum shift, \( U(T) \), allows for real-time measurement of temperature by the CC-FPI.

\[ U(T) = K_c \cos (K_z \cdot (T - T_0)) \]

\[ \tau(T) = 2 d_T \cdot c_{T_0} / c \]

3. Demonstrated temperature monitoring by single point MCCC-FPI sensors

Research: MCCC-FPI: alumina tube as insulator and air gaps as refractors

Examples of ceramic disc refractors

(Note: all MCCC-FPI sensors reported here used stainless steel tube and wire was outer and inner conductors, respectively.)

Conclusions:

(1) Single point MCCC-FPI sensors have been successfully fabricated with various materials for insulation and refractors;
(2) For all MCCC-FPI sensors, the wavelength shift exhibited generally linear dependence on temperature indicating the capability for in-situ temperature monitoring.
(3) The sensors tested passed up to 900°C
(4) The positioning of the refractors and insulation must be stabilized and secured for required accuracy and consistency.

Literature: