Fiber Optic Temperature Sensors in TPS: Arc Jet Model Design & Testing

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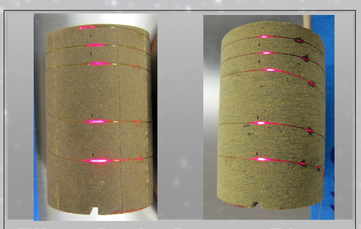
Introduction

This poster describes an IFOS-NASA collaboration resulting in the first-ever arc jet testing of fiber optic temperature sensors

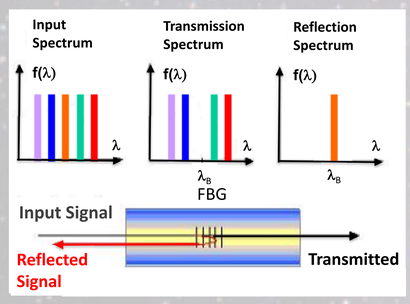
IFOS Corp. has developed fiber optic temperature sensing technology for Thermal Protection System (TPS) materials

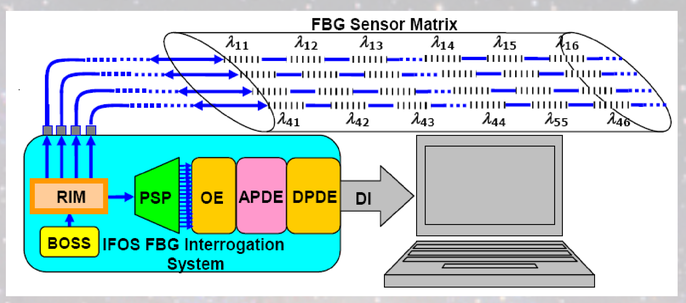
Fiber optic-based temperature sensors offer potential improvements over state-of-the-art thermocouples (TCs), as described below



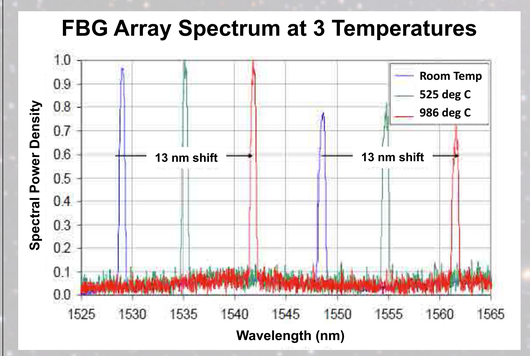
Fiber Optic Sensor Plugs

Background: Fiber Bragg Grating Based Sensing





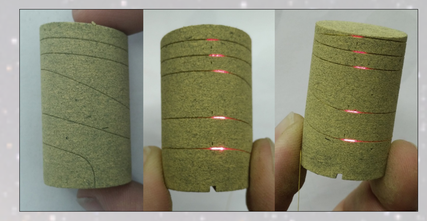
- Fiber Bragg Gratings (FBGs) are designed to reflect precise wavelengths of light
- Many FBGs, each of a unique wavelength, can be produced on a single fiber



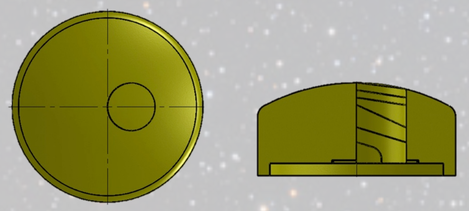
- Reflected FBG spectrum is temp. dependent
- Compared to thermocouples (TCs), fiber optics have lower thermal conductivity (therefore perturb local thermal gradient less) and are non-electrically conductive (which is problematic for some TPS materials with TCs)
- Fibers with many FBG sensors offer higher spatial resolution of temperature sensing compared to TCs

Arc Jet Model & Fiber Optic Plug design

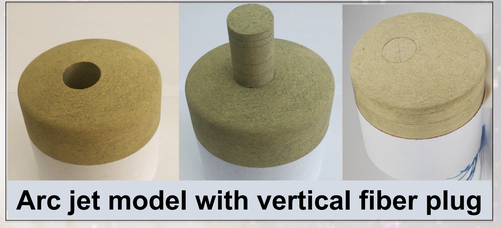
- The primary design consists of 1” diameter plug with fiber optic wound around the circumference in a precisely-machined groove to align FGBs along two axes
- Five FGBs along centerline axis and 5 offset to detect sidewall heating
- 4 mm long FBGs parallel to the outer surface to limit in-depth thermal conduction
- Thermocouple and fiber optic models were instrumented with the same sensor locations to facilitate comparison of the two techniques



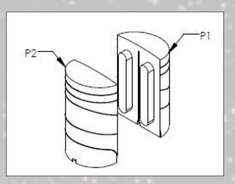
Wound plug with FBGs 180˚ apart to measure centerline & sidewall heating



4” diameter Iso-q arc jet model with plug



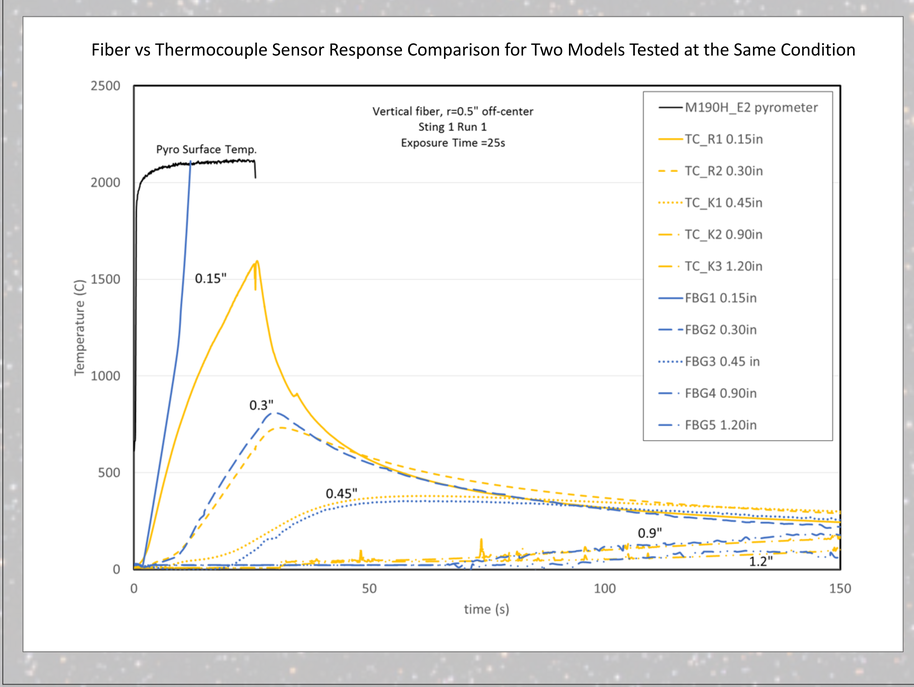
Arc jet model with vertical fiber plug



A few models were produced with vertical fiber FBG plugs

Arc Jet Testing & Preliminary Results

- A total of 18 PICA and BPA models were arc jet tested at a cold wall heat flux of 240 W/cm^2, at a pressure of 9 kPa, and for durations of 15 to 60 seconds
- In each arc jet run, one TC model and four fiber models were tested
- Testing was recently completed, data analysis is ongoing



- In-depth sensors responded similarly (0.3” below surface and lower)
- The 0.15” FBG response shows much higher temperatures than expected, but is also well beyond the ~1000 ˚C max calibration range

Conclusions & Future Direction

- Fiber optic temperature sensing of TPS materials in a planetary entry-relevant heating environment has been demonstrated based on IFOS interrogation of FBG-reflected spectra in PICA and BPA arc jet coupons
- Fiber plug design allows for many sensors per plug, high data rates (kHz)
- In-plane distribution of sensors enables assessment of 2D/3D heating effects (still under evaluation for this test series)
- Fiberglass-based FBG sensing is reliable to at least 1000 ˚C
- High temperature fiber optic sensing limits could be increased using sapphire fibers, which is currently under development by IFOS
- Other parameters tested during this series include the effect of FBG size (trading signal for location precision with decreasing size) and a vertical fiber orientation are still under evaluation

BPA before & after arc jet testing

PICA before & after arc jet testing

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