Additive Manufacturing of Smart Parts with Embedded Sensors for In-Situ Monitoring in Advanced Energy Systems

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Objective

Prove and demonstrate the new concept of sensor-integrated "smart part" that can be easily installed in existing and new energy systems for in situ monitoring of the health statues of critical components and key operational parameters under harsh conditions.

Background

INTRODUCTION

- Demands: Success of clean coal technologies will rely heavily on sensors and instrumentation for: advanced process control/ optimization, Key components protection, System maintenance and lifecycle management
- Requirements: Sensors need to survive and operate in the high-T, high-P and corrosive/erosive harsh environments for a long of time.
- Status: Current sensor and monitoring technologies capable of operating in harsh conditions are extremely limited

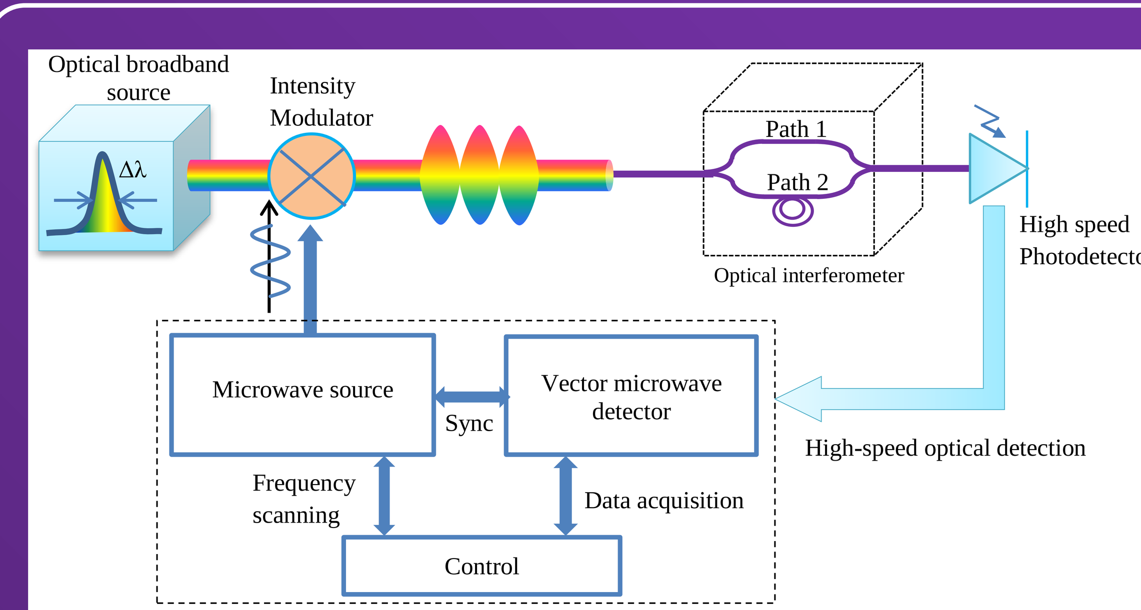
CURRENT TECHNOLOGIES AND LIMITATIONS

- Traditionally, sensors are attached to or installed onto the component after the structure is fabricated
- Costly and complicated sensor packaging before installation
- Poor survivability and reliability of the sensors
- Discrepancy between the sensor reading and the actual status
- Potential performance compromise of the host materials/structures

OPPORTUNITIES - SENSOR-EMBEDDED "SMART PARTS"

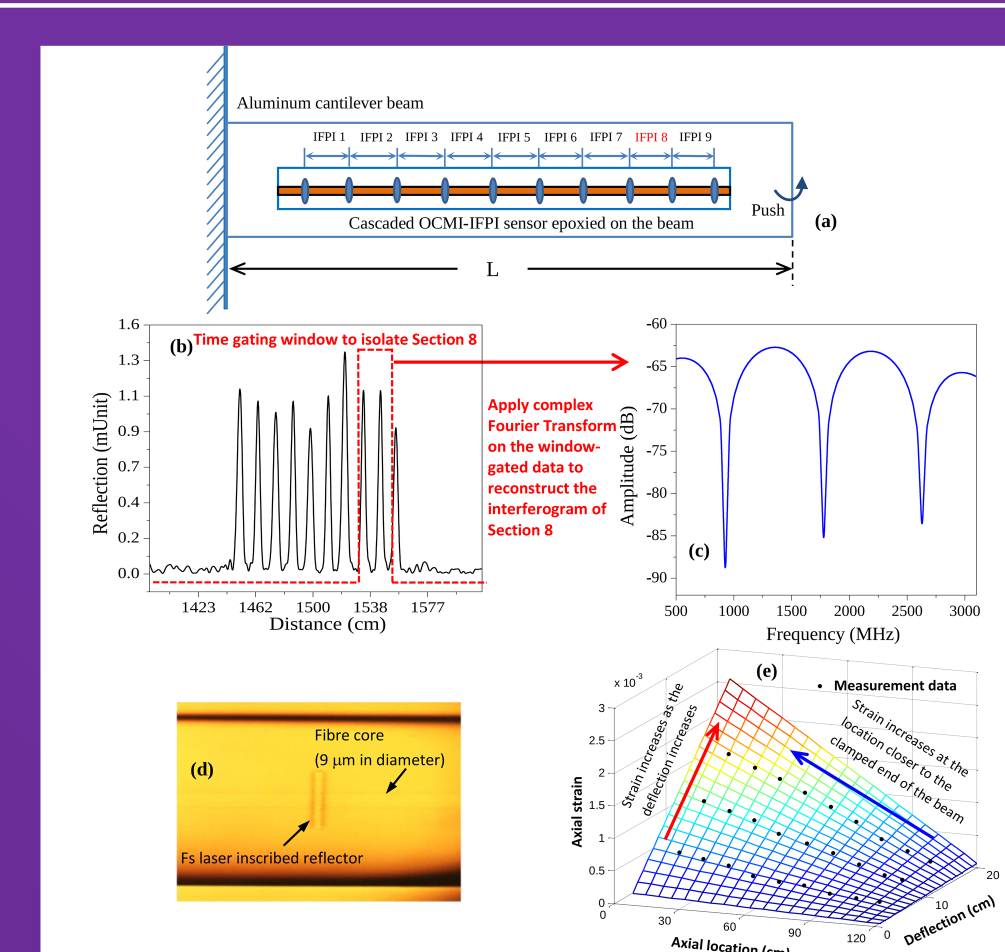
- Smart parts – widely used and proven successful in structural health monitoring (SHM)
- Provide the real-time information on the component and system
- Reduce the complexity in sensor packaging and installation
- Increase the robustness and reliability of the system

Novel Optical Carrier based Microwave Interferometry (CCMI)

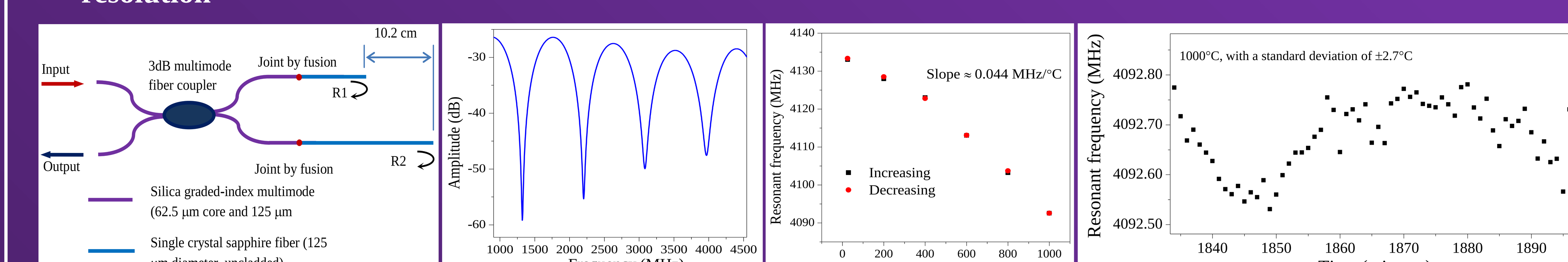


The essence of OCMI is to read optical interferometers in microwave domain. the system offers many unique features that are particularly advantageous for sensing applications

- High signal quality and excellent visibility
- Relieved requirement on fabrication
- Insensitive to the variations of polarization
- Low dependence on multimodal influences and can be implemented in special optical fibers (e.g., multimode, single crystal sapphire, polymer fibers) and free space
- Spatially continues distributed sensing with high resolution

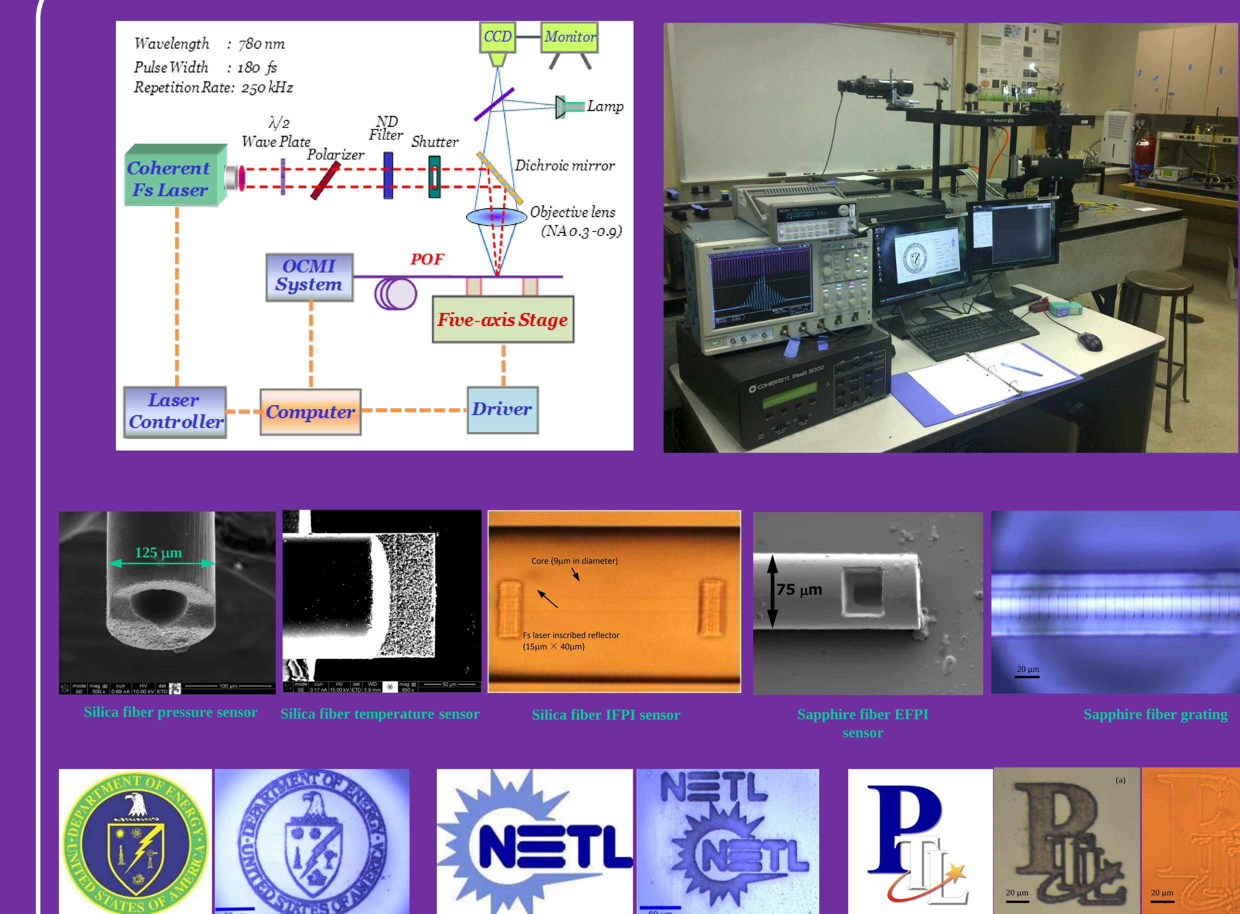


Spatially continuous distributed strain measurement using cascaded intrinsic Fabry-Perot OCMI sensors. The spatial resolution can be as high as 1 cm. The distance can be as long a few kilometers.



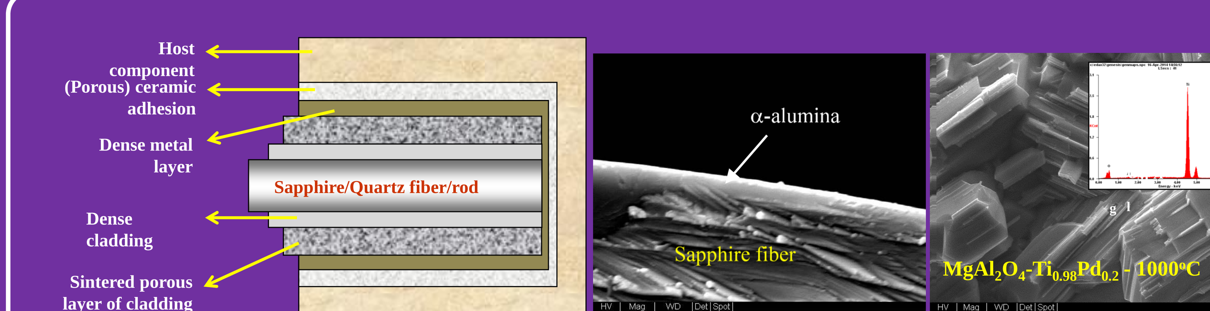
Single crystal sapphire fiber Michelson OCMI sensor for high temperature and strain sensing. Excellent signal quality, temperature measurement repeatability, and stability.

Assembly-Free Sensor Fabrication



Femtosecond laser micromachining

Protective transition layers



Multiple layers of coatings to interface the embedded sensor and the host and to provide the chemical, thermal, mechanical and optical protections of the embedded sensors.

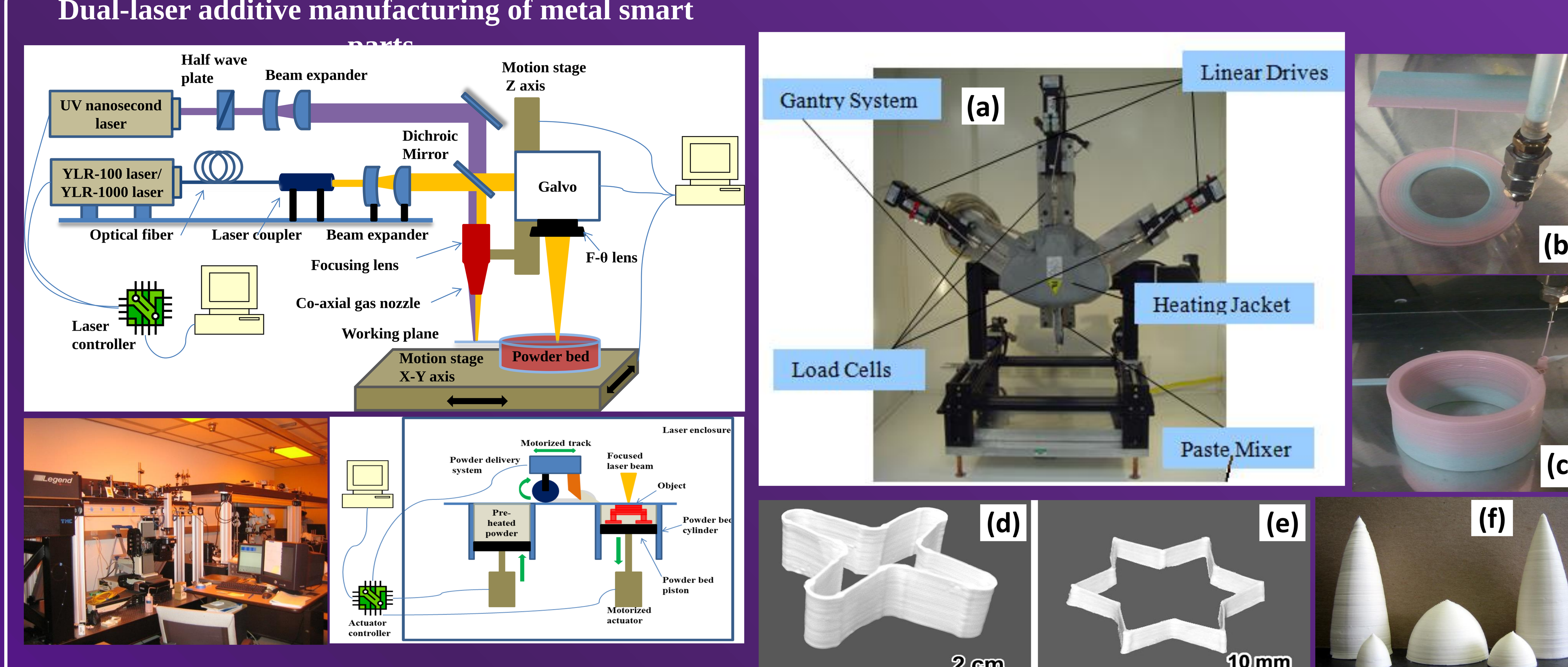
Smart Parts

Scope of Work

- Robust, high-temperature tolerated, embeddable optical carrier based microwave interfereometry (CCMI) sensors
- Novel signal processing and instrumentation for distributed sensing
- Comprehensive thermal and mechanical models for optimal sensor embedment and rational interpretation of the sensor outputs
- Multifunctional protective layers between the sensor and the host for thermal, mechanical and chemical protection of the sensors
- Additive manufacturing of the "smart parts"
- Feasibility tests and performance evaluation

Additive Manufacturing of Smart Parts

Dual-laser additive manufacturing of metal smart parts



Additive manufacturing (AM) of ceramic smart parts based on freeze-form extrusion process

Summary

- Sensor-integrated smart parts: a new paradigm for sensing in advanced energy systems
- Innovative approaches to tackle challenging problems
  - **Robust sensors:** The novel concept of OCMI and fs laser assembly-free device fabrication
  - **Sensor embedment:** Additive manufacturing
  - **Survivability:** Transition layers between the sensor and host
  - **Dependable performance:** Comprehensive thermal-mechanical modeling/simulations of the "smart parts"
  - **Distributed sensing:** Joint frequency-time domain method uniquely enabled by mixing microwave with optics
  - **Demonstration:** Tests and performance evaluations in simulated laboratory conditions using existing facilities

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