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## Selective Laser Melting In Situ Temperature Monitoring **Using Femtosecond Point-by-Point Fiber Bragg Gratings**

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## Abstract

Additive Manufacturing (AM) processes rely on the layer-by-layer production of parts with complex geometries. The embedding of sensors inside the printed materials allows to perform the *in-situ* monitoring of the AM process, as well as the monitoring of the parts during their usage in potentially harsh environments. We used an array of Fiber Bragg Gratings directly written in a polyimide-coated single mode fiber using the femtosecond point-by-point technique (fs-PbP FBGs) to monitor the temperature along a 316L stainless steel specimen additively manufactured by Selective Laser Melting (SLM). These gratings can withstand temperatures up to 1000°C. The FBG array was placed inside a steel capillary, hence it was sensitive to temperature only. Monitoring of the FBGs wavelengths at a scan rate of 5 kHz allowed multi-point temperature measurements and thermal dynamics monitoring throughout the process.

### **OPTICAL FIBER SENSORS ARRAY MANUFACTURING AND EMBEDDING BY SLM**







Embedding by SLM



Manufactured parts

### $\rightarrow$ Laser scan over powder layer Layer printing time ~5.5 s (layer thickness = $30 \mu m$ )

### SLM TEMPERATURE MONITORING USING FEMTOSECOND-WRITTEN FBGs



Temperature measurement at 5 kHz by FBG E1 throughout the SLM process (68 layers deposited)

- Monitoring using si255 (Micron Optics) optical sensing instrument
  - 5 kHz on-board peak detection (based on zero-crossing of spectrum derivative)
  - 10 Hz spectral read out (3-dB bandwidth (BW) peak detection, FWHM and amplitude calculation)
- $\blacktriangleright$  Each layer  $\rightarrow \Delta T$  induced by laser scanning
- ▶  $n_{\text{lavers}} \nearrow \rightarrow \text{decrease}$  in  $\Delta T$  due to thermal insulation by upper layers
- $\blacktriangleright$  All FBG sensors show nearly identical  $\Delta T$
- $\blacktriangleright$  Baseline increase  $\rightarrow$  heat conduction into substrate plate



Successive shift of spatially distributed FBGs

Spectral chirp (FWHM increase) induced by thermal gradient

FBGs spectral distorsions (chirp) induced by thermal gradient during laser scanning (layer #11) comparison of two peak detection algorithms

## **Conclusion and Perspectives**

- Complete SLM process temperature monitoring of a 316L specimen performed
- **Thermal dynamics** successfully recorded at 5 kHz scan rate
- Measurements not severely impacted by FBGs spectral distorsions due to thermal gradient induced chirp
- Peak temperature per layer dependent on material thickness

- **Transient process modeling** under investigation
- Coming next: in situ SLM monitoring close to the melt pool with high temperature FBGs **directly embedded** inside the part
- Structural Health Monitoring (SHM) of instrumented parts operational in harsh environments

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