MULTI-MATERIAL APPROACH TO INTEGRATE CERAMIC BOXED SENSORS AND ACTUATORS IN LASER BEAM MELTED STRUCTURES FOR TAILORED SMART BIO APPLICATIONS

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THERANOSTISCHE IMPLANTATE

OUTLINE

- Introduction
- Material and methods
- Results

Introduction

To place physical gradients such as force, heat, light etc. in a shaped body exactly where it is needed and, in turn, to measure physical parameters where they work, to get digital datas, is the dream of every developer and engineer. The tailor-made and application-specific embedding of the actuators and sensors is the technological keyhole or the bridge around to make an implant smart !

- Several applications seeking for tailored smart components through the integration of sensors and/or actuators, e.g.:
  - medical implants (forced healing, detect loosening, improve long term stability, detect overload…)
  - lightweight structures (aerospace, automobile, railways, ships …)
  - turbine machinery (improved process understanding & control)
  - machine tools (predictive maintenance, cyber physical systems)

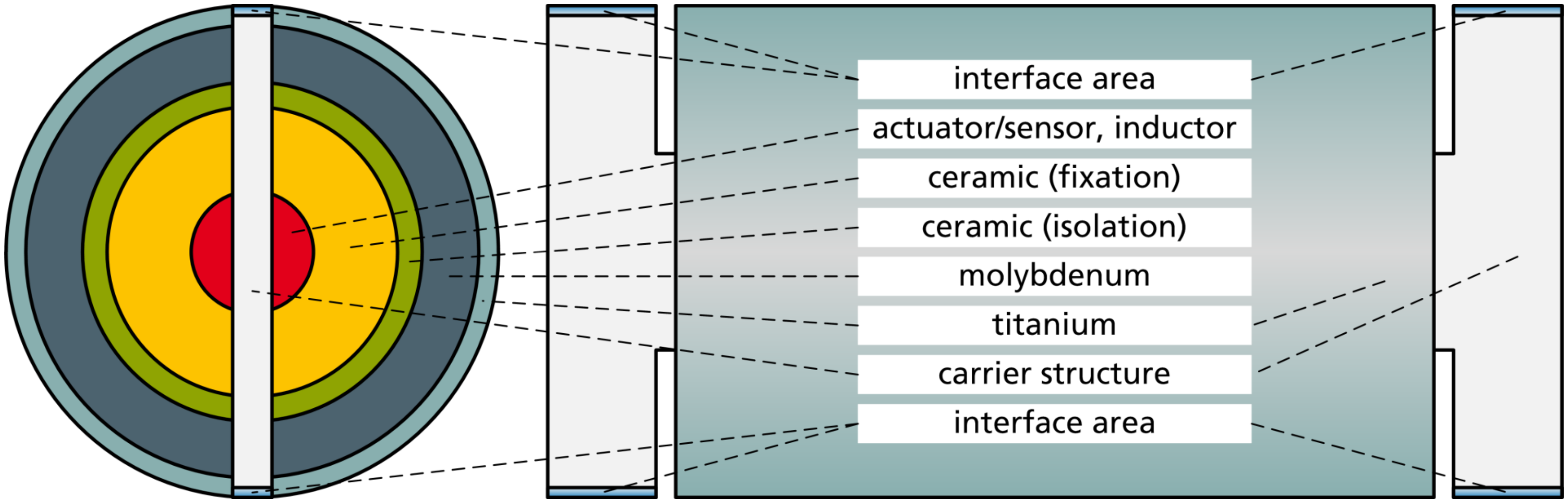
- GOALS / DEMANDS: materially bonded integration of sensors/actuators within metallic mechanical structures for high sensitivity and conversion efficiency, min. consumption of energy, application in harsh environments
- HUDLES / CHALLENGES: low temperature resistance of most smart materials (e.g. Curie and melting temperature, magnetic remanence, …)

start with sensor/actuator design & considering additive manufacturing

Material and methods

Actuator/sensor system design - Metal Ceramic Multilayer

- Actuator/sensor system design for embedding in titanium LBM part:

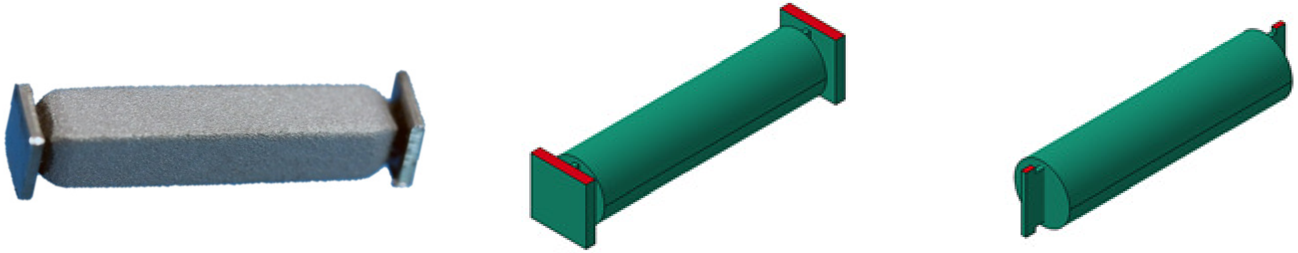


- Carrier structure in the same material as the surrounding LBM part and fixation = interface between actuator/sensor system and LBM part

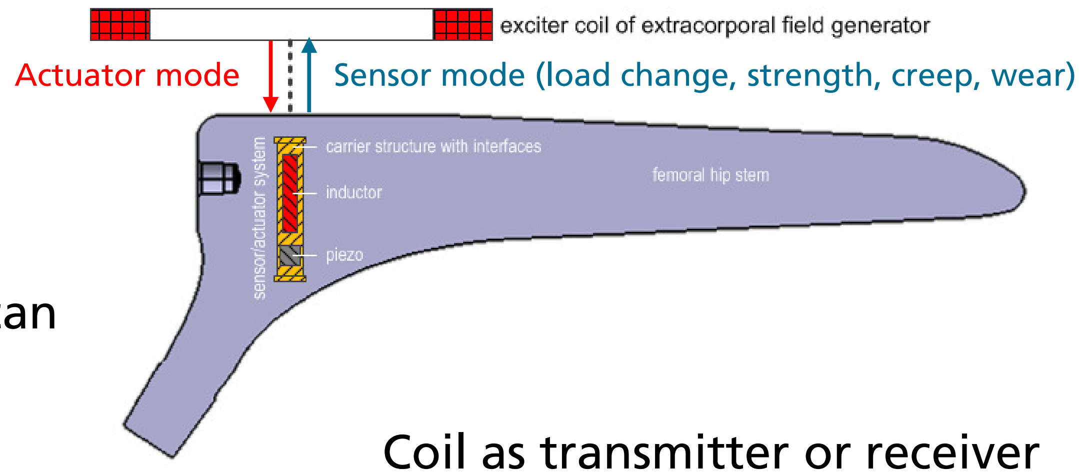
Material and methods

Actuator/sensor system design & energy transfer and control

- Self-developed sensor/actuator system with metallic carrier structure for piezo ceramic, inductor, connection and fixing technology and multi-material/multi-layer thermal protection system



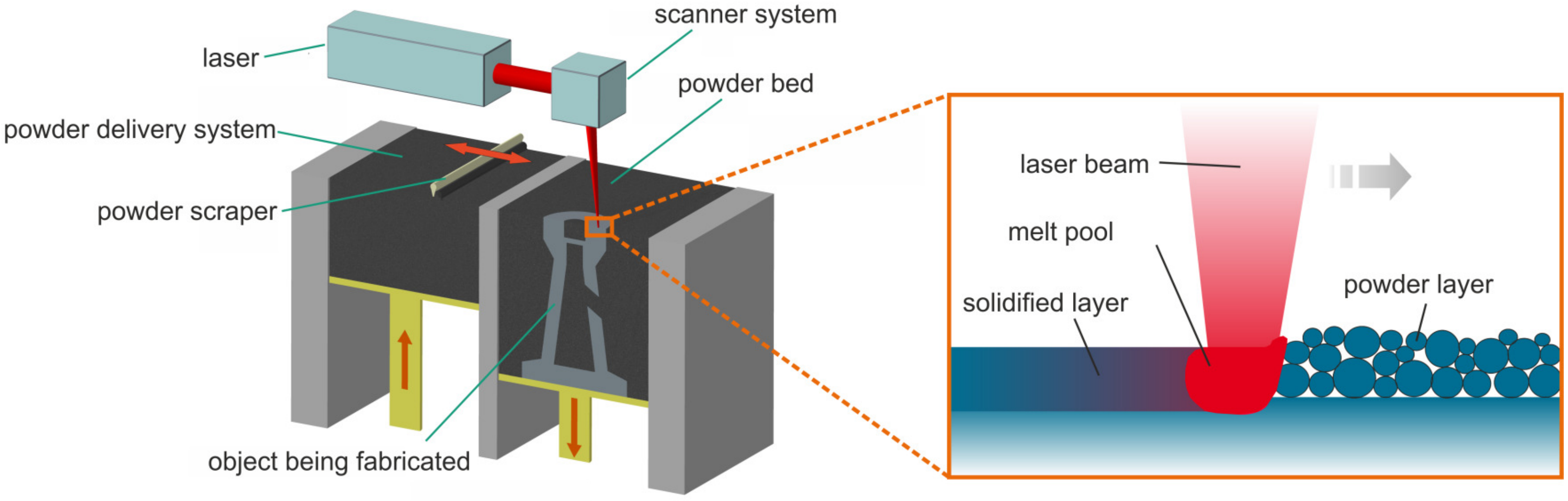
- Wireless far-field inductive energy transmission with a coil array
  - alternating and rotating magnetic fields
  - large aperture angle and range
  - transmitters and receivers can change their position and position during operation



Coil as transmitter or receiver

Material and methods
LBM embedding process

- Globally low and only selectively high heat input during laser beam melting (LBM) process



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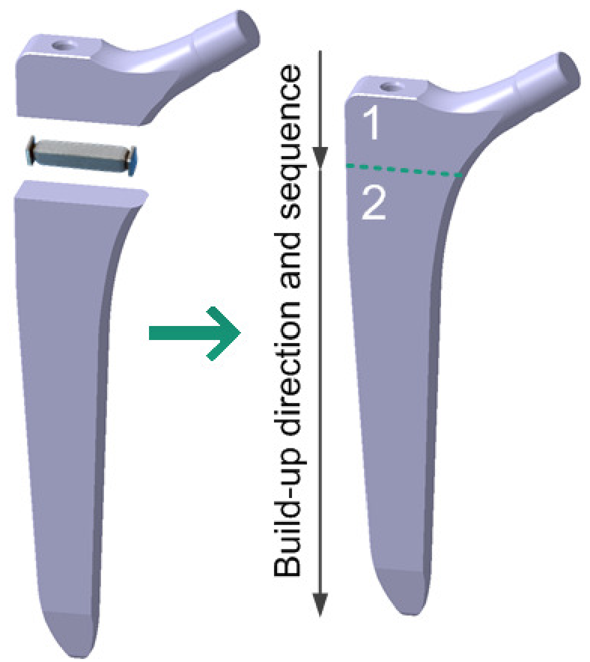
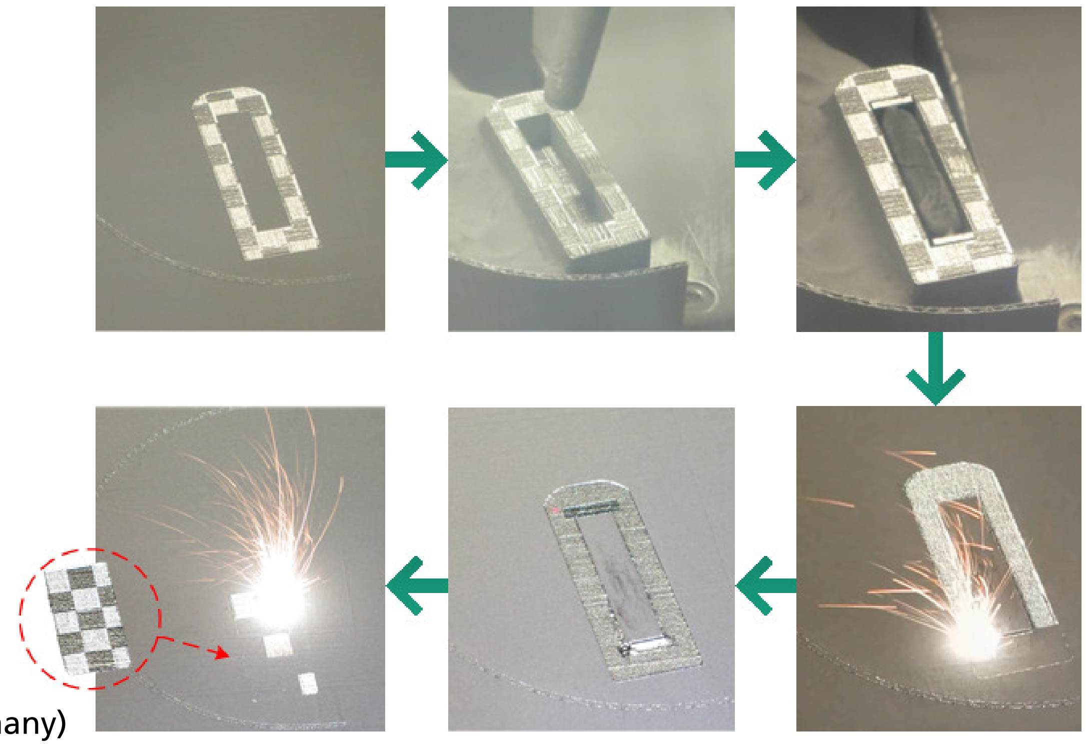
Material and methods
LBM embedding process

- LBM machine and material: GE Concept Laser M2 cusing, Ti-6Al-4V ELI
- Manufacturing sequence:

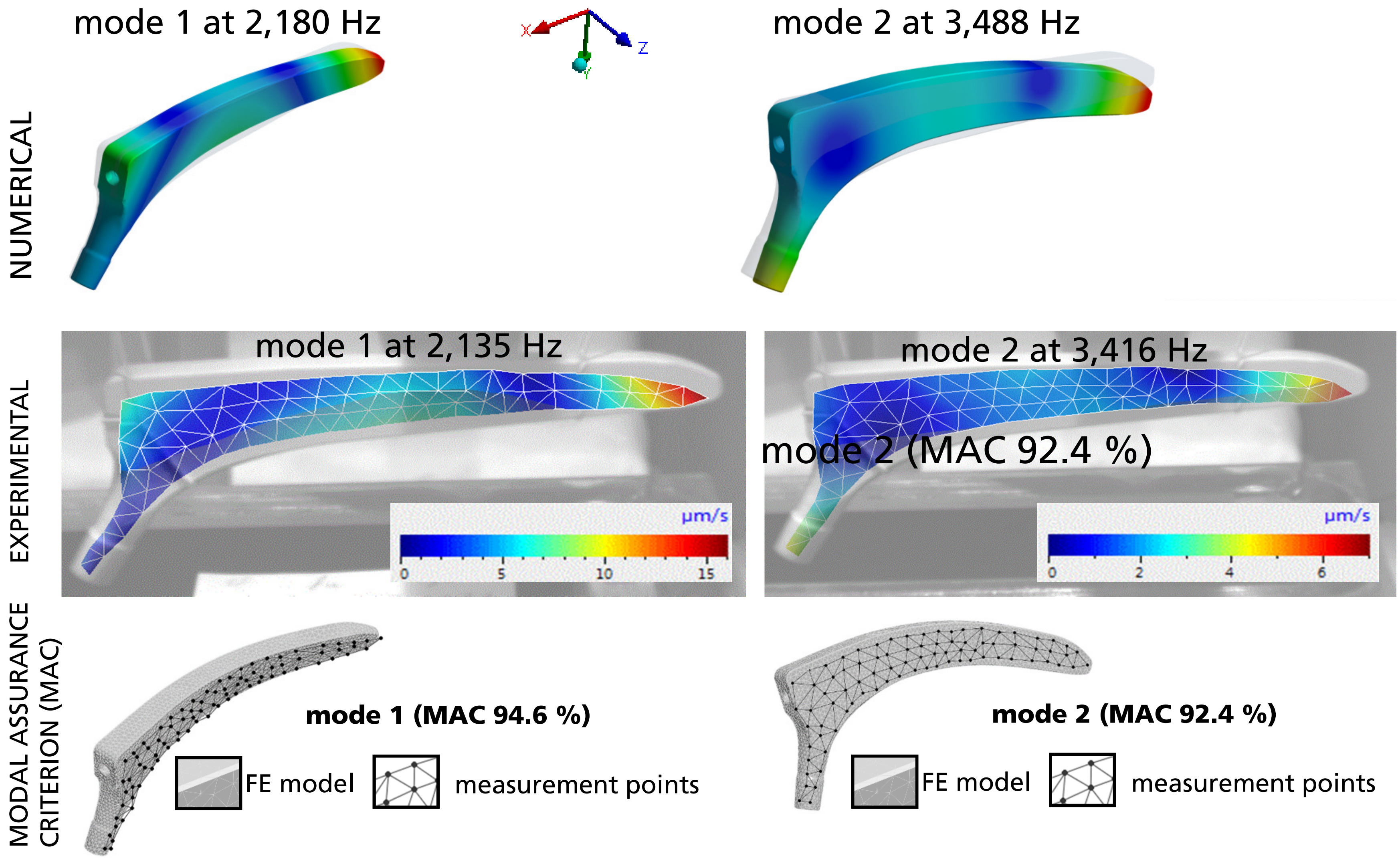


Hip stem design TRJ® by Aesculap AG (Germany)



Results

Numerical modal analysis vs. 3D laser scanning measurements



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Results and outlook

Active actuator mode allows:

- Stimulation of tissue healing by mechanotransduction / suppot of bioactive surfaces
- Immunmodulation by mechanotransduction (grafts, transplants)
- Support and Controlling of photodynamic processes, drug delivery (antibiotics / immunosuppressants)

Passive/inverse sensor mode allows:

- Monitoring of load and strength changes via osteosynthesis aid or other implants (personal healing feedback)
- Monitoring of implant - tissue - interface (overloads)
- permanent gait and motion monitoring

Basic technology for digitization and optimization of healing and modulation processes including early warning systems via permanent monitoring

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Patents are pending on the sensor/actuator system and the embedding process. [WO17054799; WO17036454]

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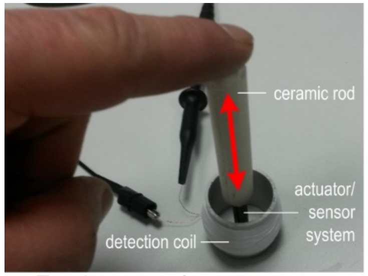
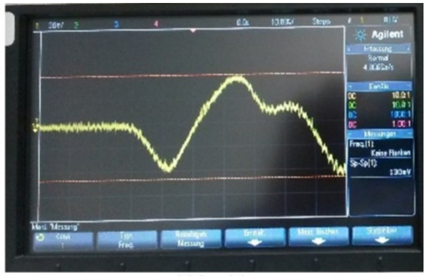
Results

Inverse sensory mode of the sensor/actuator system as a digital monitoring technology

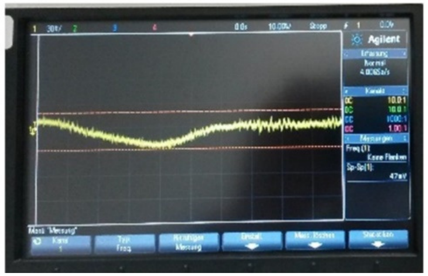




Tapping sensor/actuator system inside (top) and outside (bottom) a detection coil

306 mV
Response voltage with low resolution x-axis
47 mV

130 mV
Response voltage with high resolution x-axis
168 mV



- Energy self-sufficient sensory system – actuator as sensor and energy harvester
- Combining two or more systems in one component
  »one module is externally excited as an actuator, and a second or third or more measures the coupled-in signal energy-efficiently and spatially«
- system changes are measurable (e.g. for structural health monitoring)