POLITECNICO DI MILANO

AddMe.Lab





ADDITIVE MANUFACTURING: NEW OPPORTUNITIES FOR METALLIC PARTS

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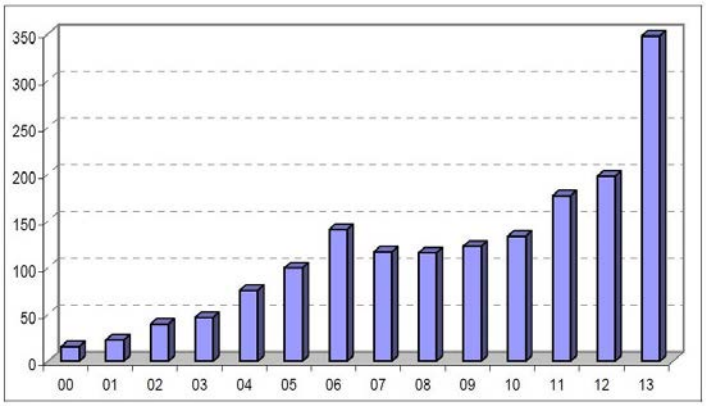
Additive Manufacturing

GE is using laser-powered 3-D printers, 3-D "inking" and "painting" machines, and other advanced manufacturing tools to make parts and products that were thought impossible to produce and which sometimes verge on art. We see advanced manufacturing as the next chapter in the industrial revolution.

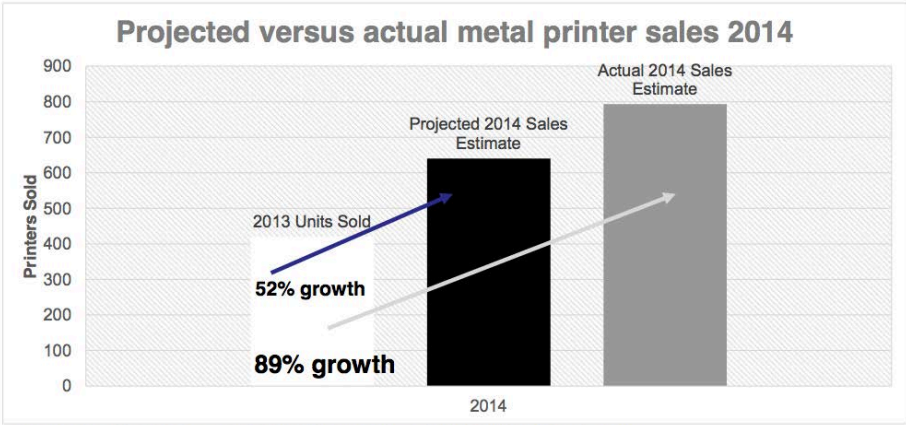
Metal Additive Manufacturing: a young market

"Metals are the fastest-growing segment of 3D printing, with printer sales growing at 48% and material sales growing at 32%".



Source: Wohlers Report 2014

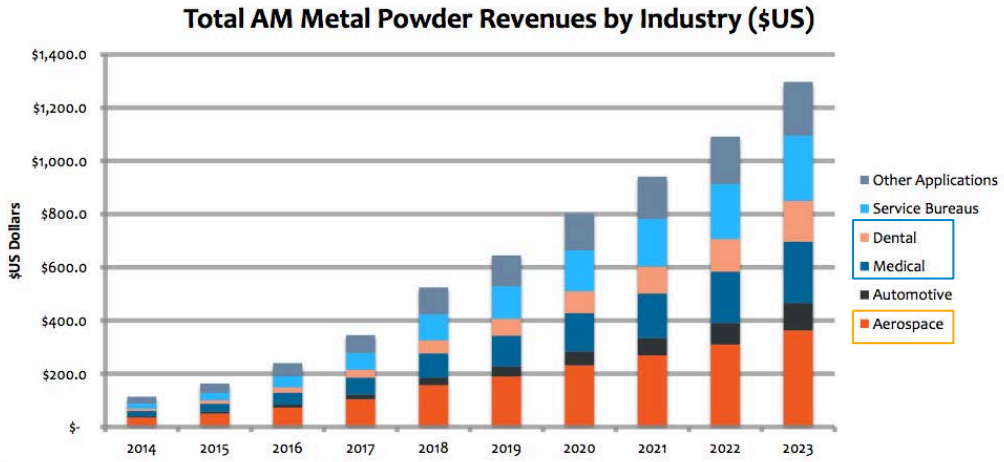
Source: Forbes



Source: SmarTech Markets Publishing, *Opportunities in Metal Additive Manufacturing*

Source: idtechex.com

Dental, orthopedic implants, and rapid manufacturing of prototypes growing fastest



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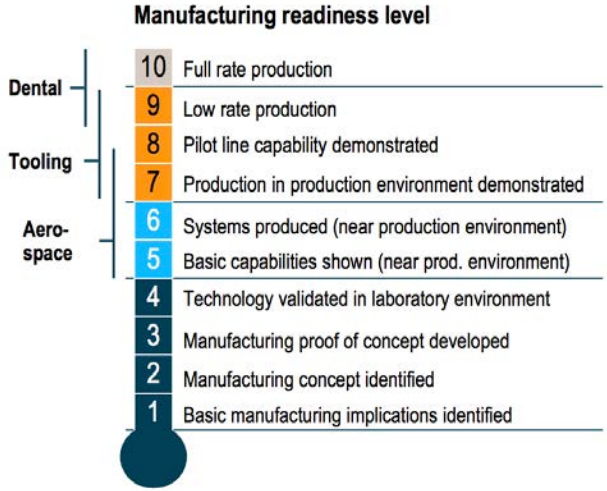


Source: Roland Berger

Aerospace

Fuel nozzle for Leap jet Engine (GE)

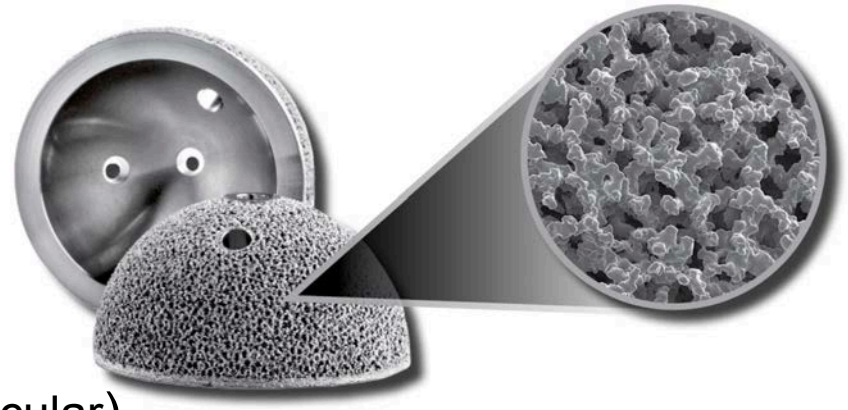
- Certified by FAA
- from 20 components to 1 (20 injectors per engine).
- **25% lighter (**new engine with expected 15% fuel savings)
- **5X more durable** than current design;

- Exp. Prod. volume ~10's of thousands per year
- May eventually need more metal AM machines (SLM) than current annual worldwide demand.
- $50million 3DP investment in Auburn, Alabama plant (7/16/14)

Airbus A380 bracket - Airbus Group Innovations

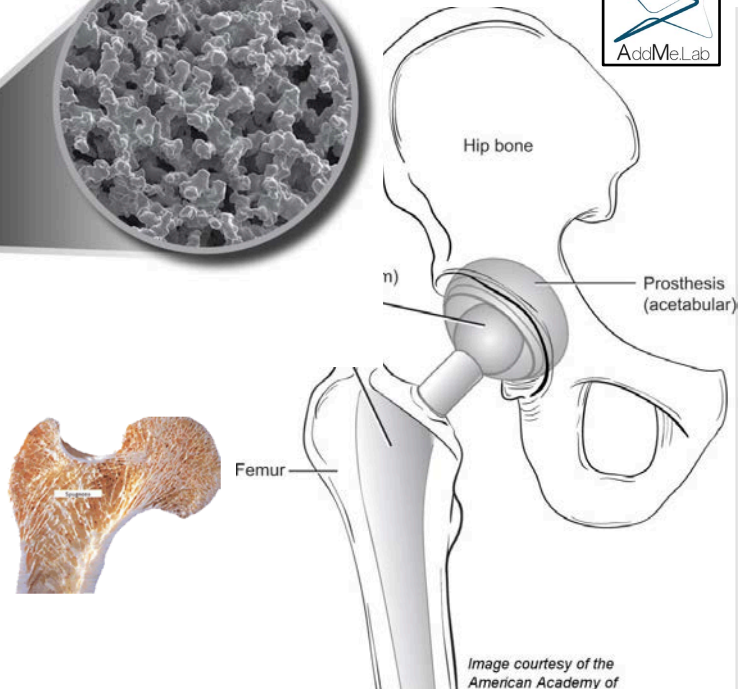
Health care

- Medical implants
- Customized
- better osteointegration (trabecular)



Source: Arcam

Source: Renishaw



- Dental implant

Lost wax: 60-65% accuracy – lot of rework

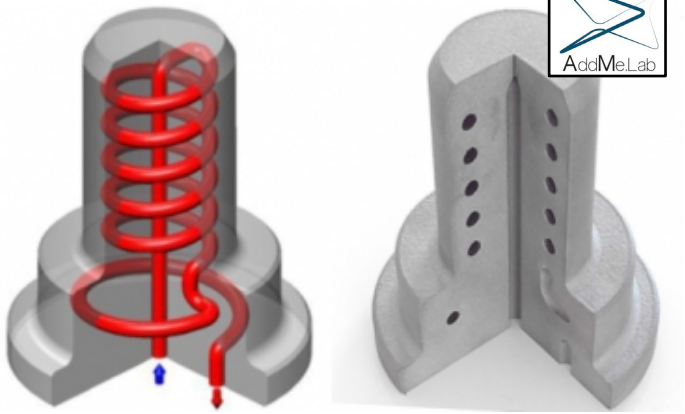
AM 90-95%success rate in much less time

Wirobond C+ three- unit bridge manufactured by BEGO USA using their EOS additive manufacturing system. Support anatomy, precise marginal integrity and smooth surfaces are produced consistently from every STL file (Source: BEGO USA).

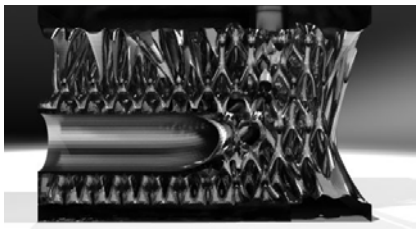
Courtesy: EOS

Machinery

- Molds and inserts fabrication: 20% cycle time reduction
- Cooling of tool core allows 50% increase in the quality of produced tools



Source: EOS



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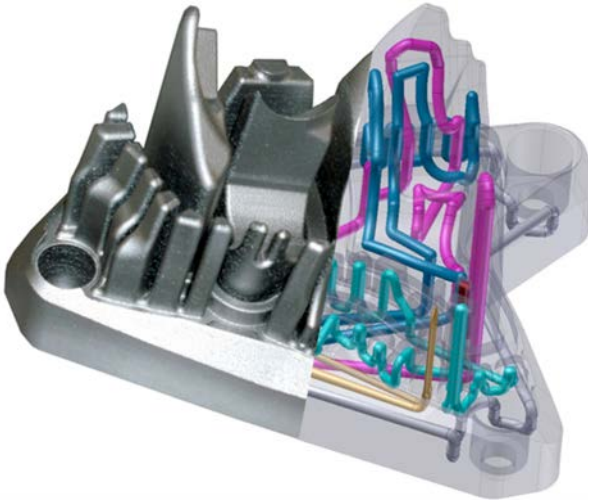
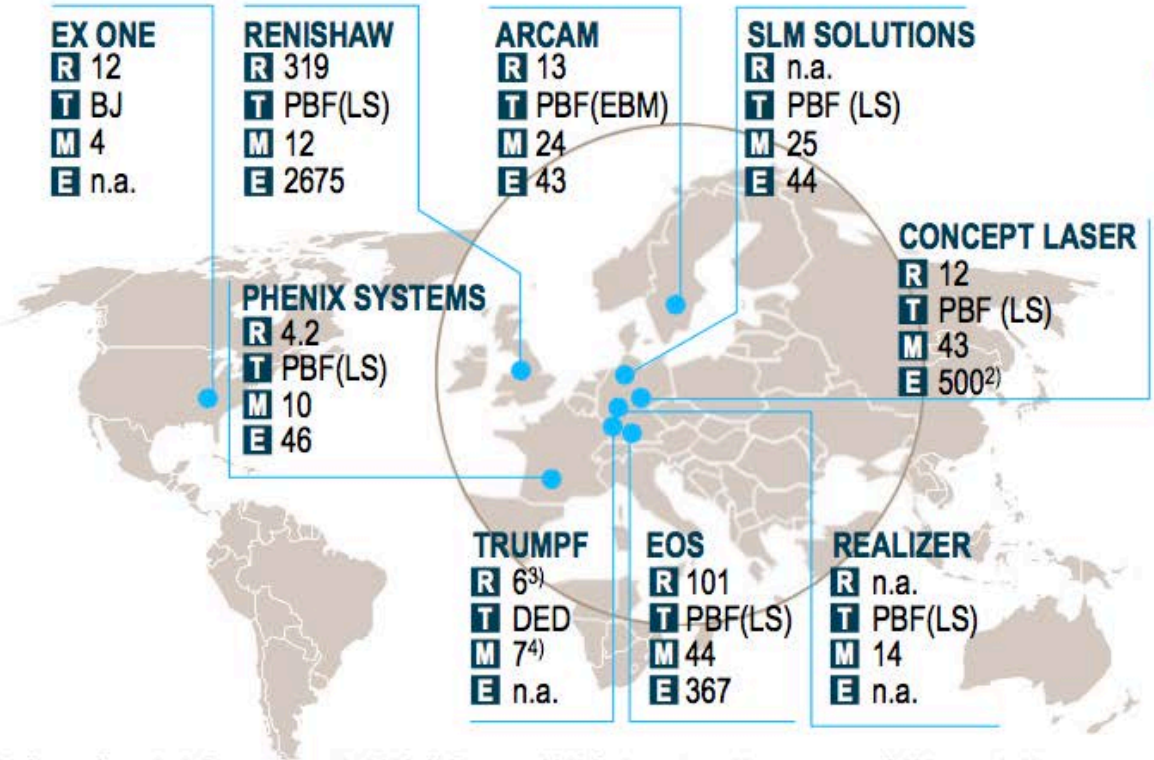


Source: Renishaw.

Worldwide challenge

Metal AM system manufacturers



AM SYSTEM MARKET

- **Around 190 metal AM systems were been sold in 2012**
- Leading **metal AM system manufacturers are located in Germany** with a combined market share of 69%
- **Recent consolidation** (e.g. 3D Systems acquired Phenix Systems, DM3D acquired POM)
- Other small companies include Beijing Longyuan (CHN), DM3D (USA), Fabrisonic (USA), Irepa Laser/BeAM (FRA), Insstek (KOR), Matsuura (JPN), Sciaky (USA), Optomec (USA), Wuhan Binhu Mech. & Elect. (CHN), which sold 2 systems or fewer in 2012

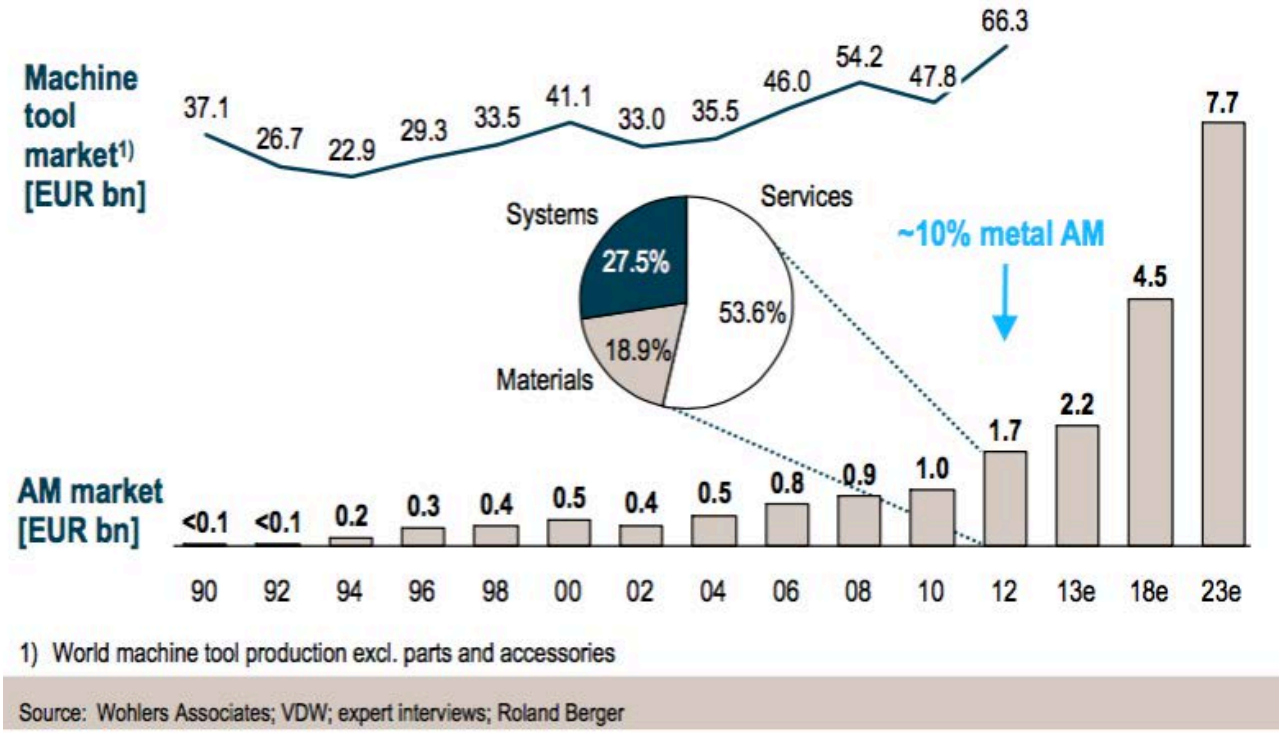
1) 2012 2) Hofmann Group incl. Concept Laser in 2012 3) Revenue 2012 for laser deposition segment 4) AM upgrade kits

R Revenue [EUR m] 2011 T Technology M Metal AM systems sold in 2012 E Employees 2011

DED = Directed energy deposition PBF = Powder bed fusion LS = Laser sintering EBM = Electron beam melting BJ = Binder jetting

Source: Companies; press research; Bloomberg; Wohlers Associates; Roland Berger

Open challenges

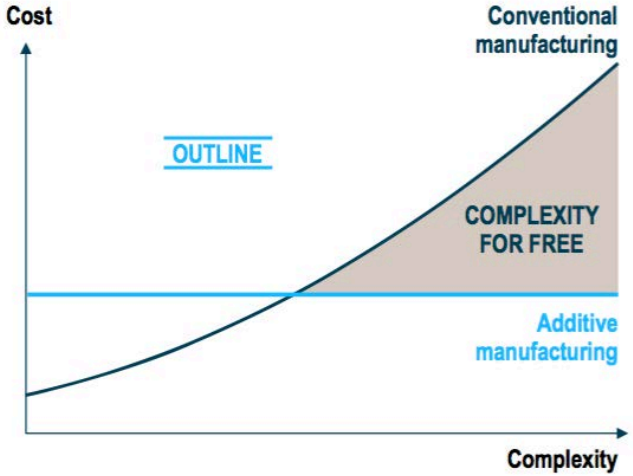


- Despite its strong growth, the AM market remains small compared to the machine tool industry – Metal AM share approximately 10%
- **AM market will see double-digit growth in the next few years** and volume will double by 2015
- **Metal AM has higher growth rates than plastic AM**

- Main actual drawbacks of Metal AM
  - Expensive
  - Low build rate
  - Small dimensions

Advantages

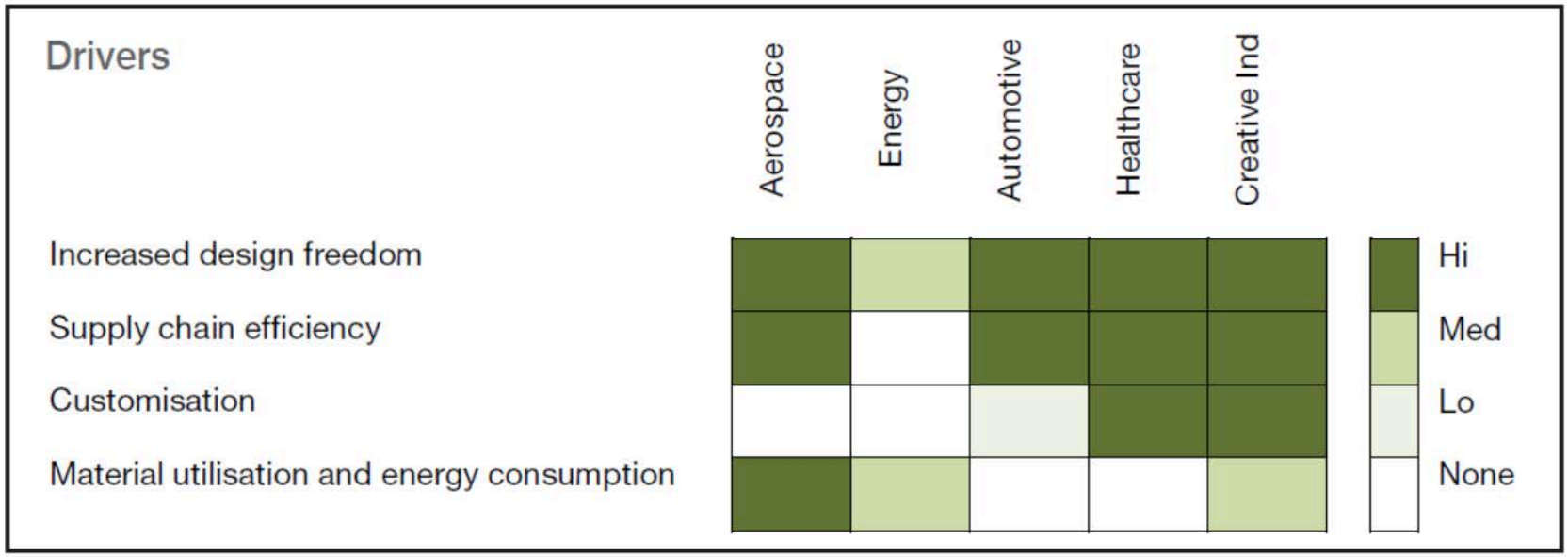
- Customization
- Produce when and where needed
- Quick turnaround from design to part
  - Limited need for tooling
  - Design complexity has little impact on costs
- Design flexibility
  - Complex structure optimized for functionality, not producibility
  - Lightweight
  - Improved heat transfer
  - Reverse engineering



Drivers

Figure 1

Generic drivers for AM technology adoption

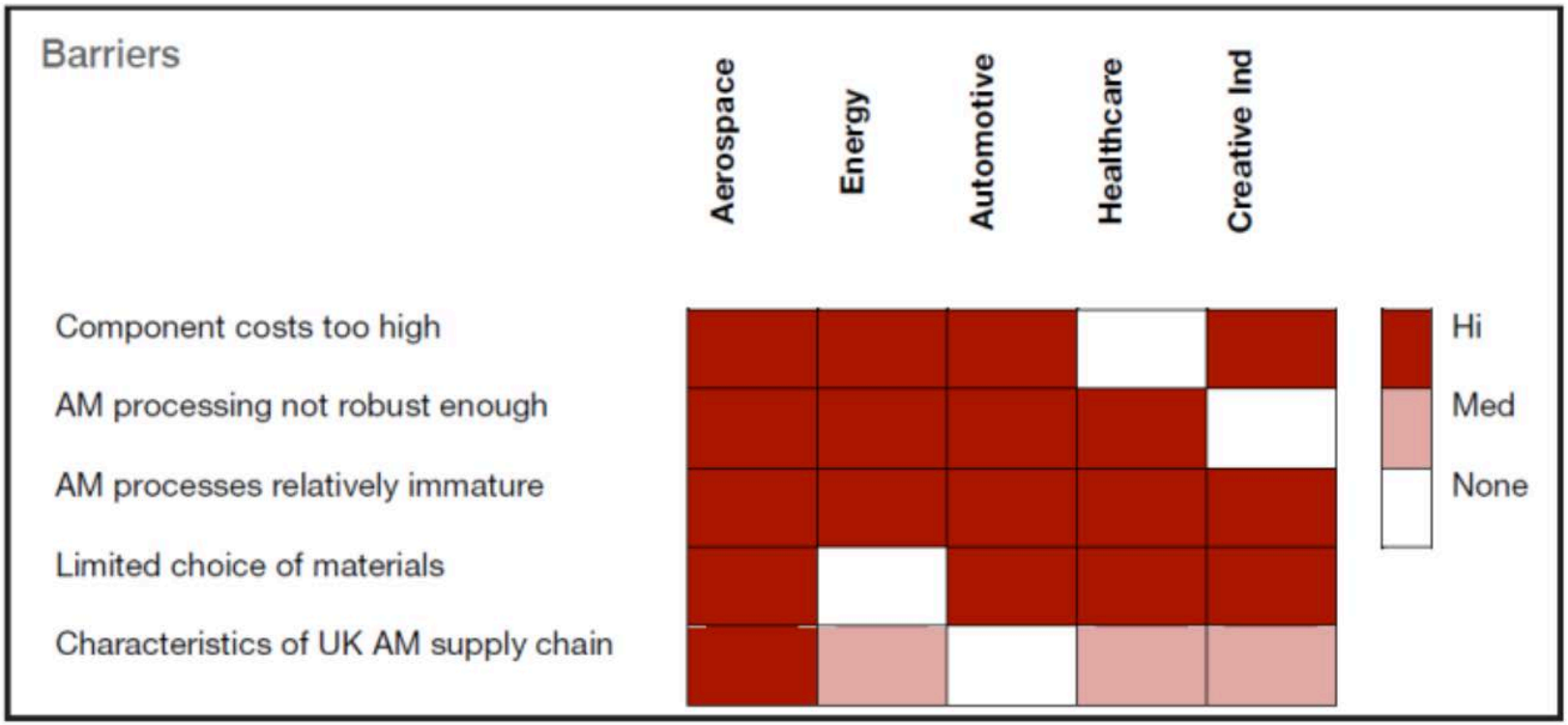


"SHAPING OUR NATIONAL COMPETENCY IN ADDITIVE MANUFACTURING" (UK industry interest group)"

Barriers

Figure 2

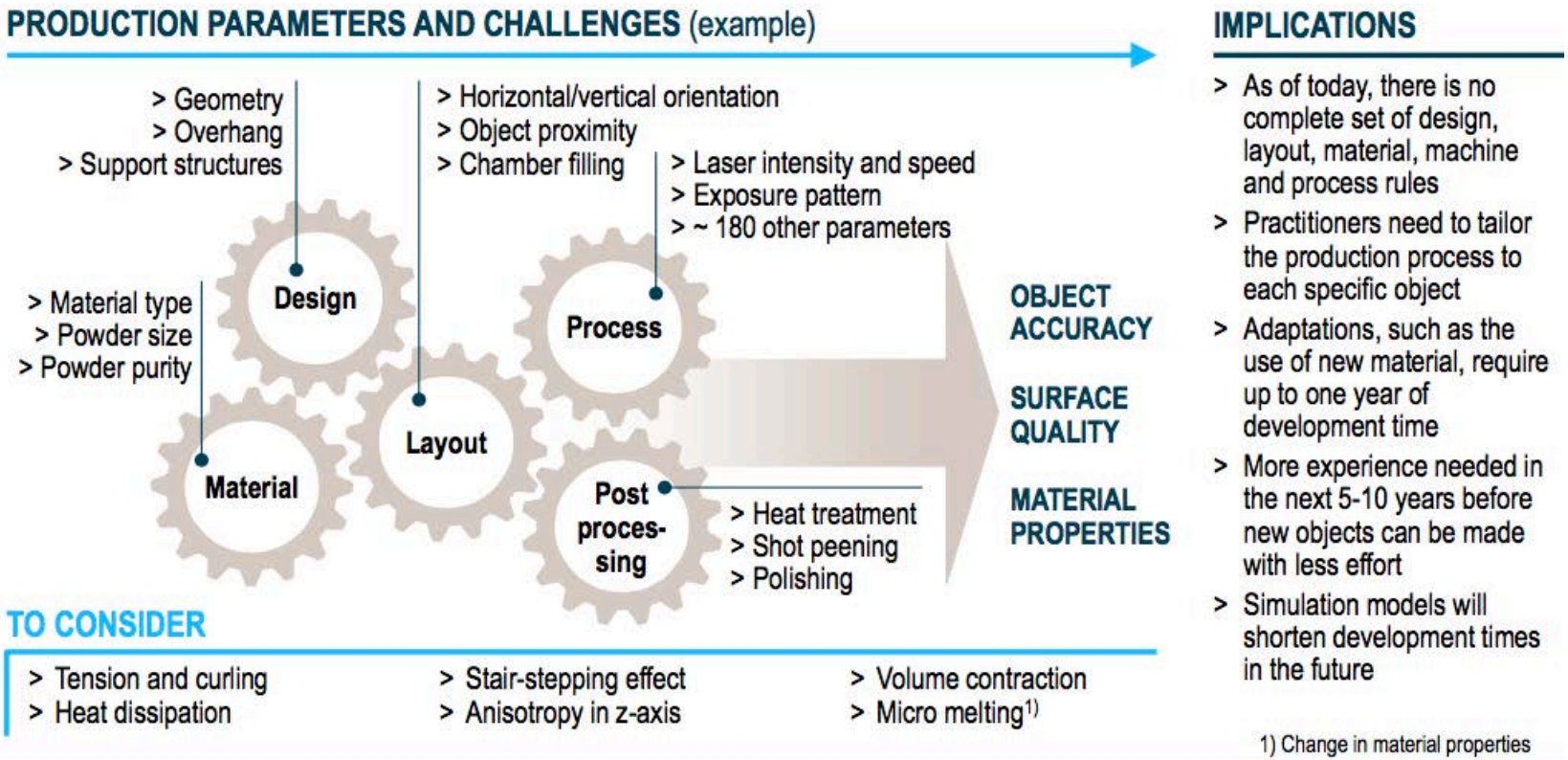
Generic barriers for the key sectors



"SHAPING OUR NATIONAL COMPETENCY IN ADDITIVE MANUFACTURING" (UK industry interest group)"

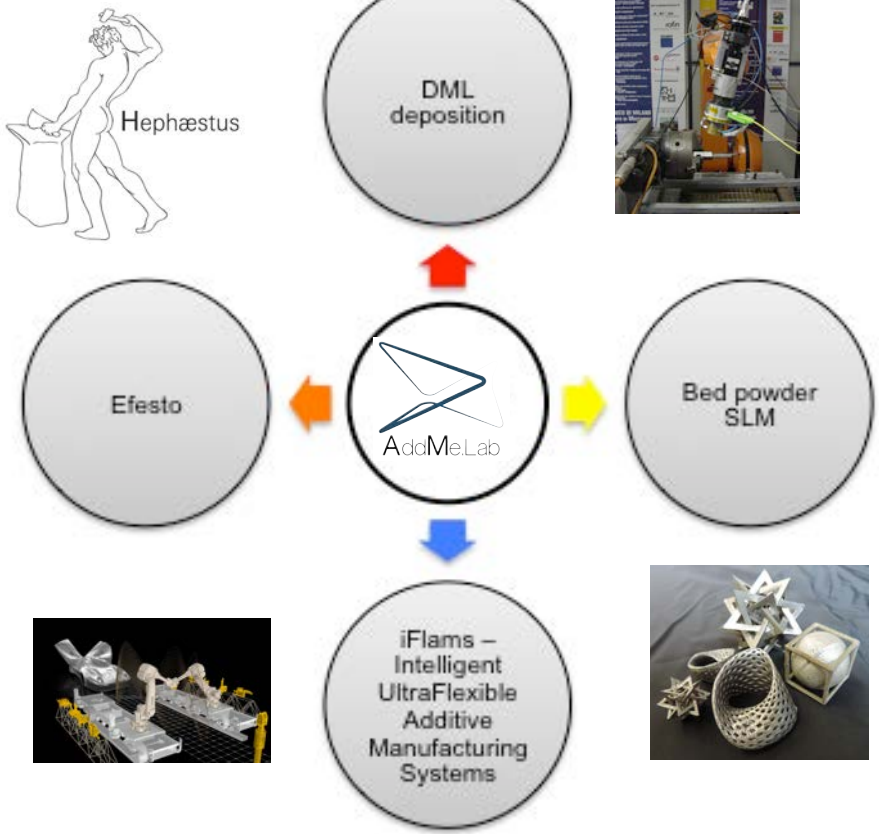
A multidisciplinary challenge

Complexity of AM production process



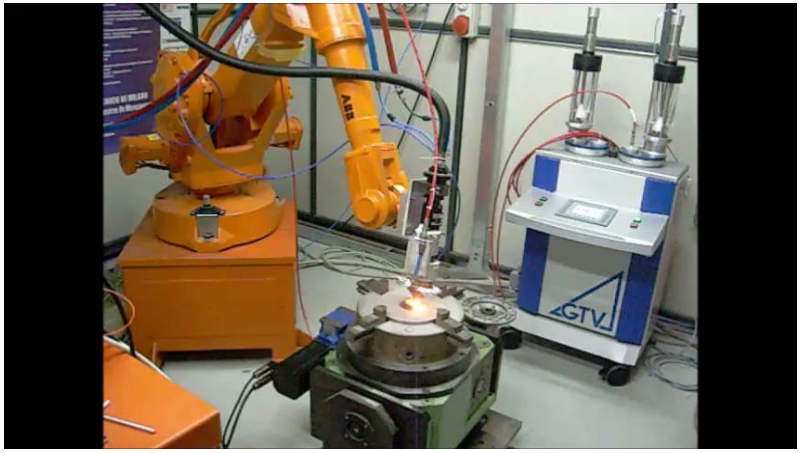
AddMe.Lab – Mechanical Engineering Department

- DYNAMICS AND VIBRATIONS
- MACHINE AND VEHICLE DESIGN
- MANUFACTURING AND PRODUCTION SYSTEMS
- MATERIALS
- MEASUREMENTS
- METHODS AND TOOLS FOR PRODUCT DESIGN



AddMe.Lab – Dipartimento di Meccanica

SITEC
Laboratorio per le Applicazioni Laser

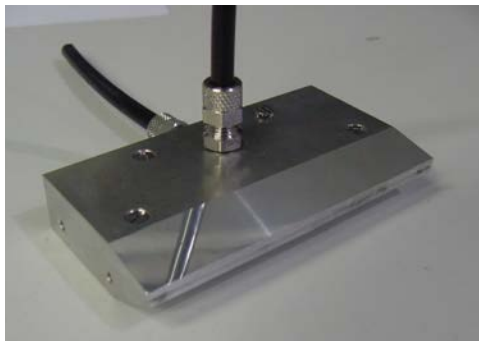


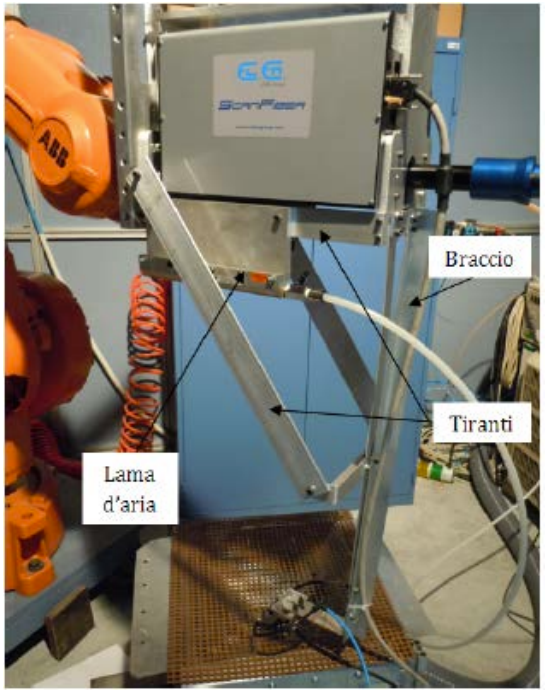
DIRECT LASER METAL DEPOSITION

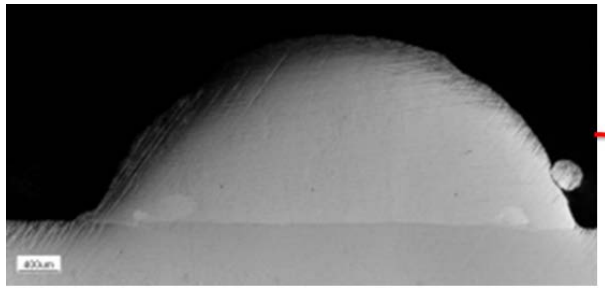
Direct Laser Metal Deposition – Productivity

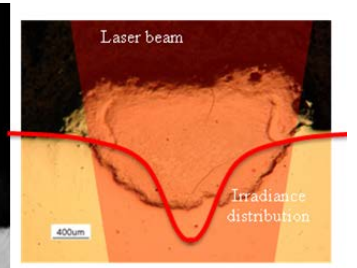
PRODUCTIVITY

- Barriers
  - Spot dimensions
  - Powder delivery
  - Working area
- Solutions
  - Increase in power and laser sources
  - Beam shaping
  - Hybrid architectures

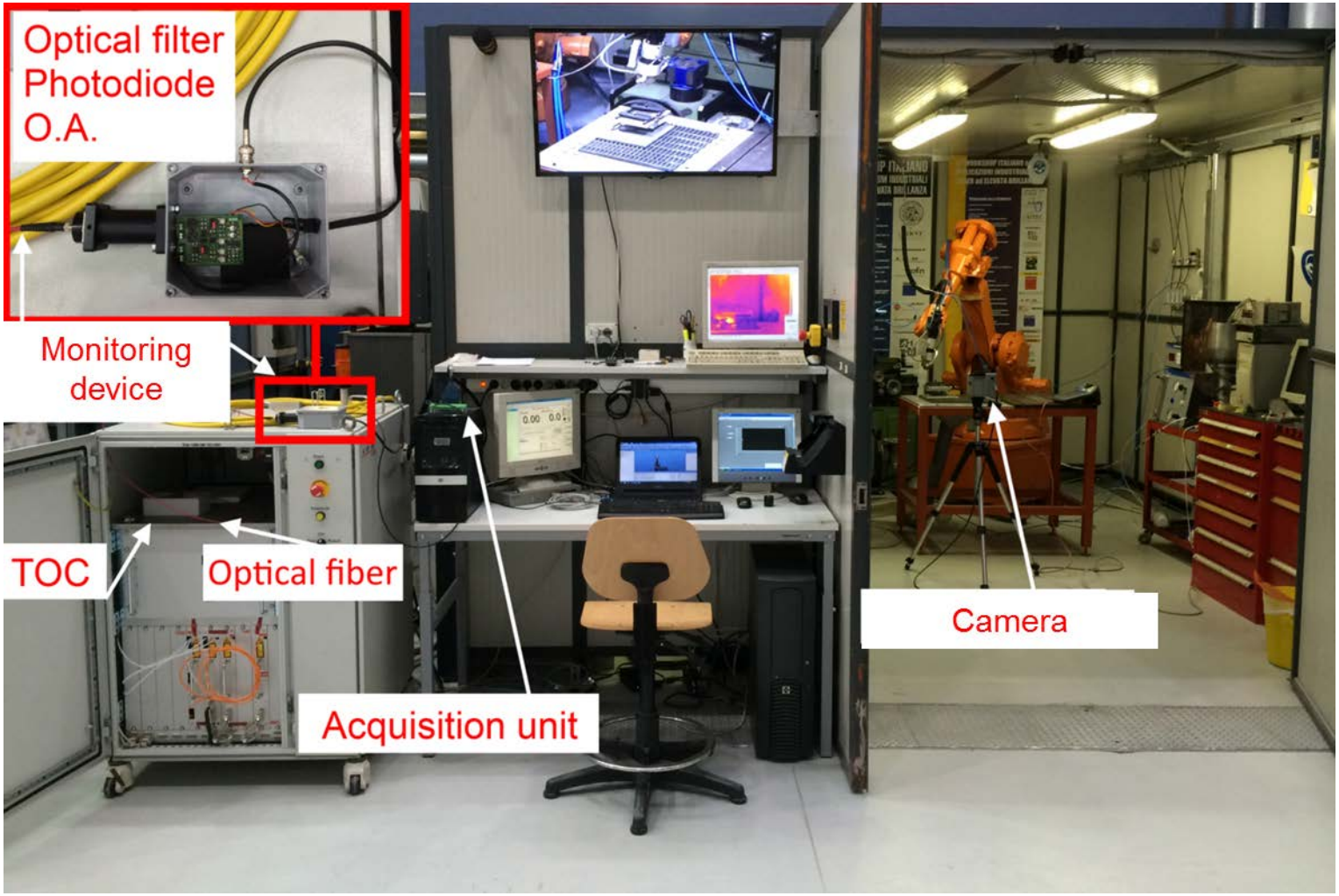








Direct Laser Metal Deposition – Process control (temperature)



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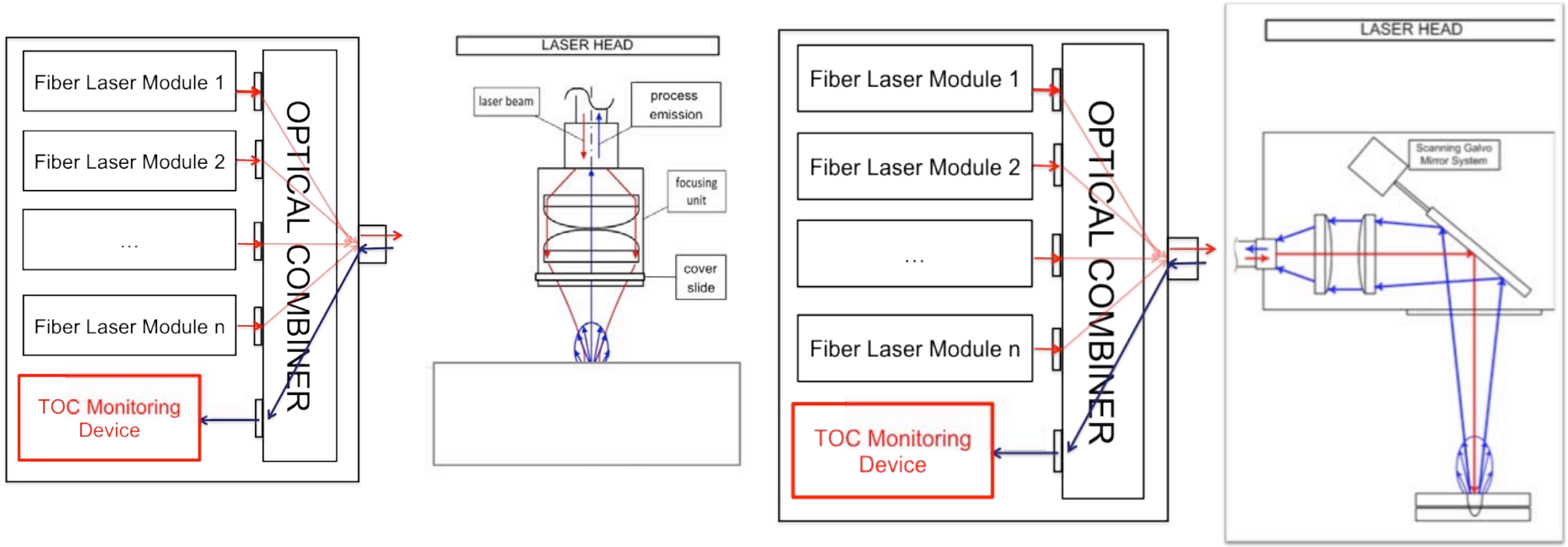
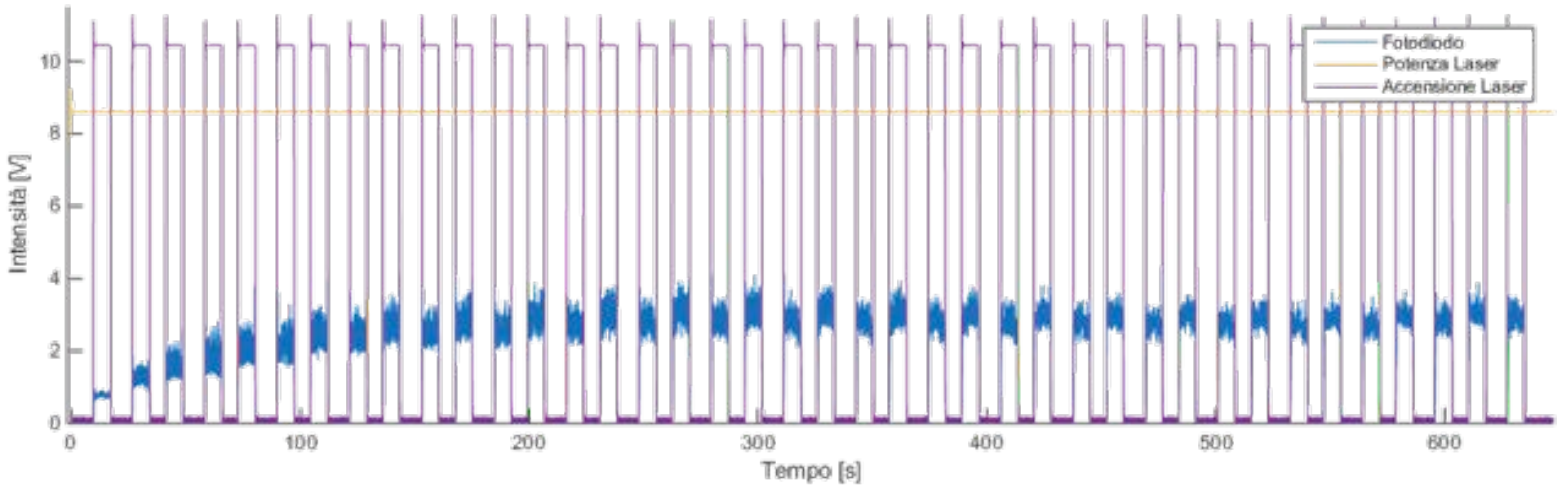


1. Industrial high power fiber laser system with optical monitoring assembly - G. Moroni, D. Colombo, B. Previtali, S. Cattaneo, L. Rossotti - WO/2012/036664 – IPG Photonics

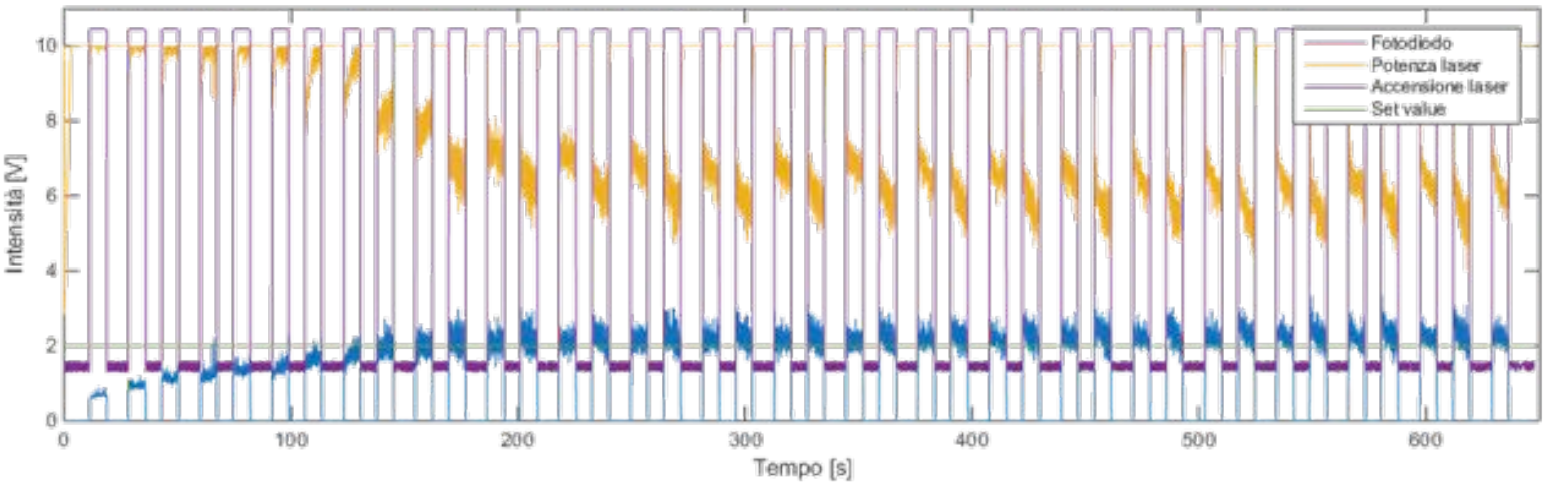
2. Method for controlling a laser cutting process and laser cutting system implementing the same - M. Sbetti, S. Bertoldi, D. Colombo, B. Previtali, G. Riva, M. Danesi, L. Molinari Tosatti, D. Parazzoli – BLM group

Direct Laser Metal Deposition – Process control (temperature)

Without feedback control



With feedback control



Direct Laser Metal Deposition – Process control (temperature)

Without feedback control

With feedback control

Direct Laser Metal Deposition – Process control (temperature)

BLM GROUP

MARPOSS

Titalia

Maspero

SAPIO GRUPPO

RENISHAW apply innovation™

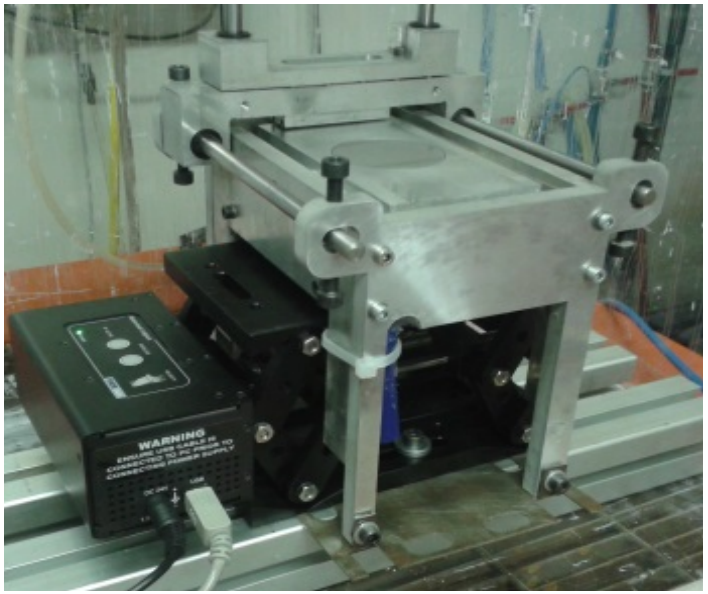
DIPARTIMENTO DI MECCANICA

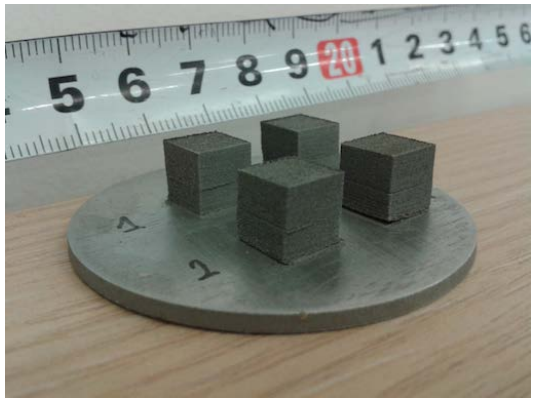
mecc

SELECTIVE LASER MELTING

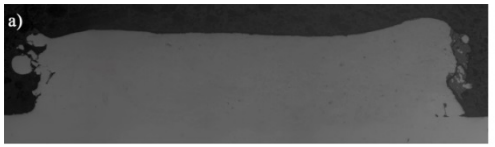
Selective Laser Melting : new biodegradable metals

SLM of new bio-degradable alloys (Fe, Mg, Zn) for biomedical applications

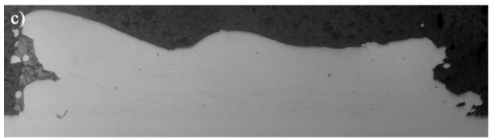




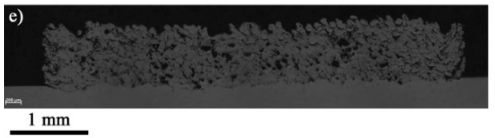
AISI 316L



Fe

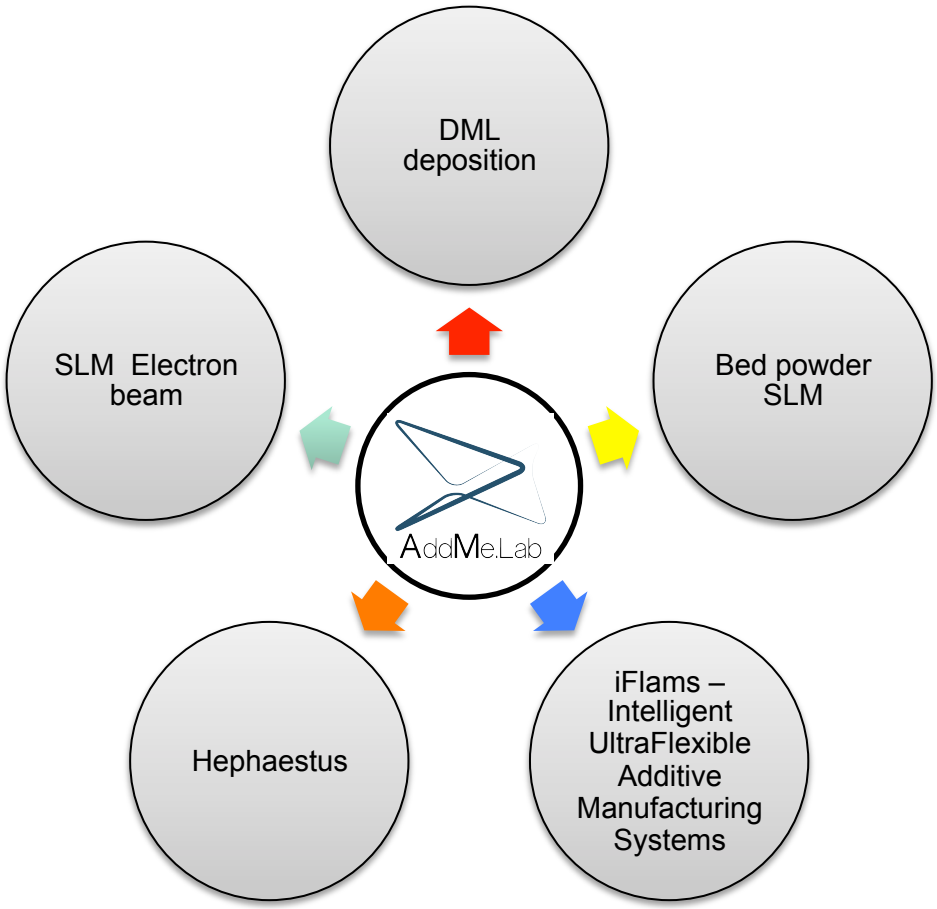


Zn



3D X-Ray CT-Scan microtomography (NSI 160 kV)

AddMe.Lab Prospettive



- Fully equipped laboratory for Additive Processes for metals
- New materials and powder
- Process monitoring and controlling
- Quality and performance evaluations

Grazie per l'attenzione!

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