INFN DIAM

Istituto Nazionale di Fisica Nucleare

Development & Innovation on Additive Manufacturing

Additively manufactured Refractory Metals for high temperature ISOL Target and Ion Source Systems

ADDITIVE MANUFACTURING WORKSHOP 2019

Presente Futuro della Fabbricazione Additiva nel tessuto Industriale e nella Ricerca

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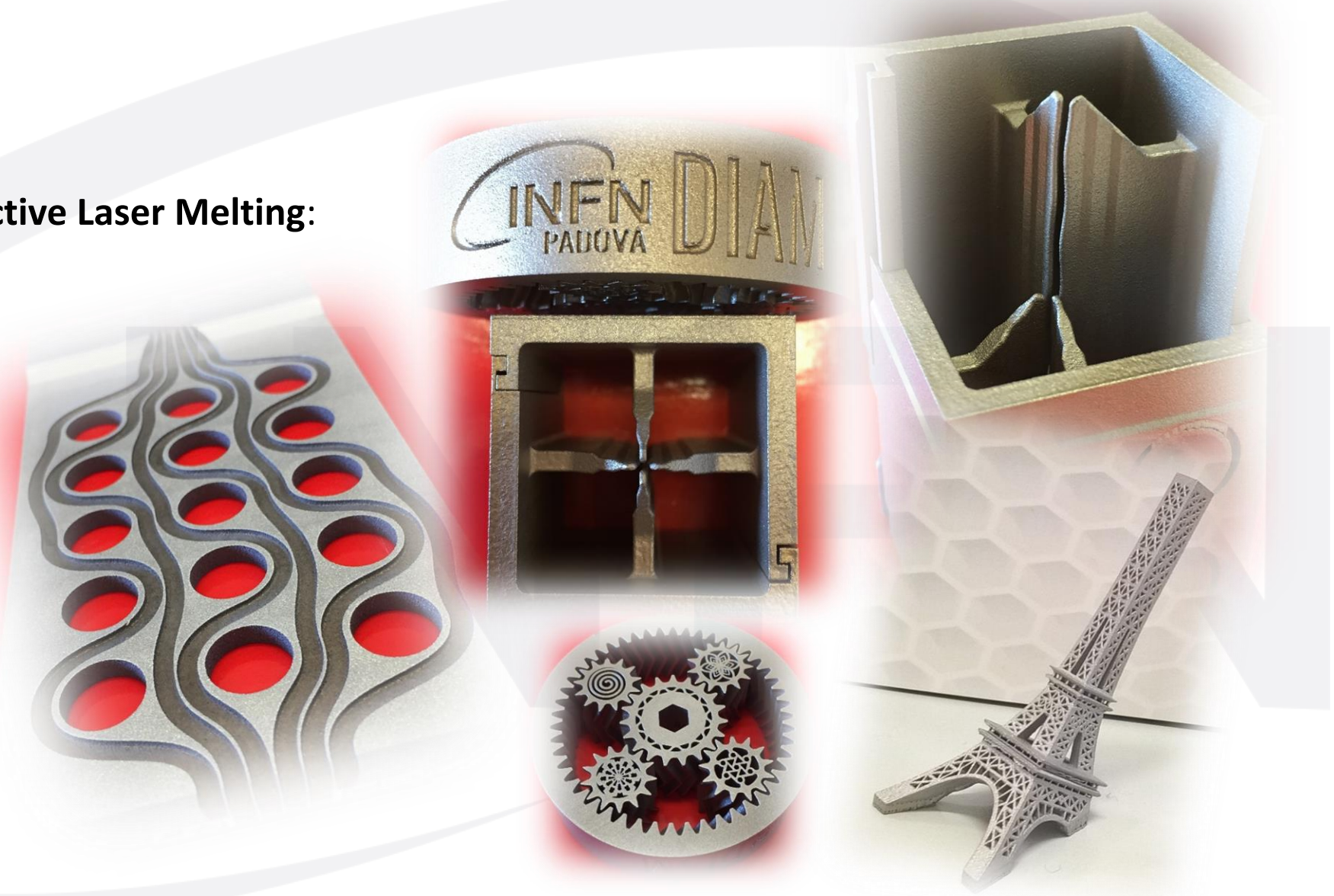
Agenda

Additive Manufacturing & Selective Laser Melting:
- From Design to Production
- SLM

Material development:
- Why SLM for ISOL
- SLM of Refractory Metals
- W, Ta and Mo @ DIAM

SLM for ISOL System:
- Topological Optimization
- Design for Assembly
- Characterization plan



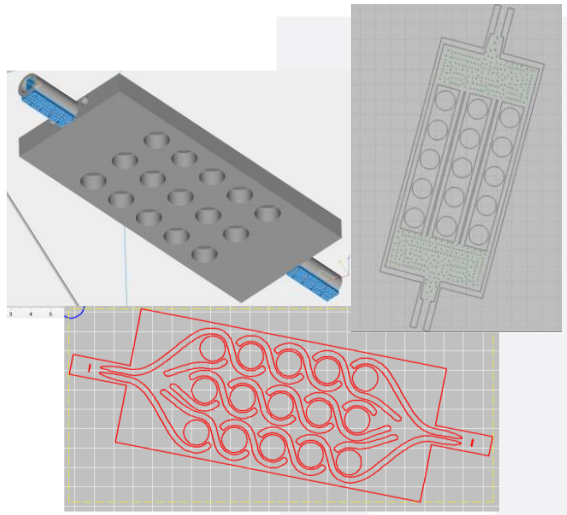
ADDITIVE MANUFACTUIRING

ASTM standard F2792-10:

"Process of joining materials to make objects from **3D model data**, usually **layer upon layer**, as opposed to subtractive manufacturing methodologies, such as traditional machining."

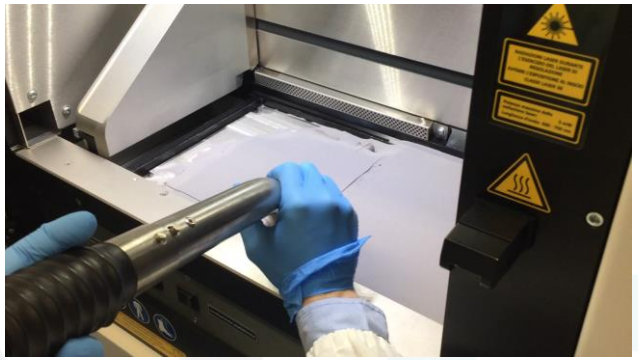
A NEW WAY TO DESIGN

- CAD file based on -
- Something that rise
- Light Weight
- Complex Geometry
- Topological Optimization



DATA PREPARATION

- Materialise Magics
  → support generation
- Slicing and Positioning on Platform



MACHINE TOOLING

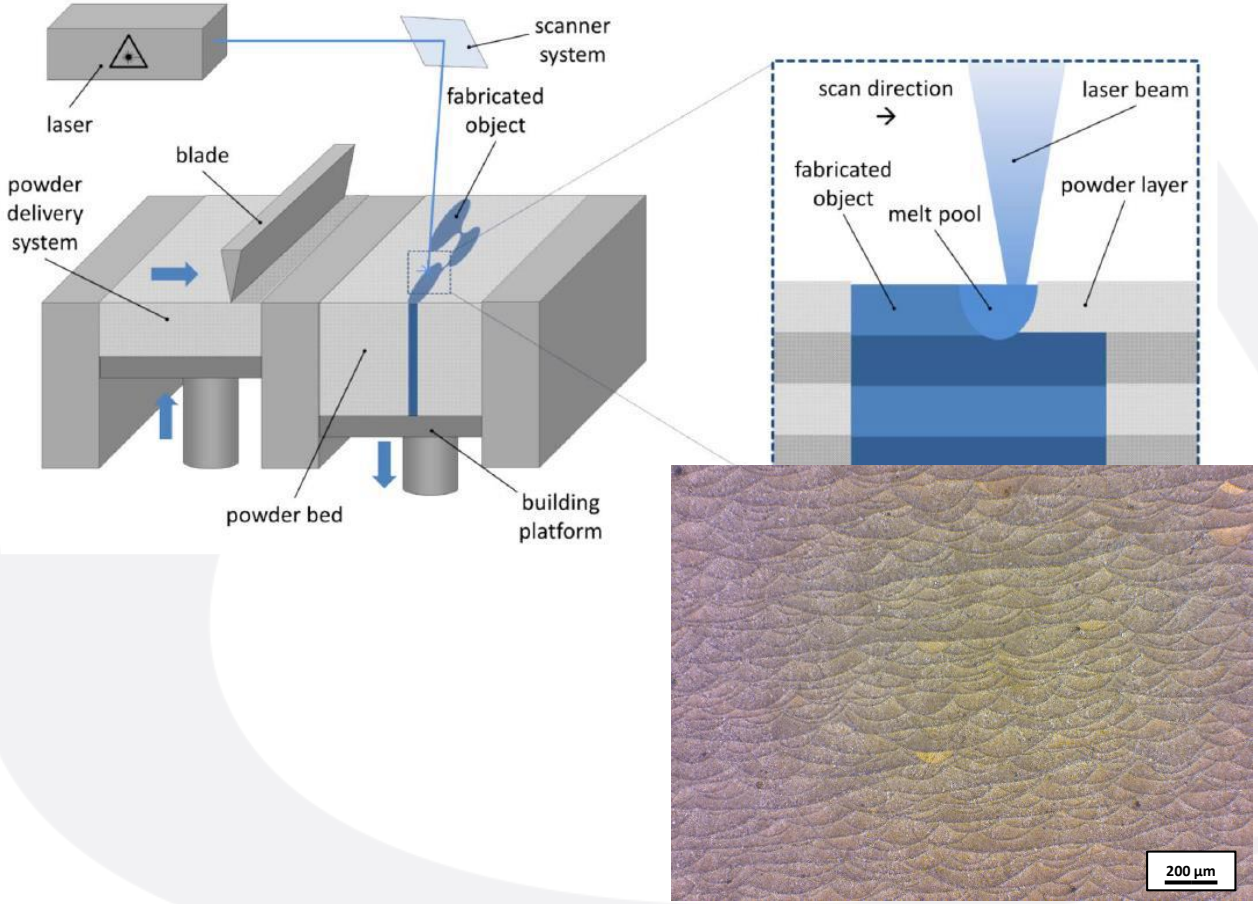
- Preparation of the chamber before printing
- SLM printing
- Removal of Parts & Platform and cleaning

POST PROCESSING

- Removal of Supports
- Stress Relief
- Removal of parts from the Platform
- Surface refinement

Metal Powder Bed Fusion Process: Selective Laser Melting

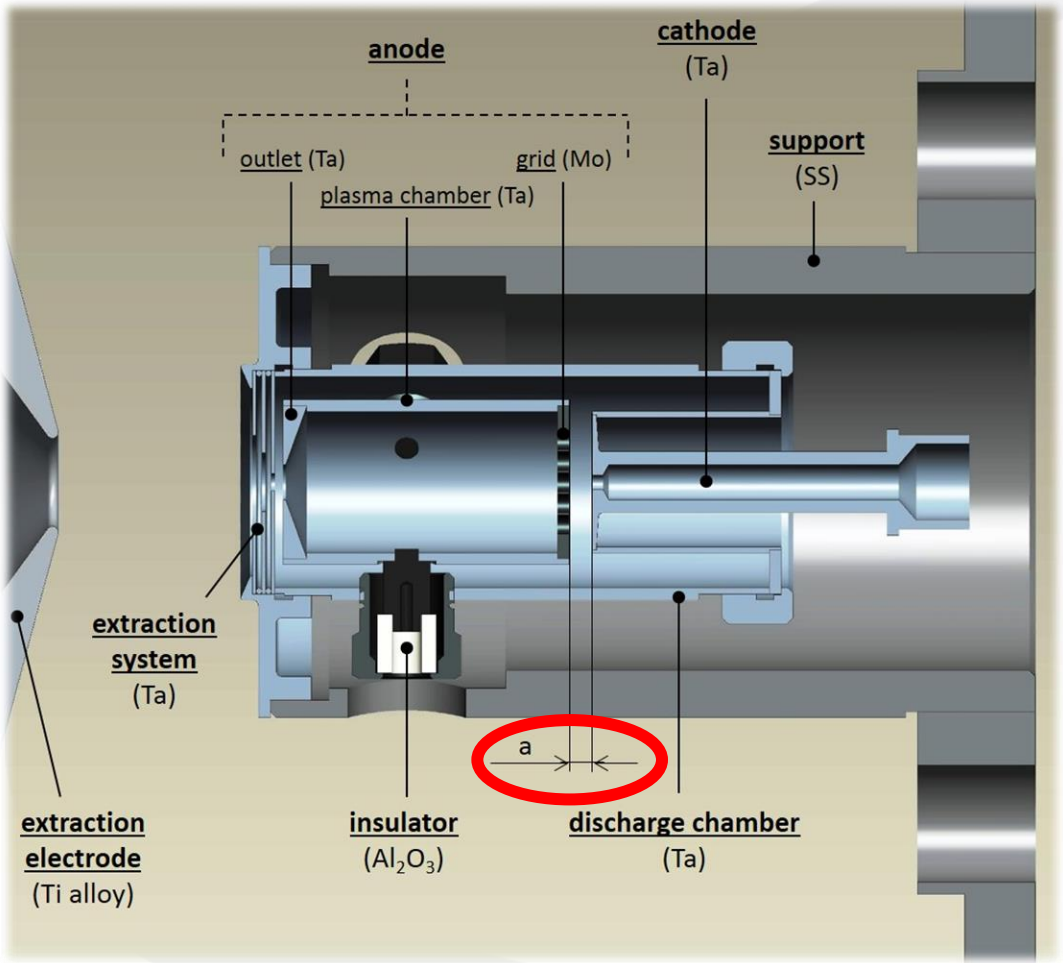
Process where focused energy (laser beam) is used to selectively melt a layer of a powder bed.



Al-Si10-Mg

WHY SLM for ISOL System

1st FEBIAD ion source prototype used at SPES



Courtesy of the SPES Target Group

Shabalin, I. L. (2014). Introduction to Ultra High Temperature Materials. In *Ultra-High Temperature Materials I* (Vol. 2).

Melting points T_m (°C) of chemical elements in the periodic table

1/IA	2/IIA	3/IIIB	4/IVB	5/VB	6/VIB	7/VIIB	8/VIIIa	9/VIIIb	10/VIIIc	11/IB	12/IIB	13/IIIA	14/IVA	15/VA	16/VIA	17/VIIA	18/VIIIA
H 259																	He
Li 181	Be 1278																
Na 98	Mg 650																
K 64	Ca 839	Sc 1539	Ti 1660	V	Cr	Mn	Fe	Co	Ni								
Rb 39	Sr 764	Y 1523	Zr 1852	Nb 2470	Mo 2620	Tc 2200	Ru 2250	Rh 1966	Pd								
Cs 29	Ba 725	La* 920	Hf 2150	Ta 3000	W 3410	Re 3180	Os 3050	Ir 2450	Pt								
Fr 27	Ra 700	Ac** 1050	Rf 2100	Db ?	?	Bh ?	Hs	Mt ?	Ds ?								

*	Ce 795	Pr 935	Nd 1010	Pm 1042	Sm 1072	Eu 822	Gd 1311	Tb 1360	Dy 1412	Ho 1470	Er 1522	Tm 1545	Yb 824	Lu 1656
**	Th 1750	Pa 1600	U 1132	Np 640	Pu 640	Am 994	Cm 1340	Bk 986	Cf 900	Es 860	Fm 1527	Md 827	No 827	Lr ?

Nb	Mo	Tc	Ru	Rh
2470	2620	2200	2250	1966
Ta	**W**	**Re**	**Os**	**Ir**
3000	3410	3180	3050	2450

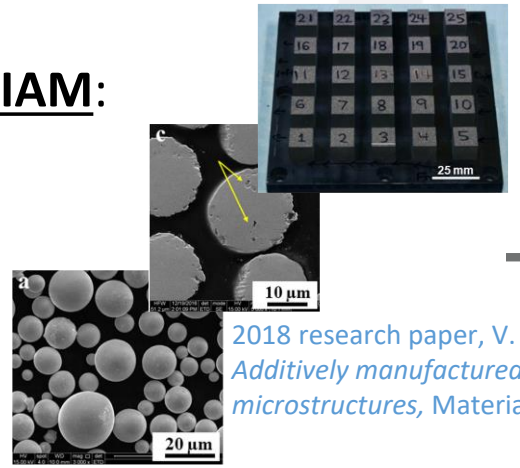
Ultra-High temperature materials

Refractory Metals Powder @ DIAM:

Ta Powder → 1550 EUR/Kg → 7,5 Kg

Mo Powder → 275 EUR/Kg → 10 Kg

W Powder → 275 EUR/Kg → 10 Kg

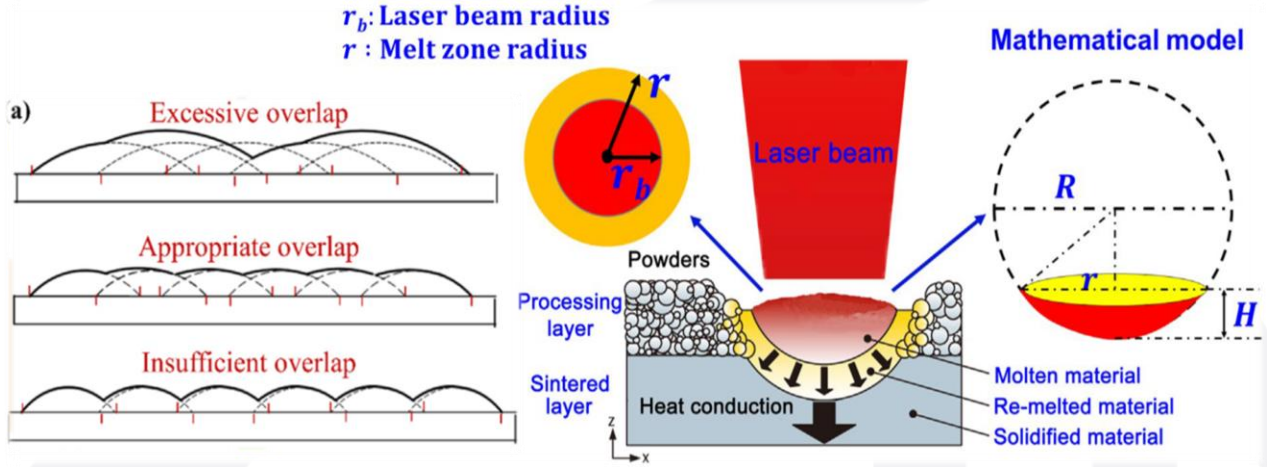


TEKNA

2018 research paper, V. Livescu et al. *Additively manufactured tantalum microstructures,* Materialia 1, 15–24

SLM of Refractory Metals

Critical issues of Additively Manufactured TUNGSTEN



1 ***High melting Point (3420 °C)***

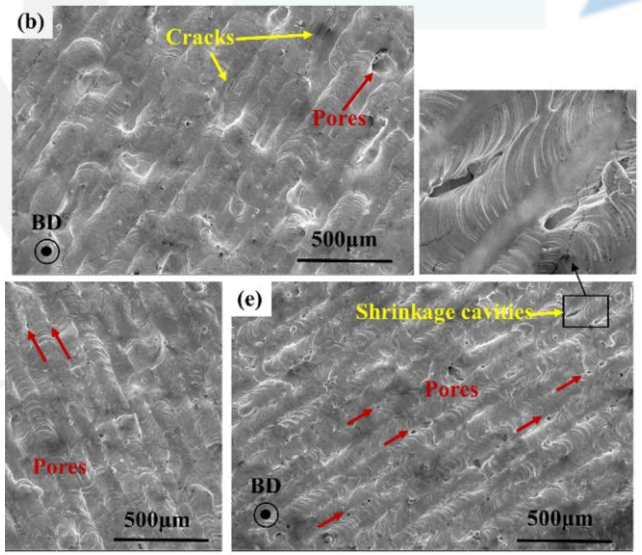
2018 research paper , Tan, C. et al. Selective laser melting of high-performance pure tungsten.

$$Q_p = \rho C_p \left(T_m - T_o\right) + \rho L_f$$

$$Q_v = \frac{\pi r_d^2 E_{\text{in}} \Delta t}{V_m}$$

the volumetric laser energy per unit volume

$$Q_v \geq Q_p$$



- ***POWER***
- ***SCAN SPEED***
- ***HATCHING***
- ***LAYER THIKNESS***

2 ***High melting Point – High surface tension – High cohesive energy***

2019 research paper, Wen, S. et al. High-density tungsten fabricated by selective laser melting.

High Dinamic Viscosity $\mu = \frac{16}{15}\sqrt{\frac{m}{k_B T}}\gamma$

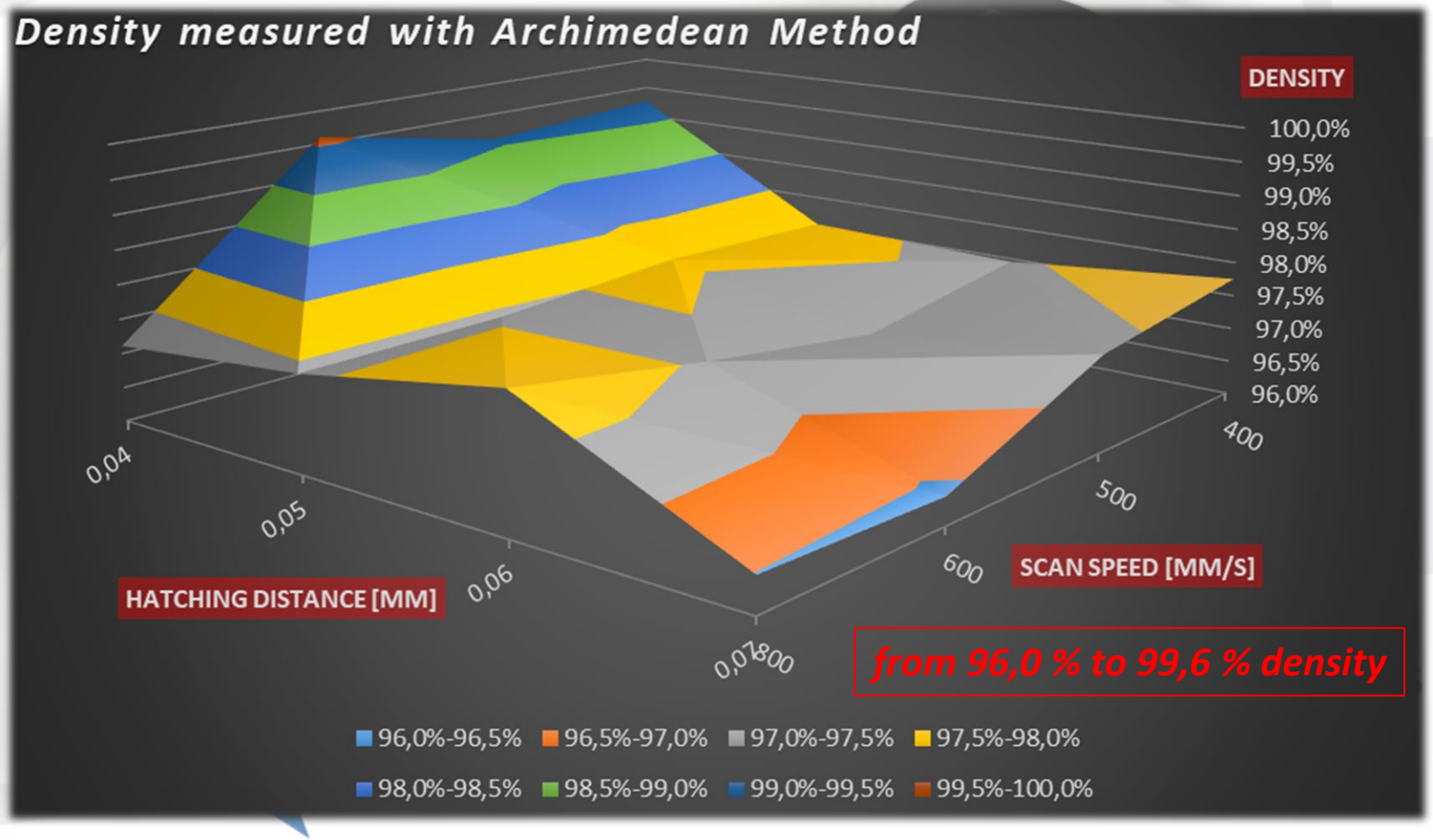
Poor flowability of the molten pool

Sufficient overlap between the scan tracks is needed

Tungsten, Tantalum and Molybdenum @ DIAM

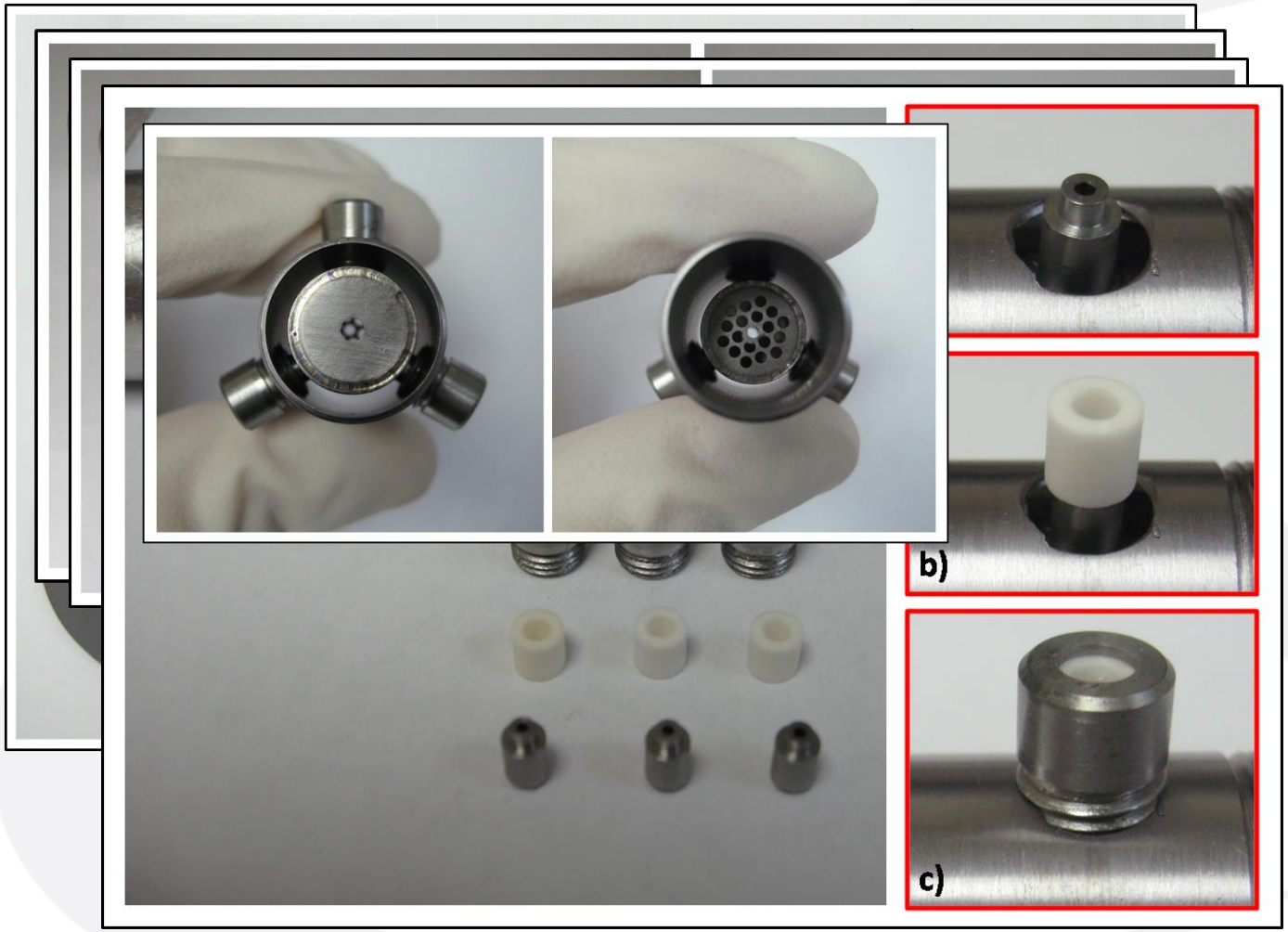
Material Characterization & Process Parameters Tuning:

- Block production for **PARAMETERS OPTIMIZATION** - with **EOS M100**

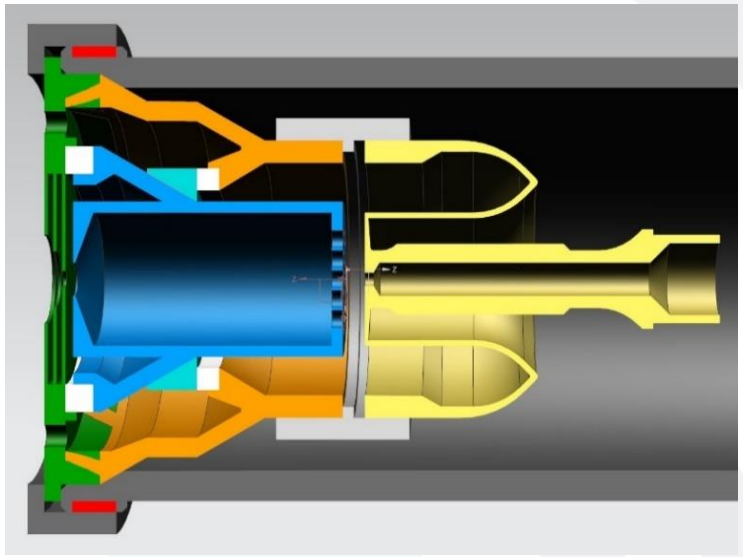


1° Advantage Design for Assembly

Courtesy of the SPES Target Group



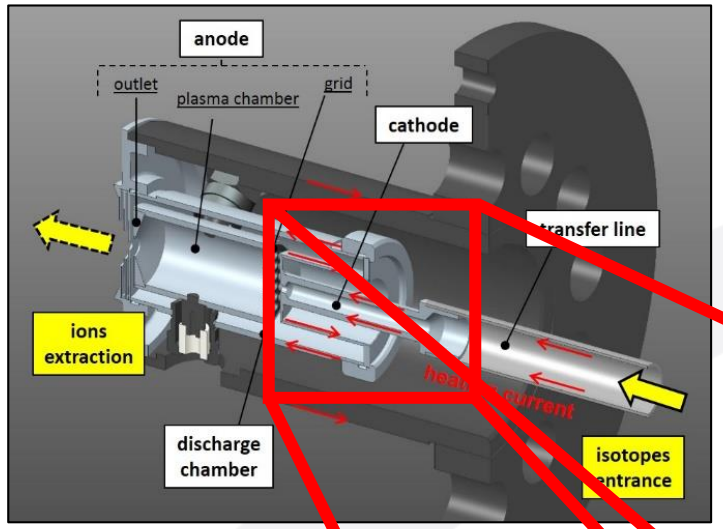
More than 20 components for ASSEMBLING and MANUAL ALIGNMENT

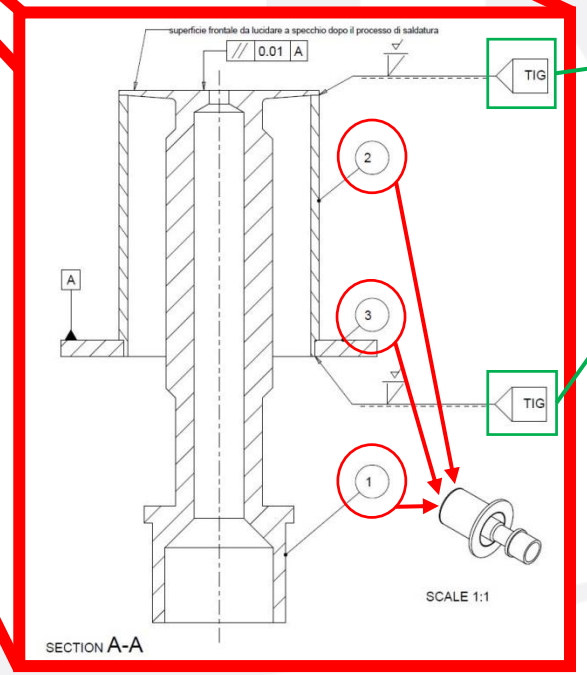


AlSi10Mg protoype

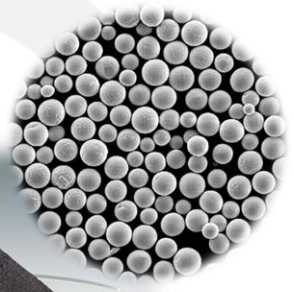
8 components: SELF ALIGNMENT during the ASSEMBLING
4 post-processing steps: threading

2° Advantage: Topological Optimization





Additively Manufactured *CATHODE*



Stainless Steel 316L - Prototype

AlSi10Mg - Prototype

CATHODE

Traditional Production

a possible Characterization Plan

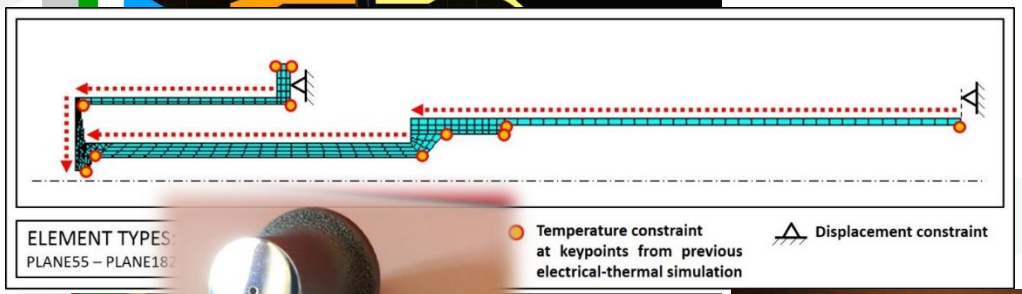
→ **NEW DESIGN**: Work in synergy to integrate **SPES GOALS** and **AM TECHNOLOGY**

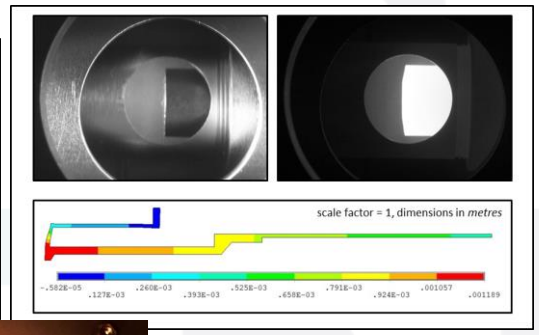
→ **ELECTRICAL-THERMAL FE** ANALYSES and **TESTS for VALIDATION**

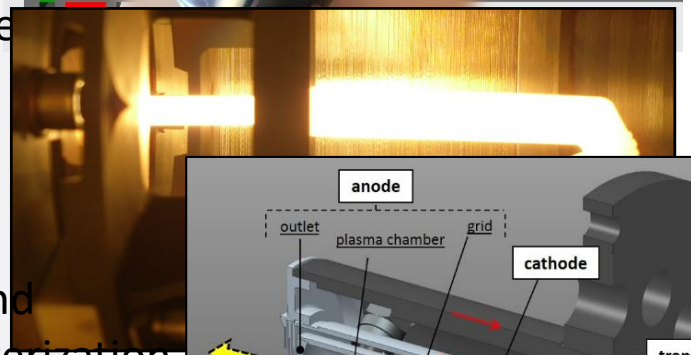
→ Influence of **ROUGHNESS** & **SURFACE REFINEMENT** improveme

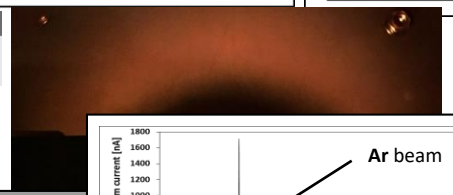
→ **HIGH TEMPERATURE** tests

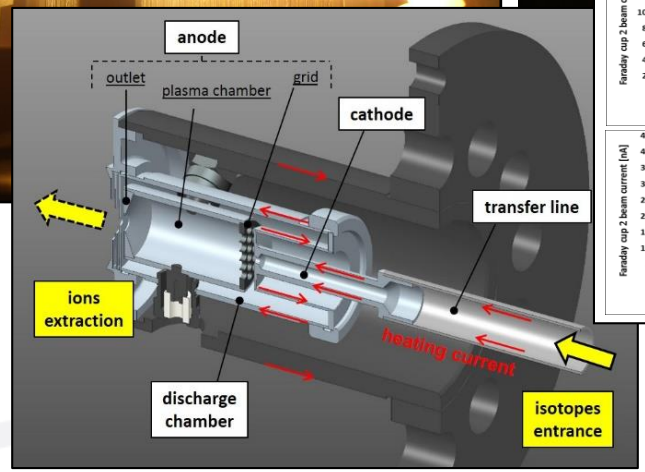
→ **BEAM** production and **ION SOURCE** characterization **(ionization efficiency and emittance measurements)**

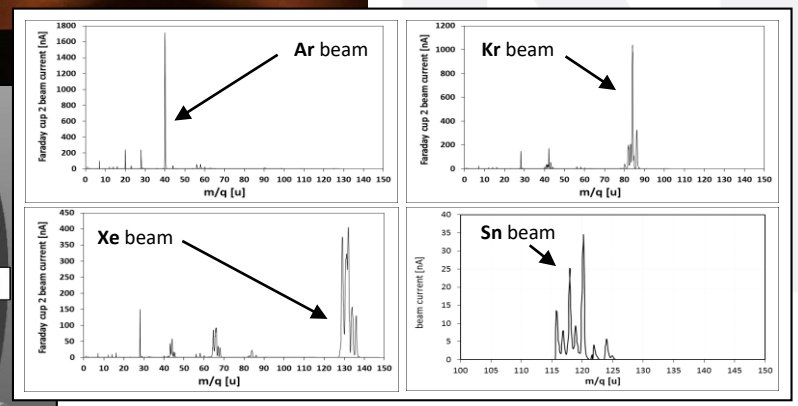


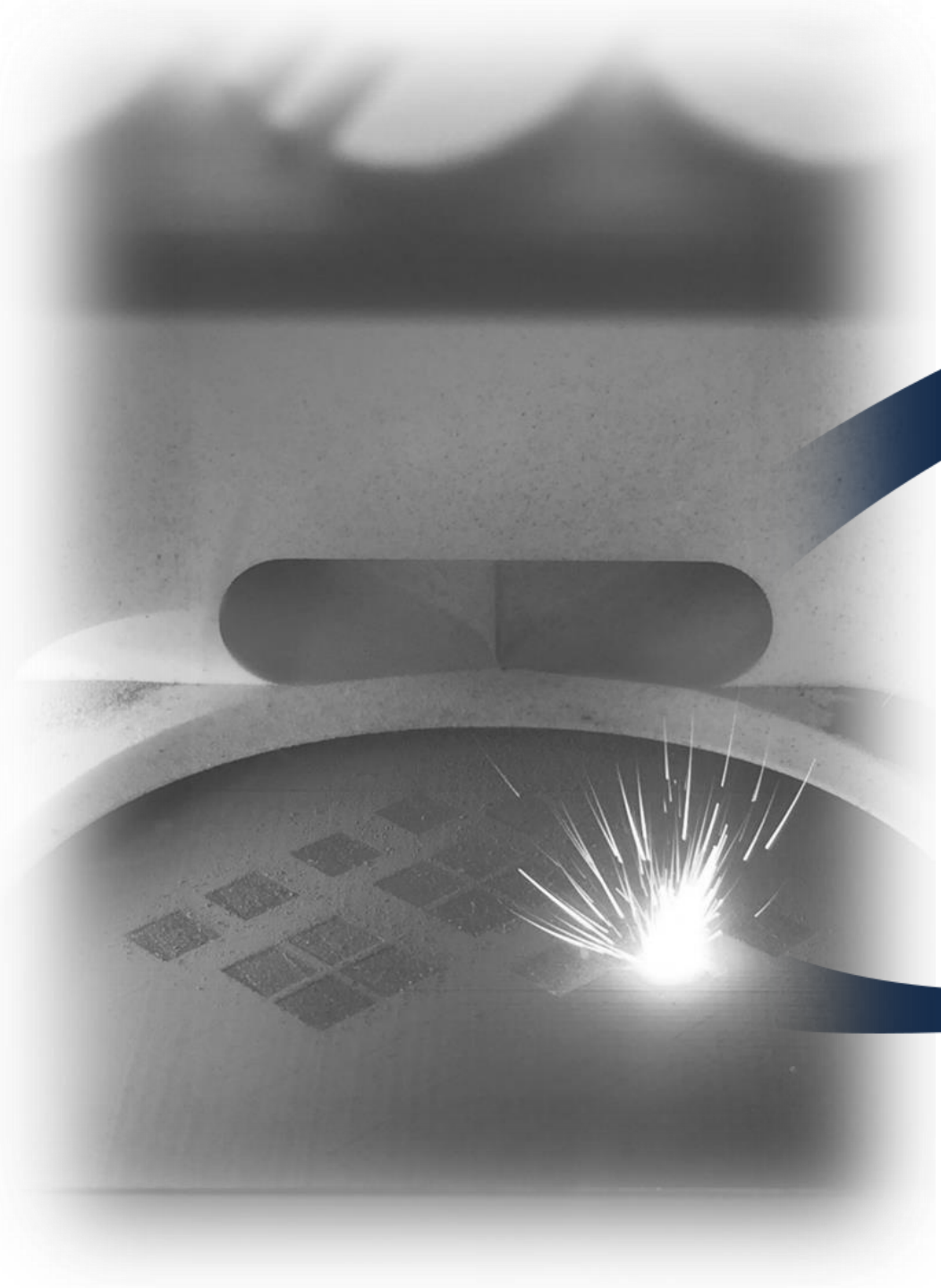












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GRAZIE