Istituto Nazionale di Fisica Nucleare

DIAM

Development & Innovation on Additive Manufacturing

SLM Development on Copper and Copper Alloy for Nuclear Fusion Physics (DTT, ITER, DEMO)

ADDITIVE MANUFACTURING WORKSHOP 2019

Presente Futuro della Fabbricazione Additiva nel tessuto Industriale e nella Ricercca

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Agenzia Spaziale Italiana

Materials Development for Nuclear Fusion Physics

SLM OF COPPER

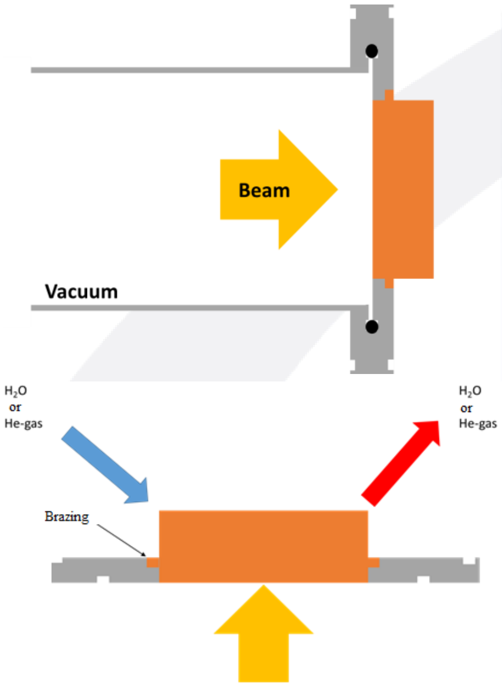
Nuclear Fusion:
- **Acceleration Grids for Neutral Beam Injector**

Complex Geometry
- Complex cooling channels
- Larger surface area

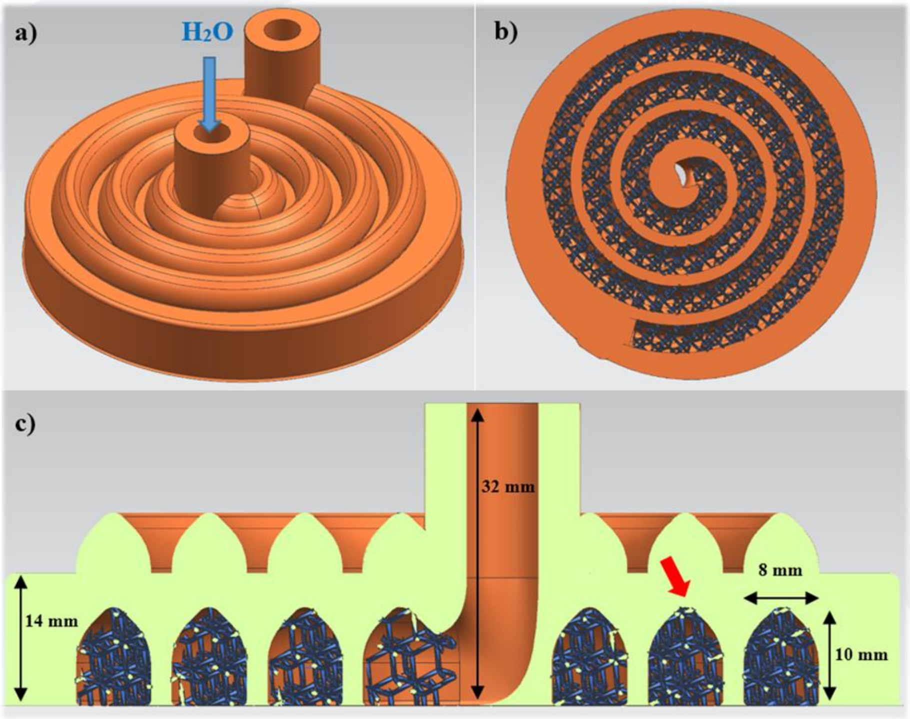
Materials Development:
- Grids: **Copper** and **Copper Alloy**
- Permanent Magnets: Samarium Cobalt, Alnico, Neodymium Iron Boron

https://www.iter.org/construction/NBTF

POR-FSE 2016 - New SLM Cu Beam Dump



30 kW on 21.4 cm^2



GOAL

- Beam Dump **for proton H beam** (INFN SPES project)
- Pure **Cu for heat dissipation** (max 30 kW on 21.4 cm^2)
- **Water cooled** or He cooled

ADVANTAGES

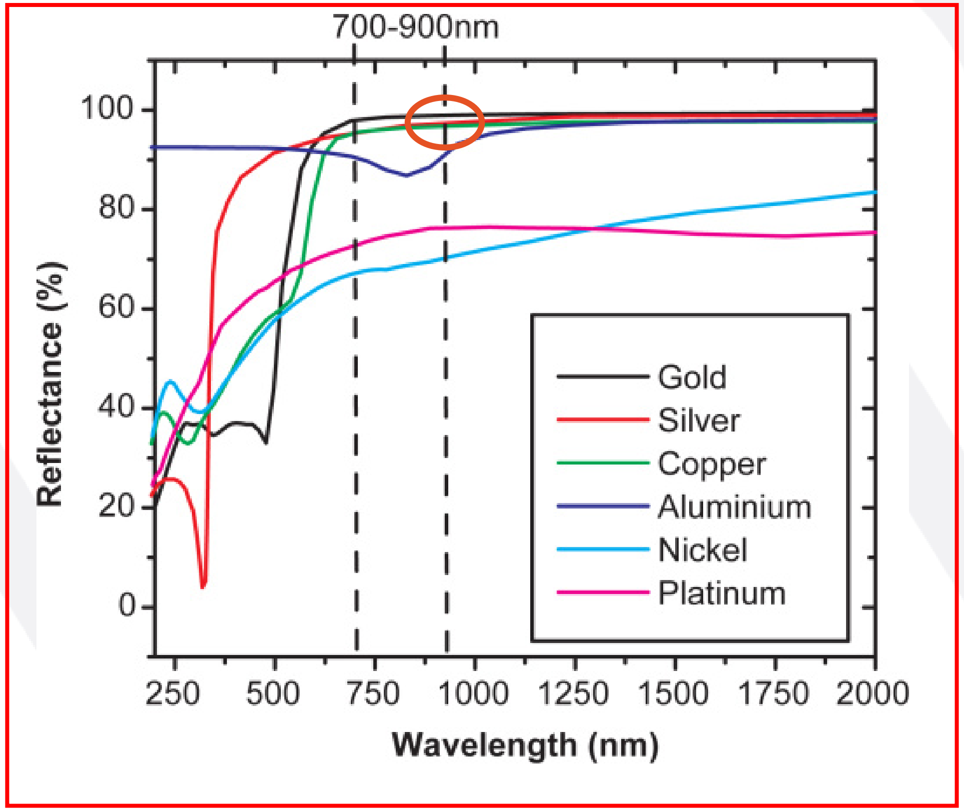
- **Two manufacturing steps**: SLM production and brazing with the ISO K-100 flange (↓ time to product)
- **Conformal cooling design** with potential filling metallic foam
- **Lighter and smaller**

Eng. Mirko Sinico
Dr. Giacomo Cogo

Copper problems for SLM

MAIN PROBLEMS

- **High reflectance of near infrared wavelenght** may limits power that can be put into powder to melt it
  → > 60 % reflectance on pure Cu powder, > 90 % reflectance on bulk (1070 nm, Nd:YAG)
- **High Cu thermal conductivity** (390-400 W/mK) may limits maximum local temperature that can be attained and limits successful bonding between weld lines



HIGH POROSITY!

SOLUTIONS

- **Higher Laser Power**
- **Lower laser wavelength** (ex: green 515 nm)
- **Divert to Cu alloys:** ↓ reflectance, ↓ thermal conductivity

POR-FSE 2016 Research

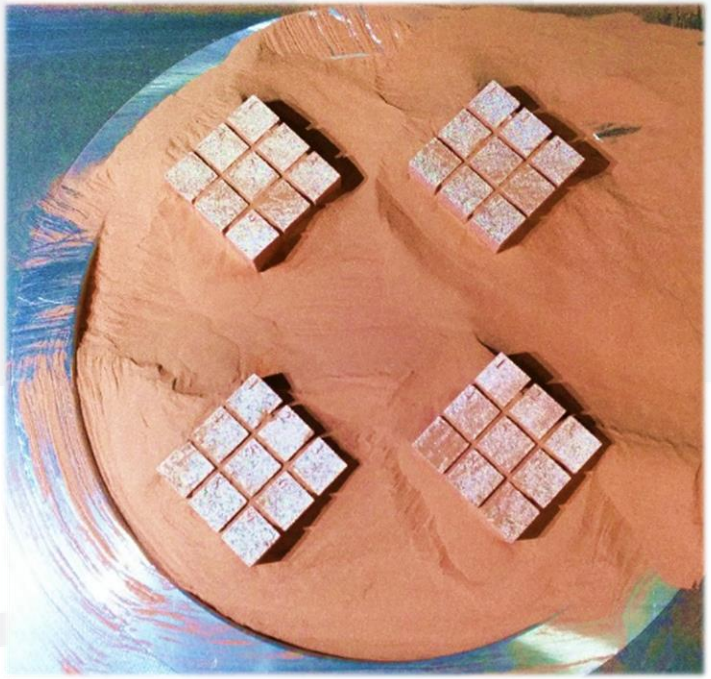
SISMA mysint100PM

- **200 W maximum Laser Power** (1070 nm)
- **Small Laser Spot** (d = 30 μm)
- **Small Layer Thickness** (t = 20 μm)

TWO SELECTED PURE CU POWDERS

- "Standard" **15-45 μm distribution** gas atomized 99.9 pure Cu powder → ***from 70 % to 88 % density*** *depending on parameters*
- Fine **selected distribution** under NDA → ***from 93 % to 98 % density*** *depending on parameters*

→ Deep **research on processing parameters**



OPTICAL OUTCOME

➢ **Lower total porosity !**

M. Sinico, G. Cogo, "Influence of Powder Particle Size Distribution on the Printability of Pure Copper for Selective Laser Melting" - *Solid Freeform Fabrication Symposium Proceedings 2019*

Current Research on Pure copper

EOSINT M280

- **370 W maximum Laser Power** (1070 nm)
- **Laser Spot d = 80 μm**
- **Small Layer Thickness** (t = 20 μm)

Study of the effect of Particle size distribution

Powmet®	amp Advanced Metal Powders	TLS Technik Spezialpulver

Research on processing parameters

Block production
- Improve density
- Microstructural characterization

Sample production
- thermal conductivity measurements

Bar production
- mechanical characterization

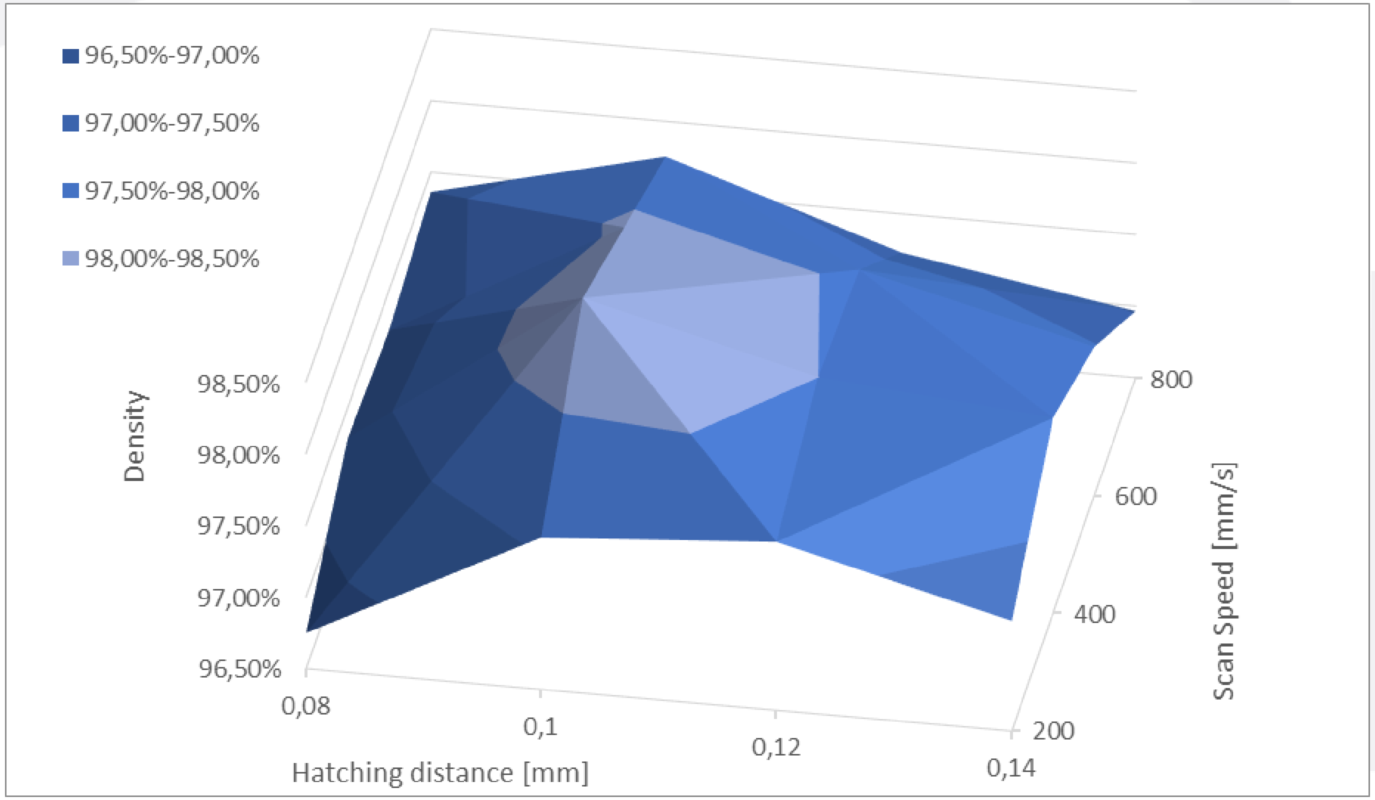
Sample production
- Influence of ROUGHNESS & SURFACE REFINEMENT

Possible Cu Alloys	Precipitation strengthened **CuCrZr**	Lower Reflectivity (powder)
		High thermal conductivity
		High mechanical properties

Wallis, C., & Buchmayr, B. (2019). Effect of heat treatments on microstructure and properties of CuCrZr produced by laser-powder bed fusion. *Materials Science and Engineering A*

Printing of Pure copper – Work in Progress

Powder: Powmet®

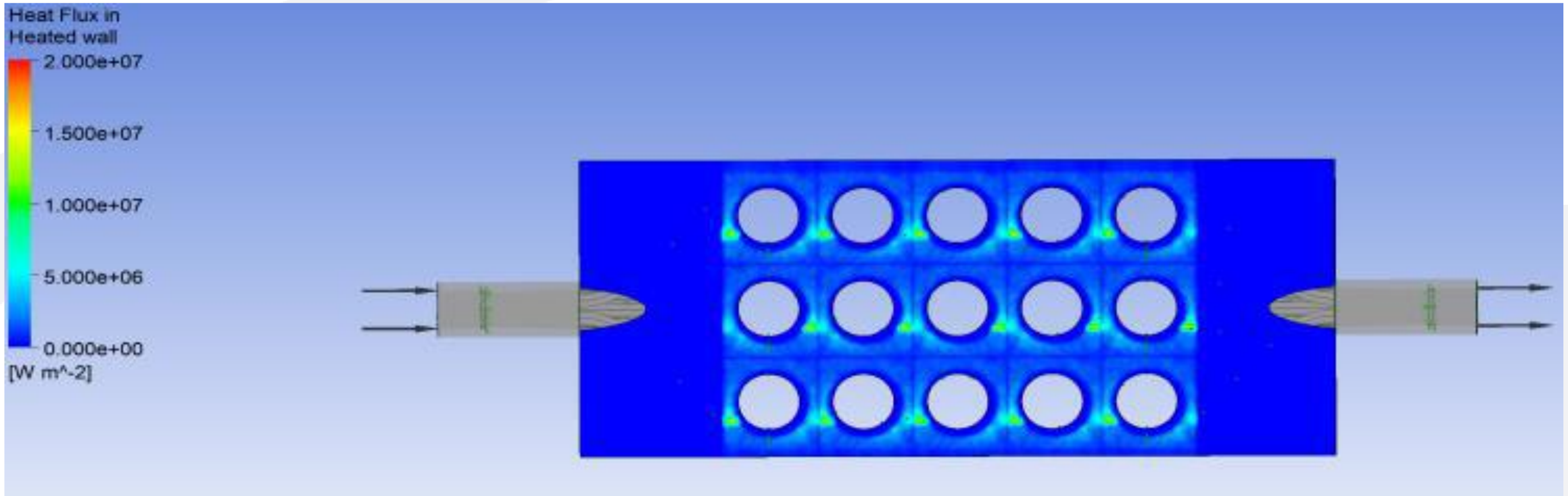


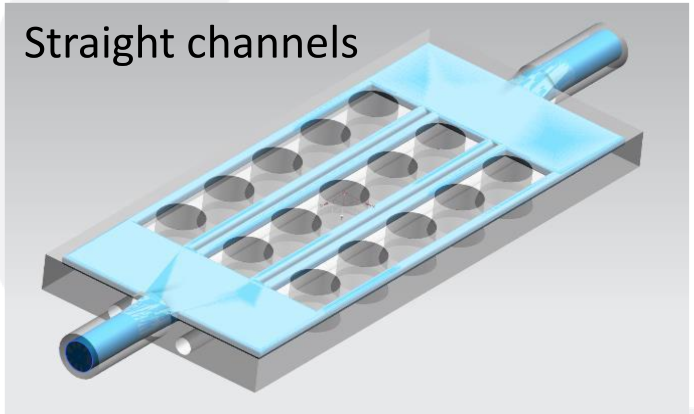
DENSITY MEASURED WITH **ARCHIMEDE'S** METHOD

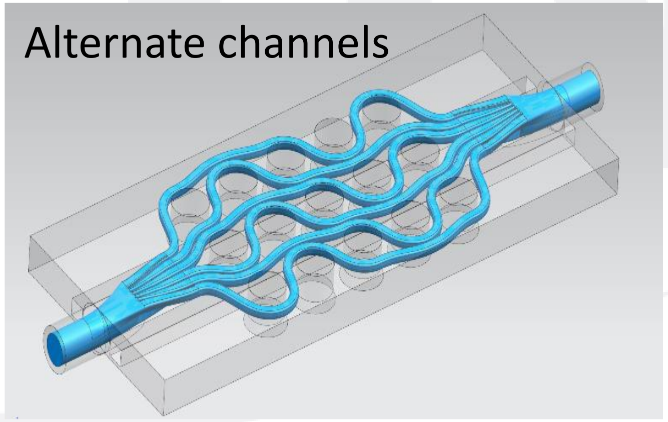
from 96,5 % to 98,5 % density
depending on parameters

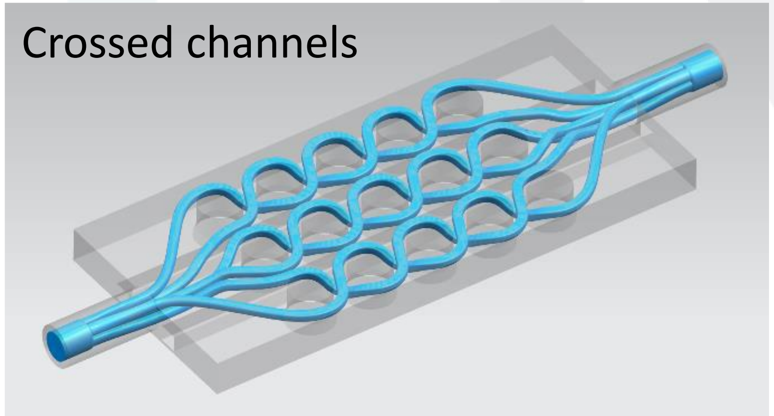
Design of new AM cooling channels for NBI Plasma Grid

CAD DESIGN
Siemens NX







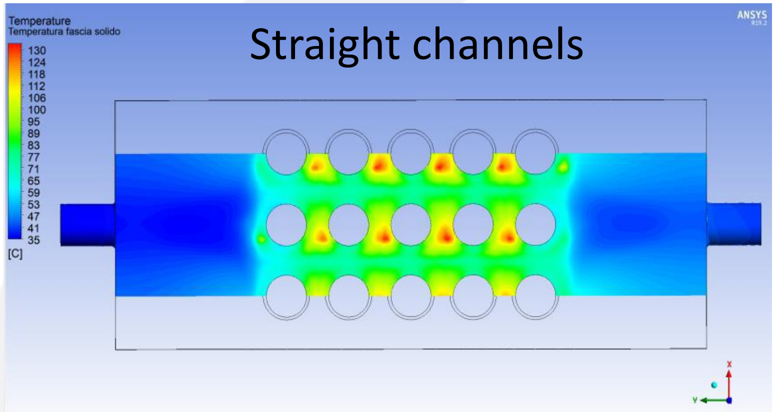


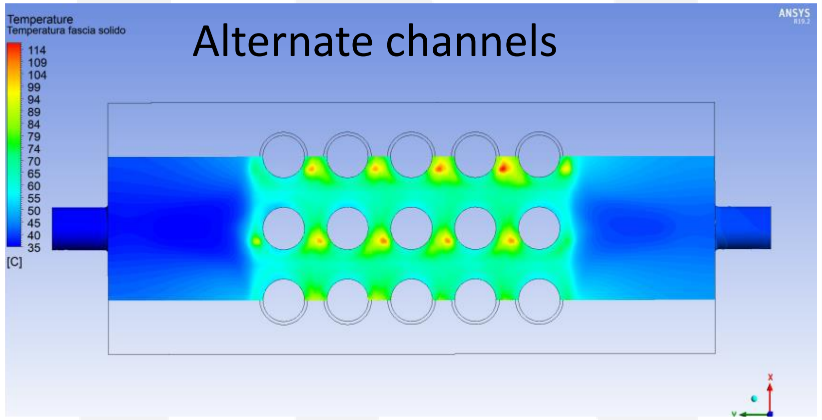
P. Agostinetti, G. Chitarin, N. Marconato, D. Marcuzzi and A. Rizzolo, "Manufacturing and Testing of Grid Prototypes for the ITER Neutral Beam Injectors," in IEEE Transactions on Plasma Science, vol. 42, no. 3, pp. 628-632, March 2014.

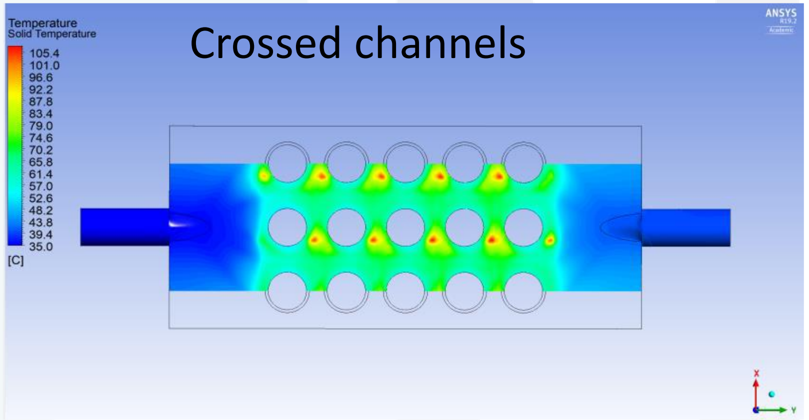
Design of new AM cooling channels for NBI Plasma Grid

CAD DESIGN
Siemens NX

SIMULATION
ANSYS CFX







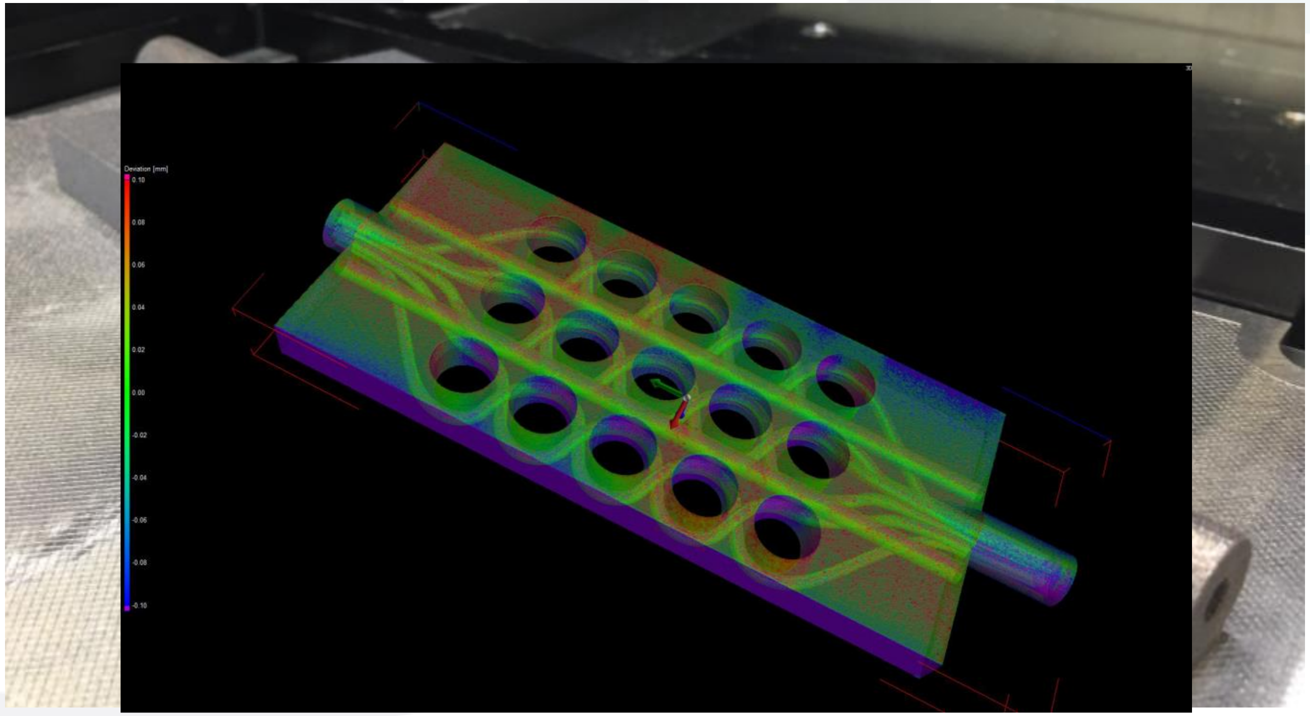
Inlet Speed [m/s]	6	6	6
Maximum speed of the Fluid [m/s]	10	11,6	11,9
Load Loss [bar]	0,85	1,44	1,6
Maximum Temperature of the Solid [°C]	**133,2**	**116,4**	**107,6**
Maximum Temperature of the Fluid [°C]	**93,9**	**92,9**	**89,5**

Design of new AM cooling channels for NBI Plasma Grid

CAD DESIGN
Siemens NX

SIMULATION
ANSYS CFX

FABRICATION
USING SLM
AlSi10Mg



Design of new AM cooling channels for NBI Plasma Grid

CAD DESIGN
Siemens NX

→

SIMULATION
ANSYS CFX

→

FABRICATION
USING SLM

AlSi10Mg

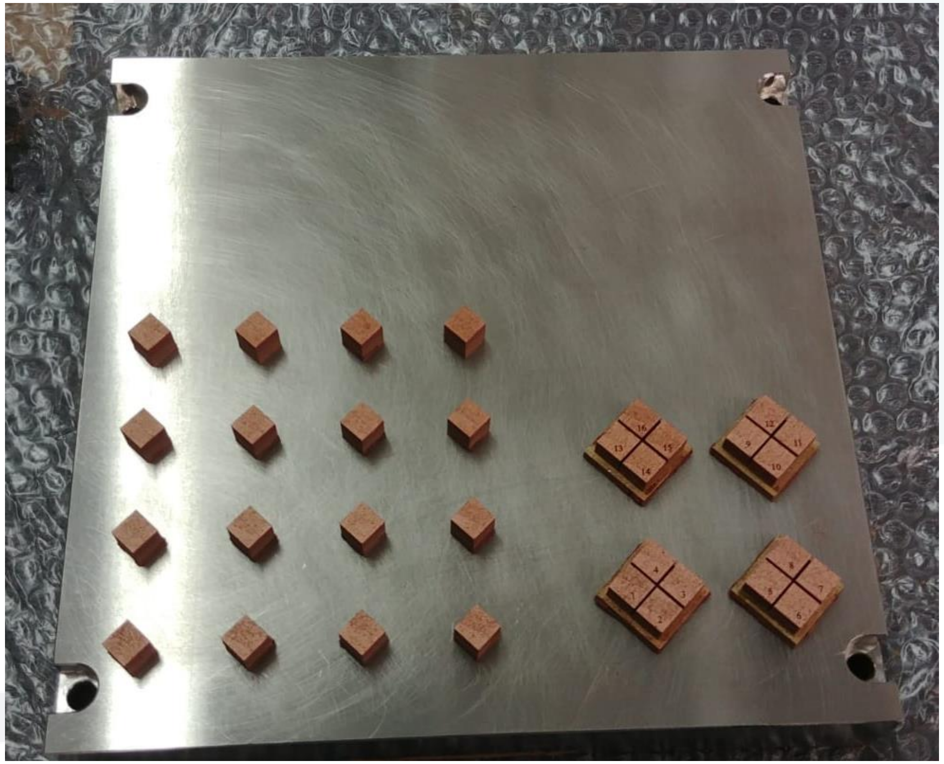
→

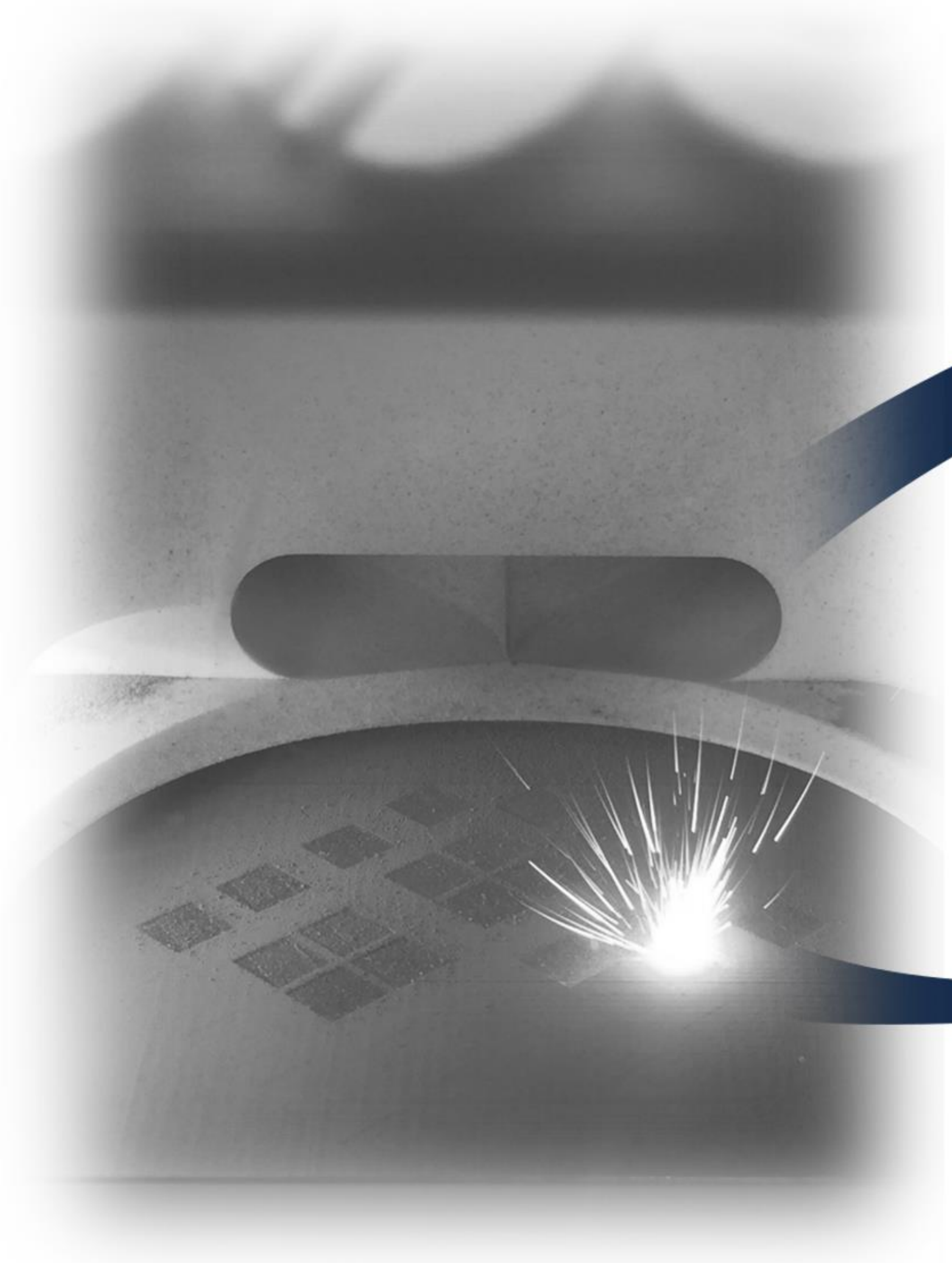
FABRICATION
USING SLM

Pure Cu

→

TESTING AND
EXPERIMENTATION





INFN

GRAZIE