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**IFAST**

**WP 10.4**

# **Additive Manufacturing of pure Cu and pure Nb SRF cavities**

20. 04.2023 - Trieste, I.FAST Annual Meeting

Adriano Pepato – INFN Section of Padova



# Task 10.4 Additive Manufacturing of pure Cu and pure Nb SRF cavities

- Develop the design approach and test relevant properties of AM-manufactured Niobium RF cavities
- Develop the design approach and test relevant properties of AM-manufactured Ultra-Pure Cu-made RF body cavities - coated by a Niobium thin layer at the inner surface
- Both to be tested at room and at cryogenic temperature.

Deliverable: done December 2022 (Cu and Nb based SRF cavities produced and qualified)

Milestone: December 2023 (room and cryogenic temperature tests for Nb and/or Cu SRF Cavities)

## Steps:

- Characterization of pure Cu produced by LPBF
- Production of Cu 6 GHz cavity prototypes
- Preliminary tests on prototypes
- Surface treatments on copper cavities
- Characterization of pure Nb produced by LPBF
- Production of Nb 6 GHz cavity prototypes
- Tests and surface treatments of niobium cavities
- Issues

# Pure Copper

Printability of copper cavities:

- Orientation
- No internal supports
- Different down skin parameters



EOS M280  
Yb fiber laser  
Spot diameter: 80-100  $\mu\text{m}$   
 $\lambda = 1060\text{-}1100\text{ nm}$   
Nominal power: 400 W



# Pure Copper

Pure copper printed with different laser wavelengths and power



Green laser (515 nm, 1 kW)



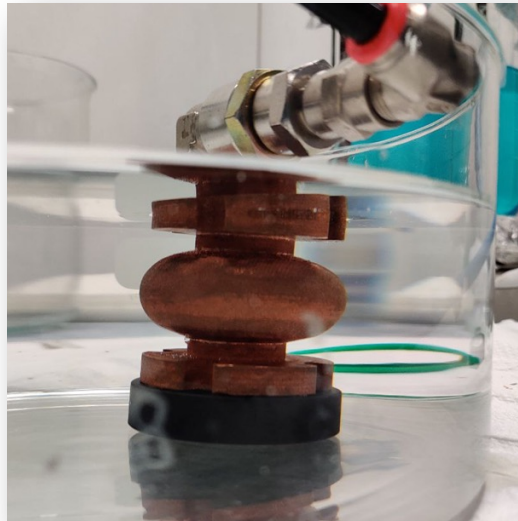
Red laser (1060 nm, 370W)



First prototypes (reduced height).

# Acceptance tests performed.

Leak test:



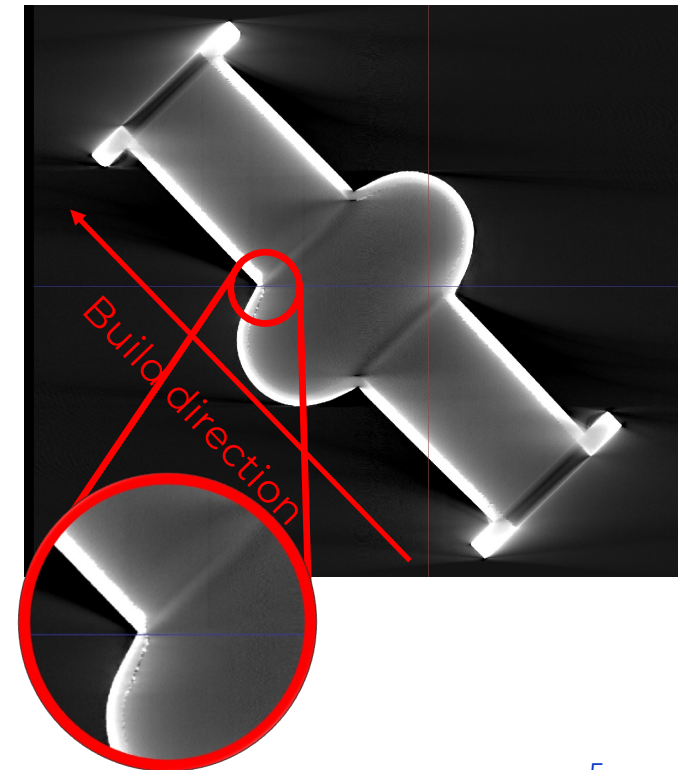
N<sub>2</sub> 2 atm, room temperature  
Under vacuum

Frequency at room temperature

Cavity	Frequency (GHz)
T1	5.9871875
T2	5.986250
L1	5.9956250
L2	6.0015625
L3	6.0043750
P1	5.9481250
P2	5.9418750
P3	5.9390625



Computed tomography



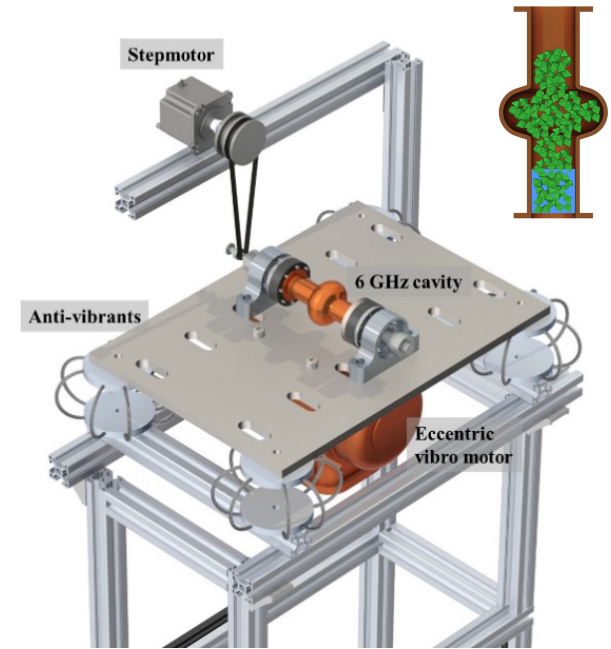
# Surface treatments

- Rösler Italiana Srl

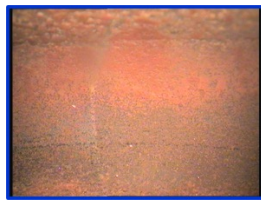
Traditional Mass finishing + chemically assisted mass finishing + final polishing

- INFN LNL

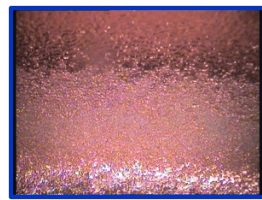
Electropolishing + Vibrotumbling



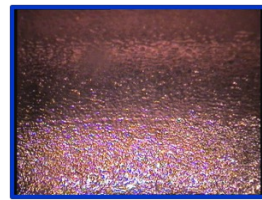
Vibrotumbling apparatus



As built



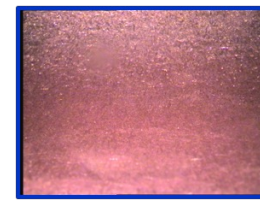
After EP1



After EP2



After VT 1

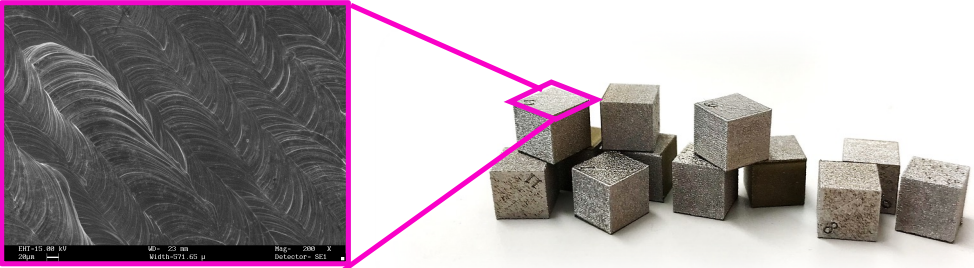


After VT 2

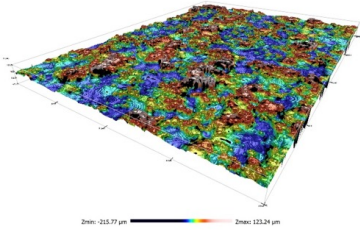
# Niobium

Process parameters deeply investigated:

- Maximization of density;
- Improvement of as-build surface quality



Maximum density achieved: 99.8%  
(Archimedes method)



Adriano Pepato – I.FAST AM April 2023

EOS M100  
Yb fibre laser  
Spot diameter: 40 μm  
λ = 1064 nm  
Nominal power: 200 W



Elements	Quantity
Nb	99.9 %
C	<50 ppm
H	<50 ppm
N	<100 ppm
O	<600 ppm
Ta	<100 ppm
Cr	<50 ppm
Fe	<50 ppm
Ni	<50 ppm
Hf	<50 ppm
Mo	<50 ppm
Zr	<50 ppm
W	<50 ppm

**Inclined walls:**

Angles investigated: 18° 20°, 22°, 25°, 30°, 35°, 40°, 45°, 50°

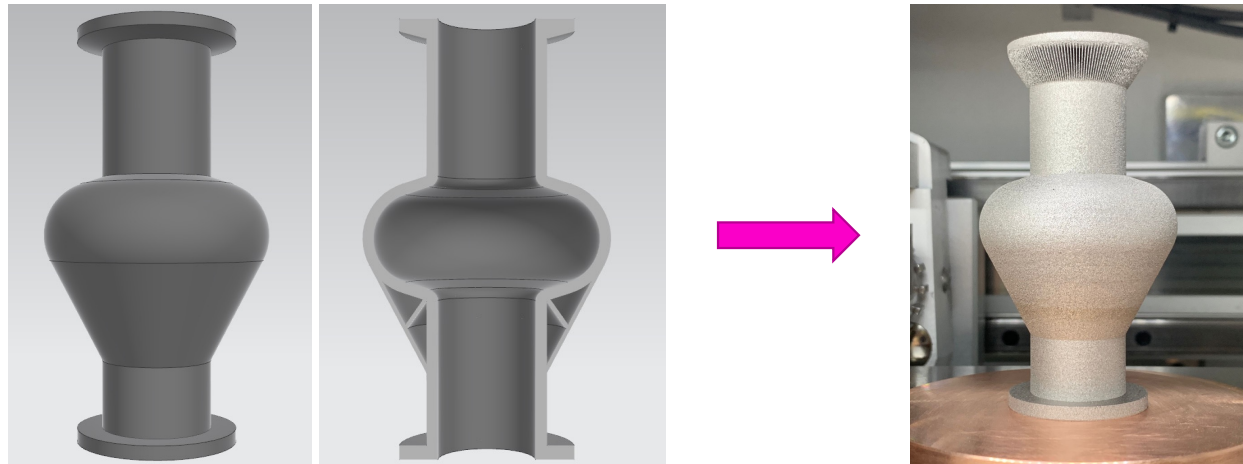
Acceptable results only for angles higher than 35°.

NEED TO APPLY THE NO CONTACT SUPPORT APPROACH



# Niobium

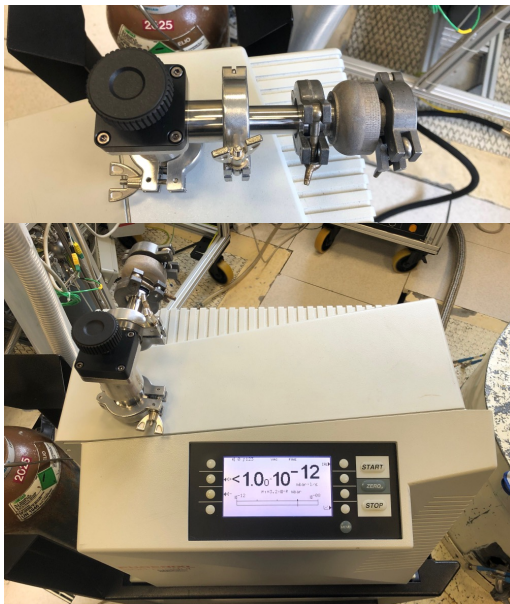
- Seamless niobium cavities successfully printed
- Supporting structures optimized to reduce the building time and material consumption





# Acceptance tests performed.

Leak test:  
Under vacuum



Frequency test at room temperature

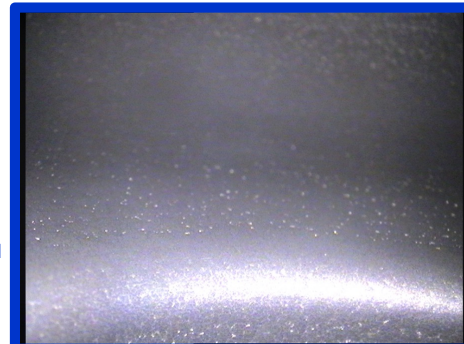
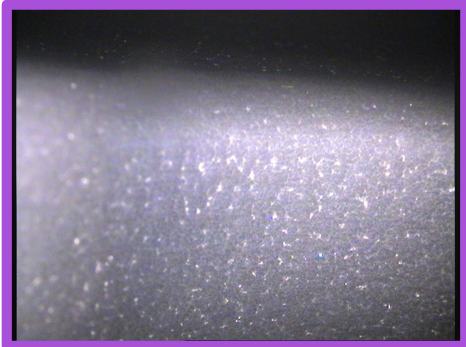
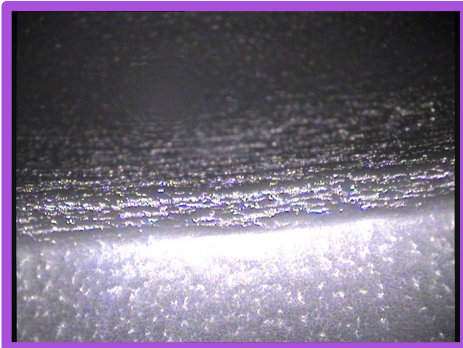
Cavity	Frequency (GHz)
Nb small	5.999
Nb big	6.027



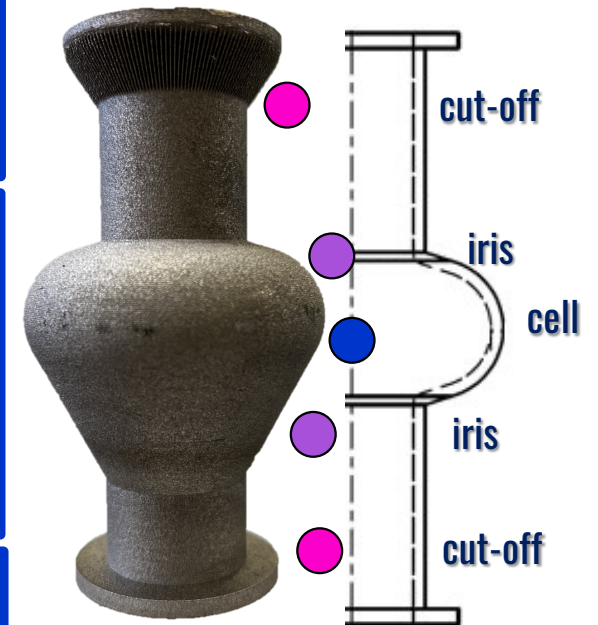
Computed tomography



# Surface treatments



INFN LNL:  
Mechanical treatment  
Electropolishing  
Work in progress



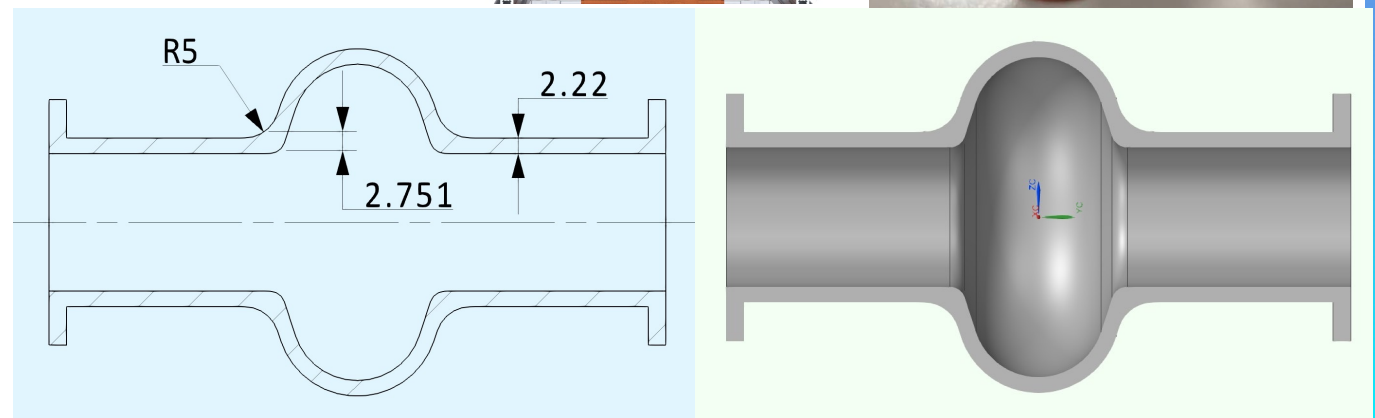
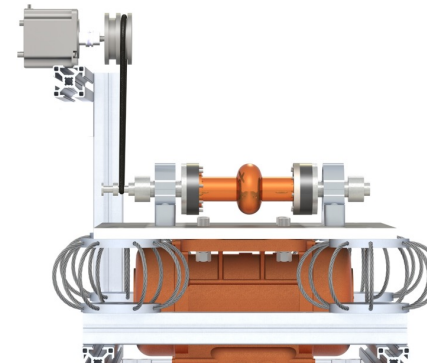
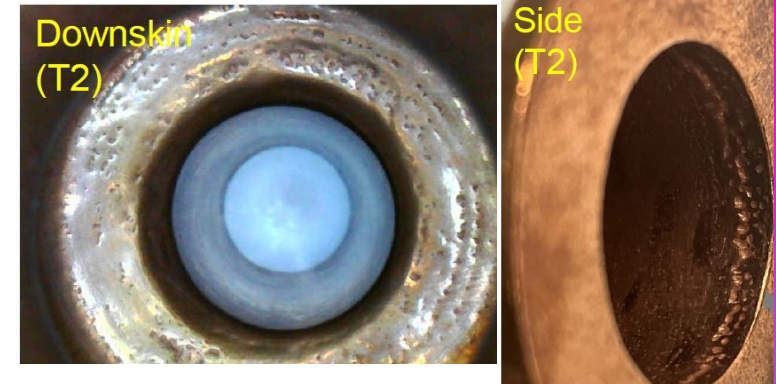
Printed cavities Nb, Cu

# Issues.

Scratches and pitting appeared during the surface treatments performed by Rösler on both T1 and T2.

Due to mechanical loads, Vibrotumbling apparatus, caused ruptures in correspondence of the iris of the copper cavities.

We'll produce a couple of Cu cavities with a different fillet radius between IRIS and cut off, while maintaining a reduced wall thickness to guarantee a high temperature uniformity at cryogenic temperatures.



**Thanks for your attention**

