SPL CAVITIES PROTOTYPING & MATERIAL STUDIES FOR SPL CAVITES

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EUROPEAN SPALLATION SOURCE

- Introduction
- Niobium cavity
    - Cavity
    - Interfaces between cavity and tank
    - Brazing test I / II /III
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    - Anodizing test
- Mock-up copper cavity
    - Shaping of half-cells and extremities
    - Welding tests
    - Extremities
- R&D
    - Cold gas dynamic spray
    - Nb/Ti weld
- Conclusions

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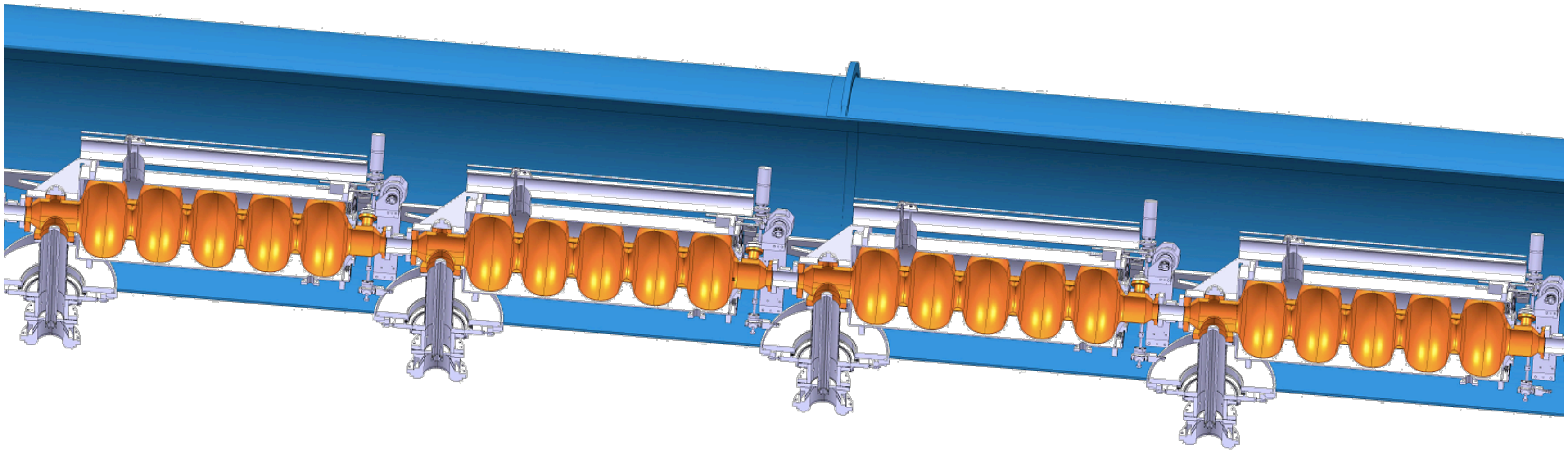
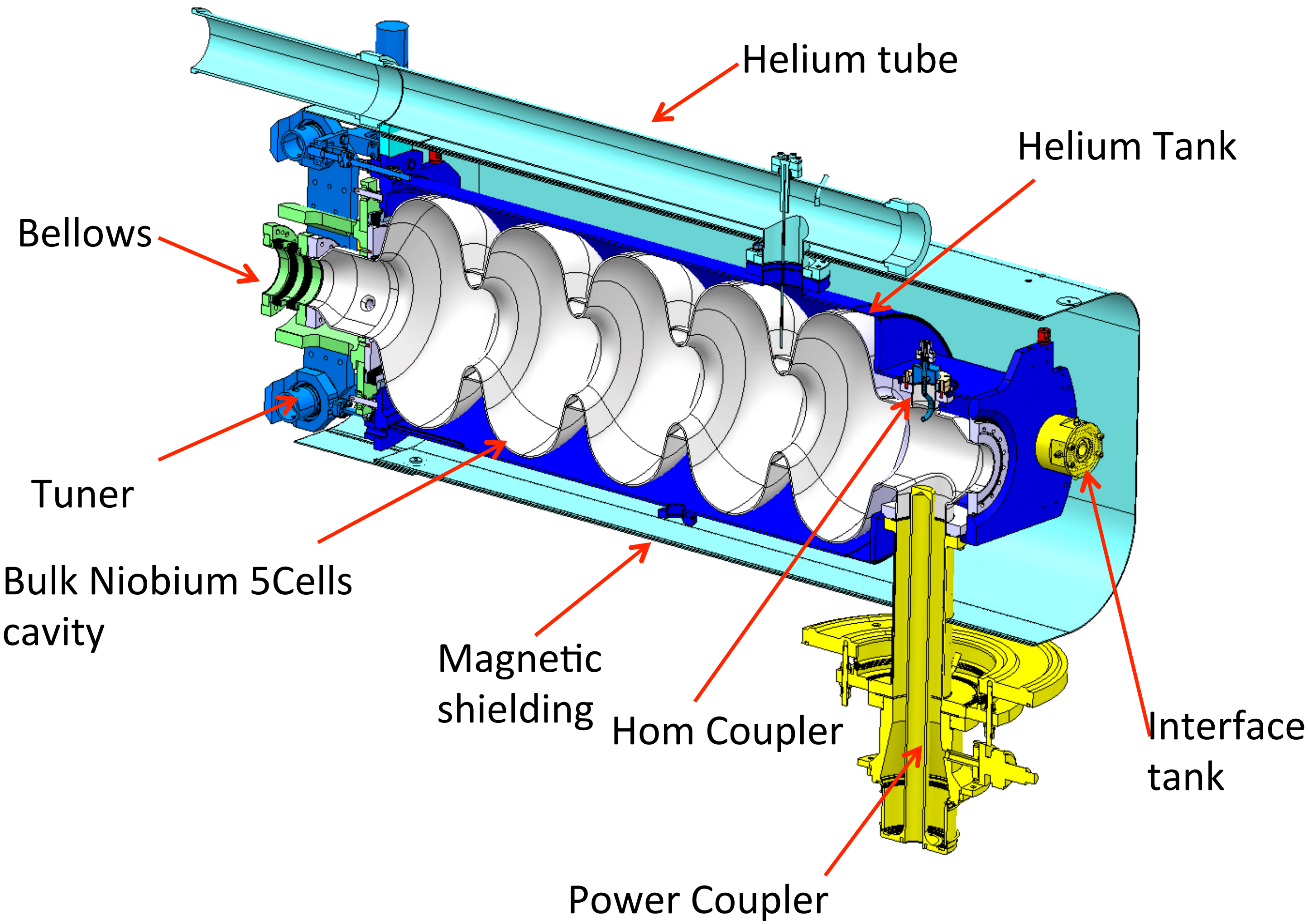
Introduction

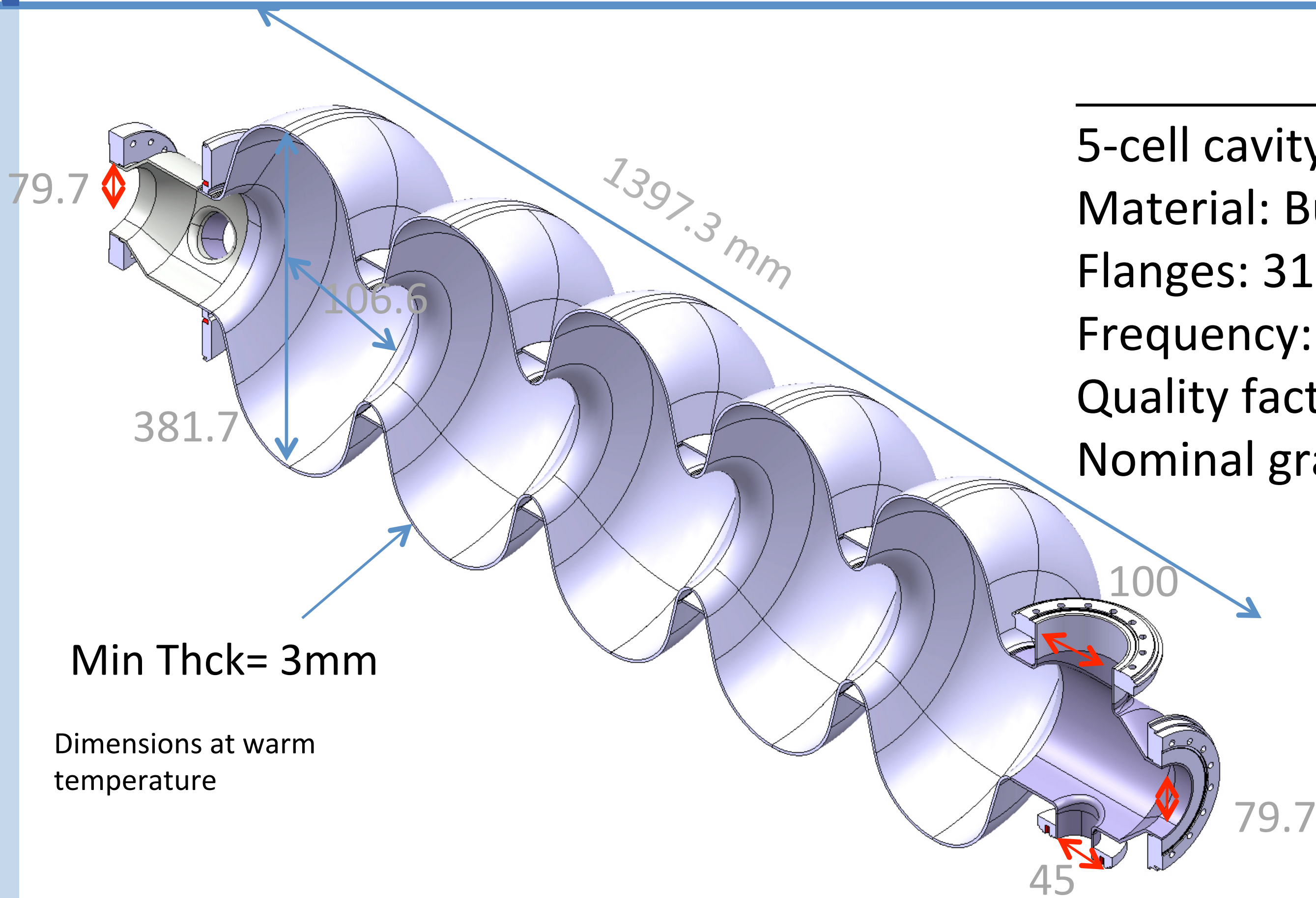
A string of 4 equipped β=1 bulk niobium cavities to be tested into a short cryo-module by 2014.



Four bulk niobium β=1 equipped cavities to be fabricated



Cavity



Dimensions at warm temperature

PROPERTIES

5-cell cavity
Material: Bulk Niobium
Flanges: 316LN
Frequency: 704.4 MHz
Quality factor: 10^{10}
Nominal gradient E_{acc}= 25 MV/m

Cavities under fabrication:

4 niobium cavities β=1 in industry (RI)
2 copper cavities β=1 at CERN (prototyping)
1 niobium cavity β=1 at CERN

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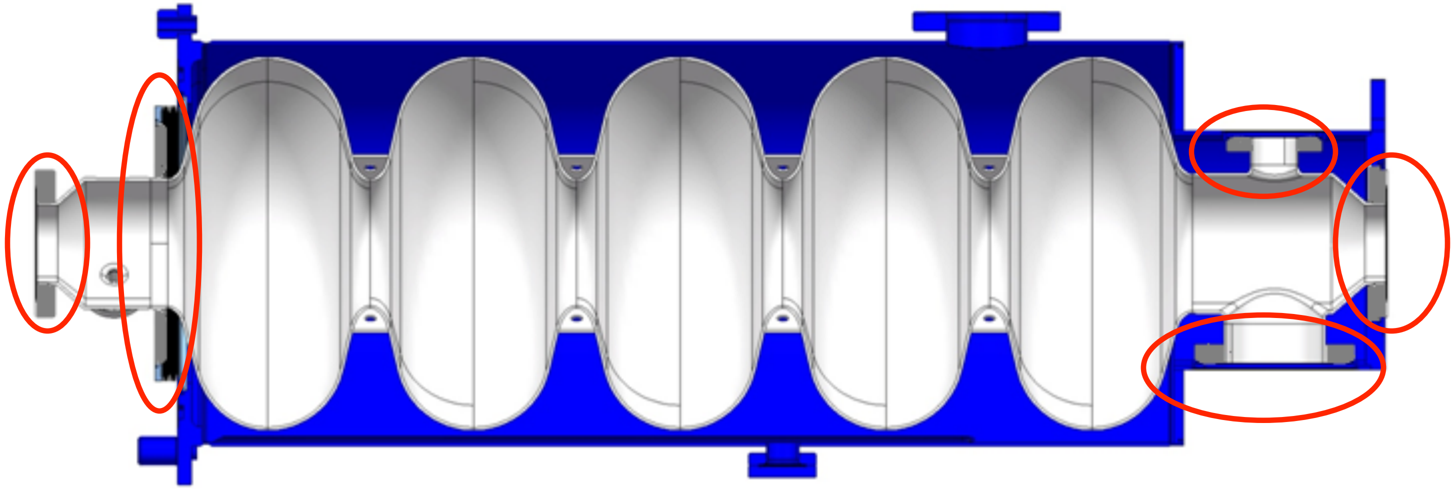
Interfaces between cavity and tank



SS flanges joined to the niobium cavity by brazing

3 brazing tests undergoing to study:

1. The mechanical behaviour of the joint
2. If the chemical etching bath damages the brazed joint
3. Possible effects of EB weld close to a brazed joint

Brazing test I

Brazing Nb / SS 316 LN is a key technology

Developed at CERN in 1987

Difference in thermal expansion of Nb/SS

Nb tube fitted to SS flange

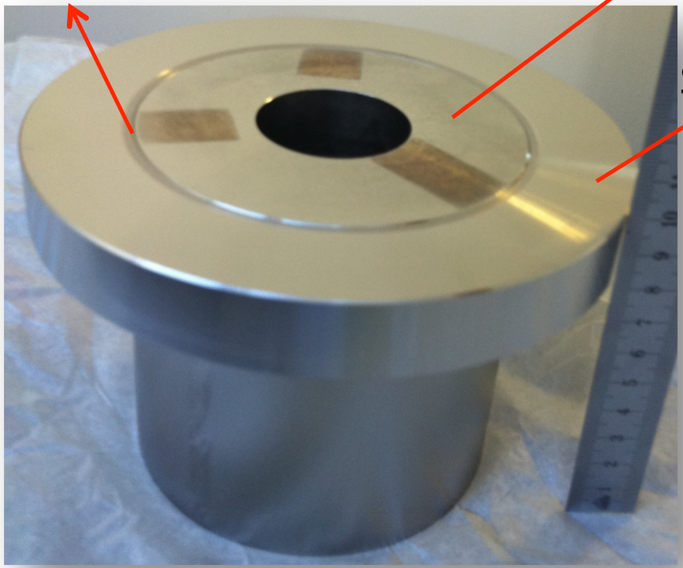
Clearance ≤ 20 µm

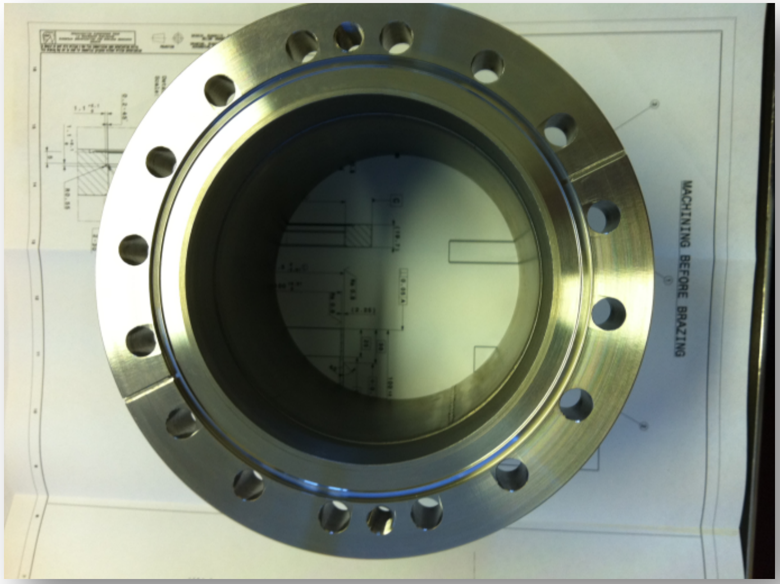
SS plug to expand the Nb

Pure Cu filler metal

Brazing temperature 1100°C, Δtime <<

P< 10-5 mbar





Flange after machining the SS plug

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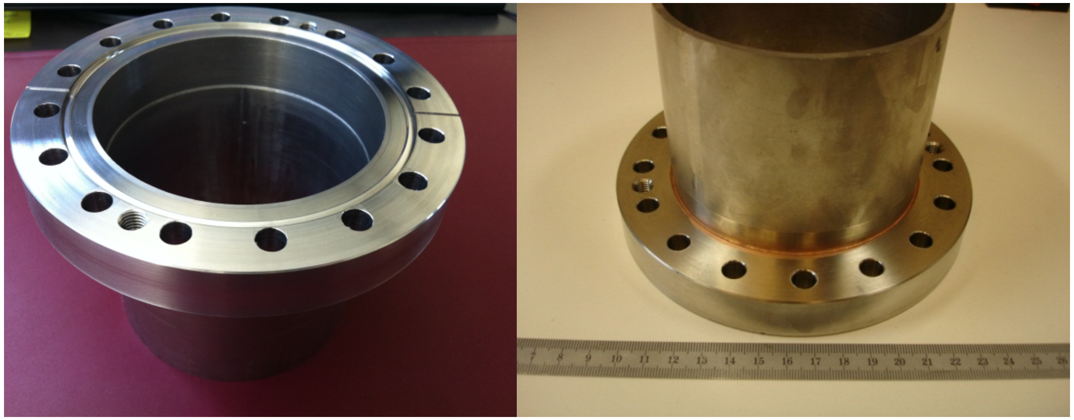
Brazing test I

- Ultrasonic examination ✓
- Leak test ✓
- Thermal shock liquid N_2 (x5) ✓
- Ultrasonic examination ✓
- Leak test ✓
- Electropolishing ✓
- HT (600°C/24h) ✓
- Electropolishing ✓
- Leak test ✓
- Ultrasonic examination ✓
- Thermal shock liquid N_2 (x5) ✓
- Ultrasonic examination ✓
- Leak test ✓
- Shear test ✓
- Leak test ✓
- Ultrasonic examination ✓
- Assembly test
- Macroscopic examination
- SEM assesment

2 brazing samples tested



Shear test (3 tons)

Ultrasonic examination (by immersion) of the brazed area

Thermal shock liquid N2 (x5)

Ultrasonic examination (by immersion) after tests

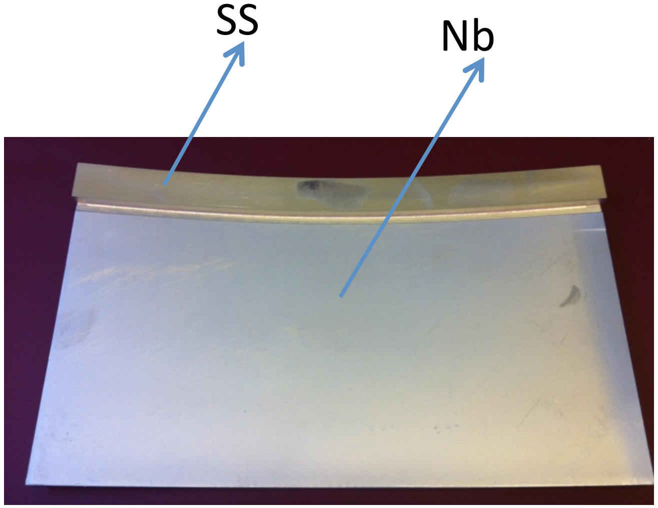
Brazing test II: Effect of Chemical etching to the brazing

Chemical etching of niobium 8 hours before EBW to avoid oxidation and degradation of RRR

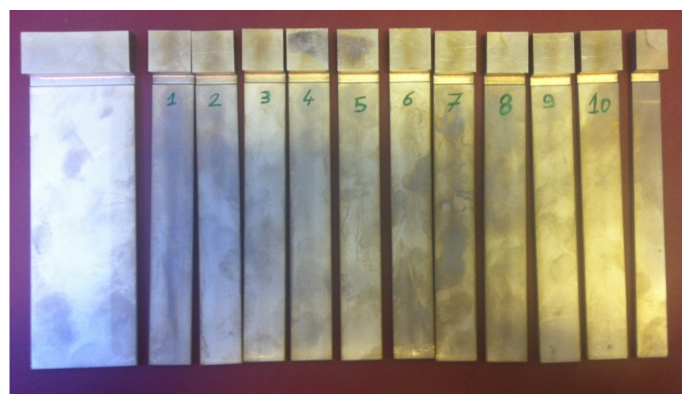
Bath: (1:1:2) 40%HF, 65% HNO_3, 85% H_3PO_4

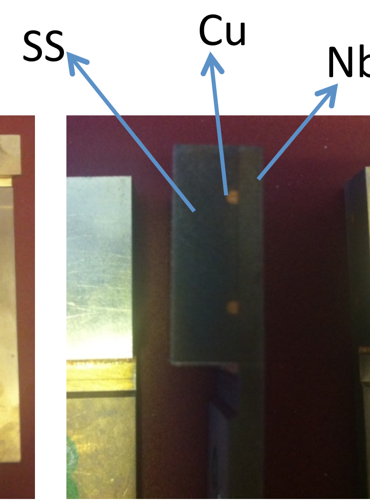
Does the bath damage the brazed joint??

10 samples introduced in the bath at different conditions (without masking the brazed joint).



Brazing Nb/SS

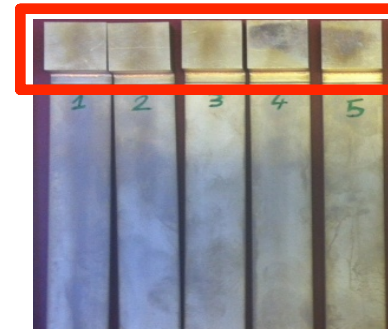




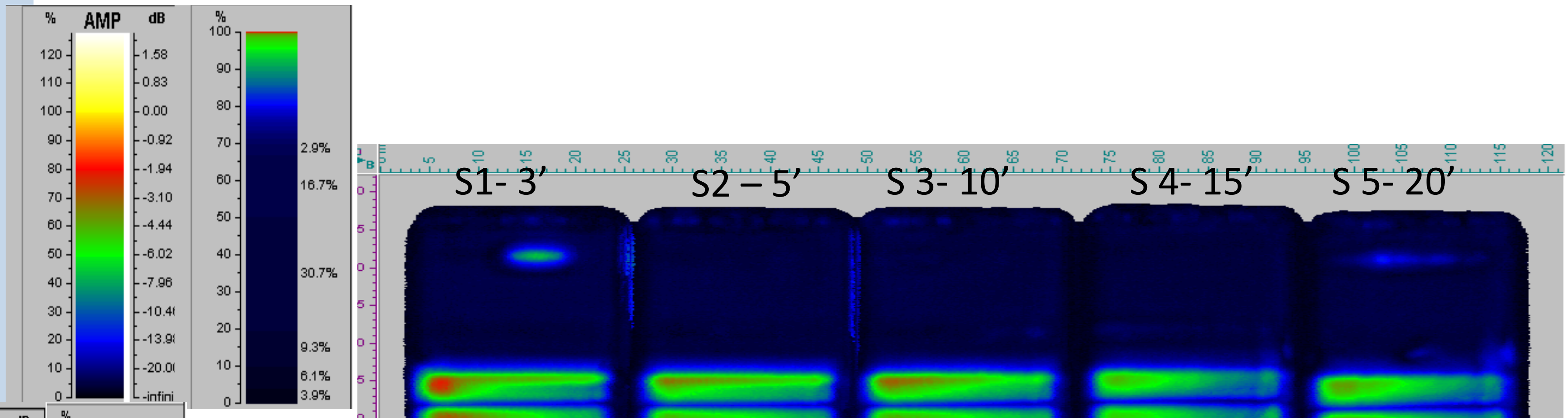
10 Brazing samples

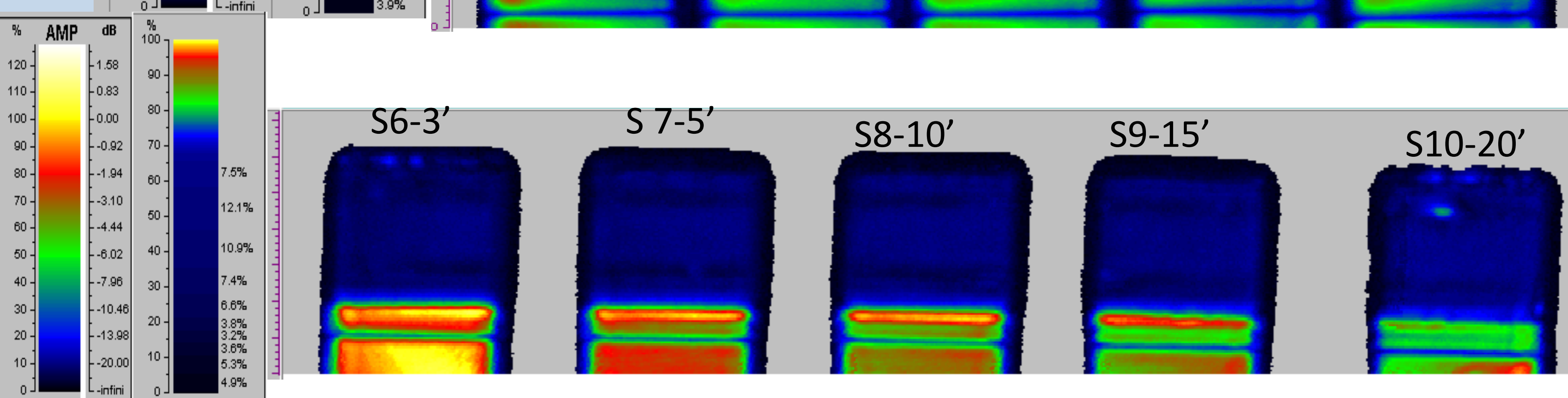
Brazing test II

Ultrasonic examination of the brazing joint after chemical etching

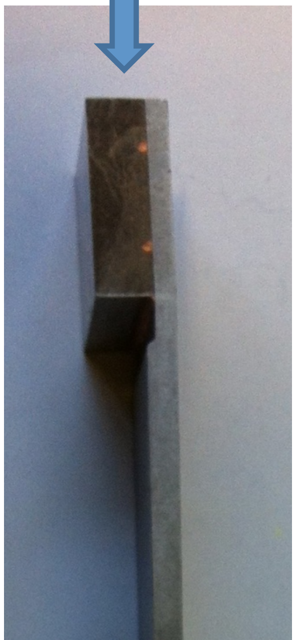


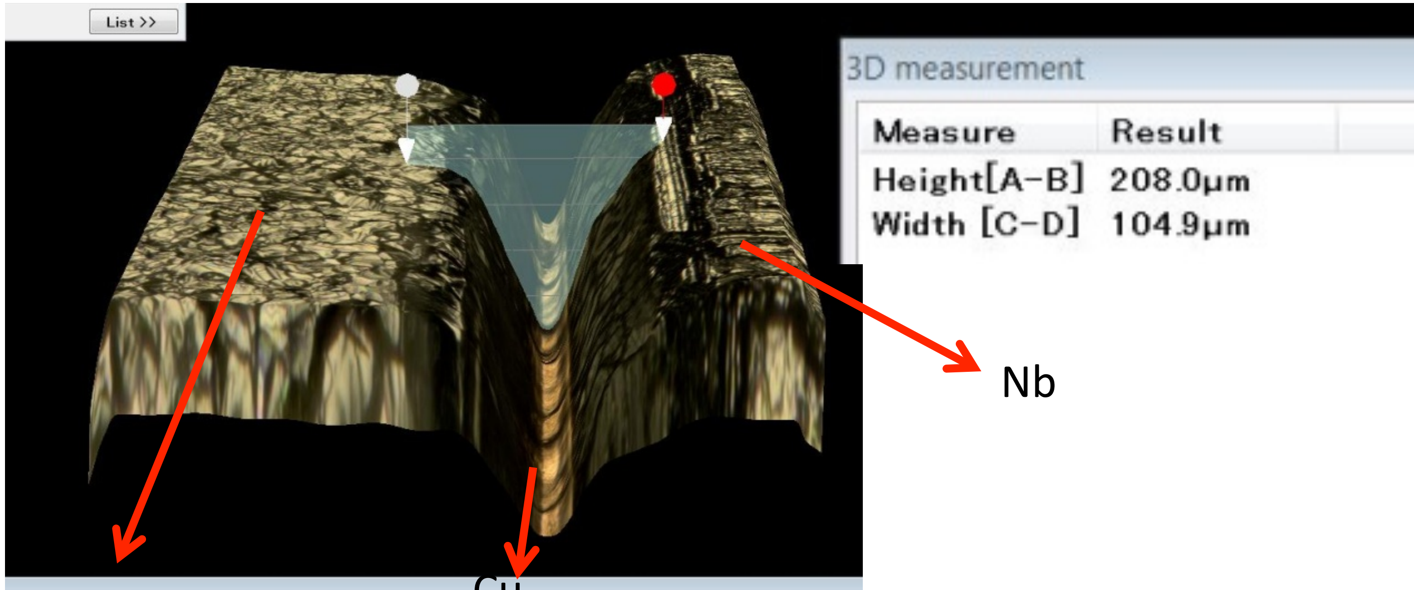
Samples 1-5 →Bath refrigerated: Starting T°: 11.9°C, Final T° : 14.6 °C
Samples 6-10 →Bath non refrigerated: Starting T°: 21°C, Final T° : 25.4 °C





Brazing test II

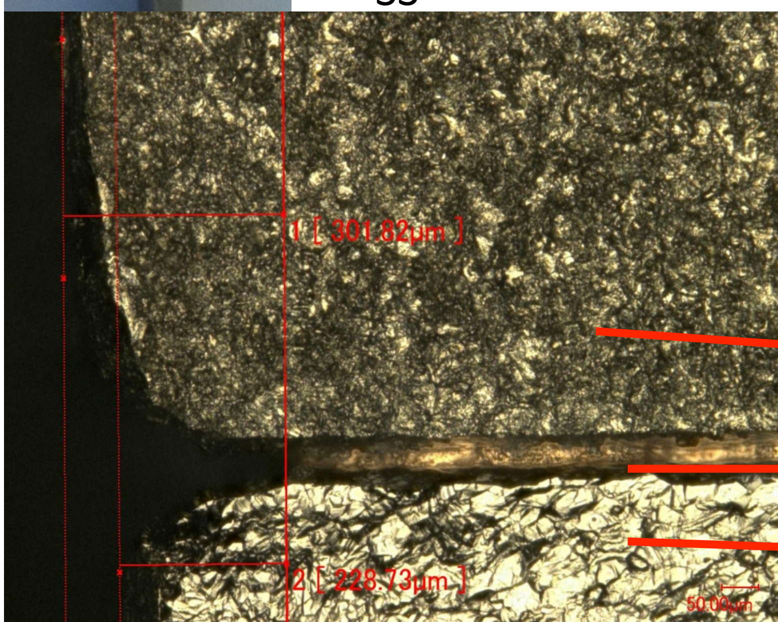




Nb

Cu

SS



SS

Cu

Nb

<u>Firsts results:</u>

The bath removed ~ 300 µm of Cu

The bath attacks more the Nb than the SS

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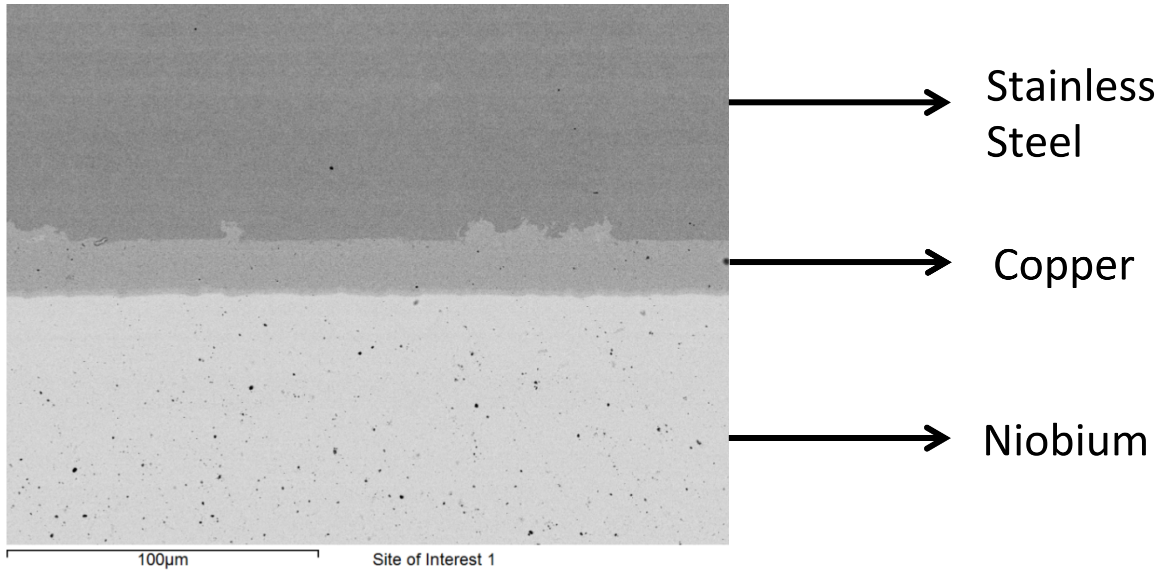
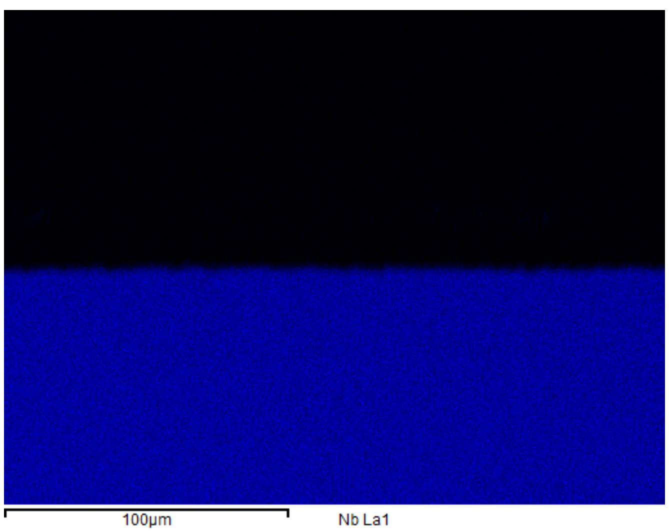
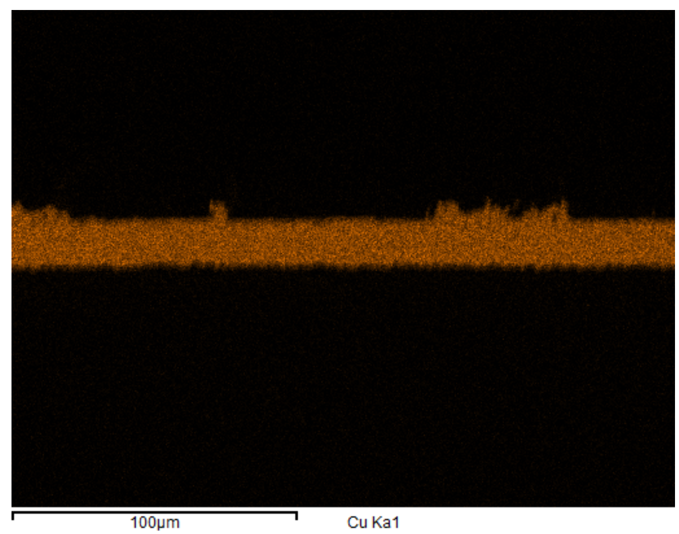
Brazing test II

EDS analyses







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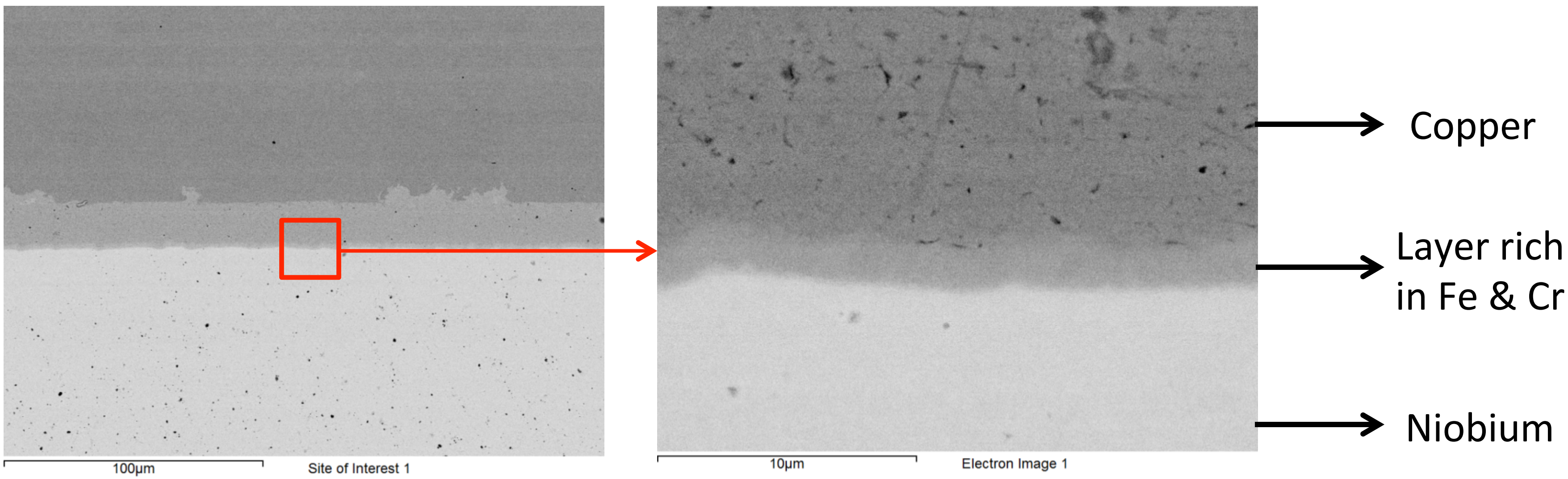
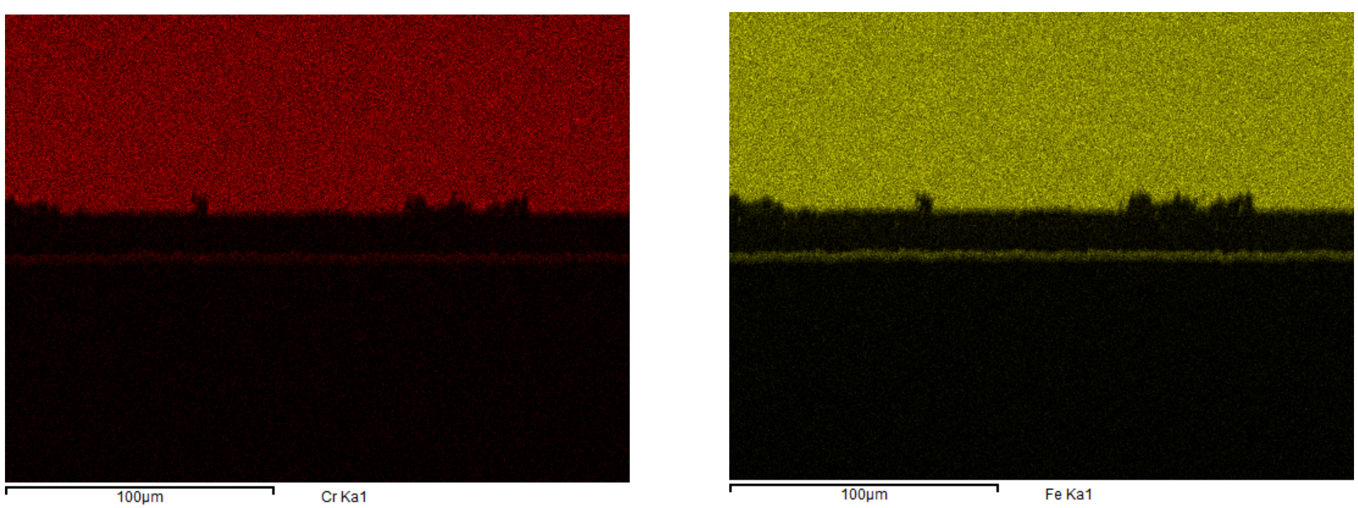
Brazing test II

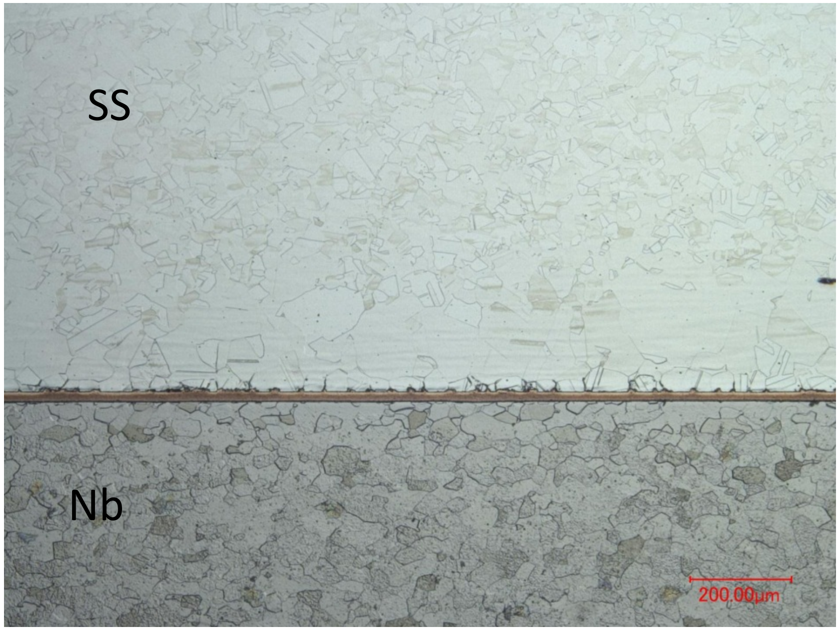
EDS analyses

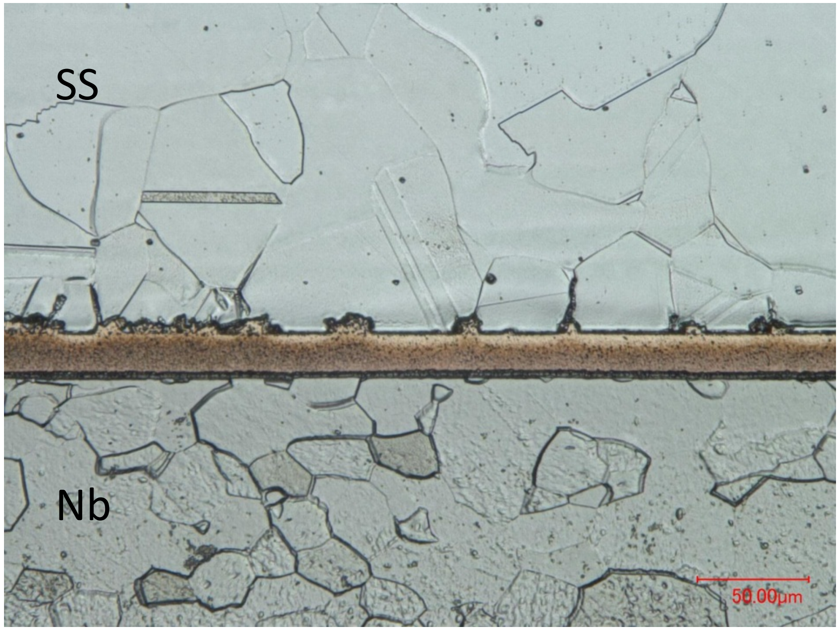




Brazing test II

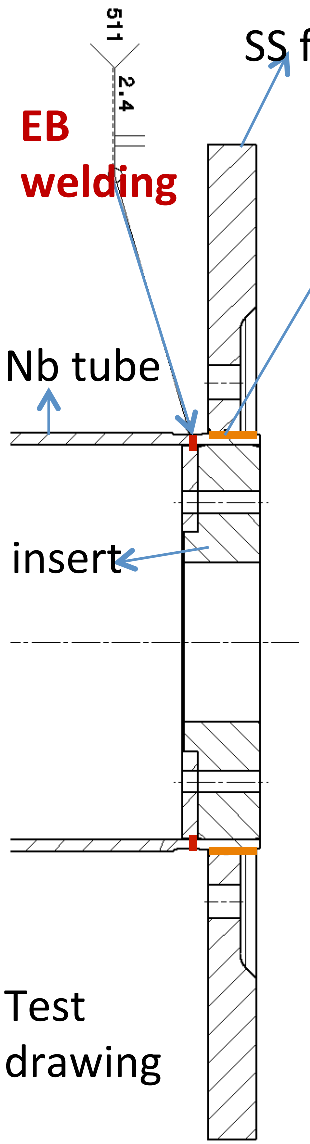
Metallographic examination



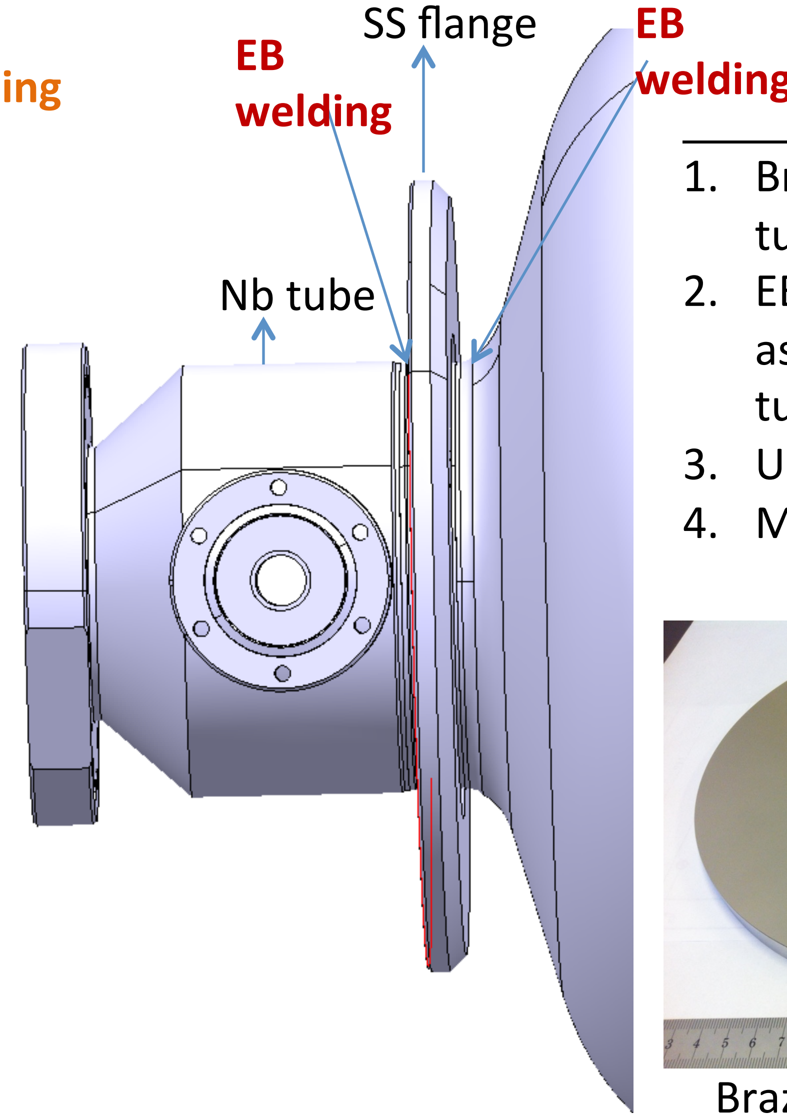


Brazing test III

Does the EB weld affect the brazing joint?

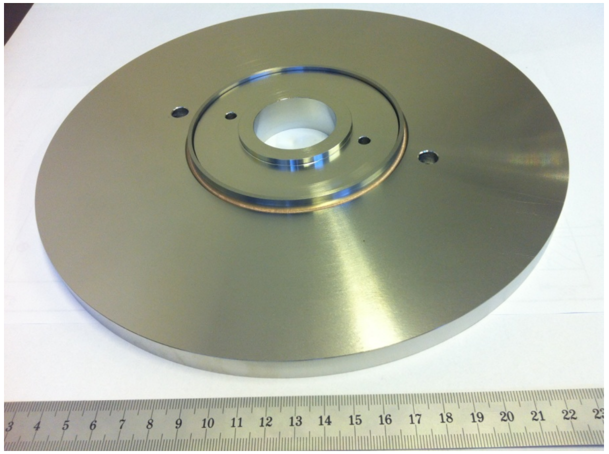


Test drawing



STEPS:

1. Brazing SS Flange to Nb tube
2. EB welding brazing assembly to the cut-off tube
3. Ultrasonic examination
4. Macroscopic examination



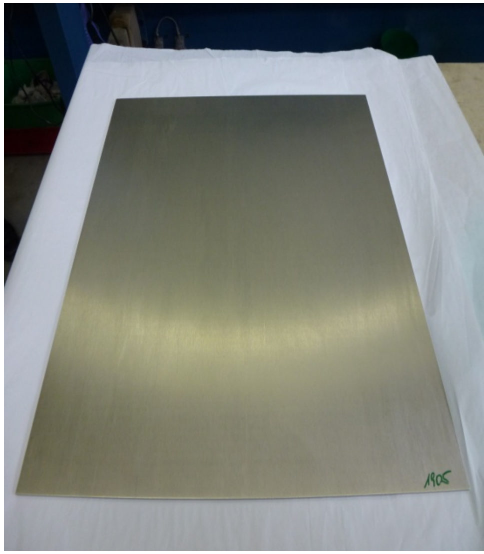
Brazing assembly

Niobium procurement

Niobium material :

Plansee (Austria)- Total weight: 556 kg

- 520 x 520 x 3.6 mm RRR 300 sheets (60)
- 180 x 240 x 3.2 mm RRR 300 sheets (12)
- 700 x 1000 x 3 mm RRR 40 sheet (1)
- Seamless tubes 3.2 mm thick RRR 300



Ningxia (China)- Total weight: 49 kg

- 520 x 520 x 3.6 mm RRR 300 sheets (4)
- 350x 350 x 3.6 mm RRR 300 sheets (4)

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Niobium material

Comparison between Plansee and Ningxia Niobium

	CERN spec	Plansee	Ningxia
RRR value	> 300 (@4.5 K)	259 – 330 (@10K)	280 (@9.5K)
Grain size (ASTM)	>6 (Local grains size 4 are acceptable)	3 - 6	6.5 – 9.5
Yield strength min/max	>50/100 N/mm^2	64 - 75 N/mm^2	115 – 129 N/mm^2
Tensile strength	>140 N/mm^2	165 - 180 N/mm^2	205 - 213 N/mm^2
Elongation	>30%	46% – 60%	43% – 50 %
Vickers hardness HV_{10}	≤60	43 - 50	62.4 - 66
Roughness (Rt) on the RF side	<15µm	5.2 – 19.8 µm	10.08 – 22.70 µm

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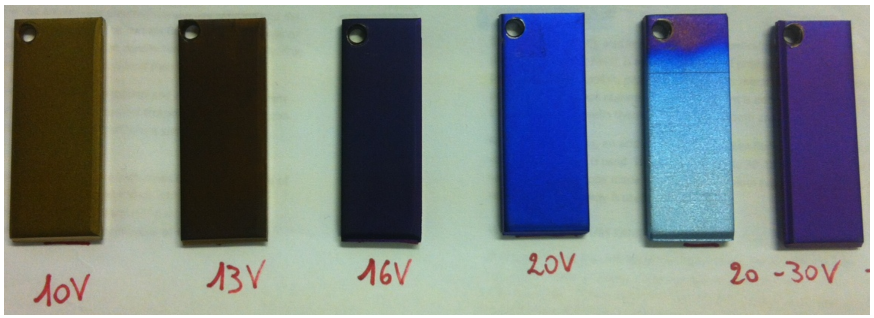
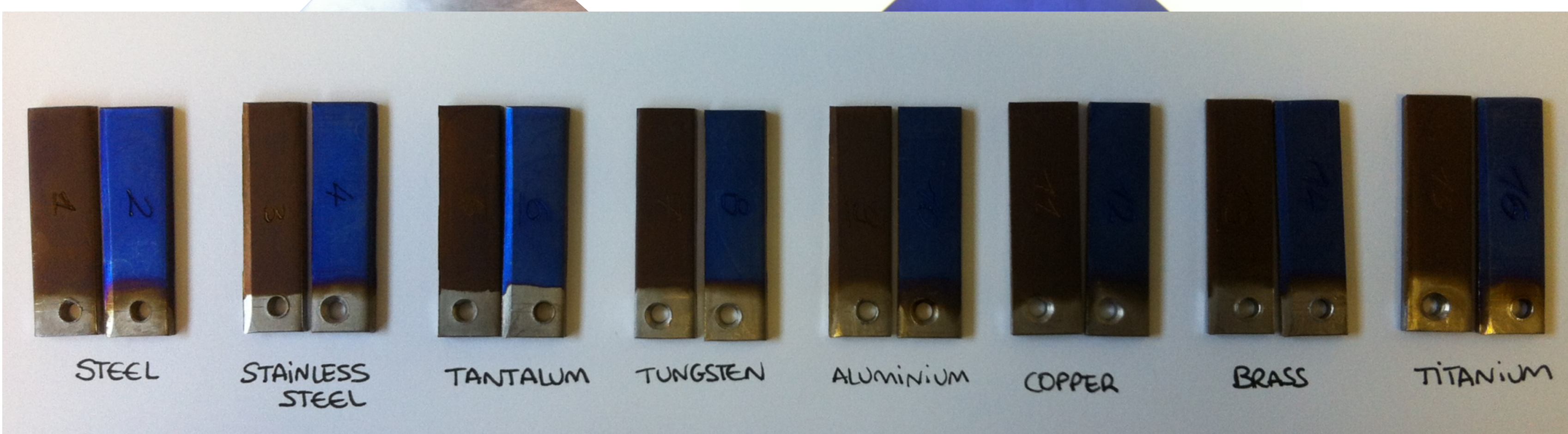
Anodizing

Checking the suitability of anodizing to detect defects and inclusions of foreign material



Anodizing of Nb samples at different voltages



Niobium before anodizing

Niobium after anodizing

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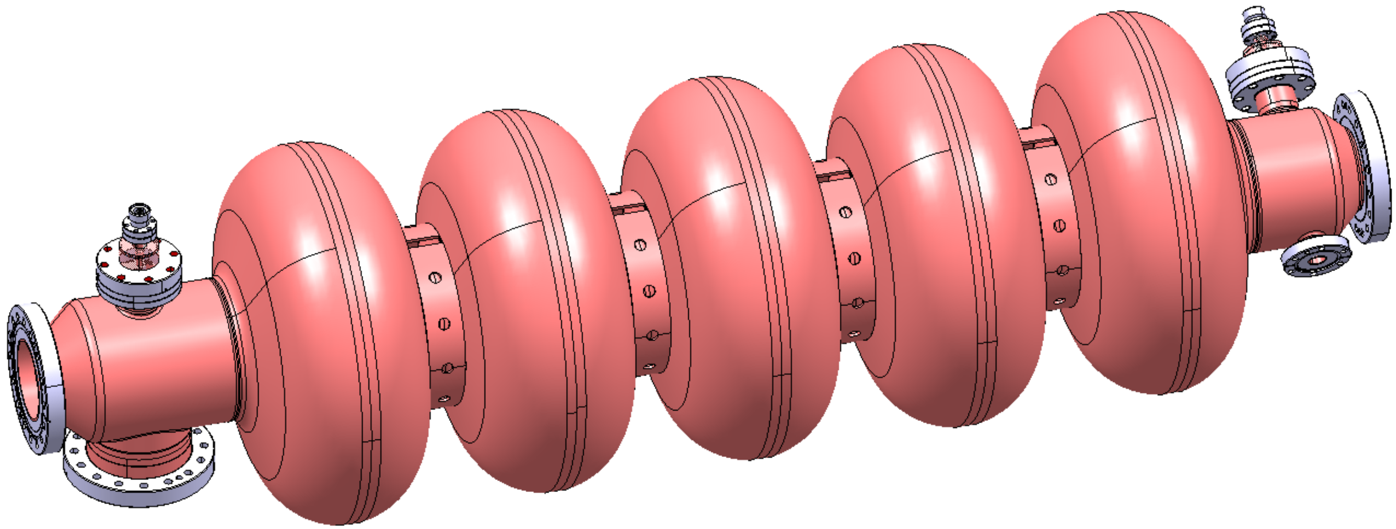
Copper cavity

Two copper cavities(mock-up) are under fabrication

-To learn during the fabrication process

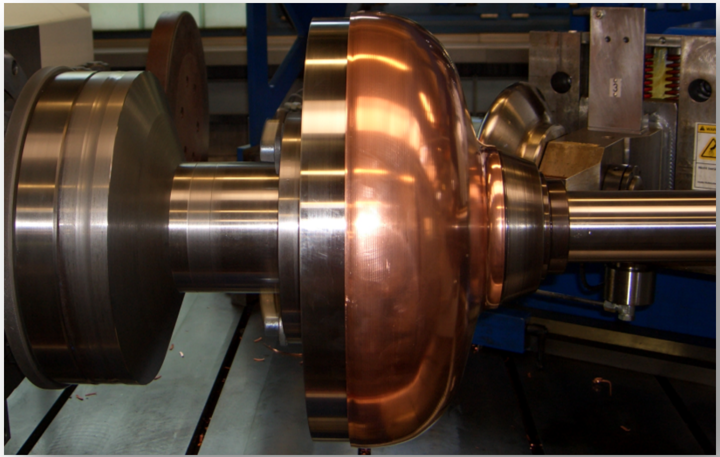
- To carry out RF measurements of the dumb-bells and complete cavity with the HOM.

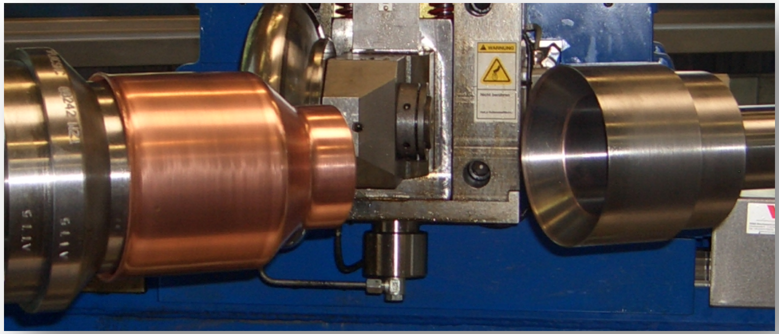
-For surface treatment purposes



Shaping of half-cells & cut-off tubes

Fabrication of half-cells and extremities by spinning.
Subcontracted to Heggli





Dimensional control by CMM

The average shape accuracy achieved is ± 0.150 mm

The best half cell: shape accuracy ± 0.119 mm

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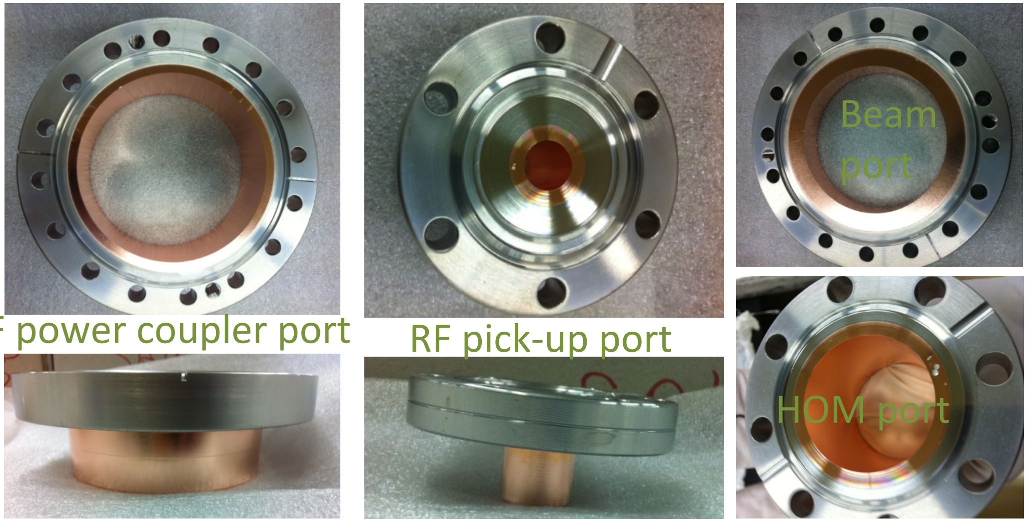
Extremities

1. Nozzle necks made by extrusion.

2. Nozzles - Cu tubes and SS flanges joined by brazing



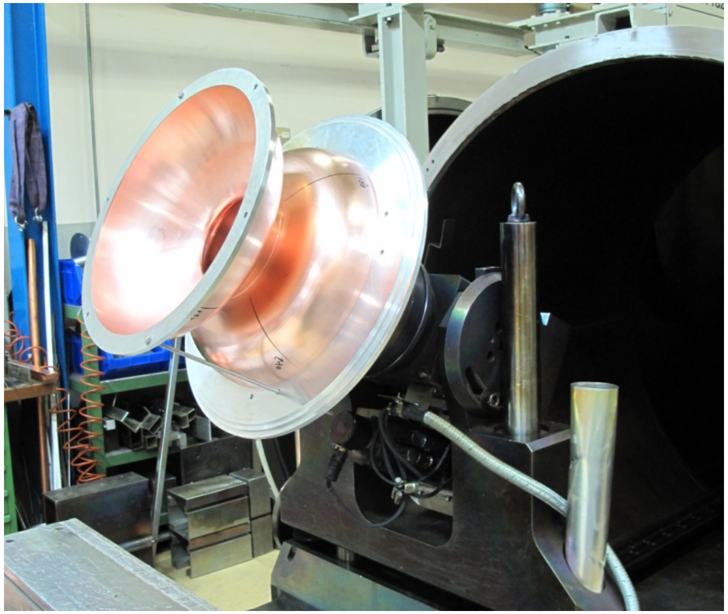
3. EB welding of nozzles to the cut-off tube

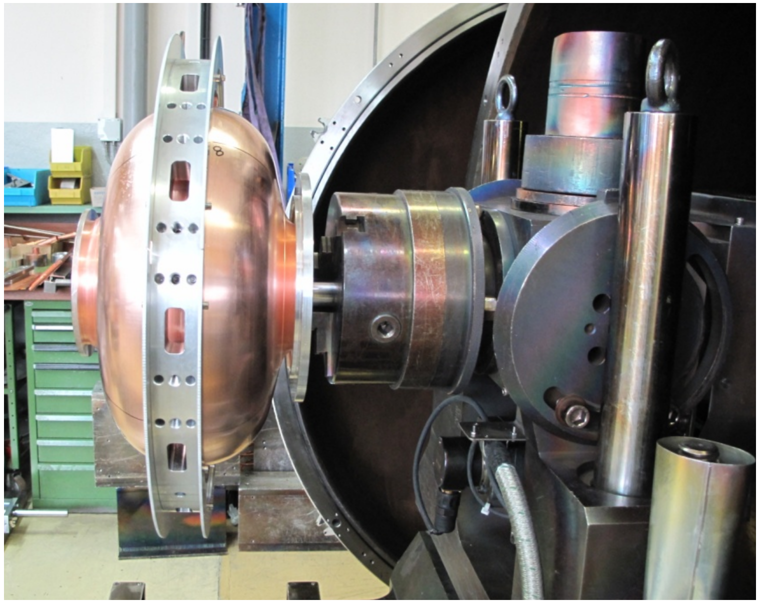
4. EB welding of half-cell to the cut-off tube

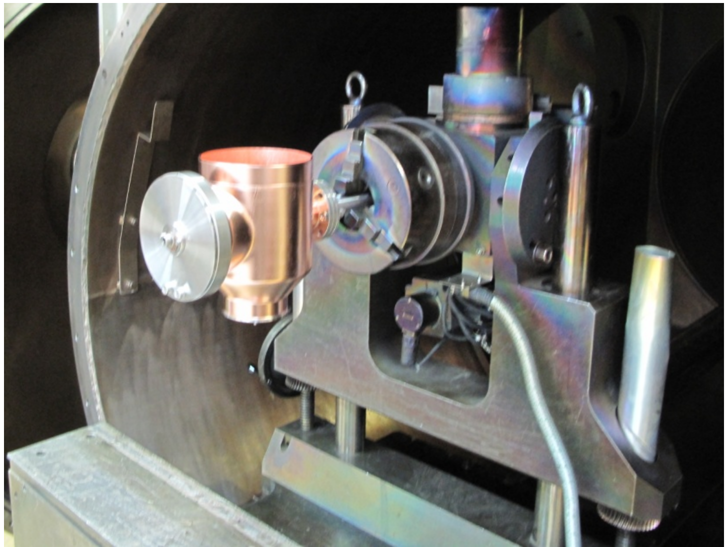
CERN

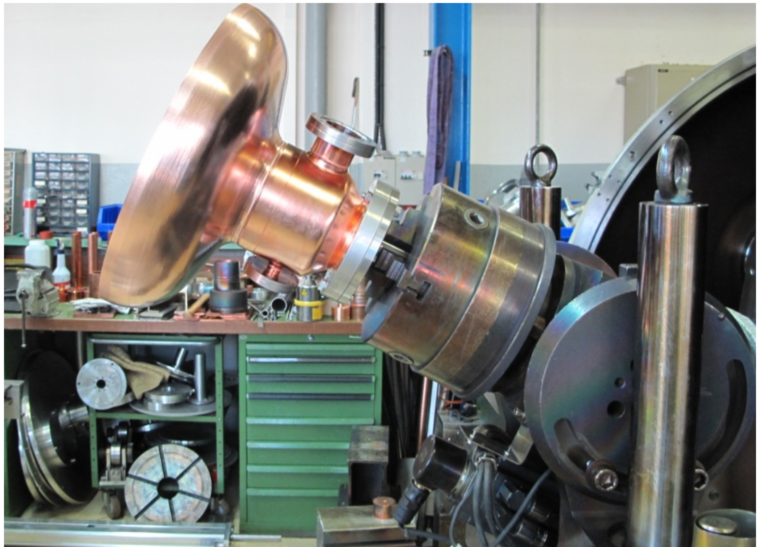
Welding tests

EB welding tests to study the welding parameters and the shrinkage.









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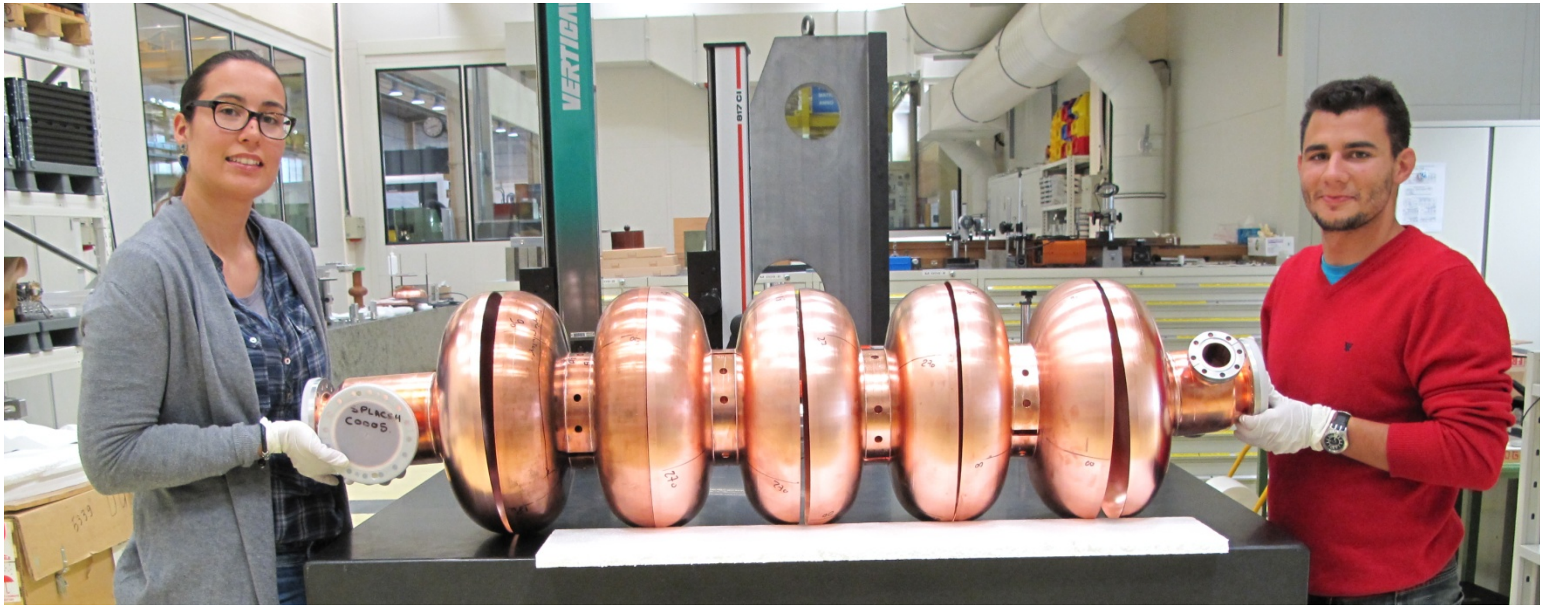
Final assembly



Complete copper cavity ready for final assembly

Cold gas dynamic spray

Solid-state coating deposition method

a supersonic gas (N2) jet that propel fine
coating powder particles (1-50 μm) at
very high velocities (500-1200 m/s).

Advantages:

- powders are not melted
- almost absence of oxidation during the process
- allows materials to be constructed layer upon layer

Nb sheet (t=1 mm ,3 mm) under cold spraying

Test performed (after heat treatment):

Tensile test (room T°)

Tensile test (4.2 K)

Metallurgical characterization

Microhardness test

Adhesion strength test

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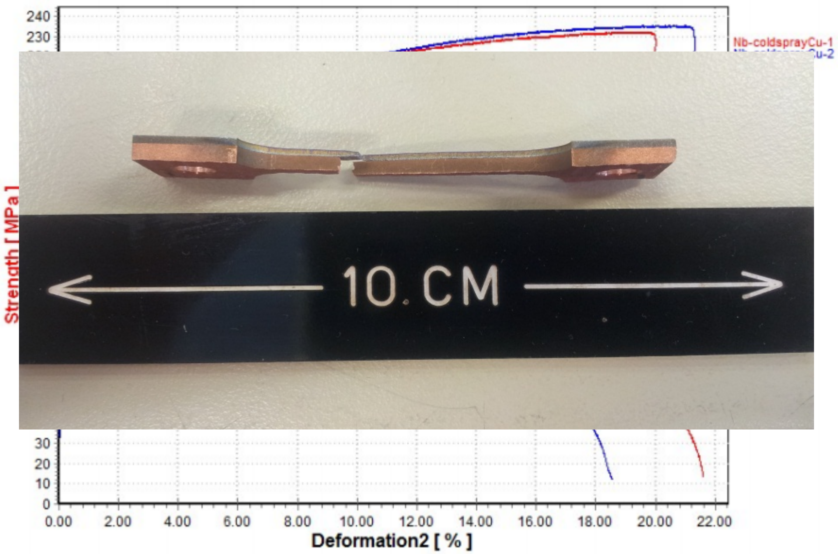
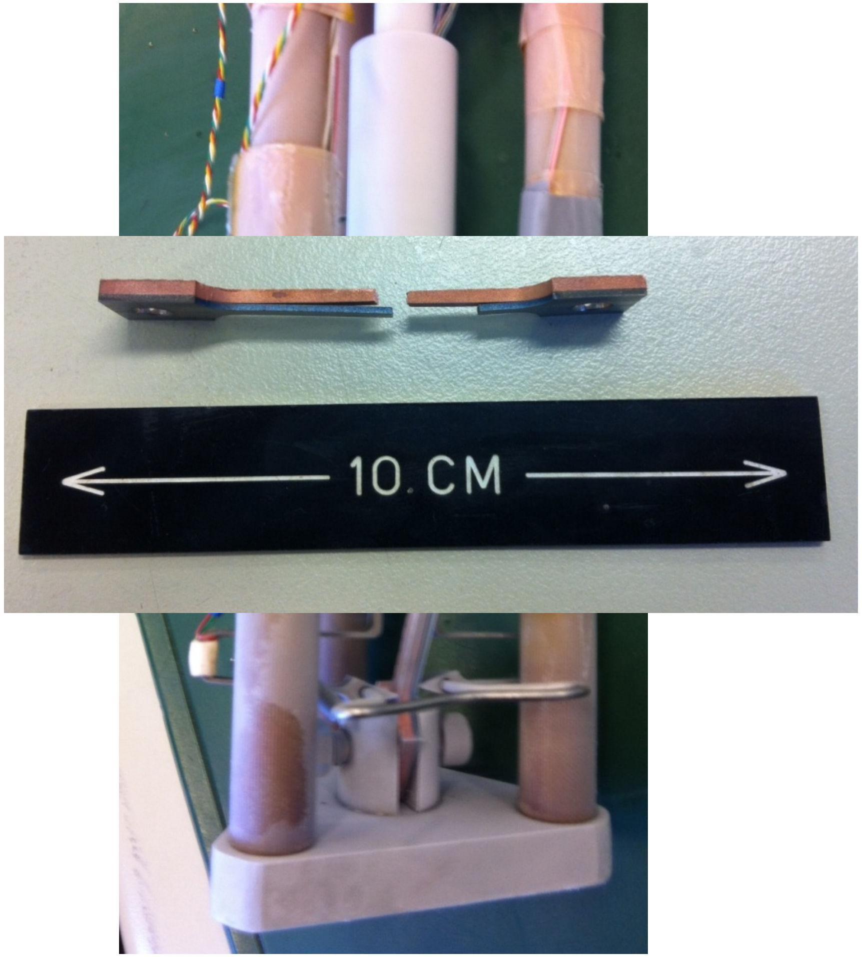
Cold gas dynamic spray

Tensile test (room T°)

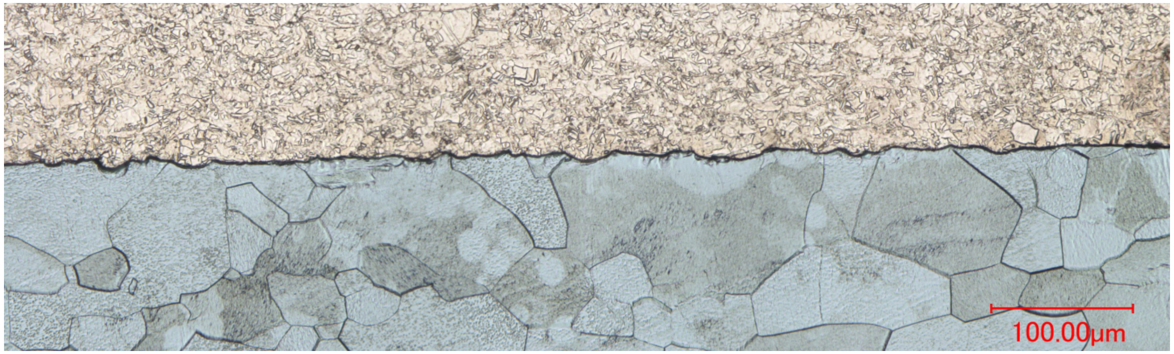


Tensile test (@4.2 K)



Cold gas dynamic spray

Metallurgical characterization



Microhardness test in the coating ($HV_{0.3}$)

Before HT	After HT
148	69.9
149	70.5
152	69.3
150	68.2
146	66.7

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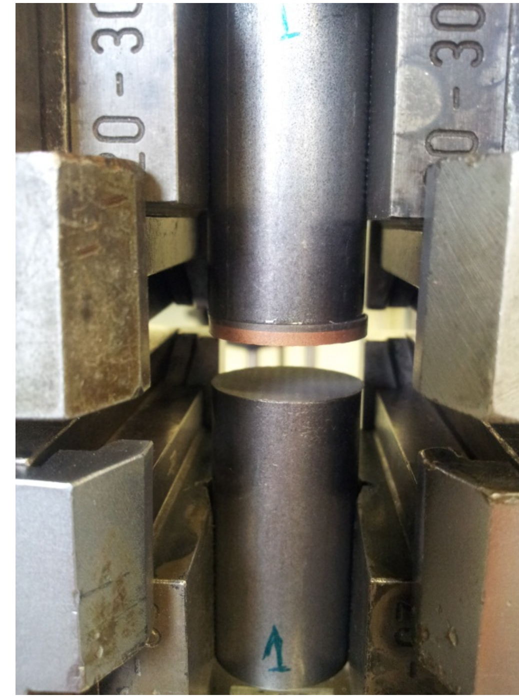
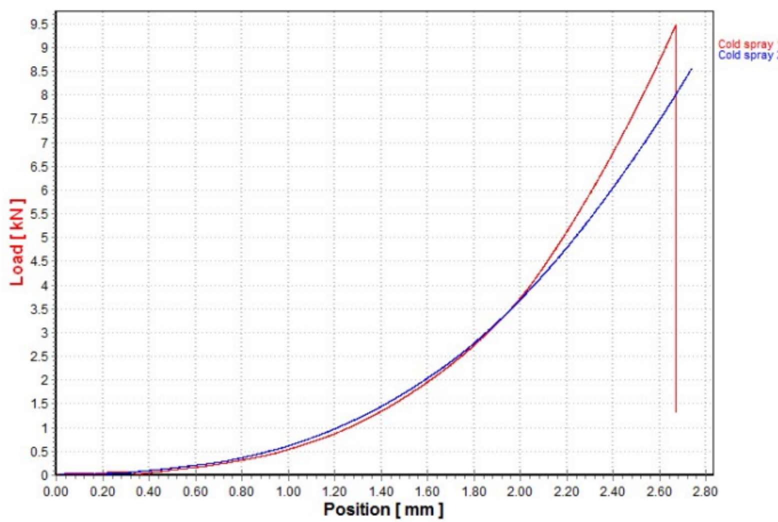
Cold gas dynamic spray

Adhesion strength test

- Sand blasting
- Araldite® 2011
- 24 h under uniaxial pressure



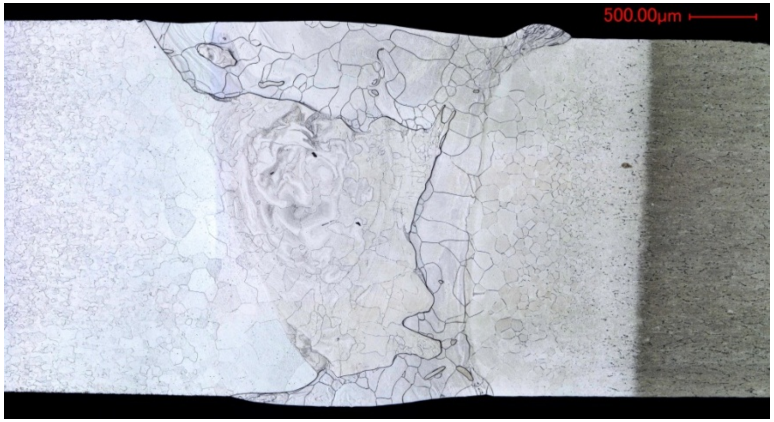


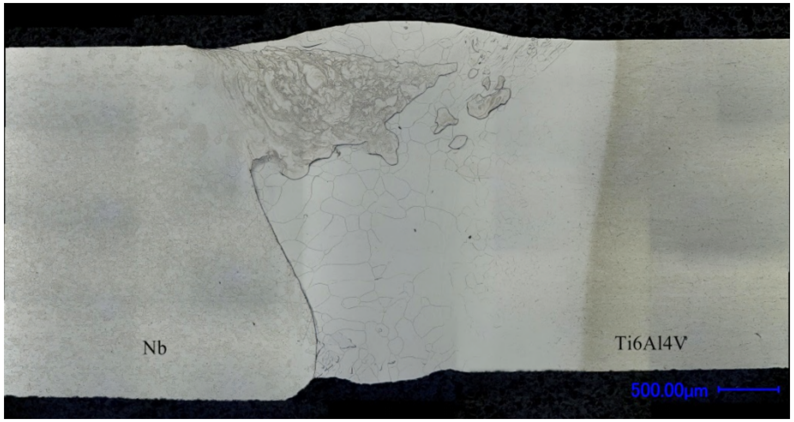
According to ASTM C633-01

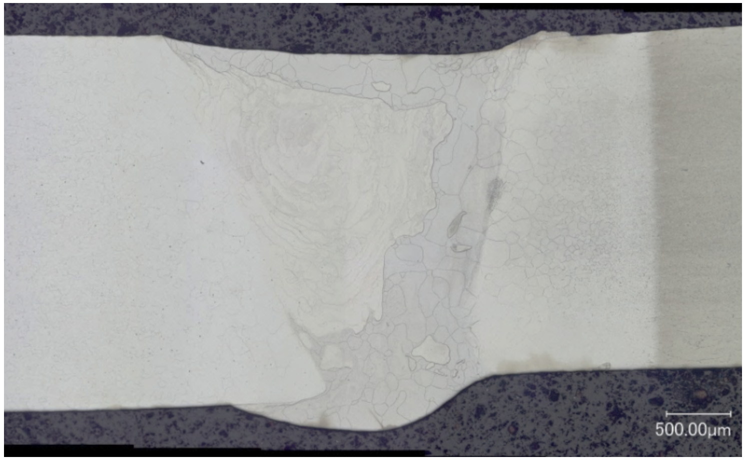
- Cohesive failure of Araldite at ~ 18 MPa

Nb/Ti weld

EB welding tests with different parameters



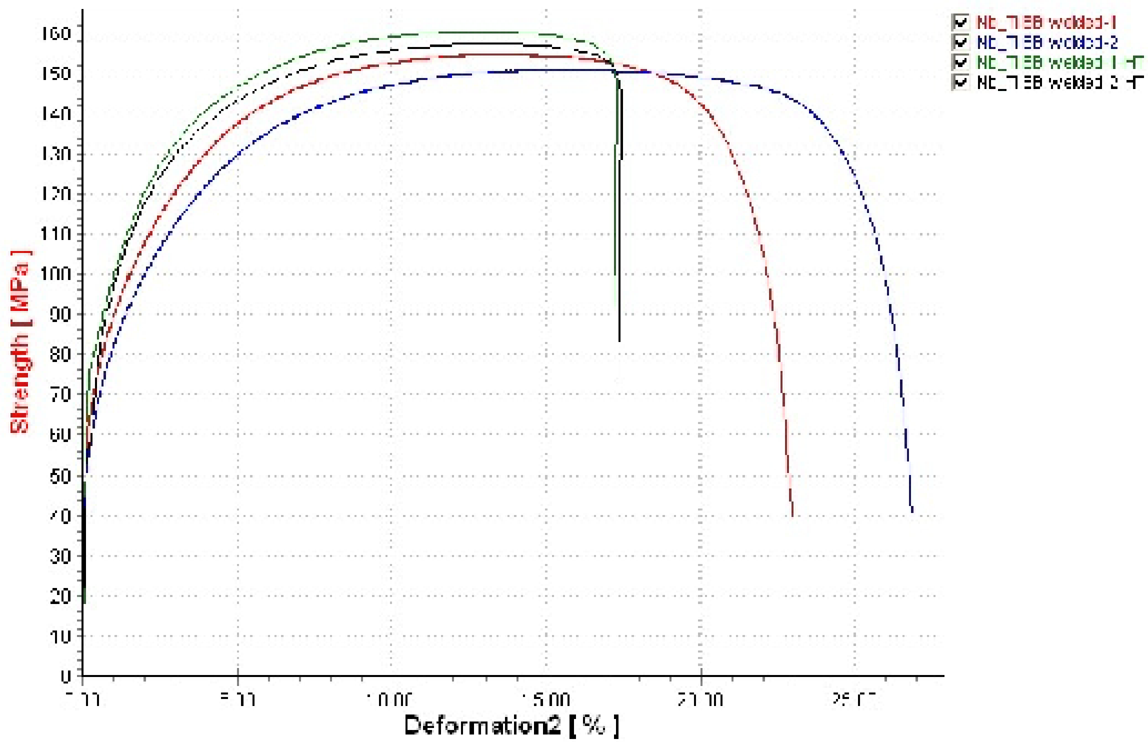


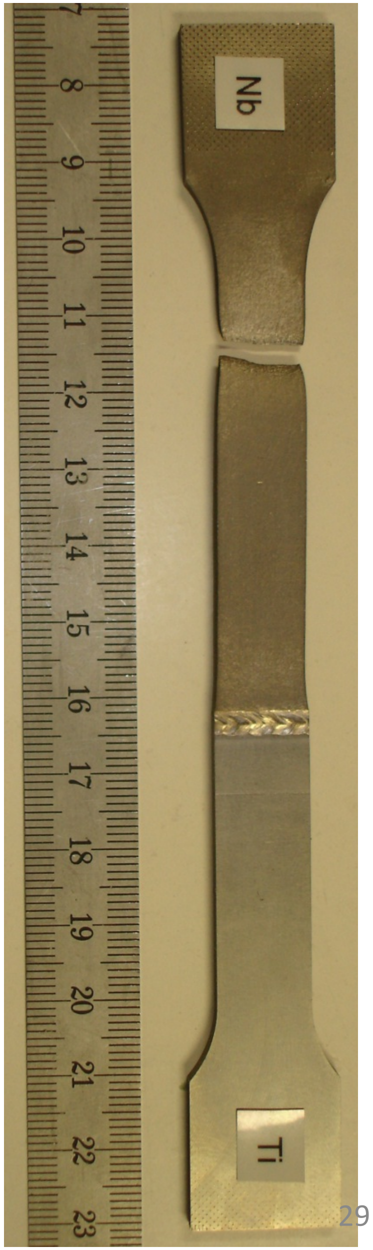


Nb/Ti weld

NDT

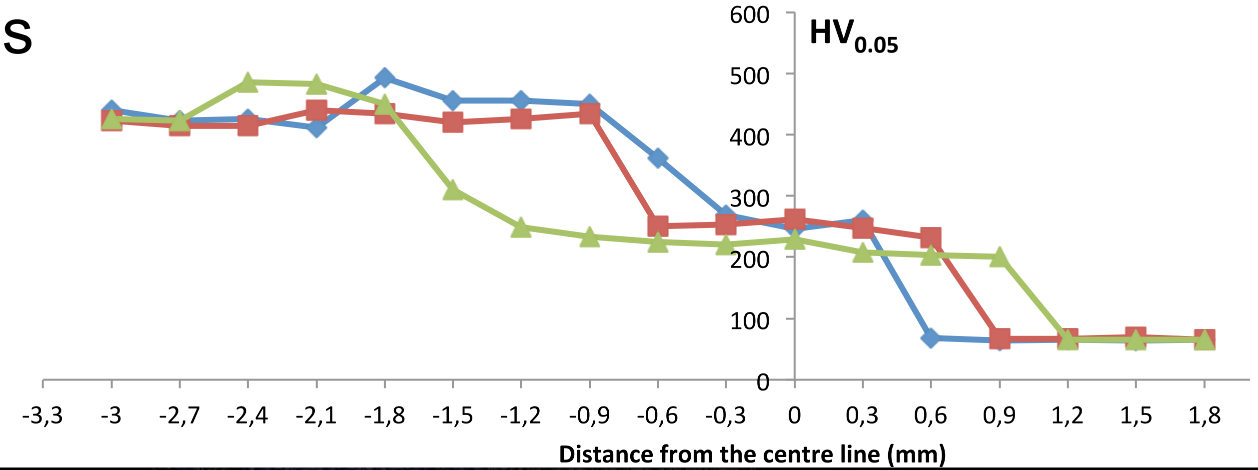
Tensile tests

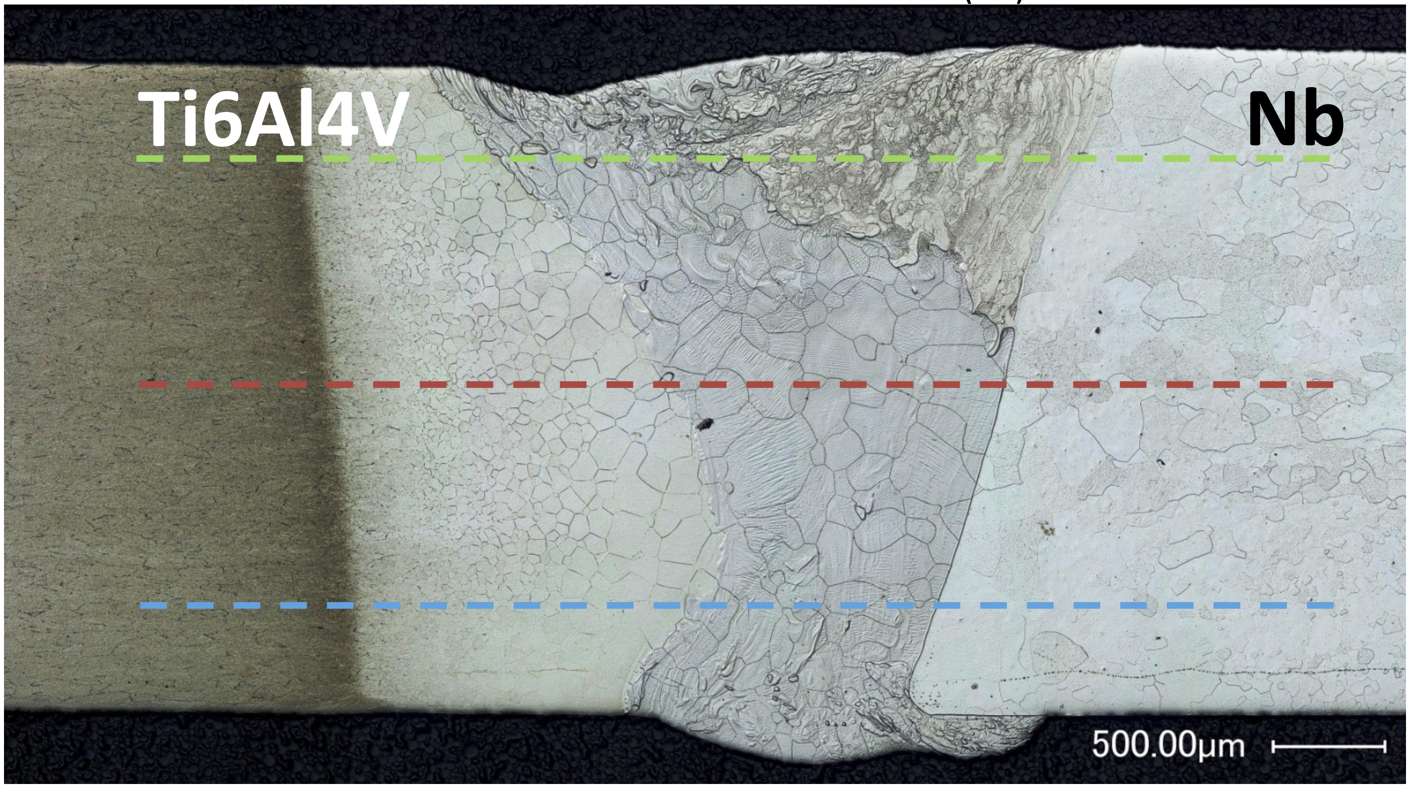




Nb/Ti weld

Hardness

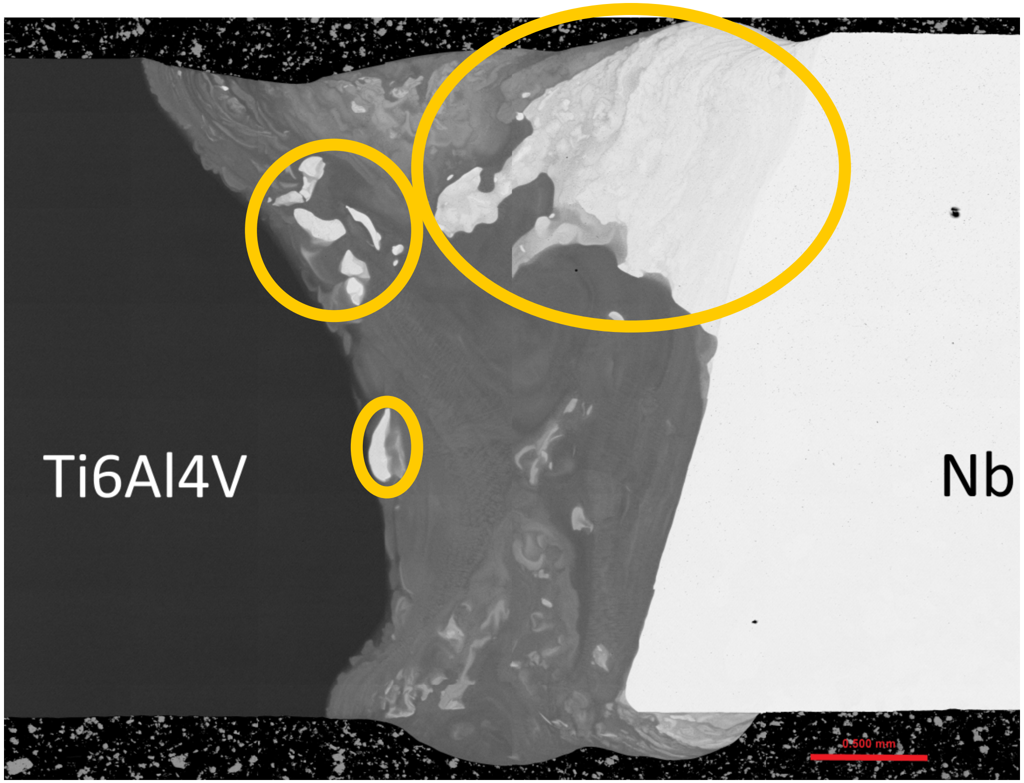




Nb/Ti weld

Macroanalysis

- AsB detector



- Heterogeneities

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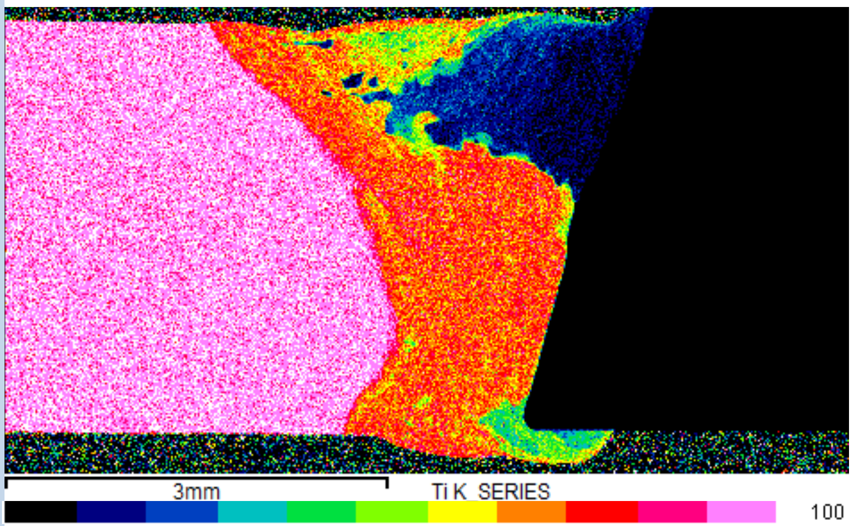
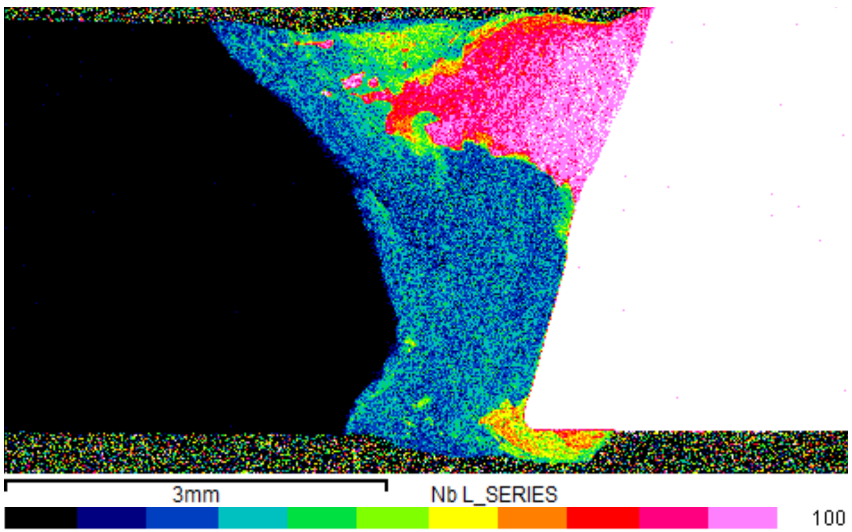
Nb/Ti weld

EDS microanalysis
(quantitative composition maps):

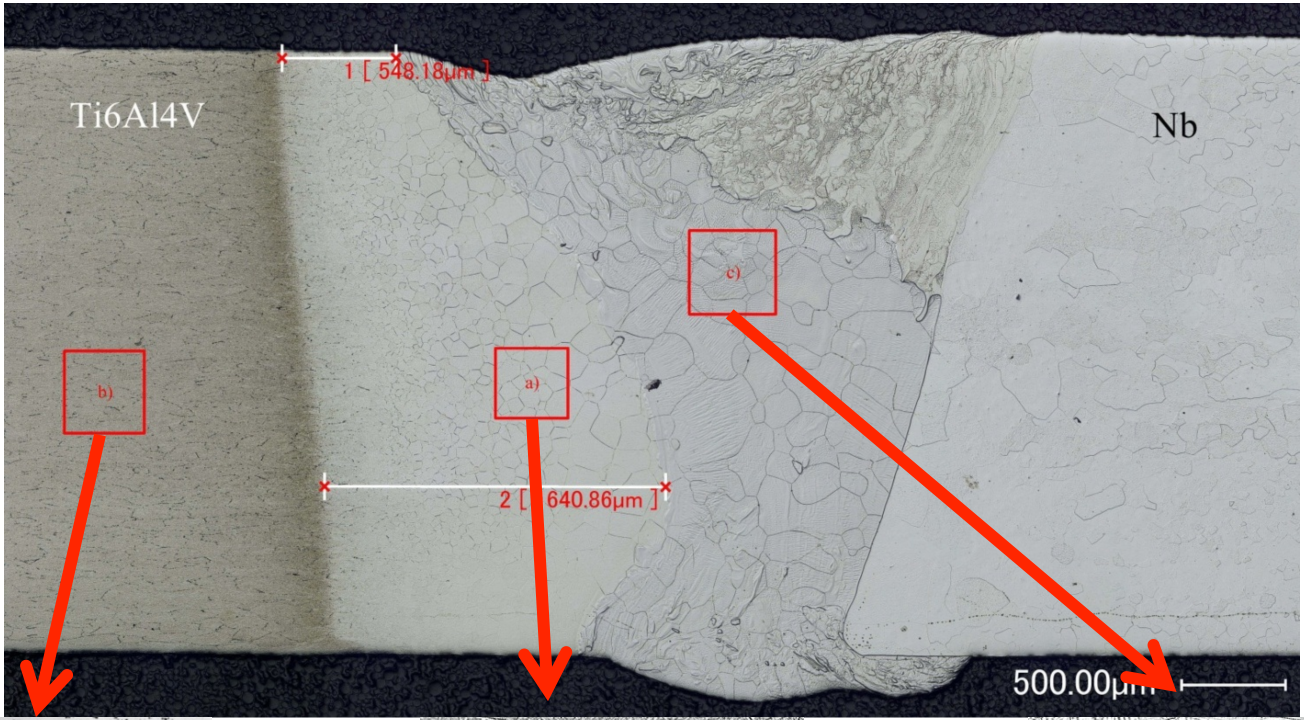


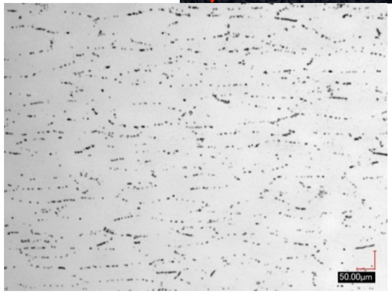


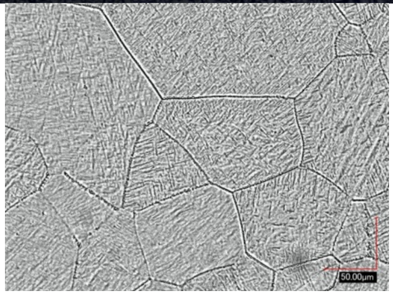
- Rich in titanium
- Heterogeneities rich in Nb

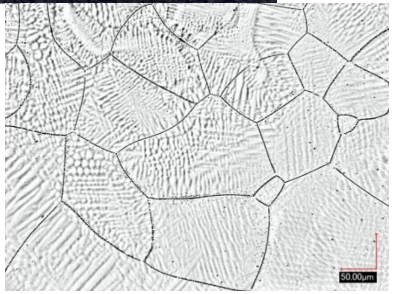
Nb/Ti weld

Microstructure









Conclusions

- Two copper cavities under fabrication.
- We learn from the fabrication of copper cavities.
- Many fabrication steps will be retained for the fabrication of the niobium cavity.
- Assembly tooling of copper has been validated and it will be used for the niobium as well.
- One copper mono-cell β=0.65 under fabrication.
- Four niobium cavities β=1 have been subcontracted. First cavity will be delivered mid 2012 and last cavity end 2012.
- One niobium cavity β=1 under fabrication at CERN.

EUROPEAN SPALLATION SOURCE

Overview

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Thanks for your attention!!