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I.FAST task 7.5: CompactLight Prototype Accelerating Structure

3rd I.FAST Annual Meeting - 18/04/24

G. D'Aura on behalf of Task 7.5 Collaboration

iFAST

CompactLight Prototype Accelerating Structures

Objective:

Build and test, at low and high RF power, two prototypes of the X-band (12 GHz) accelerating structure designed for the CompactLight (XLS) project, a new class of linac-driven FEL facility.

Deliverables:

D7.5: Construction of the XLS accelerating structure pre-prototype.

Development of production process and RF tests of the pre-prototype, Dic. 2023

D7.6: Construction of the XLS accelerating structure full prototype.

Production process analysis and validation, RF tests of the full prototype, Apr. 2025

Task 7.5 partners:

Elettra Sincrotrone Trieste

CERN

INFN Istituto Nazionale di Fisica Nucleare

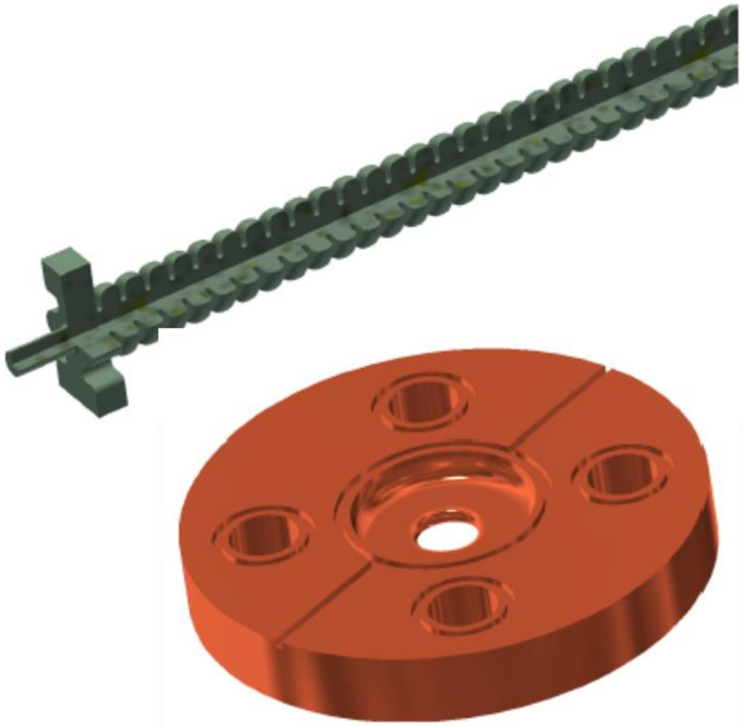
VDL

COMEB

TMD

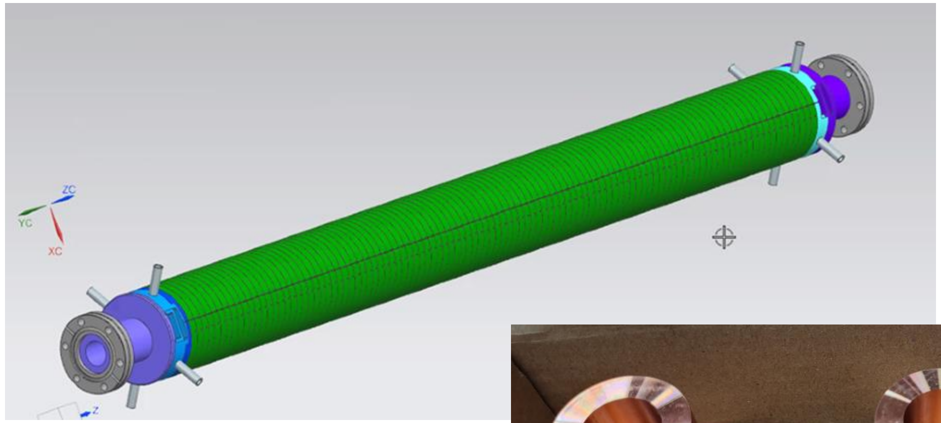
iFAST

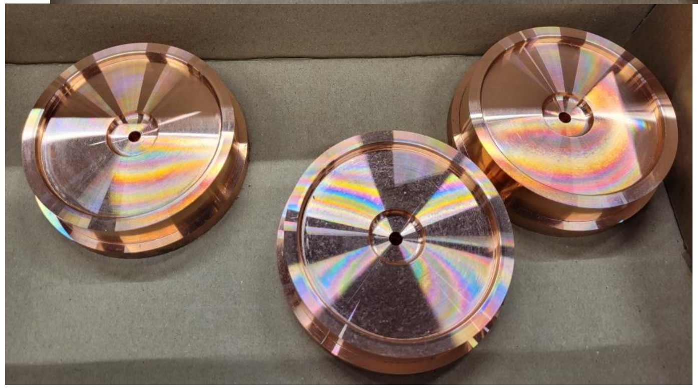
Main parameters of the CompactLight Accel. Struct.		
Parameter	**Units**	**Value**
Frequency	GHz	11.994
Phase advance per cell	rad	2π/3
Average iris radius a	mm	3.5
Iris radius a	mm	4.3-2.7
Iris thickness t	mm	2.0-2.24
Number of cells per structure	No	109
Accelerating cell length	mm	8.332
Structure length Ls	m	0.9
Group velocity vg /c	%	4.7-0.9
Filling time tf	ns	146
Peak klystron power (100 - 250 Hz)	MW	50
Peak klystron power (1000 Hz)	MW	10
RF pulse-length (250 Hz)	µs	1.5 (0.15)
Waveguide power attenuation	%	≈ 10
Unloaded SLED Q-factor	Qo	180000
External SLED Q-factor	Qe	23300
Shunt impedance R	MΩ/m	85-111
Effective shunt impedance Rs	MΩ/m	349
Peak modified Poynting vector	W/µm	3.4
Repetition rate	Hz	100 - 250 - 1000
SLED		ON - OFF - ON
Required klystron power	MW	44 - 44 - 9
Available klystron output power	MW	50 - 50 - 10
RF pulse-length	µs	1.5 - 0.15 - 1.5
Average accelerating gradient	MV/m	65 - 30 - 30
Energy gain per module	MeV	234 - 108 - 108



Courtesy M. Diomede

First prototype production at VDL



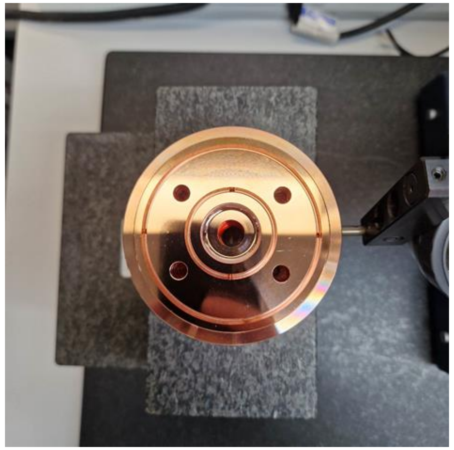


Courtesy M. van den Berg

Cell tests

The main purpose of the test:

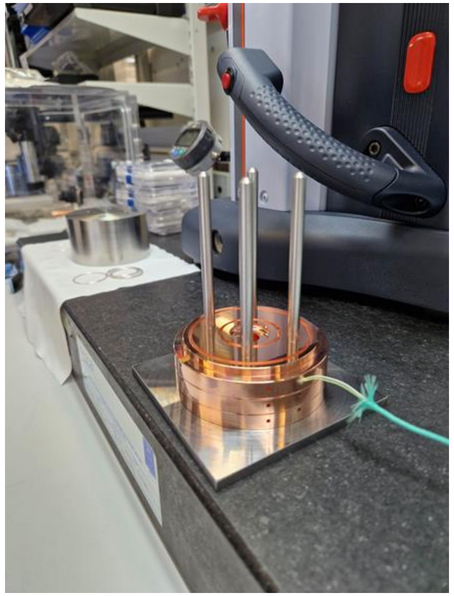
- Verify the shrink-fit assembly
- Validate the assembly method
- Check the correct positioning of the cells after the heat cycle
- Check the BFM to be used in the final prototype (material composition and ratio)

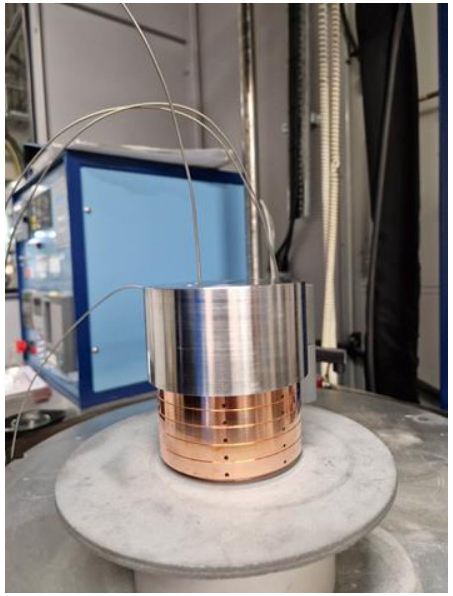


ZEISS CALYPSO
7.6.0403

Metrology crosscheck

CERN-METROLOGY
iFAST xband disk 049
EDMS N°: 2977953



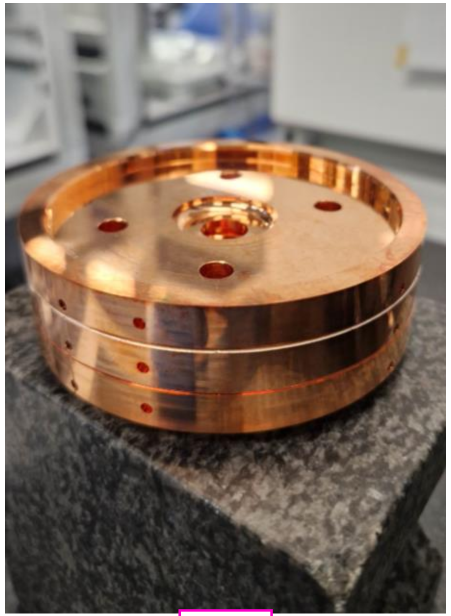


Brazing tests

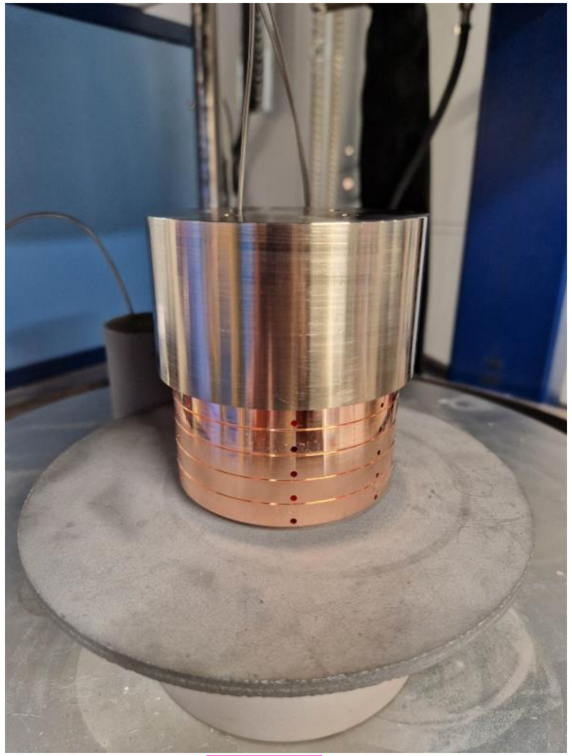
3 Trials have been carried out with different conditions:

- Machinability
- Interlocking alignment
- Brazing material
- Leak tightness
- Weight

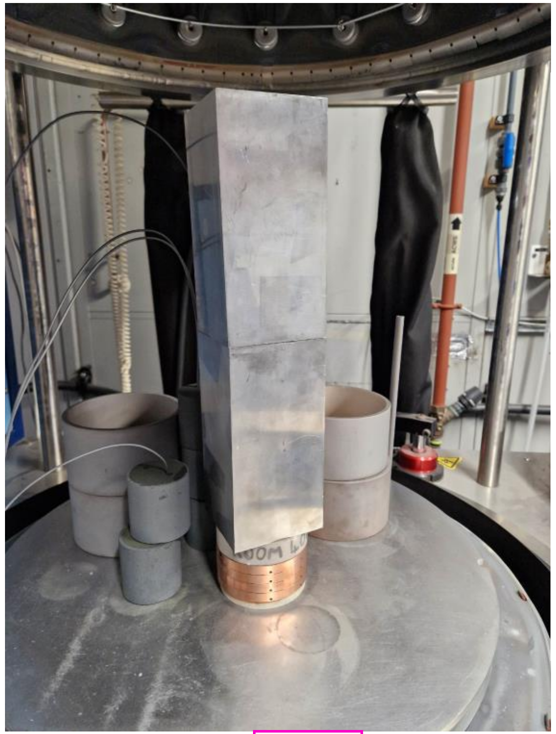
- The alignment and flatness of the structure were kept as expected after the cycle with the 40kg on top.



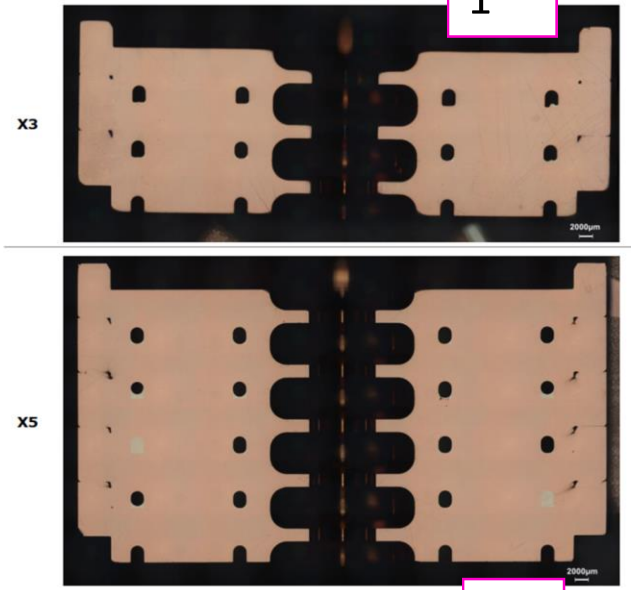
1st



2nd



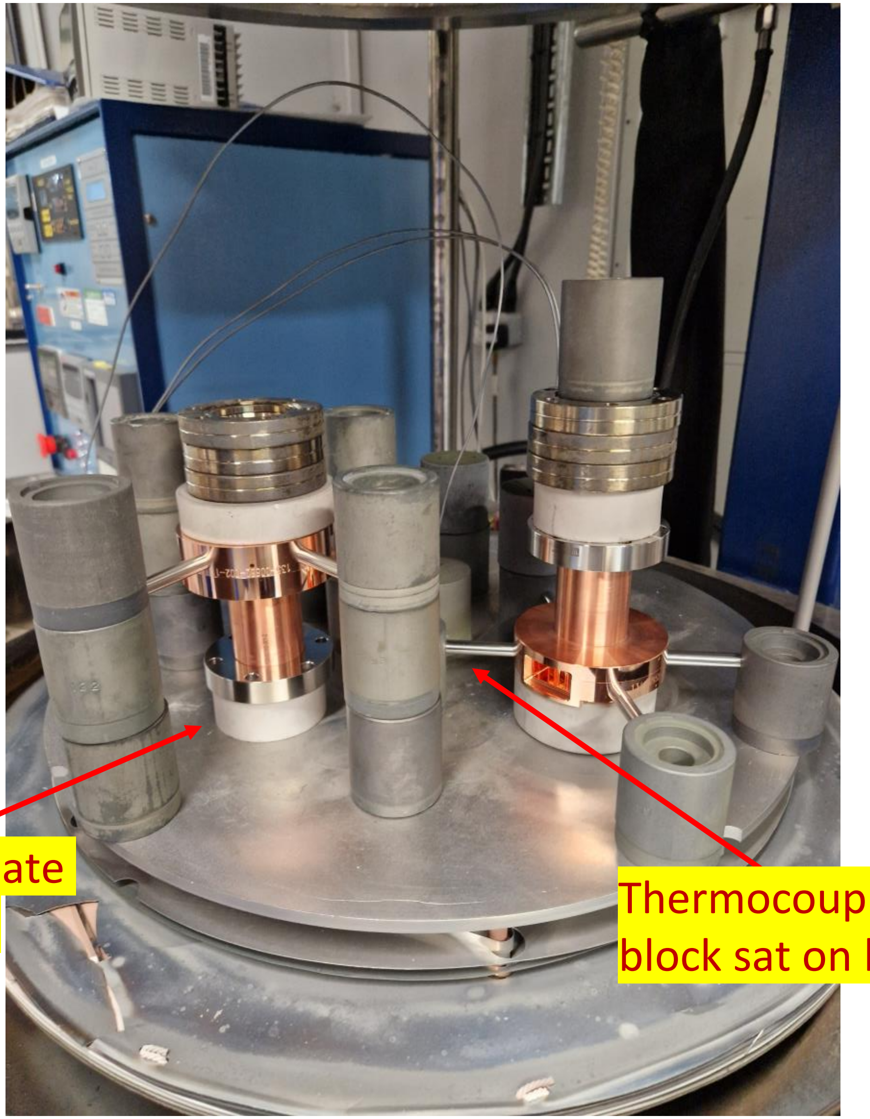
3rd

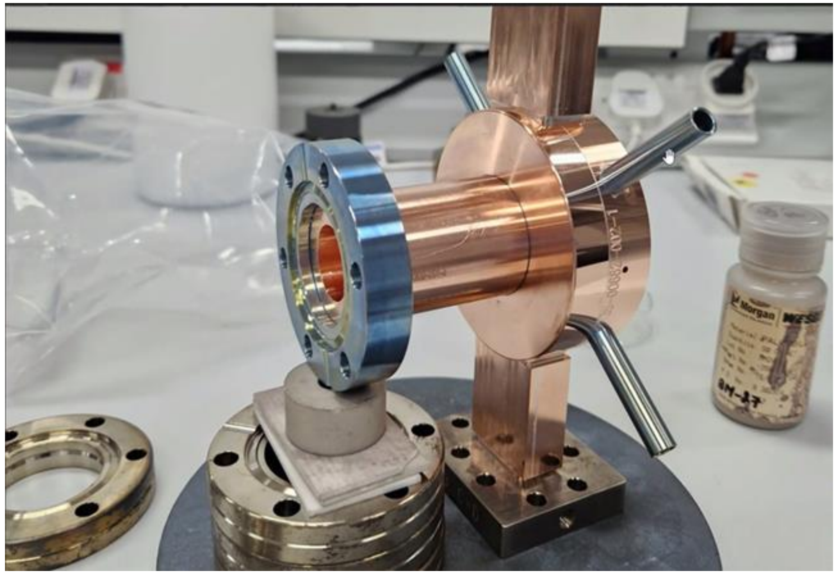


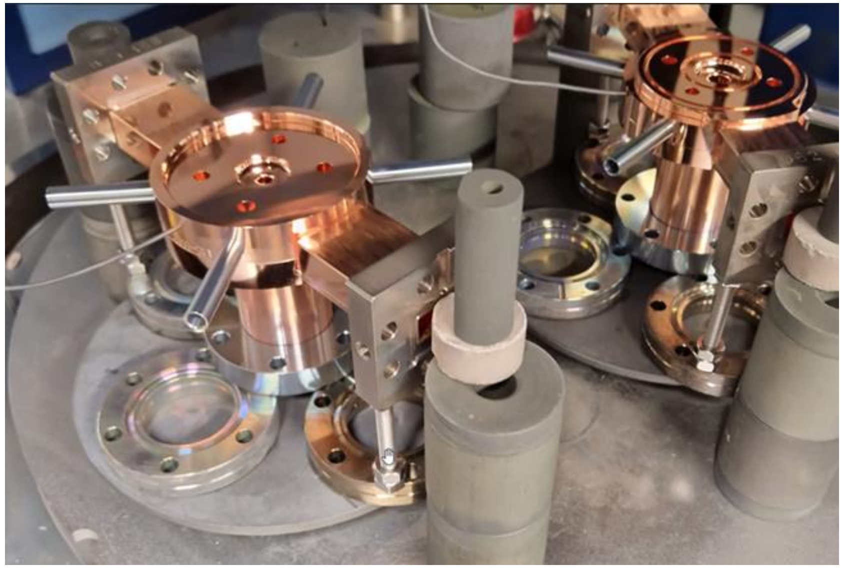
1st

2nd

End stack brazes

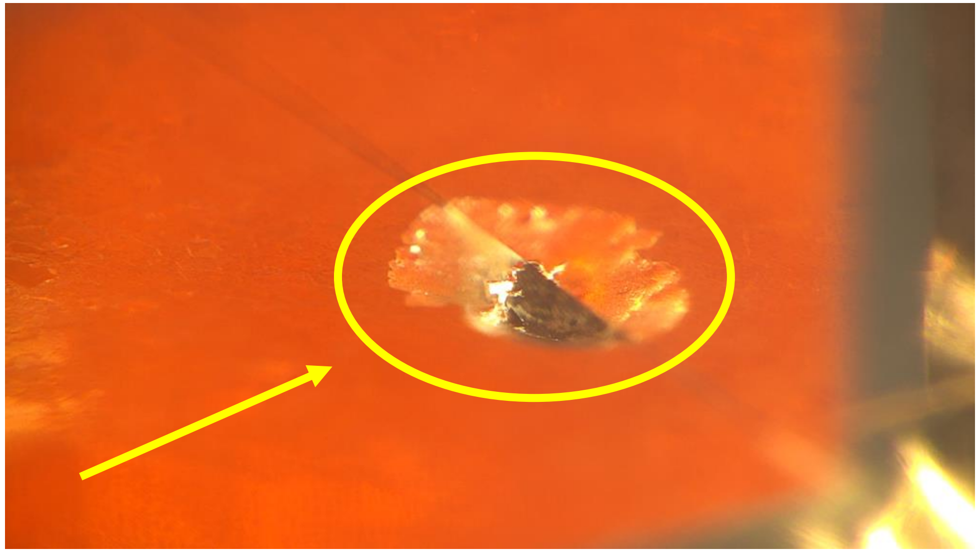


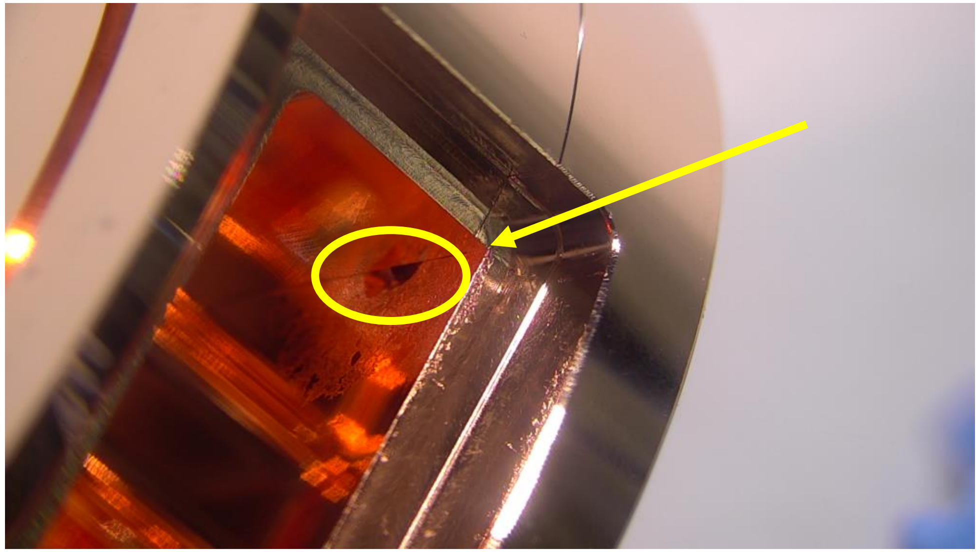


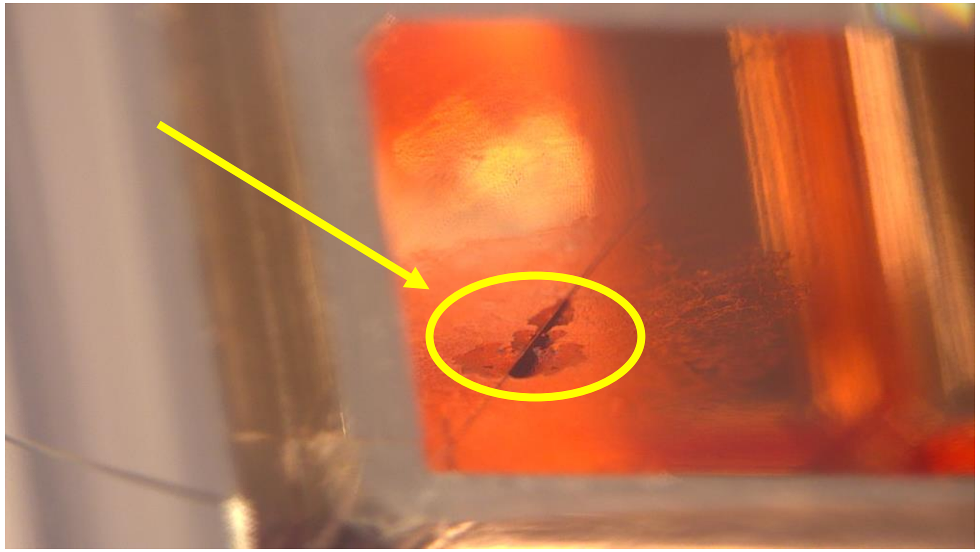


End stack brazes II

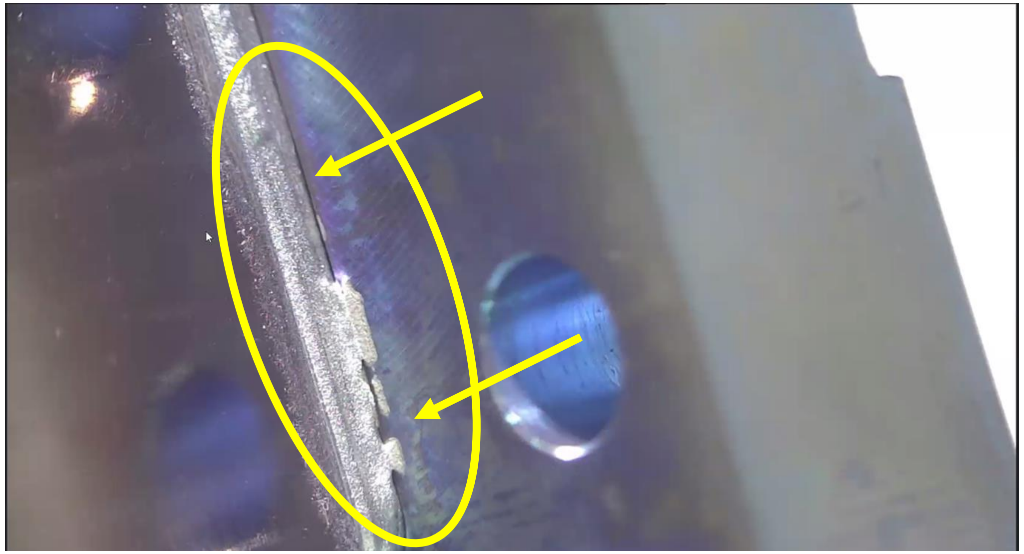
- One end stack brazed well, and both stacks had visible evidence of the braze flowing.
- Clear evidence however of the braze eating into the copper in second end stack.
- Visible hole in cavity wall in 2 places, not present in other side of disk.

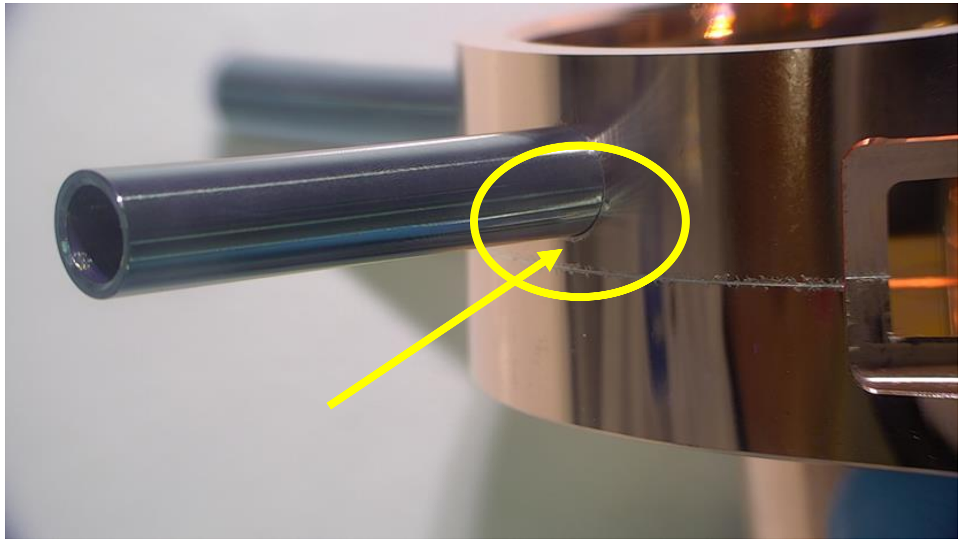


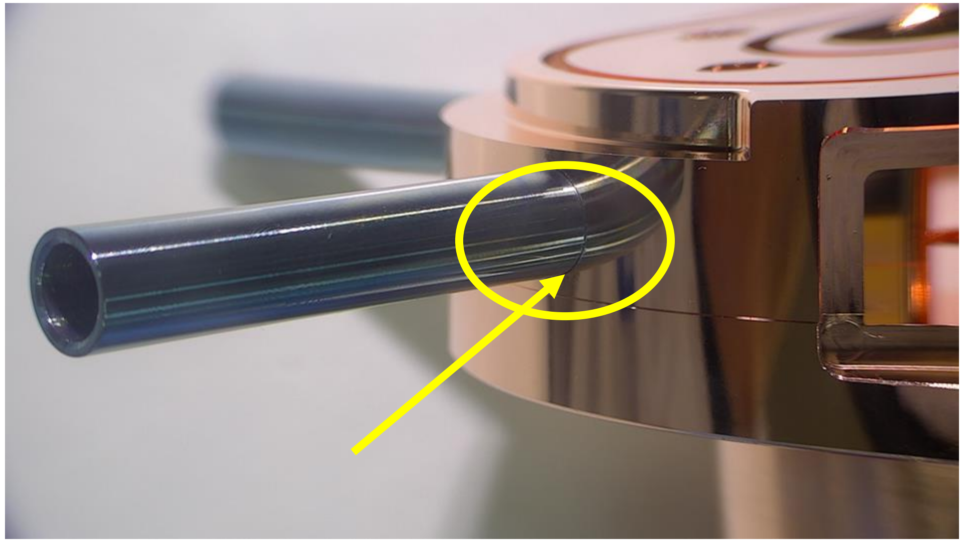




End stack brazes III

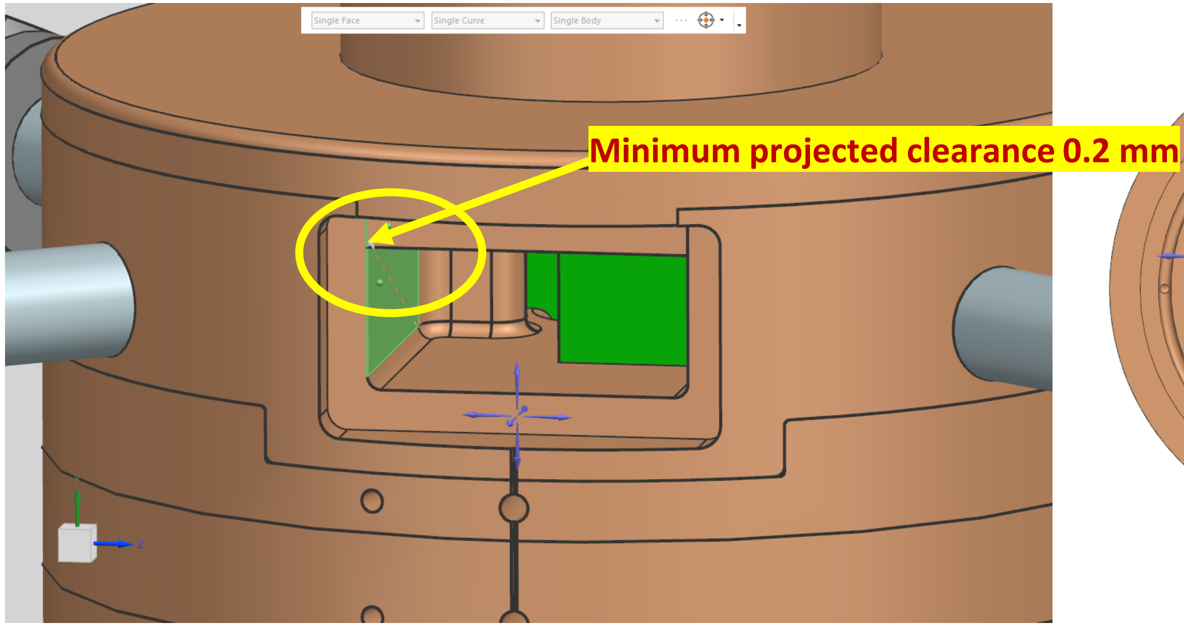


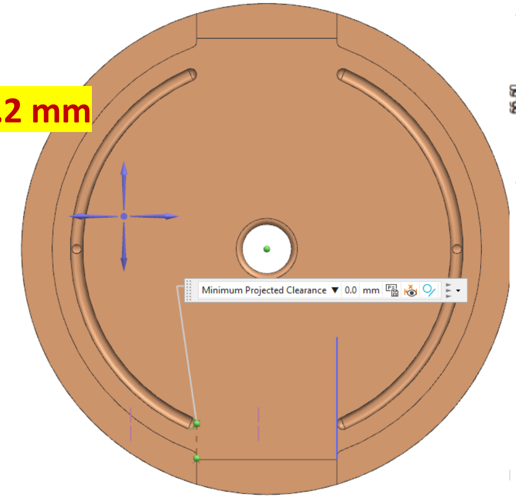


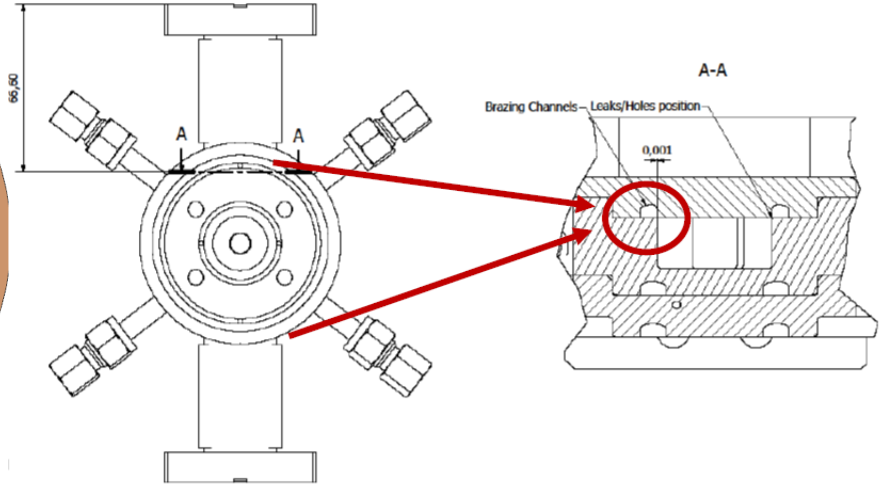


End stack brazes IV

- Unsure exactly why the braze ate into the copper
- Concern however that braze channel appears to touch inner cavity wall







End stack brazes results

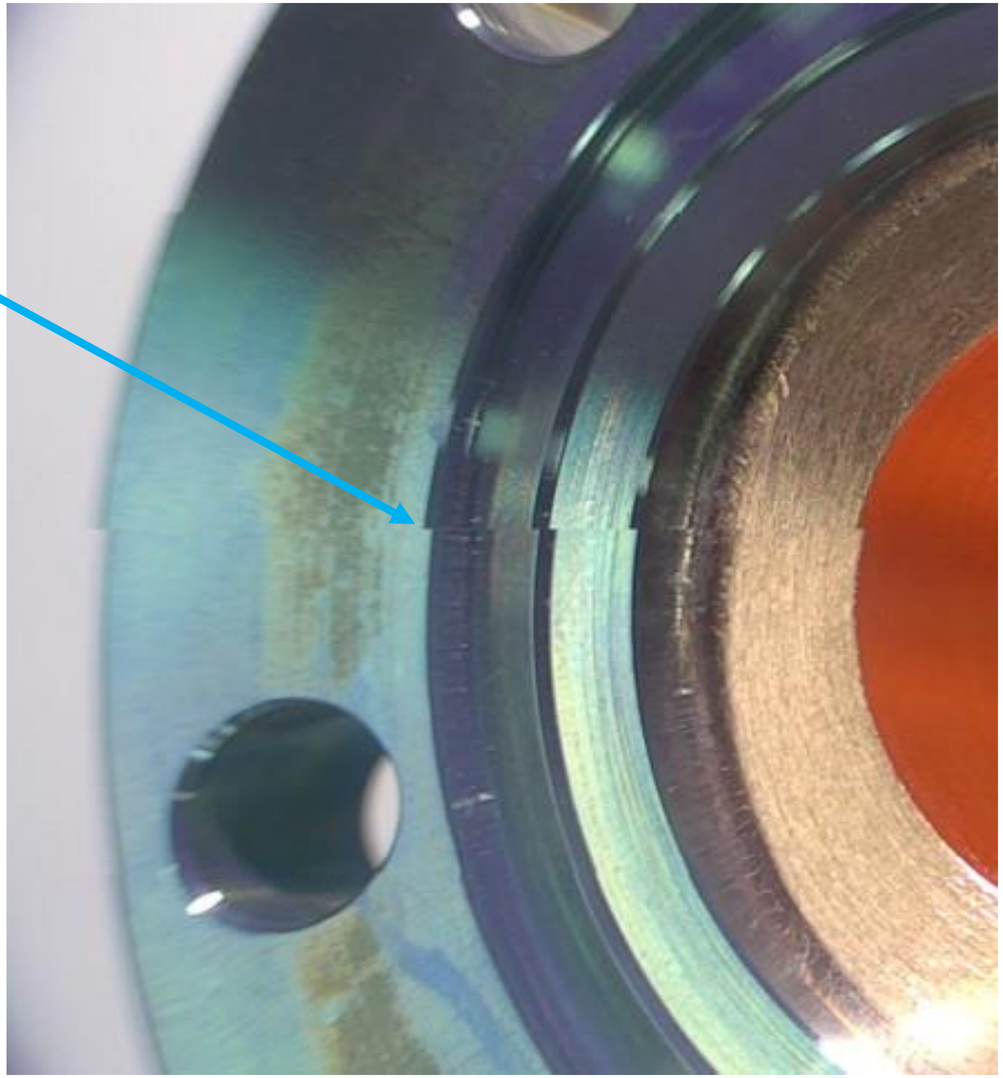
- Waveguides run individually, OK (4 runs)
- Stack ends constructed using the same braze material and run simultaneously with the same braze program, however 1 stack end brazed very well, 1 stack end had less visible braze run but some braze has eaten the copper and exposed the braze channel through the cavity wall
- Visible hole in cavity wall in 2 places.
- Unsure exactly why the braze ate into the copper (temperature too high?), but the fact the braze channel appears to touch inner cavity wall appears to be an issue.
- Three problems were found on the furnace used for brazing:
  - vacuum leaks;
  - hydrogen contamination with oxygen;
  - large differences and low accuracy in the measurement of the temperature profile (made at different heights in the furnace).

Fournace leaks

The hydrogen inlet of the furnace might also have introduced bubbles of Air, which caused the oxidation of the flange (**Blueing ~300°C).**

- A leak in the hydrogen piping would cause the formation of air bubbles which would be pumped in together with the Hydrogen during the brazing process.
- This might have weakened/influenced the bonding strength of the braze
- Further tests are required before proceeding:
  Introduce a stainless steel part into the furnace and carry out a similar brazing cycle.
  The furnace shouldn't be vented until circa 100°C (as a precaution)

➢ If no blueing occurs then this phenomenon has been caused by early venting which should be avoided for the next brazing cycles



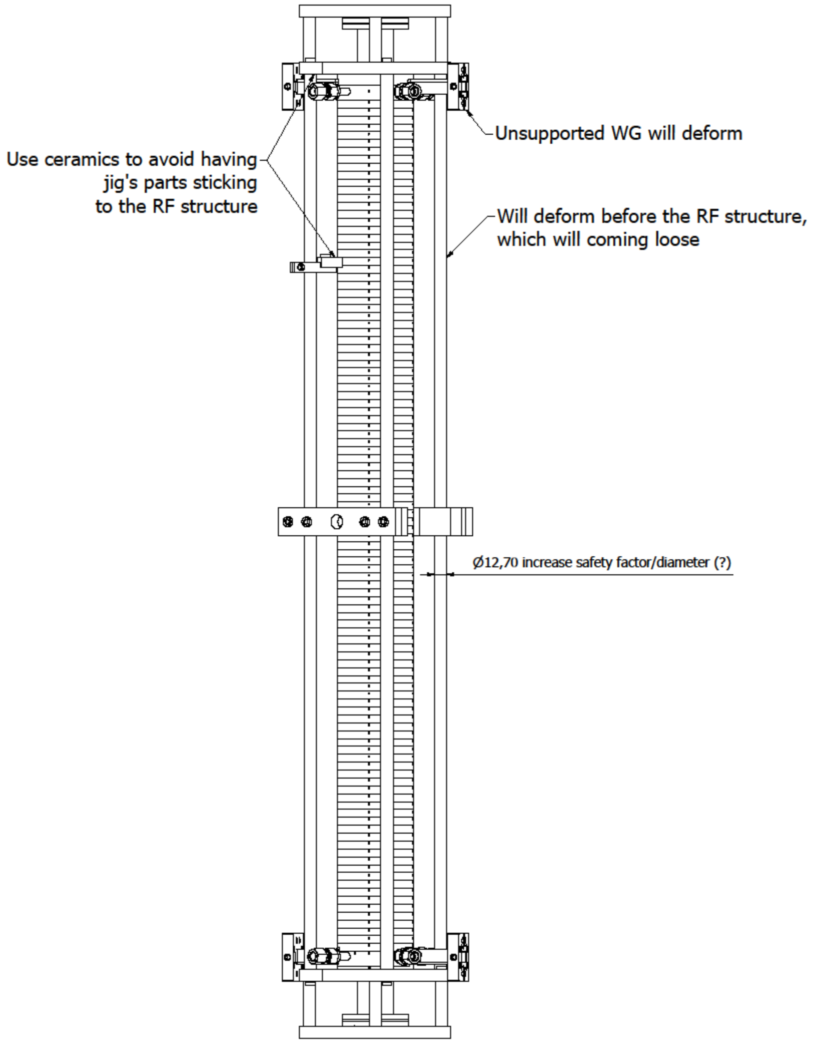
TMD jig modifications

The use of screws in a jig furnace is unrecommended.

The difference in mass between the RF structure and the steel jig leads to a sensible difference in thermal inertia that could cause the structure to get free of the jig during both the heating and cooling phases.

- **Heating Phase:**
  The jig heats up and deforms faster than the RF structure, the rods lengthen faster, and the top of the RF structure is no longer in contact with the jig
- **Cooling Phase:**
  Jig cools down faster than the RF structure compressing it more than anticipated, potentially resulting in the deformation of the RF structure due to buckling strength

Waveguides should be adequately supported during brazing to avoid unnecessary deformations



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Conclusion and next steps

- The two couplers will be shipped by TMD to COMEB, which will attempt to re-braze them with the CuSil ABA (end of May).
- In the event that the new brazing fails, COMEB will attempt to dismantle the steel flanges to recover the couplers brazing two new flanges (in June).
- In the meantime, VDL, which is completing the accelerating cells for the second structure (expected by the end of June), will prepare the parts for two new couplers, which should be ready by the end of June 2024.
- July/August will see the brazing of the new couplers and the first accelerating structure.
- We expect to braze the second structure by the end of 2024, after validating the brazing procedures of the first structure.

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Thank you!

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