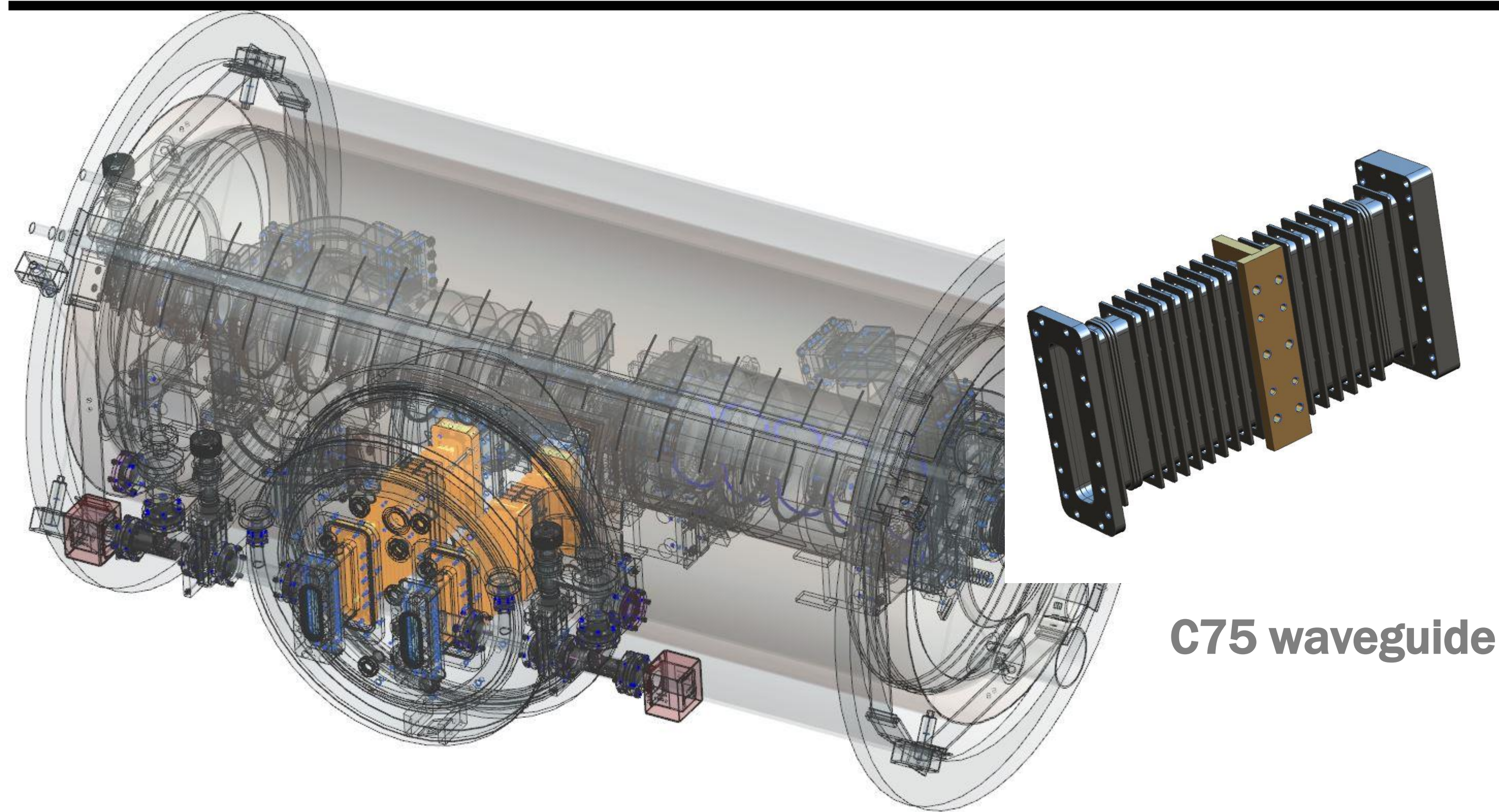


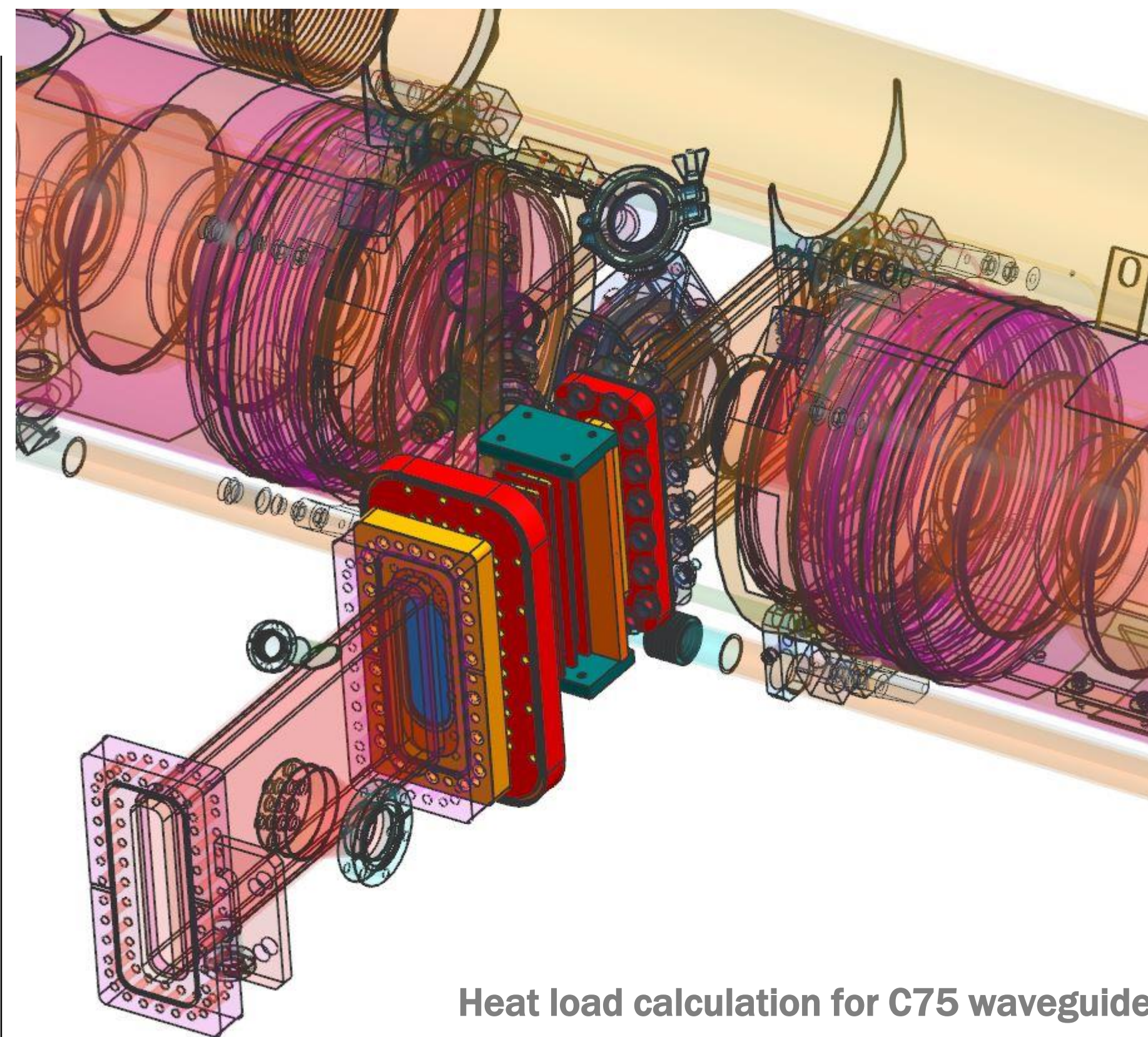
## Abstract

To provide sufficient energy for CEBAF operation, cryomodules and components are being refurbished yearly as necessary. Copper plated fundamental power coupler waveguides are important components of the cryomodules. The integrity and quality of copper plating is critical to reduce the heat load from the waveguides into the He bath at 2.07 K. A search of copper plating resources is underway for plating or re-plating CEBAF-style waveguides. This effort ensures a continuous capability of copper plating on cryomodule components, especially on waveguides. To qualify plating vendors, the waveguide copper plating specifications were revisited, and a thorough plating evaluation process is being developed. The evaluation process ranges from coupon testing to sample waveguide qualification. Recent results are summarized and future work is planned.

## Background



C75 waveguide



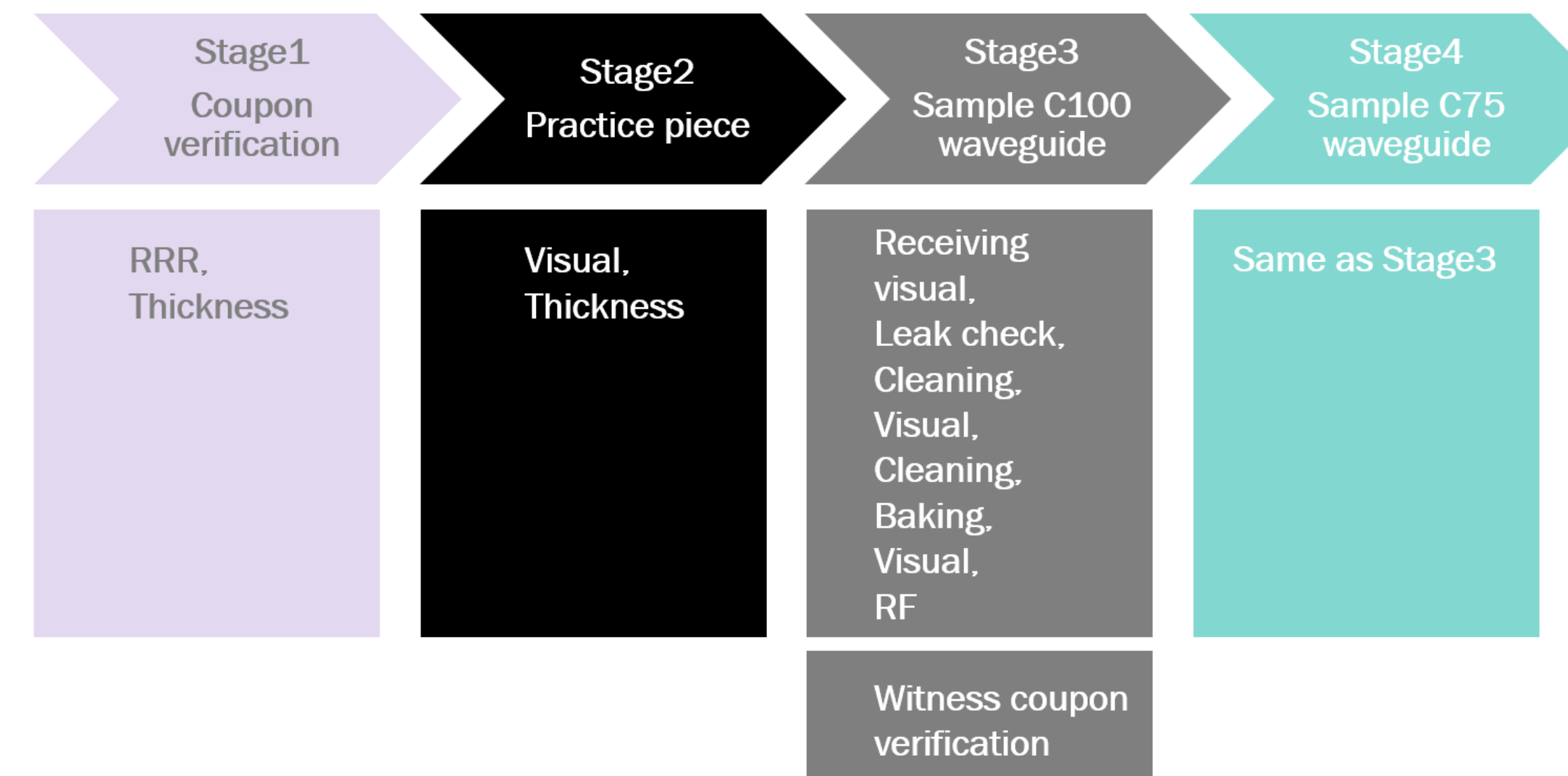
C100 waveguide

Heat load calculation for C75 waveguide with different copper coating thickness

Coating Thickness (μm)	2 K Q <sub>tot</sub> (W)	50 K Q <sub>tot</sub> (W)	300 K Q <sub>tot</sub> (W)	2 K Q <sub>inc</sub> (W)
0.2	2.76	24.71	15.79	0.00
15 & 3	1.55	7.71	1.29	-1.21
5	1.84	7.67	0.97	-0.93
10	2.24	7.95	0.17	-0.53
15	2.62	8.27	-0.63	-0.14

Main adjustment to C75 waveguide plating specification: Thickness 10±5 μm

## Qualification process flow



## Sample analysis

RRR measurement from 3 plating vendors

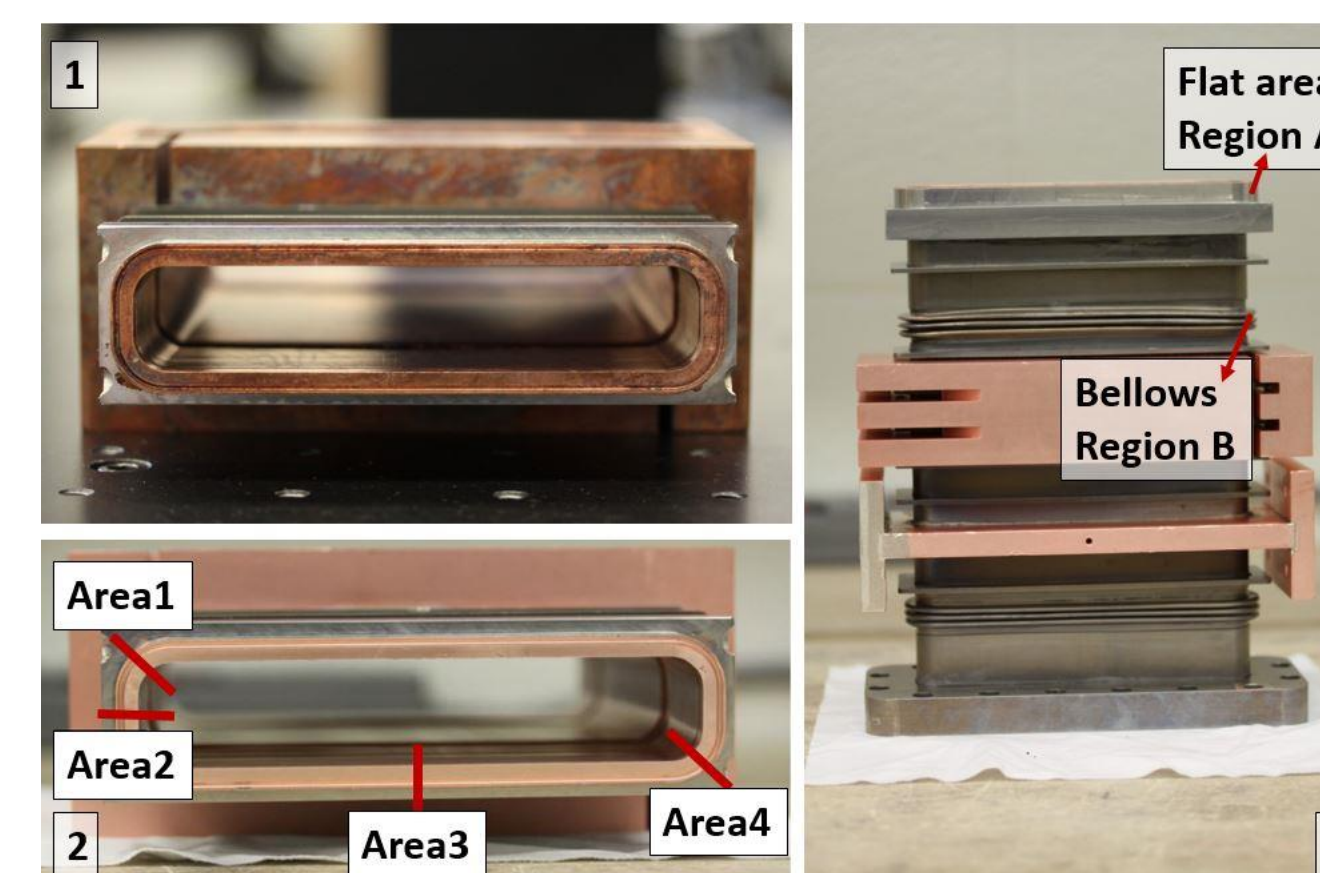
Vendor	# 1	#2	#3			
RRR	50	18	15	18	38	121
Without SS Substrate	x					
With SS Substrate		x	x	x	x	x
After Baking			x		x	x

- 10 data points taken on one coupon from each vendor.
- Measured thicknesses are:  
Vendor #1, 12.1 +/- 0.5 μm;  
Vendor #2, 15.1 +/- 1.9 μm;  
Vendor #3, 20.4 +/- 2.4 μm.

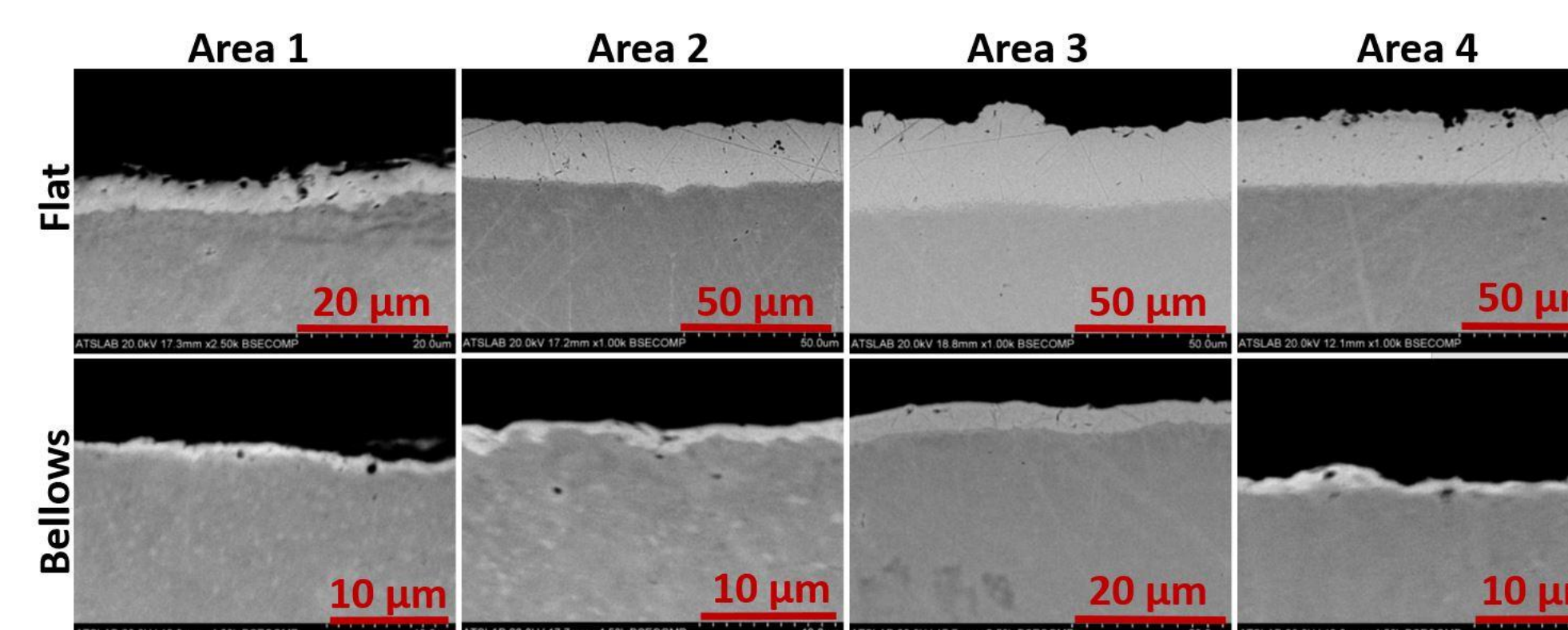


Cross section and thickness measurement from 3 plating vendors

## Practice piece



- Area #1A, 4.4 +/- 0.4 μm; Area #1B, 1.4 +/- 0.1 μm;
- Area #2A, 20.2 +/- 0.7 μm; Area #2B, 1.5 +/- 0.2 μm;
- Area #3A, 28.5 +/- 3.0 μm; Area #3B, 3.5 +/- 0.4 μm;
- Area #4A, 24.0 +/- 1.0 μm; Area #4B, 1.3 +/- 0.3 μm.

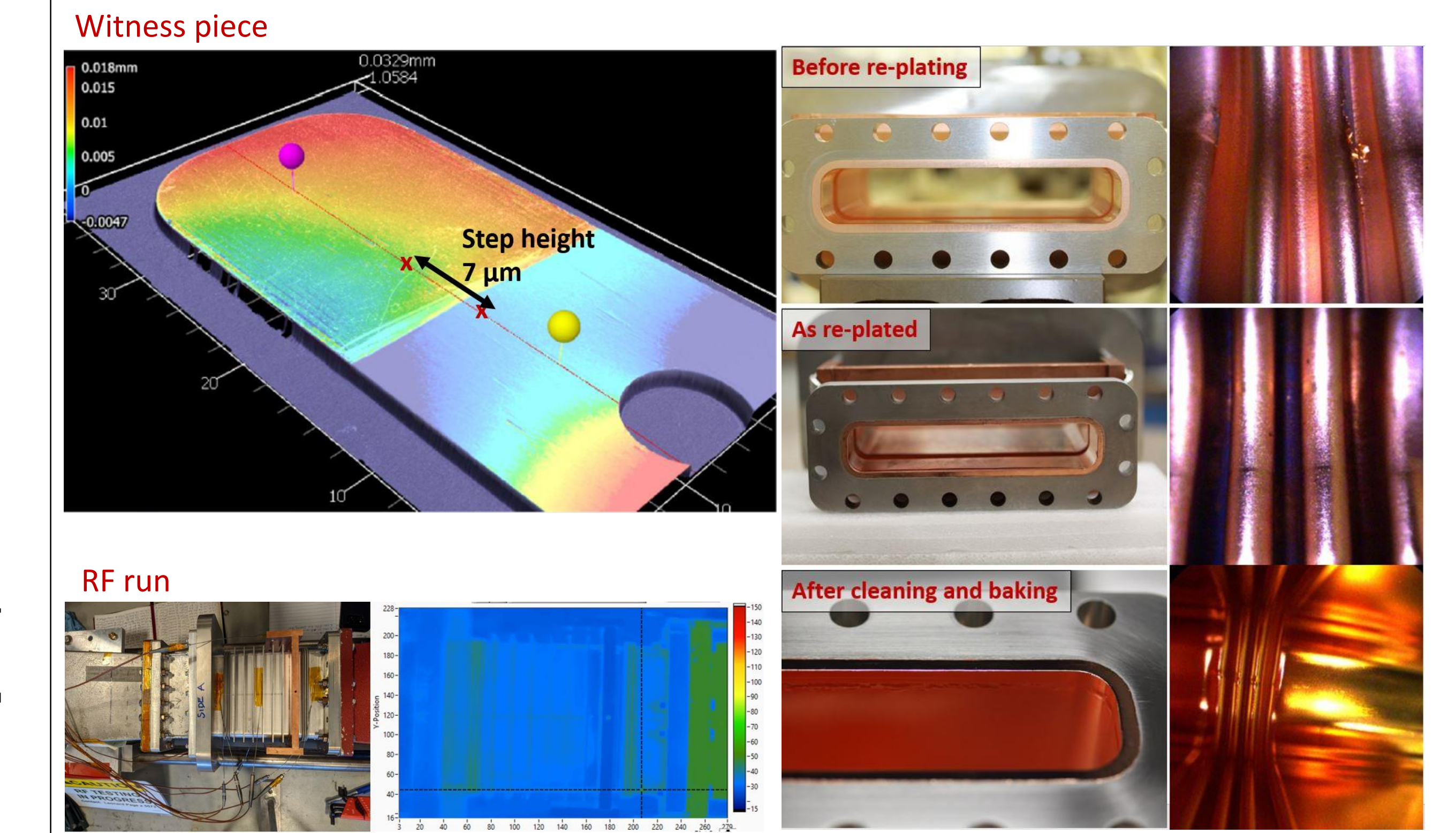


Cross section and plating thickness measurements

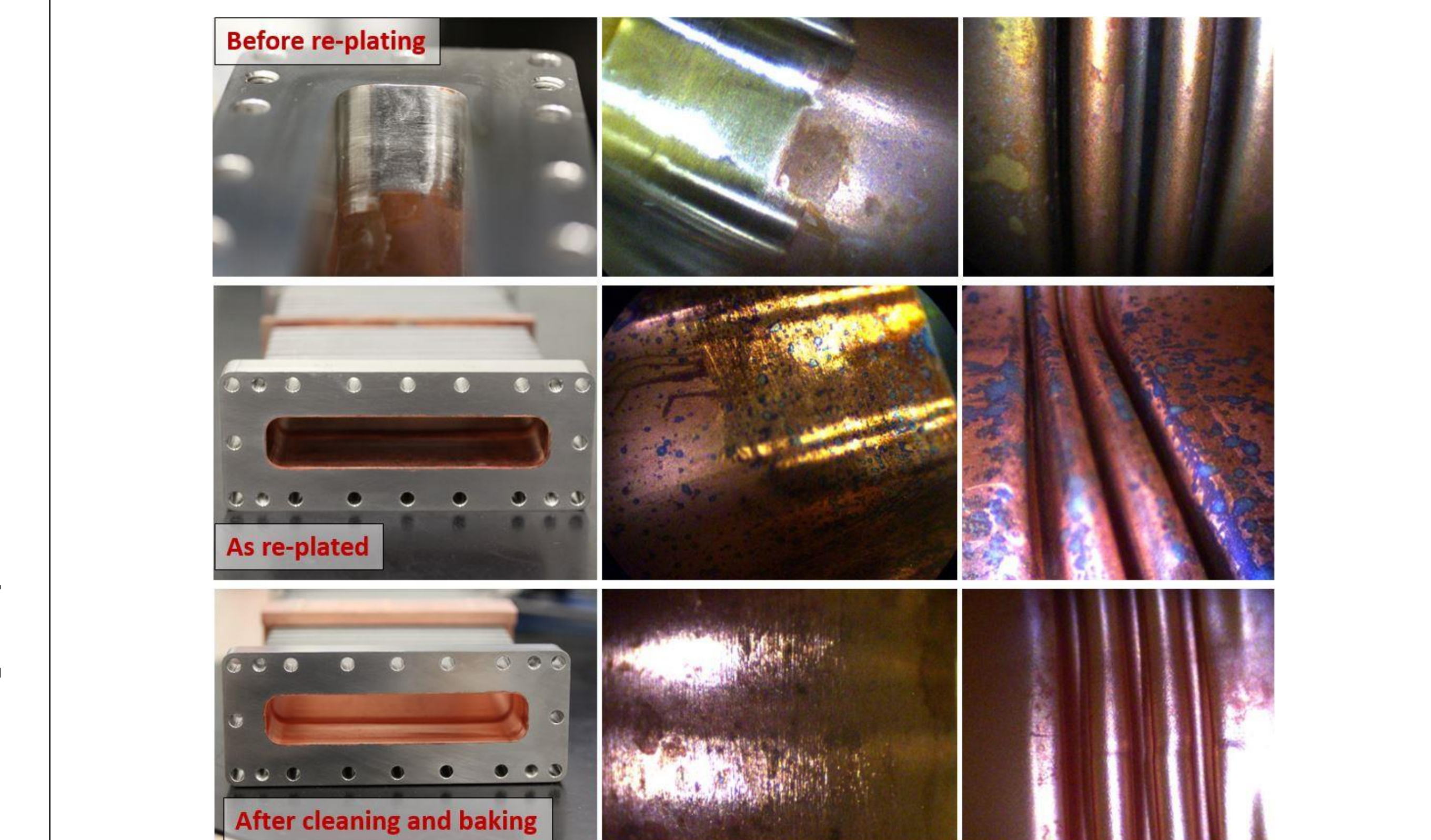
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## Sample C100 WG



## Sample C75 WG



## Summary

- Plating vendor #1 showed promising results, although heavy oxidation on the plated surface was noticed. The oxidation can be removed by cleaning and baking. It is proven to be challenging to achieve uniform coating thickness on rectangular waveguide with bellows.
- Continuing work includes:
- More vendors will be qualified using the same process if needed;
- Alternative coating techniques other than traditional electro-plating, such as pulse and pulse reverse electrodeposition, and high power impulse magnetron sputtering (HIPIMS), are also being considered;
- More plating evaluation tools are being considered; for example, measuring plating resistance directly on the WG instead of coupons, and measuring the WG heat load under conditions resembling that of cryomodules.

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