AUP RFD HOM Couplers

Naeem Huque – JLAB

11th HL-LHC Collaboration Meeting, 19-22 October 2021

Outline

- Introduction
- Scope of Work
- Current Status
- Production Highlights and Lessons
- Manufacturing Inspection Plan (MIP)
- Pre-Series Work
- Summary

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Introduction

- Dressed RFD cavities have several ancillary components:
  - Horizontal HOM Damper (and Feedthrough)
  - Vertical HOM Damper
  - Field Antenna (Pick-Up)
- Three sets of the ancillaries are being fabricated at JLab as Prototypes
  - To be used for vertical cavity tests
- Three sets of Pre-Series dampers will follow prototype production
  - To be used in the prototype cryomodules

HHOM Feedthrough

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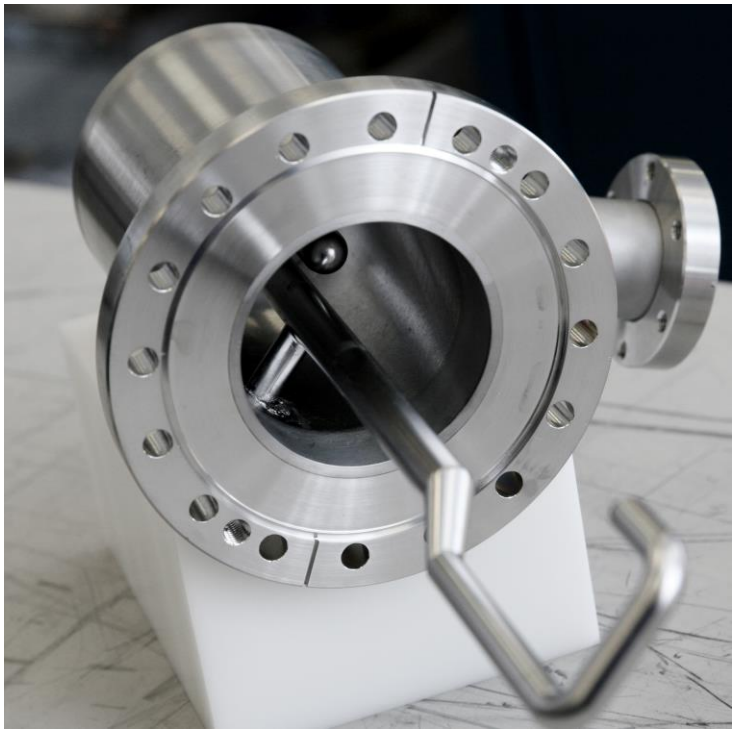
JLab Scope of Work



- Fabricate sets of RFD Cavity Ancillaries
  - Prototype: 3 sets (FY21/FY22)
  - Pre-Series: 3 sets (FY22)
  - Series: 8 sets
- RF design is provided by AUP
- Development strategy and manufacturing drawings
  - Leverages the JLab SRF Department's experience with EBW, Brazing, and Fabrication work centers
- Pre-series and production units will be based on full adherence to the requirements of the engineering specification (EDMS 1389669)

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Current Production Status

- **3 HHOM Dampers completed**
  - Ready for RF Testing. Final BCP to follow
- 2 HHOM Damper Feedthroughs Complete (1 in progress)
- 1 VHOM Damper Complete (2 in progress)
- 3 Field Antennas in Progress

HHOM Damper

VHOM Damper

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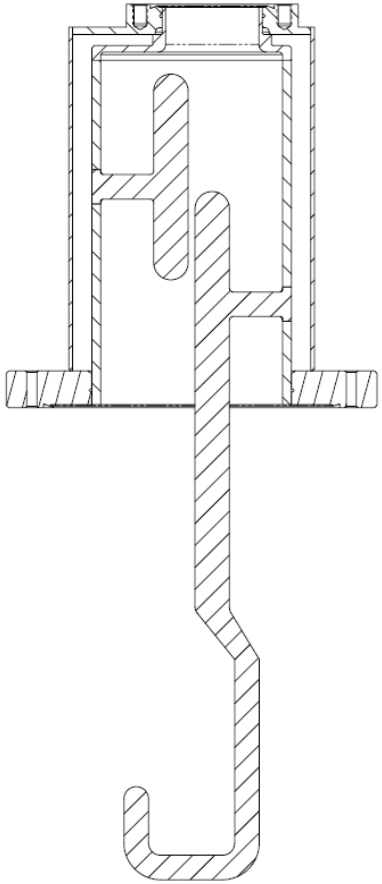
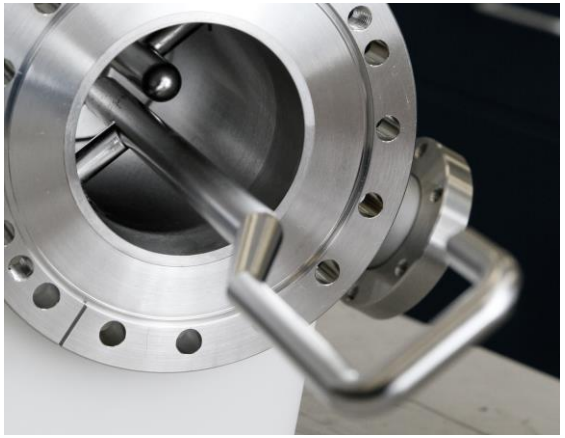
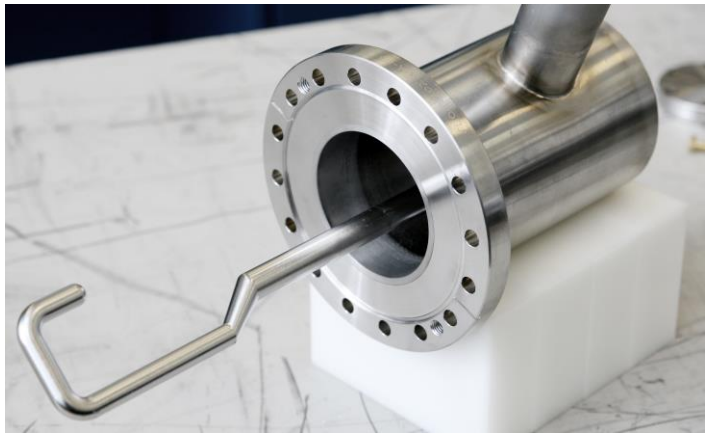
HHOM Highlights

- The HHOM Damper is constructed primarily of Nb, with 316LN Stainless Steel flanges brazed on, and a 316LN helium jacket







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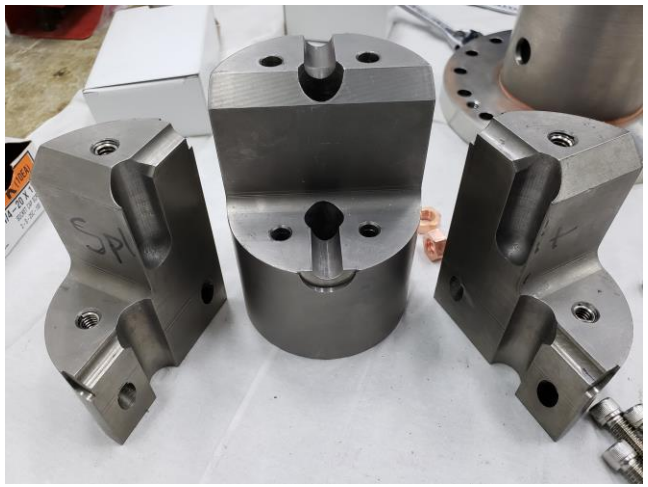
HHOM Highlights

- The most critical welds are those of the Hook and the Tee to the inside of the Nb can
- The gap between the parts the components must be 2.5-3.1mm
- **EBW fixturing designed for this weld allowed a consistent gap of 2.6 mm for each of the three prototype units built**



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HHOM Lessons

- **The EBW Fixture was able to achieve much of the required tolerances**
- The fixture is a large heat-sink during the Hook/Tee welds, which resulted in a number of additional weld passes being required
  - A number of the welds had a large underbead as a result
  - More testing is required to reduce the number of required passes
  - Tests will need to be on assemblies almost identical to production units in order to mimic the heat transmission
- Improvements will be made to the fabrication process

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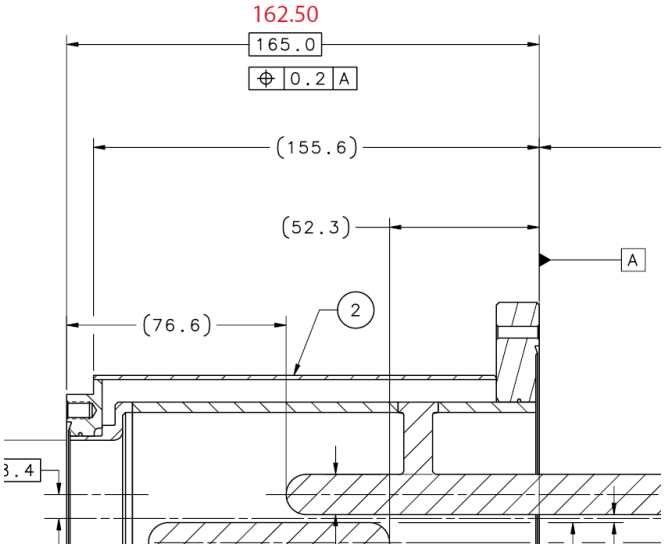
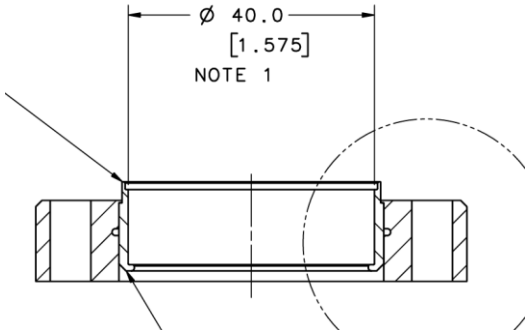
HHOM Lessons

- The final Nb lid weld had a lot more weld shrinkage than anticipated
  - The first unit welded had ~2.5mm shrinkage due to the process of fine tuning welding parameters
  - RF simulations are underway to determine if the damper meets the specifications
- The Pre-Series design will have the weld shrinkage taken into account

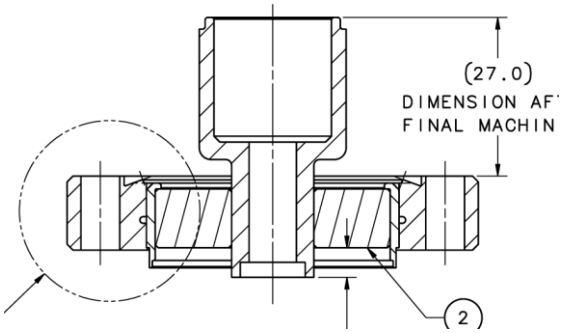


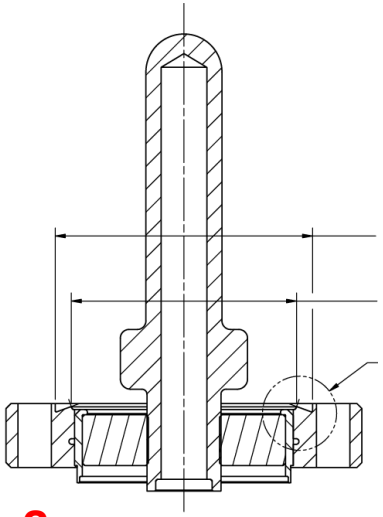
VHOM / HHOM-FT / Field Antenna

- The VHOM, HHOM-FT and Field Antenna all have different copper probes installed on the same flange/ceramic assembly
  - The flange/ceramic/probe braze is identical for all three
  - The parts differ by unique probe dimensions and EBW layouts
- The brazes are done in two steps: SS-to-copper, and Copper-to-Ceramic-to-Copper
- The copper ring between the SS and ceramic acts as a buffer between the different expansion coefficients of ceramic and stainless steel
- The design differs from the CERN design, which has ceramic brazed directly to titanium flanges



Braze 1

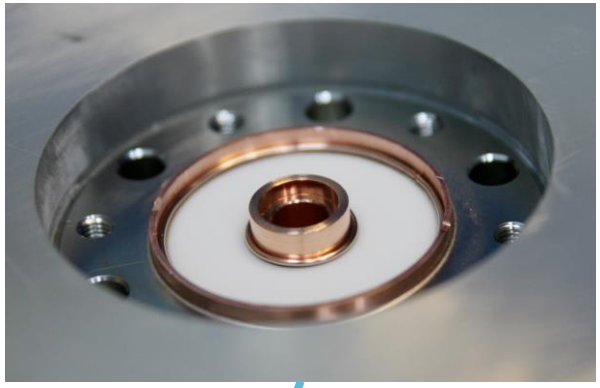




Braze 2

Brazing/EBW Sequence

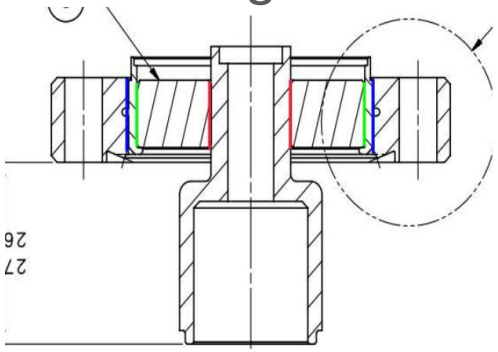
Concept is derived from JLab experience with coaxial windows



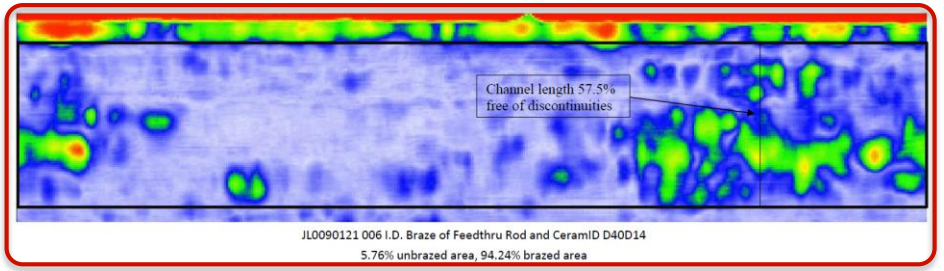
Braze 1 → Leak Check → Mach. → UT → Braze 2 → Leak Check → UT → Mach. → EBW → Leak Check → RT

Brazing Inspections

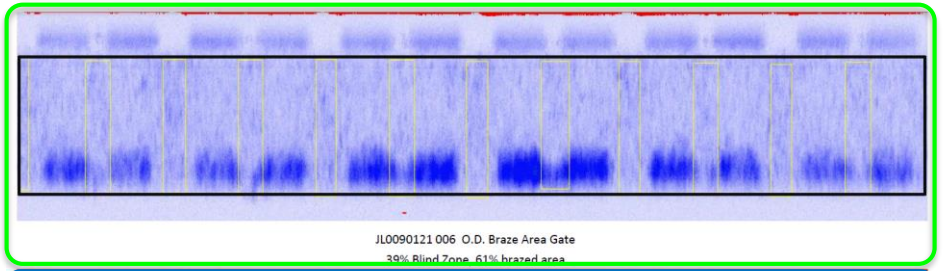
- All brazes are ultrasonically tested according to ISO 18279 Level B
  - Some brazes can be only partially scanned and these results are used only for reference
- In the example below, the top scan is the ID of the copper probe and the bottom two scans are the two outer brazes. The holes in the flange created blind spots in the latter



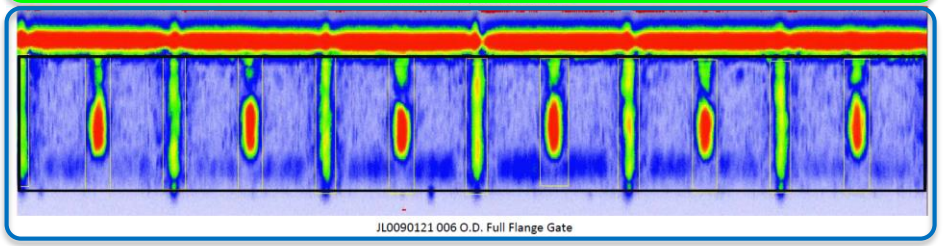
Braze 1



Braze 2

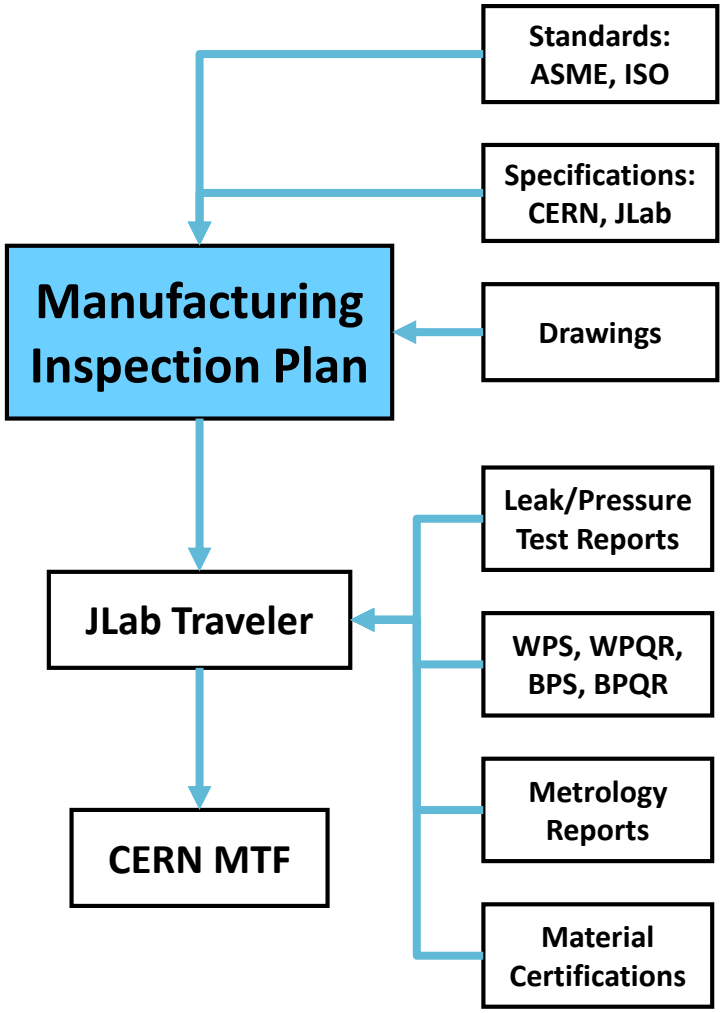


Braze 3



Manufacturing Inspection Plan (MIP)

- A separate MIP is developed for each ancillary component
- **The MIPs are based on the design, required standards and the CERN engineering specification**
  - The MIP is the master document that lists all the fabrication steps
  - The MIP defines the structures of the individual travelers
- Each part drawing/process is tracked with a traveler in the JLab Pansophy system
- The travelers collect relevant data during production e.g. test reports and dimensional inspection results
  - The travelers also collect sign-offs that particular operations have been carried out
- The information from the travelers are transferred manually to the CERN MTF



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Manufacturing Inspection Plan (MIP)

Jefferson Lab HiLumi HL-LHC PROJECT

EDMS NO.	REV.	VALIDITY
2379706	0.1	DRAFT

REFERENCE: MIP-JL0086007

HL-LHC: Quality
Manufacturing and Inspection Plan

Prepared by: N. Huque **Date**	**Project:** HL-LHC	**Supplier:** AUP (J-Lab)	**Item Eq. Code:** ACFHC	**Asset Code (LHC Part Identifier):**
Verified by: H. Garcia Gavela, N. Valverde Alonso **Date:**				
Approved by: R. Calaga, E. Montesinos **Date:**	**Work Package:** WP4 - Crab Cavities & RF	**Client:** CERN	**Item description:** RFD H-HOM Coupler Prototype	**EDMS Report No:**

No	ACTIVITY / OPÉRATION	APPL. STANDARDS / NORMES APPL.	APPLICABLE DOCUMENTS / DOCUMENTS APPLICABLES	REV. DOC.	INSPECTION / CONTRÔLE								NOTES / COMMENTAIRES
					AUP		CERN				INSPECTION REPORT / RAPPORT D'INSPECTION	REV. DOC.	
					Code	Signature/Date	Code	Signature/Date					
0	**TRACEABILITY OF MATERIALS**										Material Certificates		Material Certificates for all the raw materials used in this production
1	**MANUFACTURING Nb Hook**		Drawing Nº JL0086021										
1.1	Machining												
1.2	Degreasing		JLab Spec CP-AUP-CAV-CHEM-DEGR; EDMS 2365964										
1.3	Metrology												
1.4	Degreasing and 30um BCP		JLab Spec CCP-AUP-CAV-CHEM-ACID; EDMS 2365955										
2	**MANUFACTURING Tee**		Drawing Nº JL0083868										
2.1	Machining												

Example of MIP

Jefferson Lab
Thomas Jefferson National Accelerator Facility

TRAVELER

Pansophy
A System of Universal Knowledge

Step No.	Instructions	Data Input
1	Serial Number of part	[[CURINGSN]] <<CURINGSN>>
	Confirm JL0089865 Material Specification meets ASTM F68 as per CERN No. 2001 Ed. 8 and EDMS No. 790779. Upload Material Certification, as well as any relevant photos and/or comments.	[[INVTech]] <<SRF>> [[INVTime]] <<TIMESTAMP>> [[INVComm]] <<COMMENT>> [[INVCert]] <<FILEUPLOAD>>
MACHINING PROCESS		
2	Machine the part as per drawing JL0089865. Upload any relevant documents and/or photos	[[MACHTech]] <<SRF>> [[MACHTime]] <<TIMESTAMP>> [[MACHComm]] <<COMMENT>> [[MACHFile]] <<FILEUPLOAD>>
CHEMISTRY PROCESS		
3	Degrease JL0089865 as per JLab CP-AUP-CAV-CHEM-DEGR. Upload any relevant photos and/or comments.	[[CHEMTech]] <<SRFCVP>> [[CHEMTime]] <<TIMESTAMP>> [[CHEMComm]] <<COMMENT>> [[CHEMFile]] <<FILEUPLOAD>>

Example of JLab traveler

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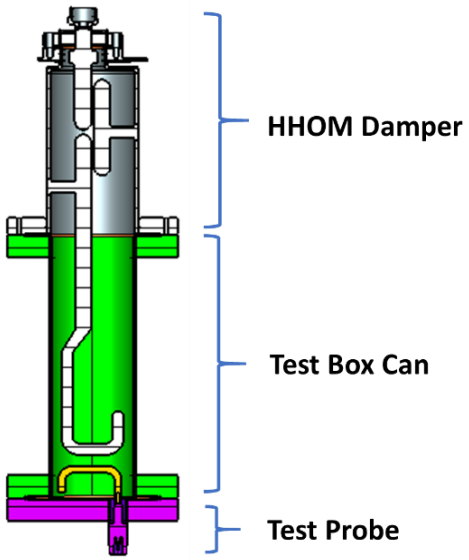
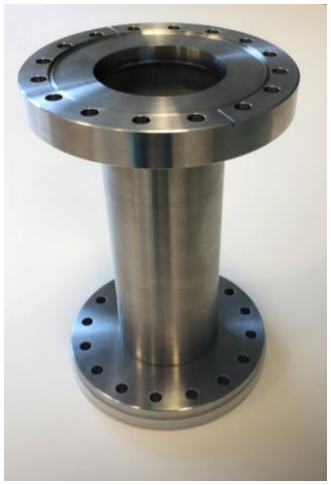
HHOM Damper Qualification

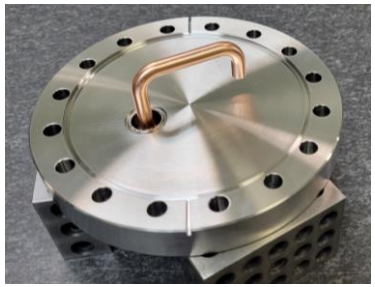
- HHOM Dampers are qualified using an RF Test Box

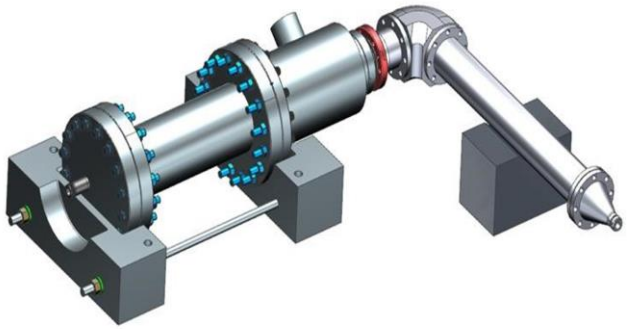




Test Box Can

Test Probe





- 2 sets of rf test boxes (Test Box Can + Test Probe) are completed
- CMM inspection shows that Test Box Cans and Test Probes are within tolerances → Impact on S_{21} due to fabrication deviations are negligible
- Set up uses an impedance adapter to transition from 25 Ω to 50 Ω

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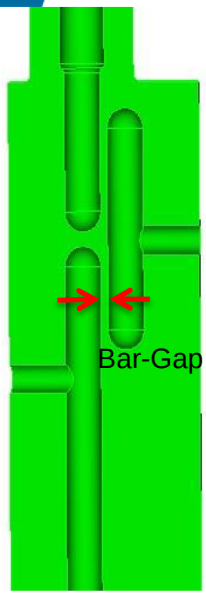
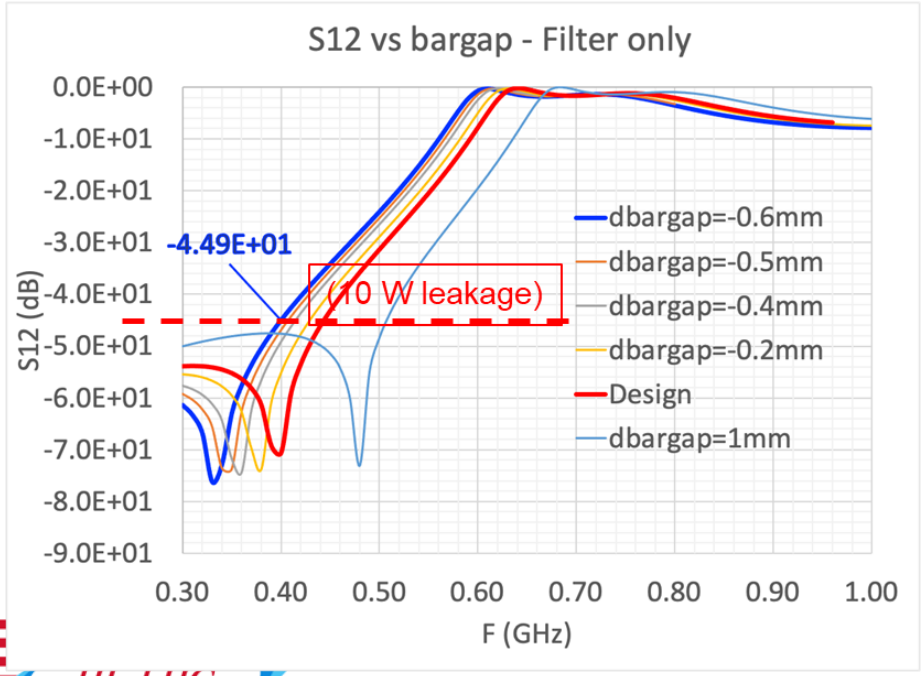


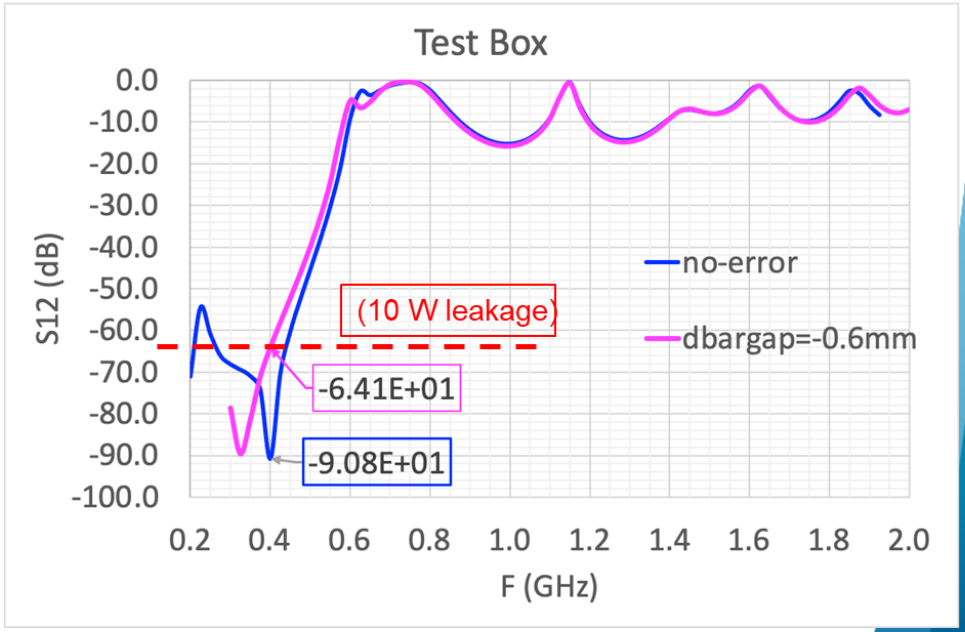
HHOM Damper Qualification

- S_{21} transmission will be measured to qualify notch and transmission above 600 MHz up to 2 GHz
  - Transmission above 600 MHz needs to be within the mask
  - Notch at 400 MHz < -60 dB
- HHOM feedthrough will be machined to adjust for notch
- RF measurements have started this week

(S12: HHOM coupler filter only)



(S12: HHOM coupler + test box)



Pre-Series Work

- Long lead raw material for the Pre-Series work has been ordered
  - Niobium: At US customs
  - 316LN Stainless Steel: Awaiting Shipment
  - OFE Copper: PO in place
  - Ceramic: PO in place
- A number of the qualification documents (e.g. WPQRs, BPQRs) cannot be completed without this new batch of material
- Fabrication work cannot start until the Final Design Review is complete

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Summary

- Fabrication of prototype ancillaries is nearing completion at JLab
- Lessons learned will be integrated into the Pre-Series design
- Procurements have started for the Pre-Series fabrication
- Work control documents (e.g. MIPs and travelers) will also be updated for Pre-Series
- RF test boxes are ready for HHOM damper qualification

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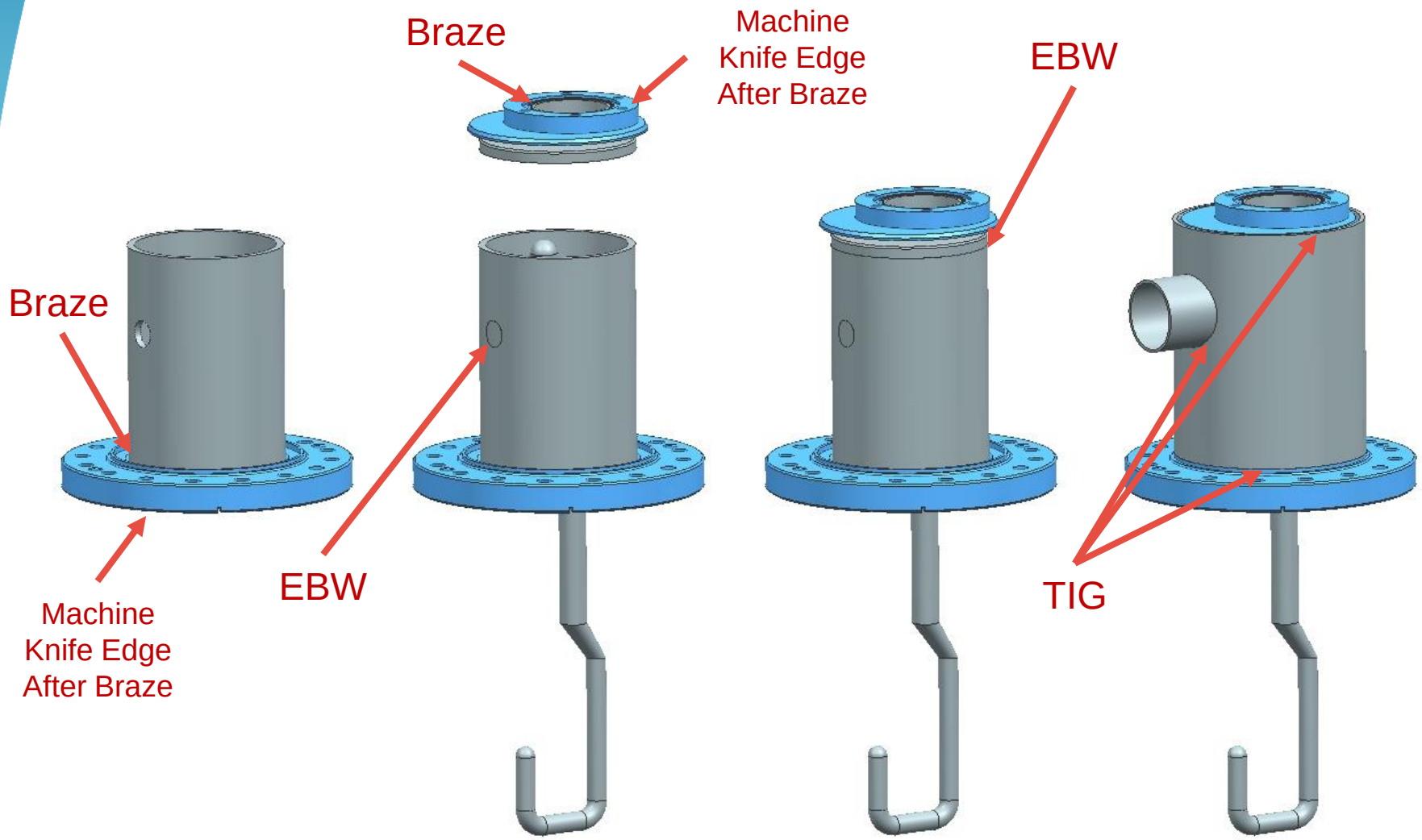
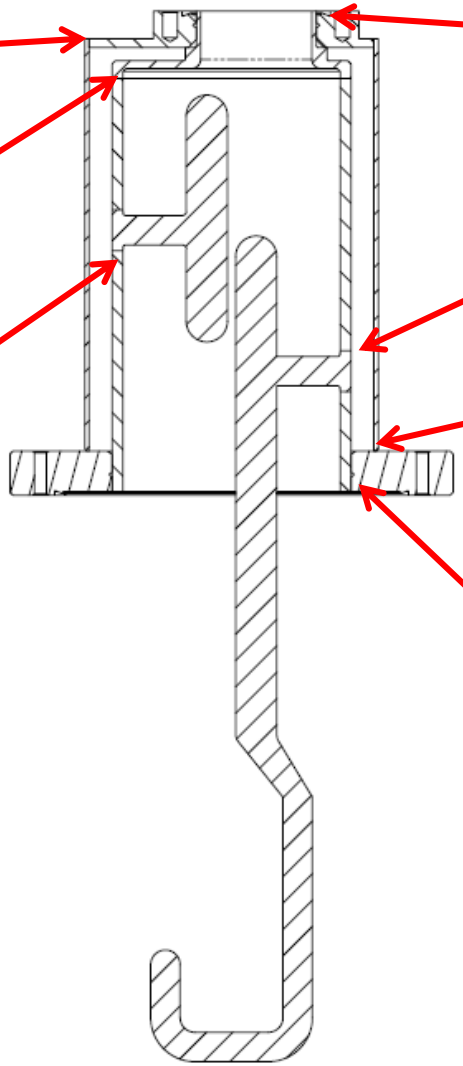
Back-Up Slides

AUP HHOM Damper Fabrication Sequence



Qualification of Weld/Braze Joints



SS/SS TIG
WPQR xxx3
WPS xxx3

Nb/Nb EBW
WPQR xxx2
WPS xxx2

Nb/Nb EBW
WPQR xxx1
WPS xxx1

Nb/SS Braze
BPQR xxx1
BPS xxx1

Nb/Nb EBW
WPQR xxx1
WPS xxx1

SS/SS TIG
WPQR xxx3
WPS xxx3

Nb/SS Braze
BPQR xxx2
BPS xxx2

All qualifications are to meet requirements in CERN engineering specification

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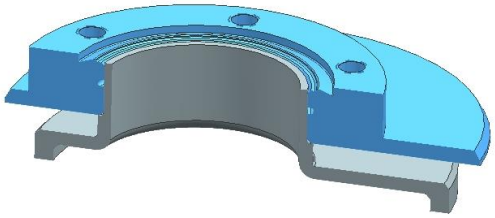
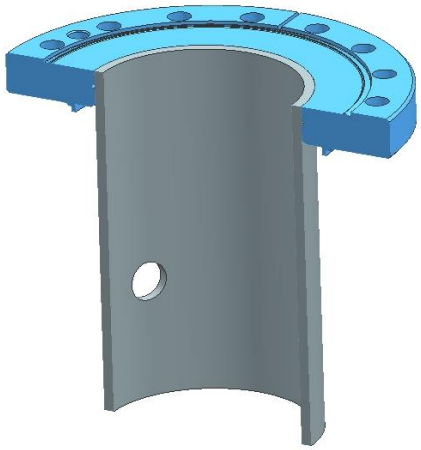
Brazing Scheme – Nb to SS

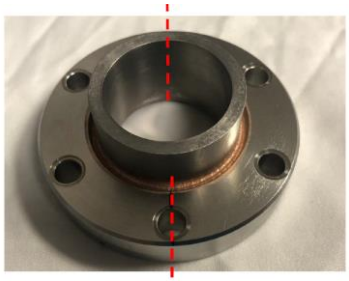
- A DN100 flange is brazed to the Nb tube, forming in the inner Nb chamber of the HHOM damper (right image)
- Filler material is OFHC Copper
- The process goes through several CMM and inspection processes
- The knife edge of the DN100 CF flange is machined after the braze
- The braze for the DN40 flange (bottom image) is carried out with the same steps

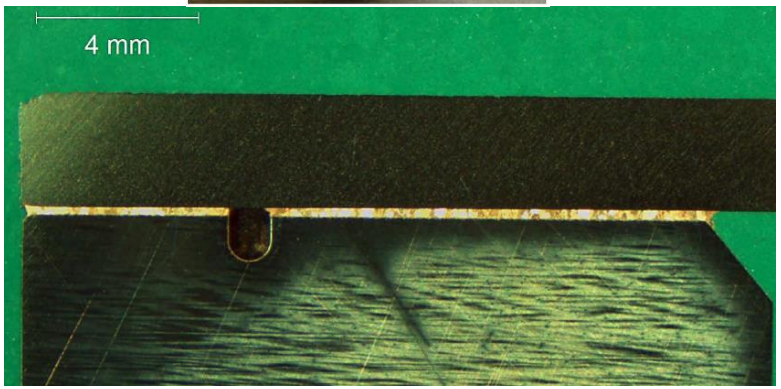


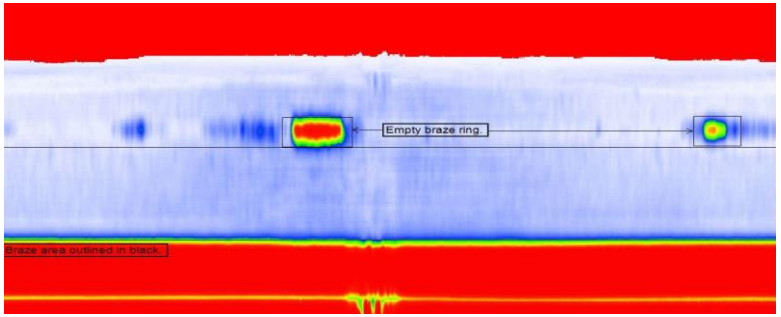


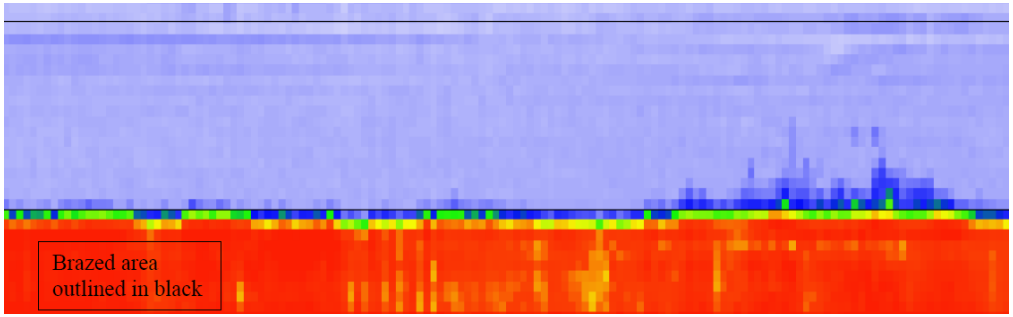
NB-SS Braze Qualification

- Assemblies passed leak check after thermal shock
- Brazes were good to ISO 18279 Level B+









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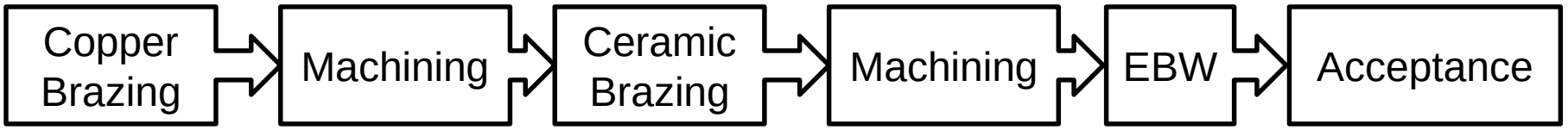
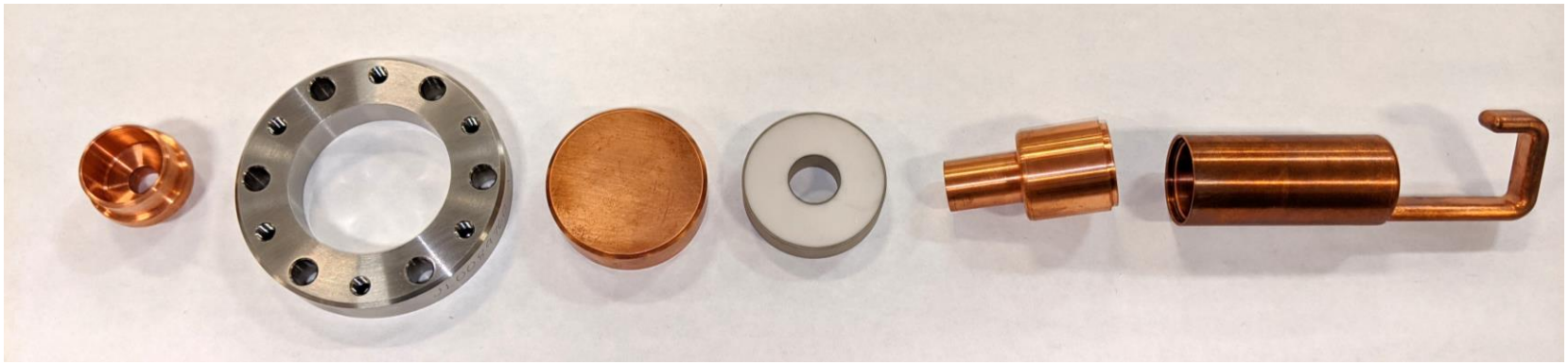
VHOM and Field Antenna Fabrication

- All components have been fabricated
- Initial dimensional inspection has been completed





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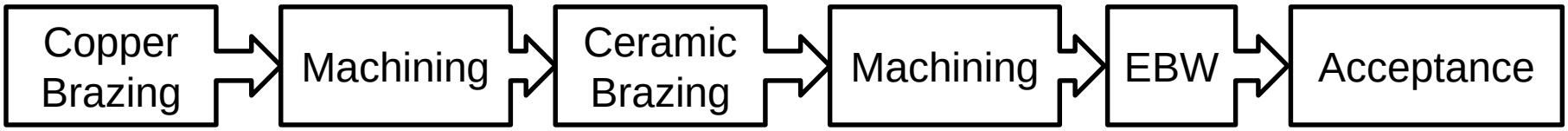
HHOM Feedthrough Fabrication

- All components have been fabricated
- Initial dimensional inspection has been completed



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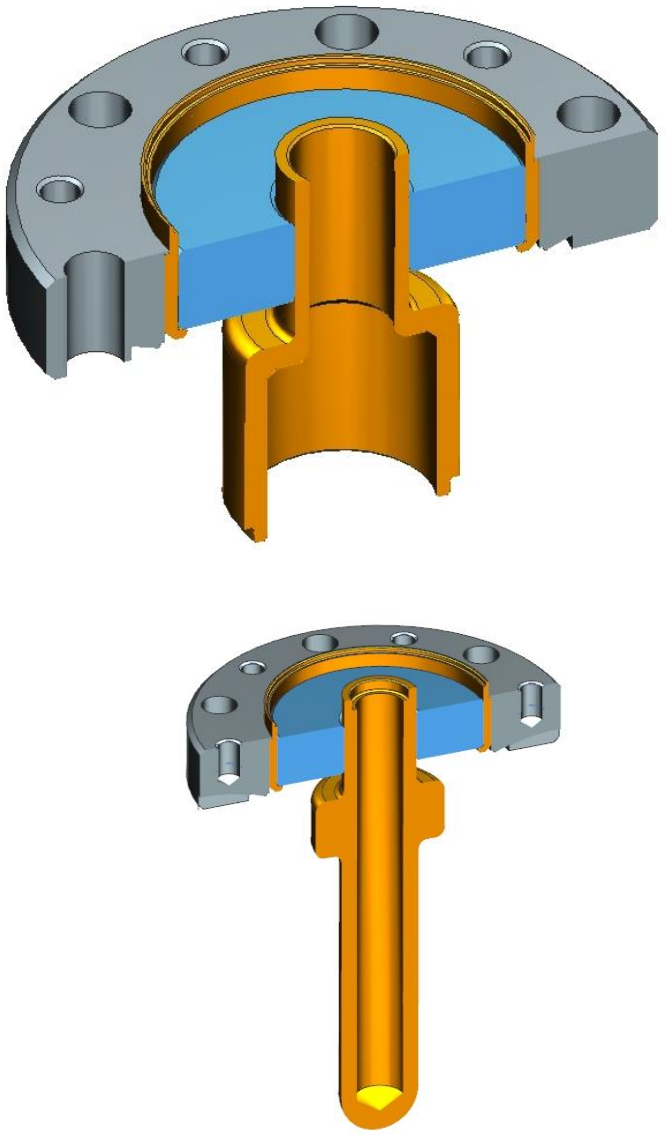
Brazing Scheme – SS to Ceramic

- The HHOM Feedthrough, VHOM damper and Pick-Up all use copper probes brazed on to ceramics
- Braze interfaces will be designed using a thin copper ring between the stainless steel flange and the ceramic
- The ring is formed by a solid Cu piece, which is subsequently machined
- The copper ring acts as a buffer between the different expansion coefficients of ceramic and stainless steel
- The stainless steel flange will be fit inside a molybdenum ring



Brazing Alloys

- The original plan was to use 65Cu-35Au (i.e. 65% Cu and 35% gold) braze alloy (liquidus temp 1010C) for the first braze and 50Cu-50Au alloy (liquidus temp 970C) for the second braze
- Supply-chain issues meant that the 50-50 alloy was not available in time to support production
- 65-35 alloy was used for both steps of the braze, which meant the first braze would be re-melted
- UT on the brazes has shown no detrimental affects on the first braze due to the re-melt (though there are blind spots on the scans)
  - Qualification units with no blind spots will be brazed and tested
- In parallel, several assemblies were brazed using the 50-50 alloy when it became available
  - **Both styles have consistently passed Leak Check and UT**

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