HOM Couplers and RF Antennas for HL-LHC Crab Cavities: Developments for Manufacturing

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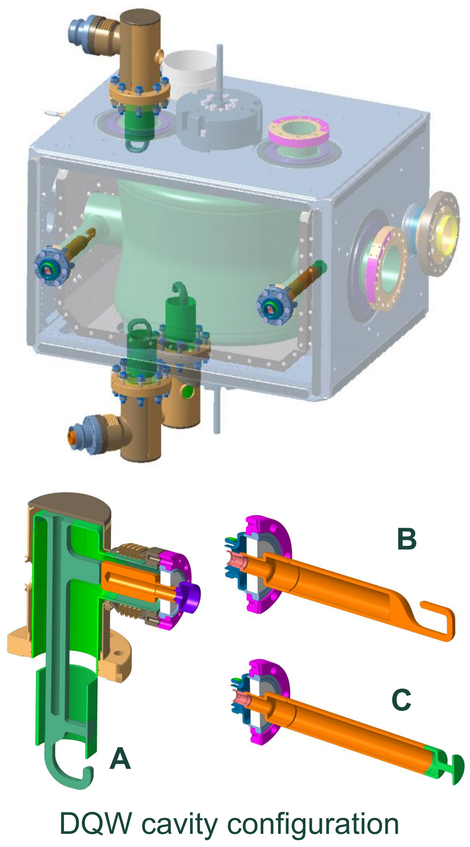
Introduction

Superconducting RF crab cavities are being manufactured as part of the High-Luminosity LHC project at CERN. Amongst its related ancillaries, radiofrequency HOM (High Order Modes) couplers and field antennas are essential for reaching nominal performance during operation with high energy beams. This work presents recent developments on manufacturing techniques and processes for production of said RF components.

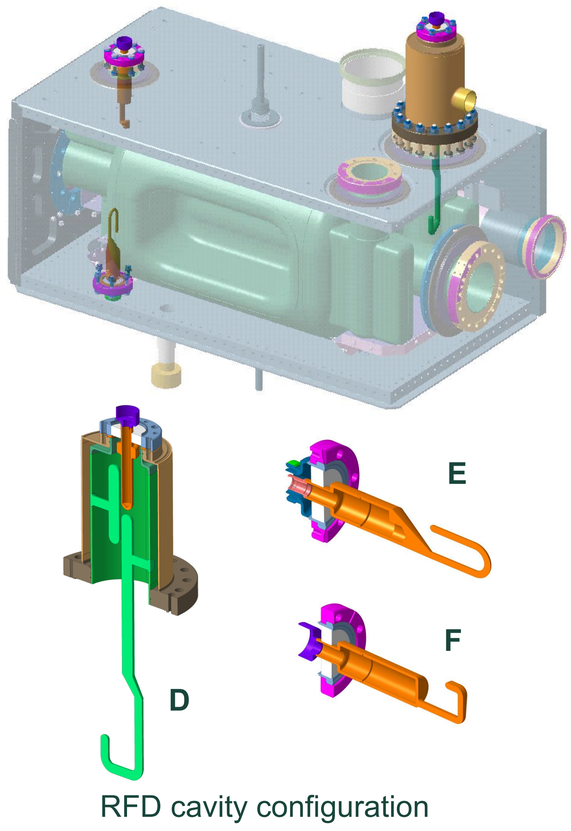
Design Specificities vs. Manufacturing Challenges

Specific variants of the so-called High Order Modes (HOM) couplers and RF field antennas have been engineered for both cavity types. Each system features 3D shapes with demanding manufacturing and assembly tolerances. SRF requirements impose tight precision on the final assemblies, with tolerance values reaching ± 0,2 mm.

Symbol	Coupler type	Tip geometry and specificity
Double Quarter-Wave (DQW) Cavity		
A	High-Order Mode supressor	Niobium hook with active LHe cooling, shape tolerance ± 0,15 mm
B	RF Field Antenna	Copper hook, shape tolerance ± 0,15 mm
C	HF-HOM suppressor	Niobium mushroom, shape tolerance ± 0,1 mm
Radiofrequency Dipole (RFD) Cavity		
D	Horizontal HOM supressor	Niobium hook with active LHe cooling, shape tolerance ± 0,1 mm
E	RF Field Antenna	Copper hook, shape tolerance ± 0,15 mm
F	Vertical HOM suppressor	Copper hook, shape tolerance ± 0,1 mm



DQW cavity configuration

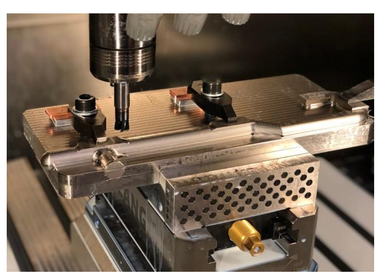


RFD cavity configuration

Fabrication Process Highlights

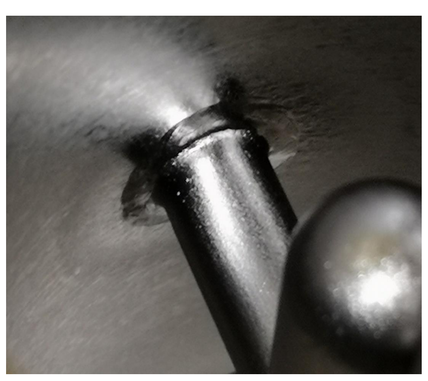
Machining

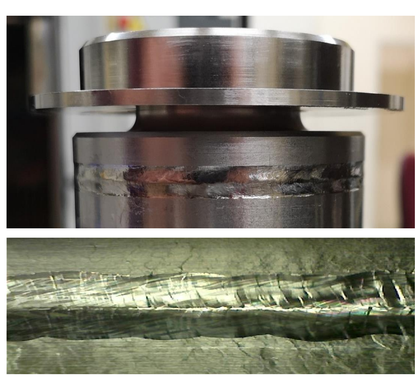
- Near Net Shape blanks and incremental machining as baseline for Nb and Cu tips.
- Performance assessment of several lubrication oils'.



Electron Beam Welding

- Definition of ideal joint designs.
- Extensive test campaigns to define the optimum parameters.

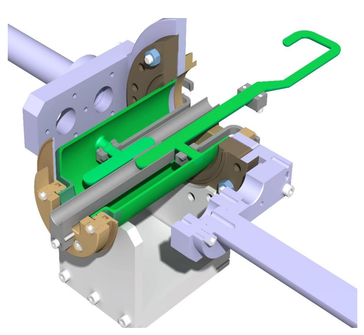


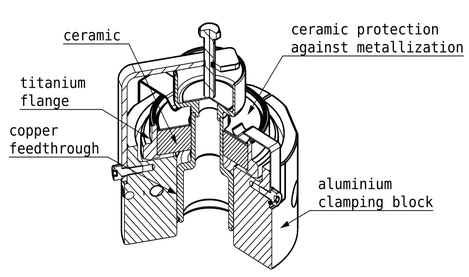


Synergy of multi-technology fabrication, R&D, strong on-site coordination and traceability follow-up

Tooling Design

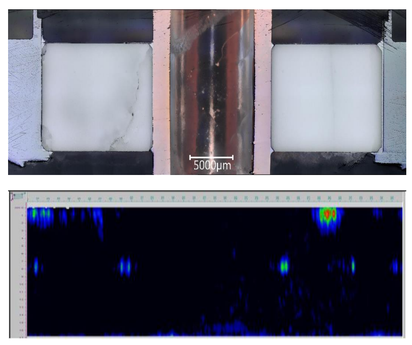
- Focus on final assembly tolerances.

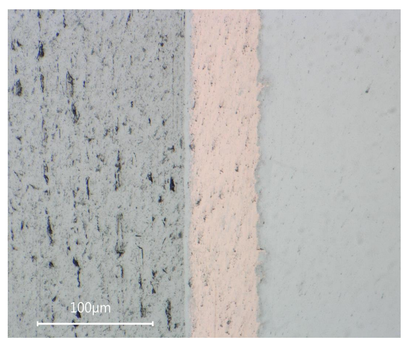




Vacuum Brazing

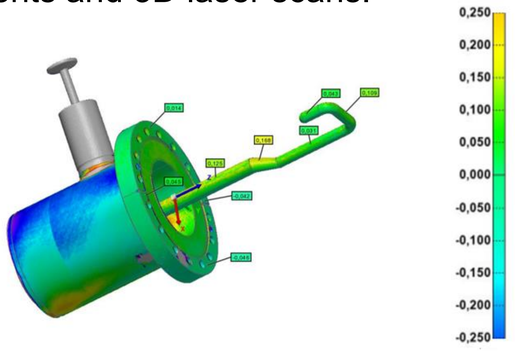
- Development of new brazed configuration for RF feedthrough.
- Systematic test campaign (thermal, mechanical shocks, NDT).





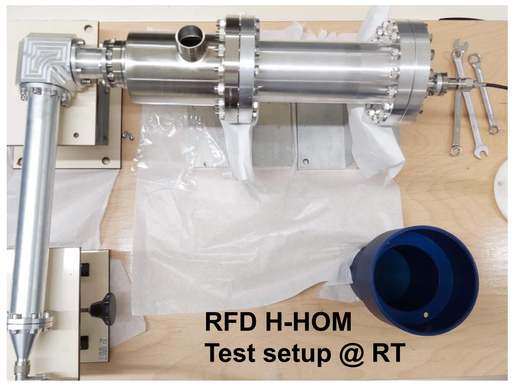
Metrology

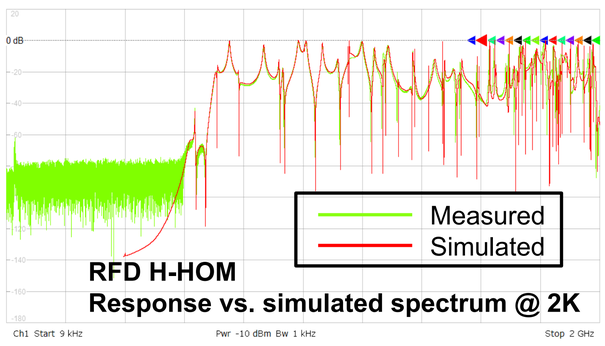
- Complex shapes impose combination of several solutions such as conventional, CMM measurements and 3D laser scans.



RF Validation

RF measurements both at room temperature and 2 K were performed and compared to the simulated response, to confirm that the manufactured couplers operate as intended. The measured frequency and quality factor of each HOM confirmed that the HOM couplers provide the correct amount of damping at the required frequencies.


RFD H-HOM
Test setup @ RT



RFD H-HOM
Response vs. simulated spectrum @ 2K

Conclusion

A full set of RF HOM couplers and field antennas was successfully manufactured at CERN main workshop, in compliance with the tight specifications imposed by SRF requirements. All procedures and parameters have been validated through various inspections and final RF measurements. Related inspection and quality strategy has ben thoroughly followed in line with the HL-LHC project standards.

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