XFEL Third Harmonic Superconducting Cavity Prototypes: Fabrication and Processing Experience

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Three superconducting 3.9 GHz cavity prototypes have been fabricated for the XFEL linac injector, with minor modifications to the RF structures built by FNAL for the FLASH linac. This paper describes the production procedures and the RF preparation experience , the chemical processing and the plans for the vertical test at INFN Milano for the characterization of the structures

Production

A small production of three RF structures has been tendered (under the supervision of INFN personnel) to one of the companies qualified for the XFEL cavity production, which will be responsible for the cavities fabrication and processing, up to the preparation for the vertical qualification tests at INFN/LASA.

For the development of the fabrication procedures and to assist in the commissioning of the necessary tooling for these new structures at the company (for fabrication, welding, field flatness tuning and surface processing) first a simplified copper RF mockup and later a complete Niobium mockup (using non RF-grade material, from discarded sheets after scanning) have been produced and the rf properties characterized at warm.

	Frequency MHZ	Length mm
3HZ01	3903.523	506.70 (+0.7)
3HZ02	3903.516	506.85 (+0.9)
3HZ03	3902.176	506.35 (+0.4)

Three structures have been fabricated and, based on the experience gathered from the mockups, the cavity length are within a mm from its nominal value, after a field flatness tuning and frequency adjustment following the fabrication.

To reach this length tolerance the cavities have been raised by 3 MHz than originally estimated by initial assumptions on the fabrication procedure.

Final frequency adjustment will be performed by increasing the nominal etching by less than 100 um (thickness is 2.8 mm)

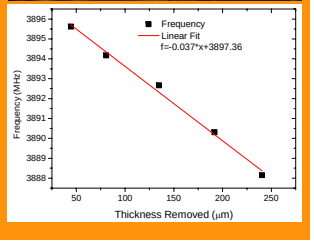
BCP Etching

The cavity etching facility has been designed and installed by the vendor. The system has a closed BCP circuit with an heat exchanger to keep the acid below 15 °C during the whole chemical process.

The niobium mockup has been used for the system commissioning and to asses the cavity sensitivity coefficient to etching.

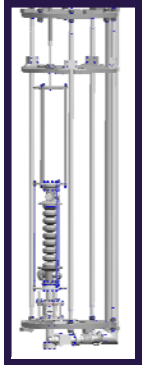
Material removal has been measured by cavity weight reduction, and cross-checked with on line Niobium samples.

For the facility commissioning the mockup cavity went through five steps of etching with a total material removal of 250 um. Fitting the frequency change with the material removal we obtain a sensitivity factor for chemical etching of 3.7 MHz / 100 um, in line with the FNAL experience.



Vertical Test at LASA

The existing large vertical cryostat, developed for 500 MHz cavities, is being modified for testing the 3.9 GHz cavities. The current subcooling pumping system is able to guarantee stable 2 K operation up to 13 W of dissipated power.



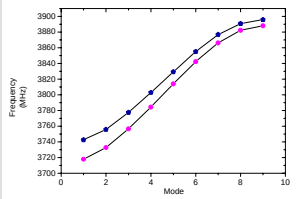
A class 10 clean room for equipping the cavity with the test antennas, and a High Pressure Rinsing system complete the available infrastructure.

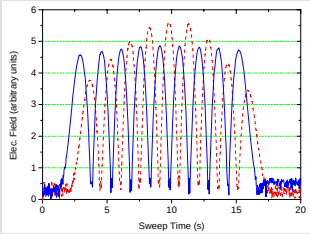
A variable antenna scheme provides optimal coupling to minimize reflected power. A room temperature linear actuator, will move the cavity in its frame within a 50 mm range (with precision of 8 um/half motor step), while the antenna is fixed to the bottom plate of the insert.

Cryogenic commissioning of the upgraded facility will be performed soon.

RF Characterization

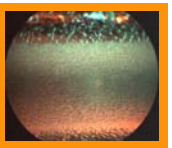
Each cavity has been tuned to the proper length and with a field flatness better than 95 %. The tuning procedure requires few iteration to converge.
The field flatness for niobium mockup has been checked after the etching and it was reduced to 50 % (blue curve). After two tuning cycles the field flatness was restored to 95 %.





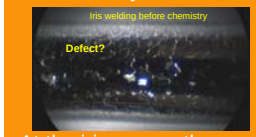
Analisys of the bandwidth change indicates a removal ratio of a factor of 2 between iris and equators.

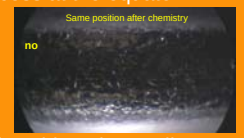
Optical Inspection before and after chemistry



Using a rigid boroscope system and a LED-based illuminating system, each cavity has been inspected before and after the chemistry.

The welding seam and the heat affected zone are clearly enhanced by the chemical process at the equator.





At the iris a smoother surface is achieved as well. Several suspect “defects” after fabrication disappeared after etch.

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