INFN MILANO - LASA ACTIVITIES FOR ESS

P. Michelato#, M. Bertucci, A. Bignami, A. Bosotti, J. Chen, L. Monaco, M. Moretti, R. Paparella, P. Pierini, D. Sertore, INFN Milano – LASA, Segrate (MI), Italy
H. Zheng, IHEP, Beijing, China
C. Pagani, Università degli Studi di Milano & INFN Milano - LASA, Segrate (MI), Italy

Abstract

INFN Milano – LASA is involved in the development and industrialization for the production of 704.4 MHz medium beta (β = 0.67) cavities for the ESS project. In this framework, we are designing a medium beta prototype cavity exploring both Large Grain and Fine Grain Niobium for its production as well as a high beta (β = 0.86) Large Grain cavity. In the meanwhile, an activity is ongoing for upgrading the LASA test facility to be able to test these kind of resonators.

INTRODUCTION

INFN is involved in the ESS project [1], contributing in kind with the Proton Sources and LEBT (low energy beam transport) system, the Drift Tube Linac and 36 massive Niobium Medium Beta (β=0.67) Superconducting cavities. INFN - LASA, in the framework of the WP5, in collaboration with CEA Saclay, is in charge for the development and industrialization of the 36 medium beta Superconducting Cavities.

The cavities will be fully produced, chemically treated and prepared for RF measurements at the industry, and will leave the company equipped with the He tank, ready to be cold tested in a vertical test facility. The LASA responsibility includes the cold characterization tests that will be performed in a qualified large European infrastructure capable of delivery a suitable test rate. The cavities, after the successful cold test, will be delivered to CEA Saclay for the string assembly and its integration in the cryomodule. The delivery of the first three cavities is scheduled for the end of 2017. The foreseen delivery rate for the series cavities is at least of one cavity per week, in order to comply with the present Project installation schedule.

Our strategy for the ESS medium beta cavities production is based on the design and construction of two “CEA design plug-compatible” medium beta cavity prototypes, employing both Large Grain (LG) [2] and Fine Grain (FG) Niobium. These cavity prototypes will be fully treated by the industry in order to qualify the production and treatment infrastructures for the series. This prototypical activity will allow us to carefully prepare, analyse and optimize procedures and develop tools that will be needed for the series production. In fact up to now no ESS cavity has been ever fully treated in an industrial infrastructure capable of delivery the needed production rate. Moreover, the possibility to compare the performances of the two medium beta cavities, based on the same geometry, but produced with different materials will be of great scientific interest for future superconducting linac based projects.

We intend also to design and build one prototype of a High Beta cavity (β=0.86) for ESS, using the same LG material which is already available for the medium beta cavities. Three prototypes will be then built: two medium beta cavities (one FG and one LG) and one LG High beta.

CAVITY PROTOTYPING

The cavity prototypes we are developing, have to be fully “plug compatible” with the CEA existing design and fulfil the interfaces as defined and documented by ESS. These interfaces are provided in order to fit the cryomodule, power coupler and tuner already developed by CEA for ESS.

For the medium beta superconducting cavities, the strategy, we followed, is based on an integrated approach where the electromagnetic and mechanical design are developed iteratively.

We explored two different possible cavity designs. The first one, identified as “Type 1”, is characterized by an asymmetric structure, with beam pipe tubes with two different diameters: a large tube diameter on the coupler side and a smaller diameter tube for the other side. This geometry is inspired by the SNS structures [3]. The second design, identified as “Type 2”, is instead a symmetric structure with tubes of the same diameter on both sides of the cavity. Figure 1 shows a sketch of the “Type 2” cavity.

Parameters of the two cavity designs are presented in paper THPB006 [4] while HOM calculations are discussed in paper THPB004 [5], both at this Conference. Mechanical analysis, for the final optimization of stiffening ring position, Lorentz force detuning, vacuum sensitivity, natural frequency evaluation, etc. is currently progressing with the development of the RF design.

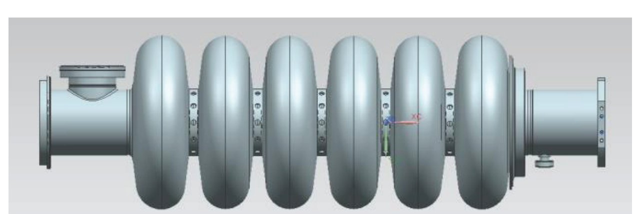

Figure 1: Sketch of the “Type 2” medium beta cavity.

Paolo.Michelato@mi.infn.it

ISBN 978-3-95450-178-6

As already discussed, we intend to produce two prototypes (one medium beta one high beta) cavities using Large Grain niobium, with the aim to explore the possibility that this material could offer a reduction of cost for the realization of future large scale superconducting linear accelerators. CBMM (Brazil) produced a high RRR Large Grain Nb ingot with a diameter compatible with the medium beta and high beta ESS SC cavities (about 480 mm), by using a special crucible and metallurgic techniques. The ingot was prepared this spring and it was available in July this year.
In order to produce cavities, the ingot must be sliced in disks. However, such a large and heavy ingot requires special machines. Heraeus GmbH at Hanau has such a machine and the slicing is foreseen for next October (week 43). Figure 2 shows the two ingots at Heraeus in preparation for the slicing process, just arrived from CBMM.

Figure 2: CBMM Large Grain ingots at Heraeus in preparation for the slicing process.

Figure 3 shows the wire sawing machine at Heraeus for an ingot of 300 mm diameter Nb.

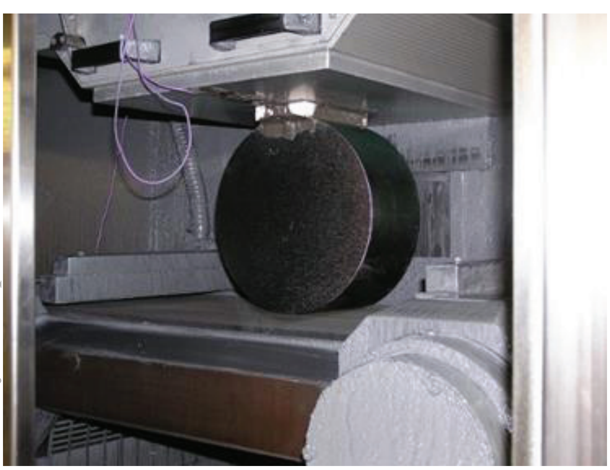

Figure 3: Wire sawing process at Heraeus for a 300 mm diameter ingot.

After the slicing process the Nb sheets, before the deep drawing of the half-cells for the cavity prototypes, will be chemically etched (BCP 1:1:2) to remove the few micrometers of mechanically damaged layer and heat treated at 600 °C in vacuum for restoring the RRR value.

European companies that are producing cavities for the E-XFEL are nowadays in the best position, both from the point of view of the knowledge and for the infrastructure status, for the first production of the three ESS plug compatible cavities.

LASA already tendered the construction and full treatment of the three cavity prototypes, starting from the half-cell deep drawing, up to the final assembly of ancillaries in the clean room. All wet processes (cavities will be etched using 1:1:2 BCP) will be done at the company, as well as all intermediate and final High Pressure Rinse (HPR) treatments. A total of about 150 micrometres will be removed by different chemical etching steps.

For these prototypes, based on the experience of the XFEL mass production and, in view of the future industrial production optimization, all the possibly significant process parameters will be recorded at each step of the production including cavity weight loss and frequency changes of the cavity fundamental modes when appropriate. The main treatment steps and the related parameters are summarized in Figure 4.

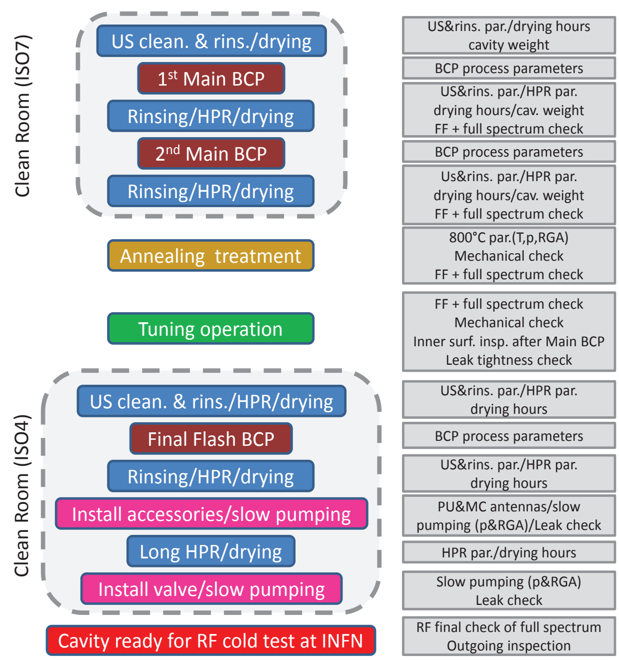

Figure 4: ESS prototype cavities treatment flow and recorded parameters.

Using the same strategy, we successfully applied for the E-XFEL cavities, each prototype structure will leave the company ready for the cold test at LASA, fully equipped with all ancillaries, and under vacuum.

First test of the medium beta prototypes at LASA are foreseen before mid 2016.

Due to the limited size of our infrastructure, only the prototypes will be tested at LASA, as the cryogenic infrastructure and manpower availability are not suited for testing the 36 medium beta series cavities in a time frame compatible with the project schedule. The cavities of the series production will be tested in a qualified infrastructure able to cope with a testing rate compatible with the ESS project tight scheduling.

LASA INFRASTRUCTURE UPGRADING

The LASA infrastructure needs anyway to be upgraded from its present state, in order to be able to handle and test the ESS prototypes.

Until the end of 2015 and for the first months of 2016, the LASA infrastructure will be still used for the characterization of the spare components for the 3rd harmonic system for the E-XFEL project (see paper MOPB007 at this conference [6]). Up to now, ten cavities had been successfully tested and other 10 are scheduled to be tested in the next 6 months.

LASA is equipped with a large bore cryostat (700 mm diameter, 4750 mm length), properly suited for the testing of the ESS prototypes. To avoid delays and any interference with the E-XFEL 3rd harmonic activities, we decided to design and build a new vertical insert dedicated to the ESS activities. A sketch of the new vertical insert is shown in Fig. 5. Its construction is in the starting phase and the delivery is foreseen by the end of 2015.

Figure 5: Model of the new cold insert for the ESS cavities test.

The cold insert vacuum system (cavity vacuum) is upgraded by the installation of a Residual Gas Analyzer (RGA) and of a turbomolecular pump (TMP) that is operated in parallel with a sputter ion pump (SIP). Both pumps are equipped with valves. This give chances to test successfully a cavity even in case of a small cold leak, and to perform leak checks of the system avoiding the He background produced by the SIP He backflow.

Recently, also in view of the upcoming ESS prototypes activity, we upgraded the LASA sub-cooling system with a 4000 m^3/h Roots type pump, thus extending the cryogenic capability of our test station to more than 40 W at 2 K. Available cooling power vs. temperature is shown in Figure 6.

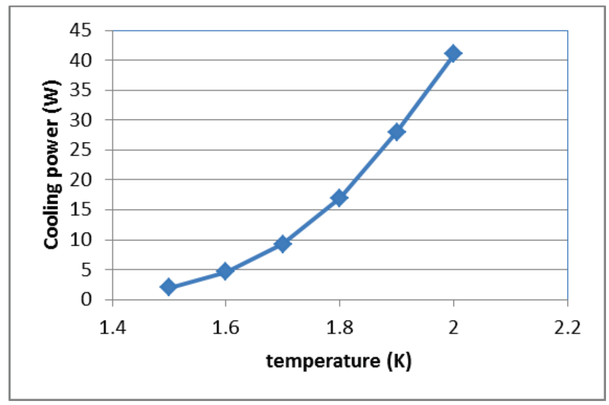

Figure 6: Cooling power vs. temperature for LASA cryogenic sub-cooling system.

The sub-cooling process is now fully controlled by a custom PID system that acts both modulating the aperture of a motorized valve on the fore pumping line and changing the speed of the Roots pump lobes.

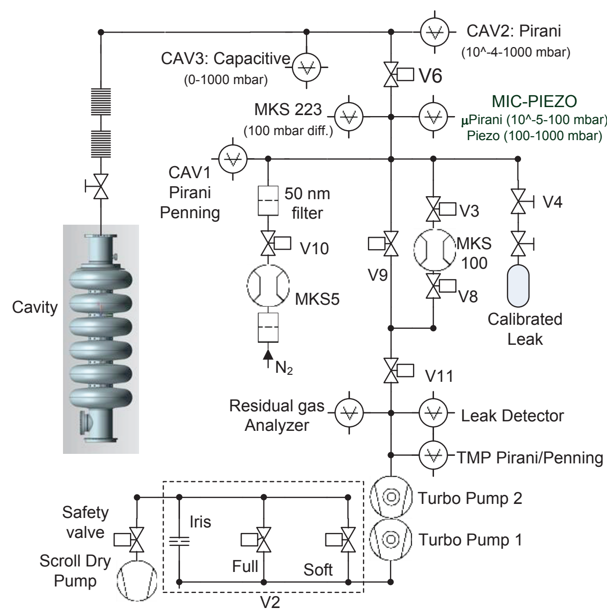

Figure 7: Layout of the LASA SPSV system.

Figure 7 shows our fully automated slow pumping slow venting system (SPSV), that was qualified and

ISBN 978-3-95450-178-6

demonstrated excellent reliability during the 3.9 GHz activities, will be used for the ESS prototypes, with updated parameters to handle the much larger vacuum volume of the cavities.

LASA Ultra-Pure Water (UPW) system is now able to produce 170 l/h of ASTM E2 electronic grade water, with an accumulation storage tank of 6000 l, and a maximum throughput of 600 l/h.

The RF system to test 700 MHz cavities is under realization. A power amplifier providing up to 600 W in the frequency range 500 – 800 MHz is already available at our lab.

The field flatness and frequency tuning of the cavity prototypes will be performed at the company, by INFN personnel together with the support of company trained operators, using the cavity tuning machine already existing at LASA (Fig. 8), designed and used for previous programs based on 700 MHz cavities [7].

Figure 8: The LASA cavity tuning machine.

The tuning machine will be refurbished in the next months and adapted to the ESS prototypes geometry.

The same tuning machine will be presumably used at the industry for the production of the series 36 medium beta cavities and the experience acquired during the prototype activities will be largely beneficial.

The LASA Clean Room, although it has a small footprint of only about 10 m^2, can be used for the handling of the ESS prototypes with limited changes: we could perform HPR (LEWA membrane pump, KARKER and CAT multi piston pumps), antennas assembly, leak check and pumping. However, as reported in the introduction, we plan to do as much as possible of the production steps at the industry, using and adjusting the infrastructure currently available for XFEL cavities and limit to the minimum any use of the LASA Clean Room. This strategy is mandatory in view of the future 36 medium beta series production and we plan to implement it already with these prototypes.

CONCLUSION

LASA has taken the responsibility for the production of the 36 medium beta superconducting cavities for ESS linac.

Two medium beta prototypes, with LASA optimized design and "plug compatible" with ESS cryomodule boundaries conditions and interface specification documents, will be built and tested before launching the series production. These tests will allow a direct comparison of the performances of two cavities built with the same geometry but with LG and FG material, respectively.

Moreover, in view of the cavity mass production for ESS, these prototypes will be produced and fully treated at the industry. Up to now, the first CEA ESS prototypes had been built in the industry but treated at CEA Saclay. Therefore, our prototypes will be used for a first set-up and verification of the future industrialization process of the series production. This choice represents also a first attempt to produce and full treat an ESS cavity in the industry.

Our actual plan, it is to have all three prototype cavities available for test at the LASA test facility by mid of 2016.

During 2016, we will have also to start the procurement of Nb for the series production and, by the end of the year, we will need also to launch the tender for the production of the series cavities. Indeed, series production needs to start at the beginning of 2017 and the first four cavities are expected to be ready at CEA for the integration in the ESS cryomodule by the end of 2017.

REFERENCES

[1] C. Darve et al., "The ESS Superconducting Linear Accelerator", MOP004, Proc. SRF2013, http://jacow.org/

[2] P. Kneisel et al., "Review of ingot niobium as a material for superconducting radiofrequency accelerating cavities", NIM A **774**, 133 (2015).

[3] J. Stovall et al., "Superconducting Linac for the SNS", TUD22, Proc. LINAC2000, http://jacow.org/.

[4] J. F. Chen at al., "Improvements of BuildCavity Code", THPB006, *these proceedings*, SRF2015, Whistler, BC, Canada (2015).

[5] H. J. Zheng et al., "HOM calculations for different cavities and beam induced HOM power analysis of ESS", THPB004, *these proceedings*, SRF2015, Whistler, BC, Canada (2015).

[6] D. Sertore et al., "Vertical Tests of XFEL 3rd Harmonic Cavities", MOPB077, *these proceedings*, SRF2015, Whistler, BC, Canada (2015).

[7] A. Bosotti et al., "Report on cavity A (TRASCO 502) Fabrication and Tests", CARE Note-2005-001-HIPPI, 2005.