SRF ACTIVITIES AT INFN MILANO - LASA

Carlo Pagani
University of Milano and INFN, LASA, Via Fratelli Cervi 201, I-20090 Segrate (MI), Italy

Abstract

The INFN Milano Group at LASA is involved in the TESLA/TTF Collaboration, with the responsibility of the design, manufacturing and assembling of the long (12 m) cryomodules and, in the past, of implementing with national industry the required know-how to produce a bunch of high quality SC cavities for TTF. In addition to that, our group is involved in the design and construction of reduced beta SC cavities for the TRASCO Program, a joint ENEA/INFN program for the design and prototype components of an Accelerator Driven System (ADS) for nuclear waste transmutation. A local test stand for the assembly and RF measurements of the cavities has been commissioned in LASA.

1 TESLA/TTF ACTIVITIES

In the framework of the TESLA/TTF International Collaboration, our group has designed and followed the fabrication with the Italian company ZANON, of all the six 12 m long cryostats that contain the active cold mass of the Phase II TTF linac. The group has been also responsible for the integration of the cold mass, quadrupoles and cavities with ancillaries, into the cryostats, in order to prepare the cryomodules for the installation in the TTF tunnel. The successful operation of both the prototype cryomodule and of the revised cryomodules installed for the Phase I of the TTF linac allowed to further improve and reduce the costs in a third revision of the cryomodule design. On this basis a longer version of the cryomodule, containing 12 instead of 8 cavities has been designed for the TESLA collider, and included in the Technical Design Report (TDR) [1].

1.1 3rd generation cryomodules

The third generation of the cryomodule design is the first that fulfills the TESLA500 requirements, and is compatible both with a semi-rigid coupler solution and with the possible use of superstructures. The major improvements in the design have been reported elsewhere [2-4] and part of them, mainly related to the cavity suspension system, are shown in Figure 1.

Three cryostats of the new type have been produced, pre-assembled in the factory and delivered to DESY. The first of them has been successfully assembled in July 2001, while the last two will be completed as soon as the cavity strings will be prepared and tested. We expect to have the three modules ready for the installation in the TTF tunnel by mid-2002. These new modules, together with the first three already assembled and (two of them) in operation, will complete the TTF Phase II and the Free Electron Laser (FEL) facility.

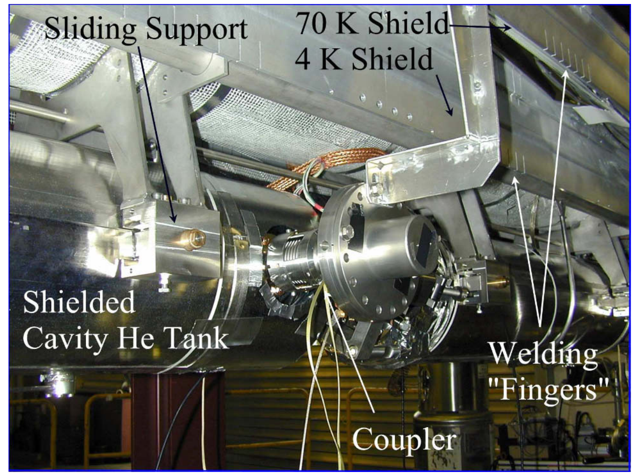

Figure 1: Details of the 3rd generation TTF cryomodule cold mass during installation in DESY.

Huge assembling tools are required to connect and align the active string to the HeGRP (He Gas Return Pipe), to integrate all the ancillary components, to weld and insulate the thermal shields and finally to slide the complete cold mass into the vacuum vessel. The existing tools have been modified and commissioned at DESY in order to be compatible with the old and new cryomodule designs. The modifications were required mainly because the last cryomodule design, the so-called 3rd generation cryomodule, has a smaller transverse cross-section and the longitudinal positions of the three suspension posts have been changed in order to guarantee a better stability of the quadrupole doublet against the external forces induced by the connection pipes.

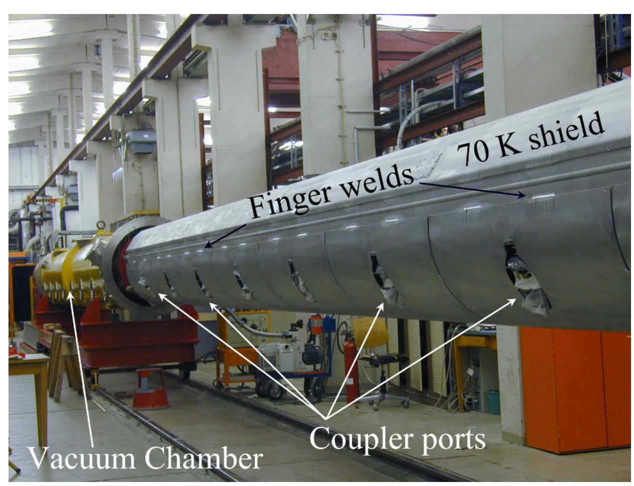

Figure 2: The assembled cryomodule, before the installation of the 30 layer MLI blanket and insertion into the vacuum chamber.

A picture of the cold mass on the assembling tools, before the installation of the last multi-layer insulation (MLI) sheets on the 70 K shield and the sliding into the vacuum chamber, is shown in Figure 2.

An industrial feasibility study for the mass production of the 2500 TESLA cryomodules has been performed and the results included in the TESLA TDR, together with the extrapolation to the new TESLA design that is foreseen to reduce the number of cryomodules (approx. 1700) of increased length (~17 m instead of ~ 12 m).

1.2 Cavities for TTF/TESLA

As already reported in the past Santa Fe workshop [2], our group has also been involved in the successful fabrication (through the Italian company ZANON) of some of the nine-cell cavities for the TTF linac. A total of 12 cavities have been fabricated for installation on the TTF linac. The best experimental result obtained so far is that presented on the TESLA TDR [1] that refers to the cavity A16, produced by INFN/ZANON, after the EP treatment performed at KEK. Figure 3, taken by the TDR, shows this outstanding result.

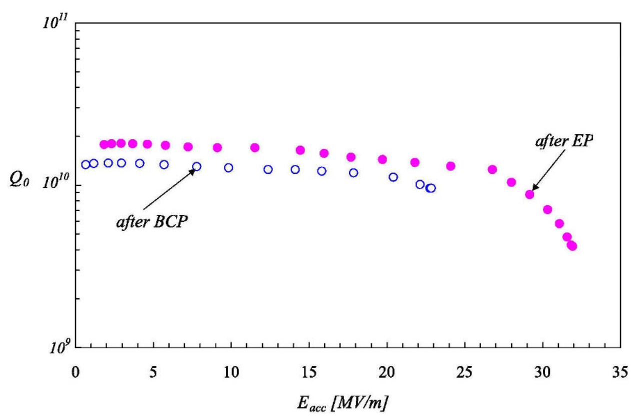

Figure 3: Best experimental results of the cavity A16, produced by INFN/ZANON, as measured at DESY after EP performed at KEK.

Similarly to the cryomodules, an industrial feasibility study for the mass production of the 20,000 TESLA superconducting cavities has been performed and the results included in the TESLA TDR.

1.3 New cavity tuner (blade-tuner)

The stiffening against the Lorentz force induced detuning and the longitudinal space requirements suggest the development of a completely different tuner design [5], and set its main parameters. With the collaboration of DESY a system based on bending joints has been dimensioned and produced. Figure 3 shows a detailed view of the final product. The tuner is completely made of titanium alloy, in order to be easily linked to the titanium helium vessel. The two outer rings are fixed to the helium tank by hard screwing while the central ring is divided into two independent semicircular parts, as suggested by H.-B. Peters [6]. The shape and the geometry of the bending joints (blades) produce the tuning movements when the two half rings are turned in opposing direction, the rotation is, in fact, transformed by the joints in longitudinal movements.

To avoid buckling of the thin joints, these are pre-bent to half of the total allowed movement. The rotation of the two half rings is driven by a cold step-motor acting a pivoting leverage system that multiplies the force of the driver to bend the flexural joints and to tune the cavity.

The main modification we have introduced in the tuner design with respect to the proposals of Refs. [5,6] is the use of e-beam welded blades. This drastically reduces the costs, with respect to the complex fabrication procedure originally envisaged, while improving the performances.

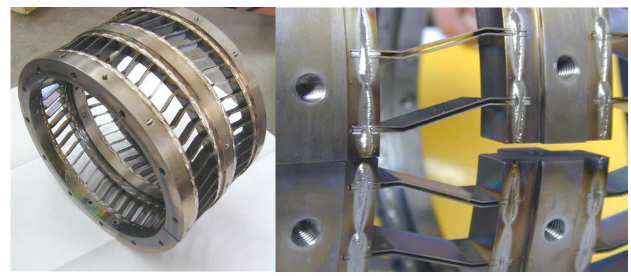

Figure 4: Left: Picture of the new blade tuner. Right: details of the blades electron-beam welding.

2 TRASCO SC LINAC ACTIVITIES

As part of an extension of the TRASCO Program [7,8], a test area for cavity assembling and tests has been commissioned in LASA, and is now ready to perform cold RF tests.

In the meanwhile, four single cell β=0.5 cavities of the TRASCO design [9] have been manufactured by ZANON, both with reactor grade and with high-grade (RRR>250) niobium sheets. The two low niobium grade cavities have been chemically treated and tested at CEA/Saclay, and, in spite of our limited expectances from the test, have exceeded the TRASCO specifications [8]. A single cell high-grade cavity has been sent to TJNAF for the chemical treatments and for the RF tests.

We have ordered the high-grade niobium for the manufacturing of two five-cell structures.

2.1 Commissioning of the cavity test facility

For the tests of the TRASCO cavities a RF test bench system is being set up in our laboratory. The test area consists in a vertical cryostat for RF measurements, a class-10 clean room for the assembly of cavity components and a high-pressure water rinse (HPR) station using ultra pure water (18 MΩ cm).

The class-10/100 clean room (3 m times 3 m) has been recently completed and put into operation.

The RF test stand is equipped with a 500 W amplifier in the UHF band (400-800 MHz), and a rotating fixture in the cryostat allows the thermal mapping of the cavity during the measurements.

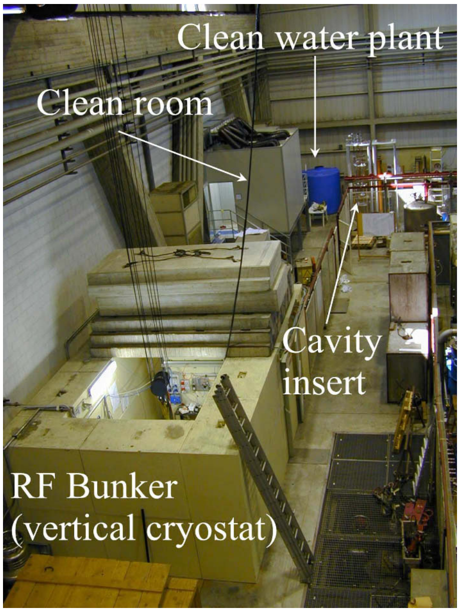

Figure 5: The RF test area in LASA.

The RF test system (amplifier, phase-locked loop and read-out electronics) has been successfully operated last year during the measurements with an existing 500 MHz SC electron cavity and has been integrated in the computerized control and data acquisition system of the facility. A new adjustable insert [10] for the existing large vertical cryostat (700 mm diameter, originally designed for another INFN program with 500 MHz SC cavities) has been fabricated, for the measurements of the different TRASCO cavity prototypes (single-cell and multi-cell cavities with different lengths). The insert fits into a smaller (580 mm diameter) helium vessel that allows reducing the helium consumption for the 700 MHz measurements.

Figure 6: The Clean room area.

The HPR system is being fabricated and will be assembled in the clean room area for the final rinsing of the cavity before the RF tests. The ultra pure water system has been commissioned and is in operation (providing a 10 l/min flow of 18 MΩ cm water and a stock of 6000 l of 1 MΩ cm water); the test area will be ready to receive the first 700 MHz cavities at the end of 2001.

A thorough cryogenic test on the vertical cryostat (without placing any cavity in the insert) has been performed this year, reaching a temperature of 1.8 K by pumping on the He bath. The test was particularly aimed at testing the new adjustable cryostat insert and at verifying the natural convection pre-cooling procedure that is employed during the cooldown, allowing us to minimize He use and to prevent gas mixture between He and N_2 [10].

Finally, an arrangement with a local chemical company is being set up for the buffered chemical polishing (BCP) treatment of the cavities needed before the RF tests.

The Z101 cavity has been prepared at Saclay with a different assembly to fit our vertical insert and will be tested soon in LASA for the final commissioning of the test area.

2.2 β=0.5 single cell cavity tests

Two single cell cavities have been built with reactor–grade niobium mainly to test all the fabrication tooling. Nonetheless, since our test area was not yet commissioned, we sent the two cavities to CEA/Saclay for chemical treatments and RF measurements. A standard BCP with an acid mixture of HF, HNO_3 and H_3PO_4 (1:1:2 in ratio) was used for 115 minutes, removing approximately 100 μm on both the internal and external cavity surfaces.

Figure 4 shows pictures of the two β=0.5 cavities measured in Saclay.

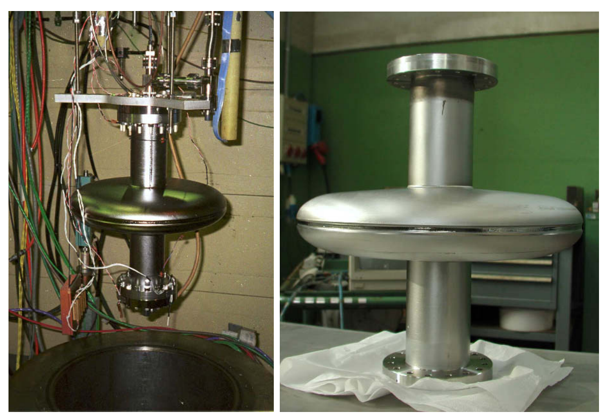

Figure 7: Left: the Z101 cavity at Saclay during measurements. Right: The Z102 cavity in ZANON.

The results of the measurements are shown in Figure 5. The red dots correspond to the Z101 cavity and the blue squares to the Z102 cavity. Both cavities showed a good behavior of the measured Q_0 with respect to the accelerating field E_{acc} up to the field of approximately 10.5 MV/m, where a sudden quench was experienced.

No evidence of multipacting barriers that could not be successfully processed was found during the measurements.

The total surface resistance R_s at 2 K was estimated to be approximately 4 nΩ. This result is consistent, in terms of residual resistances, both with the TESLA experience [11] and with the recent measurements of the RIA β=0.5 single-cell cavities performed at TJNAF [12]. In all cases the residual surface resistance contributes with a few nΩ to the total surface resistance.

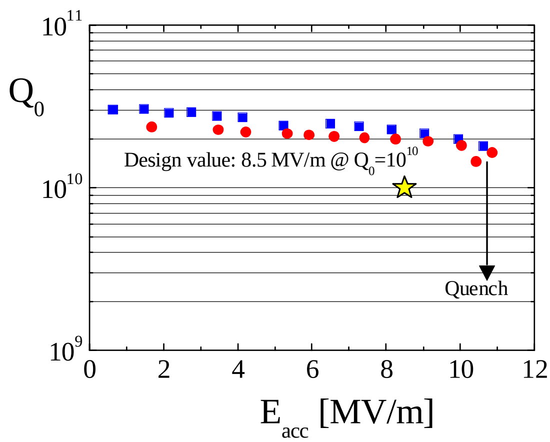

Figure 8: The Q_0 vs E_{acc} curve for the two low-grade niobium cavities (Z101: red dots and Z102: blue squares).

For sake of completeness, the main geometrical and electromagnetic cavity parameters are reported in Table 1.

Table 1. Z101 Cavity parameters

Geometrical β	0.47
Nominal Frequency [MHz]	699.6
E_p/E_{acc}	2.81
B_p/E_{acc} [mT/(MV/m)]	5.39
Geometrical factor [Ohm]	147.8
Iris bore radius [mm]	40.0
Cell length (iris to iris) [mm]	100.0
Wall inclination [deg]	5.5
Equator ellipse aspect ratio	1.6
Iris ellipse aspect ratio	1.3
Cavity Diameter [mm]	187.04
Length of each beam tube [mm]	160.0

2.3 Further developments with CERN

The TRASCO program foresees also an R&D activity in collaboration with CERN on the development of sputtered (Niobium on Copper) β=0.85 cavities. Both a single cell and a five cell cavity prototype have been built and tested in a vertical cryostat at CERN [13], exceeding the design goals. After these successful tests, the five cell cavity has been equipped with standard LEP-II components (main and HOM couplers, tuners and ancillaries), an Helium tank and installed in a spare LEP-II horizontal cryostat. The results of these tests are reported in a separate contribution to these Proceedings [14].

3 ACKNOWLEDGMENTS

We are greatly indebted with the CEA/Saclay and IN2P3/Orsay SC RF cavities group for the chemical treatments and the tests of the Z101/Z102 cavities.

We would also like to thank the support from Zanon, in particular G. Corniani, G. Basoni and M. Festa, for the cavity fabrication, tooling and electron beam welding.

4 REFERENCES

[1] TESLA, TECHNICAL DESIGN REPORT, DESY 2001-011, ECFA 2001-209, TESLA Report 2001-23, TESLA-FEL 2001-05.

[2] C. Pagani, SUPERCONDUCTING RF ACTIVITIES AT INFN MILANO-LASA, in Proc. of the 9th Workshop on RF Superconductivity, Santa Fe, NM USA, 1999.

[3] C. Pagani, ADVANCES IN CRYOMODULE DESIGN AND NEW APPROCHES, in Proc. of the 9th Workshop on RF Superconductivity, Santa Fe, NM USA, 1999.

[4] C. Pagani, D. Barni, M. Bonezzi, J.G. Weisend II, FURTHER IMPROVEMENTS OF THE TESLA TEST FACILITY CRYOSTAT IN VIEW OF THE TESLA COLLIDER, Advances in Cryogenic Engineering, Vol. 45A, Edited by Q-S. Shu, Plenum Press, New York, 1999.

[5] H. Kaiser, NEW APPROACHES TO TUNING OF TESLA RESONATORS, in Proc. of the 9th Workshop on RF Superconductivity, Santa Fe, NM USA, 1999.

[6] H.-B. Peters, Private communication.

[7] The TRASCO_AC Group, STATUS OF THE HIGH CURRENT PROTON ACCELERATOR FOR THE TRASCO PROGRAM, Internal Report INFN/TC-00/23, 21 December 2000; http://www.lnf.infn.it/sis.

[8] D. Barni, THE TRASCO PROJECT, in these Proceedings.

[9] P. Pierini, D. Barni, A. Bosotti, G. Ciovati, C. Pagani, CAVITY DESIGN TOOLS AND APPLICATIONS TO THE TRASCO PROJECT, in Proc. of the 9th Workshop on RF Superconductivity, Santa Fe, NM USA, 1999.

[10] D. Barni, C. Gesmundo, C. Pagani, G. Varisco, BETA TUNABLE 700 MHZ INSERT WITH NATURAL CONVECTION PRECOOLING, in Proc. of the 9th Workshop on RF Superconductivity, Santa Fe, NM USA, 1999.

[11] B. Aune et al., SUPERCONDUCTING TESLA CAVITIES, Phys. Rev. ST-AB, Vol. 3, 092001 (2000).

[12] W. Hartung et al, NIOBIUM CAVITY DE-VELOPMENT FOR THE HIGH-ENERGY LINAC OF THE RARE ISOTOPE ACCELERATOR, in these Proceedings.

[13] E: Chiaveri et al, PROCUCTION AND TEST OF THE PROTOTYPE BETA 0.85 FIVE CELL CAVITY FOR THE TRASCO PROJECT, in Proc. of the 9th Workshop on RF Superconductivity, Santa Fe, NM USA, 1999.

[14] E: Chiaveri et al, HIGH POWER TESTS OF THE PROTOTYPE 352 MHZ BETA 0.85 FIVE CELL CAVITY FOR THE TRASCO PROJECT, in these Proceedings.