RF SUPERCONDUCTIVITY AT INFN_GENOA

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Abstract

The main activities of the Genoa Group are endowed by INFN under the ENEA-INFN joint Project for the development of the prototype components for an Accelerator Driven System for Nuclear Waste Transmutation. (TRASCO project)

The Genoa Group (jointly with the INFN_Milan Group) works on the development of the Prototype structure of the High-Energy section of the linac (proton beta ranging from ~0.5 to ~ 0.85).

The results achieved in the 1999 on that project are quite encouraging; a 5 cell sputtered cavity (beta 0.8, built and tested at CERN in 1999) reached the design values for the accelerating Field (5.5MV/m) and the RF Losses (Qo=2.5e9 at the design field) [1]

At the side of the Trasco Project the group is working to the development of a detection system for small Displacements (10e-20 cm) using Two coupled superconducting cavities. (PACO Project) [2]

If successful the method should be used for the development of a Gravitational Waves detector covering an interval of the frequency spectrum not accessible to the Gravitational-Wave detectors today tacking data or under construction.

The two main activities of the group are backed by a wide experimentation on the effect of the surface preparation and contamination of the niobium (sputtered or Bulk) on the RF Losses and the maximum achievable Field in RF cavities [3], [4]

This activity is performed by XPS-Auger analyses coupled to the tests of RF cavity prototypes used to translate to a real accelerating device the information gathered on the small test samples.

1 REDUCED BETA PROTOTYPE CAVITIES AND STRUCTURES.

The main activities of the Genoa Group are related to the Italian R&D effort for the development of the main components of an Accelerator Driven Nuclear Power Plant.

This R&D project TRASCO is jointly financed by INFN and ENEA trough a two-year grant for the Technology Transfer of the Italian government.

The Genoa Group works, jointly with the Milano-LASA INFN group, to the design, development and test of the High Energy section (100 Mev to 1Gev) of the high current (30 mA) proton linac driving the neutron source used to keep running the sub-critical nuclear boiler.

The Genoa Group is responsible for the part of the R&D program involving the production and tests of reduced beta cavities of the main linac operating at 350 MHz.

The β=0.85 cavities are produced at CERN by sputtering, using the “Standard LEP ” cavity building procedure.

Minor changes are introduce to match the slightly different geometry of the Trasco Linac.

The development of the 350 MHz prototypes is jointly performed by the CERN SL-CT Group and INFN under a Collaboration agreement.

The First step of this programme was the production and Test of a single cell cavity to assess the quality of the Niobium Film on the Trasco β=0.85 Geometry.

The cavity exceeded the Trasco Design Goal (Qo=3×10^9 @ 4.5 K and 5.5 MV/m accelerating Field) at the second film deposition, after only 600 seconds of Helium processing; the accelerating field @ Qo=10^9 was 8.5 MV/m .

The Qo versus accelerating field Plot for the single cell cavity is shown on figure 1.

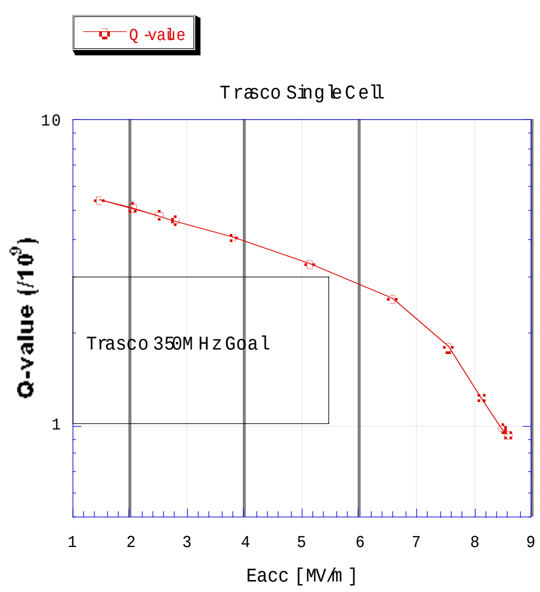

Figure 1: Q versus accelerating field Plot, single cell cavity

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The set of deposition parameters used for the Niobium sputtering was used for the deposition of the five-cell cavity of the prototype five-cell module.
The resulting Qo versus field curve is shown in figure 2.

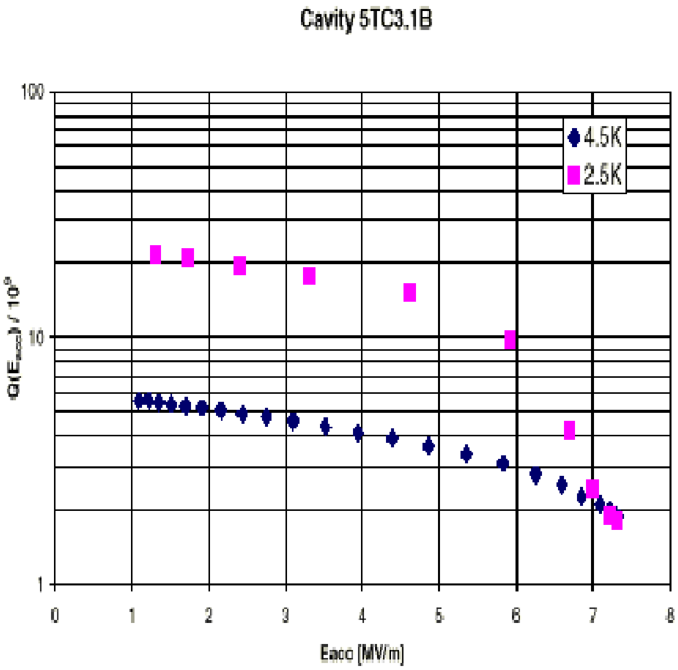

Figure 2, Qo versus accelerating field for the five cell Trasco Structure; the measurements re taken at 4.5 Kelvin (the foreseen operating temperature) and 2.5 Kelvin.

The next step in the Program is the extension of the Collaboration agreement to allow the tests of the β=0.85 module (fully equipped with a power coupler and HOM couplers) in a LEP Style Cryostat. The aim of those tests is the demonstration of the behaviour of a fully equipped accelerating module in a "Ready for the linac" environment.

The CERN-INFN agreement foresees also the possibility of chemical polishing and testing at CERN the β=.5 bulk niobium prototypes produced for the Trasco Project.

The Genoa Group is working on that part of the Program developing models and checking the construction technique and the measurement system to fine tune the Low beta structure to achieve an optimum field flatness.

A Typical prototype of a β=.5 multicell cavity is shown on figure three.

As a side activity on that program The Genoa group is extensively performing computer simulations on the Multipactoring discharges and electron loading of the Trasco RF structures using the Proprietary Codes OSCAR2d and TWTRAJ [5],[6].

The group is also designing the couplers for the modules checking the effect on the axial field distribution produced by the large coaxial feeder.

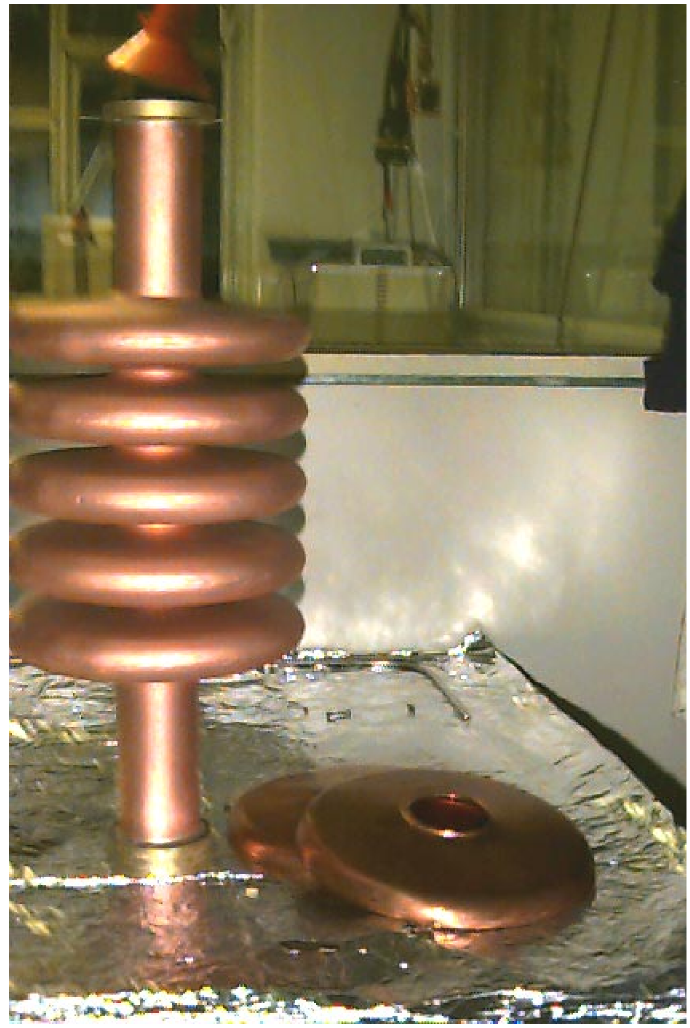

Figure 3, low beta structure and half-cells built in Genoa for mechanical, electrical and fabrication tests.

To do that The HFSS Code [7] is used together with some ad Hoc post processors specially developed in Genoa.

2 NON ACCELERATING CAVITIES FOR GRAVITATIONAL WAVE DETECTORS

The second line of research of the Genoa Group is the development of a prototype of a gravitational wave detector using two coupled S/C cavities working as a **PA**rametric **CO**nverter.

This research programme is endowed by INFN trough a three research grant called "PACO EXPERIMENT"

The basic idea of this detector comes from an idea developed in the late seventies by L. Radicati et al. [8] at CERN and at the Scuola Superiore Normale in Pisa in the late seventies.

The interaction between the Gravitational Wave (if any) and the Electromagnetic field stored in the lower mode of two coupled superconducting cavities will up-convert with

a great efficiency RF power to the upper mode of the system.
The concept of the detector was experimentally implemented by A.Melissinos and co-workers [9] at the Rochester University in the early eighties.
The device takes advantage of The High quality factors of superconducting cavities to enhance the detection sensitivity of the Electromagnetic field up-converter.
In our scheme (using a double input and double output port) an higher rejection of the RF leakage from the Input to the output port is obtained improving the system sensitivity by a factor hundred at least (we have 10^4 as goal).
The First prototype of the Cavity is now extensively used to check the behaviour of the electronic circuits used to push the rejection of the unwanted RF signals.

Figure 4, The PACO Cavity and the test Set-up.

The detector is now in the early commissioning stage. Despite some serious mishaps in the Cavity construction, we reached at the first trial a sensitivity of 10^{-16} Watts corresponding to gravitational wave amplitude of $5x10^{-16}$.
The main limitations comes from a light unbalance between the coupling loops of the drive port of the cavity.
The PACO cavity and the test Jig, before the insertion in the measurement cryostat, are shown on figure 4.
The research on that detector is foreseen to last for the 2000 FY having the goal of demonstrating the possibility of an ultimate sensitivity of 10^{-20} for the detection of a gravitational wave.

4 STUDIES OF LIMITATIONS IN SUPERCONDUCTING CAVITIES

The third activity of the group is a basic research in the field of the RF superconductivity. The aim is to assess the fundamental mechanisms underlying the limitation so often encountered in the field of the RF superconductivity.
The starting point of our activity is a cross-fertilisation of the experience we gathered in the RF superconductivity field with the wide activity on the surface science and material science existing in the Genoa University Physics Department.
The use of a state of the art XPS Auger surface analysis system, allowed us to get paramount information about the chemistry of the niobium surface on a microscopic (few microns) scale.
The combination of that information (with the possibility of analyse in a non destructive way the composition of the first 20 layers (30 nm) of the material) allows us to fine tune the surface treatments of our S/C cavities and get invaluable information on the effect of different treatments on the cavity performances.

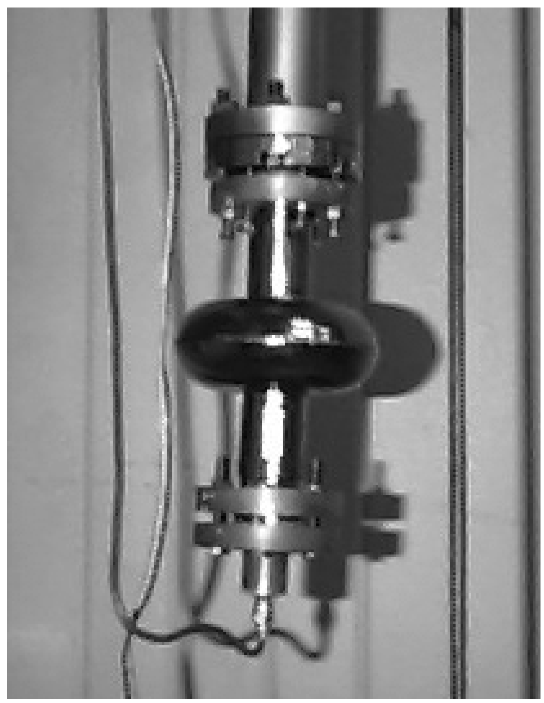

Figure 5, Typical 3 GHz cavity used in Genoa to test surface treatments.

Using the aforementioned information we succeeded to define a surface treatment procedure resulting in a 45% improvement (from 20 MV/m to 32 MV/m) in the maximum achievable accelerating field of a 3GHz-accelerating Cavity.
This process, based upon a dry oxidisation of the cavity surface after a medium temperature annealing, gives us

also the side benefit of increasing the Niobium work function 5.2-5.4 eV, with a very strong reduction of the NREL of the cavity at High Field.
The Intensity of the Fowler–Nordheim electrons is completely undetectable.
The typical plot of the Qo versus accelerating field for a Dry Treated cavity is reported on Figure 6.

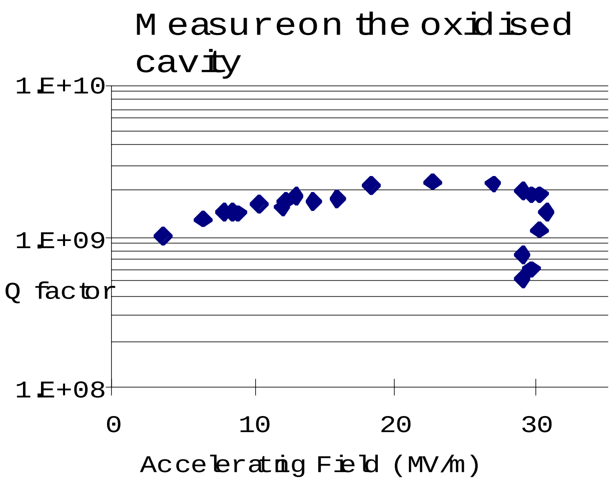

Figure 6, Qo vs Accelerating field for the Dry Oxidised Cavity.

The cavity was installed on the test set-up, without any further surface treatment, the maximum accelerating field was reached in a smooth and regular way without any need of further conditioning of the cavity surface.
The surface of the cavity was very stable and the cavity characteristic does not change substantially even after a lot of thermal cycling from 1.8 to 300 Kelvin.

The ESCA AUGER System used in Genoa is shown in figure 7.

Figure 7, XPS Auger Surface Analysis System used for Surface investigation of the Niobium properties.

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