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 2001 on that projects are quite encouraging; a "Linac Ready"5 cell sputtered cavity (beta 0.8, built and tested at CERN in 2000) was tested in a machine ready configuration.

At the side of the Trasco Project the group is working to the development of a detection system for small Displacements (10^{-20} cm) using two coupled superconducting cavities. (PACO Project)

The method was proven successful achieving a sensitivity 10^{-20} with a prototype cavity working at 3 GHz.

This new detector is now the basis for the design of a two spherical cavity resonator to 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 (in collaboration with the CEA Group) 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 cavity

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

Last the group is pursuing the analysis of the Multipacting (MP) in RF cavities by updating and developing the TRAJECT code for MP simulation. The results of the simulations are validated by comparison with measurements on prototype cavities (mainly low beta).

1 TRASCO CAVITIES

The β=0.85 five cell cavity tested for Qo and Maximum Field in the early 1999 [1] year was installed in Modified LEP II Type Cryostat to test the module performance

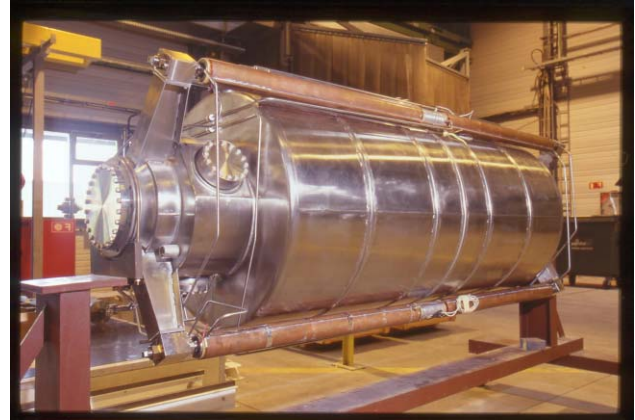In a " machine ready" configuration under an extension of the INFN_CERN agreement on this subject

Figure 1, Five cell β=0.85 Trasco Cavity housed in the helium tank

Despite some bad luck during the tests, preventing us to get the ultimate field of the cavity the preliminary results show no degradation of the Qo of the cavity at list up to the maximum field reached (4MV/m)[2].
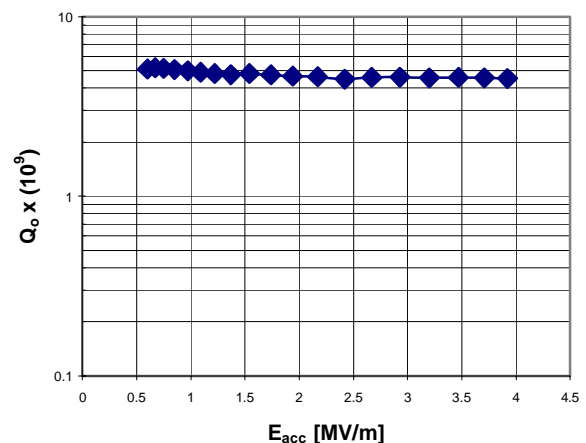
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Figure 2, first results for the Horizontal Cryostat cavity test.

The limitation in the maximum Accelerating field was due to the maximum available RF power.

The limitation was produced by the impossibility of tuning the module to the right Klystron frequency due to a broken fast tuner

The obtained result even if preliminary, confirms the viability of the niobium on copper option to build a High Intensity Proton linac.

2 DEVELOPMENT OF A PROTOTPE GRAVITATIONAL WAVED DETECTOR

At the side of the Trasco Project the group is working to the development of a detection system for small Displacements (10^{-20} cm) using two modes of a resonator obtained coupling two superconducting cavities. (PACO Project).

The method was proven successful achieving a sensitivity 10^{-20} with a prototype cavity working at 3 GHz.

This new detector is now the basis for the design of a two spherical cavity resonator to 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.

2.1 Recent Results

The power transfer between the levels of a resonator made up of two pill-box cavities, mounted *end-to-end* and coupled by a small circular aperture in their common end wall, was checked in a series of experiments by Melissinos et al., where the perturbation of the resonator volume was induced by a piezoelectric crystal.

Recently the experiment was repeated by our group with an improved experimental set-up; we obtained an order of magnitude sensitivity to fractional deformations of the resonator length as small as $\delta\ell/\ell \approx 10^{-20}$ Hz$^{-1/2.}$

The cavity developed is shown on figure 3

Figure 3. PACO cavity mounted in the test cryostat.

2.2 Detector developments

The new detector now under construction at Genoa will be used to demonstrate the viability of a real detector including all the relevant features of the final Detector (on a one to four scale).

The main points to assess are

- The possibility to obtain the sensitivity of $\delta\ell/\ell \approx 10^{-20}$ Hz$^{-1/2.}$ At a detection frequency in the 1-10 KHz range.
- The possibility to precisely tune the detector to a given frequency (of astrophysical interest) by changing the coupling of the cavities giving the frequency splitting of the two resonator modes

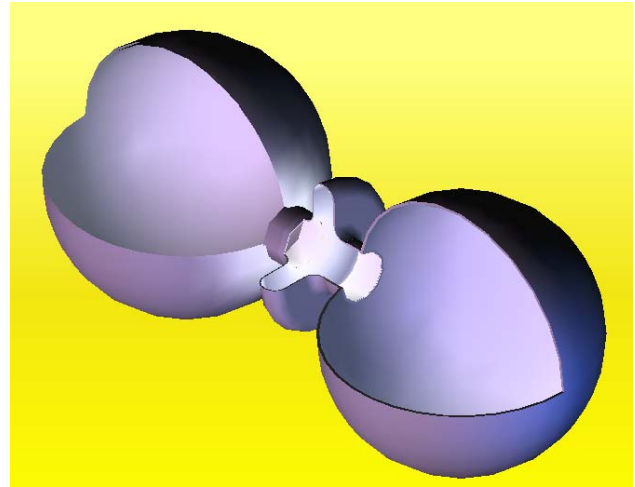The artistic view of the resonator, now at the production stage, is shown on figure 4.

Figure 4, artistic view of the Paco Cavity detector

2.3 Building technique.

The choice between bulk niobium or niobium-on-copper for the final design is still under investigation. Both techniques give in principle advantages and drawbacks. A first prototype resonator in bulk niobium will be built at CERN in 2002.

A single cell, seamless, copper spherical cavity has been built at INFN-LNL by E. Palmieri and will be sputter coated at CERN (see Figure 5).

Figure 5. Single cell, seamless, spherical cavity, built at INFN-LNL, to be sputter coated at CERN.

3 NIOBIUM SURFACE CHEMISTRY

The two main activities of the group are backed by a wide experimentation (in collaboration with the CEA Group) [4] 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 cavity

3.1 The experimental Set-up

This activity id 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.

The Surface analysis System is shown in figure 6.

Figure 6, The XPS-Auger apparatus used for the Niobium surface analysis.

The apparatus combines a moderate resolution XPS System (minimums spot 30 μm) with Chemical Imaging possibility, (using a monochromatic aluminium Kα source) and a sub micron (Typical lateral resolution 300 nm) Auger electron gun with possibility of Secondary and Backscattered electron microscopy with energy in the range 1-10 Kev.

The analysis system is equipped with an Argon Ion Gun for surface cleaning and depth profiling and a sample Holder allowing heating the sample up to 1300 K with a temperature stability of less than one Kelvin.

3.2 Niobium surface analysis

In Figure 7 and Figure 8, some pre-processed XPS data for Nb and O are shown. As it is easily seen, some spectra almost overlap and some are very different.

We assume that each spectrum is a linear combination of a certain number of well-defined chemical states and we say that the difference in the spectral shape is due to the different weights of these chemical components.
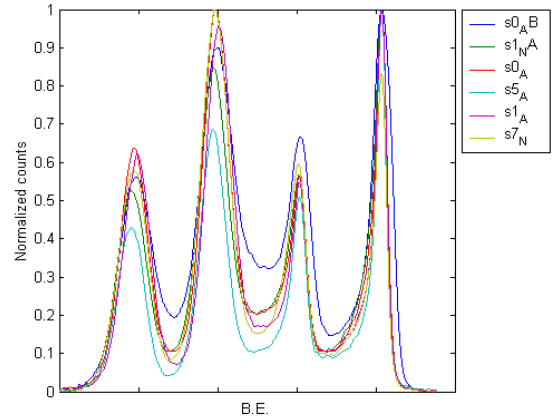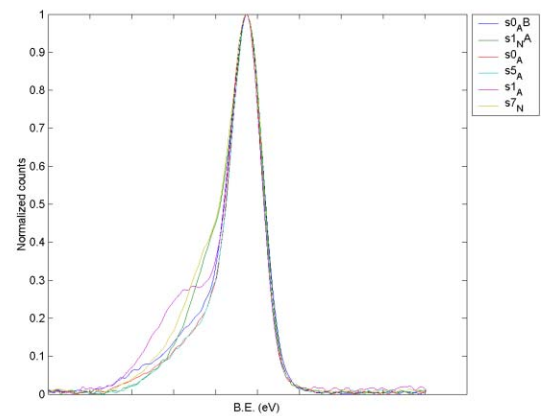

Figure 7: Niobium spectra, take-off angle 75º

Figure 8. Oxygen spectra, take-off angle 75º

Statistical analysis of the spectra components, corresponding to different chemical stated of the niobium, to will (we hope) give information about the effectiveness of a different surface preparation techniques in obtaining High Field values and lower RF losses.

4 MULTIPACTING SIMULATION CODE

Last the group is pursuing the analysis of the Multipacting (MP) in RF cavities by updating and developing the TRAJECT code for MP simulation. The results of the simulations are validated by comparison with measurements on prototype cavities (mainly low beta).

4.1 The simulation code Twtraj

The TWtraj code [5] (A.K.A. in the past as NEWTRAJ and TRAJECT) program is developed from the early version written in KFK-Karlsruhe by Juergen Halbritter in the middle seventies.

The code, together wit on OSCAR, the companion code computing the RF fields used for the simulations was in the 2000 revised to run on a standard PC.

The TWtraj code reads the field from the Oscar2D solution and computes the trajectories

The latest version includes some features formerly developed for special purpose application, like the possibility of computing trajectories in Travelling Wave structures, or the possibility of superimposing a Static Magnetic field (as usual in normal conducting Buncher cavities and low energy sections of Normal Conducting linacs)

A typical Plot of computed trajectories in a 1300 MHz TESLA like cavity at 27 MV/m accelerating field level is shown on Figure 9
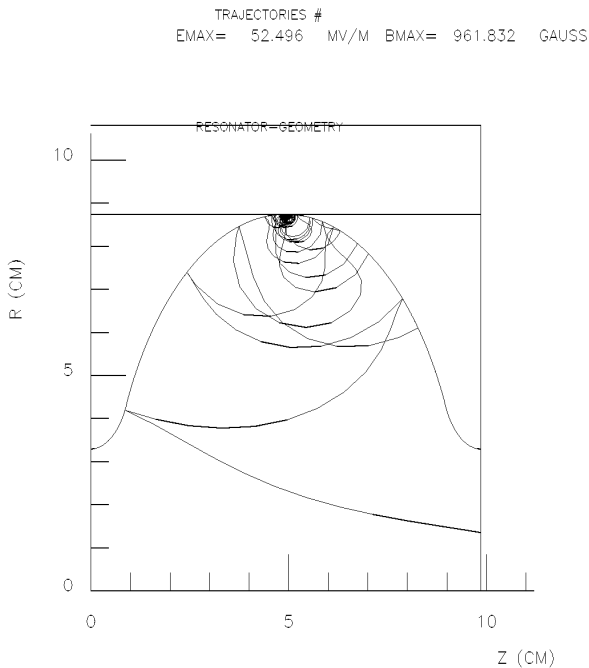

Figure 9, typical electron plot showing a possible 2-point MP level at the cavity equator.

4.2 Statistical Treatment

The results of the simulations are treated statistically to find regions of possible MP barriers.

We take fully advantage, in this treatment, of the built in capability of the program (since the original Karlsruhe version) to restart a trajectory at any impact following one of the possible different reemission processes for the given impact energy.

The code (depending upon the impact energy) allows for:

- Elastic and inelastic scattering
- True secondary electrons
- Back scattered electrons
- Enhanced backscattered electrons

To do the analysis we sweep the field across the operating field range of the cavity geometry to be tested computing a reasonable large number of trajectories at each.

We sort out the electron surviving up to the maximum allowed number of impacts prefixed in input.

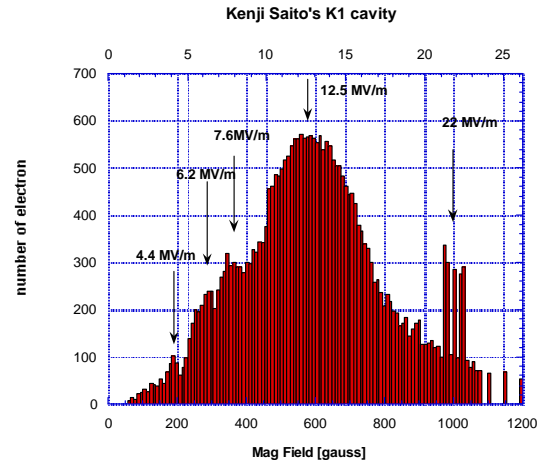A typical plot of the surviving electrons per field level is shown in figure 10

Figure 10. Surviving electrons versus cavity field, the arrows show the position of increased number of surviving electrons corresponding to MP barriers.

From the same data further information about possible dangerous MP regions can be gathered using the recorded Yield and impact energy.

Figure 11 reports the computed electron Yield versus field and figure 12 the Qo drop due to energy absorption as computed assuming a Secondary electron Coefficient $\delta=1.7$
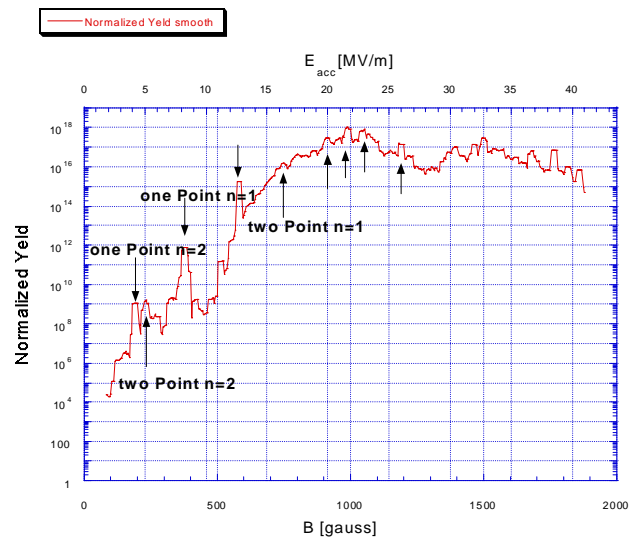

Figure 11 Electron Yield versus cavity field; in this representation the peaks in the Yield corresponding to MP barriers are even more evident.
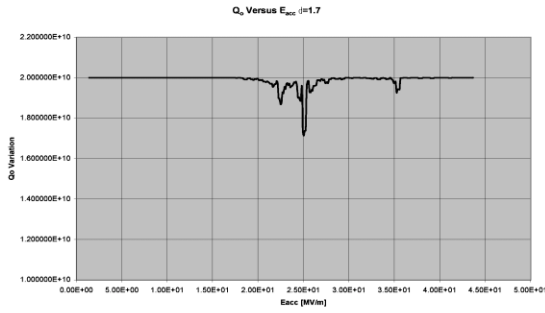
Figure 12, RF Absorption versus Accelerating field, computed as Qo drop, in a 1300 MHZ cavity

Figure 14. Comparison between tests and simulation on a typical Run before and after helium conditioning

Data shown are consistent with measured electron activity (Courtesy of Kenji Saito)

4.3 Experimental validation

To assess the validity of the method we checked the obtained results against the Experimental data from different labs, to avoid any "Cross Talk" between experiment and simulations.

We also performed in house experiment as a "Home Work" having the possibility of changing at almost at will the experimental conditions.

We measured a β=0.5 niobium cavity built as a scaled down prototype for the low energy section of the Trasco linac [6]

Figure 13. the 1400 MHz test cavity

The cavity showed a strong MP barrier at Low field, exactly at the field level corresponding to a mean secondary coefficient greater than one in the TWtraj simulation (Figure14)
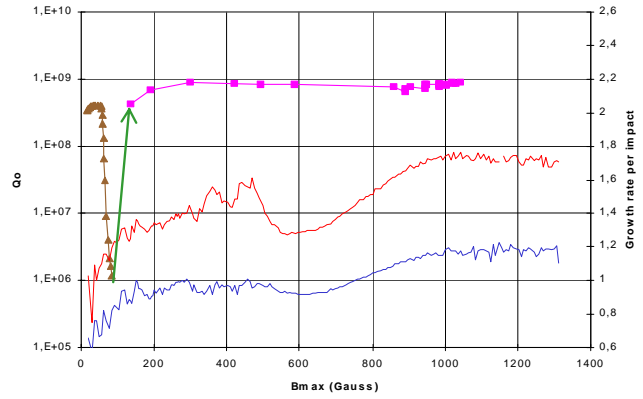
5 AKNOWLEDGEMENTS

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