

SRF ACTIVITIES AT INFN-GENOA

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Abstract

The activities of the INFN Genoa in the field of the RF Superconductivity are shifting toward the application of Superconducting Cavities to a Gravitational Wave detector operating in the 4-10 KHz frequency range of the Gravitational Wave spectrum.

The first prototype of the detector, built at CERN under an INFN-CERN collaboration agreement, is under test in Genoa.

As a side activity the Genoa Group is developing a small R&D project to check the achievable limits (field and Quality Factor) for Pipe Cooled cavities.

The Genoa group is still refining and updating the Twtraj Code for the simulation of electronic discharges (resonant or not) in accelerating cavities.

CAVITIES FOR GRAVITATIONAL WAVE DETECTORS

The main in house project of the Genoa_INFN Group is today the application of SRF to cavity to be used for the detection of gravitational Waves. [1][2]

Aim of the Experiment

The aim of the Paco Experiment is the development of a narrow band gravitational detector with a sensitivity $\Delta L/L=10^{-20} \text{ Hz}^{0.5}$ tuneable in the gravitational wave frequency range of 4-20 KHz.

This sensitivity will give a reasonable detection probability (few events per year) for fast Gravitational Wave sources belonging to our galaxy

The detector uses a two coupled cavities operating On the TE_{011} mode for maximum electrical Q_0 and minimum electric field on the cavity surface. The detector works as a parametric converter.

The Gravitational Wave (GW) interacting with the cavity walls pump the energy, stored on a mode of the double cavity resonator, to the adjacent empty mode of the resonator.

The Energy transfer is maximum when the GW frequency equals the mode splitting. [3]

The detection frequency being only given by the Mode splitting of the fundamental mode of the two cavities, the detector can be easily tuned to cover a broad GW frequency range (4-10 KHz) with a substantially constant sensitivity to the amplitude of the GW signal.

This sets the strongest difference between the PARAMetric Converter (PACO) detector and the standard Resonant Bar Detectors.

The prototype cavity operating at 2 GHz on the TE_{011} mode is shown on figure 1.



Figure 1: Prototype tuneable detector cavity (variable cell to cell Coupling), Bulk Niobium.

Cavity Construction and Tests

The first cavity Prototype was Built at Cern under by the SRF Group of the SL division under a collaboration agreement between CERN and INFN. The half cells were formed by spinning and EB Welded after a 100 μm Chemical Polishing (CP) rinsed in ultra pure water (Electronic Grade), and dried with a moderate baking (80-100 C). A picture of the cavity with a fixed RF Coupling is reported in figure 2.



Figure 2: Fixed coupling cavity Built and tested at CERN.

The test was quite successful, as shown in the plot of figure 3; the limitation was due to vacuum instabilities produced by a super fluid leak in a vacuum feedthrough leading to RF discharges in the Input coupler. Nonetheless the magnetic surface field was a good 55% of the design goal of 100 mt and the stored energy (the relevant parameter in our detector) was 3 Joules.

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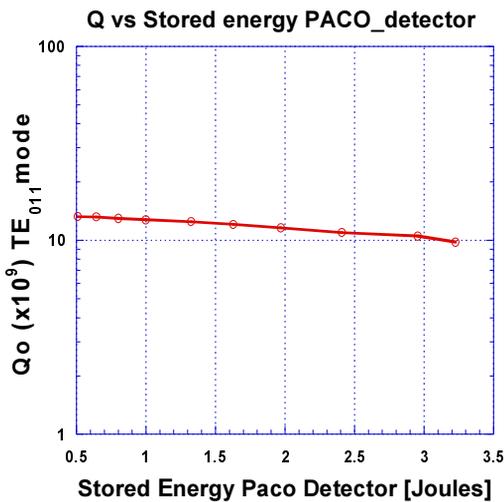


Figure 3: Q versus Stored energy for the fixed coupling cavity prototype.

A second tuneable Detector prototype, on the frequency range 4-20 KHz, is now ready for testing in Genoa. The cavity was built and surface treated at CERN.

Sputtered Niobium on Copper Cavity Prototype



Figure 4: Prototype sputtered single cell cavity. The cavity was built by Spinning In LNL (V.Palmieri) and coated at CERN.

As an alternate way of building the resonator, a sputtered “Niobium on Copper” spherical cavity was built

and tested in a cooperative effort INFN-Ge, INFN-LNL (V.Palmieri) and CERN.

This cavity was built to prove the possibility of using the “niobium on copper” production technique foresees as an alternate production method.

The Detector Goal $Q_0 \sim 10^{10}$ at a stored energy of 10 Jules was obtained since the first test.

At $Q_0 \sim 10^{10}$ the stored energy was 14 Joules, with a safety margin $\sim 40\%$. The Q versus field plot is reported in figure 5.

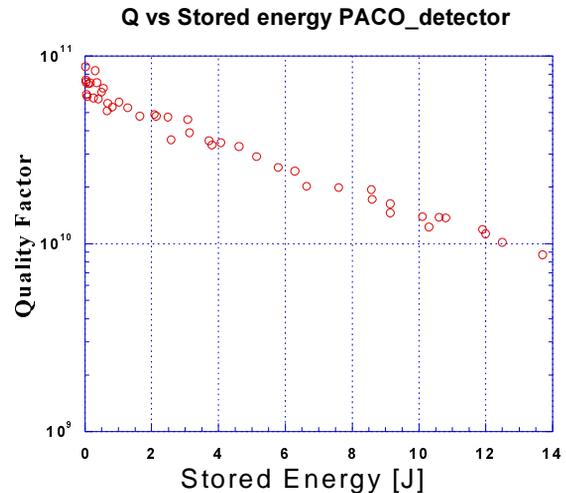


Figure 5: Quality factor versus stored energy for the Sputtered test cavity.

PIPE COOLED CAVITIES

Cooling a cavity by a surrounding Helium bath is the only way used till today in SRF accelerators.

Nevertheless the possibility of using Pipe Cooling will be quite interesting, resulting in a simpler cryogenic system a smaller inventory of liquid helium to handle and store during accelerator operation.

Pipe cooling will be very attractive for low frequency large bore cavities as the 200 MHz cavities foreseen for the muon acceleration in the muon colliders.

Furthermore pipe cooling will greatly improve the reprocessing of cavity surface after performance degradation due surface exposure to contaminants as in the occurrence of vacuum accident or RF Window failure.

The Oscar Thermal Post Processor

To assess the possibility of pipe cooling in accelerating cavities we specially developed a Thermal Post Processor [4, 5] for our “In house” cavity simulation code OSCAR. The postprocessor uses the field distributions along the cavity walls, the Surface Resistance of the Superconductor as computed using the Wilson’s Formula [6], the thermal conductivity of the cavity walls, and the thermal resistance at the cavity wall helium bath Interface.

Starting from the RF power dissipation, at a given field level, and the cooling condition along the cavity surface (Liquid helium temperature, position a n width of the

cooling loops) the thermal equilibrium for the whole cavity is found using a finite differences method. [7] Once the equilibrium distribution temperature found, the quality factor of the cavity is computed; the computation is performed on a given RF field interval, to evaluate the Q degradation induced by the RF power dissipation. A Typical comparisons between bath and a Pipe cooled bulk Niobium cavities are reported in figure 6.

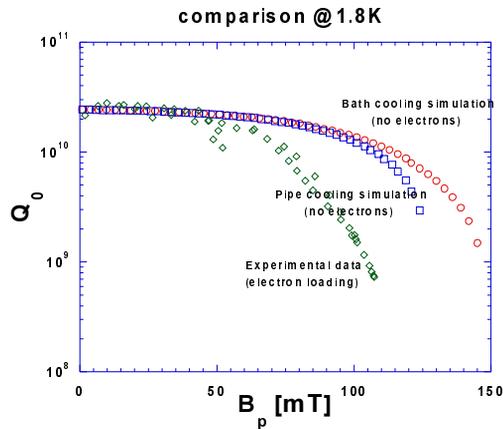


Figure 6: Comparison between Pipe cooled bath Cooled cavity; the thermal Breakdown field is higher then the measured due to the electron loading in the prototype.

The plot shows that the reduction in performance (maximum achievable field before breakdown) for a pipe-cooled cavity is only 10-15%;

The Proposed Experimental Program



Figure 7: Exploded view of the pipe cooled cavity.

To test the correctness of the simulation method, we proposed an experiment to cool a 3 GHz cavity using an array of tubes. The tubes are obtained by deep drawing a 0.5 mm niobium skin EB Welded on the outside of a bulk

niobium cavity. The exploded layout of the cavity is shown in Figure 7.

With a suitable choice of the refrigeration system [8] the performance of the bath cooled and pipe cooled cavity can be tested in the same test run.

The experiment is granted from INFN for the FY 2004-2005.

TWTRAJ CODE DEVELOPMENT

The code is extended to the computation of the trajectories when a DC Magnetic field is superimposed to the RF Fields of the cavity.

This extension allows for computation of electron discharges in buncher cavities and in the low energy sections of linacs where, often, magnetic Focusing lenses are used.

The extension is the first step toward the computation of discharges in RF modes with RF field variation along the Φ coordinate.

The results of simulation in a Buncher cavity with superimposed a 0.3 Tesla uniform field along the axis are shown in figure 8.

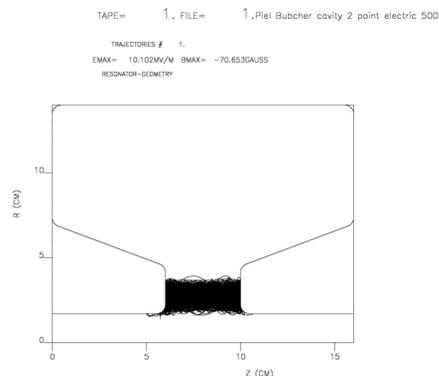


Figure 8: Trajectory plot for a Buncher cavity in a uniform Magnetic Field of 0.3 T along the Z axis.

The emitted electrons bouncing back and forth in the cavity gap are focused in the gap region by the magnetic field allowing for electron multiplication and vacuum discharges.

The situation is quite different in case of no staticMag Field Shown on figure 9.

In this case the electrons in the cavity gap are free of leave the cavity gap when the reemission angle is not perpendicular to the metallic surface of the cavity.

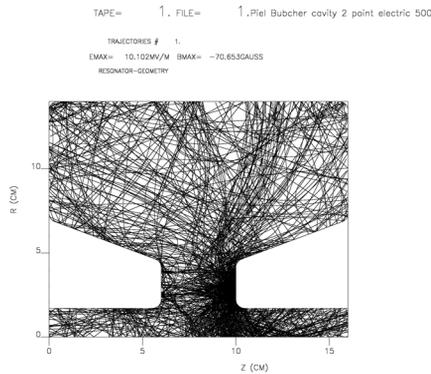


Figure 9: Trajectory plot for the same cavity of figure 8. For the same starting condition and RF field level but NO DC Mag Field.

The next step in the Twtraj development will be the possibility to simulate the electron discharges in the field of azimuthally symmetric structures with fields depending on the azimuth (e.g. TM_{111} like modes) as in RF Separators.

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