R.F. CHARACTERIZATION OF SMALL SCALE CAVITIES

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Abstract — The R.F. characterization of samples is an useful diagnostic tool to accurately investigate local properties of superconducting materials. However the most common limitation of systems used for this, consists often in the difficulty of scaling the measured results to the real resonator. The most direct way for measuring material R.F. properties would be the use of micro-cavities completely equal in shape to the real scale model. Using the spinning technique, it becomes feasible to produce small scale resonators in little time, negligible cost and in large quantity. Therefore we provided 6 GHz cavities and developed a suitable R.F. test “plug and measure” bench. The emphasis is placed on the cryogenic and R.F. facilities as well as the first results obtained on bulk Niobium spun cavities.

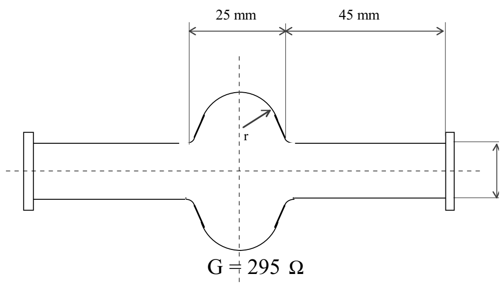
I - INTRODUCTION

Niobium is largely used in superconducting particle accelerators as metal sheet in the Jefferson Laboratory 1.5 GHz linear accelerator, in 1.3 GHz cavities tested at T.T.F[(1)] for the Tesla project or as a sputtered film on a copper substrate in the LEP2 collider at CERN...etc. Pushing forward the performances of high gradient accelerating cavities requires in addition to the high care in the production process, a better knowledge of surface superconductivity and numerous tests on samples to study the involved parameters. Many advantages of a direct method account for the choice of using a small scale cavity as a sample and this paper intends to show the feasibility. To be a valuable method for Niobium characterization, we would like to achieve a residual surface resistance in the nano-Ohm range.

II - EXPERIMENTAL SET-UP

II -1 GEOMETRY: ADVANTAGES AND DRAWBACKS.

[(1)] : Tesla Test Facility



The geometrical factor, (Superfish profram) is: G = 295

Fig.1

6 GHz cavities have a 115 mm total length and a 45 mm diameter cell: they are therefore light and easy to handle; they can be fastly substituted and cooled down directly by immersion in a Dewar of Helium. As a comparison, let us consider the triaxial cavity in which the sample to study is part of the wall of a complex resonant cavity. The size and position of the sample are critical since its center should be in an intense field zone to maximize sensitivity, whereas its edges should see nearly zero field to minimize losses at the seal. Hence It would require a fine tuning of the cavity and very fine mechanical tolerances, high cure when mounting the sample avoiding contamination since the cavity contribution is supposed to be known. This is also valid for the pill box cavity excited on the TE011 mode . An over-heating might cause irreversible deformation and destroy the host cavity itself. The losses on the flange must be calibrated. However the evaluation of these resistive losses remains difficult as they are statistical and thermal measurements are critical. With the whole cavity as a sample, we do not encounter these drawbacks; furthermore, the cylindrical symetry of our cavity is in favour of minor multipactoring.

However indirect the losses' evaluation is, flat samples are suitable for further surface analysis or for special crystal film growth. Since it was possible to spin a 0.3 mm thick Niobium sheet, it opens the possibility to study a multilayer cavity (ex: Nb/Cu). The geometry of our samples scales the accelerating cavities and simulates the effects of material stresses.

II -2 Cryogenic Infrastructure

The cryogenic power consumption is also significantly reduced, avoiding any loss during a transfer into a cryostat: One measurement at 4.2 K requires roughly 30 liters of liquid Helium. We could achieve 2K by pumping directly over the bath, consuming another 70 liters to complete the measurements at low temperature. We could benefit from the same pumping equipment used for 1.5 GHz cavity tests. The insert was designed on the dimensions of a 450 l or 250 l Dewar. As it must enter the Dewar's neck, it is very compact: On the cylindrical top part, the insulation with external environment is realized by successive thermal screens, letting pass through the two RF cables, a thermal probe, one translating axis, which is forseen for future moving input coupler.

The cavity is closed by two stainless steel flanges, on which are welded the RF SMA connectors. A 1.2 mm diameter Indium wire is squeezed between a packing groove carved on the flange and the cavity flat border with two stainless steel half moons, screwed on the flange.

A 5 mm diameter pumping tube is welded from one side on the pick-up RF connector and is mounted at the other side by a Swagelock assembly. One external valve keeps under vacuum a tomback, linking the insert to the turbo-molecular pump.

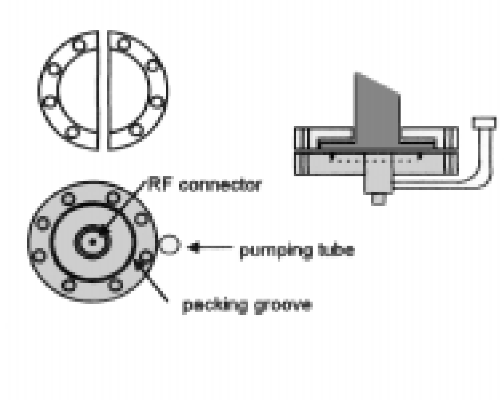


Fig. 2 :cavity closing

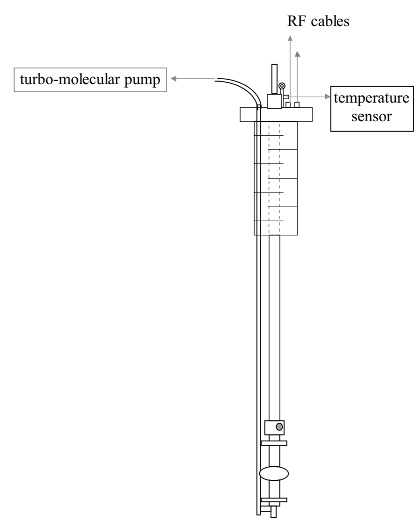


Fig. 3: insert

II -3 R.F. MEASURING BENCH

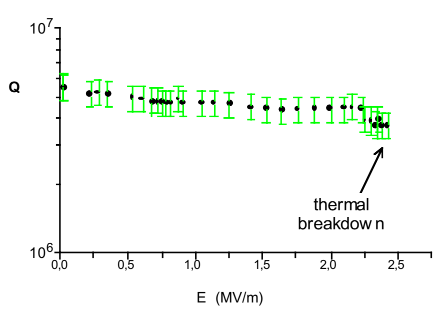
We could benefit from instruments we already had for 160 MHz quarter wave resonator test and 1.5 GHz cavity test, inserting a new phase lock loop and a power amplifier running at 6 GHz. The same generator, frequency-meter, directionnal couplers, power dividers, power measurement heads could be used. Most of instruments are computer controlled. The RF test bench is also very compact (cf the scheme in annexe I). Very few modifications in the program were necessary to carry out tests at this new frequency.

III - FIRST RESULTS

Three cavities K1, K2, K3 were spun on an aluminium mandrel, dissolved later on in a sodium hydroyde solution. Their preparation is summarized in table 1. Niobium chemical treatment is the common HNO_3, H_2PO_4, HF mixture. The R.F. measurements have been performed without screening the earth magnetic field. In a screened area, we expect the BCS surface resistanceas the residual surface resitance to be proportionnal to the frequency square, hence a quality factor around 3.5 10^7 at 4.2K whereas the expected value at the lowest temperatures is 2 10^9.

Name	wall thickness	chemistry	heat treatment	remarks
K1	2 mm	1:1:1	10’	H_{earth} not screened
K1_b		1:1:1	10’+30’	H_{earth} not screened
K1_c		= K1_b		H_{earth} screened
K2	3 mm	1:1:1		-
K3	2 mm	1:1:2		-

Table 1: samples preparation



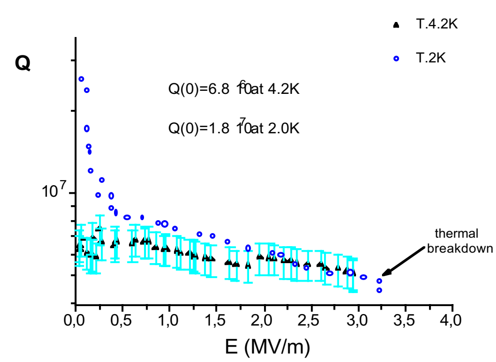


Fig 4 :first two results on cavity K1 without earth magnetic field shielding

In order to avoid parasitic dissipation, due to fluxons trapped during cooling down in the presence of the terestrial magnetic field, it was made a cylinder of -metal

(CONETIC AA), 77 mm diameter and 500 mm high. It was nessary to heat treat it at 1121 °C / 3h to recover its magnetic properties: After this treatment, the maximum residual fied measured in the cavity axis $B_{//}$ and in the orthogonal plane $B_{\perp}$ is:

$B_{//}$ =0.3 μT ± 0.1 μT

$B_{\perp}$ =0.0 μT ± 0.1 μT

at the cavity cell's higth and still 200 mm above the cell.
The secreen hangs on the insert by four stainless steel wires.

The same cavity K1 remained under vacuum and was tested again with the screen around: The surface resistance did not show any change though the better environmental conditions.

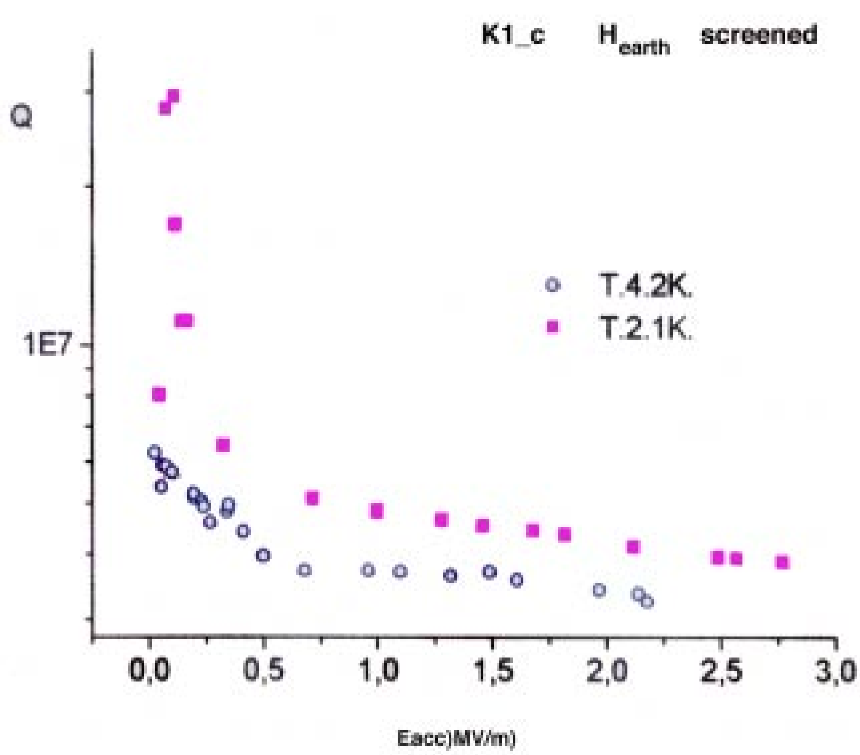


Fig. 5 Temperature dependence in screened case

The residual surface resistance is not dominated by the trapped earth field fluxons. After 2.5 MV/m it was not observed a real thermal quench but rather thermal instabilities at the maximum available power (14 Watt input). Actually the reflected power started to rise and limited the presicion with the coupling we had.

A next step is a thermal treatment under vacuum, using a Titanium network as a Getter material, in order to reduce significantly the residual surface resistance.

IV - CONCLUSION

We proved this can be a suitable tool to investigate material properties with a wider sensitivity, once a low surface resistance can be obtained. Many kinds of surface treatment can be studied, from the point of view of surface resistance modifications. It also allows to investigate other materials such as Nb_3Sn, Nb Ti N or multi layers materials.

References

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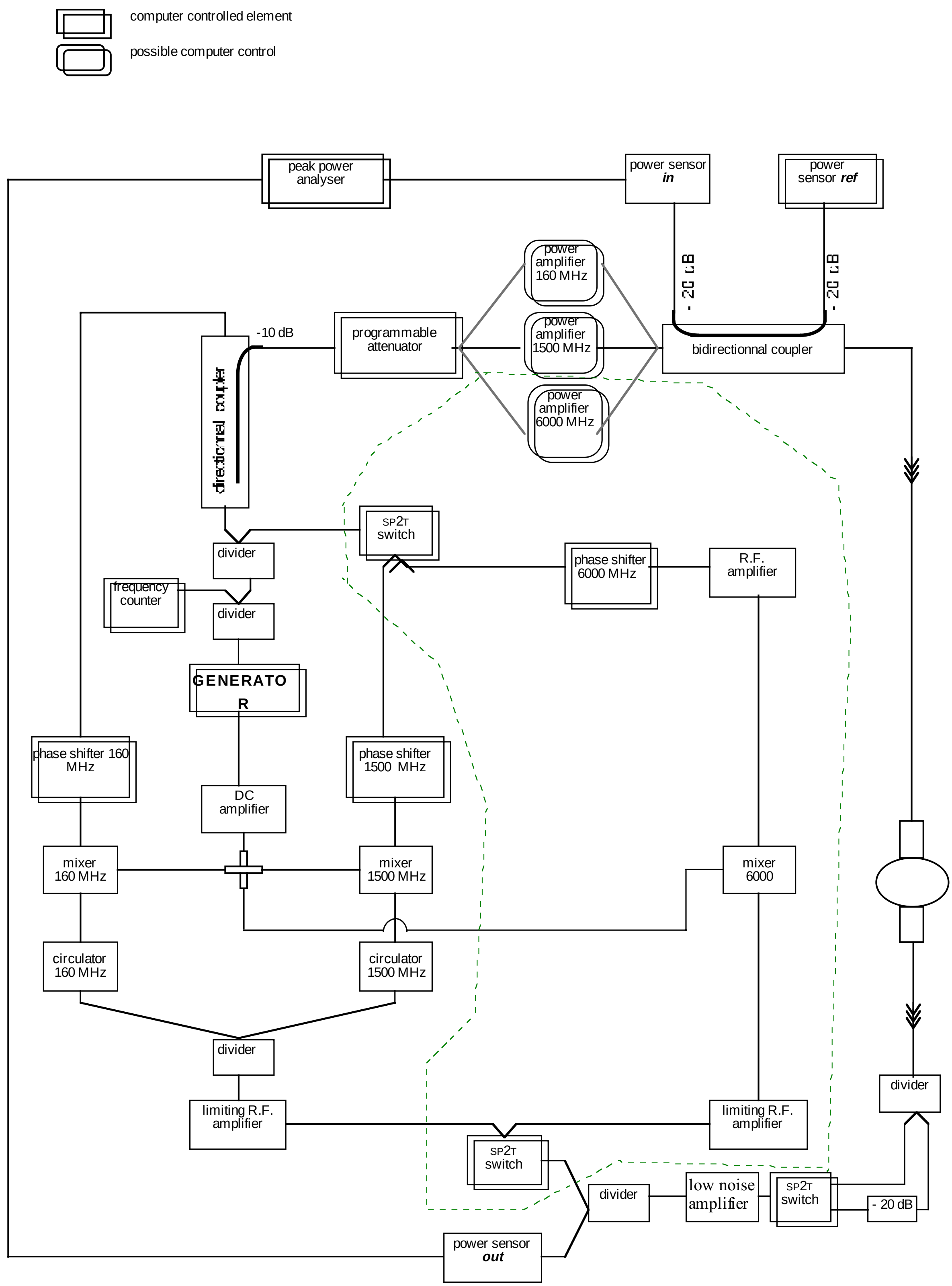
computer controlled element
possible computer control
peak power analyser
power sensor *in*
power sensor *ref*
power amplifier 160 MHz
power amplifier 1500 MHz
power amplifier 6000 MHz
-10 dB
programmable attenuator
- 20 dB
- 20 dB
bidirectionnal coupler
directionnal coupler
SP2T switch
divider
frequency counter
divider
GENERATOR
phase shifter 6000 MHz
R.F. amplifier
phase shifter 160 MHz
DC amplifier
phase shifter 1500 MHz
mixer 160 MHz
mixer 1500 MHz
mixer 6000
circulator 160 MHz
circulator 1500 MHz
divider
limiting R.F. amplifier
limiting R.F. amplifier
SP2T switch
divider
low noise amplifier
SP2T switch
- 20 dB
divider
power sensor *out*