Activities on SRF Cavities and Cryogenic Systems at the IPN Orsay Laboratory

T. Junquera

Institut de Physique Nucléaire (CNRS-IN2P3) . 91406 Orsay cedex . France

INTRODUCTION

The activities of the IPN Orsay group fall into three main subjects: 1) Cryogenic Systems for SRF cavities , 2) Diagnostic Systems for cavities, and 3) Studies on field electron emission. During the last two years the efforts of the group have been concentrated on the TTF (TESLA) project, and on basic studies for improving the performances of superconducting cavities. Four papers are presented to this workshop which describes in more detail these activities, so this laboratory report only outlines the main trends and the principal results.

1. CRYOGENIC SYSTEMS : The TTF Capture Cryostat [1]

The first injector (Phase I) of the TTF Linac is actually under construction by a collaboration of three french laboratories (CEA/DAPNIA Saclay, LAL and IPN Orsay) [2]. Our laboratory, with the help of the LAL mechanical engineering department, has the responsability of the design, construction and test of the capture cryostat which must house the capture cavity. This cavity plays an important role in the injector, it bunches the beam delivered by the electron gun and provides an acceleration of ~ 15 MeV before the injection into the main modules of the linac. The capture cavity is a standard TESLA cavity: 1.3 Ghz, 9 cells, equipped with a helium vessel, cold tuning system, and couplers. The french company CERCA S.A. has constructed three TESLA cavities, and the second of this series reach a very good performance. After a standard preparation procedure (chemistry, high pressure water rinsing), it was tested in a vertical cryostat at the DESY Laboratory: after a HPP conditioning phase, a maximum field of 21 MeV/m was obtained in a cw test (Fig.1), followed by a quench. This value is larger than the design value considered for the injector: E_{inj} > 12 MeV/m, so the cavity was accepted for the following assembling steps before the final mounting in the cryostat: welding of the helium vessel, mounting of the cold tuning system, mounting of the HOM and main coupler. During this mounting procedure several intermediate tests are foreseen in a horizontal cryostat (CHECHIA) at DESY, in order to control the eventual influence of the different cavity components on the initial performances obtained in a

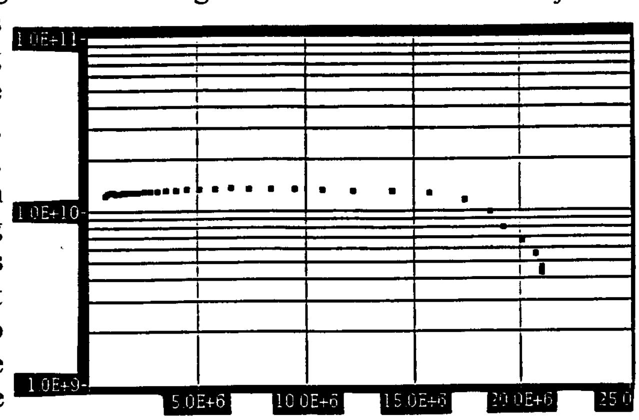

Fig. 1 Capture cavity test in a vertical cryostat

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vertical cryostat. The completely equipped cavity will be mounted and its position adjusted into the capture cryostat at Orsay at the end of this year. At this point of the development, two types of tests are scheduled in France for a complete check of the cavity in real operating TTF conditions: cryogenic test at 1.8 K at Orsay, and RF power test with the definitive klystron and associated control system at Saclay.The final assembly of the cryostat into the TTF linac at DESY is foreseen during the first quarter of 1996.

The capture cryostat (CRYOCAP) has been designed to fit with the TTF cryogenic distribution system at DESY. A common feed-box must provide cooling for Cryocap and for the main cryomodules. The cryostat (Fig. 2) minimizes the static heat losses, with a design goal of 1.5 W at 1.8 K (0.3 W at 4.5 K and 52 W at 60 K). A radiation shield is maintaned at a temperature within the range of 60 to 70 K: for the cryogenic tests in France the shield will be cooled by LN_2, and, in normal operation at DESY by Helium gas at 14 bar. The main coupler is cooled at two different locations: close to the cavity, the external side of the coaxial line is cooled by a loop of liquid Helium at 4.5 K, and at the level of the ceramic window the external side of the coupler is anchored to the radiation shield at 60 K.

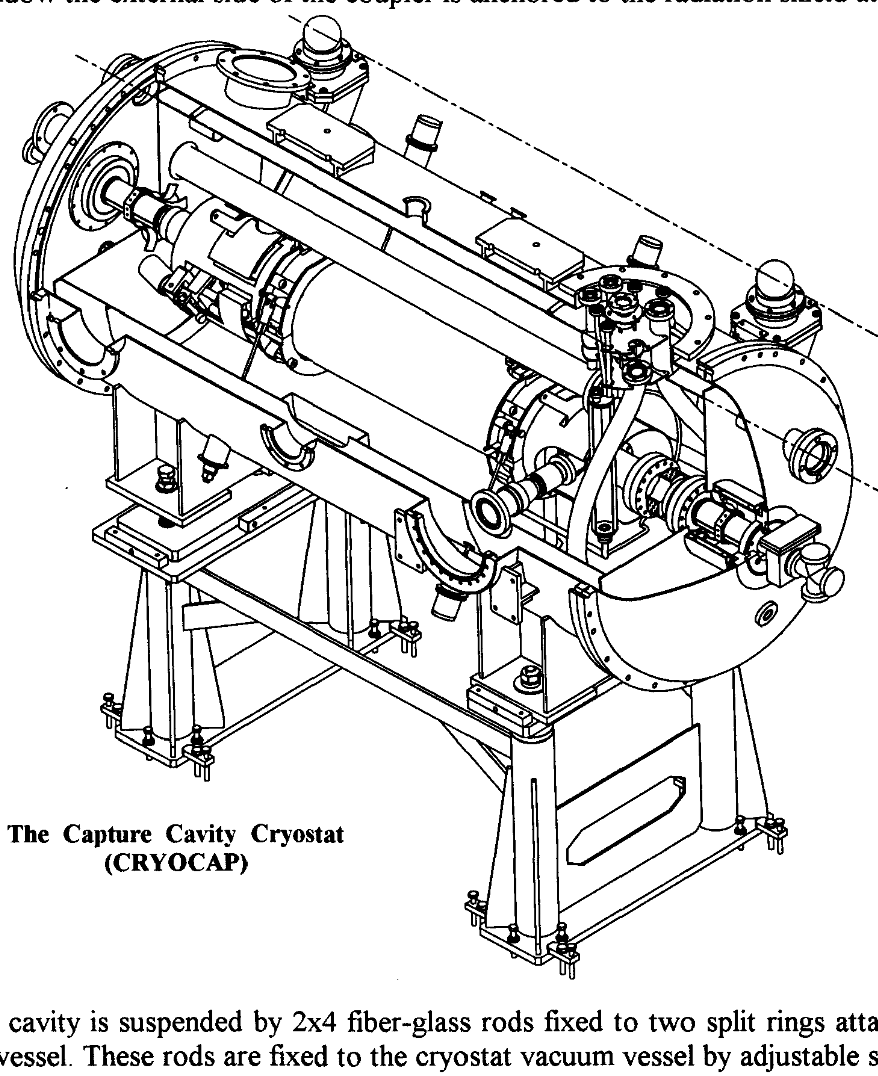

Fig. 2 The Capture Cavity Cryostat (CRYOCAP)

The cavity is suspended by 2x4 fiber-glass rods fixed to two split rings attached to the helium vessel. These rods are fixed to the cryostat vacuum vessel by adjustable supports allowing a careful alignement of the cavity relative to the external references of the linac. This cryostat do not incorporates a big helium pumping line, like the main cryomodules, and the pumping for operation at 1.8 K is directely connected, through a phase separator, to the standard helium feed tube located on top of the cavity helium vessel.

The test of this cryostat at Orsay for cryogenic measurements, and at Saclay for RF measurements, requires some special cryogenic interface between the storage containers and the feed port, which has been designed to fit the TTF refrigerator and intermediate cold feed-box. A special cold box has been designed at Orsay allowing the operation of the cryostat from liquid helium and liquid nitrogen storage dewars. This box includes several heat exchangers and valves which controls the different cryogenic process phases. Cold helium vapours from the cryostat may be handled in two ways: either warmed to the room temperature by a heater, or by recovering the enthalpy of cold vapours in a heat exchanger, to liquify some helium (with the help of a external compressor) in order to reduce the supply from the external storage (economizer mode).

Preliminary tests of this interface were performed recently: the total static losses including the transfer lines were lower than 2.5 W at 1.8 K. The helium level in a small reservoir simulating the cavity helium vessel was controlled with a heat load of 10 W, and finally, using the interface in the economizer mode, the external supply of liquid helium was reduced by 50 %.

2. DIAGNOSTIC TECHNIQUES FOR CAVITIES : Surface Thermometry in TESLA cavities.

The work in this field was started several years ago, in collaboration with the Saclay group, for testing 1.5 Ghz monocell cavities and for basic studies on surface resistance. Several contributions were presented at the DESY workshop [3] and at the CEBAF workshop [4]. Continuying a special development of surface thermometers for the CERN [5], we enter in a close collaboration with the DESY group in the frame of the TTF project. The goal was to install 116 thermometers in a rotatig frame mounted in the vertical cryostat in order to test the first 9-cell TTF cavities. The IPN Orsay laboratory took in charge the design of the thermometers, and the supervision of their fabrication by a french company (PANTECHNIK). The calibration and some complementary tests were performed at Orsay, along with a basic work for analysing the results of the first experimental tests.

After different mechanical and electrical improvements very interesting results were obtained: a) Field emission was detected in correlation with special photodiodes mounted in the same rotating frame, b) Cavity quenchs were clearly located, and in some experiments a small heated area was detected before the quench. In the Fig. 3, the temperature map measured during the quench in a TESLA cavity at 12 MeV/m is shown. The high values of heating were difficult to be explained when considering the bad efficiencies of this kind of thermometers working in superfluid helium. Careful calibration of the

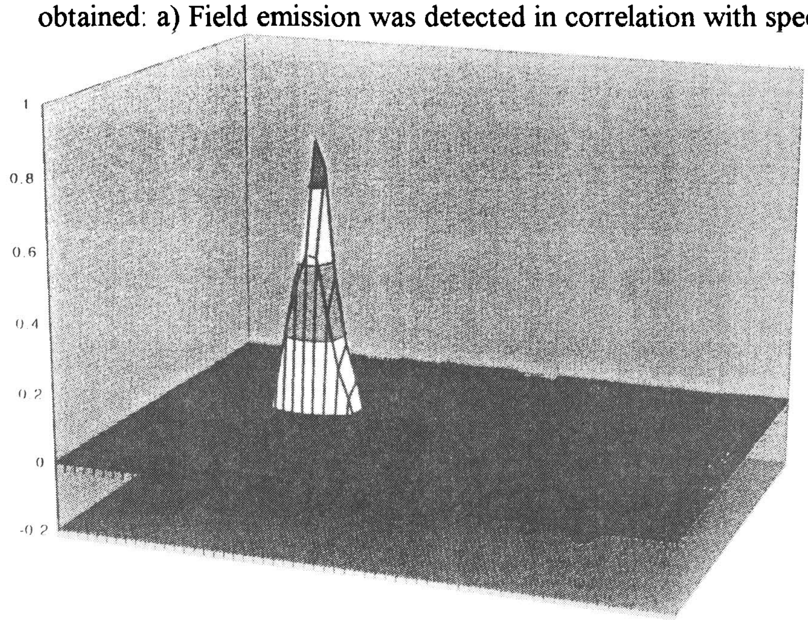

Fig. 3 T-map of a quench at 12 MV/m in a TESLA cavity

thermometers at low heat power density showed a low efficiency (1 to 2 %) and a large dispersion of the response. This value must be compared to the typical efficiency values of 25 to 30 % measured with fixed thermometers using a thermal bonding agent to improve the contact with the niobium surface. In order to study in more detail this point, some experiments were performed at Orsay with a special chamber incorporating a copper rod, equipped with heaters and thermometers, welded to a stainless steel plate. High heat flux density levels, reaching 5 W/cm^2, were obtained. The surface thermometers were tested in this chamber without any bonding agent, and they show a nonlinear response as a function of the heat power density. The low efficiency values were again measured at levels under 10 mW/cm^2, but it increases very sharply with the power, and for levels bigger than 100 mW/cm^2 the response was just 50 % lower than the fixed thermometer response, following a quite linear dependence for higher power levels (Fig. 4). The important heating measured on cavities can be analysed with higher confidence using these recent calibrations. Several contributions presented at this workshop give more detailed information on this point [6] [7].

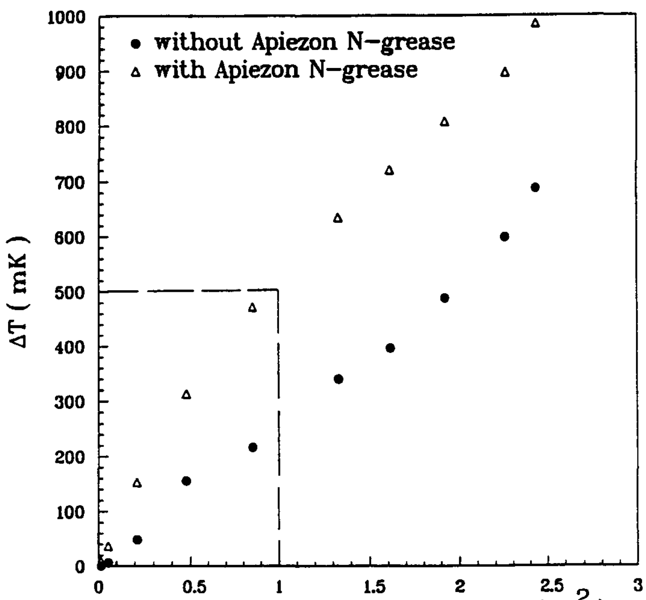

Fig. 4

3. FIELD EMISSION STUDIES

Associated to the Saclay group, the IPN Orsay group has developed several experimental devices which allows to get new insigths on the field emission phenomenon :

3.1. Studies with a copper cavity [8]

A special copper cavity was designed by the Saclay group in order to study field emission on removable samples. This cavity, feeded by a 5 kW klystron with pulse lengths of several miliseconds, allows to reach high electric surface fields (> 50 MV/m) on the top of the removable sample. At the IPN Orsay a modified version of this cavity was designed, it includes an optical window for the examination of the sample during the experiments. An optical device composed of a mirror, a set of lenses, a prism, and associated sensitive ligth detectors and cameras for locating and measuring the luminous effects taking place at the sample (Fig.5). A high sensitivity camera localizes the luminous spots which can be individually isolated by a couple of motorized slits; Different optical detectors make possible the characterisation of the light radiation of one single spot in terms of intensity, glowing duration and spectral distribution.

The samples (Nb, Cu) were contaminated with small particles of two types: metallic (iron) and dielectric (alumina). With iron particles some displacements of the particles over the sample were observed, some particles were ejected out of the surface and

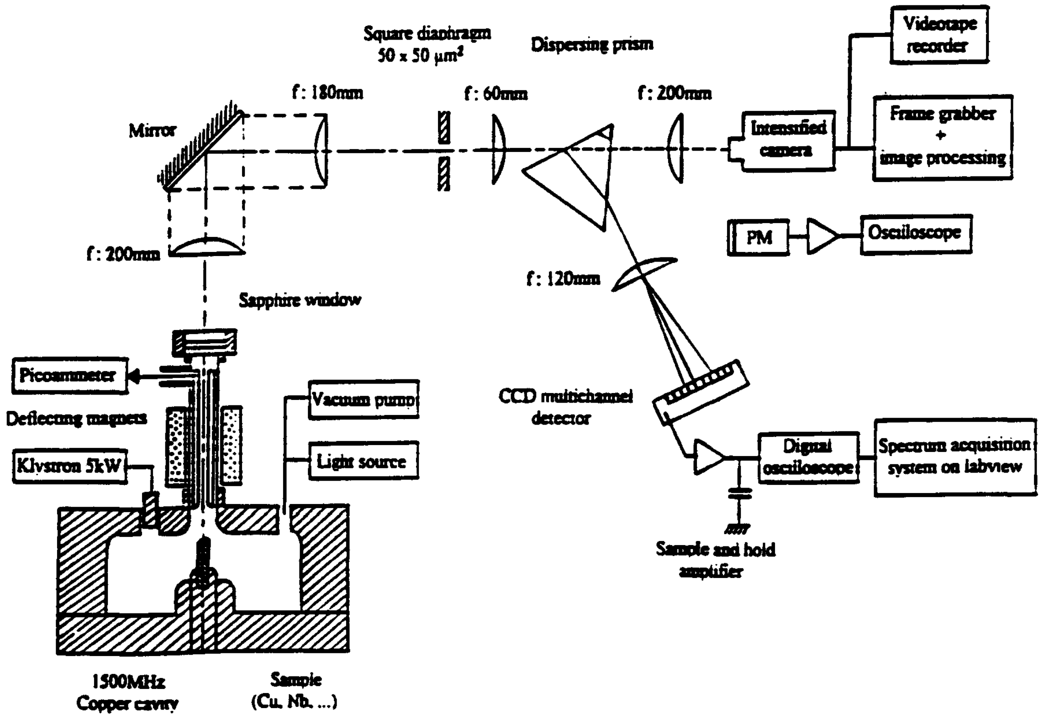

Fig. 5 Optical system for light detection in RF cavitites

piled up along lines perpendicular to the surface. Several luminous flashes were detected during the field increasing phase, but no stable light activity was recorded, even at high field levels corresponding to intense electron emission.

In the case of alumina particles the observations were quite different. With small particles of size ~ 1 µm, the light activity was only detected at high field values, and the luminous spots stay for a short period of 1 or 2 RF pulses (several miliseconds). After the experiment, the observation of the sample with a SEM microscope revealed small craters on the sample surface. With large alumina particles (~ 50 µm) an impressive light activity was detected. A big number of stable spots start to shine at moderate field levels with a luminous intensity proportional to the electric field. At a sample surface field of 10 MV/m explosions were triggered giving intense luminous tracks accompanied with strong gas desorption.After the initial conditioning period both the electron current and the light activity were more stable. Some spectra were recorded at different field levels showing a characteristic bell shape in the 600-800 nm wavelength range.

Two models have been considered in order to explain the luminous activity: 1) electroluminescence, 2) thermal radiation. The measured spectra are easily explained by thermal radiation than by electroluminescence. The particles can reach very high temperatures when submitted to high RF electric fields. These temperatures are close to the melting point of the alumina and can be reached in a short period of time. The calculated luminous intensity of the spots seems to agree with the measurements but the evolution of this intensity with the electric field fits quite well the laws of the electroluminescence. The main disagreement with respect to the electroluminescent model is the spectra shape: no narrow peaked spectrum has been observed for the moment.

3.2. Studies with a superconducting cavity [9]

A special SRF cavity operating at 3.6 Ghz in the TM020 mode has been designed and succesfully tested (Fig. 6). A similar cavity constructed by the Cornell group reached very high field levels and supply interesting observations of the surface conditioning at high electric field. The work made at the IPN Orsay focused, during the initial tests, on the calibration of the surface electric field using X-rays diagnostic and measurement devices.

After a careful heat treatment, chemistry, and mounting procedure, the cavity exhibit a good Qo at low field, and reach a very high maximum surface electric field at the center of the lower plate of the cavity (Fig. 7). The maximum field level, limited by the TWT amplifier, was confirmed in different tests: Emax = 95 MV/m, with field emission starting at Emax = 40 MV/m.

Several electron trajectories impacts were located with good accuracy by an array of photodiodes rotating around the cavity. According to these results, a calibrated NaI detector with a collimator was placed close to the cryostat with its axis aligned to the previously determined X-ray emission area. The maximum energy of the X-ray was measured for different values of the cavity electric field. The location of the impacts and the energy were confronted to the electron trajectories calculations in order to evaluate the emission site location and the electric field at this point. The agreement between the simulation and the experimental results was quite good: i.e. 580 keV measured by the NaI detector, compared to 620 keV calculated from electron trajectories.

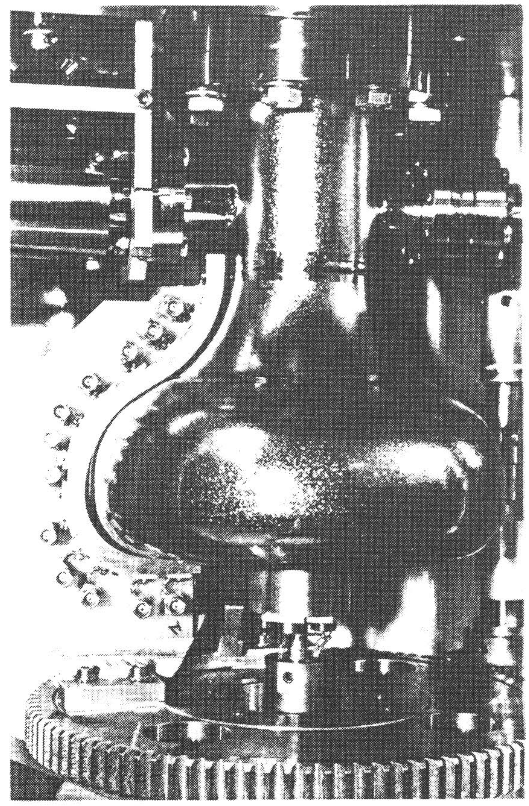

Fig. 6 3.6 GHz Superconducting Cavity (TM020 mode)

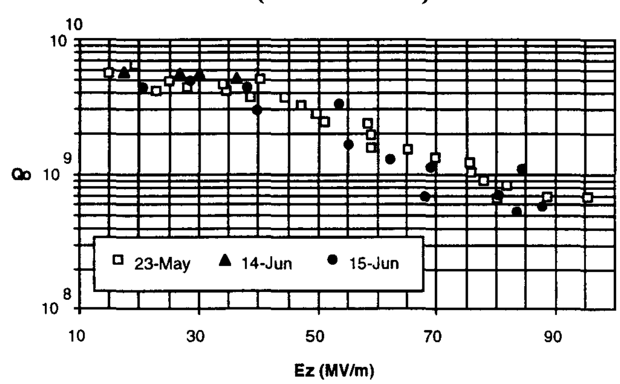

Fig. 7 TM020 Cavity Tests at 1.8 K

These results opens an interesting field of investigation on electron emission occurring from contaminated surfaces. A precise calibration of the electric field and the availability of sensitive X-ray diagnostic system could help to study this phenomenon in a large range of surface electric field at superfluid helium temperatures.

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REFERENCES

[1] S. Bühler et al. these proceedings.
[2] M. Bernard et al. Proc. of the 4th EPAC, London 1994.
[3] M. Fouaidy et al. Proc. of the 5th Workshop on RF Superconduct., Hamburg 1991
[4] S. Bühler et al. Proc. of the 6th Workshop on RF Superconduct., Newport News 1993
[5] Ph. Bernard et al. Proc.of the 6th Workshop on RF Superconduct, Newport News 1993
[6] Q.S. Shu et al. these proceedings.
[7] M. Fouaidy et al. these proceedings.
[8] S. Maïssa et al. these proceedings.
[9] M. Fouaidy et al. these proceedings.