OVERVIEW OF SUPERCONDUCTING RF ACTIVITIES AT IPN ORSAY

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Abstract

During the last two years, the SRF activities at the IPN Orsay were mainly directed toward R&D associated to the study of high intensity protons accelerators. Design and test of SRF proton cavity prototypes have been performed in a close collaboration with the CEA Saclay, presented good results, and now, a 700 MHz five cell cavity (beta = 0.65) is under construction. Concerning the intermediate energy part of the accelerator, a program has begun to define, optimize and then fabricate a 2 gap spoke cavity (beta = 0.35). Another important activity is the construction of the CryHoLab test facility, an horizontal cryostat designed to test multi-cell cavities and their associated components. The mounting of CryHoLab is achieved, and is currently undergoing a first cryogenic test. The program concerning the study of cavity stiffening using thick plasma sprayed copper coating is almost achieved: a technique based on inert gas plasma spray allows us to obtain copper layers meeting the required thermal and mechanical performances.

1 INTRODUCTION

The SRF activities in the IPN Orsay laboratory is mainly directed toward R&D on high intensity proton accelerators which are considered for different applications: neutron sources, neutrino factories, nuclear waste transmutation or radioactive ion beams. In Europe, two projects have entered an active phase of conceptual design and thus drive an important R&D program. The first one is the Experimental Accelerator Driven System (XADS) [1] which propose the study and construction of a demonstrator (600 MeV, 20 mA, CW) for nuclear waste transmutation. The second project is a radioactive nuclear beam facility, EURISOL (1 GeV, 5 mA, CW), based on the ISOL (Isotope Separation On Line) technique [2]. Other projects are also based on the same driver accelerator (Fig 1): the European Spallation Source (SNS) and the neutrino factory at CERN, the Superconducting Proton Linac (SPL).

During the next 4 years, the roadmap which has been defined for XADS and EURISOL settle the R&D program for critical components of the driver.

The low energy section is studied within the frame of the IPHI (High Intensity Proton Injector) project in France.

Concerning the intermediate section of the driver, an important program has recently started in the IPN laboratory to design, fabricate and test spoke cavities. Our objective is to test a first prototype of β = 0.35 before summer 2002.

During the last two years, a Franco-Italian collaboration (INFN Milano, CEA Saclay, IPN Orsay and LAL Orsay), originated by the french ASH project and the Italian TRASCO project, has worked on the design of the high energy part of such a driver.

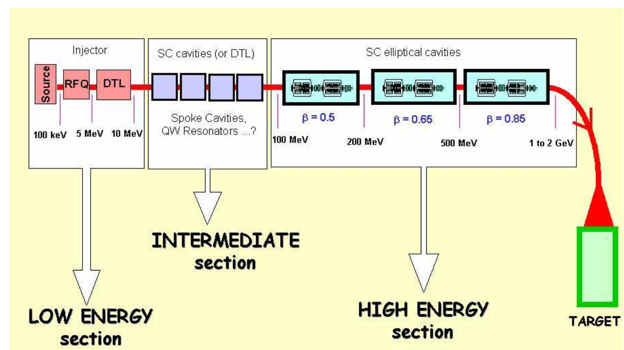

Figure 1: High intensity proton driver accelerator for XADS and EURISOL projects.

2 SPOKE CAVITY INVESTIGATIONS

An alternative solution for the classical Drift Tube Linac (DTL) to cover the energy range between 5 to 85 MeV is the use of spoke resonators. At the IPN, an important program has started to design and construct 2 gaps prototypes operating at 352 MHz. A preliminary study showed that the energy range from 12 to 85 MeV could be covered with only 2 different cavity types (2 gaps), β = 0.18 and β = 0.35 [3]. The energy gain per cavity as a function of the proton energy is shown on the figure 2.

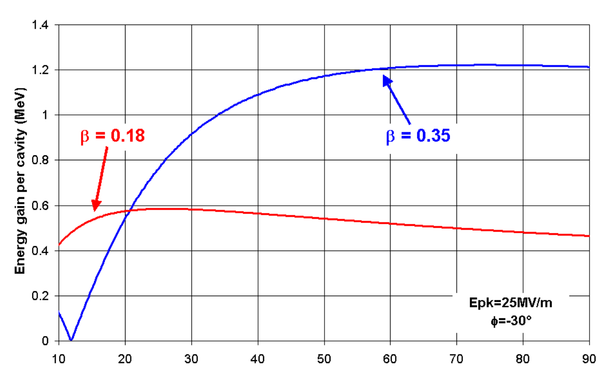

Figure 2: Energy gain per spoke cavity as a function of the proton energy for the two different beta.

At first , we are focusing on the β = 0.35 cavity. A shape optimization has been performed in order to achieve a good compromise between the lowest possible value for Epk/Eacc and Bpk/Eacc, and a reasonable shape which is compatible with the fabrication procedures (shape forming and welding). The electromagnetic parameters, computed with the MAFIA code using 1.4 mm mesh size (4 000 000 mesh points) are given in the table 1.

Table 1: Electromagnetic parameters for the β = 0.35 spoke cavity

Epk/Eacc	3.1
Bpk/Eacc	8.51
Q_0@ 2K	$8.7\ 10^9$
G	97

The cavity resonator geometry is shown on the figure 3. The overall cavity length is 20.0 cm with a spoke thickness at beam hole aperture of 67 mm.

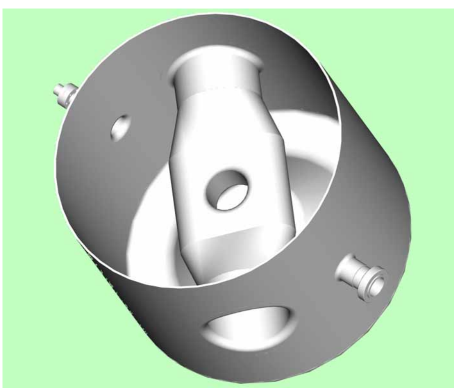

Figure 3: β = 0.35, 2 gap spoke cavity shape.

First mechanical studies have also been performed to evaluate the resonator mechanical stability. The effect of a 2 bars external pressure on the cavity has been calculated. The calculated value for the peak Von Mises Stress is 386 MPa (with fixed ends), far above the niobium yield strength (50 MPa). To solve this problem preliminary design of supports to stiff the cavity have been study (Figure 4).

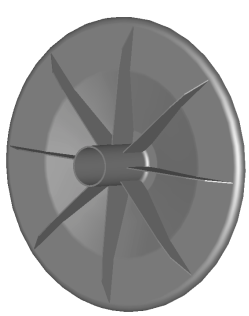

Figure 4: Supports for spoke cavity stiffening.

With the supports, the peak Von Mises stress is reduced to 49 MPa and the peak displacement reduced by a factor 10.

The first prototype, probably made with low RRR niobium, will be ordered to CERCA before the end of the year, and the delivery is expected before summer 2002.

3 R&D ON SCRF CAVITIES FOR THE HIGH ENERGY SECTION

The design of the proton accelerator for the high energy part is based on the original study performed for the French ASH project (CEa Saclay and IPN/LAL Orsay) and for the Italian TRASCO project (INFN Milano).

Several sub-sections of elliptical 700 MHz bulk niobium superconducting cavities compose the high energy part beginning at 80 MeV. For the XADS, two different sections are foreseen (β = 0.47 and 0.65), and three for EURISOL (β = 0.47, 0.65 and 0.85). A good compromise for energy acceptance and linac length lead us to choose 5-cells cavities.

The french collaboration focused on β = 0.65 cavities. Several monocell cavities were fabricated using high RRR 200 niobium of 4 mm thickness to validate the shape of the 5-cell cavity. Best results have been obtained for the cavity A102 (inner cell geometry) and A105 (half cells of the external cells) with Eacc above 25 MV/m for both cavities, and Bpk above 120 mT. These results are presented on the figure 5.

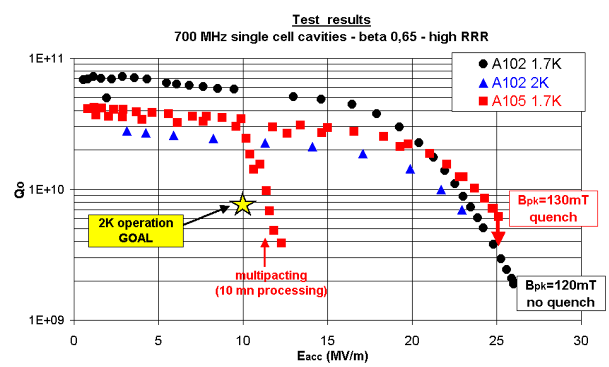

Figure 5: results of the A102 and A105 700 MHz β = 0.65 monocell cavities.

The A105 cavity (figure 6), composed of the first and last half-cells of the 5-cell cavity, has a coupleur port, helium tank flanks and was used to validate a technical choice: a stainless steel helium tank, brazed with copper onto the niobium. This leads to a drastic cost reduction as compared to the classical titanium helium tank. Preliminary tests on a simple mock up have shown no leaks in superfluid helium.

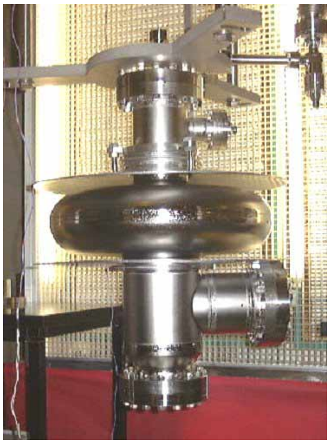

Figure 6: 700 MHz A105 Monocell cavity with its helium tank flanks.

Encouraged by these performances, a 5-cell β = 0.65 cavity has been designed (figure 7) and ordered to the CERCA company. The delivery is expected for the very beginning of the year 2002.

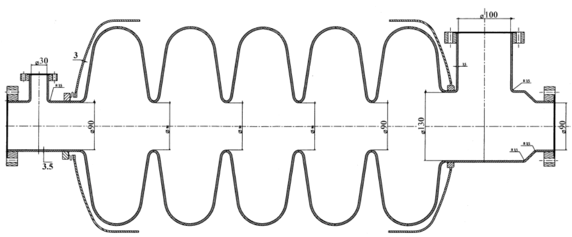

Figure 7: 700 MHz, 5-cell, β = 0.65 cavity design.

In parallel, a cold tuning system (CTS) is under study for the 5-cell cavity [4]. It is based on the SOLEIL cavity CTS. It uses a stepping motor and a gear reduction linked to a double lever arm by a feed screw (see figure 8).

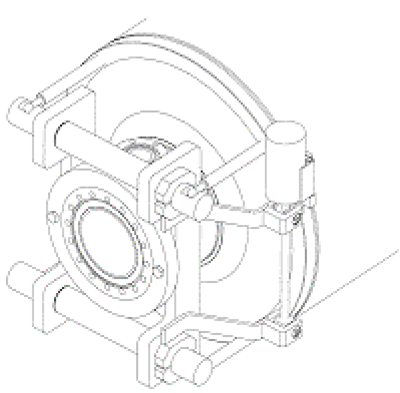

Figure 8: Design of the cold tuning system.

The CTS characteristics are the following: lever arm ratio of 5, mechanical resolution of 50 nm (10 Hz), total range of about 3mm, helium tank and CTS stiffness of 20000 N/mm, far above the 1592 N/mm longitudinal stiffness of the cavity itself.

Several positions are possible to introduce piezo actuators which are currently under characterization in our lab.

4 CRYHOLAB: A CAVITY TEST FACILITY

In a close collaboration with the CEA Saclay, an horizontal cryostat has been designed and fabricated [5] to test 700 MHz or 1300 MHz multicell cavities with all their associated components (helium tank, power coupler, cold tuning system, ...).

The cryostat is made of a stainless steel vacuum tank, 2.5 meter long and 1.2 meter of diameter. A copper thermal shield cooled with liquid nitrogen and 30 layers of super insulation insure the thermal insulation from the 300 K part. The cryostat and its associated cold box is now installed in the CEA Saclay laboratory (figure 9) close to the cryoplant (120 l/h) and its associated 2000 liter dewar. The pumping capacity (8 g/s at 30 mbar) of the Saclay cryogenic installation will allow us to reach temperatures below 2 K.

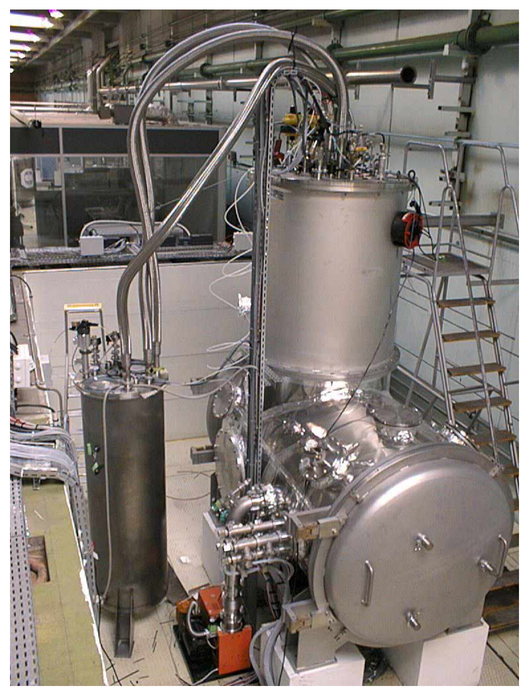

Figure 9: CryHoLab test facility for horizontal multicell cavity test.

The whole system has just been validated from the cryogenic point of view. The first cavity test at low RF power (700 W) is scheduled for the end of the year on the A105 cavity equipped with its helium tank. In the beginning of 2002, the 80 kW 700 MHz RF source (solid state amplifier) will be installed.

5 CAVITY STIFFENING BY THERMAL SPRAYING

Since a few years now, an alternative method for cavity stiffening has been studied in the IPN laboratory. The main goal is to increase the cavity mechanical stability with the addition of a copper layer on the outside cavity walls. The coating is done by thermal spraying, a technique widely used in the industry.

Previous experiments have shown that the nature of the copper layer drastically differs from one spraying process to another, leading to important changes of the mechanical and thermal properties of the copper coating [6]. Numerical simulations of the bi-metal cavity behavior gave us criteria to evaluate if these properties are good enough for our application. Systematic measurements of these properties, for different spraying process, have been performed and showed the difficulty to have at the same time a high coating Young modulus, mandatory for an efficient stiffening, and a high copper conductivity, needed to leave the cavity thermal stability unaffected by the coating.

A new technique has recently being investigated: the inert gas plasma spraying (IPS). The advantage of this technique is to avoid in-flight oxidation of the copper molten particles which was suspected to be the cause of the poor thermal properties of the layer obtained either by atmospheric plasma spraying (APS) or high velocity oxi-fuel (HVOF).

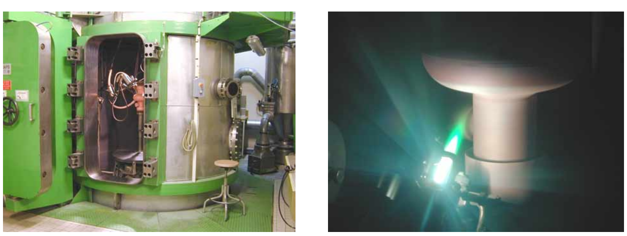

Figure 10: Sealed chamber for IPS and a 1.3 GHz cavity during the deposition process.

Thanks to the controlled atmosphere, the thermal and mechanical properties of the copper layer obtained with this technique are very interesting, as shown in table 2, as compared to the other techniques.

A 1.3 GHz prototype cavity has also been fabricated and tested before and after copper deposition [7]. The result on the cavity sensitivity to Lorentz forces detuning is shown on the figure 11, were the frequency shift is plotted as a function of the accelerating field: the effect of the copper layer is clear with a reduction by a factor 3 of the detuning factor.

Table 2: Comparison of the thermal and mechanical properties of the copper layer obtained with different spraying techniques.

Coating Process	Porosity (%)	E (GPa)	Thermal Resistance Increase $K.m^2.W^{-1}$	Measured K_L before/after Cu
APS	20...30	25	$4.0\ 10^{-4}$ (Cu 2mm)	-8.2 / -5.2
Optimized APS	5...7	63	$>>1.8\ 10^{-3}$ (Cu 3mm)	No data
HVOF	2...3	66	$>>1.4\ 10^{-3}$ (Cu 3mm)	-9.2 / -2.2
IPS	7...8	72	$4.7\ 10^{-4}$ (Cu 3.5mm)	-7.5 / -2.9

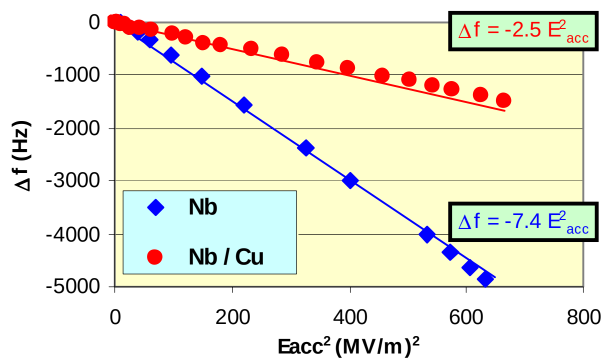

Figure 11: Experimental (points) and calculated (lines) frequency shift as a function of the accelerating field before (blue, square) and after (red, dots) copper coating.

6 REFERENCES

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