STATUS OF THE CRYOMODULES AND CAVITIES DEVELOPMENT FOR THE SPIRAL2 SUPERCONDUCTING LINAC

G. Olry#, S. Blivet, N. Hammoudi, D. Longuevergne, F. Lutton, G. Martinet, G. Michel, H. Saugnac, P. Szott, CNRS/IN2P3, Université Paris-Sud, IPN Orsay, France.

P-E. Bernaudin; P. Bosland, G. Devanz, C. Madec, A. Pérolat CEA/Saclay, DAPNIA, SACM, France

Abstract

The French laboratories CEA/Saclay and IPN Orsay, involved in the SPIRAL2 project, are now preparing the final tests of the two qualifying cryomodules (called respectively A for the beta 0.07 cavities and B for the beta 0.12 cavities) in order to start the series production in 2008. Each cryomodule A and B will be tested at 4.2 K and nominal power (10 kW, CW).

This paper presents an update of the cryomodules and cavities developments (first results at room temperature, first assembly…) which have been presented in [1].

INTRODUCTION

The GANIL's SPIRAL 2 Project [2] aims at delivering high intensities of rare isotope beams by adopting the best production method for each respective radioactive beam. The unstable beams will be produced by the ISOL "Isotope Separation On-Line" method via a converter, or by direct irradiation of fissile material.

The driver will accelerate protons (0.15 to 5 mA – 33 MeV), deuterons (0.15 to 5 mA – 40 MeV) and heavy ions (up to 1 mA, Q/A=1/3 14.5 MeV/u to 1/6 8.5 MeV/A). The superconducting linac is composed of a low energy section composed of 12 so-called type A ($\beta = 0.07$) cryomodules with one cavity and a high energy section composed of 7 so-called type B ($\beta = 0.12$) cryomodules housing 2 cavities.

The cryomodules A in the low beta section are developed by CEA/Saclay while the high beta section ones, cryomodules B, are developed by IPN/Orsay. Both types of cavities will be equipped with the same power coupler specified for a maximum power of 20 kW, which is developed in a third French laboratory, LPSC/Grenoble. The latest results of the coupler tests are reported in [3].

General development programs are quite similar for both cryomodule types: a first qualifying cryomodule, under assembly now, will be tested before the series. These two qualifying cryomodules will be first installed in the linac and should become in the future the spare ones. Except the fabrication of the components, i.e. the cavities and the cryomodules, everything will be made in the respective labs: chemical treatments, High Pressure Rinsing, assembling in clean room, RF tests of the cavities in vertical cryostat and RF power tests of the cryomodules.

NB: E_{acc} is defined as $E_{acc} = V_{acc}/(\beta_{opt}\lambda)$, where $V_{acc} = \int E_z(z)e^{i\omega z/\beta z}$.

CRYOMODULES A - β=0.07

Resonator

Details of the cavity and cryomodule designs were described in [4,5]. A first prototype cavity was realised and successfully tested during the APD phase of the SPIRAL2 project. The qualifying cavity has two main differences with this prototype cavity. First, due to beam dynamics considerations, the beam tube diameter of the low beta cavities was increased from 30 mm up to 38 mm. Second, the large flange of the dismountable bottom plate was changed from NbTi alloy to a stainless steel one on which the helium tank (also in stainless steel) is welded. This technical choice implies brazing the large stainless steel flanges with the niobium cavity body, 230 mm diameter tube.

The final tuning of the cavity frequency after manufacturing will be made by deforming the cavity around the accelerating gap region. This technique was tested on the prototype cavity which could be detuned by about 50 kHz from its initial frequency.

Before the first RF tests in vertical cryostat, about 160 µm of niobium was chemically removed from the inner surface of the cavity. The frequency shift due to this chemical treatment is about + 45 kHz, twice the expected value of + 20 kHz. This effect reveals the non uniformity of the chemical attack.

Q_0 curves of cavity A0 show a low Q_0 value of 2.10^8 almost constant until the highest gradient that was reached at 11 MV/m (Figure 1). This maximum gradient was only limited by the heating of some RF components.

Multipactor barriers could be easily processed. Little electron field emission was detected at gradients higher than 10 MV/m.

Analysis is in progress in order to understand why the Q_0 value is so low.

Despite the very high level of RF power dissipated, the cavity shows a remarkable thermal stability, even in condition where only the lower part is in direct contact with liquid helium. This demonstrates that the dissipative region is located around the bottom of the cavity between

#olry@ipno.in2p3.fr

the dismountable bottom plate and the beam tubes.

The measured effect of the helium bath pressure variation on the frequency confirmed the calculated value of 3.4 Hz/mbar.

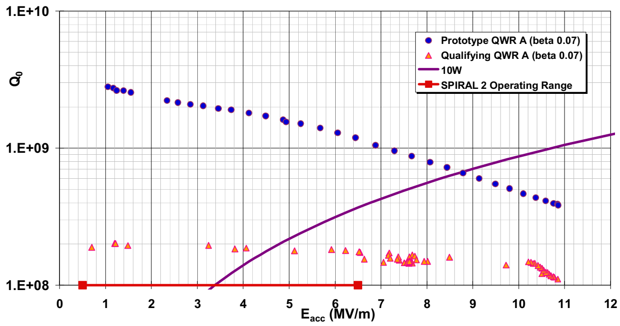

Figure 1: Q_0 curves of cavity A0 obtained in vertical cryostat at 4.2 K.

Cryomodule

It was decided to carry on the assembling of the qualifying cryomodule with this cavity which doesn't reach the specifications in terms of Q_0 value. The performances are good enough to validate the major points of the assembling sequence and of the cryomodule performances. Furthermore, it will be possible to place this cavity at the beginning of the superconducting LINAC, where the cavities are working at accelerating fields lower than 5 MV/m. Thus, the RF dynamics losses will be kept lower than 10 W, the maximum power allowed by the cryogenic system.

Before mounting the cavity in the cryomodule, a last chemical treatment and HPR rinsing will be performed, and the cavity will be tested again in vertical cryostat in December 2007.

Figure 2: Pre mounting of the cavity in the vacuum tank of the cryomodule. This operation will take place in the CERN clean room.

Part of the clean assembling will be performed in the large clean room at CERN, because Saclay's clean room is too small to house the vacuum tank: the cavity has to be connected to the vacuum tank in order to be leak tight inside the clean room. Figure 2 shows how the cavity will be mounted inside the vacuum tank in the clean room. This operation requires a large clean area and a strong floor to support the weight, about 500kg.

In February 2008 the qualifying cryomodule equipped with the power coupler developed and prepared by LPSC Grenoble [3] will be ready for the RF power tests. These tests will be performed at Saclay with a 10kW RF solid state amplifier.

The order of the cavities for the series will be placed by the end of October 2007, and the order for the cryomodule components of the series should be placed mid of 2008. A new large clean room built on the Saclay site will be ready at the end of 2008 for assembling the series of cryomodules.

CRYOMODULES B - β=0.12

Resonators

Following the fabrication and successful test of the first prototype B cavity [6,7], two more resonators, so-called "qualifying" or pre-series resonators, have been manufactured and delivered in 2007. These resonators were designed to be assembled inside the prototype cryomodule for a complete test (10-kW RF test, cryogenic losses measurements and validation of the alignment procedure).

The first qualifying resonator, equipped with its Titanium helium tank, has been tested successfully in vertical cryostat in May 2007 (Figure 3). Before this test, about 85 µm were chemically removed, followed by a 2-hour HPR cleaning through the top and bottom ports of the cavity.

An accelerating gradient of 9.3 MV/m was achieved (limited by a quench). As shown on the curve, the Qo value is above the specifications for the nominal gradient 6.5 MV/m. The sensitivity of the cavity to the helium bath pressure variations was measured to be 6 Hz/mbar.

Figure 3: Test of the first qualifying cavity. (RF parameters, E_s/E_{acc} = 4.76 & B_s/E_{acc} = 9.35 mT/MV/m, L_{acc} = 0.41 mm = $\beta\times\lambda$).

Unfortunately, the second cavity had a leak after a "light" BCP chemistry (around 35 µm). The origin of this leak is still being investigated at that time and the cavity was of course not tested at 4.2 K in vertical cryostat.

Moreover, as this cavity will not be mounted in the prototype cryomodule, some tests needed to validate the cryomodule design will not be perform (such as the alignment procedure for instance).

The manufacturing of the 16 cavities for the whole Linac has started in October 2007. More than 1.7 tons of RRR>250 niobium has been ordered to Tokyodenkai for the manufacturing, including sheets, discs, rods, thick tubes and rings. The two first cavities of the production should be delivered in March 2008. These cavities will be tested in vertical cryostat first and then, put in the prototype cryomodule for a full power test, giving us the validation for the remaining 14 cavities of the series. The alignment procedure will be tested at that time.

Cryomodule

The prototype cryomodule has been assembled for the first time in August 2007. The main purpose was to validate the assembly processes, the tooling used for the preparation in the clean room (Figure 4) and the mounting outside the clean room (Figure 5). After that, the cryomodule has been disassembled and assembled again. No problems were observed during those "assembly-disassembly" operations.

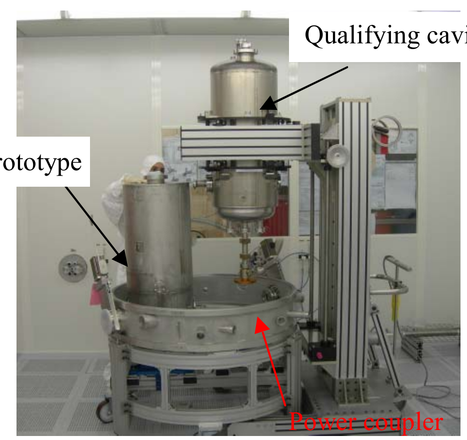

Figure 4: Cavities assembly in the clean room

Figure 5: Assembly of the 80K thermal shielding outside the clean room

Figure 6: Mounting of the movable plunger on the top of the qualifying cavity.

As shown on Figure 4, we are going to test the cryomodule with the prototype cavity instead of the second pre-series cavity. This cavity will be mounted with an antenna (at the critical coupling $\beta=1$) without any tuning system. The qualifying cavity will be tested with the power coupler at the nominal power of 10-kW. The original tuning system, which use a movable plunger in the magnetic region will also be tested (Figure 6).

The leak checks have been done and the cryomodule is nowadays being prepared in our experimental hall. The first test at 4.2 K is foreseen in December 2007.

Figure 7: Cryomodule assembled

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REFERENCES

[1] R. Ferdinand et al., "Status of the cryomodules for the SPIRAL2 superconducting Linac", PAC07, Albuquerque, USA, June 2007.

[2] Information on the Physics Case of SPIRAL 2: http://ganinfo.in2p3.fr/research/developments/spiral2

[3] Y. Gomez-Martinez et al., "SPIRAL2 coupler preparation and conditioning", 13th SRF Workshop 2007, Beijing, China, October 2007.

[4] P-E. Bernaudin et al., "Design of the Low-Beta, Quarter-Wave Resonator and its Cryomodule for the SPIRAL2 Project", EPAC 2004, Lucerne, Switzerland, July 2004,

[5] G. Devanz, "SPIRAL2 Resonators", 12th SRF Workshop 2005, Cornell University, USA, July 2005.

[6] G. Olry et al., "Development of a beta 0.12, 88 MHz, quarter wave resonator and its cryomodule for the spiral2 project", 12th SRF Workshop 2005, Cornell University, July 2005.

[7] D. Longuevergne et al., "Results of beta=0.12 Quarter-Wave Resonator For radioactive beams production at SPIRAL2 facility", 13th SRF Workshop 2007, Beijing, China, October 2007.