THE SPIRAL 2 SUPERCONDUCTING LINAC

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Abstract

The SPIRAL 2 superconducting linac is composed of 2 cryomodule families, basically one of low beta, called Cryomodule A, and one of high beta, called Cryomodule B. The low beta family is composed of 12 single cavity cryomodules. The high energy section is composed of 7 cryomodules hosting 2 cavities each. According to beam dynamics calculations all the cavities will operate at 88 MHz: one family at β=0.07, and one at β=0.12. The design goal for the accelerating field Eacc of the SPIRAL 2 QWRs is 6.5 MV/m. The configuration, cavities and cryomodule tests and status are described.

INTRODUCTION

The GANIL's SPIRAL 2 Project [1] 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). It consists of high performance ECR sources, a RFQ, and the superconducting light/heavy ion linac. The driver is also asked to provide all the energies from 2 MeV/u to the maximum designed value.

Figure 1 : SPIRAL2 superconducting linac – 2 QuaterWave Resonator (QWR) families.

The superconducting linac is composed of cryomodules type A developed by CEA-Saclay, and cryomodules type B developed by IPN-Orsay. Both types of cavities will be equipped with the same power coupler specified for a maximum power into the cavity of 12.8 kW@6.5MV/m, which is developed in a third laboratory, LPSC-Grenoble. The coupler must handle 100% reflected power at maximum incident power.

All the components of the series (cavities and cryomodules) will be fabricated in the industries. Couplers conditioning, cavities chemical treatments, HPR rinsing in clean room, assembly, and RF tests of the cavities in vertical cryostat and RF power tests of the cryomodules will be made in the respective 3 labs.

CRYOMODULES A - β=0.07

Details of the cavity and cryomodule design were described in [2,3].

The cavity tuner works by cavity deformation perpendicularly to the beam axis. This design saves room in the beam axis direction. The cavity mechanical design was optimized in order to reach a full tuning range of ±25 kHz at 4 K, without plastic deformation of the niobium cavity.

Figure 2 : Cavity A with MLI and B in clean room.

Each cavity A will be feed by 5 to 10 kW solid state RF amplifier [4]. The first cavities of this low beta section working at low accelerating field (≈ 0.49 MV/m, 0.5 kW) will require less power than the last cavities of the section.

At present, one cavity prototype and a qualifying cavity have been tested in vertical cryostat. Whereas the prototype reached the specifications, the qualifying cavity performances were not as good as expected. The maximum accelerating field, 11 MV/m, was much higher that needed, but the Q_0 value was a factor 10 below the acceptable value, about 2 10^8 (see Figure 3).

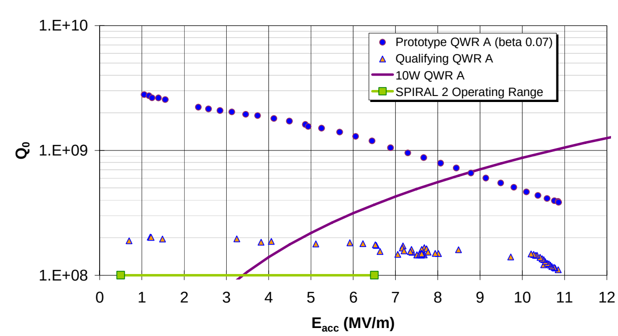

Figure 3: prototype and qualifying QWR A cavity in vertical cryostat.

Several tests were performed to localise the dissipating defects without success. We could determine that this defect is not located at the cavity extremities, at the maximum B_{peak} region, or at the dismountable bottom plate. It may be located at middle height of the cavity. At about 11 MV/m the cavity dissipates more than 100 W. Fortunately small gradients are required at the beginning of the LINAC, and the dissipations can be kept bellow the 10 W limit (E_{acc} < 4.5 MV/m).

As consequences of these low performances, the different tests induced delays, and a new call for tender was restarted for the series of the cavities, inducing more delays. The new procedure asks for 2 new cavities with 2 different manufacturers, ZANON and SDMS. A stop point exists after the cavity welding and before the helium tank welding for tests. The 2 manufacturers allow us to speed up the process while being confident on the cavity design. The remaining series cavities of this order will then be manufactured with one or both companies. These 2 first cavities are expected in February 2009. The last cavities are expected in September 2010.

The qualification cryomodule has been assembled with the faulty cavity. Because of the small size of the Saclay clean room, the clean assembly took place in two phases. At first the HPR was performed at Saclay and all components prepared for clean assembly. Secondly, the cavity and associated components, where mounted in the vacuum tank in the large clean room at CERN.

A severe vacuum leak occurred during assembling and prevented us to perform the RF power tests as expected. Only low level RF measurements and cryogenic analyses could be made. The measured static consumption of the cold mass @ 4K of the cryostat is about 7 W, within the expected value. 21 W is dissipated on the copper screen at 77 K. The valve box, cryogenic lines and cryomodule dissipate about 25 W @ 4 K, little more than expected.

Figure 4: qualification type A cryomodule (β=0.07).

Preliminary analyses of the microphonics were performed. The resonance of the stem oscillation was observed at 39 Hz as expected, and vibrations generated by the pumping systems were detected around 100 Hz. Further analysis is still needed to determine if the microphonics observed are dangerous or not and to confirm if a damping system is required.

At present the qualification cryomodule is being dismounted. It will be remounted using the IPN-Orsay SUPRATECH clean room, now available.

The RF power tests with the cryomodule in the accelerator configuration are expected in November this year.

The call for tender of the cryostat series is ongoing. The order should take place late in December this year or January 2009. The test of the last assembled cryomodule A is scheduled in March 2011.

CRYOMODULES B - β=0.12

A first “qualifying” cryomodule has been manufactured and tested with success in early 2008. The serial production of the 6 remaining cryomodules is under way.

Figure 5 : qualification type B cryomodule (2×β=0.12).

Resonators

At present time, one prototype, 2 pre-series cavities and one series cavity has been tested. The first qualification resonator equipped with its Titanium helium tank has been tested in vertical cryostat in May 2007, the second one had a vacuum leak revealed by the chemical treatment and is lost.

The ACCEL Company is manufacturing the cavities series. Three series cavities are in hand at present time. The first one has some mechanical default but was tested with excellent result. The ACCEL Company improved the mechanical manufacturing of the two other ones. They are under chemical treatment and will be tested very soon. A stop point was decided in order to validate the design with a complete set of cavities. The company will then be able to finish the manufacturing. The remaining resonators should all be in hand before the end of 2009.

The first qualification cavity, and the first series cavity named “Erentrude” on the curve Figure 7, showed good electro-magnetic performances. Another good sign is that we observe a slight improvement from the prototype to the first series production. Design gives E_s/E_{acc} = 5.51 and B_s/E_{acc} = 10.19 mT/MV/m, for a $\beta\times\lambda$ accelerating length of 0.41 mm). Despite modification of the electric field area shape, multipacting barriers, identical to the ones observed on the prototype, are measured. One barrier (around 1.3 MV/m) can be easily processed while two or more barriers at very low field (between 30 and 80 kV/m) cannot. These barriers were observed at about the same fields on the 2 cavity types (A and B).

The cavity cold tuning is performed using superconducting plungers inserted on the top of the cavity inside the magnetic volume [5].

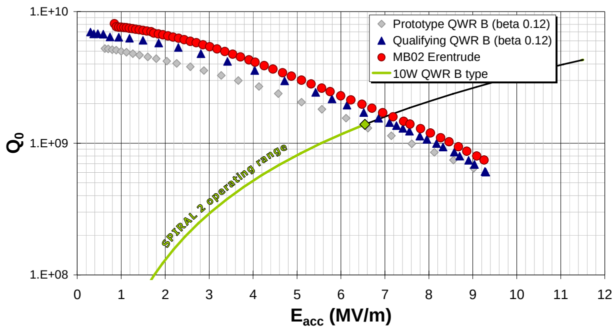

Figure 7 : Q_0 curve of the first type B cavities.

Cryostat

The call for tender of the cryostats is started. The offer will be analysed and the contract should be signed by the end of the year.

The qualification cryomodule was first used to validate the design. As the second qualifying cavity was not useable it was tested with the prototype cavity with an antenna at the critical coupling (β=1) and with the first qualifying equipped with a power coupler. In this configuration, 8 MV/m was reach in the cryomodule. The specified main performances was achieved, Eacc = 6.5 MV/m with a dissipated power < 10 W @ 6.5 MV/m, without magnetic shielding. The static dissipation was 13 W for 11 W specified, with possibilities for improvements. Good results were obtained with the power coupler, the 10 kW solid state amplifiers [4], microphonics and the cold tuning system mentioned above. Very interesting pollution tests were performed to validate the surrounding warm sections of the cryomodules [6] and the possible use of interceptive diagnostics close to the cavities. The low field multipactor problem was solved with the use of the power coupler. See details in [7].

The cryostat has been disassembled; the cavities cleaned are under re-assembly in the final configuration with the terrestrial magnetic shielding. It will be tested in November this year, focusing on microphonics, alignment repeatability, digital low level RF and usability of the power amplifier at low power.

COUPLERS

The RF couplers have to provide 12.8 kW CW power to the cavities at 88.05 MHz for the design goal accelerating field of 6.5 MV/m [8].

The coupler has a fixed coaxial antenna with a disc-shape ceramic (6 mm thickness). The coupling will be fixed, and the RF system will have to manage some reflected power. Coupler prototypes have been tested (head to head) up to

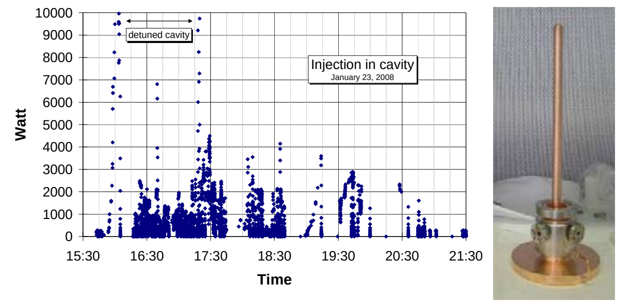

Figure 6 : Power test with the cryomodule.

40 kW CW with good results.

The transport of three qualification couplers showed some weakness and the design has been recently improved. RF simulations, mechanical and thermal simulations were carried out.

As previously describe, the full power RF test was performed using the B type cryomodule (see Figure 6). The coupler was warm and cold conditioned, we observed some low level multipactor, as with the critical coupling, but we had no difficulties to pass them.

The tender of the series was won by the SCT Company in France. The kick off meeting of the series the production was in September this year. The completion of this production is foreseen in 2010.

CONCLUSION

The different teams of each laboratory involved in this project are now preparing the industrialization. Installation in the linac tunnel is foreseen in 2011.

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