Status of the low beta 0.07 cryomodules for SPIRAL2

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P. Bosland, M. Anfreville, P. Carbonnier, F. Eozénou, C. Madec, L. Maurice, A. Pérolat, P. Galdemard, O. Piquet, Irfu, CEA Saclay
R. Ferdinand, PE Bernaudin SPIRAL2/GANIL Caen
Y. Gómez Martínez, LPSC Grenoble, CNRS/IN2P3

Abstract

The status of the low beta cryomodules for SPIRAL2, supplied by the Irfu institute of CEA Saclay, is reported in this paper. We summarise in three parts the RF tests performed on the cavities in vertical cryostat,the RF power tests of the qualifying cryomoduleperformed in 2010 and the RF power tests performed in 2011 on the first cryomodule of the series.

INTRODUCTION

CEA Saclay has in charge the delivery of the 12 low beta (b=0.07) cryomodules, named cryomodule A, for the SPIRAL2 accelerator [1]. This includes the development, the realisation, the preparations and the RF power tests. The first step consisted in the manufacturing of a cavity prototype,which reached the required performances [2]. In a second step a first ("qualification") cryomodule has been tested before the production of the series cryomodules. This qualification cryomodule will be used in the machine. All the components of the series (cavities and cryomodules) are fabricated in industry. Cavities chemical treatments, HPR rinsing in clean room, assembly, RF tests of the cavities in vertical cryostat and RF power tests of the cryomodules are performed at CEA Saclay.

The power couplers specified for a maximum power of 40 kW CW in travelling wave, are delivered by theLPSC Grenoble laboratory [3]. The same couplers are also mounted on the high beta cavities developed by IPN Orsay [4].

The "cryomodule A" project began in 2003 in the context of the moving of the laboratory from one site to the actual one at CEA Saclay. Three different clean rooms had to be used for the cavities preparation and cryomodules assembling before assembling the first cryomodule of the series. Since the end of year 2009 we have the possibility to work in the new facility that was built at Saclay for the XFEL project at DESY sharing this facility.

Two RF power tests campaigns were performed on the qualification cryomodule:between December 2008 and April 2009 for the first one, and between April and September 2010 for the second one. For the first campaign the cryomodule was assembled in the clean room at CERN.The results showed very high RF dissipations in the cavity [2] that led us to make several modifications. The refurbishment of the qualification cryomodule was made in the IPN Orsay clean room, andthe configuration of the qualification cryomodule was the nominal one required for the installation on the LINAC.

All components of the serial cryomodules were delivered before the end of year 2010.The first cryomodule of the series was assembled in the new clean room at Saclay and was tested in July 2011.

RF TESTS OF THE CAVITIES IN VERTICAL CRYOSTAT

All cavities have been delivered by two manufacturers: SDMS and ZANON. The chemical treatments wereperformed at Saclay in two different installations: first in the old installation and then in the new one since mid-2010. The high pressure rinsing (and the assembling before vertical tests) was performed in 3 different clean rooms.

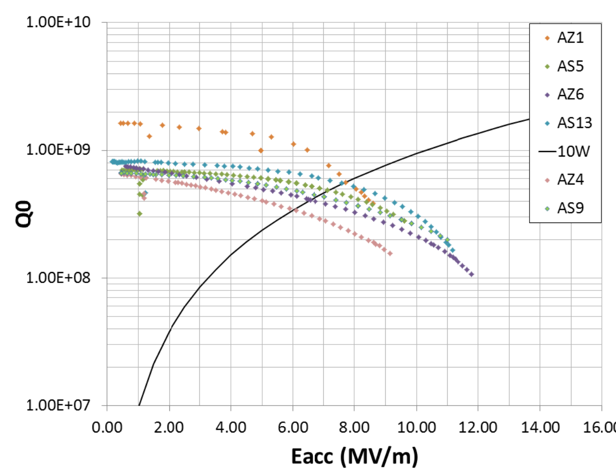

Figure1: Q curves of the 6 cavities tested with their copper bottom caps.

From all the different tests that have been performed with cavities in different configurations, the results in Figure 1 summarise only those corresponding to the cavities with their final dismountable bottom cap made out of copper. The first cavity AZ1 has its bottom cap mounted with an indium seal. All the other cavities are sealed with a Helicoflex gasket. RF tests show a large scatteringof the cavities performances. The accelerating field reached by the cavities is always well above the specification (E_{acc}=6.5MV/m), but Q levels are often lower than foreseen.Last results seem to show a decrease of the Q values from one test to the next.The Q_0 value of AZ4 cavity islower than the required specification at the nominal field (E_{acc}=6.5 MV/m) andthat of AZ6 cavity is at the limit (Q_0=4E^{10} at E_{acc}=6.5MV/m). These 2 cavities will be tested a second time after a new chemical treatment.

Analyses are in progress to determine the cause of the Q decrease that is not yet understood. Some investigations look at possible dissipations on the gasket, contamination of the ultra-pure water. AS5 cavity cannot be mounted in a cryomodule because a leak appeared on anNb/Nb weld after the RF test in vertical cryostat. The cavity needs to be repaired.A bellow of the helium tank of the AZ6 cavity was damaged during handling. This cavity needs also to be repaired.On the third cavity AS9, a small helium leak on the Helicoflex gasket caused an increase of the cavity pressure up to about 1.10^{-6} mbar. Fortunately it was still possible to reach the excellent maximum field of about 11MV/m.

At present only 2 cavities are completely qualified for assembly in a cryomodule: AZ1 and AS13. AZ1 was mounted in the qualification cryomodule and AS13 was mounted in the first cryomodule of the series.

RF POWER TESTS OF THE QUALIFICATION CRYOMODULE

The qualification cryomodule was mounted at the beginning of year 2008 and it was tested from December 2008 to April 2009. After a complete refurbishment in the IPN Orsay clean room,it was tested a second time from Aprilto September 2010.In spite of a serious leak that polluted the cavity vacuum of the qualifying cryomodule at the beginning of the tests period, all theforeseen tests have been performed.

The static cryogenic consumption was about 4.5 W,as expected from calculation. The measurement method used the helium decrease rate after closing the liquid helium valve. A second method used the corresponding helium gas outlet flow at 300 K. The heat load on the cryomodule copper thermal screen, 25W, was determined by the natural temperature increase after closing the liquid nitrogen valve.

The RF conditioning of the power coupler was made up to 10 kW first with the cavity at 300 K and then after cooling downthe cavity at 4 K.It had been calculated and also observed that no multipacting occurs in the coupler at a power higher than 1 kW. That is the reason why the pulsed mode was used for conditioning only at a power lower than 1 kW. The CW mode was applied for the commissioning from 1 to 10 kW.

Amaximum accelerating field of 7.8 MV/m was reached, limited by a quench due to an intense electron field emission. This may have been caused by the leak that polluted the cavity. The maximum gradient was still higher than the nominal value of 6.5 MV/m. Nevertheless, the pollution of the cavity increased the RF losses of the cavity to about 35 W at 6.5 MV/m;this is more than 3 times higher than the specifications (10 W maximum at nominal field).

The cavity was correctly tuned at the nominal frequency of 88.0525 MHz. The cold tuner blocked after a short period of running, because the multilayer insulation wrapped around the screw of the tuner. After repair and proper modifications avoiding this problem to arise again, the tuner worked correctly. Cycles over long and short ranges were performed in order to check its reliability over long periods. No problem occurred after running the motor up to17.10^6 motor steps. No damage could be observed on any of the critical parts. The sensitivity measured was 0.14 Hz per motor step.The backslash is very small, and it was difficult to determine it with a high accuracy because of the pressure fluctuations of the helium bath that caused frequency shifts. It seems to be around 1 Hz, and it never caused any problem of frequency adjustment during the tests.The sensitivity of the frequency to the liquid helium bath pressure was measured to be 3.2 Hz/mbar; the calculated was the same.

A LLRF system prototype developed for the accelerator [8] has been successfully tested with the frequency tuner. The phase shift could be maintained within ±0.1° with respect to the RF pilot (specifications: ±0.5°), and the field amplitude in the cavity within ±0.12% (specifications: 1%).Microphonics were analysed using a woofer fixed on the vacuum tank in order to excite them. The mode at 399 Hz was the more easy to be excited with this system. The LLRF system could reject this mode with an efficiency of 29 dB (see Figure 2).

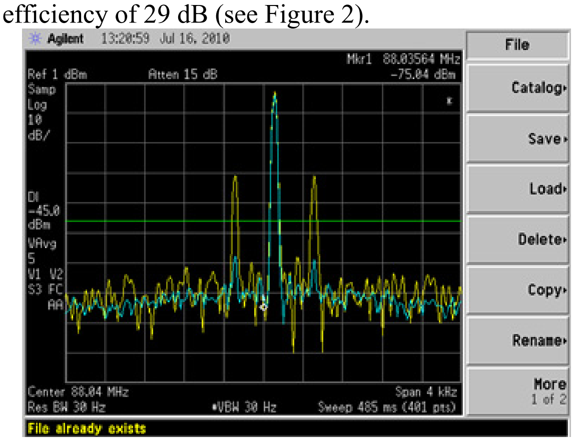

Figure 2: rejection of a microphonics pollution at 400 Hz by the LLRF system (yellow curve: without control – blue curve: with control). The cavity accelerating field is 1.6 MV/m during this test.

RF POWER TESTS OF THE FIRST CRYOMODULE OF THE SERIES

The first cryomodule of the series was entirely prepared and assembled in the new installation at Saclay at the beginning of year 2011. Some small modifications were introducedin the cryogenic pipes circuits.The AS13 cavity was mounted in this cryomodule. The first campaign of RF power tests was performed in July 2011.

Static cryogenic load at 4 K is about 6.2 W, slightlyhigher than for the qualification cryomodule (4.5 W) but lower than the specifications (7 W). The tuner works as well as the qualification one, and the cavity could be tuned with the required accuracy at the nominal frequency of 88.0525 MHz. The backslash could be measured with a better accuracy with a stable liquid helium bath pressure, and is about 1 Hz. The tuning sensitivity is 0.12 Hz/motor step.

The RFconditioning of the power coupler could only be performed up to 5 kW because of redundant problems with the RF solid state amplifier. The maximum accelerating field before the quench of the cavitywas limited by field emission at5.9 MV/m(lower than the specification of 6.5 MV/m). At E_{acc}= 4 MV/m, no field emission occurs, and the cavity dissipation measured by the increase of the outlet helium gas flow is about 2 W. This value is not accurate, but is close to the value measured during the RF vertical test of the cavity AS13. This confirms the fact that the major source of dissipation in the cavity at nominal accelerating field is electron field emission. The pollution source is not yet understood, but is possibly coming from the power coupler.

A second campaign of RF power tests will be performed in October in order to (try to)process the cavity and to increase the maximum accelerating field.

FUTURE PLAN

The general behaviours of the two first low beta cryomodules are quite similar.Very high RF dissipationsof the cavities are due to electron field emission, and limit the maximum accelerating at a value lower than the nominal field for one of the two tested cryomodules.Except the RF dissipations, all other points are within specifications and the cryomodules would be acceptable for operationin the machine.

Before going on with the assembling of the other cryomodules, we have to understand the sources of the pollution. Analysis is in progressto determine the pollution levels due to dust particles of all the components connected to the cavity vacuum. The next test of a cryomodule A will be performed using a cavity equipped with a β=1 incident power antenna (without any power coupler).

In parallel of the improvement of the cryomodules performances, investigations will be carried out to understand the source of the Q decrease observed on the latest tests of the cavities in vertical cryostat.

REFERENCES

[1] T. Junquera, P. Bertrand, R. Ferdinand, M. Jacquemet, "The high intensity superconducting Linac for the SPIRAL 2 project at GANIL", proc LINAC 2006, Knoxville, USA, p 142-144.

[2] P.-E. Bernaudin et al., “Testsstatus of the SPIRAL 2 low beta cryomodules”, PAC’09, Vancouver, May 2009, TU5PFP041.

[3] Y. Gómez Martínez et al, "theorical study and experimental result of the RF coupler prototypes of Spiral2", EPAC 06, Edinburgh, June 2006.

[4] G. Olry et al., “SPIRAL2 cryomodules: status and first results”, SRF09, Berlin, September 2009.

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