SPIRAL 2 coupler preparation and RF conditioning

T. Cabanel, Y. Gómez Martínez, D. Marchand, R. Micoud, F. Pancher, F. Vezzu

SPIRAL 2 COUPLER PREPARATION AND RF CONDITIONING

T. Cabanel, Y. Gómez Martínez, D. Marchand, R. Micoud, F. Pancher, D.Tourres, F.Vezzu, LPSC, (CNRS/IN2P3-UJF-INPG), FRANCE.

Abstract

Five radiofrequency coupler prototypes have been manufactured. Three of them will be mounted in the cryomodules of the SPIRAL 2 superconducting LINAC (LINear ACcelerator). This paper describes the coupler preparation and the first results of their conditioning.

INTRODUCTION

SPIRAL 2 is a 40 MeV-5mA deuterons and a 14.5 MeV/u-1mA heavy ions superconducting LINAC under construction at GANIL. The SPIRAL 2 superconducting LINAC [1] consists of 19 cryomodules, 12 cryomodules called A housing 1 Quarter-Wave Resonator (QWR) at beta=0.07 and 7 cryomodules called type B [2] housing 2 QWR at beta = 0.12. Each cavity is fed by a radiofrequency capacitive coupler.

The coupler transfers the power into the cavities and keeps the vacuum into the accelerator. The RF couplers have to provide 10 kW Continuous Wave (CW) nominal power to the cavities at 88 MHz for an accelerating field of 6.5 MV/m. The coupler must handle 100% reflected power at maximum incident power.

The coupler is associated with:

- An external coaxial conductor for which two locations are set to 4.2 K and 70 K temperatures.
- An internal bellows to compensate mechanical misalignments.
- A permanent cooling of pure clean air to keep the ceramic window at ambient temperature and to prevent condensation.
- One RF connection. This one is also equipped with a bellows to compensate differential thermal expansions
- One pressure compensation system.

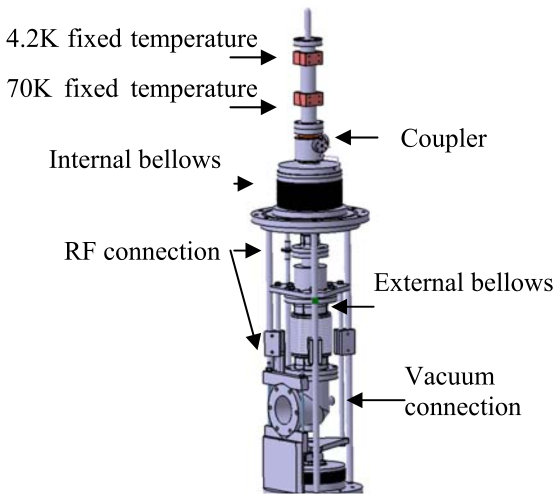

Figure 1: Coupler activity.

The Laboratory of Subatomic Physics and Cosmology (LPSC) did the design, the simulation and the test of two different technologies of couplers [3]. Since the validation and the selection of one design, five more couplers have been manufactured (from two different companies). They are currently being conditioned. Three of them are going to be tested in the SPIRAL 2 cryomodules.

Figure 2: Coupler prototype.

PREPARATION OF THE COUPLERS

The use of the coupler in superconducting cavities requires very clean internal surfaces. To reduce the conditioning time, a high vacuum level inside the coupler is necessary. For those reasons, the preparation of the coupler is primordial.

The first step is to require a high level of cleanliness of the coupler from the supplier (absence of dust, specific packing…)

Hence the reception at LPSC, the coupler is kept in a “ISO 6” clean room. The coupler will then stay inside the clean room until its departure for the assembly within the cryomodules.

Figure 3: ISO 6 clean room.

From the reception of the coupler, we check the coupler inside the clean room. We first do a visual, a dimensional and a geometrical inspection. We then measure the coefficient of reflection (S_{11}). Finally we realize a leak test. When the coupler passes the validation we start to prepare it.

The first step of the coupler preparation is to clean it. The coupler is cleaned in an ultrasonic bath at 50 °C during 15 minutes with a specific detergent. Afterward, the coupler is rinsed with ultra pure water and dried. The final step is the baking of the coupler in a vacuum oven with optimized temperature.

RF CONDITIONNING

For the RF conditioning of the coupler, a test bench was necessary. The test bench is supervised by PC software that controls the RF power and the data acquisition. A permanent monitoring is done through many interlocks.

The test bench

The test bench is located inside the clean room. A standing wave test bench was chosen instead of a travelling wave one because, at 88 MHz, the size of the resonant cavity would have been too big. Couplers are conditioned in a stand-alone configuration with an open termination, in a full stationary wave mode. Thus, the preliminary baking of the coupler in the oven and in situ are necessary to clean out its internal surfaces.

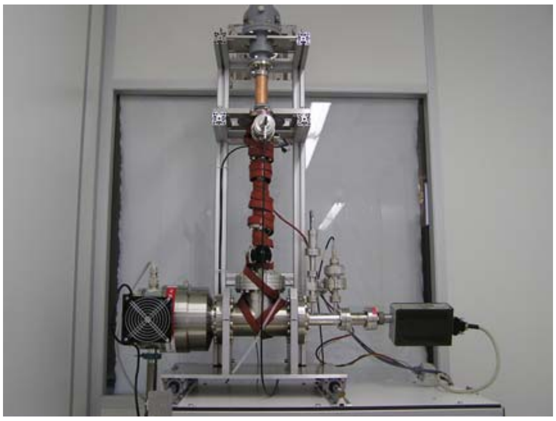

Figure 4: The test bench of the couplers.

The RF power system

Two RF power lines were installed. One is for the RF conditioning of the couplers in stationary wave mode, and the second one is for the tests at high level power (up to 40 kW) in travelling wave mode. The RF power lines are selected through a RF switch. The first RF line has a 20 kW CW circulator in order to keep the 10 kW CW nominal power in a stationary wave mode. The second line must be able to produce 40 kW CW which is four times the nominal power. For this purpose, a 40 kW CW amplifier is necessary. This amplifier is common to the two lines. A limitation of power is included in the software control for the use of the amplifier either in the stationary or travelling wave mode. A generator drives the amplifier. A modulator is able to pulse the RF from 1 µs to continuous signal.

The amplifier, the circulator and the load are water cooled.

The interlocks

The interlocks are fundamental to secure the RF conditioning of the coupler.

Four interlocks have been set up:

- Multipactor effect detection: the electron current is measured using an antenna (positively polarized) close to the coupler window. If a threshold is exceeded the RF power is switched off until no more multipactor effect is detected.
- Vacuum control: multipactor effect and outgassing decrease the necessary vacuum level. If a threshold is exceeded, the RF power is switched off until the threshold is not exceeded any more.
- Water interlock: RF power is also switched off in case of water cooling failure.
- Watchdog: the electronic watchdog monitors the control PC clock signal which should never be interrupted. In case of any interruption, the watchdog switches off the RF power.

Measurements

A vacuum measurement is done through a pressure gauge. The electron pick-up located close to the window allows the measurement of the multipacting by the electron current. Finally, a power meter is required.

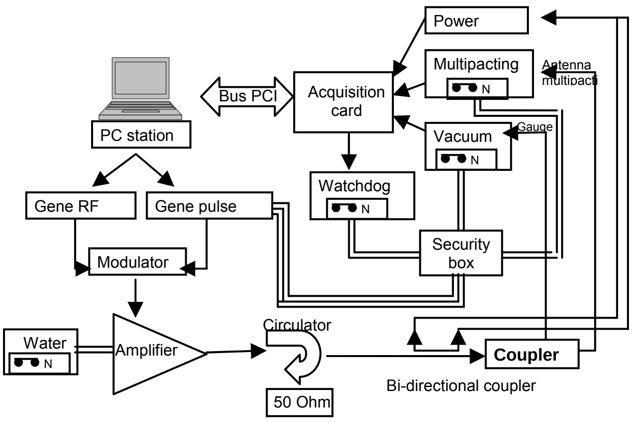

Figure 5: The test bench coupler scheme.

The procedure

Different conditioning procedures are being tested in order to decrease the time of each coupler conditioning.

In one procedure, the RF power is set to its minimum in CW mode. If the vacuum remains under a given threshold and if no anomaly is detected, the RF power is then progressively increased up to the nominal RF power (10 kW CW).

Another one procedure consists of adjusting the RF power to its minimal achievable value, in the minimal pulse mode. The RF power is then progressively increased to the nominal RF power if the vacuum remains under a given threshold and if no anomaly is detected.

Once the nominal RF power is achieved, the duty cycle is increased up to 100% (1ms). Then the RF power is decreased down to 0 W with a 100% duty cycle.

In another procedure, the nominal RF power is obtained after several cycles. The RF power is set to its minimal achievable value, in a pulsed mode. The duty cycle is progressively increased to 100% if the vacuum remains under a given threshold and if no anomaly is detected. Once the 100% duty cycle is achieved, the duty cycle is reduced meanwhile the RF power is increased by 0.1 dB. The process is iterated until 100% duty cycle and nominal RF power are achieved.

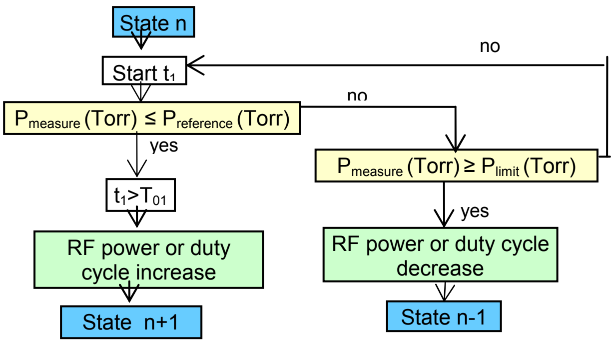

Figure 6: Vacuum control for the RF conditioning. Typical values: T_{01} = 10 sec, $P_{reference}$ ~ 10^{-8} Torr, P_{limit} ~ 10^{-7} Torr

The software

A software in C language was programmed to monitor and automate any of those procedures

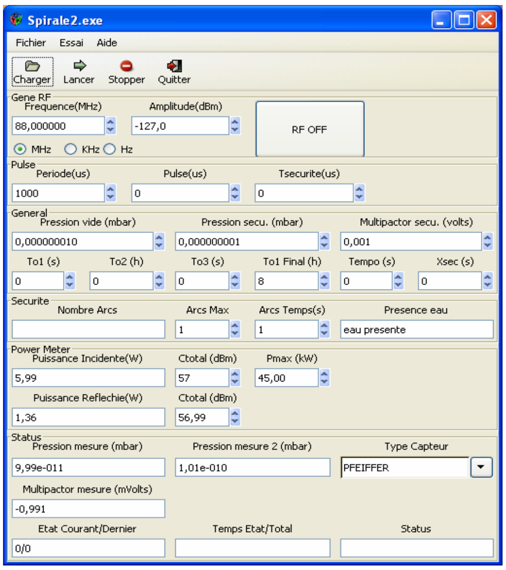

Figure 7: Software interface.

The software is used typically to drive the RF generator (increase or decrease the RF level) and switch ON/OFF the power if necessary. An input file defines the different thresholds (vacuum, multipacting level…) and the different states of RF power signal to go through (level and pulse duration).

Thus, states and procedures could be changed very easily.

The software also records into one file the vacuum level, the multipacting voltage, the different power during the conditioning.

FIRST RF CONDITIONING

Conditioning up to 10 kW CW

One coupler was prepared and conditioned up to 10 kW CW in the standing wave test bench configuration.

The vacuum in the test bench before the RF conditioning was equal to 4.5 10^{-9} Torr. After the conditioning the vacuum reached 3 10^{-9} Torr.

The power was then increased to the nominal level in continuous wave mode.

The RF conditioning was made at 88 MHz but also at 87 MHz and 89 MHz frequency around the nominal frequency.

Neither multipacting nor outgassing was then detected.

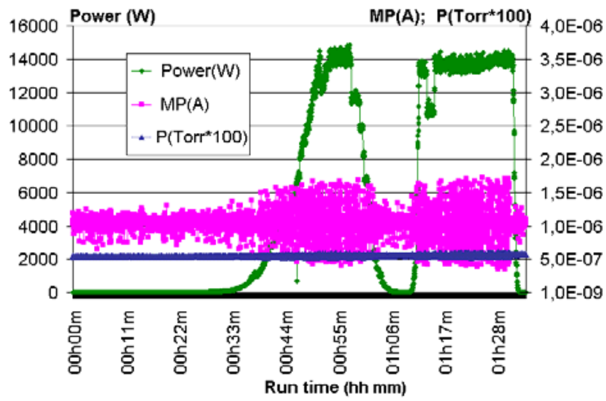

Figure 8: Power multipacting and vacuum measurement versus running time.

Conditioning up to 1 kW

One coupler was prepared and conditioned up to 1 kW CW. It is the range of power for which multipacting could appear.

The vacuum in the test bench before the RF conditioning was equal 3 10^{-8} Torr. After the RF conditioning, the vacuum reached 3 10^{-9} Torr.

We have increased the RF power level progressively from 0 W up to 1kW and for every power step, we also have increased the pulse duration from 1µs to 1ms (continuous mode).

The RF conditioning was made at 88 MHz but also at 87 MHz and 89 MHz frequency around the nominal frequency.

Insignificant multipacting and outgassing appeared at low RF power like foreseen in the previous analytical studies.

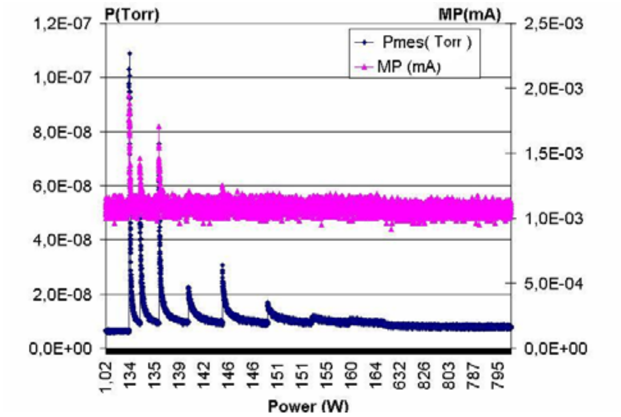

Figure 9: Multipacting and vacuum measurement versus RF power

The conditioning of this coupler up to 10 KW CW is on work.

FIRST TESTS OF THE COUPLER IN THE CRYOMODULE

The coupler that was conditioning up to 10 KW CW was mounted in the cryomodule called B at IPNO (FRANCE).

The measurement of the external quality factor, $Q_{ext} = 1.9\ 10^6$ for a penetration of 10.5 mm of the coupler antenna, fits the simulations.

The first test of the coupler in the cryomodule at room temperature and at 1 kW CW gave good results.

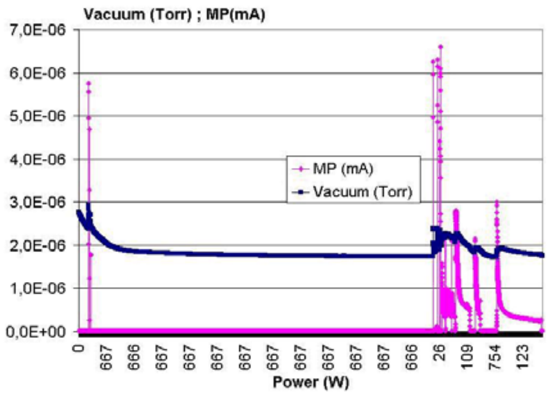

Figure 10: Multipacting and vacuum measurements versus the RF power.

Only very low multipacting (<1µA) at low power (<300W) were detected.

Not much outgassing was detected from 600 W.

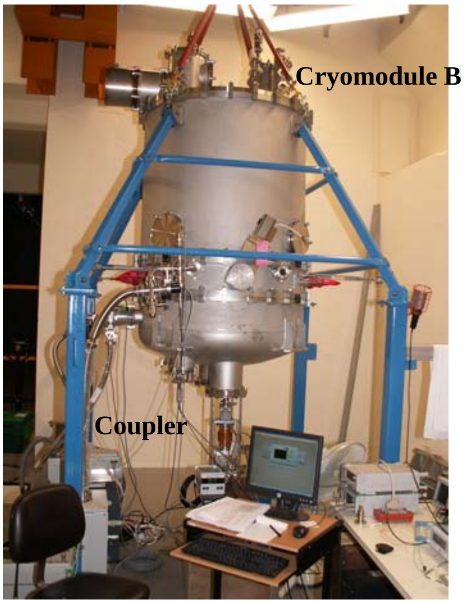

Figure 11: Coupler mounted on the cryomodule B.

CONCLUSION

The RF conditioning infrastructure of the couplers is now operational (clean room, test bench, software control system…).

The coupler preparation steps and the RF conditioning of the couplers were successfully achieved.

The validation of one coupler with the cryomodule called B has started and gave satisfaction so far. The next step is the end of this tests at full power at 4.2 K.

The goal is the call for tenders of 32 units of couplers before end of 2007 for SPIRAL 2 project.

AKNOWLEDGMENTS

Special thanks to J. Lesrel, G. Olry and S. Berthelot (IPNO), without their help the test of the coupler within the cavity would not have been possible.

Many thanks too to M.Baylac (LPSC) and JM. Carretta (LPSC) for their kind availability.

Many thanks to R. Ferdinand, M. Di Giacomo (GANIL) and T. Junquera (IPNO) for their interesting remarks and help.

REFERENCES

[1] P. Bosland et all, “Status of the cryomodules for the SPIRAL2 superconducting Linac”, PAC07, Alburquerque.

[2] G. Olry and all, “Status of the Beta 0.12 superconducting cryomodule development for the Spiral II projet ”, EPAC06, Edinburgh Scotland.

[3] Y. Gómez-Martínez et al., “Theoretical Study and Experimental Result of the RF Coupler Prototypes of SPIRAL 2”, EPAC 06, Edinburgh, Scotland.