LAST SPIRAL 2 10 KW CW RF COUPLER DESIGN

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Abstract

RF tests of the SPIRAL 2 coupler were done successfully in the cryomodules of the LINAC. Weakness during the transport has led to an updated mechanical design. We present here the results of the RF tests as well as the new design.

INTRODUCTION

SPIRAL 2 is a 40 MeV-5mA deuterons and a 14.5MeV/u-1mA heavy ions superconducting LINAC under construction at GANIL. The SPIRAL 2 superconducting LINAC consists of 19 cryomodules, 12 of them called A (including 1 Quarter-Wave Resonator (QWR) at beta=0.07) and the other 7 cryomodules called B (including 2 QWR at beta = 0.12).

The coupler transfers the power into the two types of 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 88.05 MHz for an accelerating field of 6.5 MV/m. The coupler must handle 100% reflected power at maximum incident power.

The Laboratory of Subatomic Physics and Cosmology (LPSC) realized the design, the simulation and the test of the disc shape ceramic coupler. [1].

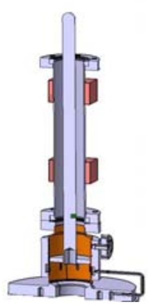

Figure 1: The RF coupler prototype.

Four coupler prototypes were manufactured and conditioned [2] and two of them were mounted in each cryomodule type. For the B-cryomodule, high power tests are finished and they were done successfully.

Figure 2: Coupler prototype.

TESTS OF THE COUPLER PROTOTYPE IN THE B-CRYOMODULE

Figure 3: Coupler in the B-cryomodule.

We measured a reflected coefficient S_{11} = -50 dB, and a quality factor $Q_{ext} = 1.1*10^6$ (beam dynamic quality factor choice).

At the resonance frequency of the cavity, the maximal accelerating field has been reached; the cleanness of the coupler is confirmed.

Outside the resonance, the coupler has been conditioned till 10 kW CW at room temperature and also at 4.2 K. During this test, weak multipactor (0.2mA) has been found only at low power (less than 300W).

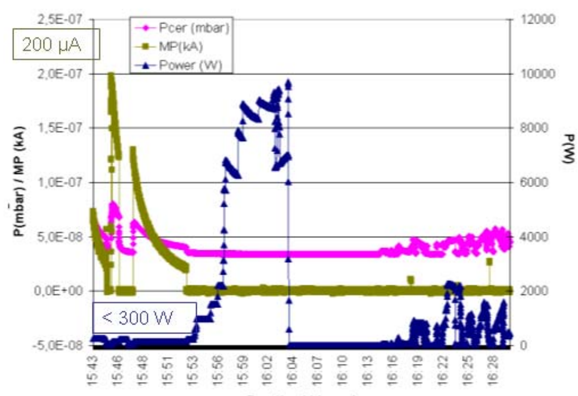

Figure 4: First conditioning at 4.2K (out of the resonance).

After those tests the RF design of the coupler was validated.

MAIN DESIGN CHANGES

The reasons of the mechanical changes were to obtain a more robust coupler especially during the transports.

The Antenna

To minimise the risks of deviation of the antenna during the transport we designed a hollow antenna. For this purpose we also have chosen a long internal support of the antenna.

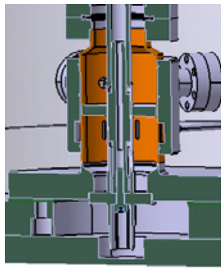

Figure 5: Connection with the internal support.

The Air Cooling Tube & the Stitchings

We increased their diameter to make them more robust.

The air cooling tube is now shorter also, to protect it from possible shocks.

Choice of Material

The initial Kovar material that was surrounding the ceramic was later excluded; it was changed by copper. Indeed, Kovar magnetic properties can disturb the good operation of the cavities.

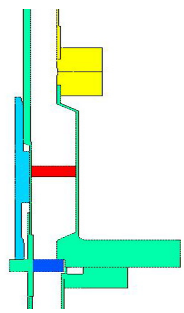

Figure 6: Materials of the updated RF coupler.

UPDATED RF COUPLEUR DESIGN

An updated RF coupler design was manufactured in 3 examples, conditioned and two of them are being mounted on the cryomodules.

Figure 7: Updated design of the RF coupler.

UPDATED SIMULATIONS

Simulations were made with the updated design and compared with the results obtained previously with the first prototype.

RF Simulations

RF performances were not changed with the new design.

The antenna penetration is not adjustable but its length was adjusted (7.5 mm for the A-cryomodule and 16.6mm for the B-cryomodule in order to minimize the RF mismatch in nominal conditions for all beams and also for all the cavities).

Mechanical Simulations

The finite element SAMCEF code is used.

- The modal frequencies of the coupler are far away of the typical motor frequency (50Hz). The design modifications of the antenna (full to hollow) had a positive effect on its modal frequencies.

Table 1: Modes (Hz) / design

Design	Mode	Frequency (Hz)
Prototype	1 – 2	59.5
Prototype	3 – 4	387
Updated	1 – 2	73.5
Updated	3 – 4	467.7

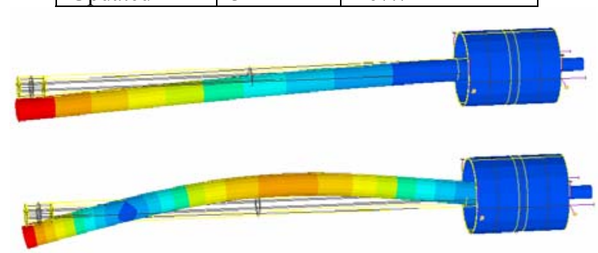

Figure 8: The mode 1-2 (up) and 3-4 (down).

- For the harmonic responses, harmonic simulations were performed with a fixed displacement of 0.01 mm on the frequency range from 0 Hz to 700 Hz. At 73.5 Hz frequency, we found the maximal displacement of the end of the antenna (0.375 mm). A displacement of 0.375 mm corresponds to a main stress of 33 MPa located at the internal radius of the ceramic window. In this range of frequency (0 → 700 Hz) the endurance stress limit of the material is never reached.

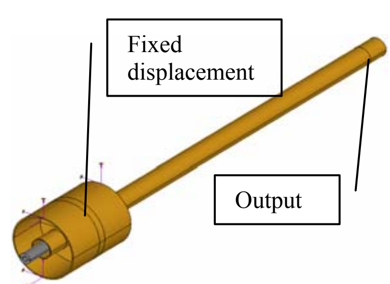

Figure 9: Imposed displacement and output in the harmonic response.

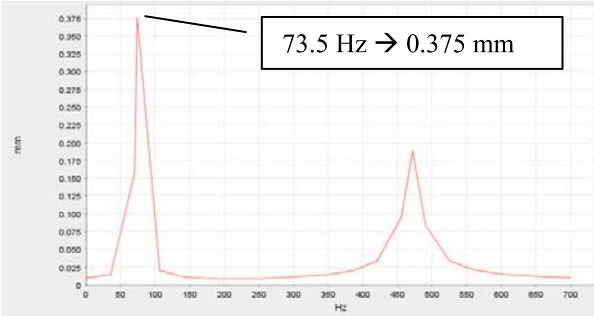

Figure 10: Displacement of the end of the antenna versus the frequency (0-700Hz)

- During the transport, the maximum acceptable acceleration is 10 g to avoid any lamination. A special transport is operated.

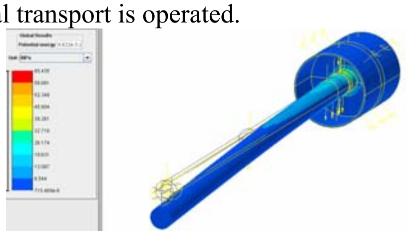

Figure 10: Stress of the coupler in the transports at 10g

Thermal Simulations

The results are very similar to the results of the prototype simulations.

Each cryomodule is set at a fixed temperature according to its thermal load limitations.

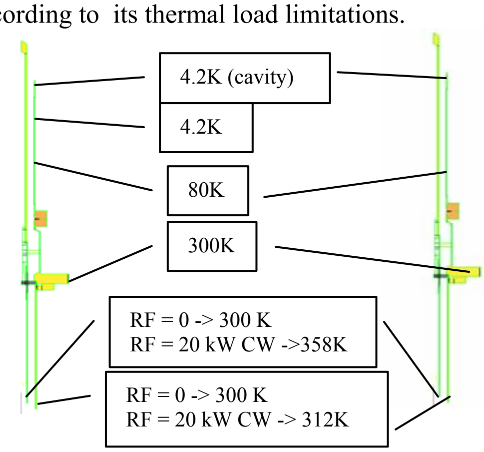

Figure 11: Thermal boundaries conditions for the coupler in the cryomodules A (left) and B (right).

Table 2: Temperatures (K) of the Coupler. Cu RRR10

Cryomodule	RF power	T_{tip} antenna	T_{Max} ceramic
A	0 kW	296 K	296.8 K
A	20 kW	349.4 K	320 K
B	0 kW	295 K	296.7 K
B	20 kW	347.6 K	320 K

One goal is to keep the temperature of the ceramic at a level higher than the water condensation temperature.

To control the ceramic window temperature an air cooling system is installed.

Table 3: Thermal Loads (watts) of the Coupler. Cu RRR10

Cryomodule	RF power	Thermal load at 4.2K link	Thermal load at the cavity (estimation)
A	0 kW	0.98 W	0 W
A	20 kW	1.28 W	0.17 W
B	0 kW	-	0.59 W
B	20 kW	-	0.934 W

The goal, a thermal load input at the cavity less than 1 W, is obtained.

During the cool down, there is a displacement of the end of the antenna. It was taken into account to have the antenna penetration of 7.5 mm for the A-cryomodule and 16.6mm for the B-cryomodule.

Table 4: Thermal Radiation from the End of the Antenna to the Cavity and the Cool Down Displacement. Cu RRR10

Cryomodule	RF power	Radiation thermal load at the cavity	Displacement
A	0 kW	-0.08 W	0.52 mm
A	20 kW	-0.16 W	0.746 mm
B	0 kW	-0.18 W	0.54 mm
B	20 kW	-0.34 W	0.758 mm

CONCLUSION

The RF coupler is validated.

The kicking off of the SPIRAL 2 coupler was done the 2nd of september 2008. The production of 30 couplers is under way by SCT company .

The goal is the conditioning of the last accelerator couplers at the end of 2010.

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REFERENCES

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

[2] Y. Gómez Martínez et al., “SPIRAL 2 coupler preparation and RF conditioning”, SRF07, Beijing, Chine.