POWER COUPLERS FOR SPIRAL 2

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Abstract

The Spiral 2 facility is in construction phase. The driver is a super-conducting linac composed of two types of QWR cavities, beta = 0.07 and 0.12 operated at 88.05 MHz. Each cavity is fed by a radiofrequency antenna coupler designed to accept up to 40kW CW. The tests of the prototype couplers have been successfully achieved in the two types of cavities. The manufacturing is finished and the processing of the 26 couplers is under way. We report the technological choices and the major issues of the process, including the absence of TiN plating. We present the main results of the tests and the processing of the couplers.

INTRODUCTION

The coupler (See Fig. 1) transfers the power into two types of cavities and keeps the vacuum into the accelerator. The radiofrequency (RF) couplers have to provide 10 kW Continuous Wave (CW) nominal power to the cavities at 88.05 MHz for an nominal accelerating field of 6.5 MV/m. The coupler must handle 100% reflected power at maximum incident power. The theoretical thermal load to the cavities is limited to 1 W.

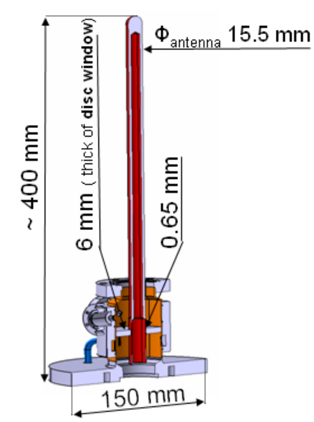

Figure 1: The power coupler.

LAST MECHANICAL CHOICES

The temperature measurements at 4.2 K in the cryomodules show, as predicted by the simulations, that the window temperature is < 5°C with no RF power. To keep the window's temperature close to 15°C in order to avoid water condensation, we have tested two systems: a hot, cleaned, dry air system, and a heating cable. Both systems gave good results but the hot air system was chosen as it allows a temperature regulation (it heats the window when RF is off and colds the window when the RF is on).

To minimise the heat flux to the cavities only a screen 70-100 K is utilised. We have not a screen 4.2 K at the coupler, the 4.2 K is given by the bottom of the cavity.

The series coupler mechanical design makes use of a hollowed antenna with an internal clamp [1] (See Fig. 2). This clamp makes the coupler more robust, especially during the transports. The maximum acceptable acceleration is 10g in order to avoid any deformation of the antenna. To make the external conductor as robust as the internal one, we have included a support for the CF40 flange. Therefore the maximum acceptable acceleration is raised from 4 to 8g to avoid any plastic deformation.

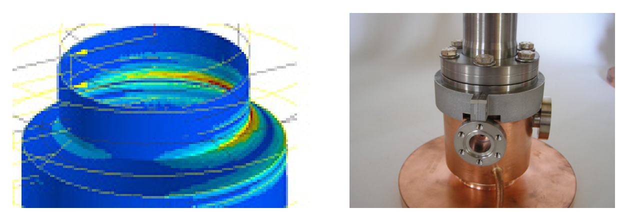

Figure 2: Constraint (left) and support of the CF40 flange.

TIN COATING WINDOW TESTS

TiN coating is usually used as a multipactor (MP) suppressor on RF ceramic coupler windows.

We have tested some 20 couplers with no window coating, one with 1±0.2 nm TiN coating and two with 30± 5 nm coating. One coupler with a 10±2 nm TiN coating, was also ordered, but the production failed as the coupler was not vacuum proof.

The TiN coatings were made by sputtering process, before window brazing, as the design of the coupler did not allow a post-brazing coating.

The stoichiometry of deposits and the effect of the brazing (similar to an 800°C baking) on the composition of the coating were quantified by Rutherford Back-scattering Spectrometry (RBS). The RBS measurement was made on samples of vitreous carbon with 10 nm TiN, 30 nm TiN coatings, and with 30 nm TiN coating after a 800°C baking.

The RBS validated the thickness of the coating and showed that TiO proportion is 10% higher after baking (see table 1); therefore the resistivity of the coating (ρ TiN ~ $25*10^{-6}$ Ω cm; ρ TiO2 ~ 10^{12} Ω cm) is increased but less than foreseen.

Table 1: TiN layer composition

Thickness	10 nm TiN	30 nm TiN	
800 °C baked	No	no	yes
Ti (%)	40	42	40
N (%)	49	50	42
O (%)	11	8	18

The coating couplers have been tested in RF in a push – pull configuration up to 40 kW 100 % duty cycle (CW) in a travelling wave mode. The power, the electronic current (MP), the vacuum and the temperature of the external conductor close the ceramic window have been measured.

Coupler With 30 nm TiN Window RF Tests

The tests of both 30 nm TiN coated couplers ended with window breaks, one at 4 kW CW and the other at 7 kW CW.

Only low current (< 0.2 mA), low power (< 200 W) MP barriers have been observed (See Fig. 3).

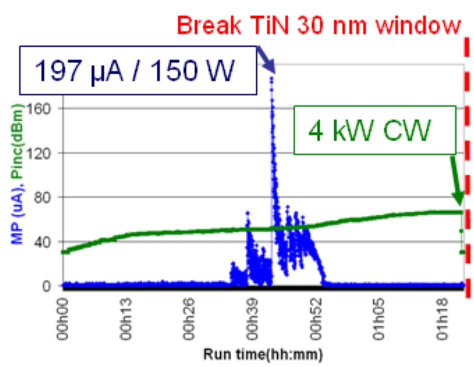

Figure 3: Power & MP in a coupler with 30 nm TiN coated window.

The coating led to temperature increase with RF power (See Fig. 4).

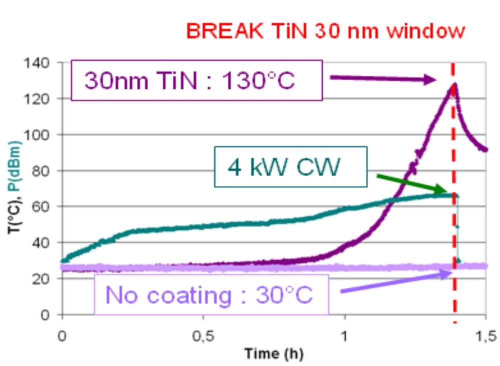

Figure 4: Power & temperature in a coupler with 30 nm TiN coated window & in a coupler with uncoated window.

The ratio between the coefficients of thermal expansion of alumina (7.4 10^{-6} K^{-1}) and copper (1.55 10^{-5} K^{-1}) produces very high constraints (more than the elastic limit of the ceramic 200 MPa), leading to the window rupture. (See Fig. 5).

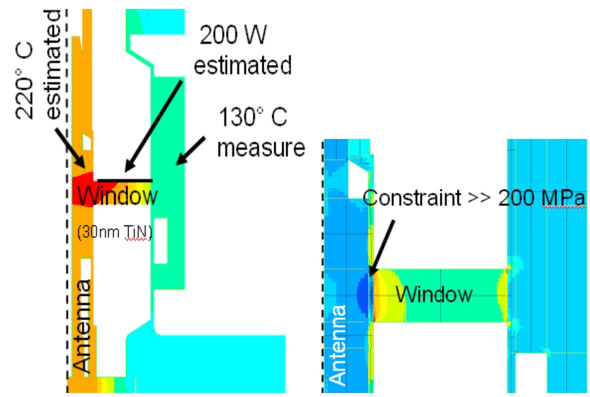

Figure 5: Temperatures & constraint in a coupler with 30 nm TiN coated window.

Coupler With 1 nm TiN Window RF Tests

A Temperature safety threshold 40° C of the external conductor has been included.

As the 30 nm TiN coated couplers, low MP was observed (< 0.2 mA at a power lower than 200 W) (See Fig. 6)

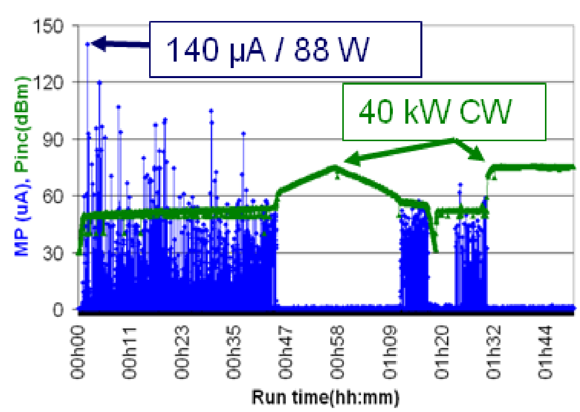

Figure 6: Power & MP in a coupler with 1 nm TiN coated window

But the coating led to temperature increase with RF power (See Fig. 7). This increase the thermal load on the cavities.

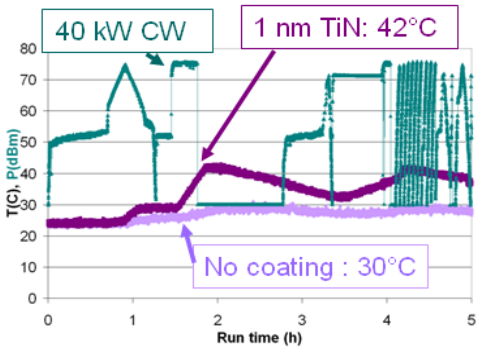

Figure 7: Power & temperature in a coupler with 1 nm TiN coated window & in a coupler with uncoated window.

And as low MP (<0.2 mA at power lower than 200 W) has been measured with an uncoated coupler, (See Fig. 8) so it was decided not to coat the window.

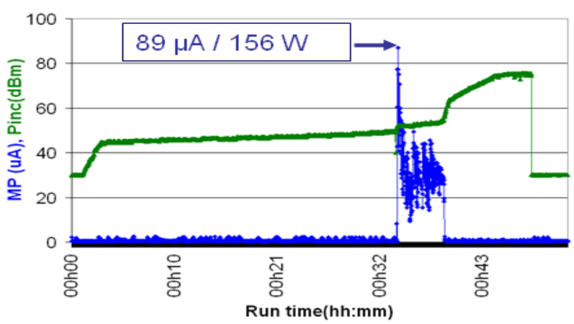

Figure 8: Power & multipactor of a non coated window.

COUPLER PROCESSING

In classical test benches, a coupler is connected to a waveguide resonator with an output coupler connected to a 50 Ohm load. At 88.05 MHz, the size of the cavity is prohibitive and a different solution has been chosen. First, at LPSC, the coupler is processed in a stand-alone configuration with an open termination, in a fully stationary wave mode. Then the coupler is processed in the cryomodules without beam, therefore also in a full stationary mode. Cryomodule processing is is performed first at room temperature (RT) and then at 4.2K; at RT the cavity is similar to an open termination, and at 4.2K it is similar to a shorten termination.

Coupler Processing At LPSC

The cleaning protocol of the RF coupler is as close as possible to the cavities' one. It includes [2] 15 minutes long ultrasonic cleaning at 50°C in Ticopur; baking during 60 h at 200 °C and 10^{-2} mbar vacuum; in situ baking during 30 h at 90 °C. Venting is always made with flow-controlled (< 1 l/min) particles filtered nitrogen.

RF conditioning is made first in pulsed mode. RF power is progressively increased to the nominal power as long as vacuum and MP current remain under a given threshold and if no anomaly is detected. Once the nominal RF power is achieved, the duty cycle is increased progressively and the power cycle restarted from 0 W, and so on until the last cycle in CW mode.

Only low current (< 0.2 mA), low power (< 200 W) MP barriers have been observed. We remarqued as the vaccum is improved by the run time of the test. (See Fig. 9)

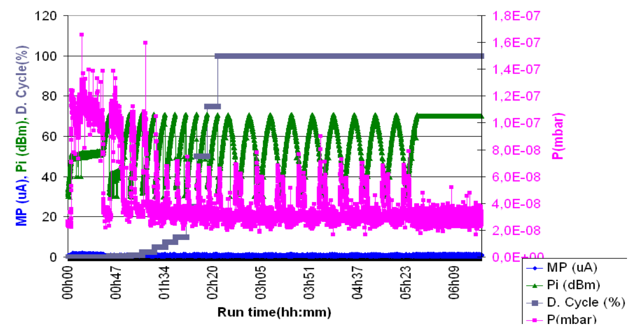

Figure 9: Power (dBm), duty cycle (%), pressure (mbar) and MP (µA) during RF processing.

Coupler Processing In Cryomodules

The power couplers have been conditioned up to 10 kW CW at 300 K and 4 K successfully in both cryomodules families.

The nominal field accelerators (6.5 MV/m) has been reached in both cryomodules. Only low current (< 0.2 mA), low power (< 200 W) MP barriers have been observed. (See Fig. 10)

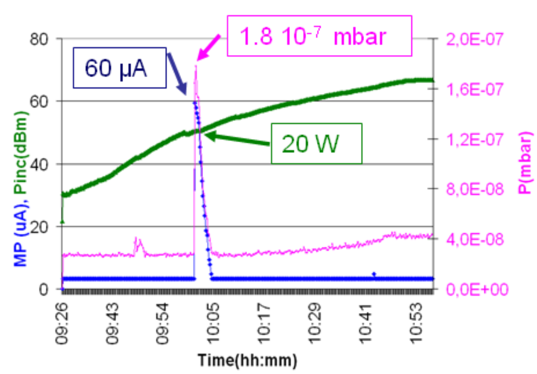

Figure 10: Processing at cavity beta = 0.07 at 4 K.

CONCLUSION

All the couplers have been manufactured and the processing is under way.

The coupler has been successfully tested up to 40 kW CW in traveling wave mode.

Power coupler processing up to 12 kW CW at 300K and 4K has been successfully performed in both cryomodules families.

More than the nominal field accelerators (6.5 MV/m) has been reached in both cryomodules families.

The ceramic window is not TiN coated because almost no multipacting was observed (< mA) and because the window coating led to a significant temperature increase

Clamps and supports have been designed to bear up to 8g accelerations (more than 6g accelerations have been measured during couplers transportation).

A hot air system has been chosen and implemented to keep the window at a minimum temperature of 15°C with and without RF.

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REFERENCES

[1] Y. Gómez Martínez et al. “Last SPIRAL 2 10 kW CW RF coupler design”, LINAC08, Vancouver, Canada.

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