DEVELOPMENT OF 704.4 MHz POWER COUPLER WINDOW FOR MYRRHA PROJECT*

F. Geslin†[1] , P. Blache, M. Chabot, J. Lesrel
Institut de Physique Nucléaire d'Orsay (IPNO), CNRS-IN2P3, Orsay, France
S. Sierra, C. Lievin, P. Denis
Thales Electron Devices, Velizy Villacoublay, France
[1]also at Thales Electron Devices, Velizy Villacoublay, France

Abstract

Myrrha is an accelerator driven system (ADS) hybrid research reactor designed for spent nuclear fuel burning. The linac controlling the reactor has to be highly reliable (low failure rate). In order to fulfill requirements of ADS projects like Myrrha, IPNO and Thales are involved in a power couplers research and development program. We develop a power coupler window, with "MAX" RF design, for 25 kW CW input power. During the study, we take account of fabrication and cost issues. We present in this paper the result of simulations needed to design this coupler window. The electromagnetic, thermal and thermomechanical simulations were performed with Ansys. The multipacting simulations were performed with Musicc3D, software developed by IPNO. The conditioning and test bench is also described as two prototypes have to be tested this autumn.

INTRODUCTION

Accelerator Driven System projects need high intensity protons linacs. Myrrha [1] require a 4 mA protons beam with a final energy of 600 MeV. The duty cycle of ADS is 100% with failure rate lower than once every ten days for a average power of 2.4 MW. To achieve this reliability the linac is composed by a double-injector, then two sections of superconducting cavities (Fig. 1). The first one is composed of 352 MHz two gap Spoke cavities and the second one by 704 MHz 5 cell elliptical cavities. There is two kind of elliptical cavities : $\beta = 0.47$ and $\beta = 0.65$. Both will be feed with the same type of power coupler.

In this context, IPNO and Thales Electron Devices are leading developement on ceramic windows.

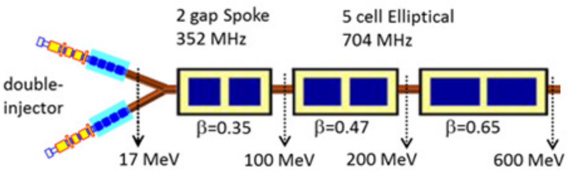

Figure 1: Layout of MYRRHA Linac

DESIGN OF THE 704.4 MHz CERAMIC WINDOW

Figure 2 gives a mechanical view of the 704 MHz power coupler. It is based on "Max RF" design [2] The coupler is basically a coaxial line with a ceramic window to ensure vacuum barrier. Cooling of inner conductor is done with water flow. Part of the outer conductor facing the ceramic is also cooled with water and it is call "waterbox".

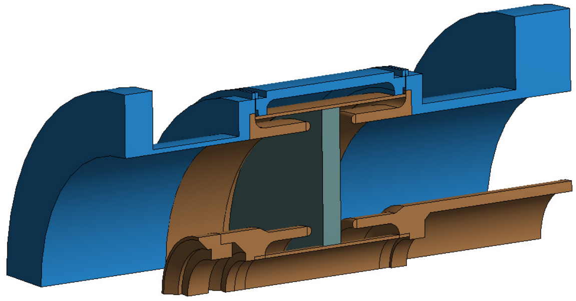

Figure 2: Geometry of the ceramic window

In the front of the ceramic window inside air and vaccum inner conductor is shape in a form call chokes. These particular shape is indeed necesary to lowered the electric field and to prevent sparks. Two important parameters for such design are the characterics of the insulator (mechanical, thermal...) and the geometry of the chokes (thickness and positions). Ceramic used in the design study was a Morgan Braze Alloys AL300 [3]. The dielectric constant of the ceramic given by the manufacturer is 9.

Thermal Simulations

Table 1 gives the power losses in ceramic window for a 25 kW CW full reflected RF incident power. As expected, losses are more important on the inner conductor than on the other part. Dissipation in ceramic is low.

Table 1: Calculated Dynamic Losses of Every Part of Ceramic Window

Losses (W)	incident power 25 kW CW full reflected
outer conductor	10.2 W
inner conductor	28.8 W
ceramic	3.9 W

---

* Work supported by Thales Electron Devices
† geslin@ipno.in2p3.fr

Figure 3 gives the corresponding temperature distrubution in the full ensemble without cooling system excepted natural convection. It was simulated with Ansys thermal unit [4]. On this figure the temperature on the inner conductor is 168 °C. It is not compatible with superconducting environement.

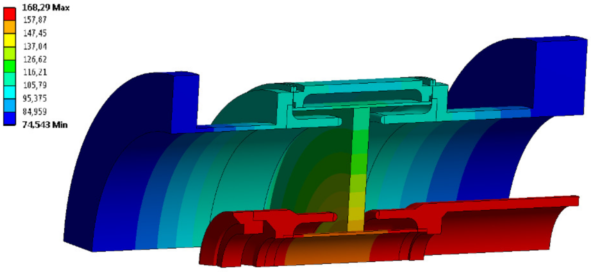

Figure 3: Temperature distribution in the ceramic window for a 25 kW CW full reflected power without cooling.

Figure 4 gives the temperature distribution in the ceramic window cooled with a 22 °C and 1 L/min water flow. Inner conductor stay bellow 23 °C. The ceramic shows a hot spot of 26.4 °C localise between both conductors. Doing the same calculation with 0.75 L/min, shows temperature of 23.4 °C on the inner conductor. The flow is not sensible parameter.

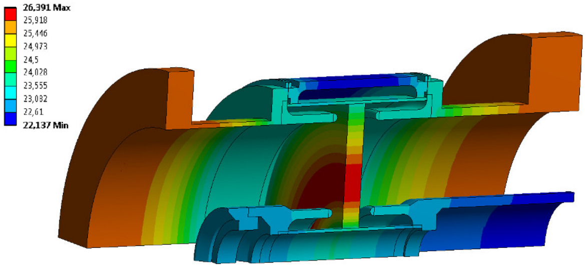

Figure 4: Temperature distribution in the ceramic window for a 25 kW CW full reflected power with a 22 °C and 1 l/min waterflow for cooling.

Mechanical Simulations

Figure 5 gives the distribution of simulated mechanical stresses in the ceramic for two situations.

Figure 5 a) without cooling waterflow, the maximum stress calculated in the ceramic is 722 MPa, twice as the flexural strength of the ceramic (300 MPa).

Figure 5 b) gives the distribution of simulated mechanical stresses in the ceramic for a 22 °C and 1 L/min waterflow. The maximum stress calculted is 33.6 MPa. It is localiseed on the frontier between conductors and ceramic. It is a ninth ot the ceramic fexural strength (300 MPa). In metal parts, the maximum thermal stress computed was 19 MPa, less than half the plastic limit of CuC2 copper.

Thermal and mechanical simulations show that cooling is necessary and a flow around 1 L/min in each cooling circuit is enough to prevent thermal stress failure.

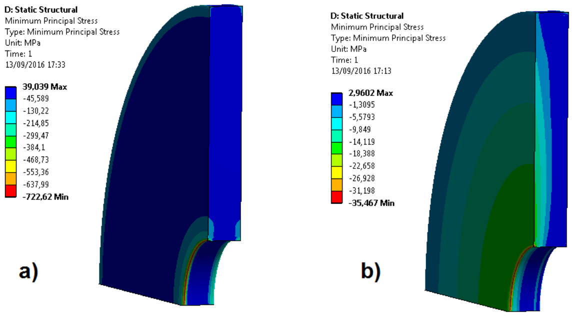

Figure 5: Simulated thermal stress distribution in ceramic, in a) without cooling waterflow, in b) with a 22 °C and 1 l/min waterflow.

Chokes Design

A study of chokes design was performed with HFSS [5]. The last design simulations results are presented here. Figure 6 gives the electric field simulated in the ceramic window for 25 kW CW full reflected power. The highest field (0.4 MV/m) is localised on the chokes tip. The electric field where defaut is suceptible to be problematic for spark has been lowered to 0.14 MV/m by the chokes. It is ten times lower than standard electric field maximum requirement [6].

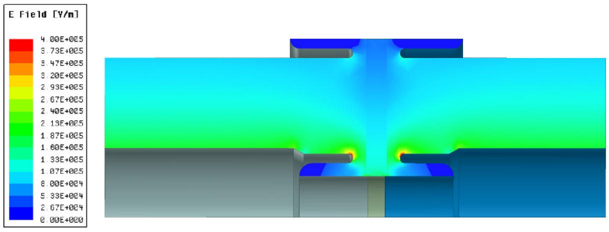

Figure 6: Simulated electric field distribution in coupler window.

Figure 7 gives the S11 parameter of the window. S11 is −53 dB at a frequency of 704.4 MHz, it shows a good adaptation of the ceramic window to the needed frequency.

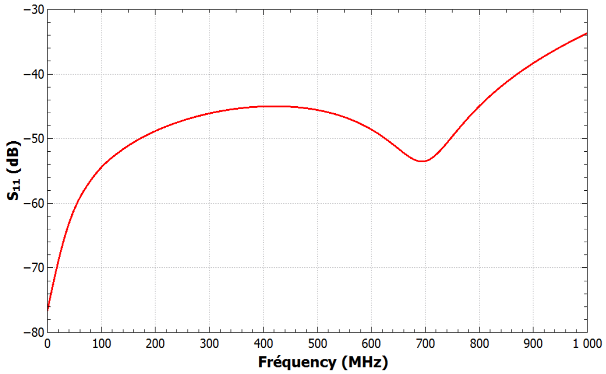

Figure 7: Simulated S11 parameter of the window.

Multipacting Simulations

Multipacting in the ceramic window was simulated thanks to Musicc3D, a code developed at IPNO [7].

Figure 8 gives the simulated multipacting barriers in the ceramic window up to 30 kW full reflected incident power. The barriers in red are between one or both conductors of the coupler. The barriers in blue are corresponding to multipacting with trajectories involving inner chokes and ceramic windows. Simulations were done with pure alumina without any coating.

The link between the amplitude of calculated barriers and its physical importance have to be tested.

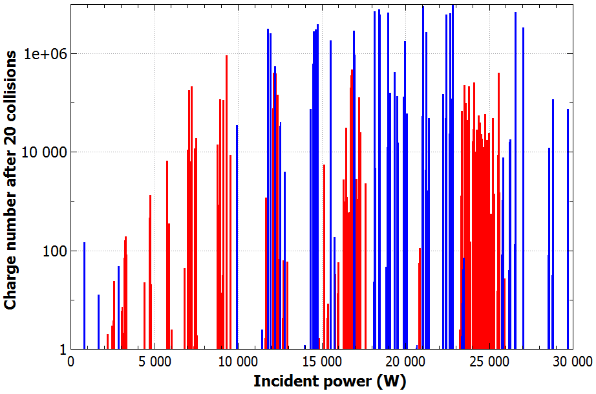

Figure 8: Multipacting barriers simulated with Musicc3D. In red, multipacting occuring between conductors, in blue barrier involving ceramic windows at some point.

CONDITIONING TEST BENCH

Test Bench Configuration

Figure 9 gives the test bench configuration. It is design to condition two power couplers in travelling wave mode via a half wave resonant cavity to a matched load cooling by water.

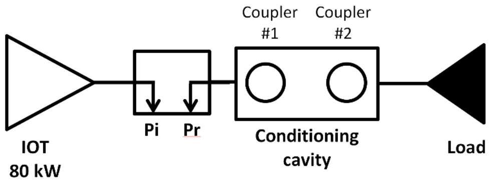

Figure 9: Test block diagram for power conditioning.

Theses test bench and the resonant cavity came from EUROTRANS development and were used in MAX studies as well [8, 9]. It is capable of feeding power couplers with 80 kW CW RF power.

RF High Power

The RF is provided by a 80 kW CW IOT build by Thales powered by a 36 kV and 4 A high power DC supply (represented in Fig. 10 a) and c).

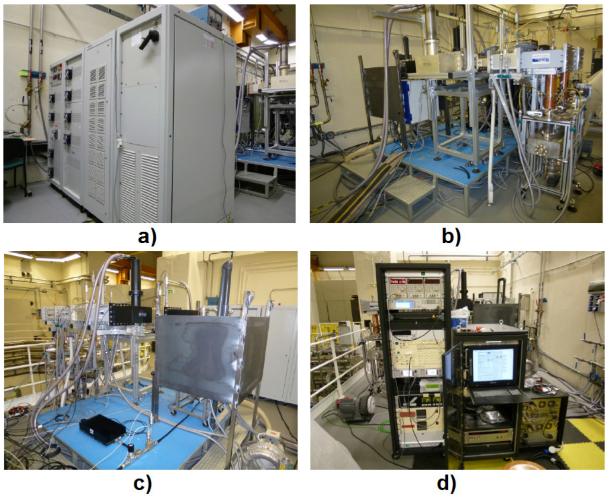

Figure 10: (a) 40 kV – 4 Amps high power DC supply – (b) Conditioning couplers test bench – (c) Lead casing of the Thales I.O.T. – (d) Diagnostics, conditioning monitoring and 1 kW RF pre-amplifier cabinets.

Figure 10 b) shows the conditioning cavity with two power couplers from "MAX" project. The IOT is preserved from reflected power by a circulator and a matched load.

Test are under progress for the present design.

CONCLUSION

ADS needs highly reliable accelerators. Power couplers can be a weak component and a risk of failure as ceramic windows are delicate parts. The simulations ran on present design show good behavior and important safety margin in both thermal stress and electric field calculations. Tests are needed to confirm.

REFERENCES

[1] Myrrha, `http://myrrha.sckcen.be/`.

[2] M. El Yakoubi, *et al.*, “Superconducting RF cavity activities for the MAX Project,” Technology and Components of Accelerator-driven Systems, Nantes, May 2015, p. 159.

[3] Morgan Braze Alloys, `http://www.morganbrazealloys.com/`

[4] Ansys, `http://www.ansys.com/`.

[5] HFSS, `http://www.ansys.com/Products/Electronics/ANSYS-HFSS`

[6] C. Lievin, private communication.

[7] T. Hamelin *et al.*, “Musicc3D: A code for modeling the multipacting”, *SRF’13*, Paris, October 2013, TUP092, p. 683.

[8] J.-L. Biarrotte *et al.*, “Commissioning of the MAX 700MHz test stand”, *LINAC’14*, Geneva, September 2014, TUPP080, p. 610.

[9] F. Bouly *et al.*, “Developments and Tests of a 700 MHz Cryomodule for the Superconducting Linac of MYRRHA”, *SRF’13*, Paris, October 2013, MOP057, p. 250.