ISBN: 978-3-95450-234-9 ISSN: 2673-5504 doi:10.18429/JACoW-SRF2023-WEPWB104

RF CONDITIONING OF MYRRHA COUPLERS AT IJCLAB

N. Elkamchi, C. Joly, C. Magueur, P. Duchesne, S. Berthelot, W. Kaabi, C. Lhomme
Université Paris-Saclay, CNRS/IN2P3, IJCLab , Paris, France
Y. Gomez Martinez, Univ. Grenoble Alpes, CNRS, Grenoble INP, LPSC-IN2P3, Grenoble, France

Abstract

Multi-purpose hYbrid Research Reactor for High-tech Applications (MYRRHA) is an experimental accelerator-driven system in development at SCK-CEN. It will allow fuel developments, material developments for GEN IV systems, material developments for fusion reactors and radioisotope production for medical and industrial applications.

In the framework of the French contribution to MYRRHA project, the IJCLab has in charge the industrial monitoring, the quality control and the RF conditioning of the power couplers up to 80 kW at 352 MHz, to equip spoke cavity cryomodules.

This paper presents the conditioning bench adapted from the successful experience of IJCLAB in the conditioning of the XFEL couplers. The results of the conditioning of prototype couplers are described and discussed.

INTRODUCTION

The MYRRHA project [1] aims to build an Accelerator Driven System (ADS) at MOL (Belgium), driven by a superconducting LINAC (600 MeV, 4 mA proton beam), for irradiation and transmutation experiment purposes. The first section of the superconducting LINAC will consist of 352 MHz single spoke cavities housed in short cryomodules operating at 2K and powered by power couplers designed to support 80 kW CW at 352 MHz

Historically The IJCLab (formerly known as LAL) has acquired within the last fifteen years a large experience in power coupler treatment (mechanical design, RF simulation, vacuum studies, cleaning–assembling procedure and RF conditioning [2]). This experience started with TTF3 couplers that were prepared and conditioned at LAL and installed later at FLASH machine. After this successful experience, the LAL was involved in the industrialisation and the preparation of the 800 XFEL couplers [3].

The MYRRHA project is a part of this continuation; it will take advantage of the knowledge of the lab as well as the human and technical resources inherited from the former experiments.

MYRRHA PROTOTYPE POWER COUPLERS

The couplers series of MYRRAH is preceded by a pre-series of six prototype couplers, which will allow testing several manufacturing technologies to choose the best adapted to the envisaged application, to make modifications and improvements if necessary. The pre-series will also allow validating the preparation and conditioning processes in order to estimate the production rate and to establish a precise production schedule. Finally, the pre-series will allow our team to get familiar with this type of task in order to make the preparation and conditioning process of the series as smooth as possible.

Two types of couplers will be tested and compared: with and without a TiN coating on the coupler ceramic window.

COUPLERS PREPARATION AND CONDITIONING

The coupler preparation process (cleaning, cavity assembly and baking) takes place in two clean rooms (an ISO5 and ISO4) inherited from the XFEL project. It allows the processing of one pair of couplers at a time over approximately ten days. Improvements will be made to the clean rooms and equipment to reduce this time to half. This limit duration can be improved after a rump up phase**.**

Coupler Preparation Process

The preparation phase includes several steps: Upon reception at the IJCLab, and after a visual inspection, a particulate cleaning is performed (ISO 5 clean room) and drying (ISO 4 clean room). All the components are then assembled on the conditioning cavity, along with ion pumping units and RGA (Residual gas analyser). A leak test is then carried out (must be less than 10^{-10} mbar/l/s for acceptance) before starting the drying cycle at 150 °C for 72 h to eliminate residual water vapour. The ion pumps are started up as soon as the drying cycle is completed.

The use of the RGA allows investigating the spectral composition of the coupler emissions. The recorded spectrum is compared with a pair of standard couplers to ensure the absence of pollutants.

After all this steps, the coupler pair can be installed on the RF bench and the conditioning can be started.

Couplers RF Conditioning Process

The conditioning bench (see Fig. 1) is composed of a solid-state amplifier delivering a maximum power of 80 kW. The couplers are operated up to this maximum power, above its nominal power (8 kW CW) in order to allow fault-tolerance schema.

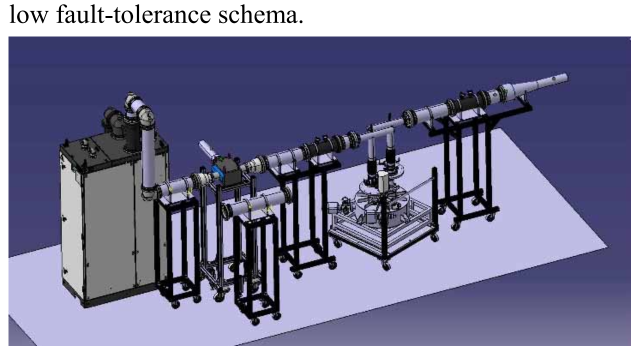

Figure 1: MYRRHA RF Conditioning bench.

ISBN: 978-3-95450-234-9 ISSN: 2673-5504 doi:10.18429/JACoW-SRF2023-WEPWB104

The couplers conditioning process is fully automatized, it follows nearly the same procedure like the XFEL couplers conditioning project, performed at LAL [3].

The conditioning procedure is done in two steps:

- Full transmission: in this case, a 50 Ω load encloses the conditioning bench. The conditioning is performed in progressive wave until the maximum power of 80 kW.
- Full reflection: in this case, a short circuit is installed at the end of the RF line, and the conditioning is performed in standing wave until the maximum power of 20 kW.

For both configuration, we will study the efficiency of the conditioning and determine the best suited to MYRRHA coupler series.

The full transmission conditioning procedure is composed of several sequences that are composed of several steps.

A sequence is defined by a repetition frequency that varies from 2 Hz to 16 Hz

A step is defined by a pulse width, which varies from 100 µs to 62 ms. Figure 2 describes the conditioning procedure.

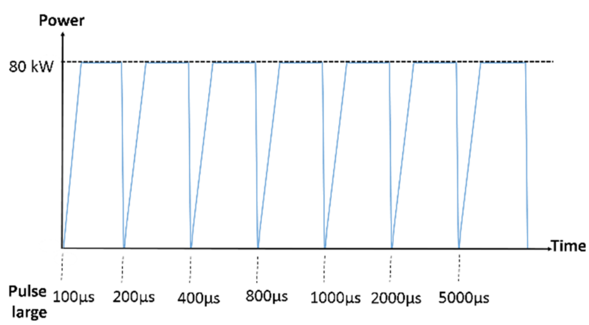

Figure 2: RF conditioning procedure description.

For each step, the automated conditioning bench allows to gradually increase the power from zero to 80 kW, while supervising the pickup current, vacuum and the heating of the couplers. At the end of each step, the power is maintained at around 80 kW for 30 min to allow the vacuum recovering and to attenuate to the maximum the pick-up current.

Interlocks System

An automatic machine protection system is integrated into the conditioning bench to protect the very sensitive and essential equipment from damage during operation. It collect default signal from different equipment (vacuum, arc detection, multipactor, power reflection, ceramic temperature…) and stops the RF power when some parameters drifts outside specifications.

The aim of a conditioning process is to minimize electronic activity within a component and reduce surface outgassing.

Concerning MYRRHA couplers, simulation showed that the Tin coating has positive effect on the coupler conditioning efficiency (see Fig. 3). It reduce the electron activity by a factor of 10^5 which reduce considerably the risk of electronic avalanche phenomenon known as Multipactor, harmful effect on couplers surfaces.

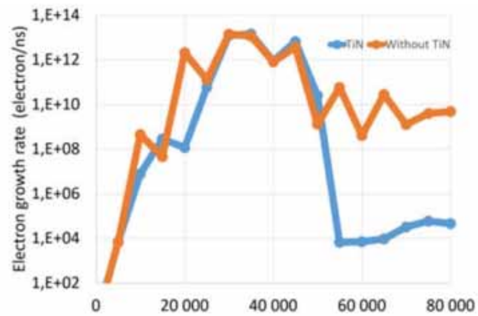

Figure 3: Electron growth rate with Tin Vs without Tin coating [4].

Simulation results are confirmed by measurements (see Fig. 4) which shows the positive effect of TiN coating on electron flow and surface outgassing.

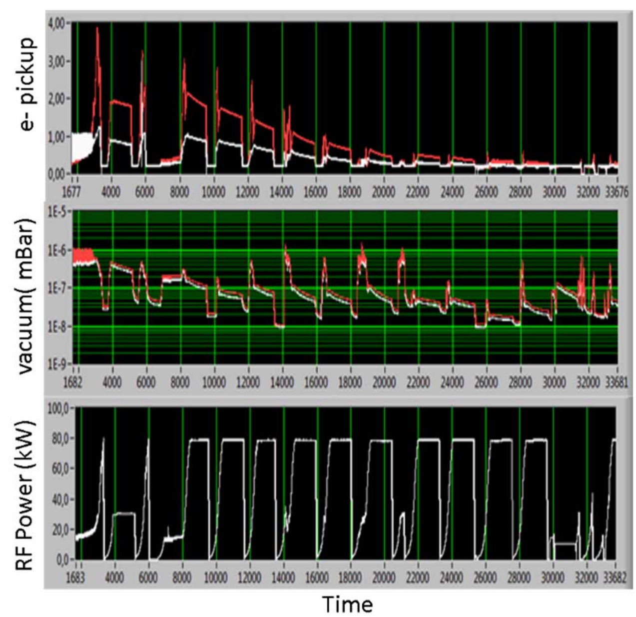

Figure 4: Pickup current and vacuum during conditioning cycles.

The figure above shows a typical conditioning sequence. It presents the RF power variation, the vacuum and Pickup current during several conditioning cycles.

The red curve present the coupler with TiN, while the white curve presents the coupler without Tin coating.

For each conditioning cycle, the pulse duration is increased to raise the average power received by the coupler. Depending on power, different multipactor modes are excited and then damped, resulting in strong degassing at low powers, then stabilization as power increases.

We also note that the coupler with Tin coating reacts better to conditioning, with faster damping of the electron flow with RF power.

The conditioning cycles are repeated as long as the electron currents remains. The process stops when the electron

ISBN: 978-3-95450-234-9 ISSN: 2673-5504 doi:10.18429/JACoW-SRF2023-WEPWB104

current is fully damped and the vacuum in the conditioning cavity has stabilized.

Practically, we consider the coupler fully conditioned when the pickup current does not exceed a few mA and the vacuum in the cavity stabilizes under 10^{-7} mBar.

CONCLUSIONS

This first phase of the project has enabled us to gain the necessary experience in processing this type of coupler, and to gain a better understanding of RF behaviour. This first phase also enabled us to introduce improvements to the preparation and conditioning processes, with the aim of making the conditioning of the series shorter, regular and more efficient.

REFERENCES

[1] H. A. Abderrahim and P. Baeten, "MYRRHA a multi-purpose hybrid research reactor for high-tech applications", 2012. https://www.osti.gov/biblio/22105664

[2] M.A. Gusarova *et al.*, "Evolution of 3D simulation multipactoring code MULTP", presented at XX Inter. Workshop on Charged Particle Accelerators, Alushta, Ukraine, 2007.

[3] H. Guler *et al.*,"XFEL Couplers RF Conditioning at LAL", in *Proc. IPAC'16*, Busan, Korea, May 2016, pp. 2125-2127. doi:10.18429/JACoW-IPAC2016-WEPMB006

[4] G. Martínez, P. Duchesne, P.-O. Dumont, C. Joly, W. Kaabi, and M. Meyer, "Complete Study of the Multipactor Phenomenon for the MYRRHA 80 kW CW RF Couplers", in *Proc. LINAC'22*, Liverpool, UK, Aug.-Sep. 2022, pp. 448-450. doi:10.18429/JACoW-LINAC2022-TUPOPA