HIGH-POWER TESTING RESULTS OF X-BAND RF WINDOW AND 45 DEGREES SPIRAL LOAD

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ABSTRACT

The X-Band test facilities at CERN have been running for some years now qualifying CLIC structure prototypes, but also developing and testing high power general-purpose X-Band components, used in a wide range of applications. Driven by operational needs, several components have been redesigned and tested aiming to optimize the reliability and the compactness of the full system and therefore enhancing the accessibility of this technology inside and outside CERN. To this extent, a new high-power RF-window has been designed and tested aiming to avoid unnecessary venting of high-power sections already conditioned, easing the interventions, and protecting the klystrons. A new spiral load prototype has also been designed, built, and tested, optimizing the compactness, and improving the fabrication process. In these pages, the design and manufacturing for each component will be shortly described, along with the last results on the high-power testing.

INTRODUCTION

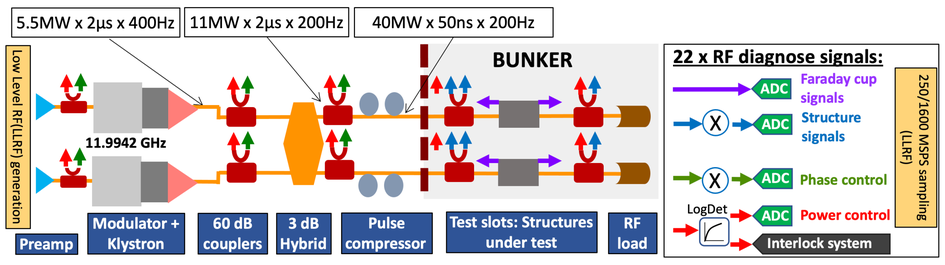
High-power RF Window

- High-power RF (HP-RF) windows are crucial components used to isolate different sections of a vacuum line.
- To be able to sustain high-power RF pulses, mixed-mode RF windows are normally used [2,3].
- Based on this principle and in order to meet the requirement of the high-power X-Band test stands at CERN, a new design was proposed, optimized to sustain high peak power and high repetition rate.

Spiral Load

- High-power RF loads are components needed in many accelerator facilities, especially when using traveling wave structures, as they are required to absorb the remaining power after de acceleration.
- In X-band, due to the small size of the structures and the limited available space, new designs have been focused in making them more compact.
- A new concept of spiral load has been developed at CERN, fabricated by additive manufacturing techniques out of titanium (3D metal printing) [4].
- First prototypes were successfully tested on the CERN X-band test facility [5].

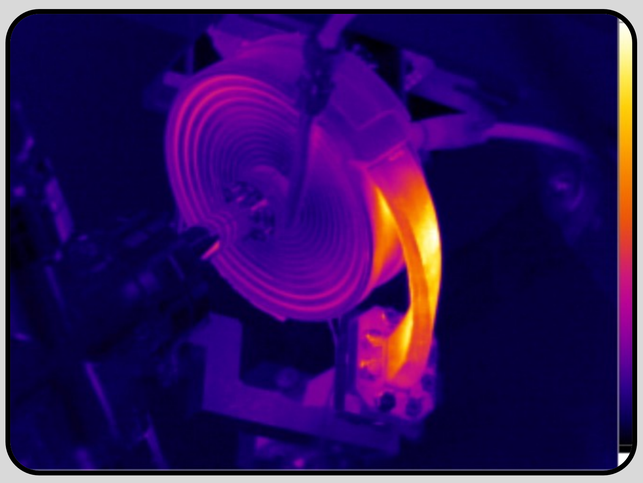
THE CERN X-BAND TEST FACILITY



Layout of the CERN X-band test facility

- The CERN X-Band test facility has been designed to combine the power of two 5.5 MW X-band (11.9942 GHz) klystrons through a 3dB hybrid and feed simultaneously two test stands.
- It is capable to feed simultaneously, two test benches up to 40 MW after pulse compression (50 ns pulse length), with a maximum repetition rate up to 200 Hz per line [1] .

SPIRAL LOAD



Thermal image of the spiral load installed on Xbox 3

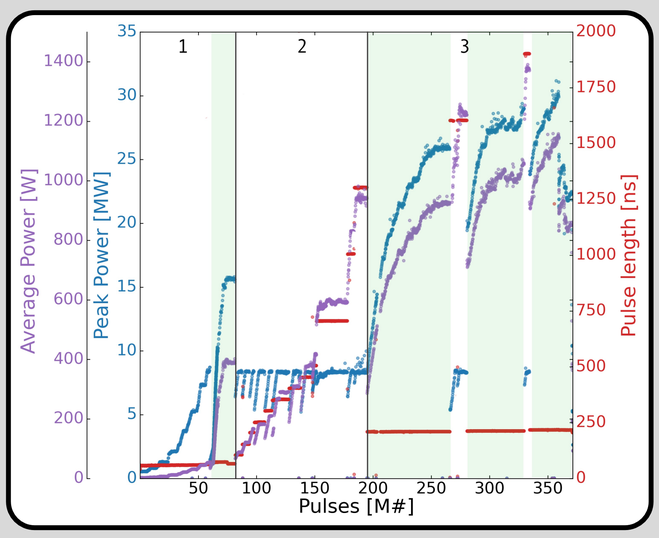
- New spiral load prototype: the cross-section of the waveguide was redesign to a hexagonal shape and the RF input to the load was elongated and twisted 45 degrees.
- The new design avoids horizontal segments and optimizes the 3D printing process, allowing to print more than one load in a single printing cycle.
- Overheating of the transition waveguide was observed, the temperature of this region increased proportional to the average power put into the spiral load.
- The spiral load operated up to 1.3 kW average power and a maximum peak power of 30 MW. The maximum peak power was limited by the load itself due to the occurrence of BD clusters.

Spiral Load Conditioning Limit

- The testing procedure consisted in raising the average power put into the load by increasing the pulse length and the peak power in separate steps, in order to determine the contribution of these parameters to the conditioning limit.
  - The limited effect of the pulse length on the conditioning process was observed, which is mostly dominated by the peak power.

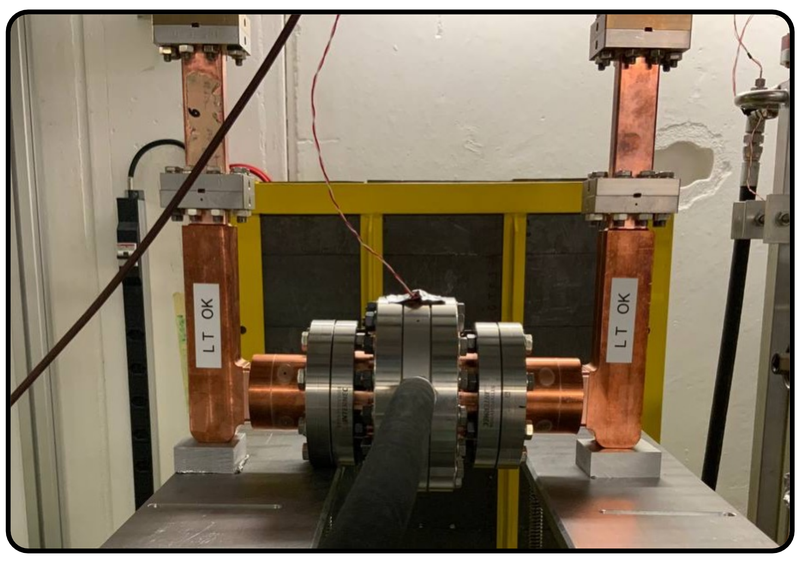
Spiral Load Performance vs Temperature

- The performance of spiral load at different temperatures, measured at the centre of the load, was also studied. To do this, the water cooling was stopped, and the operation was done at constant power and changing the repetition rate.
  - The reflected power ratio kept constant, independently on the temperature of the load, in a range from 35 to 98 degrees.



Peak power, average power, and pulse length during the processing of the spiral load. Green regions: pulse compression operation mode

HIGH-POWER RF WINDOW

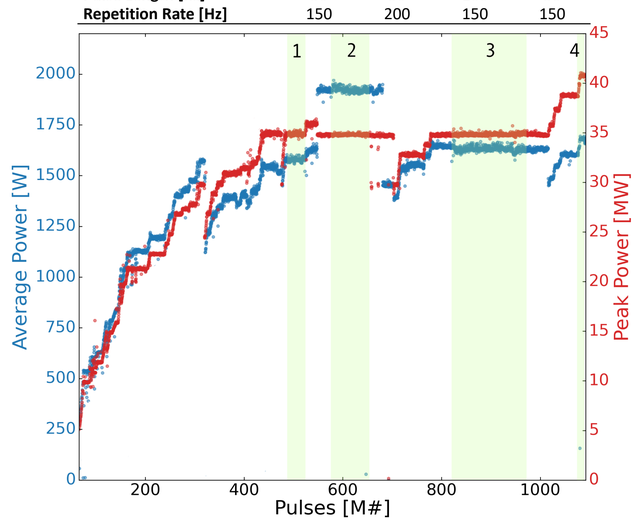


HP-RF window installed on Xbox 3

High-power test

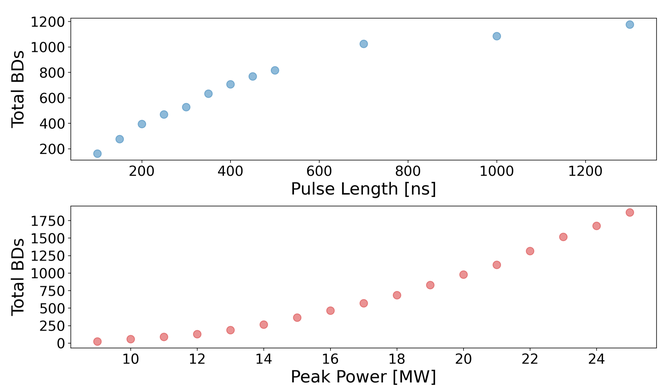
- The X-Band HP-RF window was designed to sustain up to 75 MW peak power.
- The design includes a mode converter from TE_{10} (rectangular) to TE_{01} (circular), which allows higher flexibility in terms of integration, taking advantage of the rotational symmetry of the circular mode.
- The electric field on the ceramic window was designed to be below 3.4 MV/m.
- To reduce the peak field, a ceramic disc of 65 mm of diameter was chosen. The thickness of the ceramic was defined as 2,43 mm.
- The component was tested at different pulse length and repetition rate combination, reaching up to 40 MW peak power at 150 Hz and 1.9 kW average power (35 MW peak at 200 Hz).

	R_1	R_2	R_3	R_4
Power [MW]	35	35	35	40
Average [kW]	1.47	1.9	1.6	1.64
Transmission [dB]	-0.19	0.18	-0.16	-0.15
Pulse Length [ns]	50	50	100	50
Repetition Rate [Hz]	150	200	150	150



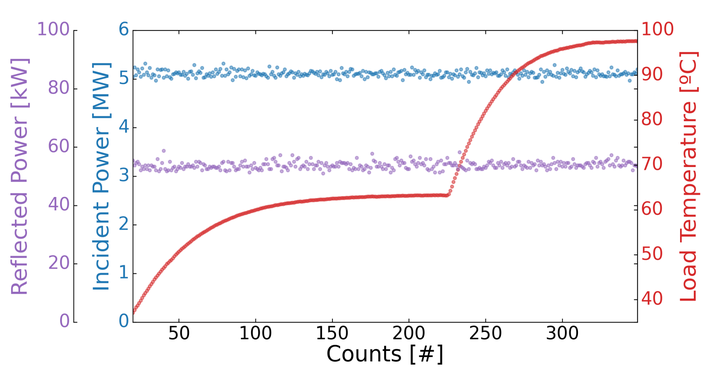
Historic of peak power and average power during the processing of the RF window

Spiral Load Conditioning Limit: Pulse Length vs Peak Power



BDs accumulated pulse length proccessing (top) and peak-power proccessing (bottom)

Spiral Load Performance vs Temperature



Spiral load performance at different temperatures

CONCLUSIONS

Driven by operational needs of the X-band high-power test stands, two key components have been redesigned, manufactured and tested at CERN. The results on the RF window high-power test have shown its capability to sustain high-power and high repetition rate pulses, reaching up to 40 MW peak power at 150 Hz and 1.9 kW average power. The spiral load design has been optimized to improve the additive production procedure. The high-power conditioning has proven the stable operation up to 30 MW peak power, although the high temperature achieved on the transition waveguide. The studies performed have shown the limited effect of the pulse length on the conditioning process which is mostly dominated by the peak-power. Moreover, the spiral load performance has been proven stable in a wide range of temperatures, making it suitable to be part of a heat recovery system for a large accelerators facility.

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