

# RF SYSTEM OF THE ALBA BOOSTER: COMMISSIONING AND OPERATION

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## Abstract

The Booster of the ALBA synchrotron light source will inject, in top up mode, up to 4 mA of current at 3Hz into the storage ring. The booster ramps the energy from 100 MeV (Linac) up to the 3 GeV of the storage ring. The RF system of the booster consist of a 80 kW IOT amplifier, a WR1800 waveguide system, a 5-cell Petra cavity and a Digital LLRF system. In this paper we will present a short description of the system, its performance during the commissioning phase and the results of operation with beam.

## INTRODUCTION

The main parameters of the RF system for the ALBA Booster are summarised in Table 1.

Table 1: Main RF Parameters of the Booster

Frequency	499.654		MHz
Beam current	4		mA
No. of cavities	1		
Energy	Injection 100 MeV	Extraction 3 GeV	
Cavity voltage	55	1000	kV
Energy loss	0.001	627	keV/turn
Cavity power	0.1	33	kW
Beam Power	0	2.5	kW
Synchrotron Frequency	13.7	9.4	kHz

The RF system of the booster consist of a 80 kW IOT based transmitter with a Pulse Step Modulator power supply, a WR1800 waveguide system -including circulator and waveguide-to-coaxial transition (Watrax)-, a 5-cell Petra cavity and a Digital LLRF system. See figure 1.

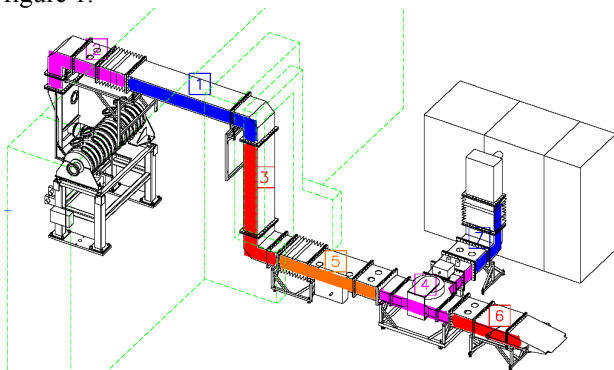


Figure 1: Booster RF plant.

## TRANSMITTER

The ALBA Booster RF systems include a complete new transmitter developed in collaboration between Thomson Broadcast & Multimedia (TBM), Thales Electron Devices (TED) and CELLS. It includes a new Pulse Step Modulator board for the HVPS and a new IOT amplifier designed with a specific carriage for mono-frequency operation [1]. Figure 2 shows the two cabinets (red) of the transmitter -the HVPS and the IOT-, the part of the waveguide system outside the tunnel and the LLRF racks (black).



Figure 2: Transmitter, waveguide and LLRF racks.

The transmitter was commissioned in October 2009 by the manufacturer Thomson with CELLS assistance. It was done in the final configuration, using the waveguide shutter after the circulator to reflect all the power to the load.

The main parameters measured at the end of the commissioning are shown in table 2.

Table 2: Measured transmitter main parameters

Beam Current	3.1	A
Beam Voltage	35.9	kV
Output Power	80	kW
Drive Power	297	W
IOT Efficiency	71.1	%
IOT Gain	24.3	dB
DC Input power	133	kVA
Overall Transmitter efficiency	60.1	%

## WAVEGUIDE

The chosen transmission line is a standard WR1800 waveguide from MEGA. Since the output of the IOT is a 6 1/8" coaxial, a transition to waveguide is the first element at the output of the IOT cabinet.

A circulator from the company Ferrite Co. isolate the transmitter from the cavity, it is designed to cope with full reflected power. The adjustment of the current to the coil is done by optimising the matching by measuring forward and reflected power via two directional couplers at the entrance of the circulator.

The load attached to the circulator is a dry load using ferrites to absorb the full power (80 kW), from AFT.

A waveguide shutter before entering the tunnel allows the operation of the transmitter without powering the cavity.

The input power coupler to the cavity has a standard 6 1/8" coaxial interface with cooling channels through the inner conductor.

Following the design performed for the Storage Ring cavities [2], a specific WAVEguide TRAnSition to coAXial (WATRAX) was designed. Figure 3 shows the CST Microwave Studio® simulation and Figure 4 shows it mounted in the cavity.

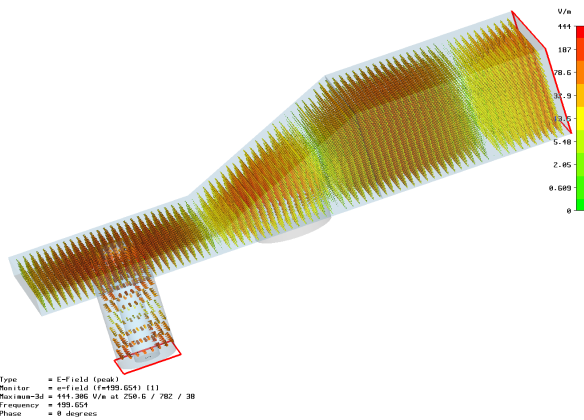


Figure 3: CST Microwave Studio® simulation of WATRAX.

## CAVITY

The main requirement of a Booster cavity is to have a high impedance to get the maximum voltage with the minimum power with no concern about High Order Mode induced instabilities. For this reason the chosen cavity is a 5 cell cavity Petra type. Table 2 gives the main parameters and Figure 4 shows the cavity installed in the ring.

Table 2: Main cavity Parameters.

Type	5-cell Petra type	
Resonant frequency	500 ± 3	MHz
Insertion Length	1.65	m
Shunt Impedance	15	MΩ
Maximum input power	75	kW

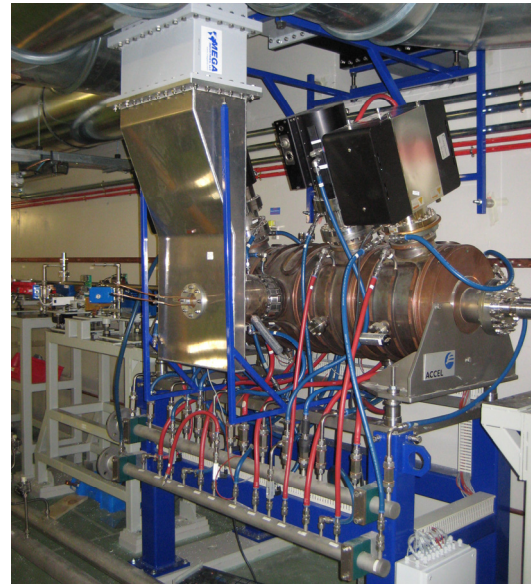


Figure 4: Cavity in tunnel.

The cavity was first conditioned up to 60 kW in a high power bench in August 2008 (figure 5) and maintained under vacuum waiting for installation. It was installed in the tunnel at the beginning of 2009 and re-conditioned again in the tunnel in November 2009 without need of further bake out.

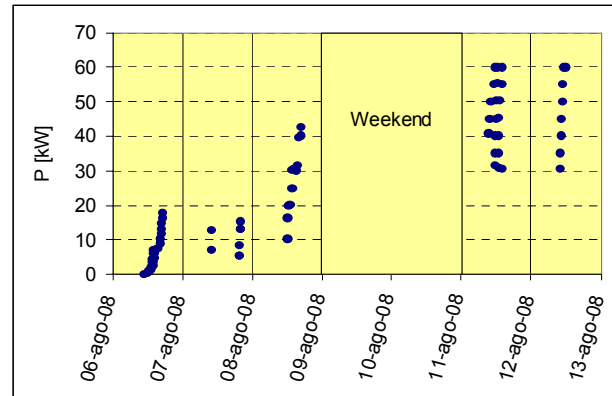


Figure 5: Cavity conditioning up to 60 kW.

## DIGITAL LLRF

The LLRF system of the ALBA Booster is the same as the one for the SR [3], with some extra features such as external trigger for ramping synchronisation and tuning blanking.

By tuning blanking we meant that the cavity is tuned only at the top of the ramp, preventing the plunger to be in continuous movement following the 3 Hz cycle of the Booster and so, minimising the mechanical stress.

Figure 6 shows the cavity voltage ramp and the motor pulses of the plunger only at the top of the ramp.

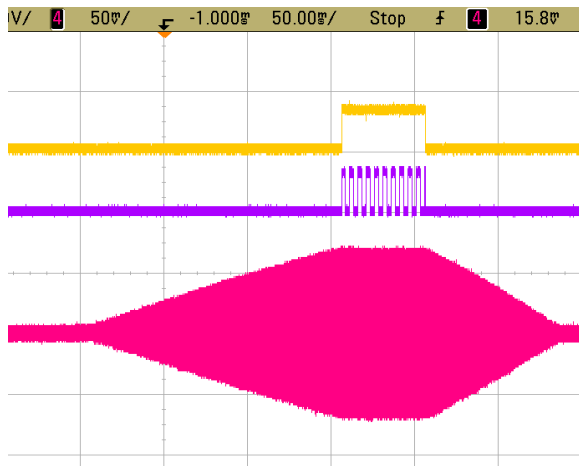


Figure 6: Cavity voltage ramping (pink) and tuning only at the top of the ramp (violet and yellow).

### OPERATION WITH BEAM

In January 2010, a two weeks period -in the middle of the Storage Ring installation- was dedicated to pre-commission the Booster, i.e. to check with beam that all the subsystems were working properly [4].

One shift of 8 hours was dedicated to adjust the parameters of the RF system.

At injection, 100 MeV, the losses per turn are practically zero, for this reason the cavity voltage was set to almost its minimum to minimise the RF energy acceptance. In our case, in order to have an operative tuning, this was around 55 kV, or, in terms of power, 100 W. Tuning loop were active but we started operation in open loop.

The other two parameters to be adjusted at injection are the RF frequency, to match the orbit path, and the phase, to match the injected beam from the Linac, which should enter the cavity at 180° RF phase.

First, we keep the frequency to its nominal value and optimised the phase by changing it and looking to the survival time of the injected beam. After few minutes we achieved a stored beam, which in a booster means that the beam was stored until next injection occurs. Figure 7 shows it for five consecutive injections.

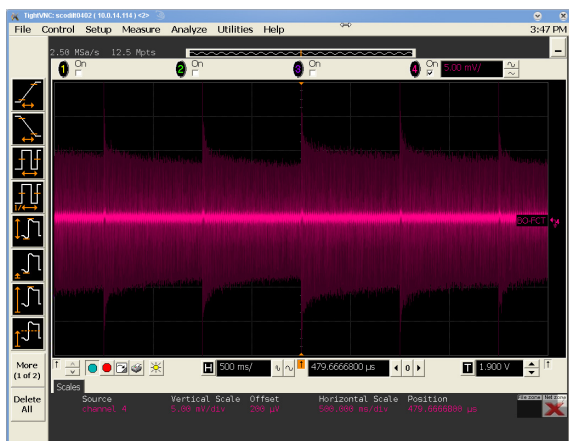


Figure 7: Stored beam in the Booster. Several injections at 1 Hz are shown.

This result did mean that the nominal frequency, 499.654 MHz, is indeed the correct frequency of the machine. We cross checked it by looking at the orbit distortion with the BPMs when changing the frequency and corroborated that the alignment group did an excellent job.

Afterwards we closed the amplitude and phase loops. Adjusting the gains of the PI loop we achieved stabilities of 0.05% amplitude error peak to peak and 0.02° phase error peak to peak.

After checking the performance of the RF system in DC mode, we set up the system for Ramping Operation. The ramping curve is parameterised inside the software of the FPGA. The operator can define the start voltage, the end voltage and the delays of the ramp, see figure 8.

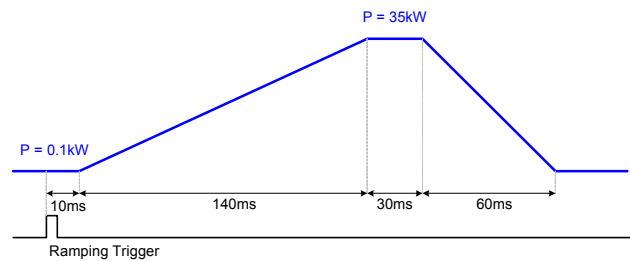


Figure 8: Ramping parameters.

Some trips happened during these tests and the spent time to recover from them was sometimes too long. Because of that, an automatic soft start-up was implemented in the RF plants to speed up the recovery after a trip with minor operator intervention. The system has already been tested at low power and it will be fully tested in the next commissioning period

### SUMMARY

The Booster RF system was commissioned and set into operation with beam without major problems.

After this experience, an automatic soft start-up has been implemented to easy operation and recovery after a trip.

### REFERENCES

- [1] P. Sanchez, M. Langlois, F. Perez, D. Einfeld, C. Bel and J. Alex, "The ALBA RF Amplifier system based on Inductive Output Tubes (IOT)", EPAC'08.
- [2] F. Perez, B. Baricevic, H. Hassanzadegan, A. Salom, P. Sanchez and D. Einfeld, "New developments for the RF system of the ALBA Storage Ring", EPAC'06.
- [3] A. Salom and F. Perez, "Digital LLRF for ALBA Storage Ring", EPAC'08.
- [4] M. Pont, "Booster of the ALBA Synchrotron Light Source: pre-commissioning experiences", these proceedings.