THE ALBA RF AMPLIFIER SYSTEM BASED ON INDUCTIVE OUTPUT TUBES (IOT)

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Abstract

The ALBA accelerator RF systems include a complete new transmitter developed in collaboration between Thomson Broadcast & Multimedia (TBM), Thales Electron Devices (TED) and CELLS. A new IOT version, based on the previous TH793 has been developed by TED: the TH793-1, dedicated to scientific applications. It has demonstrated cw operation up to 90 kW at 500 MHz. In addition, a TH18793 LS cavity has also been developed, featuring a 6"1/8 coaxial RF output, an optimized cooling system and centred operation at 500 MHz, 7 MHz bandwidth and ±5 MHz tuning range. TBM developed a new amplifier system to achieve high reliability and performance. Each IOT is powered by an individual power supply based on the Pulse Step Modulator technology. The amplifier control system was designed on a PLC controller with the possibility to interface with the Tango control system. The first amplifier was delivered to ALBA in summer 2007 and is already in use for the conditioning and testing of the first RF cavity. The remaining 13 amplifiers will be delivered in the second half of 2008. The paper gives an overview on the design and operation performance during commissioning and cavity testing.

INTRODUCTION

ALBA will house 14 RF Transmitters (RF Tx): 12 in the Storage Ring (SR) to power the 6 RF accelerating cavities (each one needing 150kW cw at 500 MHz for a beam current of 400 mA); 1 for the 60 kW cw needed for the Booster cavity; and 1 for the RF High power Laboratory, where the RF cavities will be conditioned at 80 kW [1].

The ALBA RF Tx consists of a single High Voltage Power Supply (HVPS) feeding an RF amplifier based on an Inductive Output Tube (IOT). The maximum power delivered by an IOT is 90 kW cw at 500 MHz.

The following sections are detailing the modifications developed by TED in collaboration with ALBA and implemented in the IOT, as well as the new version of HVPS developed by TBM.

Finally, the first RF Tx (out of 14) has been already installed in the ALBA RF Lab and tested up to 80 kW cw.

THE ALBA RF TRANSMITTER

Figure 1 shows the ALBA RF Tx layout which includes the HVPS and the IOT amplifier.

Figure 2 and Figure 3 show the HVPS cabinet and the IOT cabinet respectively.

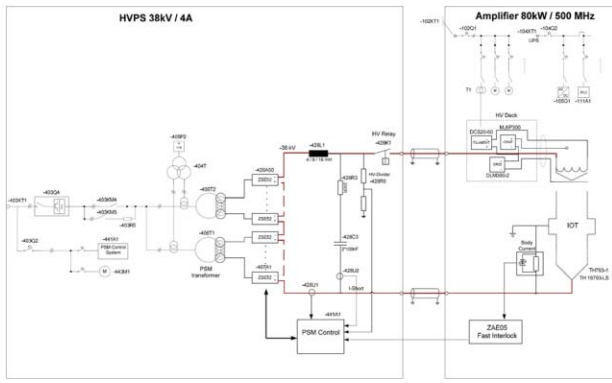

Figure 1: ALBA RF Tx Layout

Figure 2: ALBA HVPS cabinet

Figure 3: ALBA IOT cabinet

NEW RF AMPLIFIER FROM TED

The previous existing IOT tubes had a maximum rated power of 80 kW, just the limit of ALBA needs. Therefore, ALBA wanted a more reliable amplifier able to produce 80 kW with more safety margin. TED has developed (in collaboration with CELLS) several modifications on its TH793 in order to get 90 kW as maximum power. These modifications have induced also modifications in the RF output cavities. Both the IOT and the cavity modifications are presented in the following paragraphs.

Evolution to the new IOT TH793-1

The most critical part of the tube is the ceramic insulator, which stands a high electric field when operating continuously at maximum power. By increasing its diameter, the electric field is weaker on its surface, which allows higher output power. Figure 4 shows the standard TH793 as compared with the new TH793-1. In order not to modify the cathode and input cavity, the lower ceramic has been produced in a conical shape as seen in the picture.

Figure 4: Standard tube (left) vs. new 90kW tube

Induced Modifications: TH18793-LS cavity

The 90 kW produced by the new IOT is well over the limit of a 4 1/16" coaxial standard line, for this reason it was decided to increase the output line to 6 1/8", yielding to several modifications in the output circuit. Both primary output cavity (circular) and secondary output cavity (rectangular) have been simulated in CST Microwave Studio ®, as seen in Figure 5.

The ALBA RF operating frequency is a constant value (499.654 MHz), so not broadband tuning is needed. For this reason the design of the output circuit has the aim of only 10 MHz tuning capability.

Also, new water cooling circuits have been added in the primary cavity and in the coupling loop between cavities to cope with the extra dissipation.

The new circuit, named TH18793-LS, is shown in Figure 6.

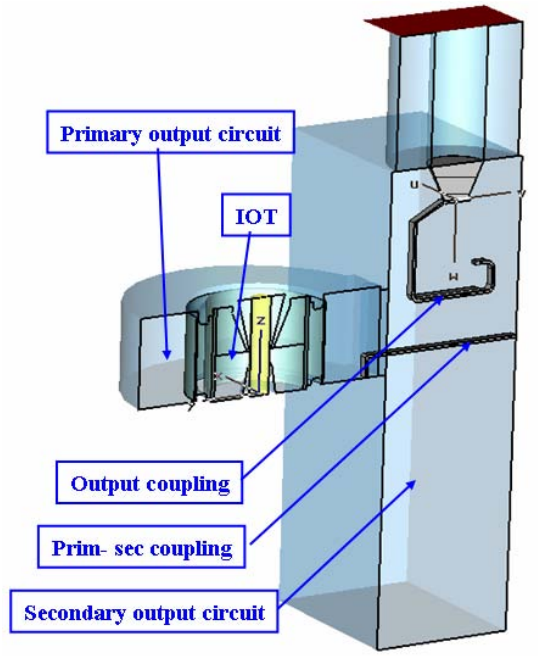

Figure 5: Simulation of the IOT output circuit

Figure 6: IOT assembly

NEW HVPS FROM TBM

PSM technology

The IOT needs -36kV DC and 3.5 A. For supplying this voltage and current, Thomson BM has developed a new Pulsed Step Modulation (PSM) module which is used in the ALBA HVPS (see Figure 7).

Figure 7: PSM module for the ALBA HVPS

Each one of these modules produces 700 V, so 52 modules are enough to produce 36 kV. Nevertheless, the ALBA HVPS has 60 modules for reliability and redundancy.

Switching frequency

The switching frequency of the modules can be set via the control system in the range between 0.05 to 12 kHz in order to avoid any coupling with the synchrotron frequency of the ALBA storage ring.

Control system

The control system is based in PLC platform, with an API which allows to be interfaced with the TANGO system used at ALBA.

TANGO Device Server and GUI is used at the RF Lab for the routine operation of the transmitter

FACTORY TESTS

The new IOT has been tested up to 90 kW cw at TED premises in Thonon (France) and Table I shows the results obtained.

The measured Bandwidth was 6.8 MHz (see Figure 8) and the IOT cavity gave +/- 5 MHz of tuning capabilities around the fundamental frequency.

Table I: Results of the new IOT

HV [kV]	Beam I [A]	Pout [kW]	Eff [%]
-36	3.18	80	69.9
-36	3.31	85	71.3
-37	3.42	90	71.1

TESTS IN THE ALBA RF LAB

The first transmitter has been installed and tested in the ALBA high power lab and it is used regularly for cavity conditioning, even at pulsed mode, and for testing the low level RF system.

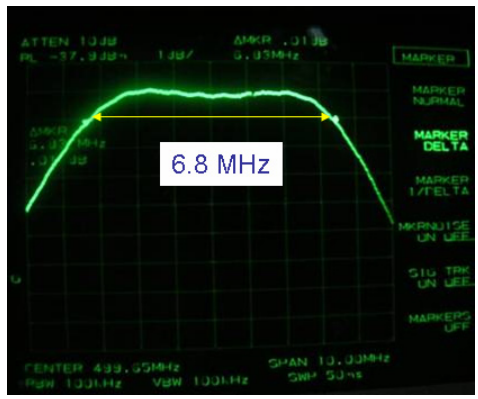

Figure 8: IOT Bandwidth

The efficiency and gain versus power is shown in Figure 9. The values obtained at the nominal full power for the ALBA accelerator (80 kW) are 70.7 % of Efficiency and a Gain of 24.8 dB.

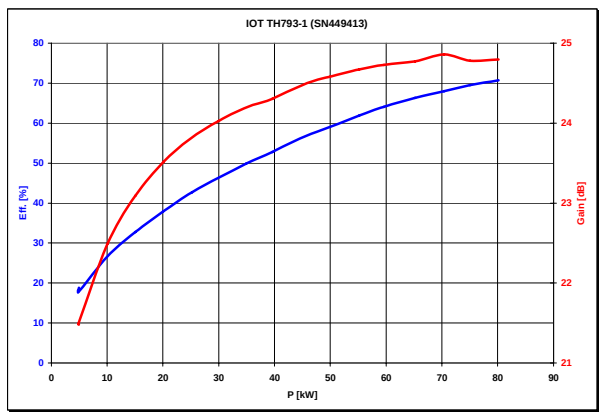

Figure 9: IOT Efficiency and Gain vs. Power

CONCLUSIONS

- The ALBA transmitter, with the IOT and PSM improvements, is running reliably at the ALBA RF Lab since December 2007.
- HVPS is stable enough to assure operation at full power 80 kW cw, or at pulsed power during cavity conditioning.
- HVPS assures redundancy (tested during factory tests at TBM and also during commissioning at CELLS, where 2 modules failed keeping the HVPS operational).
- IOT safe operation at ALBA full power (80 kW), since the maximum tested power at factory was 90 kW.
- IOT bandwidth large enough, while efficiency and gain have been improved from the standard tube.

REFERENCES

[1] http://www.cells.es/Divisions/Accelerators/RF_Diagnostics/RadioFrequency