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ALBA RF Amplifier based on IOTs

A. ALBA Accelerator

B. RF Transmitters

   I. High Voltage Power Supplies (HVPS)

   II. 90 kW-cw Inductive Output Tubes (IOTs)

C. Other High Power Components

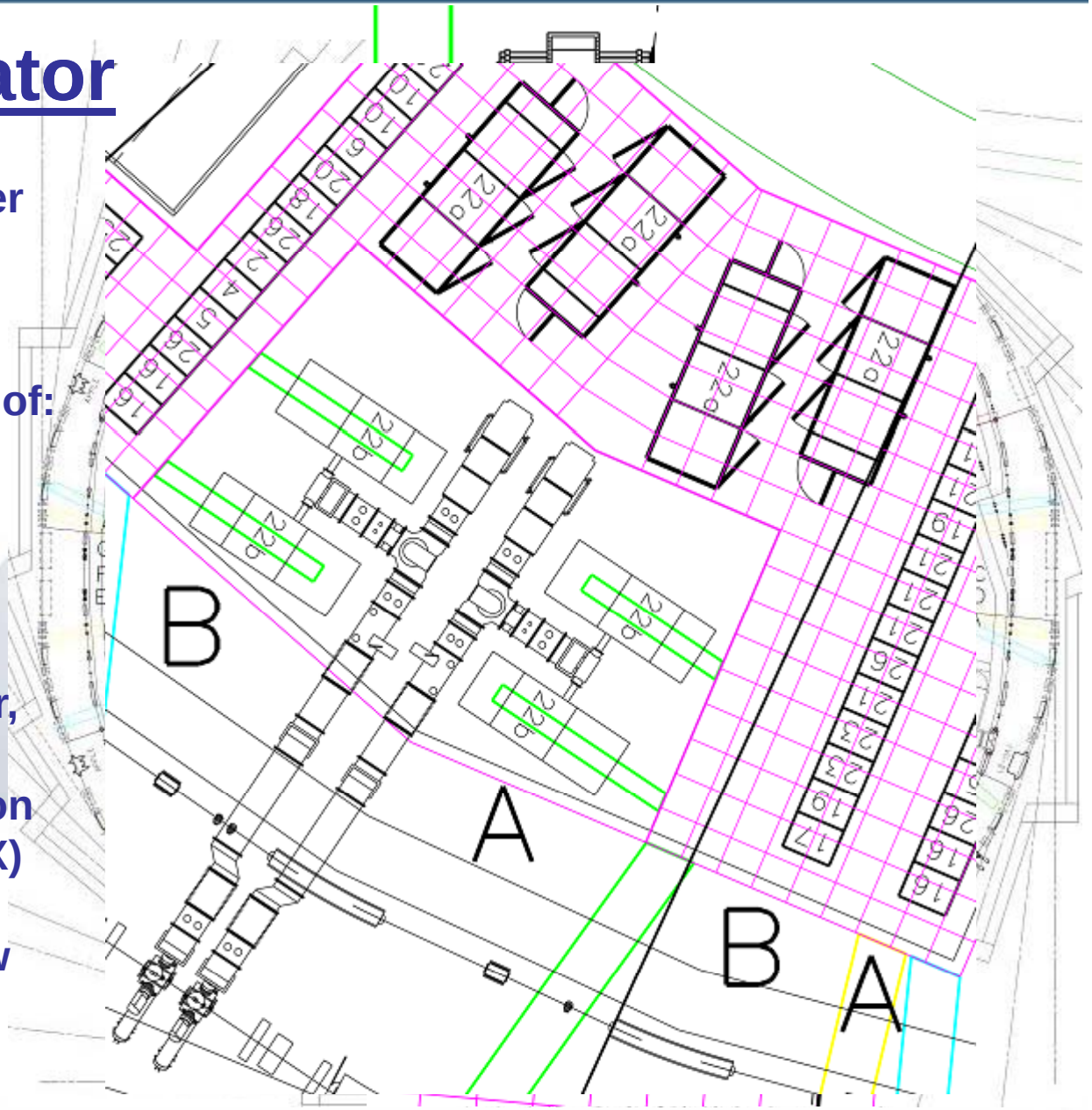
   I. Cavity Combiners (CaCo)

   II. Transitions WR1800 to Coax 6 1/8” (WATRAX)

D. RF High Power Lab

ALBA Accelerator

- 1 RF plant in the Booster (80 kW)
- 6 RF Plants in the SR (6 x 150 kW)
- Each SR plant consists of:
  - 2 RF Amplifiers combined though a Cavity Combiner (CaCo)
  - Waveguide system (WR1800, Circulator, Dry Load, Shutter)
  - Waveguide transition to coaxial (WATRAX)
  - RF Cavity
  - Digital / Analog Low Level Electronics



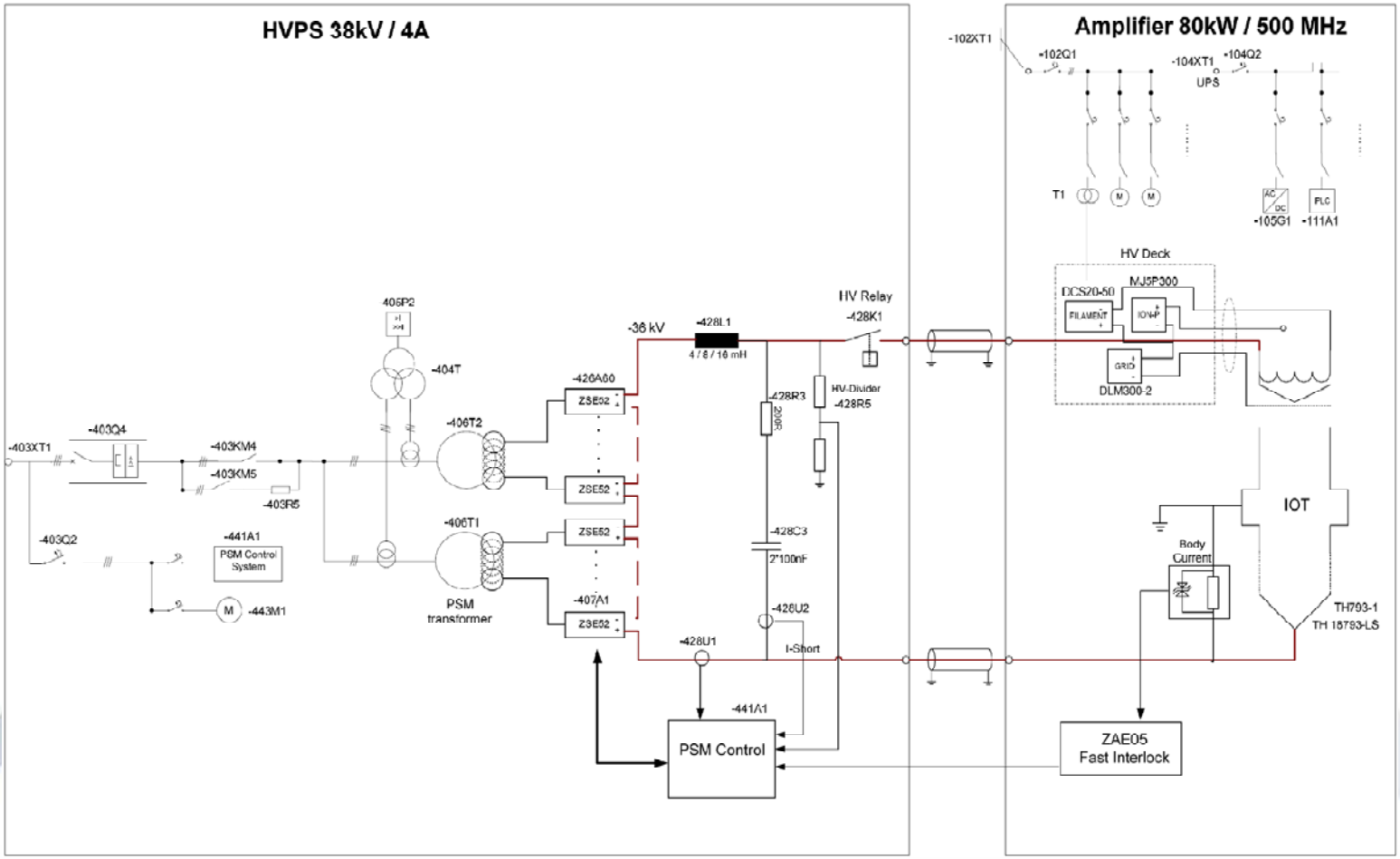
ALBA Accelerator

RF Parameters:

	STORAGE RING	BOOSTER (at 3 GeV)
Frequency	499.654 MHz	499.654 MHz
RF total Voltage	3600 kV	900 kV
Beam Current	400 mA	2 mA
Total Beam Power	540 kW	1.3 kW
Losses (including IDs)	1300 keV/turn	627 keV/turn
Type of cavity	NC EU-Cav (DAMPY)	NC 5-cell
Number of cavities	6	1
RF Voltage per cavity	600 kV	900 kV
RF Power per cavity	150 kW	30 kW
RF Transmitter	2 x 80 kW	1 x 80 kW
Synchrotron frequency	9.3 kHz	8.6 kHz

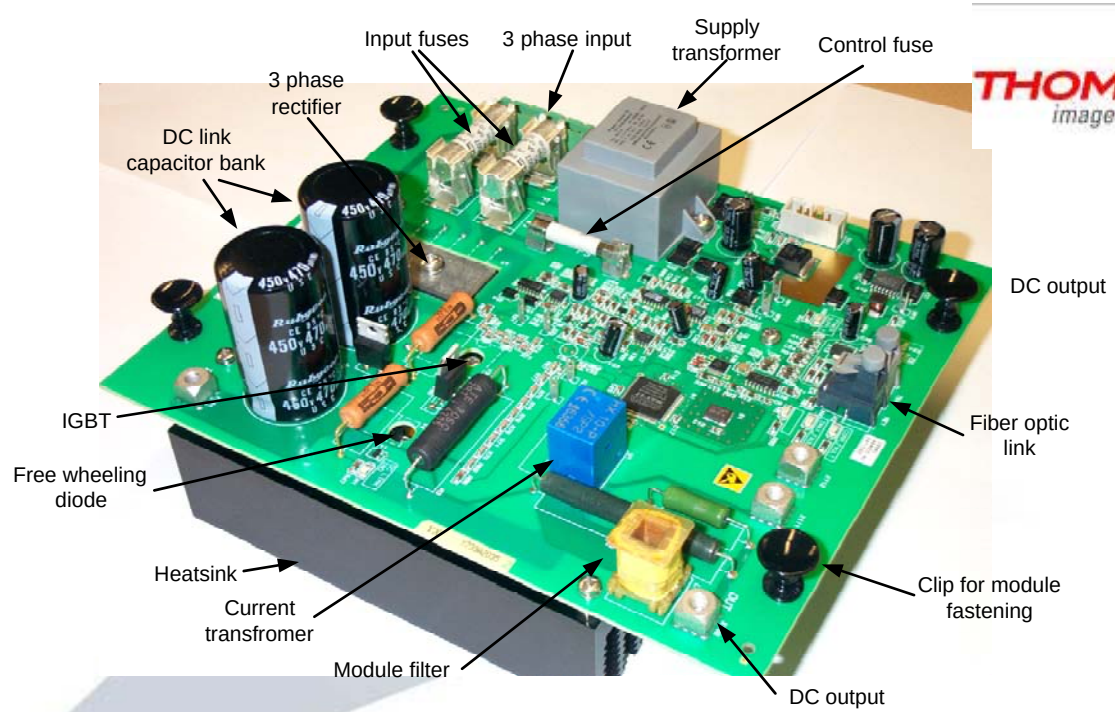
RF Transmitter

- One HVPS per IOT, based on PSM technology (Pulsed Step Modulation):



RF Transmitter – HVPS

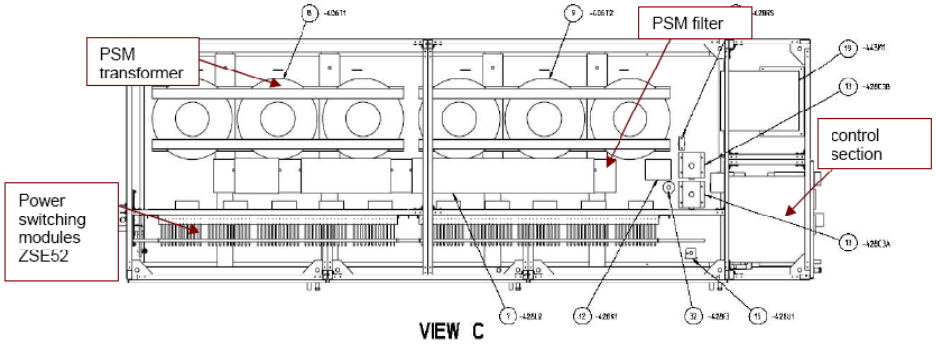
- **New PSM module design and developed by THOMSON BM**



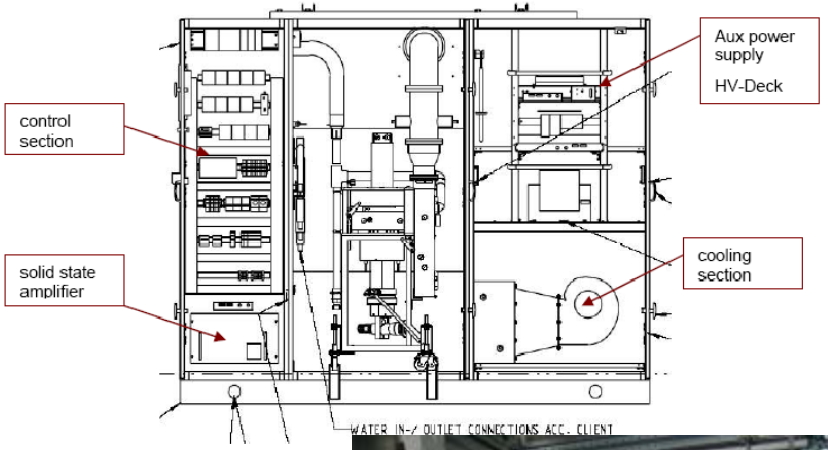
- **60 modules switching at f = 1.67 – 10 kHz**
- **V_{out} = -38 kV and I_{out} = 4 Amps**
- **Redundancy: 700V per mod ➔ 52 modules are enough for -36kV (IOT)**

RF Transmitter

HVPS cabinet



IOT cabinet



RF Transmitter – IOT

1/ Tube modifications (THALES ED)

LS version TV version

- The electron gun, the focusing, and the collector did not change.
- The diameter of the output window was made bigger.
- A conical insulator had to be placed between grid and anode.

Advantage : better suited for high power CW operation. The electric field in the ceramic insulator is decreased, so are the losses. Less stray electrons impinge on it.

Drawback : dedicated product.

RF Transmitter – IOT

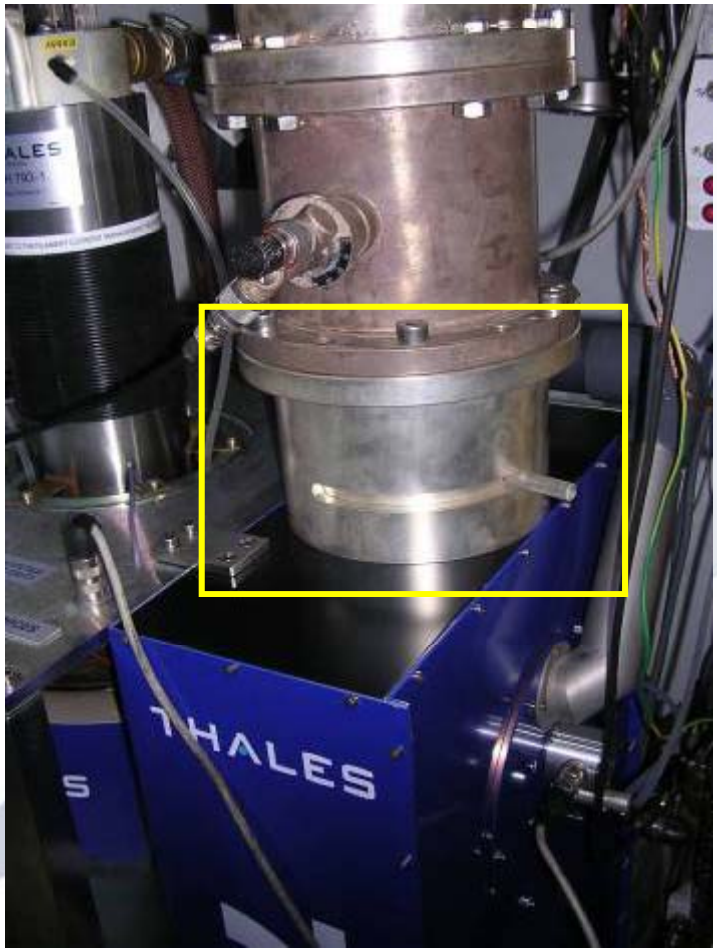
2/ IOT cavity modifications

To cope with the high CW power operation,the output circuit has been completely redesigned

Alterations

RF Transmitter – IOT

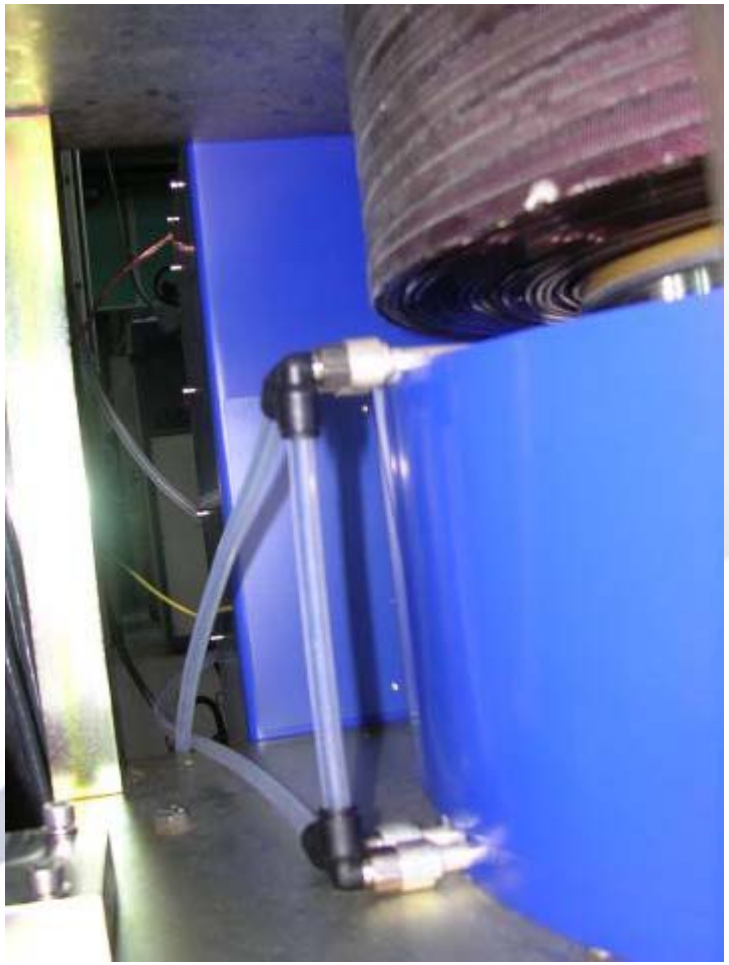
2/ IOT cavity modifications



The output coupling of the TV version was 4”1/16. It was enlarged to 6”1/8. As a consequence, the depth of the secondary output cavity was increased. The dimensions of the output coupling loop and the primary to secondary coupling loop had to be changed accordingly.

RF Transmitter – IOT

2/ IOT cavity modifications

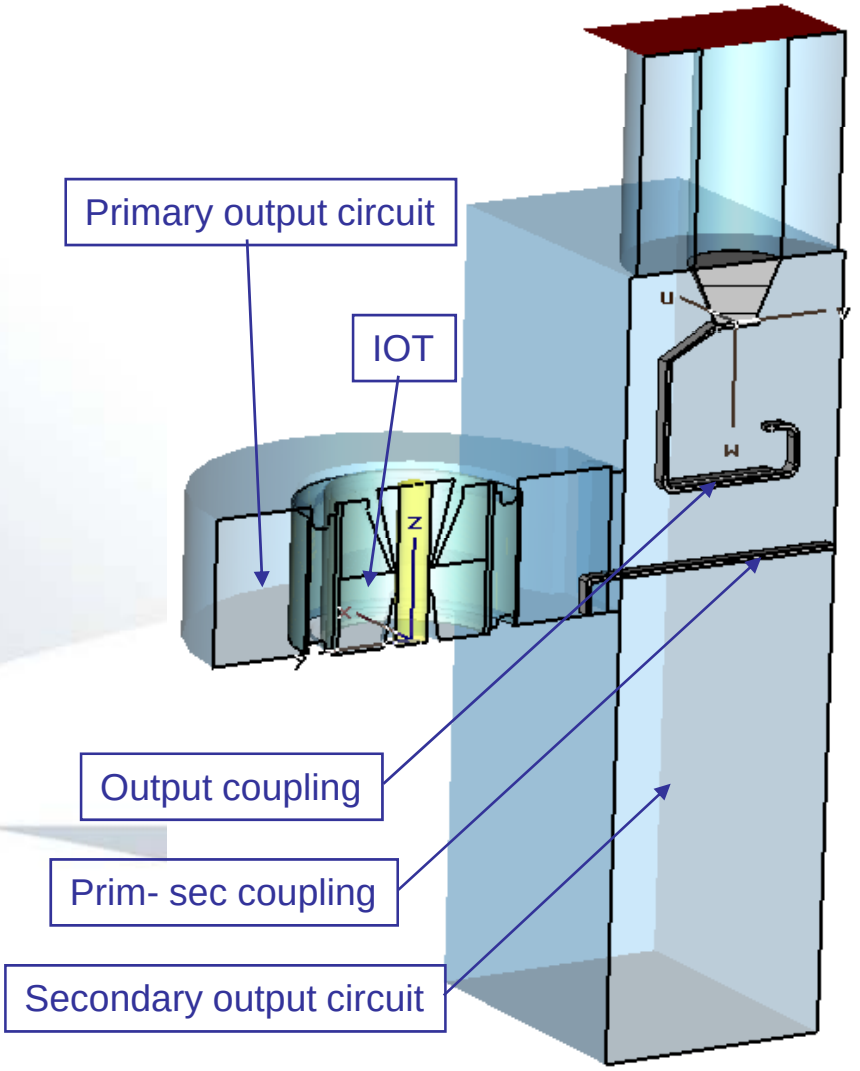


The primary output cavity was water cooled to prevent thermal frequency drift. The single frequency allowed a nearly cylindrical cavity, with simplified tuning devices. The length of fingerstocks was reduced.

RF Transmitter – IOT

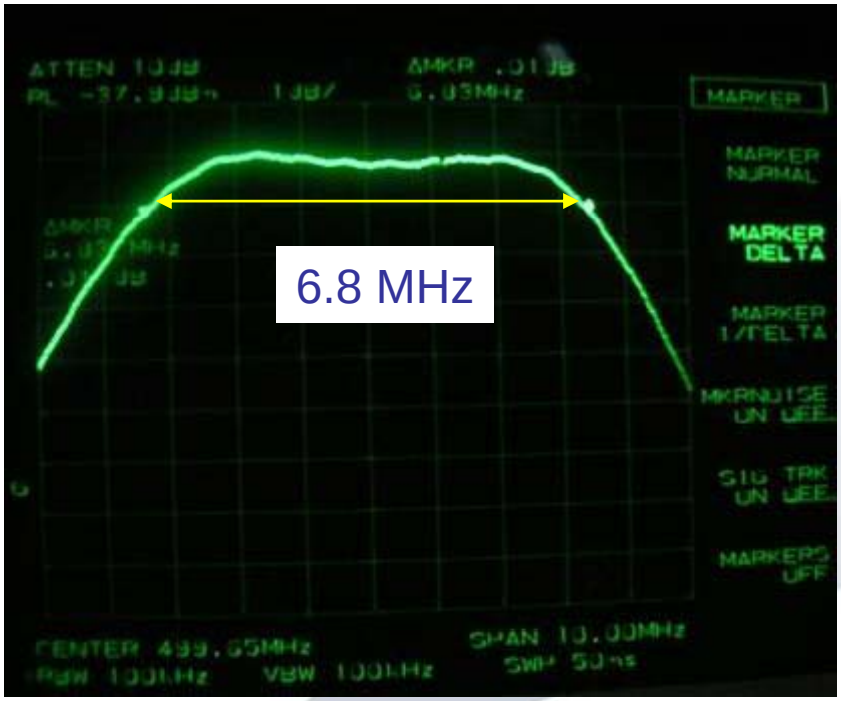
3/ IOT cavity simulations

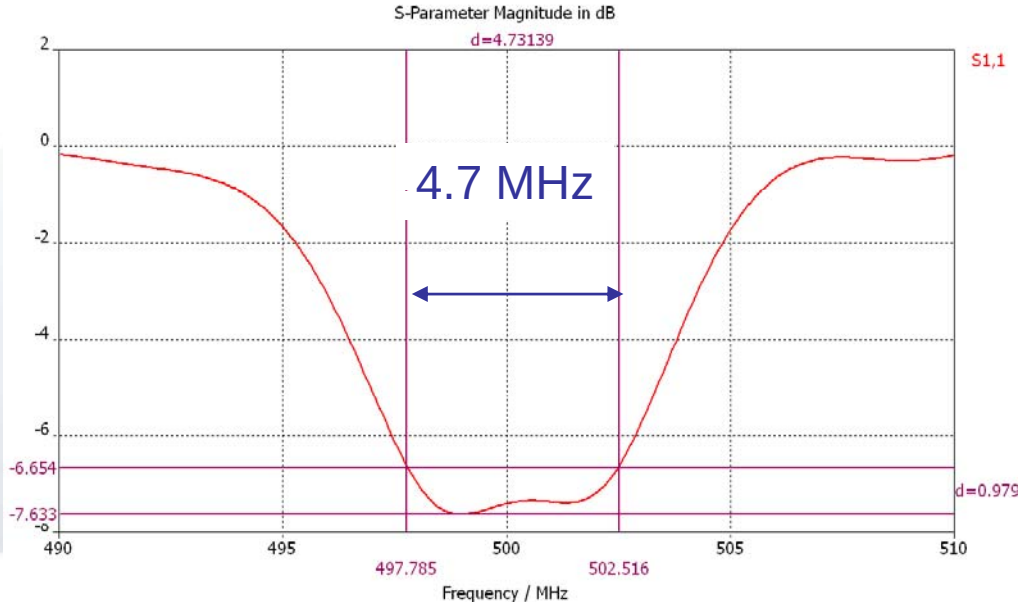
The output circuit was simulated at ALBA with Microwave studio to determine the dimensions of the cavities and the coupling loops.
A conductive material was inserted in the gap of the IOT drift tubes. Its conductivity was adjusted to get the beam voltage at 80 kW.
The bandwidth was then evaluated with S11.



RF Transmitter – IOT

3/ IOT cavity simulations



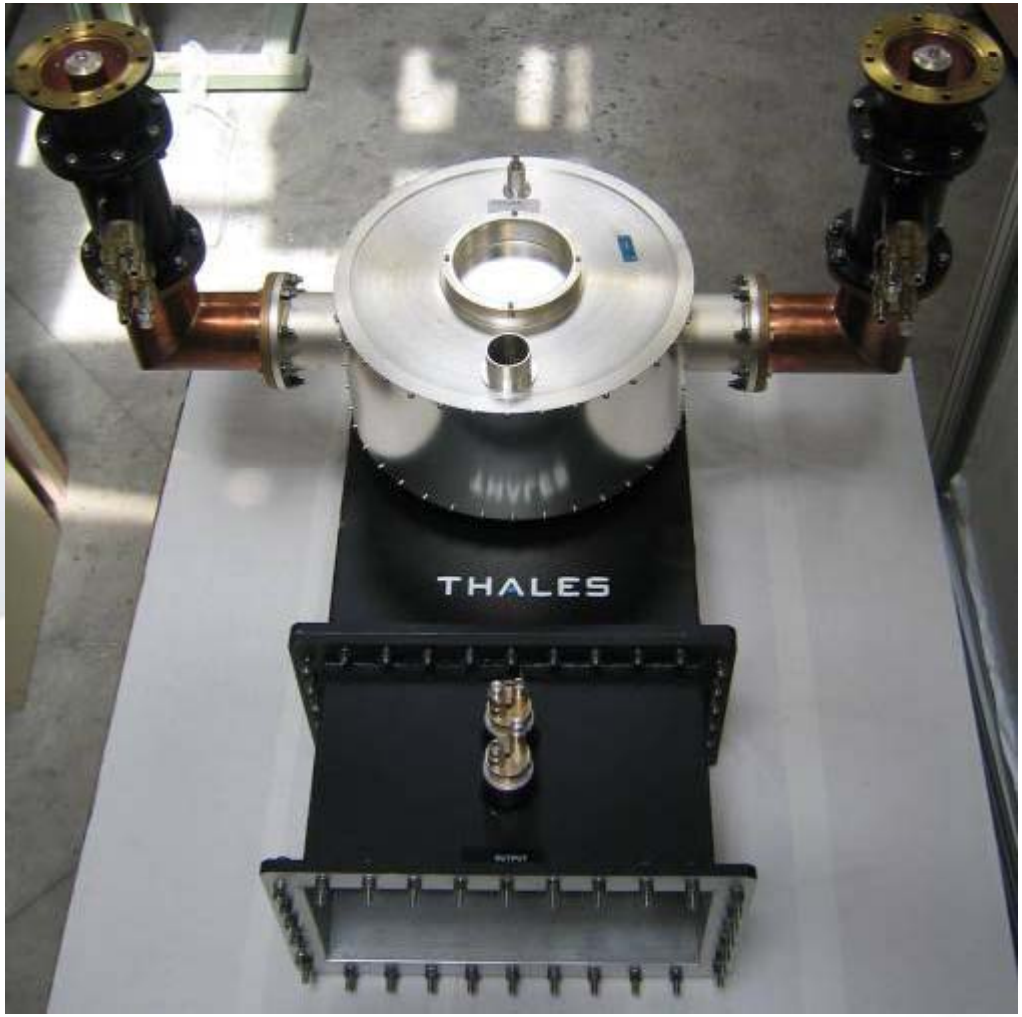


The bandwidth computed in this way was consistently narrower than the measured one .

Cavity Combiners (CaCo)

1/ 4''1/16 version

TED had developped in 2005 a resonant combiner based on a pill-box cavity.



Cavity Combiners (CaCo)

1/ 4”1/16 version

It has been tested with high power in 2006 with the following results:
(at THALES ED, Thonon)

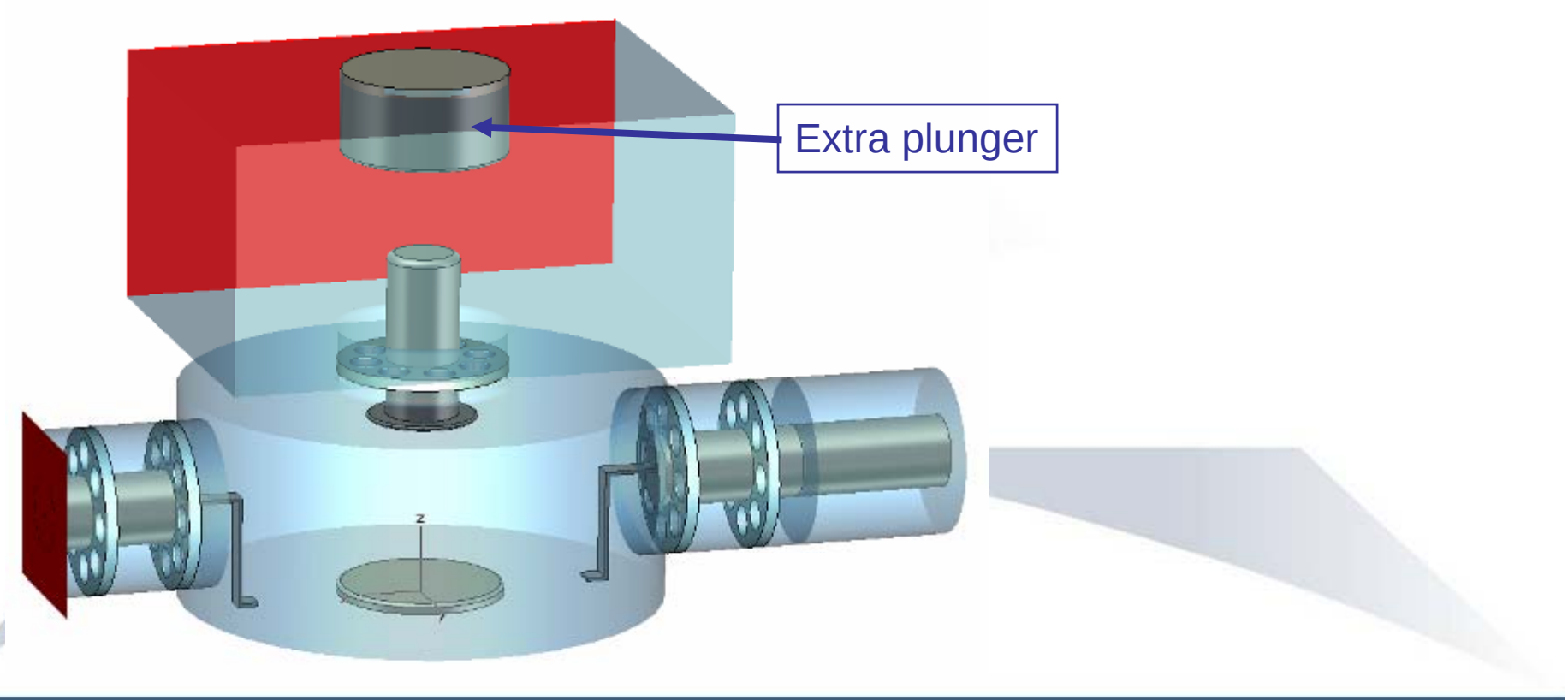
	IOT1			OUTPUT	IOT2		
	efficiency	reflected	calorimetric	POWER	calorimetric	reflected	efficiency
	%	kW	kW	kW	kW	kW	%
both IOTs on	72,0	3,5	82,8	154,2	71,4	3,1	67,0
IOT 2 off	48,8	5,6	54,2	52,2	-2	10	0
IOT 1 off	0	6	-0,1	31,0	31,1	3,9	33,7

Cavity Combiners (CaCo)

2/ New ALBA version

The models which were ordered for ALBA's TXs feature 2 improvements:

- 2 coaxial inputs are 6''1/8 instead of 4''1/16.
- A plunger was added to improve single tube operation.



Transition WR to Coax (WATRAX)

- WATRAX: WAveguide TRansition to CoAXial
- First model for the SR cavity (150 kW):
  - Fit the hexagonal geometry
  - Allow water cooling channels
- A second (straight) model (80 kW), for the Booster cavity:

Transition WR to Coax (WATRAX)

- High Power tests at DESY (summer 2006)
- SR model:
  - Over 250 kW reached
  - Around 20 kW of reflected power (much better behavior at ALBA)

Time	Klystron power [kW]	Klystron power [kW]	Power forward [kW]	Power Reflected [kW]	S11 [dB]
13:16	180	183,6	172,4	11,1	-11,(
14:16	260	268,3	257,8	18,8	-11,(

	POWER TEST of Assembly 2			
16-oct-2007		Directional Coupler		
	V_{IOT} [kV]	P_{for} [kW]	P_{rev} [W]	S_{11} [dB]
	Test at -35 kV			
08:00	-34,1	25	39,62	-28
08:45	-34,1	30	59,86	-27
08:50	-34,1	35	55,47	-28
	Test at -36 kV			
08:55	-35,9	20	25,18	-29
09:00	-35,9	30	59,86	-27
09:05	-35,9	35,6	56,42	-28
	Test at -35 kV (35 minutes)			
09:10	-34,8	30,6	24,31	-31
09:30	-34,8	30,9	61,65	-27
09:45	-34,8	31,8	79,88	-26

- Booster model:
  - Up to 160 kW reached
  - Negligible reflected power

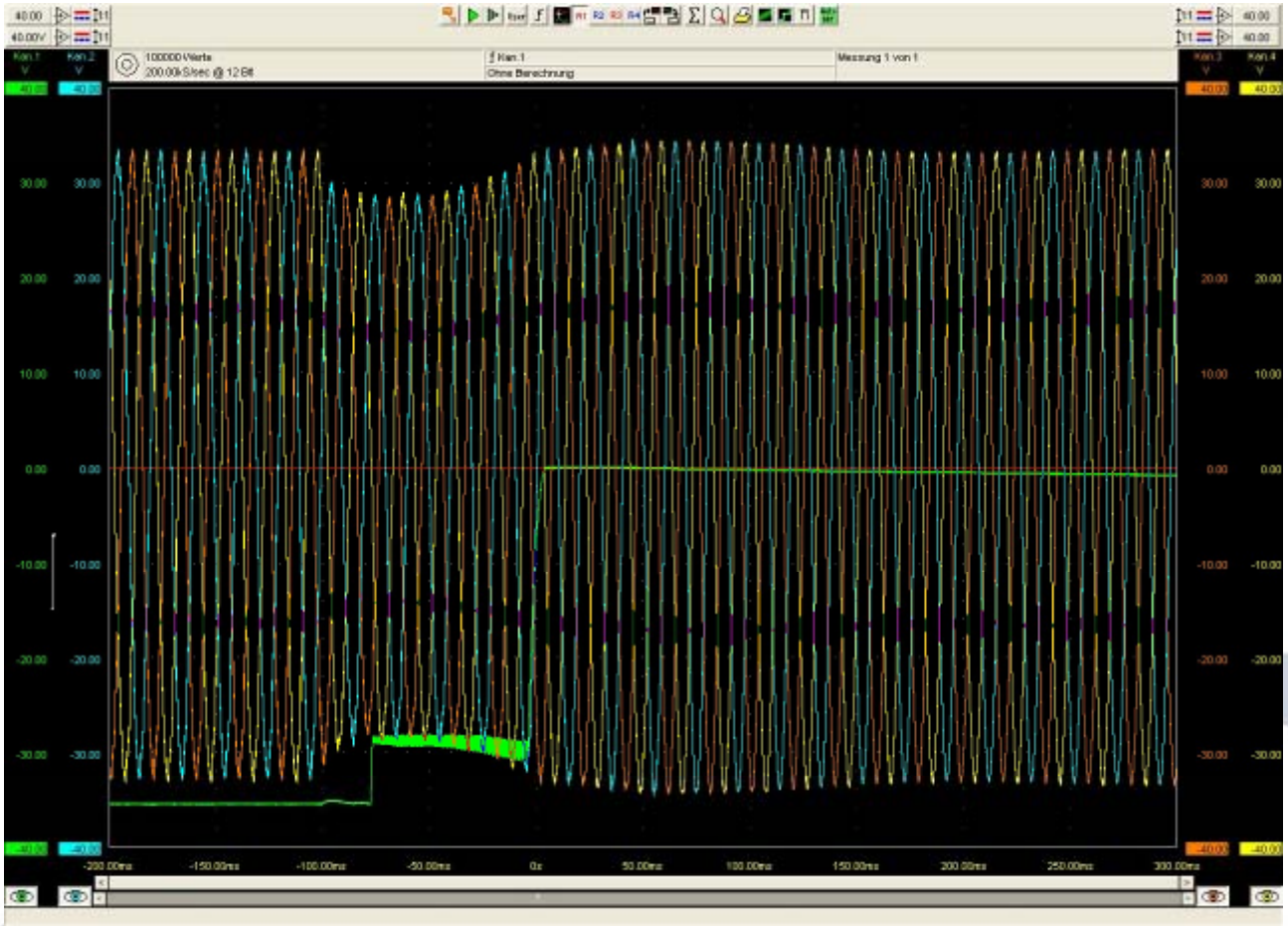
Time	Klystron power [kW]	Klystron power calor [kW]	Power forward [kW]	Power Reflected [kW]	S11 [dB]	Z1 [ºC]	Z2 [ºC]	Z3 [ºC]	Z4 [ºC]	Luft [ºC]
16:40	81	89,2	89,2	0,0	#NUM!	34,8	30 8	36,8	30	38,8
18:40	180	177,8	176,8	1,8	-18,8	48,8	41 6	61,4	41,8	61,8

High Power Lab: RF Test Plant

- 1st units delivered, installed and commissioned in Summer 2007
- Diesel generator for TX01 + its water cooling plant

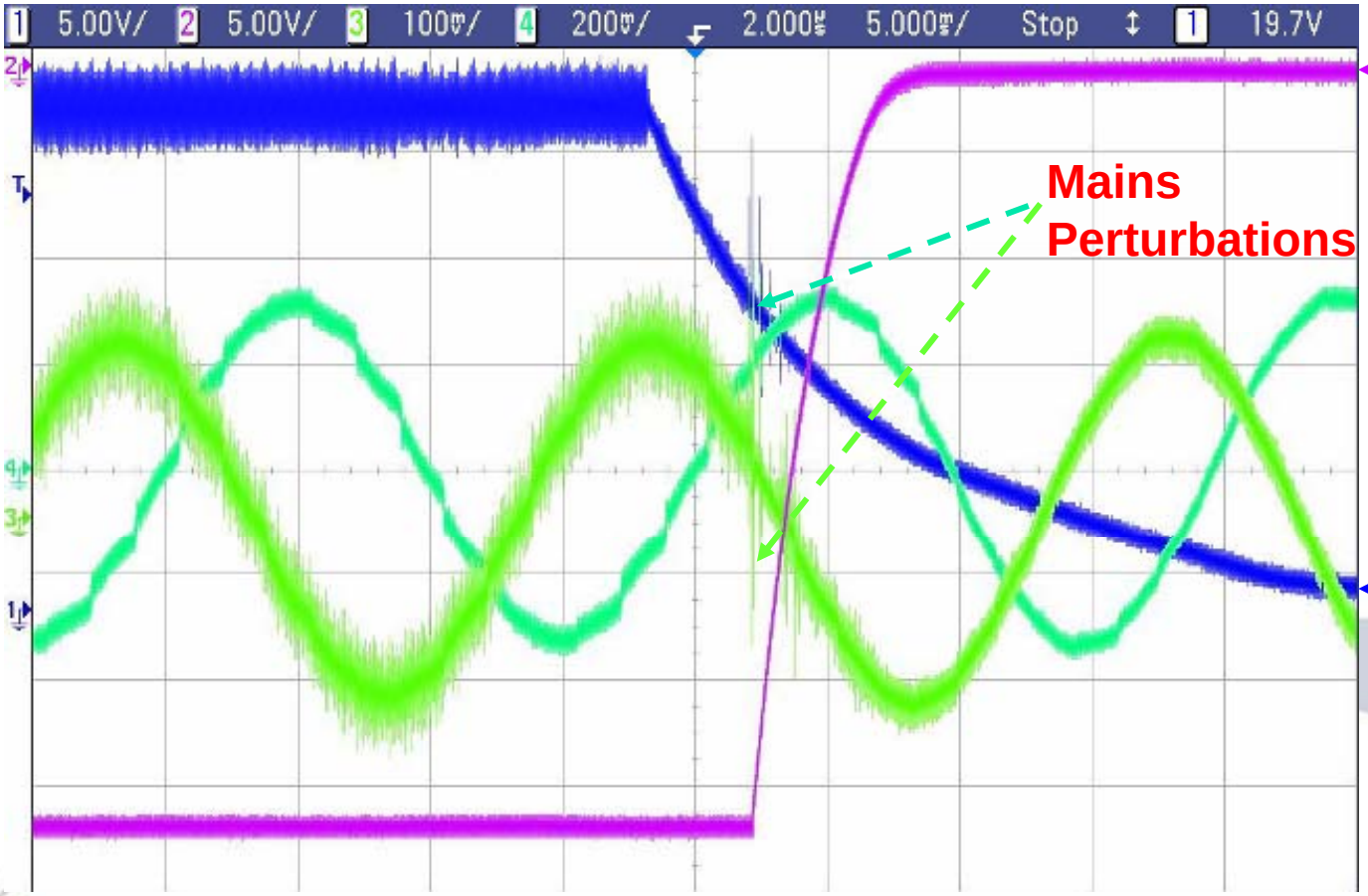
High Power Lab: RF Test Plant

- **Problems encountered in the High Power RF Lab:**
  1. **HVPS trip when 15% mains drop produced by water cooling plant start-up ➔ (Soft-starters installed: Problem fixed)**



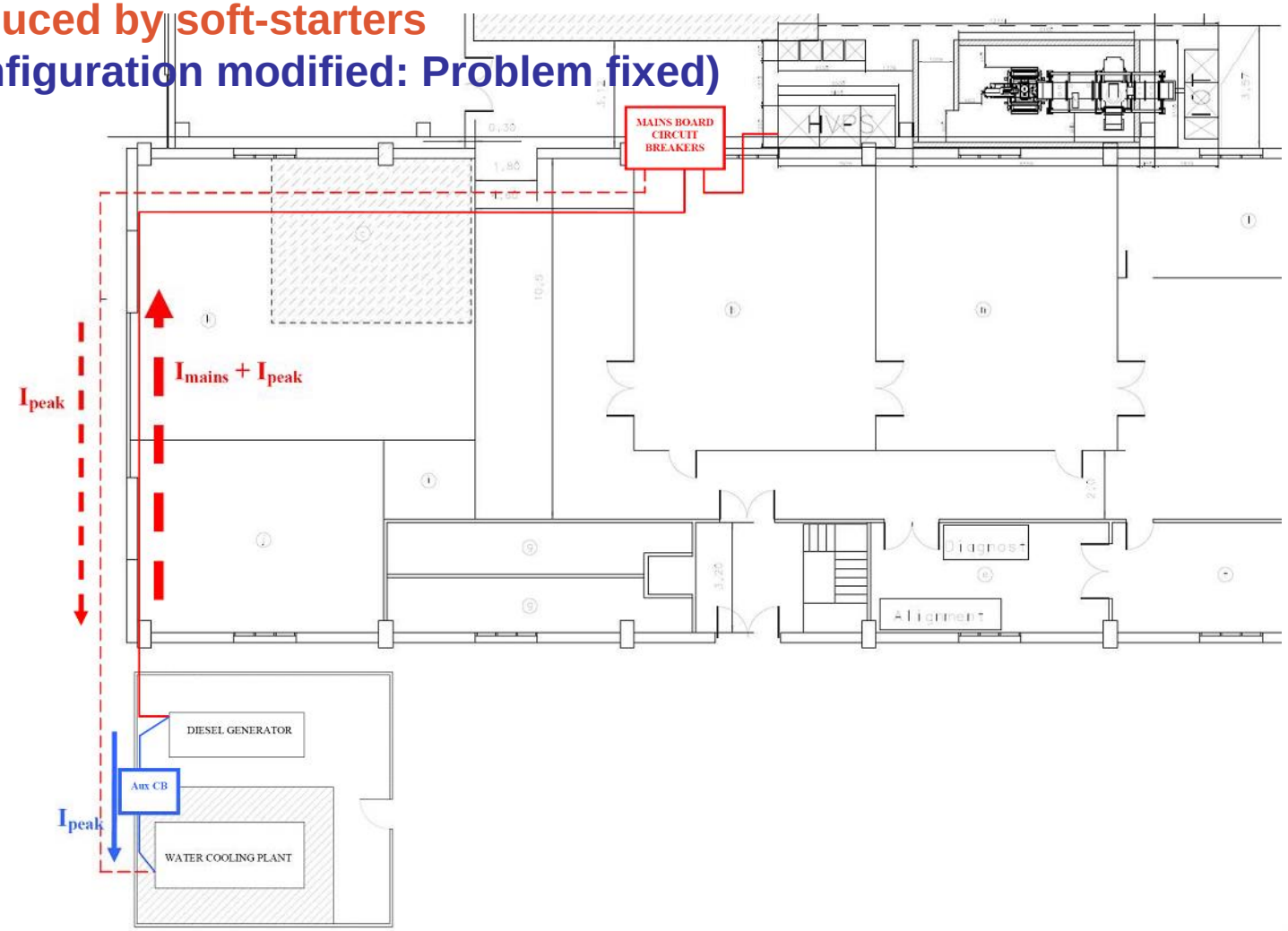
High Power Lab: RF Test Plant

- **Problems encountered in the High Power RF Lab:**
  2. **Peaks produced by soft-starters**
     (Filters + Line inductance installation: Problem still present)



High Power Lab: RF Test Plant

- **Problems encountered in the High Power RF Lab:**
  2. **Peaks produced by soft-starters**
     (Wiring configuration modified: Problem fixed)

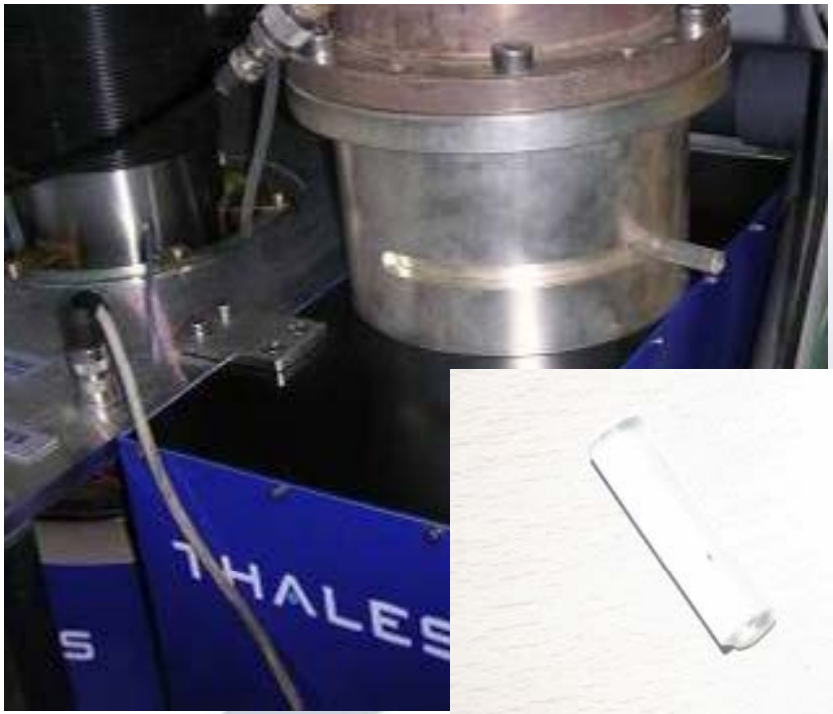


High Power Lab: RF Test Plant

- **Problems encountered in the High Power RF Lab:**
  3. **PSM module 60 burnt twice due to arcs in the HV cable**
     (New HV cable path: Problem fixed)

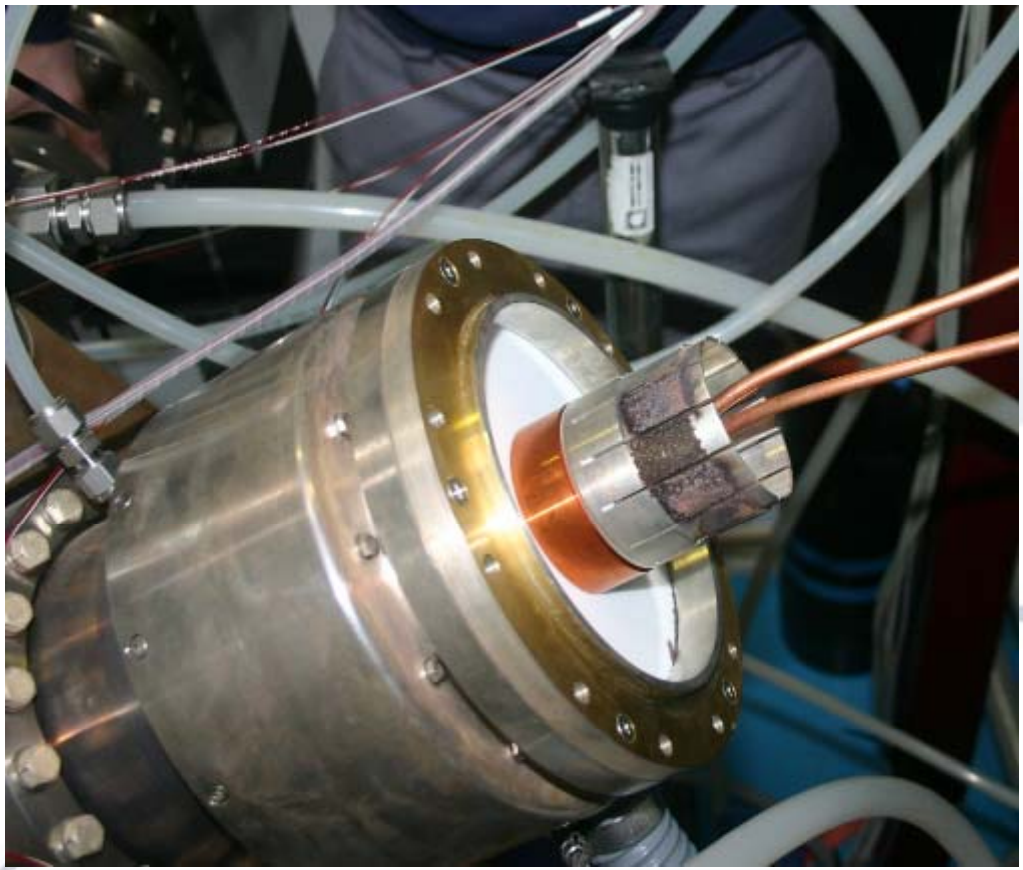
High Power Lab: RF Test Plant

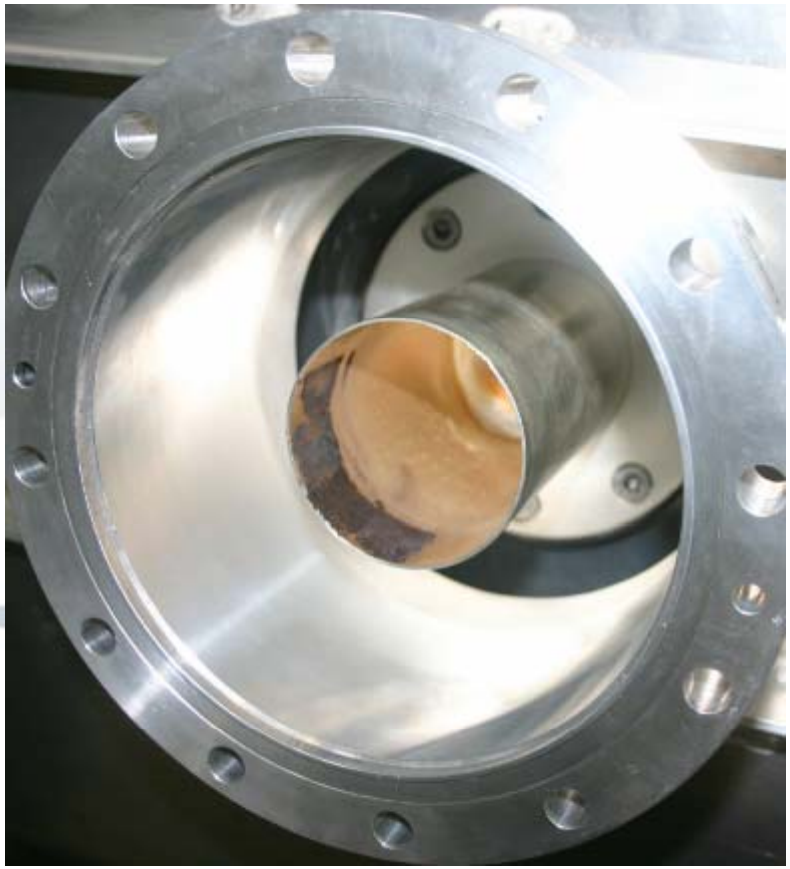
- **Problems encountered in the High Power RF Lab:**
  4. **Reticulated polystyrene matching bar broken (replaced : Problem fixed, but this is a weak point)**



High Power Lab: RF Test Plant

- **Problems encountered in the High Power RF Lab:**
  5. **Arcs due to WATRAX – RF input window misalignment (replaced and cleaned + alignment tool to be built)**





SUMMARY

The ALBA RF system includes several new designs:

- PSM modules for HVPS
- IOT for 90 kW cw, at 500 MHz
- 2 inputs combiner (CaCo)
- Transition (WATRAX) for both cavity models

All have been tested at THOMSON, THALES, DESY or in the RF ALBA Lab successfully, but not without problems.