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INTRODUCTION

ALBA is a 3 GeV, 400 mA, 3rd generation Synchrotron Light Source in Cerdanyola, Barcelona, Spain, operating with users since May 2012.

The RF System, formed out of six RF plants, provides 3.6 MV of accelerating voltage and restores up to 540 kW of power to the electron beam. One of the new developments included at the RF plants is CaCo: A cavity combiner to add the power of two 80 kW IOTs to produce the 150 kW needed for each DAMPY cavity.

CaCo is a three port device and is realized using a coupled pillbox cavity. The two inputs ports are coaxial 6 1/8” and the output port is coupled to a rectangular waveguide, see figure 1. The rectangular waveguide of CaCo is equipped with a plunger that matches the RF circuit for operation in symmetrical (plunger out) and asymmetrical (plunger in) modes. In both cases allowing full transmission of power through CaCo. All the design details and first test of this device are described in [1].

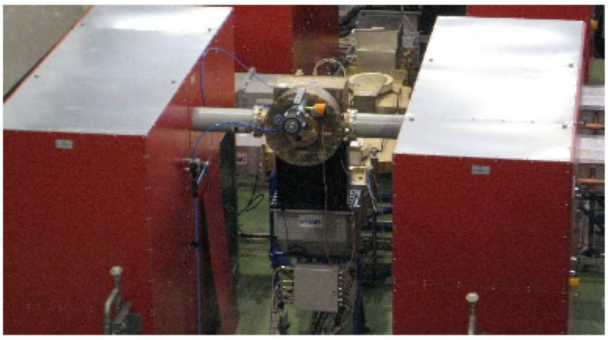

Figure 1: CaCo installed between two IOT’s.

BACKGROUND OF THE PROJECT

In the asymmetric mode of operation of CaCo only one active IOT feeds the system and the other is keeping passive [2].

This mode is intended to cope with the situation when there is a fault in one IOT and we still operate the cavity. Adding extra redundancy to the overall RF system.

During the first asymmetric full power tests, in May 2010, with an active IOT and the other passive, the result was dramatic, the passive IOT broke in two parts after few hours of operation [3].

To understand this, a simulation of the whole system was performed. The simulation shows that a standing wave is created in the passive arm. As a consequence of this a large voltage (64 kV) is created in the gap of the passive IOT (see figure 2). This high voltage in the gap will create sparks and without any cooling system (it was disconnected since it was in passive operation) it provokes a huge thermal stress in the ceramic, breaking it.

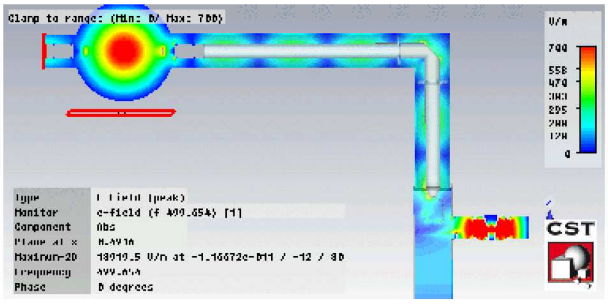

Figure 2: Simulation of the standing wave in the passive IOT arm.

COSTUB

CoStub (coaxial stub) was designed for protecting the passive IOT during the performance of the asymmetric mode. CoStub is a device formed out of a coaxial waveguide and four stubs. When the stubs touch the central conductor, this device behaves as a short circuit, in this way the passive IOT is protected.

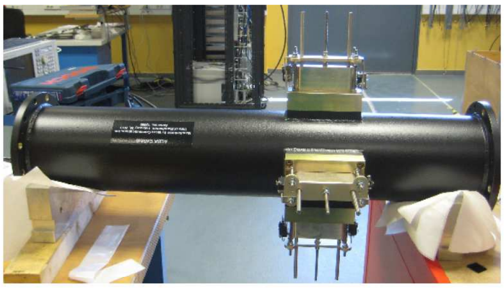

Figure 3: Picture of the CoStub.

Simulation Analysis

CST MICROWAVE STUDIO® has been used for the CaCo electromagnetic simulation [4].

The numbers of the stubs, the shape, the length and width of the stubs, the position of the stubs along the coaxial waveguide, the distance between the stubs have been optimized for a good performance in both symmetrical and asymmetrical mode.

Table 1: Characteristics of the CoStub

Number stubs	4
Distance between the stubs	90 degrees
Position respects Caco	236 mm away
Length	100 mm
Width	20 mm
|S21|	-53 dB
Power loss	10 W
Efield max around the stubs (scaled for 80000 RMS)	14000 V/m

The calculated power dissipated by the stubs is 10 W which is quite low, therefore it is not necessary a cooling system for a good performance of the stubs. The maximum electric field magnitude around the stubs (scaled for 80000 RMS) is 14000 V/m, which is lower than the electric field magnitude breakdown, so it is ensured that the stubs would have a good high power performance, this means that they do not cause sparks and overheating.

Mechanical design

After the physic design and analysis, a design suitable for ease of manufacturing and assembly was done. The detailed design and the choice of material was carried out in house, the manufacturing was outsourced.

To slide the stubs it is necessary to leave some space between the coaxial waveguide and the stubs. RF fingers were used to avoid RF leaks during high power performance.

Figure 4: RF fingers.

The bottom part of the sliding stubs was mechanized barely concave, i.e with the same radius than the outer conductor of the 6 1/8” coaxial waveguide, as is shown in figure 5. It was decided to machine them concave, despite it is more expensive than a flat piece, as it presents better RF characteristics. The concave pieces are better suited to fully short out on the inner conductor as well as with the outer one, ensuring a good performance on both operational modes.

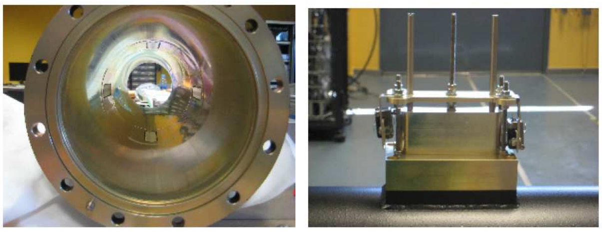

Figure 5: Stubs OUT position.

Operation Mode

When an IOT trips the EPS (equipment protection system) stops the operation of the active IOT in ms. If an IOT trips several times making the operation impossible, then the operation is stopped and the stubs of the CoStub of this IOT are placed in position IN (touching the inner conductor of the waveguide). And the operation is resumed. This operation is done manually; i.e no engine will be used for moving the stubs as the required number for all the CoStubs is really high and as it is expected doing this operation only occasionally.

The electric field and the magnetic field are maximal near the inner conductor of the coaxial waveguide. If there is a small gap between the stub and the inner conductor of the coaxial, CoStub will malfunction.

In order to ensure a good contact between the stubs and the inner conductor screws are used as is shown in the figure 6. Also the screws avoid movements of the stubs. The rods of the stubs behave as a guide. They align the stub and ensure that the stubs do not deflect during the operation of placing IN or OUT.

Each stub has two end switches one indicates that the stub is in the OUT position and the other that is IN. This was introduced for a safe operation and for avoiding human mistakes that can lead to a malfunction of the system.

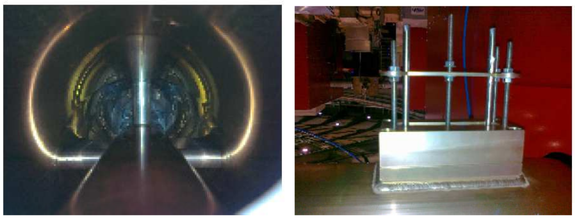

Figure 6: Stubs touching the inner conductor.

Low Power Measurements of CoStub

CoStub was assembled on the CaCo and tests were carried out with network analyzer to determine the S-parameters, as is shown in the figure 7.

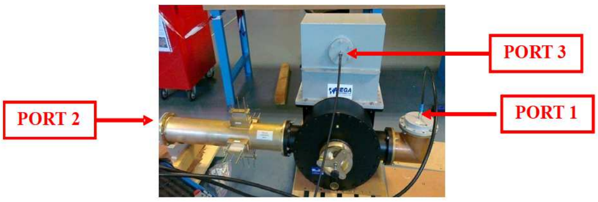

Figure 7: Setup of CaCo for the measurements.

Asymmetrical mode

An important point to understand about the performance of CoStub is why the four stubs must touch the central conductors. The following measurements show the transmission, $|S_{21}|$, from the CoStub to the passive IOT depending on the number of stubs that touch the inner conductor and explain the last issue. If the four stubs are IN almost no power is delivered to the passive IOT. The results were in agreement with the simulations.

Table 2: Dependence of the Number of Stubs that Touch the Iinner Conductor and the Transmitted Power to the Passive IOT

Number of stubs touching the inner conductor	$\lvert S_{21}\rvert$
1	-3dB
2	-20dB
3	-27dB
4	-52dB

Symmetrical mode

The two arms feed CaCo, nevertheless as is shown in figure 7 the two arms has different length. In order to compensate this asymmetry a phase shift is introduced in the port 1. Results of the measurements:

$$b_1 = s_{11} * e^{-i\varphi} + s_{12} = -42\text{dB}$$

$$b_2 = s_{21} * e^{-i\varphi} + s_{22} = -42\text{dB}$$

$$b_3 = s_{31} * e^{-i\varphi} + s_{32} = 3\text{dB}$$

From these measurements is concluded that CoStub do not perturb the symmetrical mode. Also it is shown that any asymmetry due to different lengths of the arms can be compensated during high power operation via digital low level.

High Power Test of CoStub

Asymmetrical mode

First Test: One active IOTs fed the system. CoStub was placed in the passive arm and was assembled to N-type transition and to a power meter. The power was increased till **80kW.**

No overheating, sparks neither RF leaks were observed. The result of this test are summarized in the table 3.

Table 3: Measurements Done During the High Power Operation of the Asymmetrical Mode of CaCo Assembled on the CoStub.

Power after Costub at 80 kW	0.365 W
Initial/ final temperture of the stubs at 80 kW	24ºC/26ºC
Arcs	Not detected
RF Leaks	Not observed
Power Reflected to the active IOT at 80 kW	85 W

Second test: The N-type transition was removed and the CoStub was connected to a passive and new IOT.

The passive IOT was kept at HVON during this operation, as it was conditioning. The active IOT was feeding the cavity. At the same time the cavity was conditionin, too. The system worked properly and without presenting any problem.

Symmetrical mode

The CaCo plunger was set to symmetrical mode (fully moved out) and the stubs of the CoStub were set in the OUT position. The power was increased without presenting any problem. This mode of operation has been working perfectly during the last year.

CONCLUSION

A new device, CoStub (coaxial stub), to short circuit the coaxial waveguide of the passive arm and protects the passive IOT was proposed and successfully tested at low and high power.

At this moment the SAT of 12 CoStub are performed. All of them will be installed during this year.

REFERENCES

[1] F.Perez, B.Baricevic, P.Sanchez and D. Einfeld, M.Langlois: High power cavity combiner for RF amplifiers. September 2006.

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