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IMPROVED STUDY OF THE MULTIPACTOR PHENOMENON FOR THE MYRRHA 80 kW CW RF COUPLERS

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Abstract

MYRRHA (Multi Purpose Hybrid Reactor for High Tech Applications) is an Accelerator Driven System (ADS) project. Its superconducting linac will provide a 600 MeV -4 mA proton beam. The first project phase based on a 100 MeV linac is launched. The Radio-Frequency (RF) couplers have been designed to handle 80 kW CW (Continuous Wave) at 352.2 MHz. This paper describes the multipactor studies on the coupler when it does not work in the nominal configuration without reflected power.

INTRODUCTION

The first section of the superconducting LINAC will be composed of Single Spoke Resonators (SSR) ($beta_{prototype}$ = 0.37) housed in short cryomodules operating at 2 K [1].

The energy transfer from the RF source to the SSR is made by the RF couplers. The RF coupler also seal the accelerator vacuum thanks to is window and a thermal barrier between air and the SSR while preserving its cleanliness.

As part of an ADS, the LINAC is laid out for the highest achievable reliability. Thus the coupler is studied [2] and tested up to 80 kW CW, well above its nominal power (8 kW CW), to allow the fault-tolerance schema [3] with a study of the multipactor phenomena in all the configurations that coupler can operate.

Multipactor is an undesired phenomenon of resonant electron build up encountered in electromagnetic field regions under vacuum. It appears when an electron is accelerated by the electric field and hits the enclosure's wall. Depending on the secondary electron yield of the wall, more than one electron can be emitted and accelerated by the electric field, creating a self-sustained electron avalanche.

The performance of the couplers can be greatly affected due to multipactor that could in the worst case break the coupler window venting the accelerator.

For the RF coupler of MYRRHA, first multipactor studies [4] have been carried out up to 80 kW CW of two couplers mounted in the conditionning cavity, 50 Ohm loaded.

In this case the coupler handle a traveling wave.

This configuration also corresponds to the coupler mounted to the SSR and matched to the nominal beam or with a $\beta \sim 1$ where β is the ratio of the intrinsic quality factor of the cavity (Q_0) and the external quality factor (Q_{ext}).

$$\beta = \frac{Q_0}{Q_{ext}}$$

In this paper, we show the multipactor study corresponds to the others situations:

- Case over - banwidth (OB): for the coupler mounted at the SSR at room temperature over-banwidth. In this configuration, the cavity behaves as a short-circuit and the coupler handle a standing wave with all the power reflected. This configuration correspond to RF conditioning of the coupler at the SSR.
- Cases slightly mismatched: for the coupler mounted at the SSR operating at 2 K at the resonance frequency with a mismatch. In this configuration the coupler can be undercoupling (β<1) or overcoupling (β >1) and the coupler handled a mixed wave.
- Case no beam: for the coupler mounted in the SPOKE cavity at 2 K without beam. In this configuration, the cavity is as very over coupling (β >>1) and the coupler handle a standing wave with all the power reflected. We find this configuration while testing the cryomodule to achieve the maximal accelerating field in the cavity or in the accelerator without beam.

HFSS CALCULATIONS

The coupler mounted in the SSR has been modelled and the field maps (see Fig. 1) for each configuration is created with the drivenmode solver of HFSS.

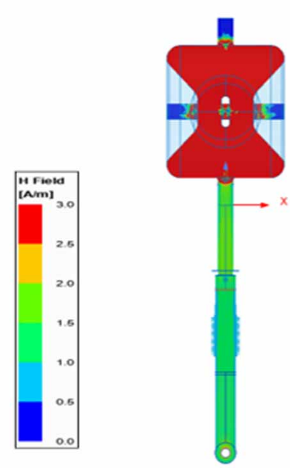

Figure 1: Magnetic field map@1 W for the coupler mounted in the SSR with β ~1.

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The external quality factor (Q_{ext}) was 1,5 10^6 as defined for the prototypes couplers.

To get the different cases, the Q_{ext} is keeped constant and the Q_0 is changed thanks to a variation of the conductivity (S/m) of the SSR walls. The goal is a $Q_0 \sim 10^{20}$ for the case of no beam, a Q_0 slightly lower than the Q_{ext} for the case of little undercoupling Q_0, and slightly higher than the Q_{ext} for the case of slightly overcoupling. The frequency used at each configuration is chosen to have the maximum power transmission (minimum of the parameter S_{11}(dB)), except for the case OB that it was chosen far away of the bandwidth (353 MHz).

Figure 2 shows the different frequencies chosen and their coupling.

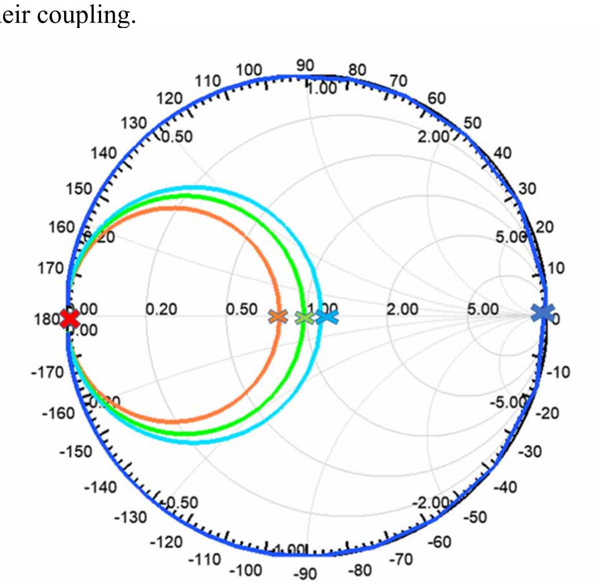

Figure 2: Smith chart of the different cases: OB in red; slightly under coupling in orange; matched in green; slightly over coupling in light blue; no beam in dark blue. Asterisk show the frequencies used.

SPARK-3D CALCULATIONS

Once we have the fields maps, we used SPARK 3D to have the evolution of the electron population with time (t). For every simulation, we computed the exponential growth factor α, defined as:

$$\bar{n}(t) = \bar{n}(t_0)e^{\alpha t} \in [t0, t1], \quad (1)$$

where $n(t)$ is the number of electrons averaged over an rf period. $t0$ is the time at the beginning of the multipactor exponential growth. $t1$ is the simulation end time.

The multipactor occurs when $\alpha > 0$.

Electron emission is the phenomenon at the origin of the electron population growth. The electron remission is given mainly by the Secondary Emission Yield (SEY) as a function of the electron impact energy. The SEY depends strongly on the nature of materials, the surface chemistry and the surface state. The SEY data used in the simulations in the Vaughan model is shown in Table 1.

Table 1: SEY of the Copper and TiN Coating

Parameter	Copper	TiN
SEY_{max}	2,3	1,75
SEY_0	0,5	0,5
E_1(eV)	35	35
E_{max}(eV)	165	250

Where SEY_{max}, SEY_0, E_1 et E_{max} is define as shown in Fig. 3.

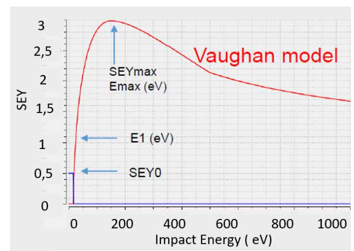

Figure 3: SEY_{max}, SEYO, E_1 et E_{Max} of the Vaughan model.

Simulations were made up to 20 kW, the maximum possible power handle of the MYRRHA coupler. Figure 4 gives the exponential growth factor for each configuration studied (OB, slightly undercoupling, slightly overcoupling, no beam) and the results of the simulation made in a matched configuration ($\beta \sim 1$).

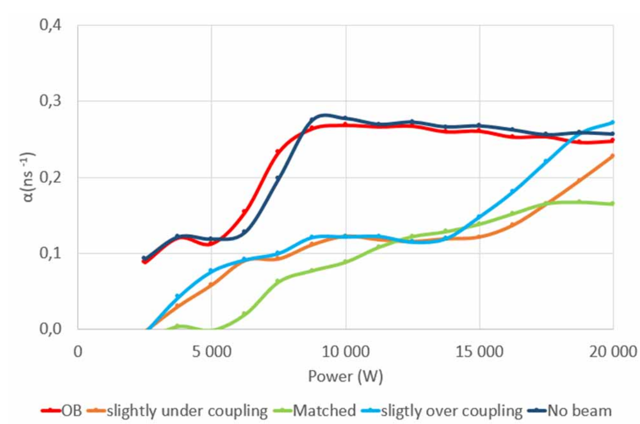

Figure 4: Exponential growth factor as a function of the power.

In all cases, the α is fewer than 0,3 ns^{-1}.

The better α, the minimum one, is for the adapted configuration with a traveling wave.

A little mismatched increase α but in a no significant way. It is at 18 kW when α reaches its maximum.

For OB and no beam, the maximum of α is reached well before (7 kW vs 18 kW) and from there it stays constant till 20 kW). Up to 6,5 kW the multipactor stayed very low. It is explained as the different behaviour of the multipactor when there is a standing wave and not more a traveling wave [5] because of the different pattern of the fields.

The multipactor locations in the coupler are showned in Fig. 5. The multipacting zones are in red.

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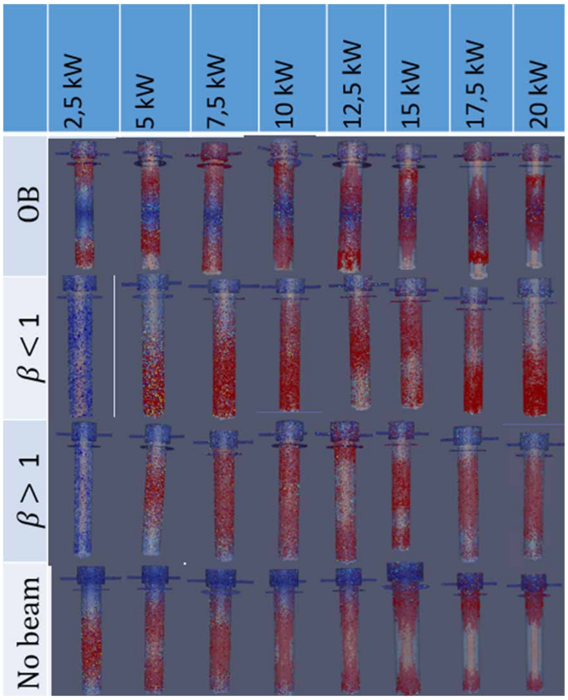

Figure 5: Multipacting zones of the coupler in red, for the different configurations studied (OB, $\beta < 1$, $\beta > 1$, no beam) and for different powers (2,5, 5, 7,5, 10, 12,5, 15, 17,5, 20 kW).

In the cases of slightly over coupling ($\beta > 1$) and slightly under coupling ($\beta < 1$) the zone of multipactor is more homogeneous at all the external conductor of the coaxial than the others cases (OB and no beam). Here they are closer to a traveling wave into the coupler.

For OB and no beam ($\beta \gg 1$), there is a standing wave into the coupler which explains that there are two multipacting zones well distinguished separated around $\frac{\lambda}{2}$, where λ is the wavelength. One of the regions is close to the cavity and the other close to the window. To note that as one of these zones is close to the window, whether or not TiN coating is simulated on ceramics influences the result.

CONCLUSIONS

A complete study of multipacting have been done for the MYRRHA RF couplers.

Results' multipactor calculations give an important information as the multipactor locations and the power ranges where multipactor might appear but the information is relative as α depends strongly on the SEY.

We found that when the couplers work in a matched configuration, the α is the lowest. Bigger is the mismatched, bigger is α. For the worst case, OB and no beam, the maximal values of α (around 0.3 ns $^{-1}$) moves to the lower power 6,5 kW regarding 18 kW in matched case.

These results show that in the normal situation of work of the coupler, matched to the beam or with a slighty mismatched, there is almost no multipactor up to the nominal power 8 kW. For the others rarely cases studied, OB and no beam, there is almost no multipactor up to 6 kW.

RF conditioning at room temperature at the test bench 50 Ω loaded have been finished for the prototypes. Two of them have been mounted to the SSR and the RF conditioned (room temperature and 2 K) have been done. Now cavities tests are ongoing to get the nominal accelerating field.

The next goal is the end of the cryomodule test. Thus we could do the comparison of the multipacting measurement (electron current, vacuum and temperature) with the result of simulation but we already see that measurements and simulations seems to correspond well.

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