XFEL COUPLERS RF CONDITIONING AT LAL

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Abstract

In the framework of the French contribution to XFEL project, The LAL has in charge the development, the production and the RF conditioning of 800 power couplers to equip 100 cryo-modules. Thus, LAL's tasks consist on the industrial monitoring and coupler quality control at two different production sites, in addition to the RF conditioning at LAL.

The conditioning process and all the preceding preparation steps are performed in a 70m^2 ISO5 clean room. This infrastructure, its equipment and the RF station are designed to allow the treatment of 8 couplers in the same time, after a ramp-up phase.

Clean room process and first conditioning results are presented and discussed.

INTRODUCTION

The large experience acquired by LAL in power coupler treatment within the last ten years made it one of the key players in this field. Several studies were carried in various domains (mechanical design, RF simulation, vacuum studies, cleaning–assembling procedure and RF conditioning [1]), to better understand the RF behaviour, to improve coupler treatment procedure and to make the RF conditioning shorter and more efficient.

Historically, LAL's activities in power coupler started years ago with TTF3 couplers, base model of XFEL ones, that were prepared and conditioned at LAL to be installed later at FLASH machine. Therefore, Thanks to the experience accumulated, LAL is involved in the industrialisation and the preparation of the 800 XFEL couplers. LAL's tasks consist on the industrial monitoring at two production sites: Thales Electron Devices-Thonon les bains-France (TED) and Research Instruments-Cologne-Germany (RI), in addition to the RF conditioning at LAL. The first task goes from the specifications setting to the final coupler quality control. The second is held in a 70 m^2 ISO5 clean room especially constructed for this purpose. In the following, we will present details on the coupler preparation process in LAL's clean room and the first conditioning results.

COUPLER CONDITIONING AT LAL

Both processes: Coupler preparation and RF conditioning occurred in a 70 m^2 ISO5 clean room especially constructed for XFEL coupler treatment.

The clean room and the equipment installed are optimised to treat 8 couplers per week after a rump up phase.

Coupler Preparation Process

Several steps are carried out prior to RF conditioning. Upon reception at LAL, the coupler pairs are introduced in clean room and after a quick visually checked, pumping groups are mounted (getter pump, valve and gauge) in each warm part and in the set of the two cold parts and the transition waveguide box. Then, a leak test is performed. Once the tightness is verified, an in-situ under vacuum baking cycle is carried out (with a landing at 150 °C during 75 h) to remove the residual water vapour. The clean room is equipped with 3 ovens allowing the treatment of 12 couplers in the same time. At the exit of the oven, the next step is the getter pump starting and the RGA mounting. A residual gas spectrum is then recorded and compared to a coupler pair "standard spectrum". The final step, before installing the coupler pair in RF test bench, is the couplers antenna tuning in order to guaranty a good RF matching and avoid power reflection. Once all these steps are successfully performed, the coupler pair is than installed in RF test bench ready for conditioning.

XFEL Coupler RF Conditioning

An RF power source delivering a maximum power of 5 MW was installed at LAL. A system of wave guide splitter allows to have 4 test stand with a maximum power of 1 MW each, which permit the conditioning of 8 couplers (4 pairs) simultaneously. The XFEL couplers are conditioned according to a well-established automatic procedure tested at LAL since years [1]. This procedure was adapted to the new RF test benches to manage the simultaneous conditioning of 4 pairs.

The conditioning procedure consists on the gradual rump up of the RF power at 4 Hz till reaching a maximum value, then keeping the power at this level during 1 h. These steps are repeated for several pulse lengths going increasingly. At the end of the procedure, 10 sweeps (successive increase and decrease of the power between minimum power and 500 kW) are performed. The figure below describes the conditioning procedure.

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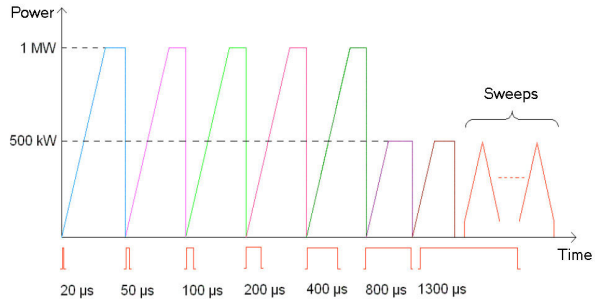

Figure 5: RF conditioning procedure description.

During the power processing, the vacuum level and the e- pick-up current in the coupler parts are monitored and kept under determined threshold by managing the power increment/decrement. Any threshold crossing triggers an interlock to avoid multipactor [3] harmful effect on coupler surfaces. Other parameters are also monitored during RF conditioning such as reflected power in coupler pair, ceramic temperature, arc detection, RF leak... all these parameters induce a hard interlock one a fixed threshold is crossed.

First XFEL couplers were successfully conditioned. Which is comforting for these new coupler design and manufacturing. In the following some results:

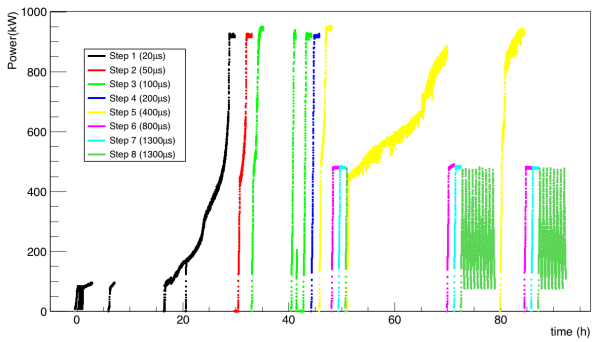

Figure 6: XFEL power coupler RF conditioning.

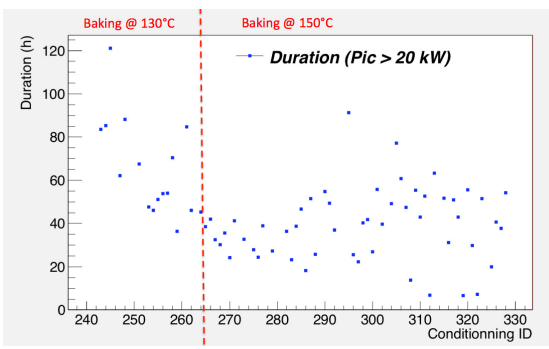

Figure 7: RF conditioning duration before and after the increase of the baking temperature.

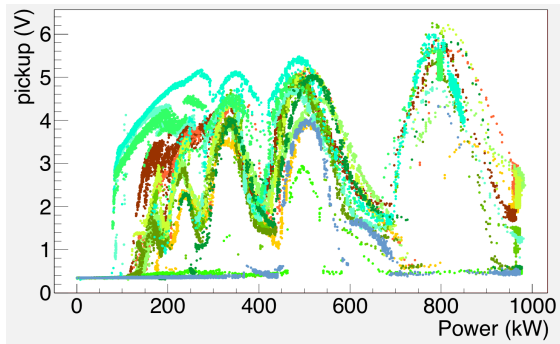

Figure 8a: Superposition of electron pickup current measurement (converted to voltage: 1µA→1V) in the cold volume, in the first step for many RF tests.

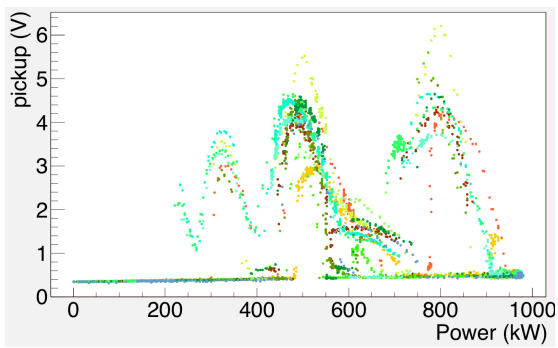

Figure 8b: Superposition of electron pickup current measurement (converted to voltage: 1µA→1V) in the cold volume, in the third step for many RF tests.

The global time duration of the RF conditioning procedure is quite variable. It depends on many factors like the coupler cleanness, the baking temperature and also on interlocks of the RF station not caused by the couplers. The XFEL conditioning procedure ends up when the 8 steps corresponding to 8 different RF pulse length (figure 5) are achieved. We consider a coupler fully conditioned when its vacuum level during the sweeps is less than 10^{-7} mBar and the pickup level less than a few mA. Generally, this 8 steps procedure is not enough to acquire such vacuum and pickup conditions. It is then necessary to go back to previous steps (at 400µs) with decreasing the vacuum thresholds.

Observations during RF conditioning

The increase of the baking temperature from 130ºC to 150ºC had a very positive effect on the conditioning duration, which decreased by a factor close to 40%. This is mainly due to decrease the level of outgassing at low power in the first conditioning step.

During the RF conditioning, unstable high order multipactors are reduced in the very first steps. They occur at low power level (less than 200kW). Then the stable low order multipactors remains till the last conditioning steps as shown on figures 8. The

superposition of many RF conditioning tests also shows that for most of the couplers, the stable multipactors occurs at the same power level. A difference in the power dependence of the multipactors could only be explained by a modification of the coupler geometry, a modification of coupler surface, which affects the secondary emission coefficient.

Part of the couplers (let's call them B-type couplers) have a slightly different behaviour: multipactor power dependence is enlarged including also lower power component. The effect is visible in both pickup and vacuum levels. The RF processing of those couplers is more difficult, and even during the sweeps, some low power multipactors are still remain. The pressure also keeps high, and different methods have been used to reduce it. The standard method by forcing the pressure level under a certain limit (we went from 6.10^{-7} mBar to 1.10^{-7} mBar) during the steps 5 (400 µs RF pulse) and 7(1300 µs) is now accompanied by long sweeping periods (from 10 to 30). If the vacuum threshold is too low, the processing will occur in a non-optimal power region, where the multipacting activity is not very high. In order to reduce the conditioning time, it is necessary to maximize the multipacting activity and find, with best vacuum threshold.

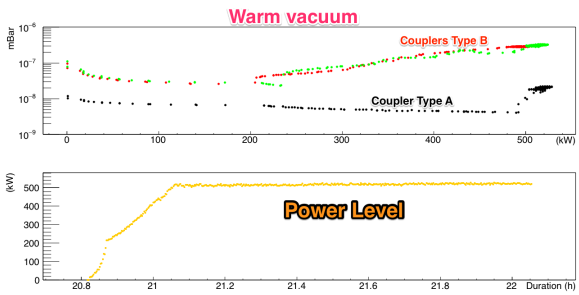

Figure 9a: Vacuum level during RF processing at 7th Step (1300 µs) for usual pairs (type A) and unusual ones (type B).

As shown on figure 9b, low power multipactors remain for the B-type couplers, even after long processing.

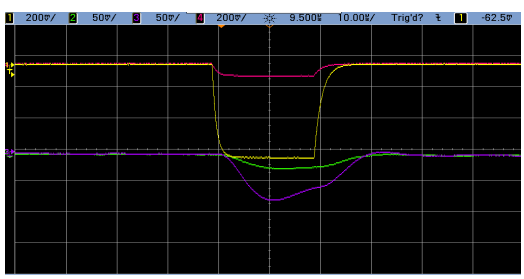

Figure 9: **Arc detector signal during RF test.** RF incident and reflected power pulse signals are in yellow and pink, and arc analogic signals are the green and purple curves.

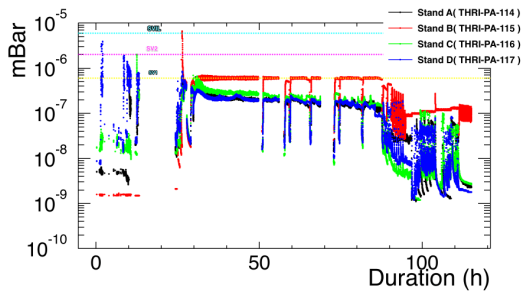

Figure 10: Vacuum level during RF tests. Warm vacuum level for the pair on bench B (red curve) is high and independent on power level. The corresponding cold ceramic had dark spots after the RF conditioning.

Arc detectors are installed to measure the light through the coupler ceramics, and interlock when the signal level is higher than a given threshold. The corresponding light could be due to arcing in the coupler, or just light generated by field effect through the ceramic (see figure 9). The later follows the RF pulse and is usually conditioned.

For B-type couplers, the light level is usually larger and could remain longer. It became an important factor to take into account and the origin is still under investigation.

After RF conditioning, some couplers have dark spots on cold ceramic. Several studies have been conducted to discover the origin and especially the composition of these dark spots. One of the studies carried out during the conditioning shows that a necessary condition for these dark spots to appear is to have a high level of vacuum in the warm coupler, and independent of the power as shown on figure 10.

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