STATUS OF THE FUNDAMENTAL POWER COUPLER PRODUCTION FOR THE EUROPEAN XFEL ACCELERATOR

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Abstract

For the XFEL accelerator, Thales, RI Research Instrument and LAL are working on the manufacturing, assembly and conditioning of fundamental power couplers. 670 couplers have to be manufactured according to strict specifications. This paper describes the full production activity from the program starting to the current phase with main measurements for the coupler characteristic: copper and TiN coating characteristics. The status of the production is given with an output rate of 8 couplers per week. The status for more than 500 couplers manufactured and conditioned is presented.

INTRODUCTION

Fundamental coupler main parameters are[1]:

- RF frequency: 1.3 GHz
- Peak Power: 150 kW
- Pulse length: 1.3 ms
- Repetition rate 10 Hz
- Tuning : ± 10 mm
- Coupling (Qext) $2x10^{6} \rightarrow 2x10^{7}$
- Two ceramics windows

The main metallic sub-assemblies of a coupler are the Warm External Conductor (WEC), Warm Internal Conductor (WIC), The Cold External conductor(CEC) and the antenna, illustrated in Fig.1.

The two other critical components are the two cylindrical ceramics.

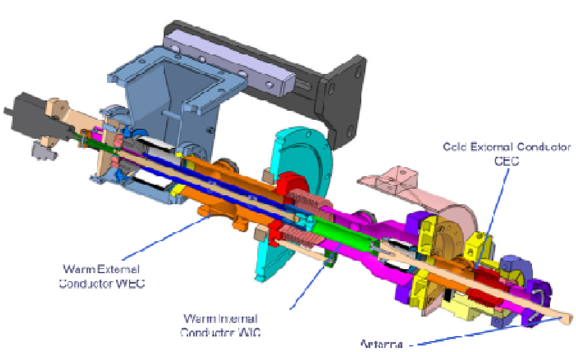

Figure 1: Coupler general layout.

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COUPLER FABRICATION

Main steps in the coupler fabrication are: parts assemblies, copper coating of RF surfaces, TiN coating of ceramics windows. When all these parts are ready, parts are EB Welded in order to achieve Warm part and Cold part of individual couplers. Then the coupler parts are clean in an ISO 4 clean room and after drying, they are integrated by pair on a transition waveguide. After a leak check and a RGA is operated couplers are send to LAL in special design shipping box. In LAL couplers are then RF conditioned up to 1 MW peak before being sent to IRFU for complete integration on cryomodules.

Thales Production Process

The XFEL couplers sub-assemblies are based on a brazing technology. This technology allows having a better reproducibility than a welded one, which is more operator dependant and also could be performed by batches, which is useful for a mass production.

Brazing material Cu-Au (50-50) is mainly used. At the beginning of the program, all interfaces particularly brazing grooves, and mechanical tolerances have been defined and qualified in order to avoid centricity problem between tubular parts and avoid gaps, edge or excessive brazing material on RF surfaces.

During the preparation of manufacturing tests have been done also on bellows in order to study the effect of brazing temperature. It has been observed that the stiffness of bellows increases by a few percent remaining in the range of the actuator capabilities for tuning the coupler.

Once the sub-assemblies are brazed and prepared, the three main one (WEC, WIC and CEC) are copper coated, as illustrated in Fig.2 and Fig.3.

The copper plating process is the trickiest step for the coupler manufacturing. This is due to the combination of very demanding specifications on thickness tolerances on complicated geometries (bellows, conical parts, big flanges), quality on the copper visual aspect and RRR specifications.

Thickness and tolerances on WEC and CEC are of 10 µm ±20 % on tubular parts and ± 30% on bellows, For WIC thickness is of 30 µm ±20 % on tubular parts and ± 30% on bellows.

RRR value initial specification was from 30 to 80.

In order to reach such demands special tools were designed and tested with a careful optimisation of the all process which implies a lot of parameters to be controlled to achieve such a goal.

For this process of copper coating dedicated and shared visual acceptance criteria has been defined by all the participants of the program in order to have common and objectives criteria on the visual aspect of copper coating. These visual inspection criteria define the magnification of the tooling for control and give details information on what is acceptable and what is not acceptable with pictures as example. This is one of the most important documents of the program.

Figure 2 : Warm External conductor.

Figure 3 : Cold external conductor.

During the overall manufacturing of couplers, parameters are always controlled and samples are used to verify continously the reproductibility of results.

RRR value and thickness measureament on real part of couplers are regularly done to check that the process results are constants as in Fig.4 et Fig.5.

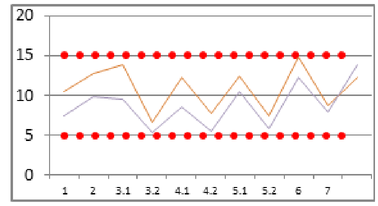

Figure 4: Copper Plating thickness on CEC.

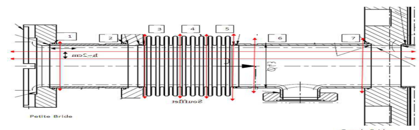

Figure 5: Position of Systematic Thickness Measurement.

RI Research Instrument Process

At RI factory, the ceramics windows are prepared with a TiN coating. The TiN coating thickness specification is of 10 nm nominally.

Once the sub-assemblies from Thales are received at RI factory, the integration of warm and cold part is done by EB welding of CEC, antenna and cold ceramic for the Cold Part and WEC, WIC and ceramic for the Warm Part.

Then Warm Part and Cold part are clean in ISO 6 clean room, dried and assembled by pair on the transition waveguide in an ISO 4 clean room.

The cleaning and assembly procedure is a well-defined procedure which has been defined by LAL[1].

Once the assembly operation is finished, an RGA is done and the spectrum is recorded in order to observe the absence of unwanted material, like hydrocarbons.

Then the coupler pair is double bagged and placed in a special shipping box and send to LAL, see Fig.6.

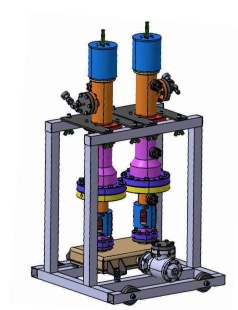

Figure 6: Drawing of coupler pair before shipment.

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LAL Process

Once received at LAL and tightness verified, an in-situ baking cycle is carried on in order to remove residual water vapour [2].

This baking cycle under vacuum is typically of 75 h at 150°C[3].

Treatment of 12 couplers in the same time is allowed thanks to the 3 ovens equipping the clean room.

In order to guaranty a good RF matching and to avoid power reflection, antenna tuning is performed before the coupler pair is installed in the RF test bench for conditioning.

An RF power source of 5 MW peak was installed at LAL by Thales and the automatic conditioning bench has been developed jointly by LAL and THALES.

A system of waveguide splitted in 4 allows performing conditioning on 4 coupler pairs at the same time with a maximum power of 1 MW on each individual test stand.

The automatic procedure consists on the gradual ramp up of RF up to 1 MW and 400 µs follow by a 500 kW for 1.3 ms[4].The sequence is described in Fig.7.

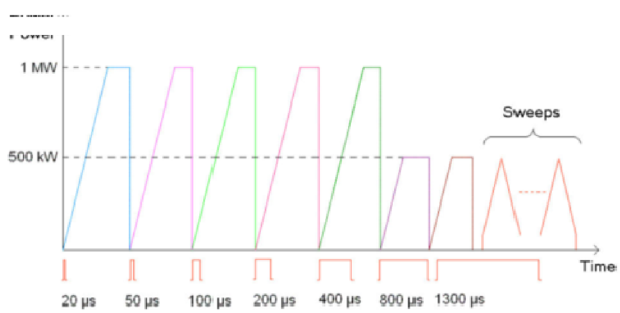

Figure 7: RF conditioning sequences.

During the process, vacuum levels, e^- pick up current in coupler parts are controlled and maintained under predetermined threshold by managing the power output of the RF source.

The global duration of the RF conditioning is nearly 33 h and a 5 coupler pairs per week capability have been demonstrated.

Overview on Coupler Production

After a long ramp up of the program where manufacturing tools and processes have been developed, a capability of 10 couplers manufacturing per week have been demonstrated over months. This capability has been demonstrated by Thales, RI and LAL.

The Figure 8 represents the production chart from sub-assemblies to delivery for cryomodule integration at Saclay.

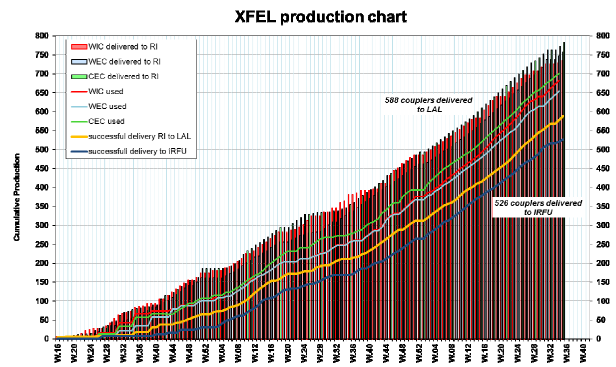

Figure 8: Overall production chart (September 2015).

CONCLUSION

XFEL coupler production of up to 10 conditioned couplers per week has been demonstrated. More than 526 couplers have been delivered at Saclay and mounted on cryomodules.

ACKNOWLEDGMENT

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