

## TEST-STAND FOR CONDITIONING OF FUNDAMENTAL POWER COUPLERS AT DESY

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### Abstract

During the construction of the European-XFEL, activities related to Fundamental Power Couplers (FPCs) were outsourced to external partners and the former FPC test-stand area at DESY was given up due to infrastructure rearrangements. For the study of various European-XFEL upgrade scenarios a new test-stand for conditioning of FPCs at DESY is required. It will be used for evaluation of new coupler preparation methods with particular emphasis on Continuous Wave (CW) and long RF pulse operation. The new test-stand has been recently commissioned. Four FPCs have been prepared and tested. RF pulses were applied to the couplers, starting with the shortest possible pulse and increasing its power until maximum power was reached. The process was repeated with several pulse lengths until the maximum RF pulse length was reached. A review of the commissioning and first operation experience of the RF system are presented here.

### INTRODUCTION

The European-XFEL utilizes a short flat-top pulse (0.65 ms) at 10 Hz repetition rate. In order to explore potential upgrades, such as continuous wave (CW) or long pulse (LP) modes, investigations are being conducted [1, 2]. The possible upgrade of the linear accelerator corresponds to the reduction of the operating

gradient of the 1.3 GHz cavities and increase of the heat loads [3]. These limitations will apply to the European-XFEL Fundamental Power Couplers (FPCs) as well.

FPCs consists of warm, cold and waveguide main parts (see Fig.1). FPC is used to deliver the energy carried by the radio frequency (RF) fields into the cavity, ultimately to the beam. To maintain the desired operating conditions of the cavities, which operate at a temperature of 2 K, it is necessary to isolate the cavity from the environment, particularly atmospheric temperature and pressure. The European-XFEL 1.3 GHz couplers achieve this isolation through two cylindrical RF windows and a vacuum. There are three separate vacuums related to FPCs: the beam vacuum (in the RF cavity), the isolation vacuum (surrounding the coupler in the cryomodule), and the coupler vacuum (between two RF windows).

The ceramic RF windows are coated with a thin titanium nitride (TiN) layer, which suppresses the secondary electron emission. Aside from ceramic windows and the antenna part on the cold side of the coupler (which is made out of oxygen free copper), the remaining components are made of stainless steel and are coated partially with a layer of copper. To overcome concerns about an overheating of the inner conductor bellow during CW and LP mode operations, the design of the new European-XFEL couplers has been updated [4].

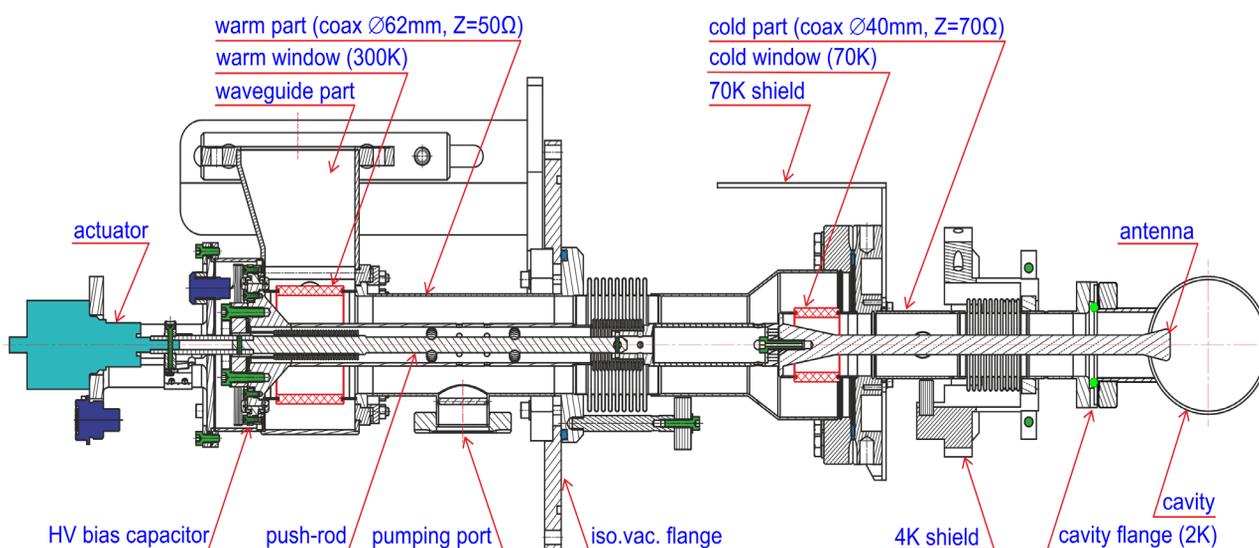


Figure 1: European-XFEL 1.3 GHz FPC.

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The thickness of the copper layer in warm inner conductor has been increased from 30  $\mu\text{m}$  to 150  $\mu\text{m}$  to better redistribute the heat along the coupler. The change in the design of the couplers remain the possibility of the inner conductor movement, so that the external quality factor of the FPC might be adjustable to the different beam requirements. The movement is controlled by the stepper motors.

The operation of European-XFEL couplers above 50 kW requires prior conditioning. A test-stand for the conditioning of the FPCs has been built in order to test their behaviour under high power of the radio frequency fields.

### TEST-STAND

The test-stand is composed of the setup for the conditioning and the preparation area. In the Fig. 2, a part of the test-stand with two couplers connected to the waveguides are presented. The setup for the conditioning consists of the klystron with modulator, waveguide distribution system, LLRF racks, and racks with power meters and technical interlock, as well as the pumps stations. There are two outputs of the waveguide distribution system, allowing for the conditioning of two pairs of couplers. In the preparation area a local clean room and an oven are located. The oven was used during the construction of the European-XFEL at LAL. In the Fig. 3 an RF scheme of the test-stand with two waveguide outputs is presented.

The test-stand is used for the conditioning of the FPCs. The process of the conditioning starts with short pulses and low power, which is stepwise increased and controlled and it is preformed until the maximum RF pulse length of 1300  $\mu\text{s}$  and maximum power are achieved.

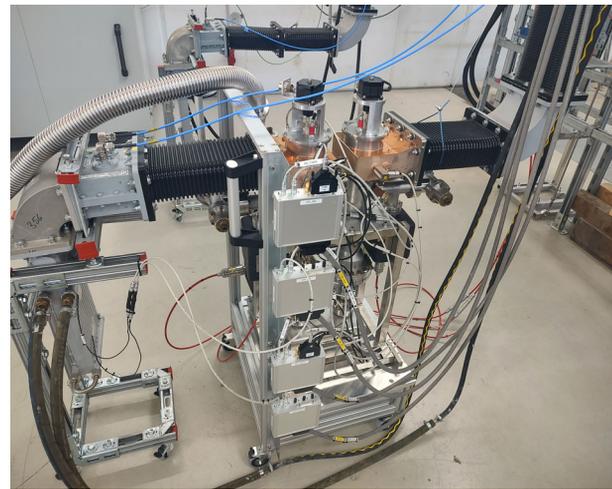


Figure 2: Two FPCs on the dedicated frame ready for the conditioning in the test-stand.

The exact procedure aligns with the one used during the serial-production of the European-XFEL couplers [5]. The maximum RF power for a single coupler during the test is limited by 1 MW of the peak power in the pulse and 2.6 kW of CW-equivalent. The maximum peak power is determined by the FPC, while the CW-equivalent power is constrained by the isolators within the waveguide distribution system.

During the conditioning, the power increase is restricted by predefined thresholds for signals obtained from diagnostic ports (electron pickups and arc detectors), temperature sensors as well as the vacuum pressure in the warm and cold part of the couplers. Moreover the forward and reflected power before and after the coupler pairs are constantly monitored.

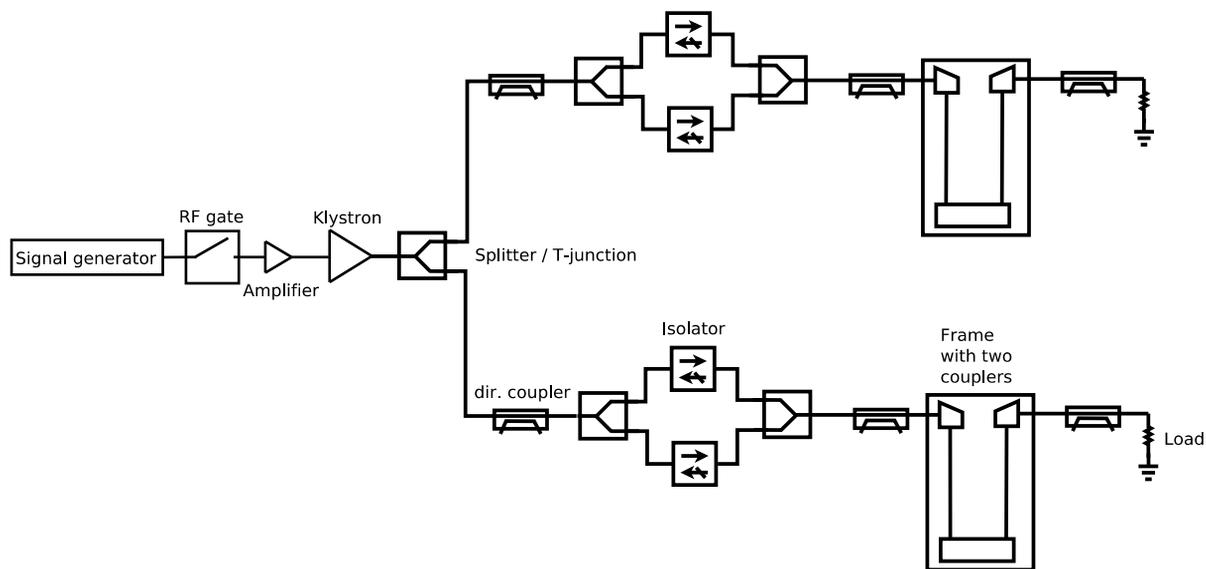


Figure 3: Scheme of the test-stand for the conditioning of 1.3 GHz FPCs.

## PREPARATION

The conditioning process is preceded by meticulous couplers preparation. The initial stages of coupler preparation take place in ISO 4 clean room, where parts of the couplers and the transition cavity are undergo thorough cleaning in an ultrasonic bath, assembled together and their leak tightness is checked. Later on, in the preparation area of the test-stand, the ISO 5 local clean room is used for the connection of the warm parts to the cold parts and also for the connection to the vacuum pump stations. All components are securely assembled on a dedicated frame, and the entire setup undergoes Residual Gas Analysis (RGA).

Next, the oven is employed for the baking process. The FPCs stays in the oven at the temperature of 130 °C for at least 72 hours. Outgassing from the surface of the coupler is pumped throughout the process. After cooling back of the couplers to the room temperature, the vacuum pressure should drop below  $5 \cdot 10^{-9}$  mbar. The waveguide part is then mounted to the warm part of the coupler.

Subsequently, the coupling between the couplers is adjusted, so that the minimum reflection occurs and the resonance in the transition cavity is minimised. At this state, FPCs are connected to the waveguide distribution system and the cabling for the technical interlock is done. Finally, the signals from the technical interlock are verified and the conditioning is performed. After the conditioning, the warm coupler parts are vented with the dry nitrogen, then they are disconnected from the cold parts and are stored in cabinets with dry nitrogen. The cold parts with the transition cavity are kept under the vacuum in order to preserve the conditioned performance. In Fig. 4 a flow diagram of the FPC's preparation and conditioning process is presented.

## COMMISSIONING

The new FPC test-stand at DESY was successfully commissioned. Both arms connecting the test-stand to the RF power source (klystron) were tested separately. Four 1.3 GHz FPCs can be tested simultaneously - for each arm of the waveguide distribution system a pair of couplers. The functionality of the test-stand was evaluated under various failure scenarios, including coupling mismatch, load overheating and any triggered interlock signal. Additional diagnostic ports are also assured in case more diagnostic ports are required.

Figure 5 illustrates the time progression of the power and vacuum pressure for one of the conditioning processes. The dedicated LabVIEW software was adapted to control the value of power and was used to record the levels of signals from the diagnostic ports. The recorded data may be used for the later analysis.

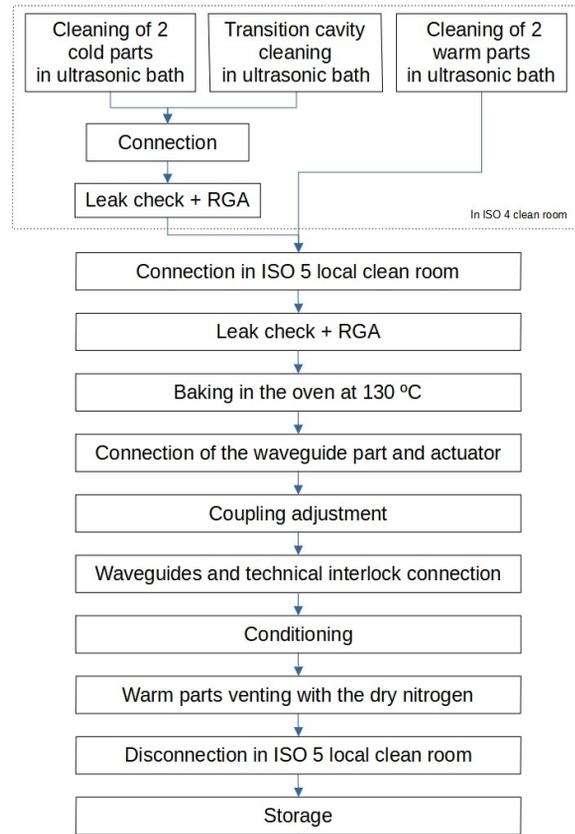


Figure 4: Flow diagram of the FPC's preparation and conditioning process.

## EXPERIENCES DURING THE CONDITIONING

- A typical duration of the processing is: 2 weeks of preparation, 1 week in the oven and 1 week of conditioning.
- The monitoring and recording of RF leakage is an essential aspect of safety during the conditioning process. Plans are underway to incorporate additional RF leakage detectors to enhance this monitoring capability.
- To ensure optimal transmission conditions during the conditioning process, the forward power before and after each coupler pair is continuously monitored. Moreover the temperature on the load at the end of the waveguide distribution system is also under control of the technical interlock. Both of these measurements serve the purpose of identifying the root cause of any issue that arises in the event of an elevation in reflected power.
- To prevent contamination, it is imperative to conduct separate cleanliness checks using RGA for both the warm and cold parts of the couplers. This approach ensures that the source of contamination is accurately identified and addressed. Since a preliminary pump is employed for both couplers, any potential contamination can spread throughout the entire vacuum system.

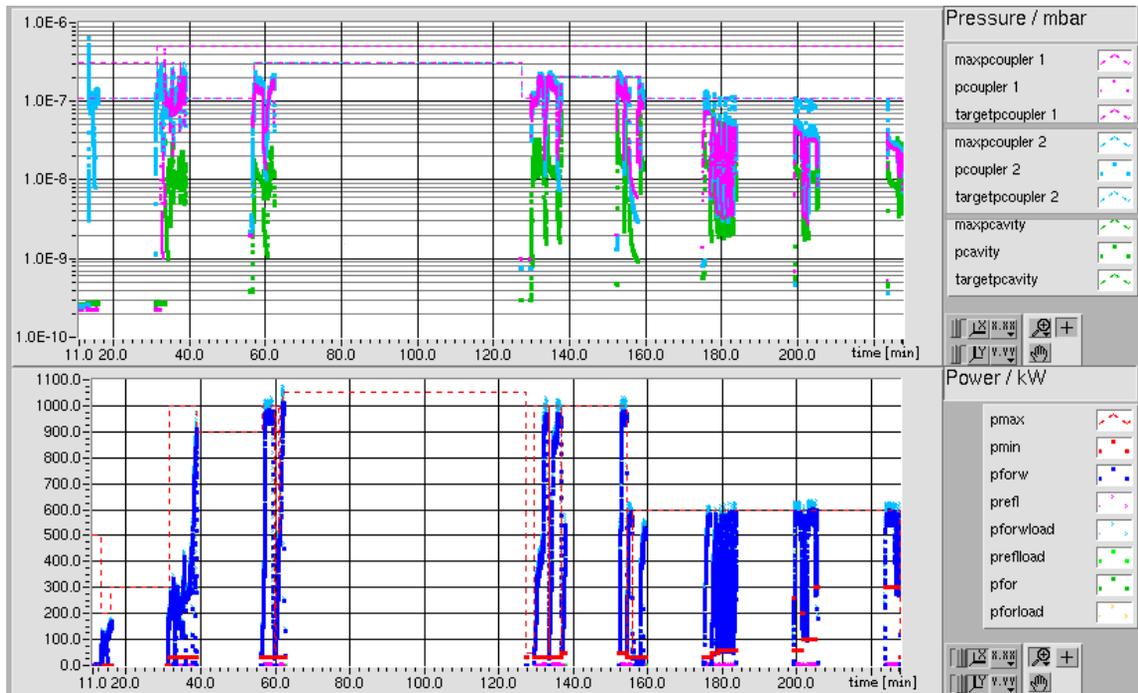


Figure 5: The time course of the power and pressure recorded for one of the conditioning.

## CONCLUSIONS

The test-stand designed for conditioning the 1.3 GHz Fundamental Power Couplers has successfully undergone commissioning. Four distinct couplers were subjected to testing. The entire process has had a favourable influence on the refinement of the coupler preparation techniques. The test-stand is ready for the further conditioning.

## FUTURE PLANS

Similar test-stand is going to be built for the 3.9 GHz couplers. However, the adjustment of the external quality factor in this test-stand will be provided by the 3-stub tuners. The preparation procedure is going to be the same as for the 1.3 GHz FPCs.

## ACKNOWLEDGEMENTS

We would like to thank DESY colleagues who supported us in the preparation of the couplers for the

commissioning, as well as in the construction and the setup of the test-stand.

## REFERENCES

- [1] The European X-Ray Free Electron Laser Technical Design Report, <http://xfel.desy.de>
- [2] K. Kasprzak *et al.*, “Test Results of the European XFEL Serial-production Accelerator Modules”, in *Proc. SRF’17*, Lanzhou, China, Jul. 2017, pp. 312-316. doi:10.18429/JACoW-SRF2017-MOPB106
- [3] R. Brinkmann *et al.*, “Prospects for CW and LP operation of the European XFEL in hard X-ray regime”, *Nucl. Instrum. Methods Phys. Res., Sect. A*, vol. 768, p. 20, 2014. doi:10.1016/j.nima.2014.09.039
- [4] D. Kostin, “Update on FPC Progress at DESY”, TTC2020, 2020.
- [5] W. Kaabi *et al.*, “Power Couplers for XFEL”, in *Proc. IPAC’13*, Shanghai, China, May 2013, paper WEPWO001, pp. 2310-2312.