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EUROPEAN XFEL INPUT COUPLER EXPERIENCES AND CHALLENGES IN A TEST FIELD

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Abstract

101 European XFEL accelerating modules with 808 superconducting cavities and input RF power couplers were assembled and then tested at DESY prior to installation in the European XFEL tunnel. In the Accelerating Module Test Facility (AMTF) warm and cold RF tests were done. The test results went directly to the operational setup for the LINAC. Input couplers did present several problems during the tests, resulting in some minor coupler design changes as well as in a few repair actions. The experience got from the said testing operation is worth to be shared and is presented here together with a discussion.

INTRODUCTION

When we started the European XFEL accelerating modules testing [1, 2] we faced the problem, that some of the modules were not okay for installing and needed a repair [3]. At the beginning we found a lot of not tightened screws. Mostly the warm part inner conductor to the cold part antenna fixing screw was not tightened with the right torque, or even loose (Figure 1). Another problem was once a left over rubber seal on top of a normal copper CF100 gasket which caused a burning of the rubber when high power RF was switched on (see Figure 7). This needed major repairs. During the cold tests on the module test benches in AMTF we faced occasionally some burnt (leaky) bellows of pushrods [4]. So some of them had to be exchanged. Also at module test stands (Figure 3) we discovered some warm parts from the last coupler productions with a lot of activities (discharge) inside or over heating during conditioning. These warm parts also had to be exchanged (Figure 2).

FUNDAMENTAL POWER COUPLERS

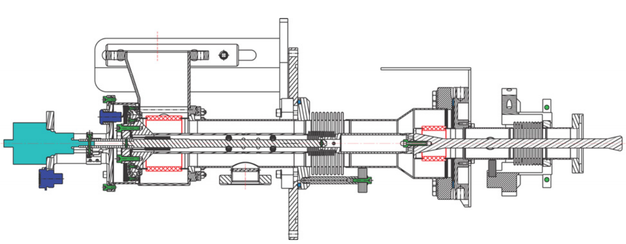

Figure 1: Drawing of XFEL-Input coupler.

Beginning with 3 so called PXFEL (prototype) modules and 3 pre-series modules, which were partly used for assembly training, we assembled at the end 101 XFEL-Modules for the linac and all of them are installed or foreseen to be installed.

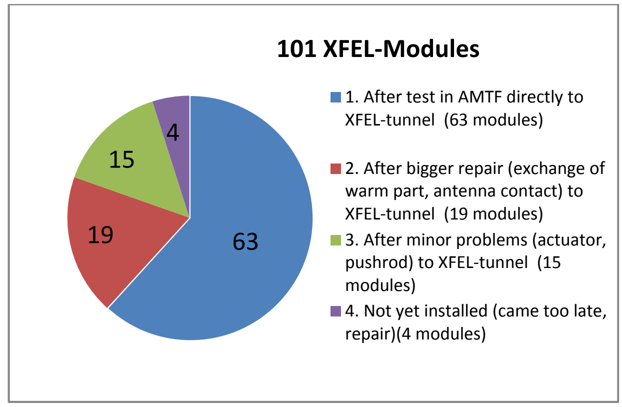

Figure 2: Diagram of module repair and installation.

In the 3 module test stands at DESY we tested all modules under the cold conditions before installation in the European XFEL tunnel (XTL).

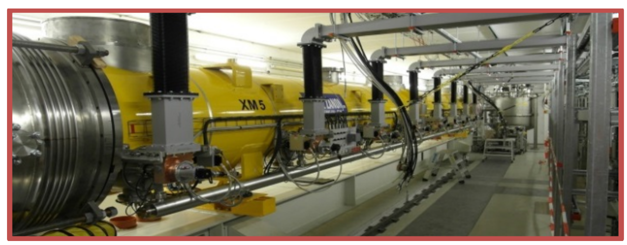

Figure 3: One of three test stands in AMTF.

REPAIR OF RF POWER-COUPLERS

During the module tests in AMTF 13 warm parts (WP) were replaced because of contact problems of inner conductor of warm part to antenna of cold part. The reason of that was, that the screw of inner conductor was loose or not tightened with the right torque. The problem was, that we could recognize it only after switching on high RF power and with a low power everything seemed to be ok. The next problem was, that for repair we had to disconnect all connections (also cryogenics and vacuum) and put the damaged module to extra repair places not to handicap the tests of other modules and to have the required time for repair. All the power couplers with the defect connection of inner conductor showed nearly the same behavior and damage picture.

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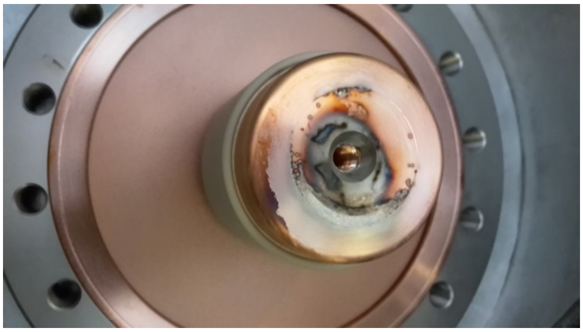

Figure 4: Burnt contact of the cold antenna.

Figure 5: Burnt inner conductor of the warm part.

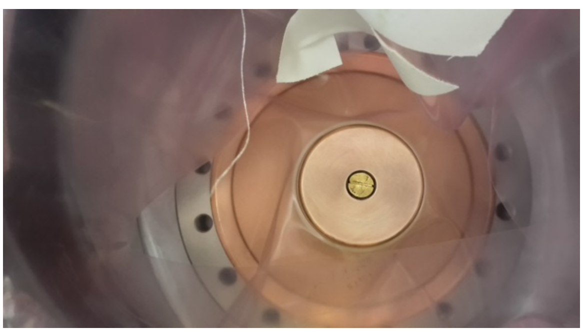

Figure 6: Cold antenna after grinding and cleaning.

Because of RF discharge damaged warm part inner conductors (Figure 5) we had to exchange the warm parts, but the cold parts with damaged interface (Figure 4) could not be exchanged without full module disassembly. (Change of cold part means putting the cavity string into cleanroom again, and before that full module dismounting). The disassembly of warm parts was done in a mobile cleanroom to keep it as clean as possible. We covered the cold part surfaces (Figure 6) as good as possible, closed the threaded hole with special screw (to seal it against dust) and grinded the surface with a very fine sandpaper. All work had to be done with a cleanroom overalls, gloves etc. After grinding we cleaned the surface with citric acid, isopropanol and dry ionized nitrogen flow. After that we did the assembly with a new conditioned warm part. In all of these cases a new conditioning was necessary and was done in most of the cases in one of the three test stands in AMTF.

In one special case a strong RF discharge followed by sudden coupler performance deterioration was observed. We discovered a very big leak in the area of the connection from warm to cold part. After disassembly of warm part we found a damaged CF100 flange knife edge of cold window (Figures 8, 9) and a forgotten rubber seal (Figure 7), which was on top of the normal copper gasket, and in combination of all parts it was leak tight before test and so we were not able to find this problem before switching the RF power on. The only chance to avoid disassembly of the whole module was to try to repair. We did several tests with some special gaskets, with some soft gaskets and at the end with a special gasket, which sealed at the shoulder of the CF100 flange knife and that was successful at the end.

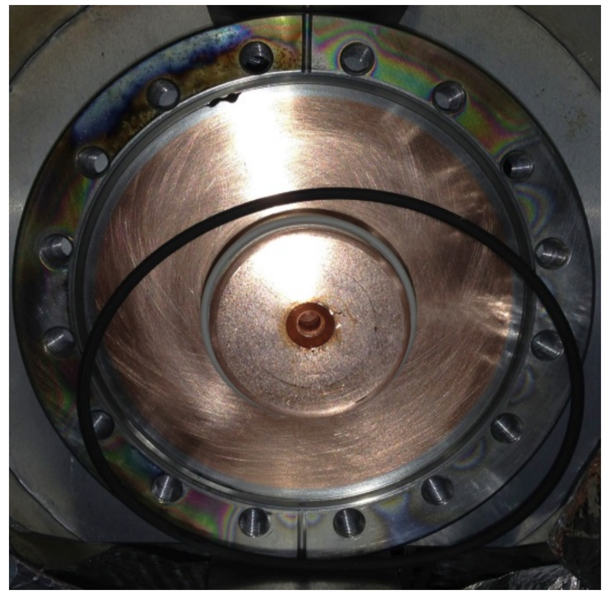

Figure 7: Forgotten O-ring on top of copper gasket.

Figure 8: Damaged CF100 flange knife edge.

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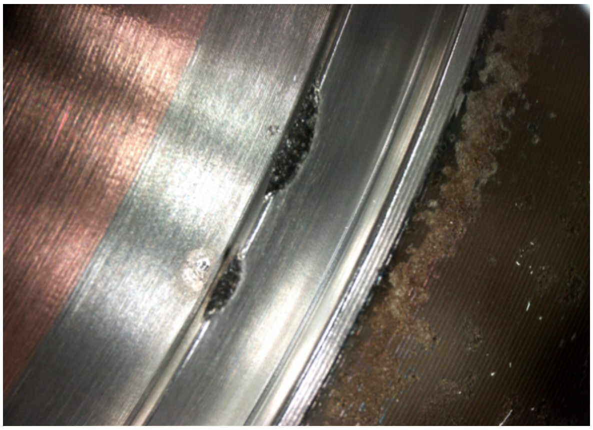

Figure 9: Burnt CF100 flange knife edge.

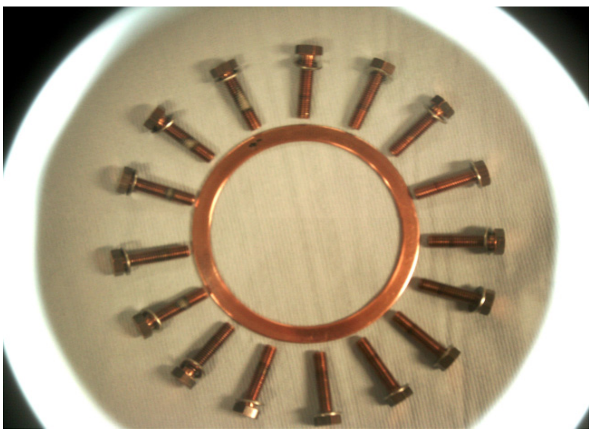

Figure 10: RF discharge stained CF100 flange screws.

In Figure 10 one could see the RF discharge stained CF100 flange screws, used for the connection of cold and warm parts. Also visible damage on the copper gasket and leftover of the rubber seal.

A problem of a different type, caused by not properly tightened HV-bias capacitor screws and thus created RF discharge, did also need some repair action (Figure 11).

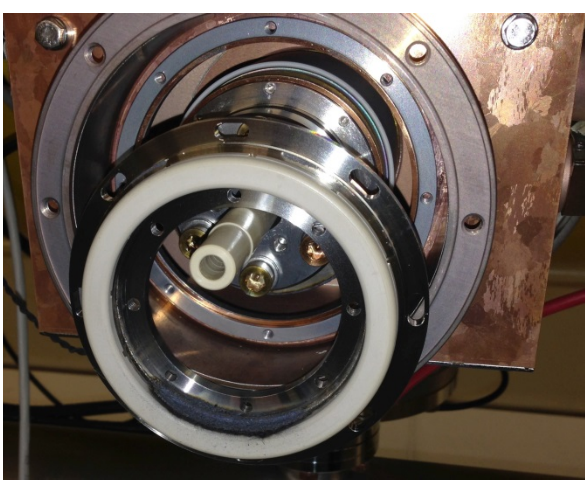

Figure 11: Burnt HV-bias capacitor.

Upon discovery of the increased vacuum RF discharge activity inside one coupler warm window detected by the high spark (light) detector signal a special test with a disabled interlock action on that signal was done. Discharge traces were found after the disassembly on and near the coupler warm window and in the waveguide box (Figures 12, 13). Both parts had to be replaced.

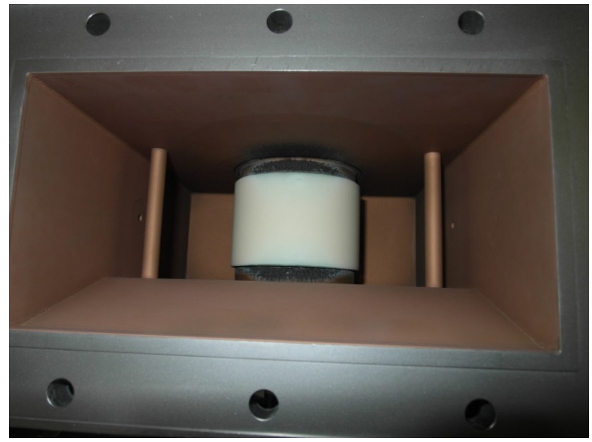

Figure 12: Waveguide-box view on warm window.

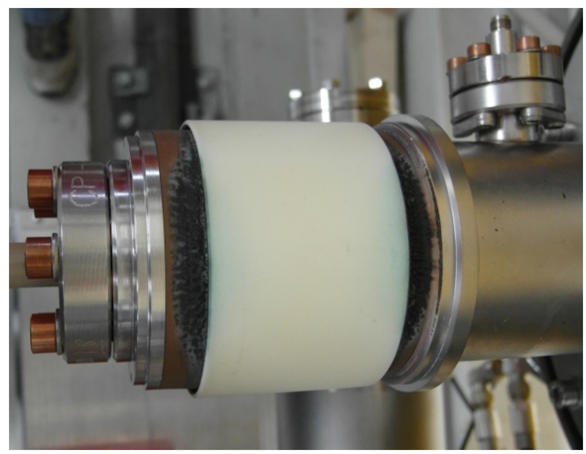

Figure 13: Burnt warm coupler window.

Another challenge was coupler pushrod vacuum leaks problem. It was found, that high power RF damages the bellows of the pushrods from inside. The reason of that is a contact discharge inside the bellow caused by the electromagnetic field penetration through a HV-bias capacitor. The contact inside was possible because of a change in the push-rod design with a longer version of the bellow. To solve this problem we dismounted all capacitors (also in tunnel) and replaced them with a so called coax gasket (a metal short). At the end we had to exchange 30 push-rods till the problem was solved. We also exchanged two waveguide-boxes (one was burnt in test, another one was damaged mechanically on the waveguide flange).

Some warm parts did overheat near the cold 70K window during the operation with high RF power. Not conditionable RF discharge inside some of the warm parts also presented a trouble. We did exchange these parts. We did face also some number of minor troubles, which were easily fixed and are not described here.

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OUTLOOK

Currently it is planned to put all modules into the tunnel. A few modules must be repaired and tested in AMTF before the installation. Some modules have to be completely disassembled and reassembled again. In a longer shut-down of the European XFEL the installation in the tunnel can be done.

SUMMARY

- 504 of 808 European XFEL input couplers did operate properly during the test in AMTF and did not need any repair actions.
- 120 couplers did have only some minor problems.
- Nearly all other couplers having problems could be repaired right after the test in AMTF before installing in European XFEL tunnel.
- An important conclusion is that the clean and careful assembly with a control of all design torque values is very important and can save many repair actions.
- To prevent the input coupler parts damage by an RF discharge careful checks of the parts are necessary.

ACKNOWLEDGMENTS

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