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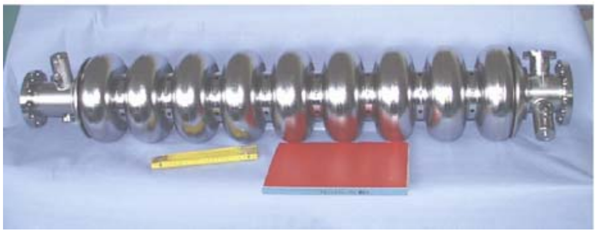

STATUS AND OPERATING EXPERIENCE OF THE TTF COUPLER

D. Kostin, W.–D. Möller, for the TESLA Collaboration, DESY

Abstract

Five accelerating modules are installed in the VUV-FEL [1] linac so far. This includes 40 high power couplers connected to the superconducting cavities, eight in a module. All of them are processed and operated up to the cavity performance limits. The coupler processing procedure is described. The performance in relation to the test results on the coupler test stands and the operating experience are discussed.

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D. Kostin, W.–D. Möller, for the TESLA Collaboration, DESY, D-22607 Hamburg, Notkestr. 85

Abstract

Five accelerating modules are installed in the VUV-FEL [1] linac so far. This includes 40 high power couplers connected to the superconducting cavities, eight in a module. All of them are processed and operated up to the cavity performance limits. The coupler processing procedure is described. The performance in relation to the test results on the coupler test stands and the operating experience are discussed.

INTRODUCTION

In the frame of the TESLA Collaboration [2] RF power couplers for superconducting cavities are developed. Three different types [3], [4] of the couplers are fabricated, tested and installed at the 5 modules in the Tesla Test Facility (TTF). The basic design parameters for the TTF couplers are:

- Frequency: 1.3 GHz
- Pulse length: 500 µs rise time, 800 µs flat top with beam
- Repetition rate: 10 Hz
- Coupling: adjustable, $Q_{ext}= 10^6$-10^7
- Safety: two ceramic windows, protection of the cavity during assembly and against window failures

During the last year the TTF is converted to a Vacuum-Ultra-Violet Free-Electron-Laser (VUV FEL) user facility. The cavities in the 5 modules are processed and operated successfully as described in [5].

Two high gradient tests with electro polished (EP) cavities and TTF3 couplers in the horizontal cryostat (CHECHIA) have been carried out. In these tests the cavity is fully equipped and corresponds to a 1/8th of a module [6].

One of the high gradient EP cavities is installed in the module ACC1 and was tested with beam.

RF COUPLER PROCESSING ON THE TEST STAND AND IN THE HORIZONTAL CRYOSTAT

Prior to the assembly on a cavity all couplers are tested and preconditioned on a test stand at room temperature. On the test stand the couplers are backed at 150 – 200 C and 24 hours. The processing is done with travelling waves. The power is cycled from low to high values, starting with short pulses (20 µs, 2 Hz). After reaching 1 MW the pulse length is doubled and the power rise starts again at low power. This procedure is repeated up to the operating pulse length of 1.3 µs. The rate of the power increase is limited by the different thresholds, set for the coupler vacuum, light and charged particles (e-) in the coupler vacuum. A hardware interlock can switch off the power at high readings of vacuum, light, electrons or ceramic temperature.

The average processing time for such a pair of couplers is 70 to 125 hours (see Fig. 1).

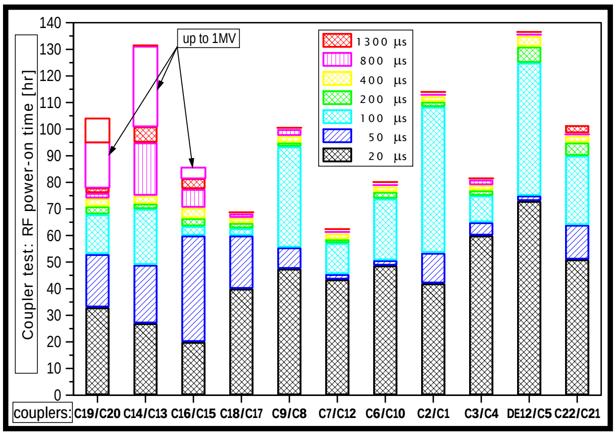

Fig.1: RF Processing times for pairs of couplers on the coupler test stand. The colours distinguish between the different pulse lengths.

After disassembly from the test stand the coupler parts are stored under dry Nitrogen atmosphere.

Due to the limited time schedule, only some of the couplers are tested together with the fully equipped cavities in the horizontal cryostat CHECHIA. Baking of the coupler is done in situ at 150 C and 24 h. The RF processing procedure before cooldown of the cavity is nearly the same that at the test stand.

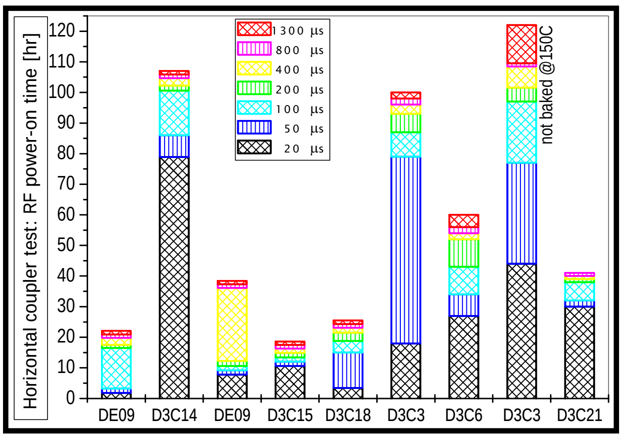

Fig.2: RF processing times for some couplers assembled to the cavities in the horizontal cryostat. The colours distinguish between the different pulse lengths. Without backing the coupler in situ the longest time is needed. Notice the big difference of needed time.

But with the cavity off resonance we have full reflection of power. The cool down is usually started during the RF processing procedure. The needed RF processing times in average is shorter (see Fig. 2). Without coupler baking in situ the longest time was needed. But also with baking the RF processing time for the couplers is very different. We believe this is due to the difference in the cleanliness during handling at assembly from test stand and to the cavity. The procedures for handling and storage have to be improved.

RF COUPLERS IN THE VUV-FEL

In Table 1 is shown were the different coupler types on the modules are installed. Due to a reassembly of the modules ACC 1, 2 and 3, we have a mix of different couplers in these modules. Module ACC 4 is completely equipped with TTF 2 couplers and the module ACC 5 with the latest coupler design TTF 3 (see Fig. 3 & 4).

Table 1: Coupler types in the different modules of the VUV FEL

Coupler type	FNAL	TTF 2	TTF 3
cold window	conical	cylindrical	cylindrical
warm window	flat wave guide	flat wave guide	cylindrical
bias	no	yes	yes
fabricated totally	16	20	62
tested	16	20	24
used in TTF modules	12	19	11
assembled in modules	ACC 1, 2	ACC 2, 3, 4	ACC 1, 5
operated	1997-2004	1998-2004	2001-2004

The assembly of the modules was done long time before the installation in the linac tunnel: ACC in 4 July 2001, ACC 5 in March 2002 and ACC 3 in February 2003.

There are two different module designs for TTF: In the older one the coupler has to follow during cool down and warm up the axial movement of the cavities of 15 mm in the extreme positions. In the newer design (ACC 4 & 5) the cavities are kept in there positions by an Invar rod. The lateral movement of the couplers at different temperatures is here only 1.5 mm.

A common pumping line for every module is connected to the coupler vacuum of 8 couplers which are pumped by one titan sublimation pump.

The 8 couplers of module ACC 3 are connected to a 5 MW klystron while the 16 couplers of modules ACC 4 & 5 are driven by a 10 MW multi beam klystron [4]. The wave guide distribution system consists of a directional coupler, a circulator and a remote controlled wave guide tuner (phase control) for every coupler / cavity.

All couplers are protected by a technical interlock system. It consists out of e- pick ups, light detectors, vacuum readouts and temperature sensors on both windows.

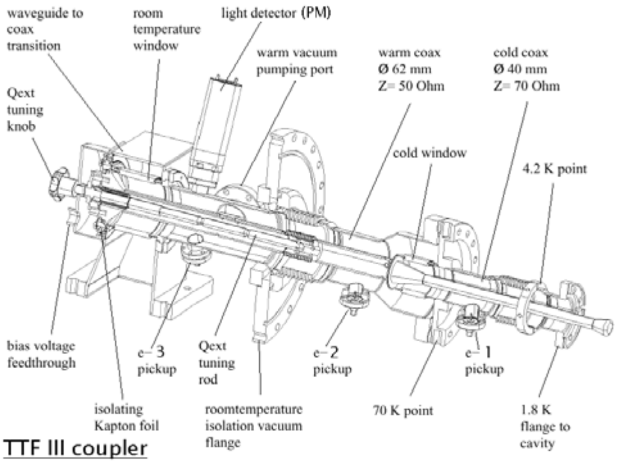

Fig. 3: Latest coupler design TTF 3 with two cylindrical windows

Fig.4: Module ACC 5 equipped with the TTF 3 couplers. Above the couplers the common pumping line for all 8 couplers is seen. Below the couplers the wave guide distribution system with the remote controlled three stub wave guide tuners, directional couplers and circulators is assembled.

RF COUPLER PROCESSING IN THE MODULES

During the period of June to September 2003 the couplers in modules ACC 3, 4 and 5 have been processed.

The RF processing procedure is comparable to the one in the horizontal cryostat. But the big difference is the parallel processing of 8 respectively 16 couplers at a time. The consequence is that always the slowest coupler sets the time needed for the whole module. The couplers are not backed in situ after the assembly to the modules. This leads to a higher starting pressure in the coupler vacuum during processing compared to the previous tests in the horizontal cryostat. In addition the maximum power in the individual coupler was limited to 310 kW for ACC 3 and 350 kW for ACC4&5 by the klystron. In Tab. 2 the processing time for the module ACC 3, 4&5 is shown. Much longer time was needed for the processing up to the full operating pulse length of 1.3 ms compared to the processing on test stand and Chechia.

Two reasons could be responsible for the long processing time: first the parallel processing and second the poor vacuum in the couplers.

For the modules ACC4&5 we always observed the limitation in processing progress by the TTF 2 couplers. The latest design (TTF3) never showed an interlock event during processing on the modules.

Tab.2: The needed RF processing time for modules ACC3, ACC4 & 5. The total power on time is only 67 % respectively 54% of the available time.

ACC 3	
Total time	1858 hr
P_{for} > 2kW (RF on)	1238 hr (67%)
P_{for} > 100kW	745 hr
P_{for} > 200kW	216 hr
ACC4 & 5	
Total time	1858 hr
P_{for} > 2kW (RF on)	997 hr (54%)
P_{for} > 100kW	627
P_{for} > 200kW	193

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For the klystrons 4 and 5 and their modulators together with the low level RF it was the first operating time. The remote control of the klystron modulator interlock for both klystrons was not completed. This caused an only 67% respectively 54% RF on time.

HIGH GRADIENT CAVITY TESTS

After applying the electrolytic polishing (EP) as an alternative surface preparation of 9 cell cavities, gradients >35 MV/m could be shown in the low power continuous wave test. Three of these cavities were equipped with helium tanks, high power couplers (TTF3), HOM coupler antennas and tuners for high power tests in the horizontal cryostat. The results of the cavity measurements are described in [6].

The cavity AC73 and the TTF3 coupler have been operated for more than 1100 hours at a gradient of 35 MV/m. The forward power was just above 600 kW (due to the not compensated Lorentz Force detuning). During setup of the low level RF system breakdowns in the coupler and quenches in the cavity were caused. Neither the cavity nor the coupler was showing any sign of degradation in their performance.

In module ACC 1 the high gradient EP cavity AC 72 was installed equipped with a TTF3 coupler. The coupler was processed at a short time and the cavity was operated with beam successfully.

INDUSTRIALIZATION

The last generation of the TTF3 couplers were ordered and produced completely by industry. Except the TiN coating of the ceramic windows, all fabrication steps have been performed by the companies. In the frame of a collaboration between the Institut National de Physique Nucleaire et de Physique des Particules – IN2P3 France and DESY, Germany the production was conducted. A new coupler preparation and test area including a clean room, ultra pure water system, vacuum oven for coupler baking and a klystron and test stand was installed. Now the first couplers from the industrial production are tested. It is foreseen to develop faster processing procedures and a reduced interlock system for the future use in a big linear accelerator.

Next steps are industrial studies on the coupler fabrication. The goal is to reduce the costs of the mass production of high power couplers.

CONCLUSION

All couplers in the VUV FEL linac could be processed to the power level needed. The parallel processing of 8 respectively 16 couplers at the modules is slower than at the test stands or in the horizontal cryostat.

TTF3 couplers are tested together with cavities at gradients of 35 MV/m (600 kW) without degradation of cavity or coupler.

Next steps in coupler development are industrial studies on the mass production of couplers with the goal of price reduction.

ACKNOWLEDGEMENT

I am thanking all the many colleagues from the TESLA collaboration who made it possible to develop, fabricate prepare assemble test and operate the described couplers.

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