TESLA RF POWER COUPLERS DEVELOPMENT AT DESY.

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Abstract

Different RF power couplers for the TESLA Test Facility (TTF) [1] are under development and operation at DESY. TTF power couplers type II which are mainly used up till now together with "FNAL" couplers [2] recently have been improved by design of coupler TTF III [3]. RF power couplers are tested normally with full RF power, at first two couplers on a test stand and afterwards each coupler together with its superconducting cavity in a horizontal test cryostat. Results of coupler tests showed stable operation at full pulse length of 1.3 ms and RF power even up to about 1 MW without breakdowns. The average power needed for cavity operation at about 25 MV/m is 230 kW. New procedures to improve RF performance and to shorten processing time, like TiN coating of the inner surfaces, are being investigated. Also, the next coupler designs TTF IV and V are being developed.

1 TTF III COUPLER

The TTF III coupler (see Fig.1) consists of the same cold window design as TTF II and is compatible with it. Unlike TTF II it has a cylindrical warm window in the half height waveguide to coax transition. The isolation foil is not in the vacuum in order to avoid outgassing. The waveguide is on air so that the surfaces in the warm vacuum are reduced. On both couplers the warm and cold coax have impedance of 50 Ohm (diameter 62 mm) and 70 Ohm (diameter 40 mm) respectively.

All couplers have detectors for e^- in the warm and cold coaxial line and a light detector on the vacuum side of the room temperature window (see Fig.1). There is also a spark detector and an infrared temperature measurement on the airside of the room temperature window

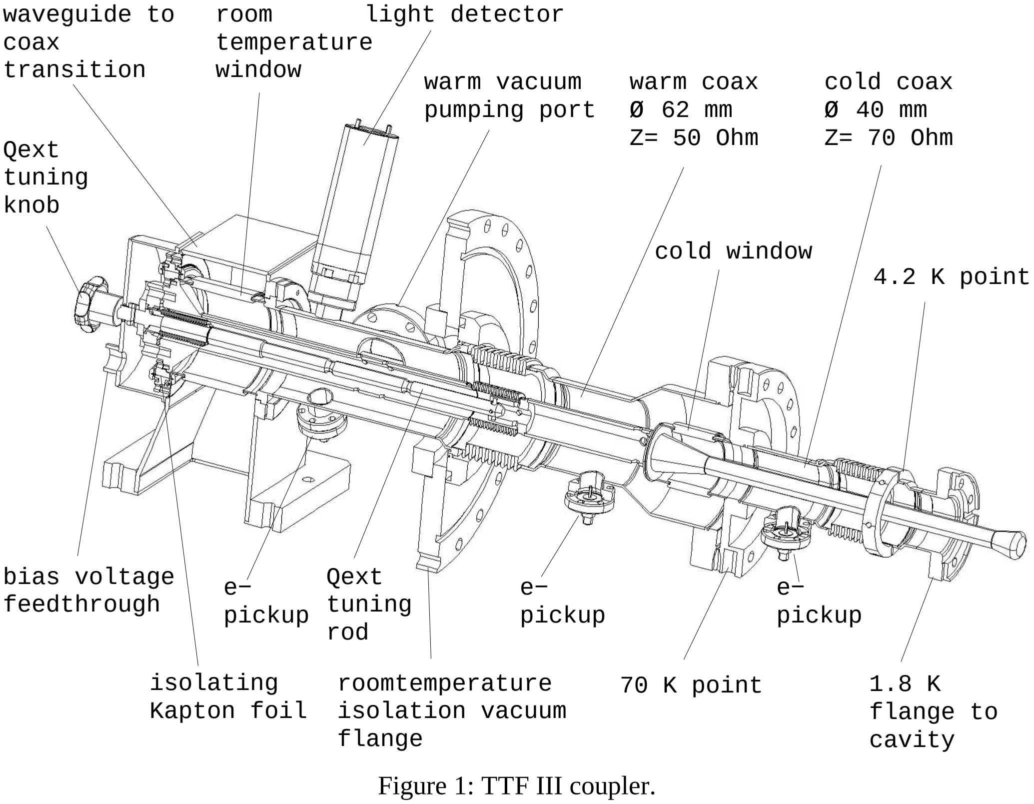

Figure 1: TTF III coupler.

Table 1. Couplers processing procedure on the coupler test stand

	Basic processing							Extra processing	
Pulse length, µs	20	50	100	200	400	800	1300	800	1300
Maximal RF power, kW	1000	1000	1000	1000	1000	500	500	1000	1000

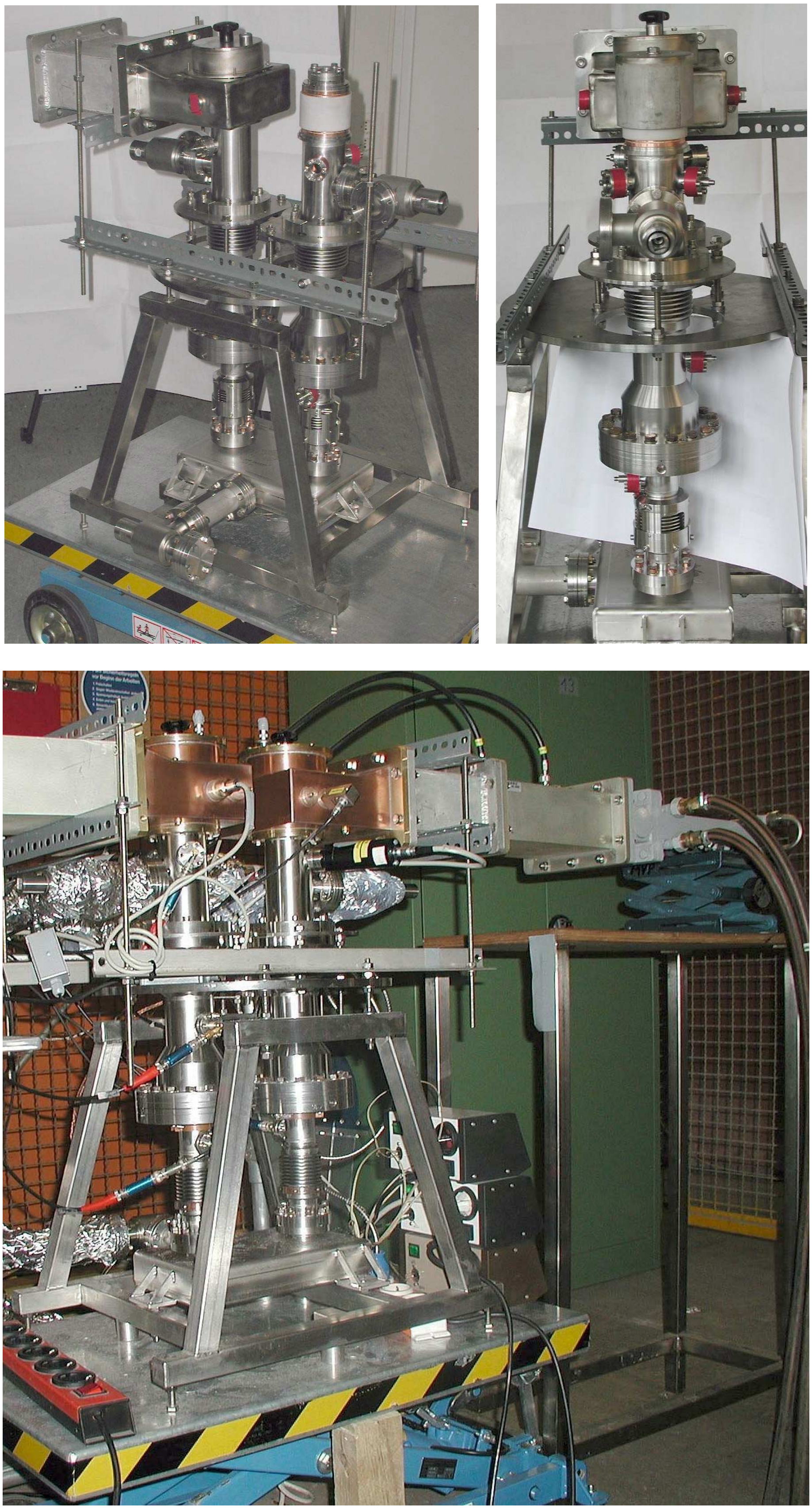

Figure 2: TTF III coupler test stand.

2 TEST PROCEDURE DESCRIPTION

2.1 Coupler parts visual inspection

On this stage the copper plating and ceramics defects or major mechanic problems could be discovered. Then, cold parts are cleaned with ultra-clean water in clean room just before assembly on the test stand.

2.2 High power test

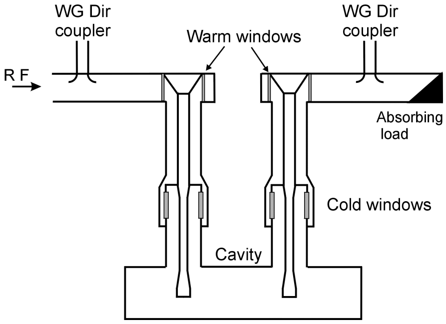

Figure 3: Coupler test stand diagram.

Two couplers are assembled with their antennas to a half height waveguide transition on the coupler test stand (see Fig.2, 3). Transition from TTF II to TTF III design didn't bring any major changes in the test set-up. Test is being done at room temperature. Prior to the test the whole assembly is baked out at 150 C and 24 h for outgassing. After cooling to room temperature the pressure is in the 10^{-10} mbar range. The processing is usually done at travelling wave. The power is cycled from low to high values, starting with short pulses (20 µs, 2 Hz). After reaching the specified power value the pulse length is doubled and the power rise starts again at low power (see Table 1). After the full pulse length of 1.3 ms is reached the power is sweeped between low value and 1 MW. The rate of the power increase is limited by the different thresholds set for the coupler vacuum, the light in the coupler and the charged particle activities measured at the e^- pick-ups. There is also a hardware interlock system, which reacts on high reading from the sensors of vacuum, light, electrons or ceramic temperatures.

At the first power rise there are typically no activities in the coupler up to a power level of 50 - 80 kW. At this power level an initial vacuum activity is observed in most cases. The first power rise at 20 µs takes most longer time (normally about 3 days). After test is done all coupler parts are stored in dry nitrogen to preserve achieved performance.

2.3 Test in horizontal test cryostat

The Coupler is being tested together with the cavity. Processing have two steps, first one, off cavity resonance during cool-down, Standing Wave (SW) regime, and second step, on resonance with the cavity at 2 K.

3 TEST RESULTS

Up to now three successful TTF III coupler tests on the coupler test-stand were done (see Table 2, Fig.4), next coupler test is running. Also one horizontal cryostat cavity test is done with TTF III coupler.

Temperature of the ceramic windows as well as temperature distribution along the coupler outer surface were measured (see Fig.5 and Table 3).

Power sweeping after processing showed the following power levels where multipacting is present: 150 and 250kW in the warm coupler part, 150 and 450kW in the cold coupler part. Those levels produce just measurable but not dangerous sensor signal levels. Applying the high voltage (HV) between inner and outer coax parts of negative value down to –3.5kV caused lots of activity and general deterioration of coupler performance, while positive values of HV up to +3.5kV made almost no difference compared to no HV at all, just shifting of the multipacting levels as it must be. So, as a conclusion, we don't need HV to operate the coupler.

Table 2. Test results.

Test	Maximum P_{for} [kW] reached at 1.3 µs pulse, 2 Hz rep.rate.	Total processing time [hr]
1.C19/C20	1000	104
2.C14/C13	1000	132
3.C18/C17	500	79

Table 3. Ceramic windows temperature measurements.

Test	P_{for} [kW]	Test stand sensors				Outside measurement			
		T_{IR} 300K [K]		T 70K [K]		T 300K [K]		T 70K [K]	
		input	output	input	output	input	output	input	output
1.C19/C20	500	312	319	301	300	304	307	305	303
1.C19/C20	1000	325	342	303	302				
2.C14/C13	1000	345	334	305	310	324	316	310	313
3.C18/C17	500	317	331	312	306	308	311	305	307

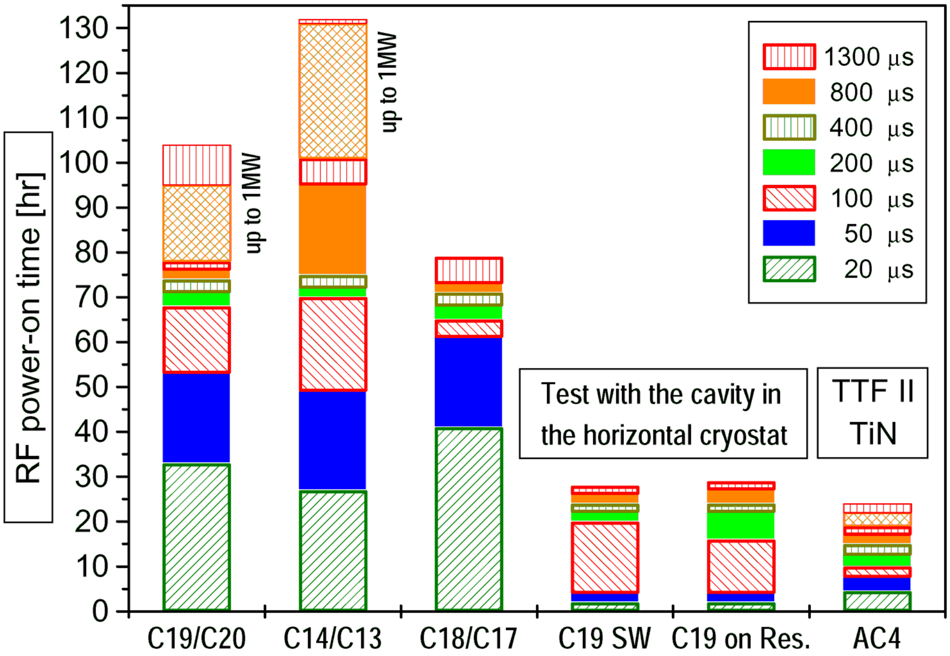

Figure 4: Coupler processing time chart.

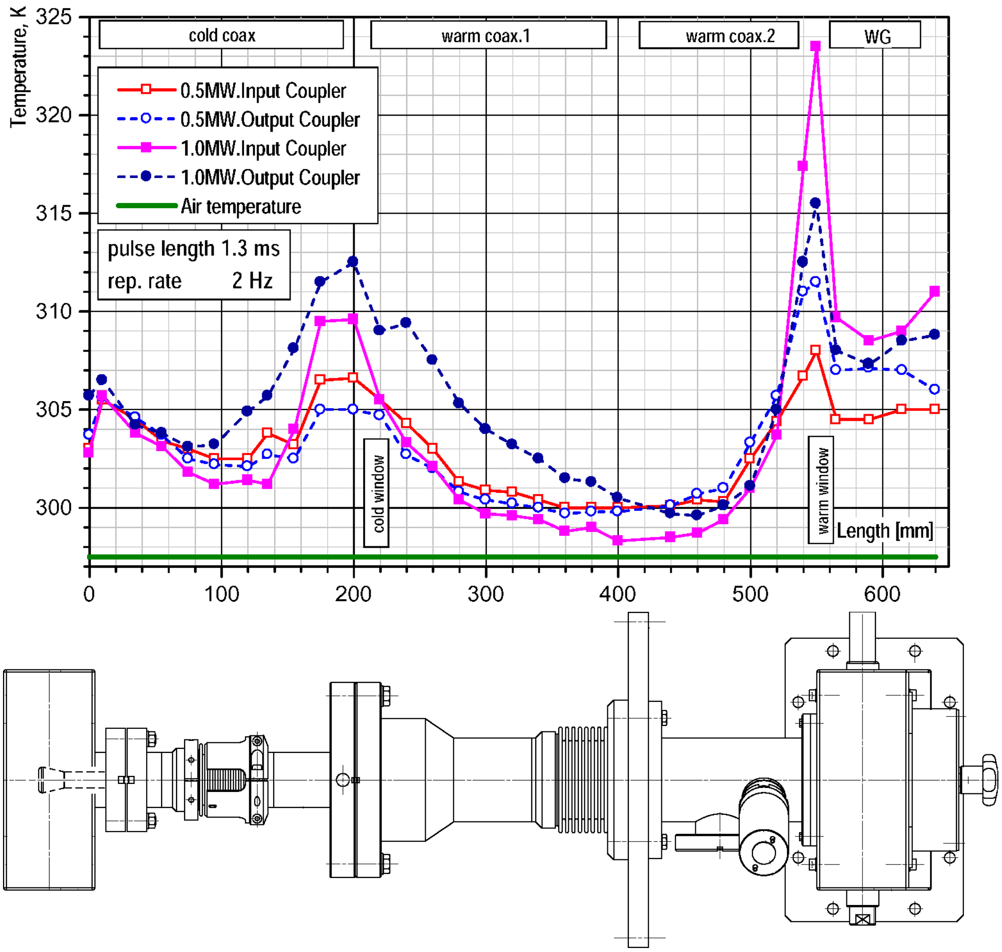

Figure 5: Temperature distribution along the TTF III coupler.

4 PROBLEMS DURING TESTS

- Cold part flange vacuum leaks.

Heating the test stand up to 200 C within standard procedure caused a problem with vacuum seal in the cold part flange connecting coupler with WG box. From now on test stand is being heated up to 150 C and that eliminates vacuum leak problem.

- RF leakage.

a) HV port short-circuit. Increasing of the filter inductance (coil diameter and number of loops were increased) helped to get rid of the problem.

b) WG part. During the welding of the WG coupler part made of a stainless steel it became not flat. The leak between the cap closing the tuning mechanism and WG part was eliminated by ensuring better mechanical connection between them and using the RF seal. Connection between warm coax part and WG also had a leak. It also caused warm ceramic window heat-up during Chechia test, mostly caused by repetitive sparks at that place. Aluminium seal was provided to solve this leakage problem. Also, new WG coupler part design will help to eliminate this problem.

- Ceramic heat-up.

During high power RF tests warm window was heated up to 345 K. Possible cooling methods, like dry nitrogen or air blowing were investigated.

- Q_{ext} tuning range was too small in the first Chechia test with TTF III coupler.

After mounting of the coupler together with a cavity in a horizontal test cryostat $0.6\times10^6 \le Q_{ext} \le 1.6\times10^6$ while 3×10^6 value is needed, it was found out that tuning range was too small and coupler antenna position could be moved within 7 mm of range, previous tests with TTF II coupler had 15 mm of tuning range. As a remedy a thread on the plastic tuning rod was elongated.

5 LAST IMPLEMENTATIONS

New WG coupler part is designed and manufactured. Implementation of this design will solve mounting as well as RF leakage and ceramic cooling problems. This part is now made of copper, ensures better mechanical connection between it and a coax one. Also cooling gas (nitrogen or air) pumping ports are made.

6 TEST OF THE COUPLER WITH TiN COATED INNER SURFACES

The total inner surfaces of the cold as well as warm parts of one TTF II coupler were coated by TiN [4]. The coating was achieved by Ti deposition from vapour phase in ammonia atmosphere (10^{-3} mbar) and keeping in ammonia at 500 mbar at a room temperature for Ti → TiN conversion.

Test was done under the same conditions as before and showed considerable shorter processing time (see Fig.4), as well as good coupler performance. The first power rise at 20μs pulse up to 1MW took only 4.5hr. To reach 500 kW at 1.3 ms pulse it took about 19 hr with additional 5 hr to reach 1 MW. Power rise was limited by coupler vacuum up to 400 kW at 20 μs. Processing up to higher power levels was successful up to 2 MW at 400 μs, but reaching this power level at longer pulses produced an event in a cold coupler part and damaged it. After disassembling metal deposition on the cold ceramic rim as well as burn marks on the antenna were found.

So, TiN coating of the coupler inner surface helps to achieve better results up to 1 MW of input power at 1.3 ms pulse. Power level about 2 MW can not be reached without serious damage to the coupler.

7 TTF IV AND TTF V COUPLERS

Next coupler designs are being developed. TTF IV is designed for 4×7cells superstructure and TTF V – for 2×9cells superstructure. Main difference is a cold part diameter (see Table 4) [5], [6].

Mechanical design of TTF IV coupler is finished, RF calculation of TTF V is being done.

Table 4. TTF IV and TTF V couplers design parameters.

type	TTF IV	TTF V
max P_{for} [kW] at 1.3 ms FT pulse	800	450
rep. Rate [Hz]	5	5
Q_{ext}	2.5×10^6	2.5×10^6
cold coax diameter [mm]	80	60

8 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 different high power couplers.

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