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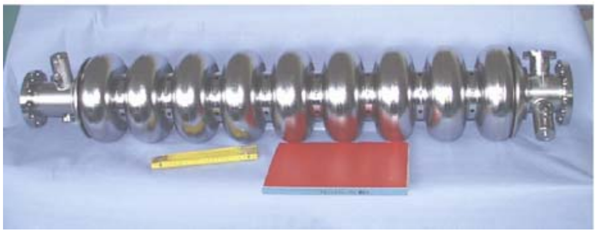

PREPARATION AND CONDITIONING OF THE TTF VUV-FEL POWER COUPLERS

H. Jenhani, Laboratoire de l'Accélérateur Linéaire, Université de Paris-Sud, CNRS-IN2P3, B.P. 34, 91898 Orsay, France.

Abstract

Recent advances in accelerator technology have permitted the manufacture of superconducting (SC) cavities with high gradients (> 30 MV/m). One ambitious aim now consists in making them operational in accelerator facilities (correctly matched to the RF source, preserve the cavity vacuum, cavity cleanliness and operating temperature conditions). The input power couplers have a crucial role in achieving all of these functions. Therefore, the input power couplers for these cavities are carefully designed and then prepared under very strict conditions.

RF conditioning of input power couplers at room temperature is an important step in their preparation before mounting them on cavities. It allows one to test the robustness of the coupler, condition away residual absorbed gases and "burn-off" microscopic surface imperfections.

The conditioning of the TTF-III couplers (for the TTF VUV-FEL accelerator at DESY) is an ideal occasion to learn about their properties and behaviour and to asses their suitability for the ILC, which will use cold RF technology. We will present the status of processing the TTF-III couplers at LAL-Orsay, an activity performed in close collaboration with DESY-Hamburg.

Contribution to the SRF 2005, Ithaca, New York, USA

Work supported by the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395).

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Recent advances in accelerator technology have permitted the manufacture of superconducting (SC) cavities with high gradients (> 30 MV/m). One ambitious aim now consists in making them operational in accelerator facilities (correctly matched to the RF source, preserve the cavity vacuum, cavity cleanliness and operating temperature conditions). The input power couplers have a crucial role in achieving all of these functions. Therefore, the input power couplers for these cavities are carefully designed and then prepared under very strict conditions.

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INTRODUCTION

The current TTF-III coupler design has been adopted for the superconducting accelerator XFEL since 2003. In the framework of a DESY/LAL collaboration, 40 TTF-III couplers will be room temperature processed at Orsay.

Couplers received from industry have to be meticulously checked, then cleaned, baked and assembled in class 10 clean room conditions. After pumping them down, their conditioning can start. Processed couplers are stored and sent to DESY to be tested on a cavity in a horizontal cryostat.

Analysis of the couplers behaviour may lead to an optimisation of the RF power conditioning procedure which would be of capital importance for reducing the time necessary to process the ~ 1,000 X-FEL couplers.

COUPLER PREPARATION AND CONDITIONING PROCEDURE

The TTF-III coupler

The TTF-III coupler was designed to be assembled on a 9-cell SC TESLA cavity and to perform to the X-FEL machine specification:

- Frequency: 1.3 GHz
- Pulse width: 500µs rise time plus 800µs flat top with beam
- Repetition rate: 10Hz
- Peak power: 150kW
- Coupling: $Q_{ext} = 1x10^6 – 1x10^7$.

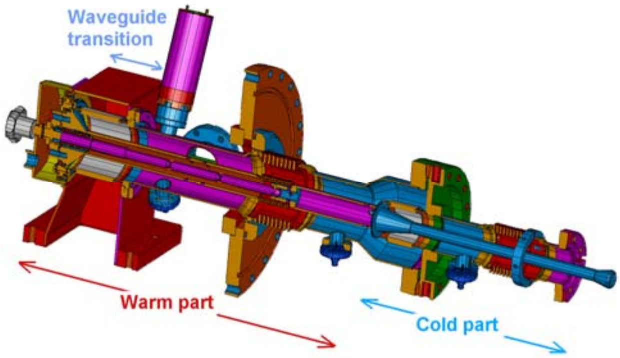

Figure 1: The TTF-III coupler

It has essentially three parts (Fig. 1): A "cold" part, a "warm" part and a wave guide transition. The cold part shares the same vacuum with the cavity and will be entirely inserted into the cryomodule. The warm part has its own separate vacuum. The transition is under atmospheric pressure. Cylindrical ceramic windows on each of the first two parts ensures the vacuum barrier of their respective volumes. The coupler has also an antenna tuning system and offers the possibility to DC bias the inner conductor.

Coupler preparation:

Careful verification of the state of all external and internal coupler parts (using an endoscope coupled to a CCD camera [1]), are made and any anomalies are recorded in our coupler database. The couplers are then transferred to the clean room where they are cleaned, baked, assembled and leak tested as following:

In the class 1000 clean room

- All coupler parts are cleaned in an ultrasonic bath at 50ºC using Tickopur R33 detergent.
- Parts are rinsed with ultra pure water until the resistivity of the draining water exceeds 14 MΩ.cm.

In the class 10 clean room

- All rinsed elements are left to dry.
- Cleaned parts blown with filtered ionized nitrogen gas at a pressure of 4mbar (cold parts and transition only) using a particle counter which must count less than 10 particles of size > 0.3

*We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395).

microns per cubic foot. If not, the parts must return to the ultrasonic bath.

- All parts vacuum baked to 150ºC for 35 to 40 hours.
- Leak test using helium gas ($1x10^{-10}$ mbar.l/s).

Conditioning procedure

The TTF-III coupler RF conditioning is based on a DESY procedure [2]. The couplers are conditioned in pairs assembled together to a wave-guide transition via their cold parts. The conditioning begins with a 20µs RF pulse width. The power is increased incrementally from 1kW to 1MW. At this value, the power is kept constant for 1 hour. After, the power is decreased to the minimum value and the same operation is repeated successively with 50µs, 100µs, 200µs, 400µs, 800µs and 1300µs, the maximum power being 500kW for the two last pulse widths (Fig. 2).

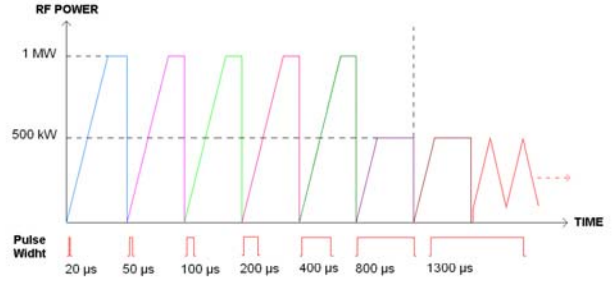

Figure 2 : The conditioning procedure.

Afterwards, we sweep the power up and down from 50kW to 500kW several times, using always 1300µs pulse widths as a preliminary test of the effectiveness of the conditioning.

The power monitoring is based only on vacuum levels (Fig. 3). The power is decreased by one increment when the first preliminary vacuum threshold is exceeded and by four increments when the second one is reached. Vacuum interlocks cut the power at 10^{-6} mbar. The conditioning safety is also guarantied by electron current and photo-multipliers interlocks activated at the levels of 5mA and 1Lux respectively.

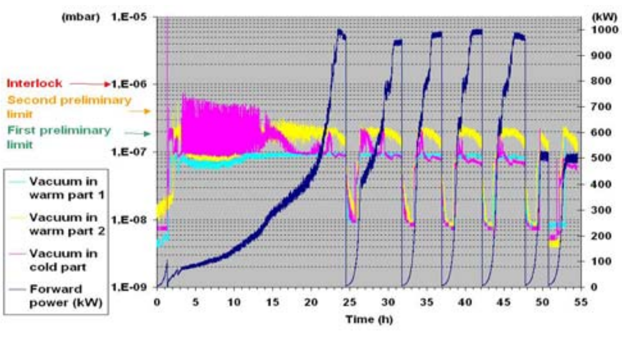

Figure 3: Forward power monitoring based on vacuum levels.

In the following parts of the paper we will not consider the sweeping period nor the constant power level period.

CONDITIONING RESULTS

General observations

As we see from figure 3, the 20µs pulse width conditioning step is the most time consuming one. The vacuum levels are very unstable, especially for the lowest powers. The vacuum is more stable in the later stage of conditioning. One can also see a noticeable reduction of the e- current during conditioning (Fig. 4).

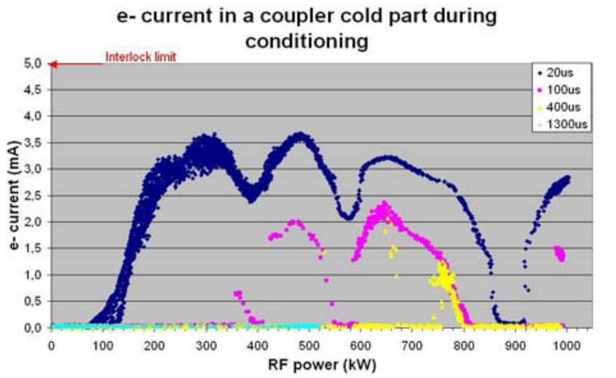

Figure 4: Example of e- current improvement during the RF conditioning procedure.

Vacuum and e- current events during conditioning can start at low powers levels (<100kW) during the first conditioning step at 20µs. These events start at higher power levels during the following conditioning steps. Some arbitrary criteria were chosen to help us to assess coupler behaviour changes during conditioning (Fig. 5). These criteria were: The first increase of the vacuum (although the pressure can stay very low), the first attainment of the first preliminary vacuum limit and the first surpassing of an arbitrary chosen e- current value (0.8mA).

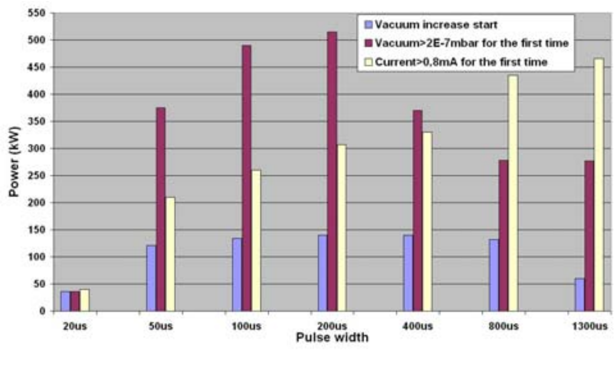

Figure 5: Lowest power levels corresponding to the first attainment of some arbitrary event levels (study done on 6 coupler pairs).

The aim of this study is to find optimal power levels below which the speed of the conditioning procedure can be increased safely in order to save time. Figure 5 shows that one can adapt the conditioning procedure for each step, but we need more statistics to optimise the choice of power levels.

In-situ baking effect

The conditioning time can considerably change from one coupler to the other. However, we find that a 150ºC in-situ baking during 5 days can drastically decrease the RF processing time which is between 45 and 50 hours for our best performance (Fig. 6).

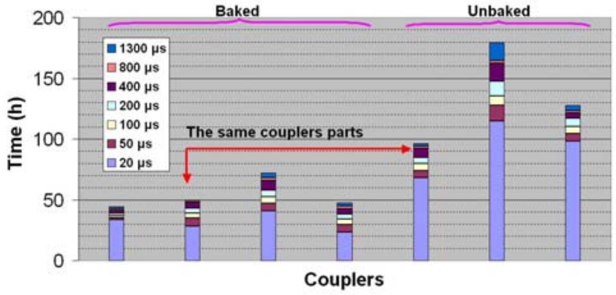

Figure 6: Conditioning time summary of seven in-situ and non in-situ baked coupler pairs.

To be sure that the differences between processing times from one conditioning to an other is not only due to some dissimilarities between pairs of couplers we have done the following experiment. We conditioned an in-situ baked coupler pair for the first time. The conditioning time was about 50 hours. This conditioning is supposed to have reduced some of the surface imperfections. After this test, these couplers were disassembled and cleaned again in the clean room. At this stage we lost the in-situ baking effect on couplers. These couplers were then re-assembled and conditioned again without in-situ baking. The conditioning time was about 96 hours.

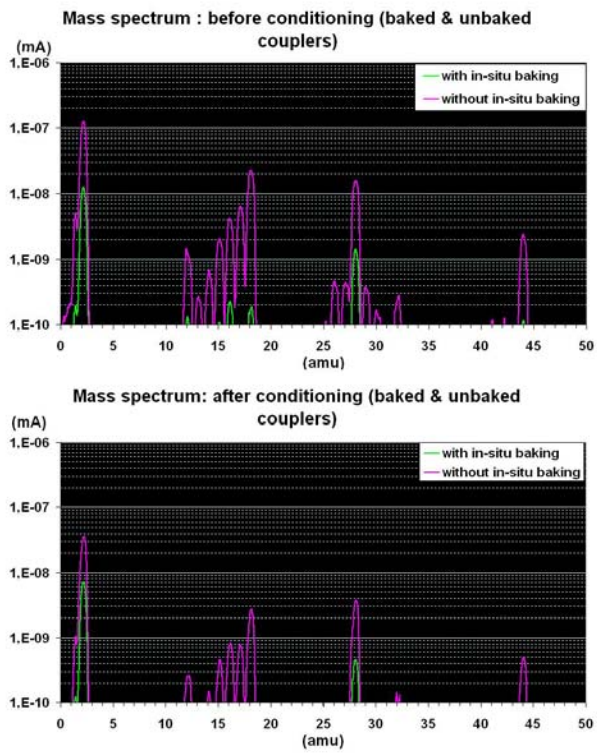

Figure 7: Residual gas analyser plots.

One can also see a huge difference between the average conditioning time of the in-situ baked couplers (4 pairs) which is about 54 hours and the non in-situ baked ones (3 pairs) which is about 135 hours. The saving in time is clearly evident during the 20µs pulse width conditioning step. At an advanced stage of conditioning the in-situ baked couplers do not always exhibit the best behaviour.

Due to the close relation between the conditioning time and the vacuum variation during processing we were interested in comparing mass spectra acquisitions done on in-situ baked and non in-situ baked couplers before and after conditioning.

The initial vacuum noticed on in-situ baked couplers is not only better than the initial vacuum of the non in-situ baked ones but also better after conditioning (Fig. 7). It seems that long conditioning does not have the same effect as baking.

The effect of in-situ baking on removing water vapour and improving vacuum is clearly seen. This leads probably to an improved coupler surface state.

CONCLUSION

The best conditioning times performances for TTF-III couplers at LAL were from 45 h to 50 h. However, the conditioning procedure itself requires 16.5 hours. A good optimization of this procedure may allow faster conditioning. Some proposals for relaxing the preliminary vacuum limits and ramping the power rise faster during the safe power regions (figure 5) could be investigated.

We have also demonstrated the 150ºC in-situ baking effect on the conditioning time which saves almost half of the time and provides better vacuum levels in the couplers.

ACKNOWLEDGMENTS

I would like to thank all my colleagues from the coupler group at LAL and MHF-SL from DESY.

I want also to express my gratitude to the secretary and computer support of the Accelerator Service of LAL.

A special thank to T. Garvey from LAL and D. Kostin from DESY.

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