

STUDIES ON INPUT COUPLERS FOR SUPERCONDUCTING CAVITIES *

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Abstract

We have recently demonstrated a dramatic reduction in conditioning time for TTF-III couplers [1]. This was carried out by a systematic study of the different parameters that play a role in the conditioning process. In addition, many investigations have been made in order to have a better understanding of the couplers' behaviour. These activities represent some aspects of a larger technology program that we are developing to study power couplers and their multipacting. This paper will give an overview of some of these studies, our future experiments on couplers and the development of the associated technology program.

INTRODUCTION

An ambitious R&D program on power couplers for superconducting cavities has been established at LAL. The LAL-DESY collaboration, which aims to study the behaviour of the TTF-III prototype couplers for the European XFEL and the reduction of their conditioning time, was at the origin of these activities. In this context, successful results, with a dramatic reduction in conditioning time, were achieved and good experience was acquired concerning the behaviour of these couplers under RF power [1]. However, much R&D effort has still to be made in order to face many other challenges. The TTF-III couplers have a very complex geometry and are composed of many sub-parts. To understand the influence of some of these parts on the coupler behaviour, multipacting (MP) simulations are being performed. This allows some correlation between the simulation results and the measured signals during the coupler power tests. Furthermore, many difficult industrial processes are needed for coupler manufacturing. Thin layer deposition of Titanium-Nitrogen (TiN) on ceramic windows is one of the processes which needs to be mastered and optimized. The TiN sputtering deposition processes is currently studied at LAL using a reactive DC magnetron sputtering bench [2]. This device will also strongly contribute to experimental MP studies. Technological solutions have also to be found for the power couplers that would be needed for the ILC in order to increase their operating RF power, while decreasing their cost. We have designed, built and tested two coupler prototypes, TTF-V and TW60, for this purpose.

A short overview on our coupler activities, including realisation of our proto-types and their test results will be presented in this paper.

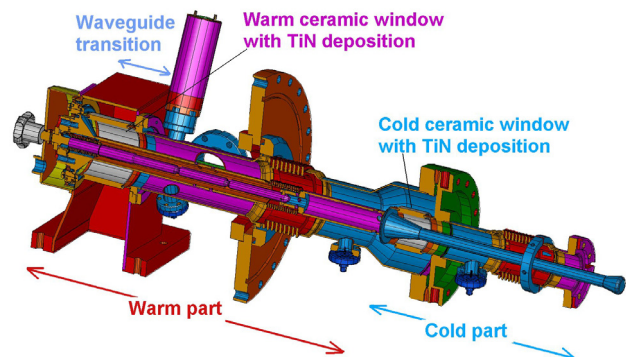


Figure 1: TTF-III power coupler (DESY design).

MULTIPACTING CALCULATION

Much effort is needed in order to understand the coupler behaviour during processing. Therefore, we have tried to find a correlation between e^- currents measured during standard TTF-III coupler conditioning and the calculation results using the 2D MP simulation program for axi-symmetric geometries named MultiPac 2.1 [3].

During TTF-III coupler conditioning, we observe that the power levels corresponding to e^- current enhancement in the cold parts are generally the same for most of the couplers. However, these similarities were not noticeable for the warm coupler parts. This may be due to the higher geometrical complexity of this part (figure 1). To perform MP simulations, we initially considered a model for the cold part that was composed of the RF window geometry and a simple coaxial line geometry. The effect of the bellows on MP levels was neglected in this approach. Consequently, simulation shows that, for a pure RF travelling wave, there is no MP on the cold ceramic window. Nevertheless, the presence of many MP levels in the coaxial line geometry was confirmed. Some incoherence between the calculated MP levels and the measured e^- currents during conditioning was noticed. In fact, we usually measure a relatively high e^- current in the cold part for a forward RF power of about 700 kW. Our simulations show complete absence of a MP threshold in this power range. In order, to see if the bellows are at the origin of this MP we integrated them into the model and made new calculations. The new results show a good correlation between the calculated MP levels and the measured e^- currents from several conditioning tests (figure 2). As a consequence, the bellows appear to be the origin of the MP power level taking place at 700 kW. Nevertheless, electron trajectory calculations show that this MP level is not built up within the bellow undulations but rather in their neighbourhood.

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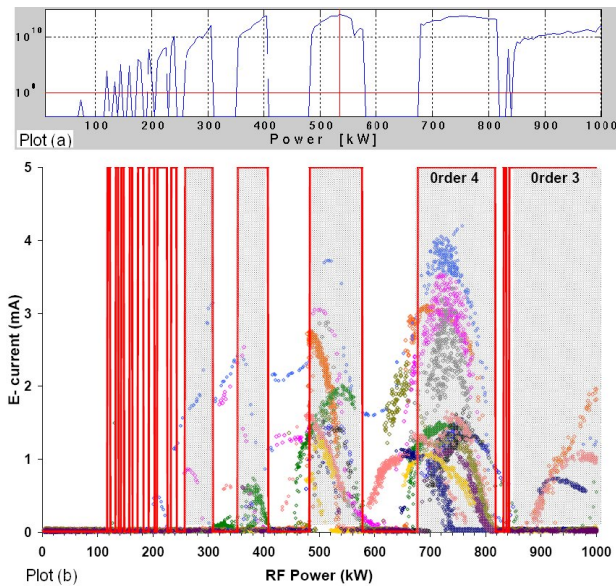


Figure 2: Comparison between MP simulation and e⁻ current measurements in the TTF-III coupler cold part. Plot (a) shows the MP thresholds given by simulation. In plot (b) the differently coloured dots represent e⁻ current acquisitions coming from different coupler tests and conditioning steps. The rectangular grey zones correspond to the MP power levels given by simulation.

TIN SPUTTERING ACTIVITIES

A thin layer of TiN coating on coupler ceramic windows is the most common technique used to prevent MP on these components. Made from Alumina (Al₂O₃), they have a relatively high secondary emission coefficient (SEC) which favours the appearance of MP and can cause irreparable damage to the coupler. A suitably thick TiN deposition on these components reduces the SEC sufficiently without causing RF mismatch due to the ceramic surface metallization. A coating thickness of around 10 nm has been found to be a good compromise.

In the framework of our R&D program on power couplers, a new activity, aimed at mastering the TiN deposition technique, has been established in order to optimize the surface properties of TiN coated ceramic windows and to study their response and evolution under MP. This is possible by producing well characterised, coated samples for processing studies using a MP resonator.

Reactive magnetron sputtering technology was chosen for the TiN deposition. A coating bench was developed and delivered to LAL at the end of 2007. The machine configuration allows a uniform deposition of TiN on both sides of disk or cylindrical ceramic window shapes. Surface cleaning of the sample inside of the sputtering machine is also feasible using an RF etching system [2]. The deposition of Ti is achieved by activation of the magnetron creating an argon plasma on the Ti target. Titanium atoms are then sputtered onto the sample and associated with injected nitrogen to give the TiN layer. A crystal-quartz micro-balance is used to survey the

deposited thickness and deposition rate during the process. Stoichiometry can be obtained by controlling the gas inlet flows.



Figure 3: The TiN sputtering machine.

The first aim of the TiN deposition activities was to obtain a stoichiometric layer on small quartz substrates. XRD analysis of some relatively thick layers showed that this aim was fulfilled as we obtained TiN_{x=1.022} [2]. The next step will be the achievement of stoichiometry for layer thicknesses of about 10 nm only. The rate of carbon and oxygen contamination of the TiN deposited layer have also to be found using XPS analysis.

COUPLER PROTOTYPES

We have designed two new coupler prototypes named TTF-V and TW60 (figure 4). To validate these couplers it was decided to use the TTF-III coupler conditioning procedure [1]. The next step will be the test of these couplers using a conditioning procedure with enough RF power constraints to make them competitive for the ILC project. However, these prototypes are still not optimized for cryogenic operation. At present, only the validation studies of these two prototype concepts using the TTF-III coupler processing procedure have been performed.

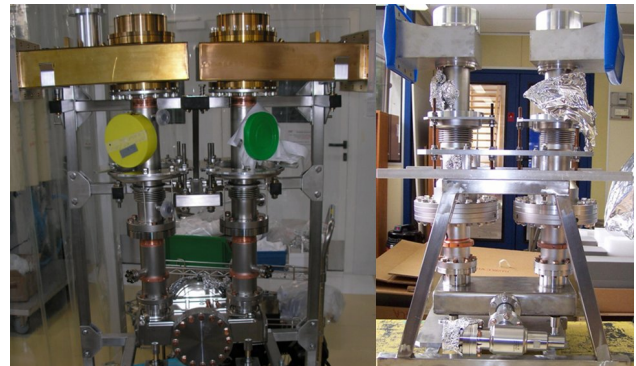


Figure 4: Coupler prototypes at LAL: TW60 at the left side and TTF-V at the right side.

TTF-V and TW60 have two very different designs. TTF-V is very similar to the TTF-III coupler, but has a larger cold part diameter in order to reduce MP effects. This geometrical modification imposed also some new design considerations for the cold window geometry. The warm part of TTF-V is almost the same as for the TTF-III

coupler. However, the TW60 coupler has a very different design. It has coaxial disk warm and cold windows, a different DC bias system for its inner conductor and a new waveguide transition design with a movable stub allowing an adjustable matching of the coupler pair assembly. This coupler also has a large cold part compared to TTF-III. Accordingly, TW60 has simpler design than TTF-III and should be less expensive.

For simplification and cost reasons, the coupler versions that are used to validate the design concepts do not have adjustable antenna penetration unlike the case of TTF-III.

Both of the coupler prototypes have been produced by ACCEL.

TW60 Coupler Prototype

An RF processing of a TW60 coupler pair was carried out after some assembly difficulties. The conditioning progress was limited by e^- current peaks correlated with vacuum bursts during the first step of the processing procedure, using 20 μ s pulses. As a consequence, it was necessary that an operator assisted the monitoring program during this step to choose adequate conditioning parameters in order to go through some MP thresholds. 1 MW RF power was reached for the first time after 54 h. After this, the following conditioning steps, using larger pulses, were performed rapidly and fully automated conditioning was possible. Finally, the coupler pair was fully conditioned (950 kW with 400 μ s pulses and 500 kW with 1.3 ms pulses using a repetition rate of 2 Hz). The total conditioning time was 67 h with some long interruptions. After conditioning, the e^- currents were very low.

The conditioning difficulties may have been caused by some surface anomalies that we have noticed. Coupler dis-assembly and inspection will allow further interpretation.

TTF-V Coupler Prototype

One TTF-V coupler pair was processed successfully. The total RF conditioning was achieved after only 24 h. Many e^- current interlocks were noticed during the first step of the conditioning. The origin of these interlocks was generally the high e^- current detected with the pick-up located on the cold part of the upstream coupler (figure 5). This current was particularly enhanced between 200 kW and 300 kW. Its fluctuations were high enough to exceed the e^- current interlock level several times. No vacuum bursts were correlated with these interlocks. The maximum power of 1 MW was reached for the first time after about 17 h. Afterwards, the conditioning was continued using larger pulses (50 μ s, 100 μ s, 200 μ s, 400 μ s to reach 1 MW and 800 μ s, 1300 μ s to reach 500 kW with a repetition rate of 2 Hz). These conditioning steps were relatively short and only one e^- current interlock occurred.

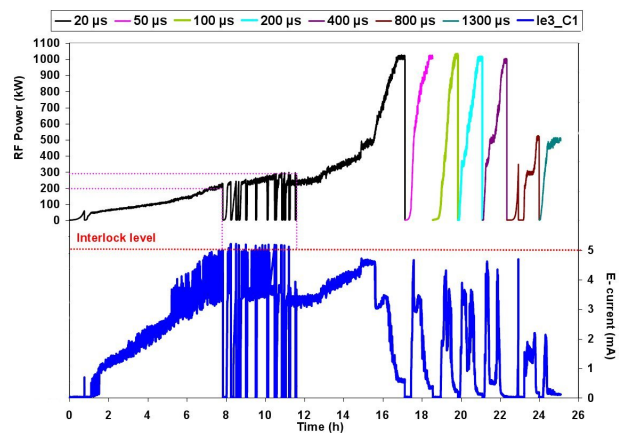


Figure 5: Power variation during the RF conditioning test of TTF-V. Ie3_C1 curve shows the e^- current measured in the cold part of the up-stream coupler.

CONCLUSION

Many activities are taking place at LAL in the framework of the R&D on power couplers and new results have been obtained. MP simulation results are in good agreement with the e^- current measurements in the cold part of the TTF-III coupler and show the strong influence of the bellows on the MP levels. The TiN sputtering bunch built in the context of a LAL-INFN collaboration was tested with success and a stoichiometric coating has been obtained. Two power couplers prototypes were realised and tested successfully.

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