CONDITIONING OF THE POWER COUPLERS FOR THE ESS ELLIPTICAL CAVITY PROTOTYPES

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Abstract

In the framework of the European Spallation Source (ESS), some power couplers have been designed and manufactured to supply, with RF power, the medium-beta (beta=0.67) elliptical cavities of the cryomodule demonstrator. The power couplers work at 704.4 MHz and are tested up to 1.2 MW (repetition rate=14 Hz, RF pulse width close to 3.6 ms). The CEA Saclay is in charge of the design, the manufacturing, the preparation and the conditioning of these power couplers. In this paper, after a general presentation of the power couplers used in the ESS LINAC and their characteristics, we give some details about the manufacturing and then we describe the different steps of the preparation (cleaning), the assembly of the couplers on the coupling box in cleanroom, the baking of the couplers and the conditioning procedure. Finally, the experimental results obtained in travelling and standing waves on the first pairs of couplers will be shown.

CHARACTERISTICS OF THE POWER COUPLERS

The couplers developed to supply in RF power the elliptical cavities of the ESS accelerator are composed of three main parts: a single window with its antenna, a double-wall tube to ensure a temperature gradient between the cavity (temperature of 2 K at the cavity side) and the window at ambient temperature, and a doorknob transition. (see Fig. 1) The couplers own different cooling circuits: a helium circuit for the tube, a water cooling circuit for the antenna and the inner conductor, and a third circuit for the ceramic (natural air). More details are given in [1].

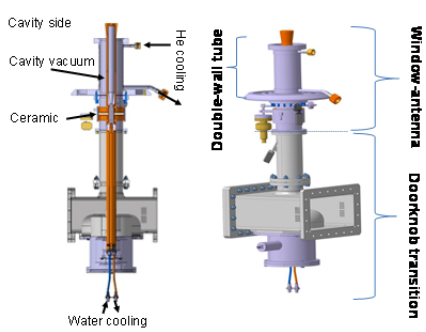

Figure 1: ESS coupler.

The main technical specifications of the couplers are presented in the table 1.

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Table 1: Technical Specifications

Features	Value
RF frequency	704.42 MHz
Repetition frequency	14 Hz
Incident RF power	1.1 MW
RF pulse width in full reflection (all phases)	500 µs
RF pulse width in travelling wave	3.6 ms
Voltage withstand (voltage between internal conductor and external conductor)	±10 kV

MANUFACTURING

To validate the design, some coupler prototypes have been manufactured and tested. The coupler components were built by different companies. Some features are presented hereafter.

A TiN coating is performed on the vacuum side of the window ceramic (requirement: 10 nm +/- 5 nm). This deposit has been characterized on samples (vitreous carbon) with a profilometer (Dektak 6M) for the control of the thickness and with some RBS (Rutherford Backscattering Spectroscopy) measurements (composition and thickness estimation): Titanium 26%, Oxygen 68%, Nitrogen 6%.

The internal surface of the double-wall tube owns a copper deposit whose thickness is required between 7 µm and 12 µm (with the acceptance of side effects) and whose RRR shall be in the range [20;40]. Some measurements have been performed on samples from an equivalent copper coated cylinder: RRR ∈ [30;39] and see Fig. 2 for profile.

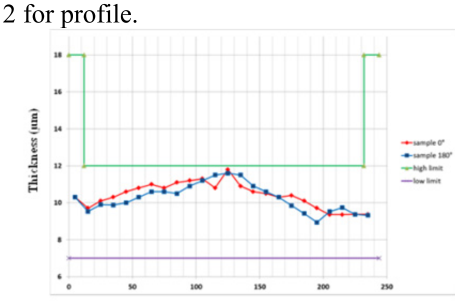

Figure 2: Copper deposit thickness.

The doorknob transition allows the possibility to apply a high voltage (±10 kV) on the inner conductor. Consequently an insulation is required and obtained with a

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PEEK tube assembled (by the shrinking fitted method) between the copper inner conductor and the aluminium knob. We control the breakdown voltage on a sample representative to the doorknob (18 kV obtained with measurement, see Fig. 3).

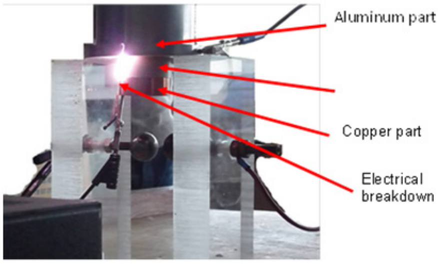

Figure 3: Test of the breakdown voltage.

A coupling box is used to ensure the correct RF transmission between two couplers during the conditioning. The vacuum tightness of the coupling box is obtained with an aluminium wire seal between the cover and the box bottom. (see Fig. 4)

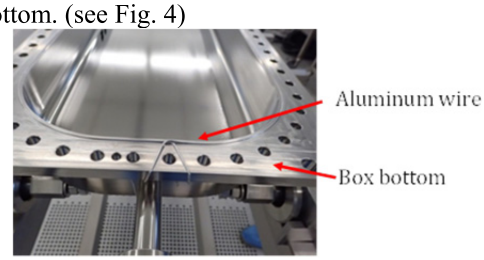

Figure 4: Seal of the coupling box.

The coupling box is entirely manufactured in stainless steel 316L, and its cooling is performed thanks to fans.

PREPARATION OF COUPLERS BEFORE CONDITIONING

Cleaning

The double-wall tube is cleaned in an ultrasonic bath with the detergent Tickopur R33 (concentration 2.75%, 25 kHz, 3 kW for 10 minutes). The window-antenna is manually cleaned with alcohol and if oxidation marks occur on copper parts, they are treated with RBS T310 then rinsed. The cleaning of the coupling box is performed in an ultrasonic bath with detergent TFD4 (the cover and the bottom of the box are separately cleaned).

Assembly in Ceanroom

In a cleanroom ISO4, two couplers are equipped with their diagnostic elements: for each coupler, a vacuum gauge IKR070 from Pfeiffer, an electron pick-up and a window (for the photomultiplier). The cover and the bottom of the coupling box are assembled with an aluminium wire seal. A window is put on the arc detection port and an all-metal angle valve is installed on the pumping port. Then the pair of couplers is assembled on the coupling box using an electric material lifter. After the assembly, the box is connected to a pumping system and the vacuum is done in the box. Before leaving the cleanroom, a vacuum leakage test is carried out. (see Fig. 5)

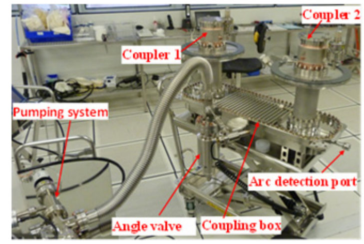

Figure 5: Couplers on the coupling box.

Baking

On the RF test stand, the couplers on the coupling box are linked to a pumping system and the whole is baked with some silicon and fibre glass heating tapes: the baking is performed at 170° C for the couplers and the box for a time in the range [72 hours; 120 hours]. The pumping system is baked at 120° C for 48 hours then at 60° C for the rest of the time.

To avoid oxidation of copper parts present on the air internal side of the window, we fill these parts with nitrogen during baking. (see Fig. 6)

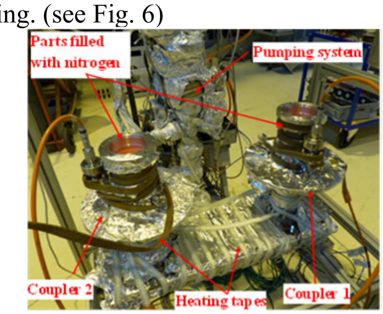

Figure 6: Heating tapes for baking.

CONDITIONING OF THE COUPLERS

Presentation of the Test Stand

During the conditioning, different elements are checked and controlled:

- Vacuum: 1 gauge on each coupler and 1 gauge at the input of the pumping port of the coupling box
- Electrical arc detection: 2 photomultipliers for each coupler (1 on the air side of the window ceramic and 1 another one on the vacuum side), 1 detector on the coupling box
- Multipactor effect: 1 electron pick-up on each coupler (DC bias of 48 V). This pick-up is also used to obtain a RF coupling (80 dB) with the coupler antenna.
- RF power: waveguide bidirectional couplers are assembled on the test bench to measure the incident and reflective powers at the klystron output, at the input and output of the couplers. (see Fig. 7)
- Water flow: 2 flowmeters allow the control of the water flow at the input of each coupler cooling circuit.
- Temperature: 3 probes are used to check the temperature of the windows and the box. 3 other probes allow checking the water temperature at the input and output of the cooling circuit.

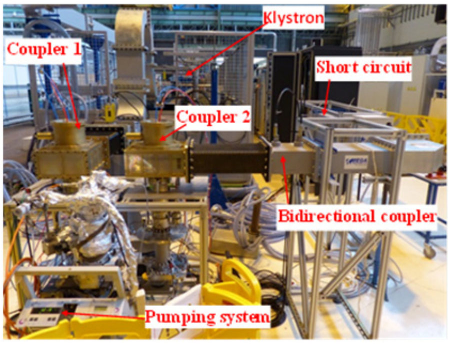

Figure 7: Conditioning test stand.

Check of the RF Characteristics on the Conditioning Test Stand

Just before the conditioning, the reflection coefficient S_{11} is measured when the output of the coupler 2 is linked to waveguides and to the 50 Ω water load of the test stand. The waveguide elements used for the connection to the klystron are replaced by a N-waveguide adapter. This measurement allows the check of the assembly and mainly the connection between the doorknob transitions and the couplers. We obtain a S_{11} close to -30 dB.

Sequence of the Conditioning

First of all, the couplers are tested in travelling waves (TW) then in standing waves (SW) [2]. The defined sequence gradually submits the couplers to RF constraints. From 50 µs to 3.6 ms, some RF power ramps are performed from a few kilowatts until 1.1 MW (first, for a repetition frequency of 1 Hz then for 14 Hz). The travelling wave conditioning is completed if the power ramp is done without outgassing superior to 2×10^{-8} mbar. In order to limit the outgassing, we define two vacuum thresholds: a hardware threshold that cuts the RF power and a software one that decreases the power until the vacuum becomes correct. Figure 8 shows the beginning of the sequence where high outgassing occurs for the first ramps.

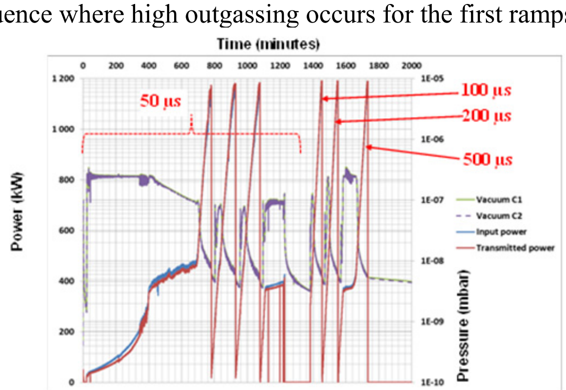

Figure 8: Power and vacuum (TW, 1 Hz).

Figure 9 presents the last power ramps for the travelling waves (from 2 ms to 3.6 ms, 14 Hz) and during the last ramp and the stage at 1.2 MW, no outgassing appears.

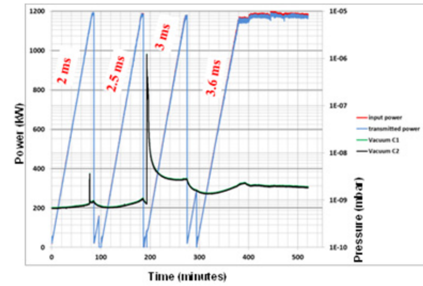

Figure 9: Power and vacuum (TW, 14 Hz).

After the travelling waves, we replace the 50 Ω load by a short circuit whose positions are defined to obtain the maximum of electric field close to the window ceramic. The whole sequence at 14 Hz and for one short circuit position is presented in Fig. 10. No outgassing occurs.

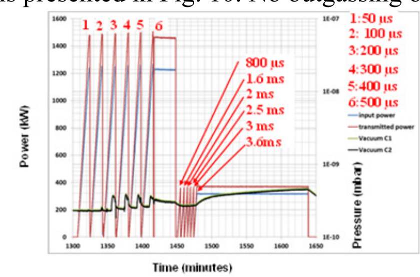

Figure 10: Power and vacuum (SW, 14 Hz).

For the three first pairs of couplers, the time for which the couplers are under RF constraints is respectively 82 hours, 88 hours and 106 hours.

CONCLUSION

The conditioning of three pairs of medium beta couplers has been successfully performed. Without outgassing, the vacuum is in the range [10^{-9} mbar, 10^{-8} mbar].

Some features shall be still tested such as the temperature behaviour of the double wall tube with helium flow and when the coupler is assembled on the cavity.

The next step is the conditioning of the high beta couplers, foreseen in June 2017. Then, the couplers of the pre-series will be tested at the end of 2017. Some improvements are foreseen such as the use of a furnace instead of heating tapes and the conditioning sequence can be also optimized to reduce the RF time.

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REFERENCES

[1] C. Arcambal *et al.*, " Status of the Power Couplers for the ESS Elliptical Cavity Protoypes", in *Proc. SRF 2015*, Whistler, BC, Canada, Sept. 2015, pp. 1309-1312.

[2] C. Darve *et al.*, "The Superconducting Radio-Frequency Linear Accelerator Components for the European Spallation Source: First Test Results", in *Proc. LINAC 2016*, East Lansing, MI, USA, Sept. 2016, paper WE1A03.

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