RF POWER COUPLER DEVELOPMENTS FOR SUPERCONDUCTING SPOKE CAVITIES AT IPN ORSAY

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Abstract

Within the framework of the European research program EURISOL on high intensity proton accelerator, and particularly on the R&D on superconducting SPOKE cavities, a power coupler has been designed to transmit up to 20 kW in CW mode at 352.2 MHz. A test stand has been designed, constructed and commissioned for the processing of two power couplers in traveling wave. In this paper we present all stages since the design of the SPOKE power coupler until the conditioning at 10 kW.

COUPLER DESIGN

EM Design

The power coupler for the superconducting SPOKE cavities adopts a coaxial geometry without water cooling in the capacitive antenna. A ceramic disc composed of alumina and thickness 6 mm realise the sealing between the vacuum of the cavity and the air of the 3"1/8 coaxial waveguide. (Fig. 1)

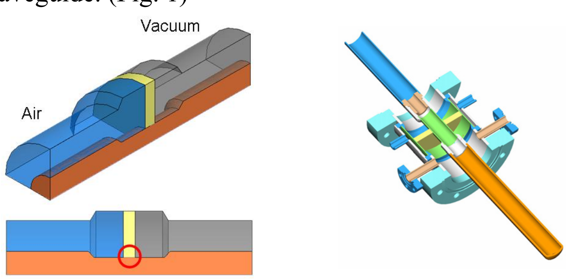

Figure 1: Geometry of the SPOKE power coupler.

To realise the impedance matching of the window no chokes are used but a local adaptation of the diameters of the antenna and the inner diameter of the external part of the coupler. By an

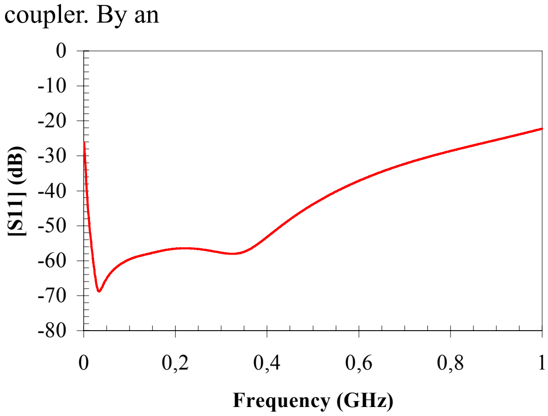

Figure 2: S_{11} parameter of the window.

EM optimisation of this area using HFSS software, the window shows a matching around -56 dB at 352.2 MHz. (Fig. 2).

At 352.2 MHz, the optimized window present a RF matching about -56.2 dB and the simulation show a good matching of the window on a broad bandwidth.

RF Window Test Stand

Two coupler windows were manufactured by the SCT Company located at Tarbes in France. To validate the design and the fabrication and before welding the antenna on the window, a RF window test stand were designed and realised to measure with a network analyzer the RF characteristics of the two windows. The mechanical system makes it possible to connect an N-type coaxial feedthrough with the DN 63 CF flange of the window. (Fig. 3)

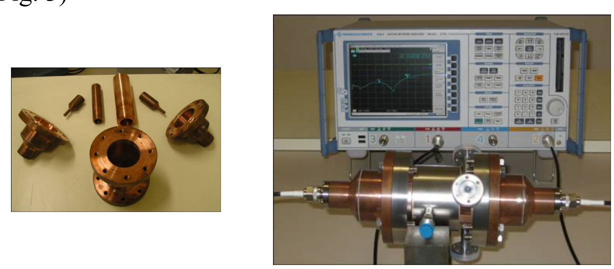

Figure 3: Pictures of the RF window test stand.

The RF measurements of the two windows can be seen in Fig. 4.

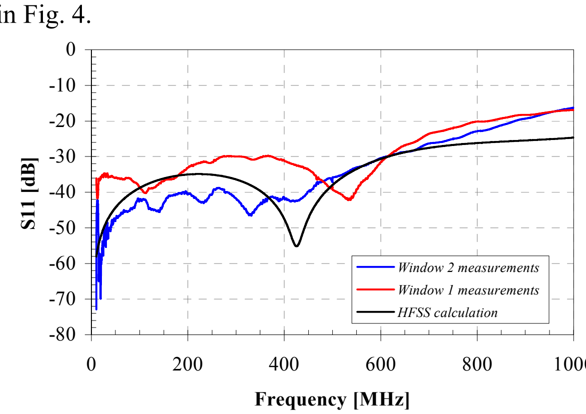

Figure 4: Simulated and measured S_{11} parameter of windows.

The measurements show a good agreement with the HFSS simulations. At 352.2 MHz, the window 1 present a S11 parameter about -42 dB and the window 2 around -30 dB instead of -56.2 dB in theory. A difference in dielectric

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permittivity of the alumina composing the ceramic disc could explain this difference between measurements of the two windows.

CONDITIONING TEST STAND

Test Stand Configuration

The test stand was designed to condition two power couplers in travelling wave mode via a half wave resonant cavity until a matched loaded cooling by water. (Fig. 5)

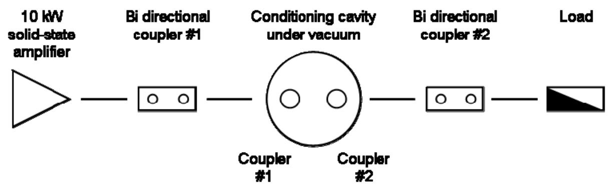

Figure 5: Test block diagram for power conditioning.

The test stand is capable of passing 20 kW CW RF power and is supervised by a Labview program [1].

High Power, Solid-State RF Amplifier

In the framework of the EURISOL Design Study, the Laboratori Nazionali di Legnaro developed in a first time a 10 kW unconditionally stable solid-state amplifier [2]. This 352.2 MHz amplifier uses 34 300 W solid-state modules with mosfets high power transistors and one preamplifier. This amplifier can accept to work in all power reflected mode because each module, except for the preamplifier, has been designed and realised with a 300 W circulator and a power termination in output.

The amplifier was housed inside a rack cabinet 0.6 m wide, 1 m deep and 2 m high. (Fig. 6)

Figure 6: Picture of the amplifier, front and rear..

The RF power of this amplifier is limited compared to DC supply currents of all the modules and each CD current must not exceed the value of 8.7 A for CW operation and 9.3 A for short periods. So the amplifier can function at 8.8 kW in CW mode and at 10 kW in pulsed mode. In any event, the protection system switches off the amplifier very quickly when critical level of current is overcome.

Test Stand Design

RF power conditioning has been performed using a specially built half wave resonant cavity to test two couplers under ultra high vacuum. In this setup, the RF power is transmitted from one coupler, through the stainless steel cavity to a second coupler and then to a water-cooled 20 kW RF terminating load. The conditioning cavity was designed and matched to provide maximum RF transmission power at 352.2 MHz. (Fig. 7)

Figure 7: Picture of the conditioning test stand.

For this, we work specially on the design of the RF way from the solid-state power amplifier to the cavity. So we have designed a matched conical coaxial waveguide part to connect the CF63 DN flange of the power coupler with the 3”1/8 standard coaxial waveguide. (Fig. 8)

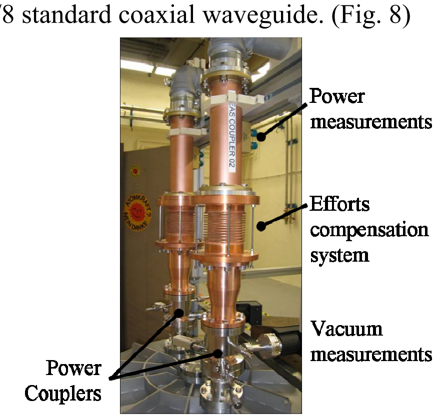

Figure 8: Layout of papers.

Also, a mechanical system has been designed and realised to compensate the efforts to which could be subjected the ceramics of the power coupler during the assembly on the test stand.

Before RF conditioning, the two power couplers and other associated mechanical parts were cleaned using a procedure developed at LAL for TESLA high power couplers

Test Stand Diagnostics

The RF power was measured with two bi-directional couplers, as illustrated in Figure 5.

The vacuum pressure was measured with one ion gauges on each window that are interlocked to turn off the RF power if the pressure inside the cavity rises above 1 x 10^{-6} mbar.l.s^{-1}.

A polarised antenna was positioned near the surface of the disc ceramic of each power coupler to measure the electrons emission of the ceramic in the presence of high RF power.

The water inlet and outlet at the same time on the solid-state power amplifier and on the 20 kW load are detected by a DC switch mounted on flow meter.

All these parameters are managed by electronic boards which are used as safety measures while cutting the RF power so only one of the parameters is lacking or its value is except ranges.

A LabView data acquisition system is used to monitor, display and record the RF power, pressure, presence of the water in the amplifier and in the load, the current corresponding to the electrons emission of the ceramic.

TESTS RESULTS

The conditioning procedure consists of beginning with a low RF power level and gradually increasing it. At each power level preset the LabView program switch ON the RF during 2 min 30 s and after switch off the RF power during 2 min 30 s so that the vacuum goes down again, and if all parameters are right, the program passes at the higher RF power level.

With this procedure, it took roughly 20 hours to condition our two power couplers. (Fig. 9)

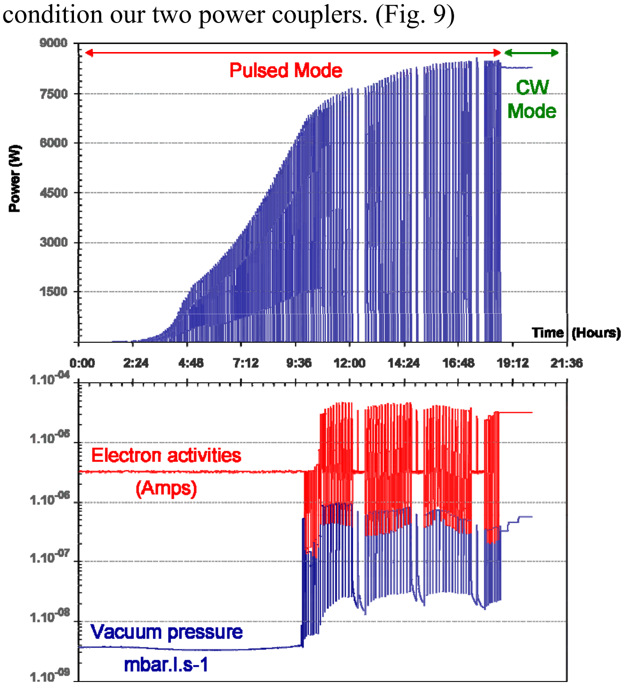

Figure 9 : Power, Pressure and Multipacting versus Time during couplers conditioning

In certain cases if on a power level, the vacuum goes back to the top of a certain limit fixed in the program, then RF power is cut during 10 minutes so that the vacuum goes down again. If the vacuum doesn't go down again the program decides to return at the precedent RF power level.

Up to 7 kW, the conditioning of the two power couplers is very well passed, without any important increase of the pressure vacuum nor the electron activity.

Above 7 kW we noticed an intense electron activity what strongly degraded the vacuum. To solve this problem the program cut the RF power so that the vacuum level is restored. The vacuum not being restored in assigned time, the program started again conditioning on the lower power level and this, up to 8.8 kW.

CONCLUSIONS

Two coaxial power couplers using ceramic disc geometry have been successfully conditioned at 8.8 kW for the EURISOL research program [3]. The conditioning results are very important because they prove the design concept of the windows and validate our conditioning test stand. The next stages are to condition two power couplers at 20 kW with two 10 kW solid-state amplifier and to test in RF power a superconducting SPOKE cavity at 4 K in the framework of the EURISOL project.

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