Tests of 1MW - 704 MHz RF couplers for elliptical cavities at CEA-Saclay

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Abstract

In the frame of the CARE/HIPPI programme, superconducting accelerating cavities for pulsed proton injectors were developed, as well as other critical components as RF power couplers. For a β 0.5 elliptical cavities operating at 12 MV/m and a beam of 40mA, 230 kW of RF power is needed assuming an optimal coupling (Qex = 1.0 e6). To be qualified, these couplers have to transfer such a power level in a travelling wave mode, which corresponds to a perfect matching to the beam. We present the results of the RF power tests of the couplers performed in our platform equipped with a 704 MHz high power RF source in the MW range. This paper is in support of deliverable CARE-HIPPI-2008-10. The deliverable included the results of high power test on cavity A and B that turned out to be impossible during the HIPPI time frame. The delay was accumulated during the manufacturing of the He cooled outer conductors and the coupling box of the test stand.

Introduction

In the frame of the CARE/HIPPI programme, CEA-Saclay designed and built accelerating components for 704 MHz proton linacs (superconducting cavities, as high power couplers, tuning systems, magnetic shielding [1]). With the 704 MHz platform for high power tests already installed, qualification of these power couplers for superconducting linacs for accelerating high intensity pulsed proton beams were possible. This paper describes the final results achieved in February 2009.

Coupler test stand

In order to process the couplers, it is convenient to connect two couplers through a coupling waveguide. A load is connected to the downstream coupler when running in TW mode, and a movable short is used to vary the maximum field location in standing wave mode. The klystron is equipped with a circulator capable of handling the reflected power up to 1 MW peak at 10% duty cycle. The connecting waveguide, or coupling box, operates under vacuum and must therefore be stiffened. It is made of copper coated stainless steel in order to reduce the RF losses by a factor 6 and can be see on figure 1.

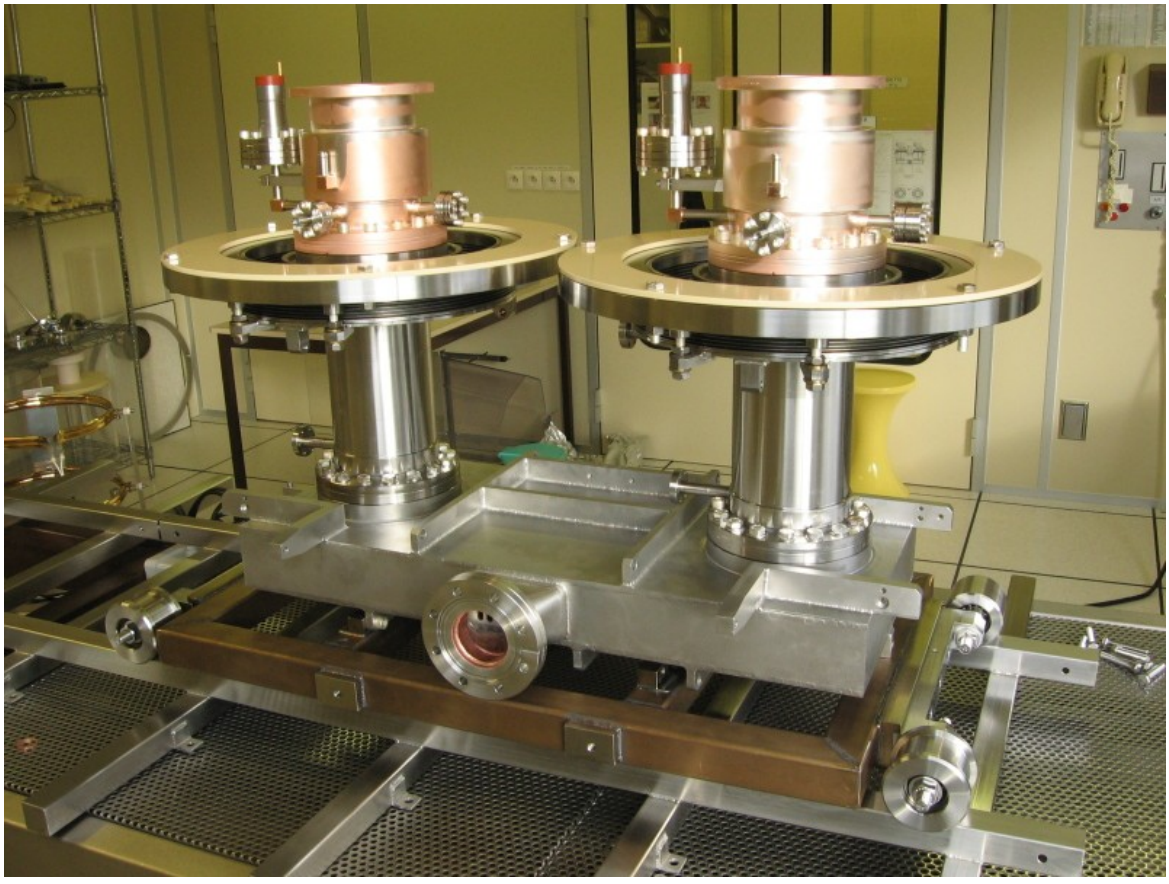

Figure 1 : Clean room assembly of couplers on the coupling box

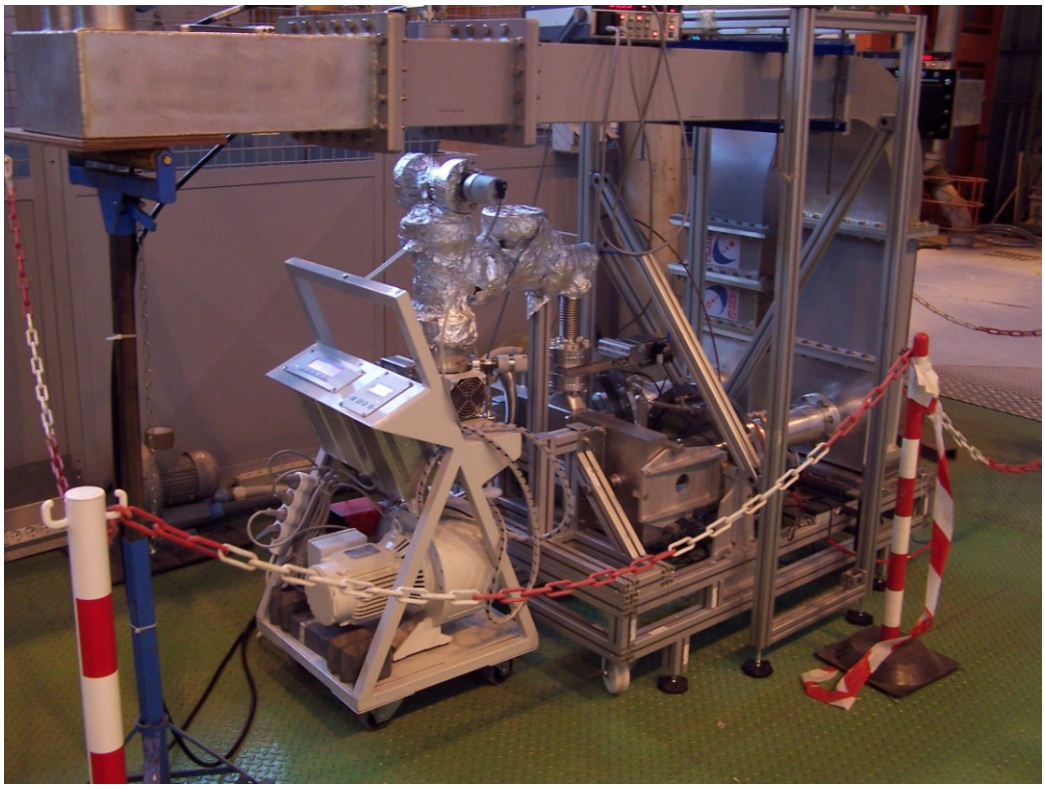

Fig. 2 : RF coupler test stand at CEA-Saclay

Coupler Conditioning in TW

The first power ramping up to 300 kW was done with 50 μs pulses exclusively, reducing the repetition rate from 50 Hz to lower discrete values of 25, 12.5 or 6.25 Hz to reduce the outgassing rate in some power ranges.
Around the 300 kW level, the RF was interrupted from the photomultiplier interlocks, but no pressure increase was involved, so the pulse were lengthened progressively in order to generate outgassing, and achieve a more efficient conditioning. The 310 kW-520 kW range was processed at 50 Hz with 120 μs pulses.

The range 200 kW-550kW was then processed using slow power ramps, gradually increasing the pulse length to 2 ms at 50 Hz, which is the nominal duty cycle of 10%. The 80 kW region had to be reprocessed, then the power could be raised up to 720 kW without vacuum events.
Above this power level, the duty cycle was reduced to process the couplers up to 900 kW.

At 6% DC (1.2 ms pulses at 50 Hz) and 900 kW (54 kW average) a water leak and arcing occurred on the air part of the inner conductor of the downstream coupler, between the RF window and the copper inner conductor of the coaxial line section. Inspection showed that arcing had destroyed the Vitton gasket ensuring the water tightness, the RF surface was pitted which could be re-polished and cleaned. The ceramic disk of the window was not damaged in the process. The coupler was re-aligned and assembled with a new gasket. The cause of this event is not fully understood since it is difficult to determine if a small water leak started the arcing, or if an arc destroyed the gasket in the first place.

The processing was resumed with 100 μs, 12.5 Hz pulses. Within 4 hours, the power could be raised to 1 MW, with light activity only at 400 kW. The pulses were then lengthened from 100 μs to 1.6 ms, keeping a repetition rate of 12.5 Hz, up to 1 MW. The conditioning is still ongoing.

The power history of the processing up to this point is shown on figure 3. Since the data acquisition can not be performed for each RF pulse, data are recorded every two seconds approximately. The total RF time can be estimated to 110 hours at the time this report is written. The vacuum level in the test stand is shown on figure 4.

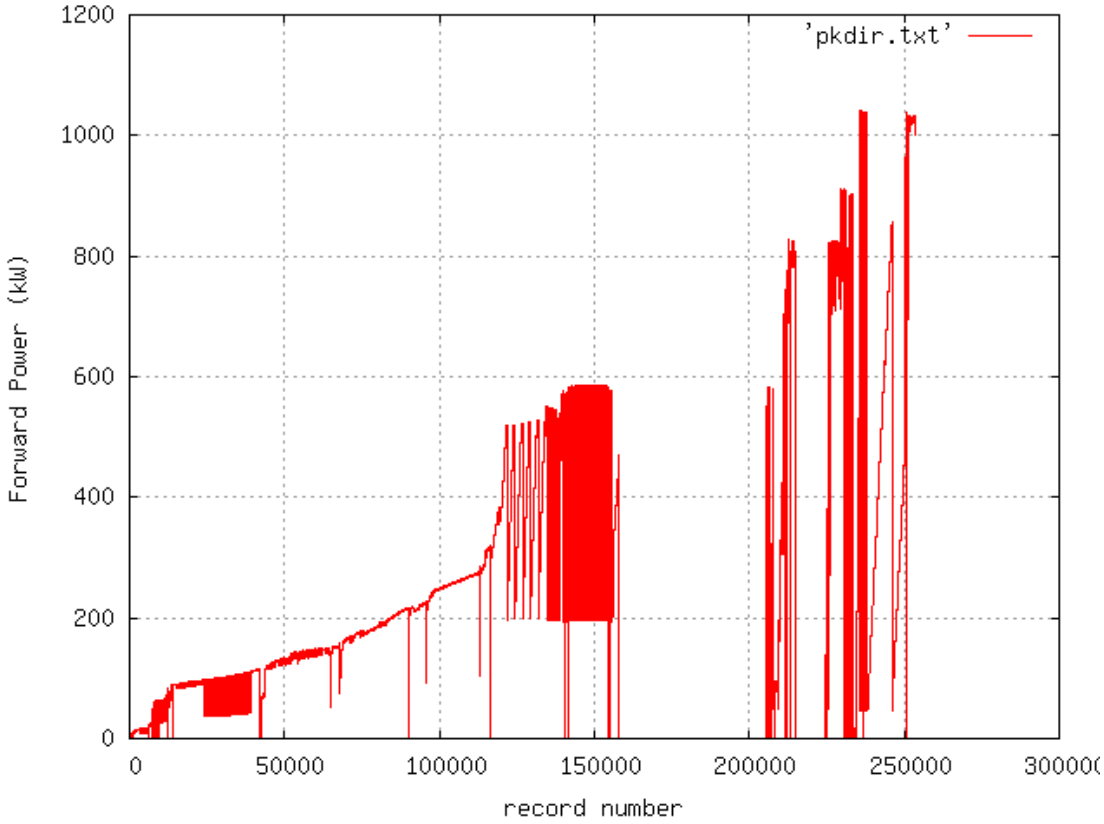

Figure 3 : History of forward power in travelling wave mode.

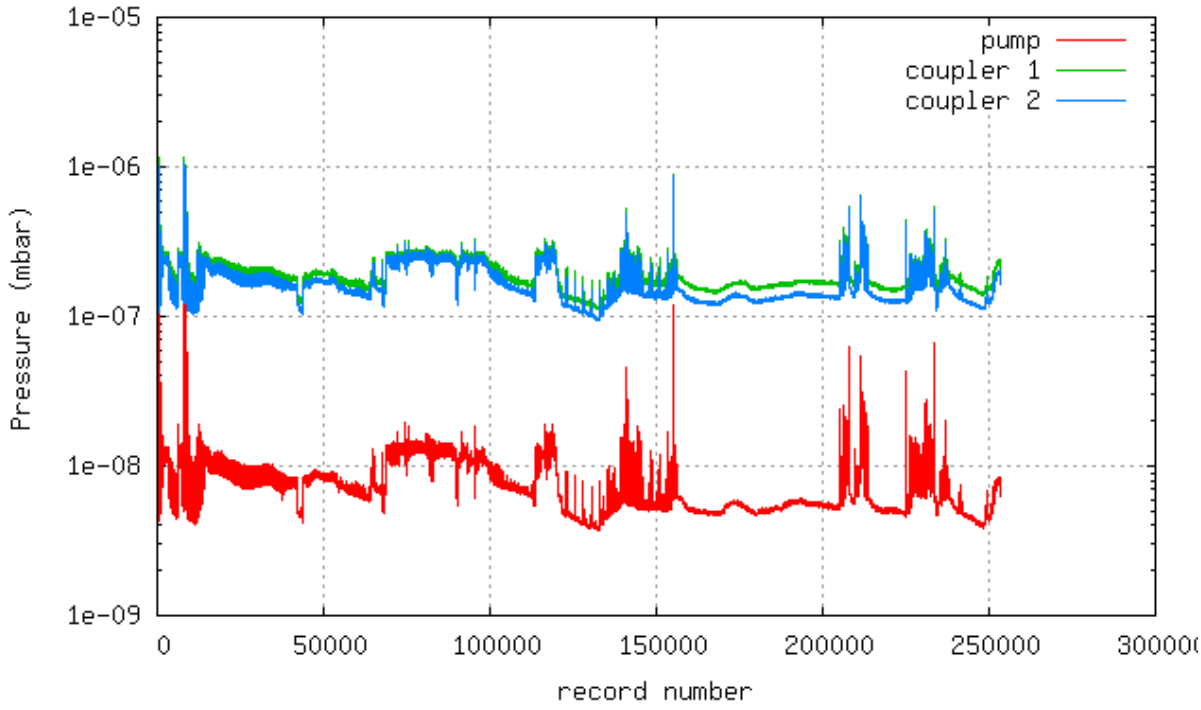

Figure 4 : Pressure evolution during the coupler processing.

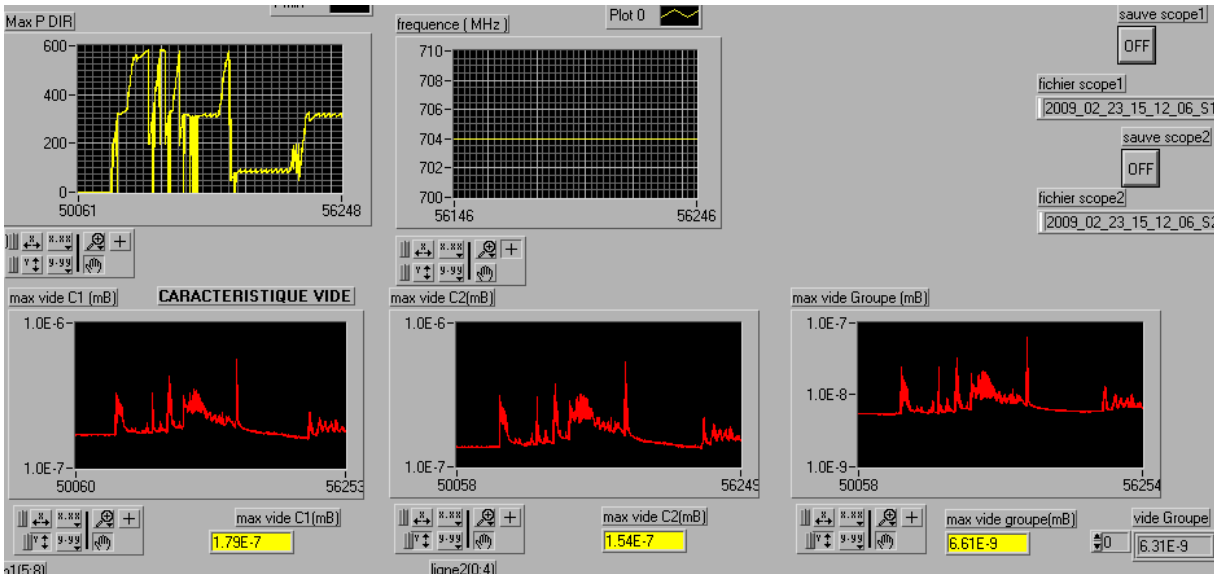

Figure 5 : hardcopy of the test stand Labview interface

Conclusion

Two identical RF power couplers were designed and built by CEA-Saclay. After some preliminary measurements and controls, these couplers have been assembled in clean room with the other main components of the RF coupler test stand (coupling box, vacuum gauges, arc detectors, pumping lines). After 6 full days of RF processing, these couplers reached the specifications for the β 0.5 HIPPI cavities: P = 250 kW in travelling wave mode at the maximum duty cycle (RF pulse length of 2 ms and repetition rate = 50 Hz). After 1 day more of processing, the couplers even met the 1.0 MW power level what is needed for the high gradient superconducting cavities foreseen in the high energy part of the SPL linac [2] (at a repetition rate of 12.5 Hz).

Acknowledgements

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References

[1] ‘704 MHZ HIGH POWER COUPLER AND CAVITY DEVELOPMENT FOR HIGH POWER PULSED PROTON LINACS’, G Devanz et al., Proc. of Linac 08, Victoria BC, 2008.

[2] ‘Conceptual design of the SPL II’, F. Gerigk et al., CERN Report ref. CERN-2006-006, July 2006