

TEST STAND FOR 325 MHz POWER COUPLERS*

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Abstract

325 MHz superconducting Single Spoke Resonators (SSR1) will be utilized in the Project X Injector Experiment (PXIE). Fermilab has developed the main coupler that will supply 2 kW CW RF power to each cavity. Fermilab developed and designed a special test stand where the couplers will be tested and design properties confirmed. This paper describes the design of the coupler test stand and preliminary results of the tests.

INTRODUCTION

The PXIE [1] accelerator includes one cryomodule with eight 325 MHz SSR 1 cavities. Each cavity requires 2 kW RF power in CW mode for 1 mA of H- beam. In future upgrades beam currents of up to 5 mA are desired in which case RF power for SSR 2 cavities (which is not a part of PXIE) will be 18 kW, CW. To satisfy all upgrade plans, couplers must be able to operate at 25 kW power at any reflection [2]. Before installing to superconducting (SC) cavity, a coupler must be tested and conditioned. For this purpose a test stand was designed and built. There are some requirements the test stand must meet. First, the tests should be done under vacuum to check the multipactor properties of the couplers; the couplers must be free of multipacting. Second, the performance of SC cavities is very sensitive to dust particles. After conditioning the couplers, they will be installed directly onto cavities without any additional cleaning procedure. Thus disassembly of the test configuration should not create or spread dust particles. To satisfy this demand a configuration with 'untouchable' antennas was chosen: during assembling/disassembling and testing, coupler antennas have no mechanical contacts with other parts.

TEST CAVITY STRUCTURE

After considering several options, the structure presented in Figure 1 was chosen. Two couplers are connected through this test cavity. The test cavity is a coaxial half wave resonator with two lateral conductors. These lateral conductors are hollow and the coupler antennas fit inside them. Diameter of the inner conductor of the resonator is 1 inch and the diameter of the outer conductor is 6 inches. These sizes eliminate multipactor in the operating range of power and provide for low losses. A low loss allows us to make the outer conductor of stainless steel. Both the inner and lateral conductors are made of copper. Figure 2 illustrates a simulated pass band for the test cavity. Wide pass band allows us to

avoid spatial tuning accessories. Simulated losses are 0.22% (-9.5E-3 dB).

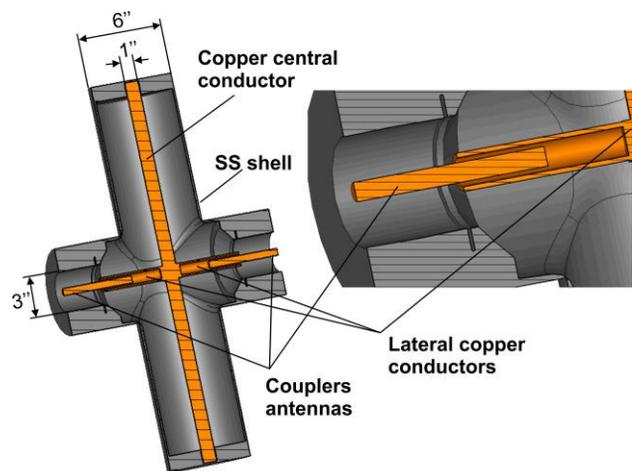


Figure 1: Structure of test cavity.

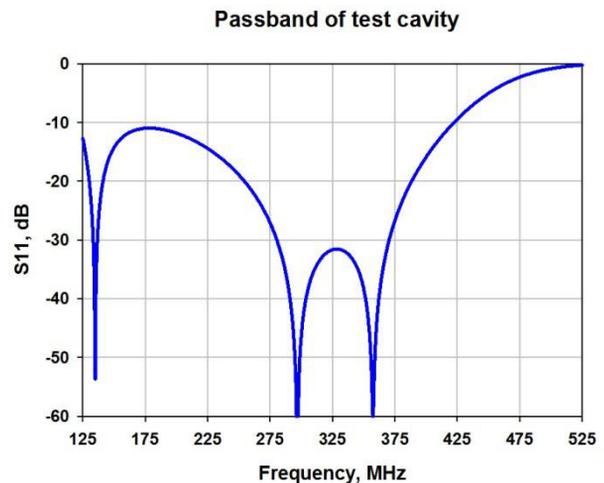


Figure 2: Pass band of test cavity.

MOVEABLE SHORT

To allow us to test couplers at arbitrary reflections, a movable short was designed. This is illustrated in Figure 3. The plunger is electrically isolated from the inner and outer conductors. There are slots between the plunger and walls which allows us to move the plunger without sparking. The inner volume of the plunger works like a choke providing good isolation (full reflection) between volumes in front and behind the plunger. From simulations the power leakage beyond the plunger is -50

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dB at operating frequency and < -30 dB at frequency range ± 5 MHz, see Figure 4.

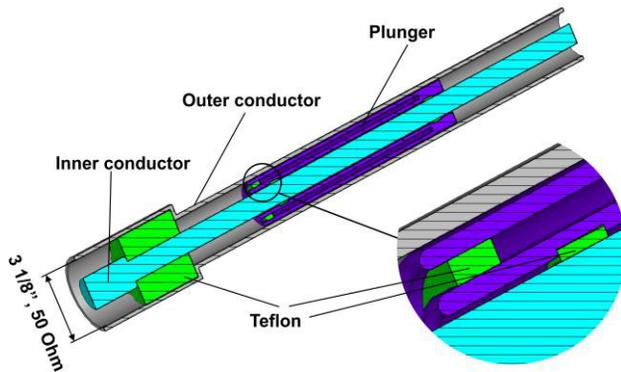


Figure 3: Moveable short

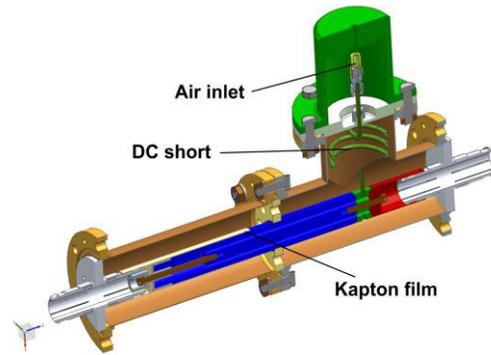


Figure 5: Structure of DC block

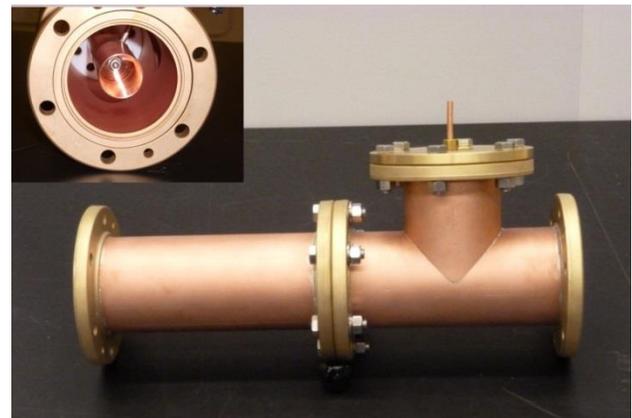


Figure 6: DC block. Tested up to 5.5 kV DC HV.

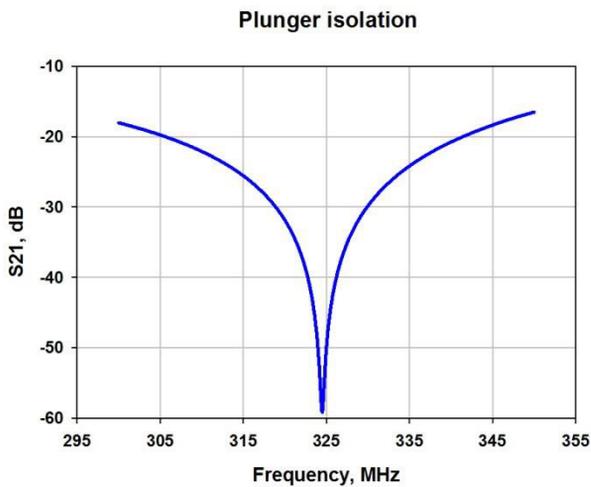


Figure 4: Plunger isolation

DC BLOCK

The coupler design allows us to apply a high voltage (HV) bias to suppress multipactor. HV bias is applied to the inner conductors of each coupler. To do this the internal conductor of each coupler has to be isolated from the inner conductor of the transmission line from the rf source. For this purpose a so called DC block was designed. Figure 5 shows a schematic of this DC Block. Input and output are standard 3 1/8 inch, 50 Ohm coaxial waveguide. The inner conductor is divided by thin kapton film to form a capacitor which passes RF power and blocks direct (DC) high voltage. To protect the RF source in case of kapton breakdown, a DC short is installed on the RF source side. This DC short is made in a spiral shape and is transparent to 325 MHz RF power. The spiral is cooled with compressed air. Pass band of the DC block is > 100 MHz ($S_{11} < -20$ dB) and is shown in Figure 7. The DC block and couplers were tested with HV up to 5.5 kV. Expected operating voltage is 2 kV.

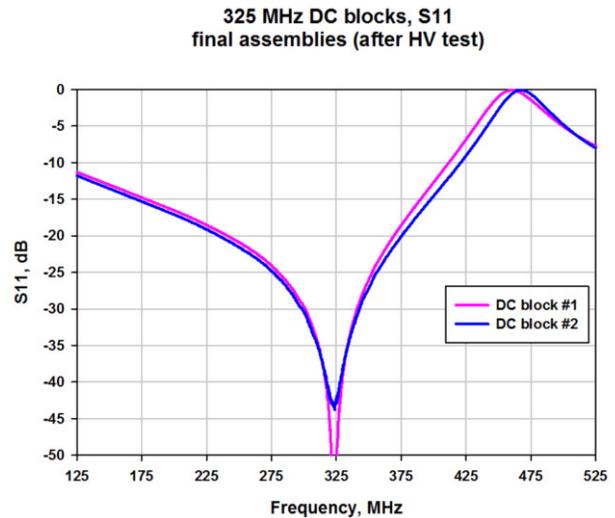


Figure 7: Pass band of DC block

TOTAL CONFIGURATION

Total configuration of the test assembly is presented in Figure 8. Besides couplers and test cavity it includes directional couplers at the input and output of the couplers, DC blocks and either a matched load or a moveable short. Directional couplers are used for power

measurements and RF pulse shape monitoring. There are eight points of temperature measurements. Signals from e-pickups allow us to recognize the presence of multipactoring. Vacuum is provided by an ion pump placed at the bottom of the table and monitored by an ion gauge. This assembly is connected to a 10 kW solid state CW amplifier using 1&5/8 inch heliax. Due to the heliax length, only ~8.5 kW can reach the couplers. Figure 9 shows a photo of the assembly in the test area.

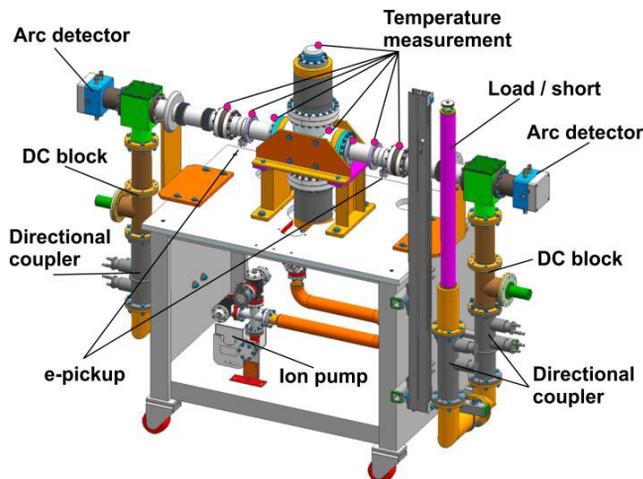


Figure 8: Configuration of test assembly.



Figure 9: Test assembly in test area.

TEST RESULTS

In the first stage of testing, couplers were tested in travelling wave (TW) mode – output of the assembly was terminated into a matched load. In this configuration multipactoring was observed beginning at a power level of ~ 4.5 kW in the coaxial parts of the coupler. Multipactor increased with increasing power level. Evidence of multipactoring was vacuum activity and

signals from e-pickups. Conditioning was started with a short pulse of length 0.1 ms and the pulse length was gradually increased till CW mode was achieved. During one day, couplers were conditioned up to the maximum power of ~ 7.5 kW, CW (RF amplifier limitations). During the next day the couplers were tested at ~7.8 kW, CW for 7 hours nonstop. There were no coupler related trips during this time and there was no evidence of multipactor – no vacuum activity and no signals from e-pickups. Temperature rise on the outside of the ceramic windows and on the stainless steel outer coupler tubes were insignificant, ~ 5 C.

For the second stage of testing the matched load is replaced with a moveable short and couplers were tested in standing wave (SW) mode. In SW mode, multipactor was more significant and started at power levels ~ 3.5 kW. The short was moved in steps of 5 cm and at each position the couplers were conditioned up to maximum power. The short was moved a total of 20 cm (5 positions) when the RF supply cable faulted. We manage to reach maximum power at each of the five positions in CW mode. Vacuum levels during this conditioning were ~ 1e-6 mbar. Vacuum activity was observed at the end of conditioning implying some amount of multipactor still existed. Temperature rises in monitored points were moderate, ~ 10 C.

The cable was repaired and in order to prevent future cable failure, operation was performed only in pulse mode with a pulse length of 0.5 s and 1 pps repetition rate. At this stage the HV bias was applied to couplers. HV bias suppresses multipactor quit well; +1.5 kV (+ at the antenna) eliminates multipactor completely up to the maximum power at any short position (0 – 50cm, 5 cm step). Negative polarity is not as effective – it requires about -3kV to suppress multipactor.

We plan to replace the existing 1&5/8 inch heliax with 3 inch heliax and continue testing up to full CW mode.

CONCLUSION

Facility for testing of 325 MHz main couplers was design and built. A pair of couplers were successfully tested up to ~7.5 kW CW in full reflection mode. No multipactor was observed in test cavity volume. Maximum temperature rise of test cavity was moderate, ~ 10C. Further work with higher power will be continued.

ACKNOWLEDGMENT

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REFERENCES

- [1] S. Nagaitsev, et al., “PXIE FRS”, Project X database.
- [2] S. Kazakov, et al., “Status of 325 MHz main couplers for PXIE”, THPP050, this conf., Linac14.