MECHANICAL DESIGN OF A HIGH POWER COUPLER FOR THE PIP-II 325 MHz SSR1 RF CAVITY*

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Abstract

The Project X Injector Experiment (PXIE) at Fermilab will include one cryomodule with eight 325 MHz single spoke superconductive cavities (SSR1). Each cavity requires approximately 2 kW CW RF power for 1 mA beam current operation. A future upgrade will require up to 8 kW RF power per cavity. Fermilab has designed and procured ten production couplers for the SSR1 type cavities. Status of the 325 MHz main coupler development for PXIE SSR1 cryomodule is reported.

INTRODUCTION

A multi-MW proton accelerator facility based on an H- linear accelerator using superconducting RF technology, Proton Improvement Plan-II (PIP II), is being developed at Fermilab to support the intensity frontier research in elementary particle physics. The PIP-II baseline design includes two types of 325 MHz superconducting cavities, single spoke resonators, SSR1, with a β=0.22 and single spoke resonators, SSR2, having β of 0.47. The first cryomodule consists of eight SSR1 cavities and will be installed in PXIE at Fermilab. Both types of cavities have a similar design and are equipped with the same size power coupler flanges. This will allow the use of the same design for power couplers that feed the RF power to both types of cavities. Power consumption of the cavities for both projects varies from 2 kW to 8 kW, thus the 325 MHz power couplers should operate up to 10 kW in the CW regime. The PIP-II upgrade plan intends to use the Linac in a continuous wave (CW) mode [1]. This means that the main coupler must reliably operate at a power level > 20 kW under conditions of full reflection. Prototype 325 MHz couplers were designed and tested at power levels ~ 8 kW in both CW modes: travelling wave (TW) and standing wave (SW) [2].This paper presents the mechanical design and production status of 325 MHz main coupler for PXIE SSR1 cryomodule.

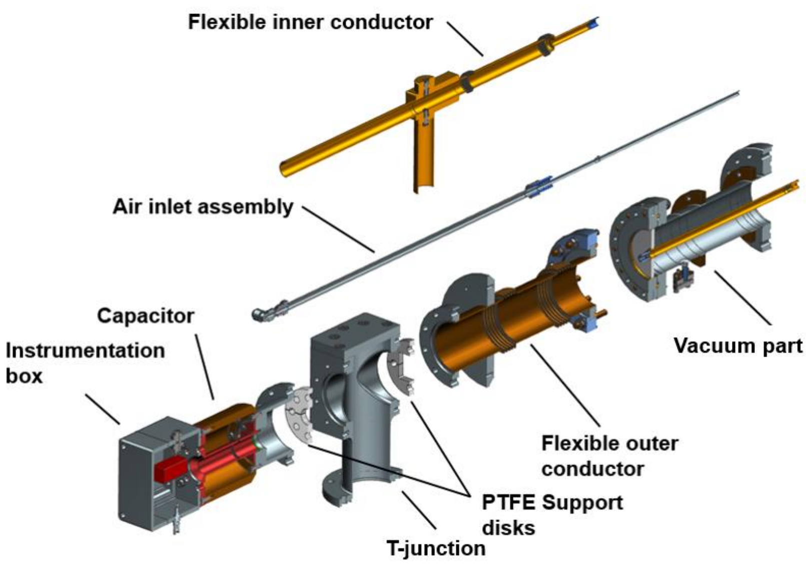

Figure 1: Exploded view of 325 MHz main coupler.

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COUPLER DESIGN

The coupler structure is presented in Figure 1. Main components of SSR1 Coupler include a vacuum part connected to T-junction with flexible coaxial line. The T-junction is followed by a capacitor and instrumentation box.

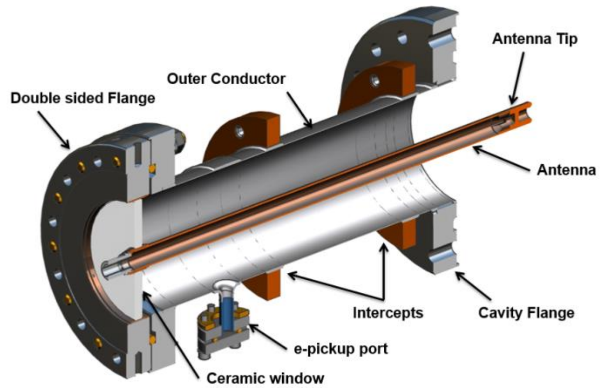

Figure 2: 325 MHz main coupler vacuum part.

The vacuum part of the coupler is shown on Figure 2. It consists of a 3 inch OD stainless steel outer conductor with a wall thickness of 0.4 mm, a 0.5 inch OD copper antenna, and a 6 mm thick ceramic window. To prevent any possible cavity contamination the inside surface of an outer conductor is not coated with copper. The coupler outer conductor has two thermal intercepts (at "5K" and "80K") located between cavity flange and ceramic window. In order to reduce secondary electron emission the vacuum side of the ceramic window is coated with TiN. The copper antenna is hollow. It is cooled with dry compressed air, which allows reducing heat load on a cavity.

The warm part of coupler is connected to the vacuum part on one side and to DC block on the other. DC-block isolate the coupler input and protect the RF amplifier from HV bias. The structure of the DC-block is shown on Fig. 3 [2].

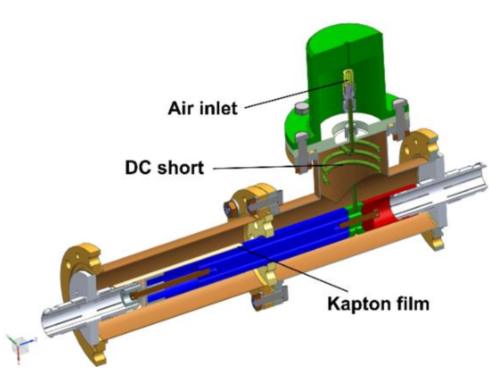

Figure 3: Structure of 325 MHz DC-block.

The warm part consists of a flexible coaxial line, T-junction, capacitor and instrumentation box. The flexible coaxial line includes copper tubes, which are soft soldered to electrodeposited nickel alloy bellows coated with a thin layer of copper. The inner conductor located in the warm part of the coupler has a bigger diameter than the antenna. This design allows applying high voltage bias to the antenna and supress possible multipactor. The instrumentation box located at the end of the coupler has the compressed air and high voltage bias connections. Inside of the box there is a photomultiplier that monitors ceramic surface activities.

COUPLER DESIGN CHANGES

During the first stage of the design process three prototype couplers were fabricated and tested at Fermilab. On the test stand, prototype couplers and DC-blocks demonstrated the ability to work at power level ~ 30 kW, CW and full reflection with arbitrary phase [3]. Based on the test experiences following improvements were made:

- Change design of vacuum flanges
- Modify air inlet tube
- Update antenna tip
- Increase coupler capacitor
- Improve pusher design
- Add thermal straps

Change Design of Vacuum Flanges

The design of vacuum flanges on SSR1 Main Coupler was changed from CF to DESY/TeSLA aluminum seal, which employs flat surfaces on the mating flanges and an aluminum circular gasket with a diamond section. Figure 4 presents two of such seals in the ceramic window area of the coupler.

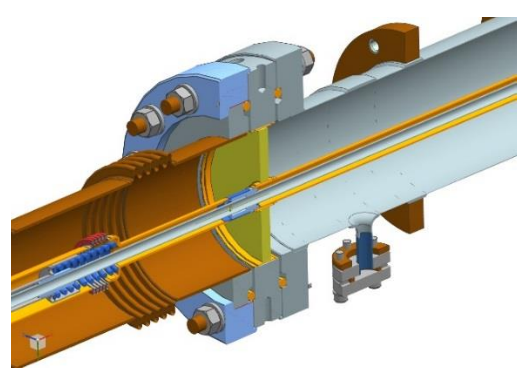

Figure 4: Vacuum flanges in ceramic window area.

Modify Air Inlet Tube

Several small diameter holes at the end of air inlet tube were removed and four slots were added to the antenna tip. (See Figure 5).

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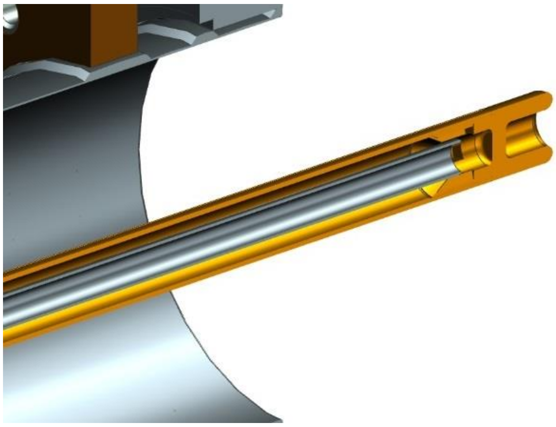

Figure 5: Updated design of antenna tip.

Update Antenna Tip

The production coupler antenna tip design was updated to allow for the material removal from the antenna tip end surface for the final coupling adjustment.

Increase Coupler Capacitor

The coupler capacitor size was increased relative to the prototype design.

Improve Pusher Design

During testing it was very difficult to remove the spring from the inner conductor. To overcome these difficulties it was decided to weld spring to the pusher and add a protective shield to prevent spring from contacting the inner conductor bellows. At the same time, the diameter of the inner conductor was increased to allow enough room for a larger pusher.

Add Thermal Straps

During cold tests the temperature of the ceramic disks fell below water freezing point, which could lead to some possible ice buildup on the non-vacuum side of the ceramic window. To prevent this from happening, both ends of the outer conductor were connected with thermal straps. This modification allows avoiding the use of an active heating element.

FABRICATION STATUS

As of right now ten 325 MHz main couplers for PXIE SSR1 cavities have been ordered; cold end assembly parts were produced and are now waiting for the final brazing. Ceramic disks were brazed into copper sleeves and are ready to be connected to the antenna and outer conductor. Upon completion of the final brazing, the ceramic window units are scheduled to be TiN coated and delivered to Fermilab. The electrodeposited bellows were manufactured. The outer and inner conductors are ready for final assembly. All other parts have been delivered to Fermilab. We plan to start RF tests in October 2015.

CONCLUSIONS

The design of the 325 MHz Main Coupler for PXIE SSR1 cavities has been updated. Ten couplers are in the final stages of fabrication. The start of RF tests is planned for the October 2015.

REFERENCES

[1] http://pxie.fnal.gov/PIP-II_RDR/PIP-II_RDR.pdf "The PIP-II Reference Design Report".
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[3] S. Kazakov, et al., "Testing of 325 MHz couplers at test stand in resonance mode", Proc. SRF2015, Whistler, September 2015, http://jacow.org/