MECHANICAL DESIGN OF A HIGH POWER COUPLER FOR THE PIP-II 162.5 MHz RF QUADRUPOLE*

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Abstract

PXIE is a prototype front end system [1] for the proposed PIP-II accelerator upgrade at Fermilab. An integral component of the front end is a 162.5 MHz, normal conducting, continuous wave (CW), radiofrequency quadrupole (RFQ) cavity. Two identical couplers will deliver approximately 100 kW total CW RF power to the RFQ. Fermilab has designed and procured main couplers for the CW RFQ accelerating cavity. The mechanical design of the coupler, along with production status, is presented below.

INTRODUCTION

A multi-MW proton facility, PIP-II, has been proposed and is currently under development at Fermilab. A prototype of the PIP-II front end, PXIE, is planned to validate the conceptual design. PXIE will supply a 25 MeV 50 kW beam, and will include an H- ion source, a CW RFQ, and a two superconducting RF cryomodule providing up to 25 MeV energy gain at an average beam current of 1 mA (upgradable to 2 mA) [1]. The ion source will deliver up to 10 mA of H- at 30 keV to the RFQ. The 162.5 MHz RFQ (Fig. 1) accepts and accelerates this beam to 2.1 MeV. The RFQ is designed to dissipate ~80 kW of RF power under nominal operating conditions. To reduce coupler power demands, two couplers will be integrated with the RFQ [2].

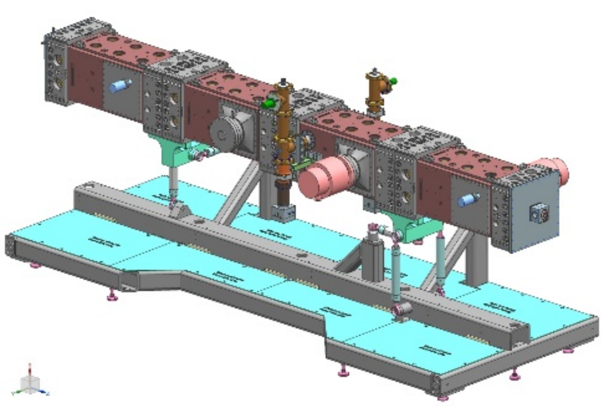

Figure 1: 3D CAD model of RFQ.

Table 1: RFQ Parameters

Parameter	Value
Ion type	H-
Beam current	1-10 mA
Beam energy	0.03-2.1 MeV
Frequency	162.5 MHz
Duty factor (CW)	100%
Total RF power	≤ 130 kW
Number of couplers	2

RFQ COUPLER

Requirements

Parameters of the RFQ (Table 1) define the requirements for the two couplers. Coupler parameters are listed in Table 2.

Table 2: Coupler Requirements

Parameter	Value
Frequency	162.5 MHz
Operating power	75 kW
Coupling type	Loop
Output port diameter	~3"
Input impedance	50 Ohm

Coupler Structure

The PXIE RFQ power coupler includes all components necessary to transport up to 75kW (each) of RF power from a 50 Ohm source into the RFQ vacuum while maintaining the RFQ vacuum integrity.

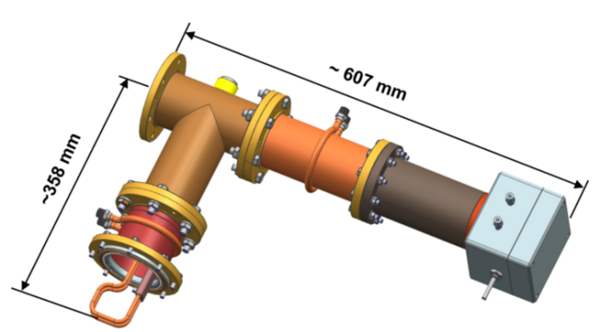

Figure 2: Overall dimensions of RFQ coupler.

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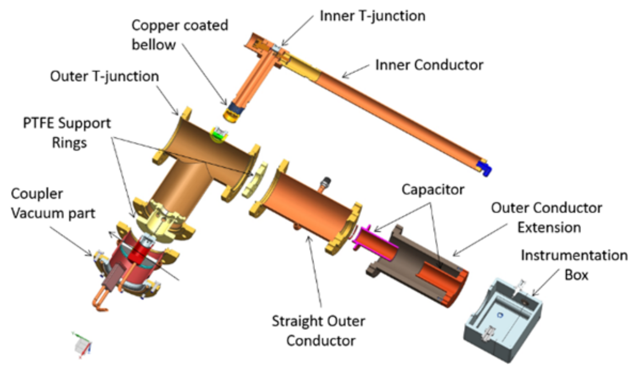

Figure 3: Internal structure of RFQ coupler.

Figures 2 and 3 presents a cross sectional view of the coupler, showing its overall dimensions and internal structure. Main parts of the RFQ coupler include: the vacuum part, T-junction, capacitor, and instrumentation box.

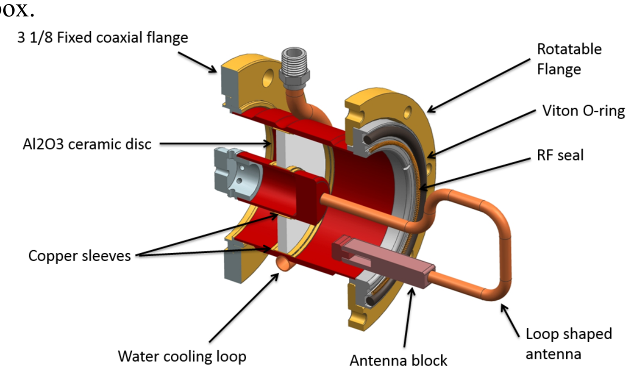

Figure 4: Main components of Coupler Vacuum part.

Figure 4 presents a cross-sectional view of the vacuum part of the coupler. The vacuum part of this coupler includes a loop-shaped antenna, which is brazed into a ceramic window. The window is connected to a copper outer conductor. On one side the conductor is attached to the RFQ by a rotatable flange. On the other side the conductor is connected to a T-junction with a 3 1/8 fixed coaxial flange. The copper hollow block of the loop-shaped antenna is connected to the inner conductor with two parallel 1/4" OD copper pipes. The cooling air flows through these pipes. The loop is electrically isolated. This allows passage of a high voltage (HV) bias to both, the inner conductor and loop antenna, to suppress multipacting. The ceramic window is made from a 77 mm outer diameter, 28.6 mm inner diameter, and 6 mm thick alumina disc. The outer conductor has dimensions of a standard 3-1/8" coaxial line. A rotatable 316 stainless steel flange provides electrical connectivity to the RFQ using a beryllium copper RF seals. Vacuum is sealed with Viton rubber O-rings.

The outer conductor has an additional water cooling loop, which is brazed to the outer surface in a close proximity to the location of the ceramic disk.

Difference between the Couplers on the Left and the Right Side of the RFQ

There are two types of the RFQ input couplers. They are differentiated by a 180 degree rotation of the coupling loop antenna relative to the water cooling loop. This design allows the RFQ input coupler water cooling connectors to face down on both sides of the RFQ, therefore avoiding interference with other RFQ cooling structures.

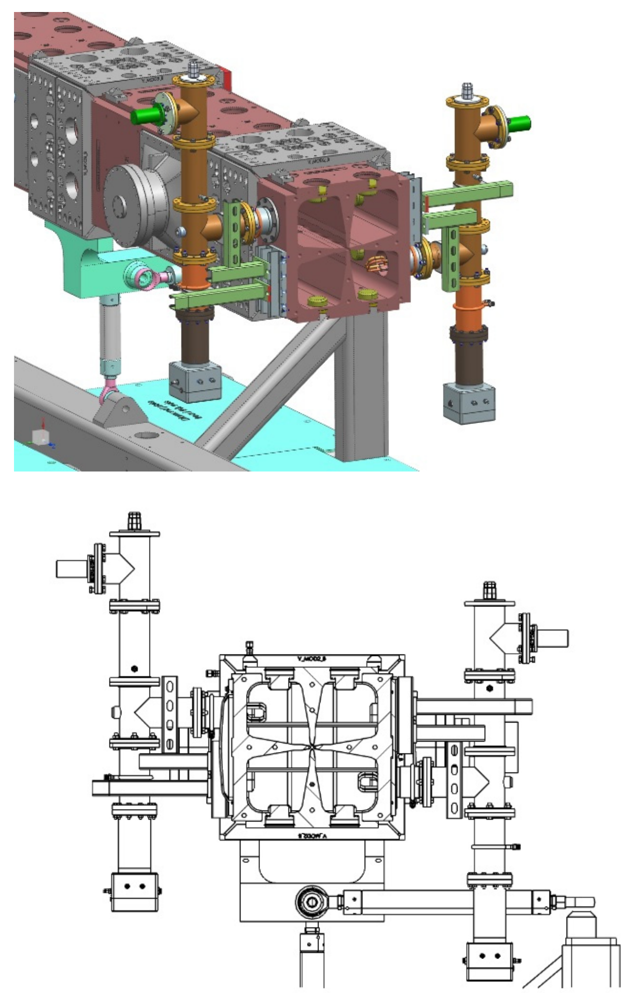

Figure 5: Left and right Couplers on RFQ.

Figure 5 shows two different couplers on both sides RFQ cavity.

The antenna loop can be rotated without changing orientation of the input port. This allows the coupler to be tuned to compensate for both simulation and manufacturing inaccuracies.

Antenna Shaping

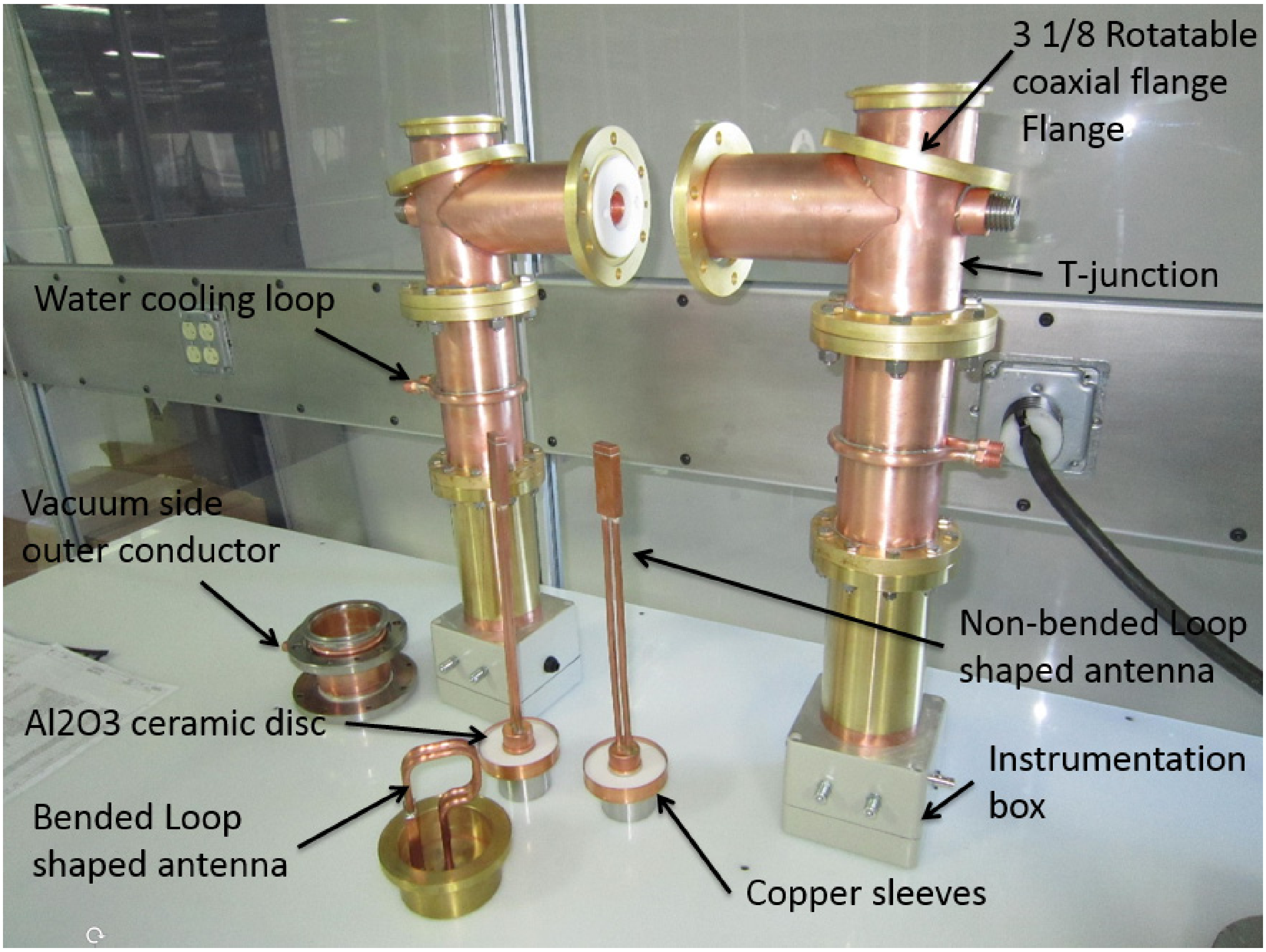

Figure 6: Couplers prepared for final brazing.

It is difficult to provide consistent titanium nitride coating to the vacuum side of ceramic disk when antenna is in the final shape. Therefor the decision was made to first braze the non-bended antenna, outer conductor and ceramic disk together. Then to coat the vacuum side of the ceramic disk with titanium nitride followed by bending the antenna into its required shape.

Figure 6 presents the main components of RFQ coupler prepared for the final brazing operation. You can see non-bended antennas brazed into ceramic disk with copper sleeves. Next to them you can see the outer conductor with a water cooling loop and mock-up of a loop shaped bended antenna.

All components of this vacuum unit are furnace brazed together. Therefore we use oxygen free copper and a 316 stainless steel materials for all parts, but the ceramic disk. The coupler will be connected to a larger size feed line through an adapter.

CONCLUSIONS

The main couplers for PXIE RFQ are designed and in the final stages of fabrication. The start of RF tests is planned for the October 2015.

REFERENCES

[1] S. Nagaitsev, et al, "PXIE: Project X Injector Experiment," IPAC'12, New Orleans, May 2012, THPPP058, p. 3874 (2012).

[2] D. Li et al, "Progress of the RFQ Accelerator for PXIE", THPME047, IPAC2013, Shanghai, China, May, 2013, p.3618.

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