RESULTS OF OPERATION OF 162.5 MHZ RFQ COUPLERS*

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Abstract

Two couplers for RFQ of PIP-II Injector Test facility were designed and manufactured. Each coupler is designed to deliver 70 KW, CW to RFQ at 162.5 MHz. First results of couplers' operation are reported.

INTRODUCTION

The PIP-II Injector Test is the prototype front end of the Proton Improvement Project II (PIP-II) linac beign developed at Fermilab. A key element of front end is a 162.5 MHz, continuous wave (CW), normal conducting, radiofrequency quadrupole (RFQ). This is RFQ designed to accelerate up to 10 mA H- ions beam from 30 keV to 2.1 MeV.[1] A photo of the RFQ in the beam line is presented in Fig. 1. The total RF power required for operation is less than 130 kW, CW or pulsed. RF power is delivered through two couplers placed at opposite sides of RFQ cavity. We describe first experience of coupler operation in this paper.

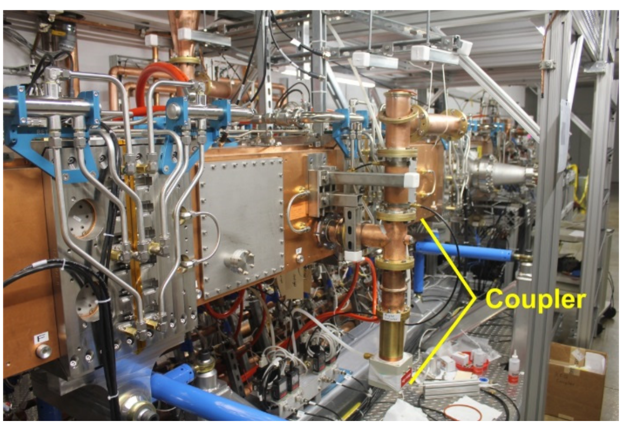

Figure 1: RFQ in test area.

COUPLER DESIGN

Coupler cut view is presented on the Fig. 2 and requirements are listed in Table 1.[2] Each coupler has one ceramic RF window made of alumina, with an outer diameter of 79 mm and inner diameter of 28.6 mm. The thickness of the ceramic is 6 mm. The end of the antenna loop is not grounded and allows a high voltage DC bias to suppress a multipactor. The coupler is designed to operate at 70 kW power level in continues wave (CW) mode and is cooled with forced air. Coupling can be adjusted by rotating the loop relative to the RFQ field.

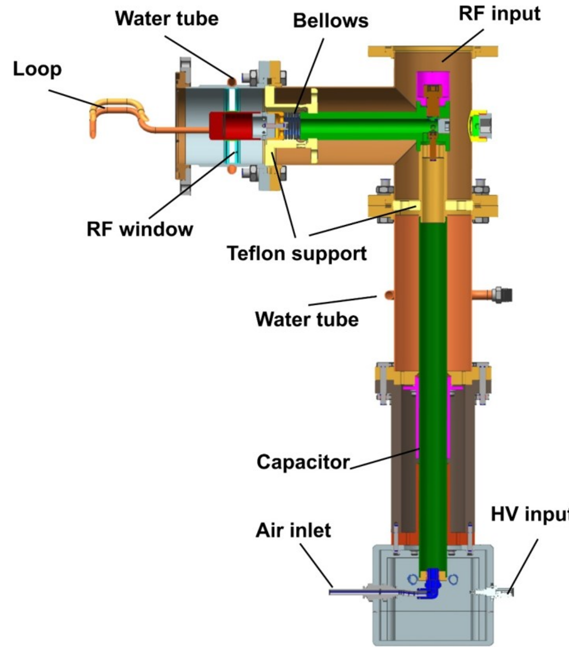

Figure 2: Cut view of RFQ coupler.

Table 1

Parameter	Value
Frequency	162.5 MHz
Operating power	70 kW
Coupling type	Loop
Input diameter	3-1/8 inch
Output port diameter	3-1/8 inch
Input impedance	50 Ohm

HISTORY OF OPERATION

Two couplers were installed in the RFQ cavity. Low power measurements confirmed computer simulations. The orientation angles of loops were close to 45^{O} with zero being orthogonal to beam direction as it was designed.

The first CW run occurred in May 2016. Conditioning began on the 4th of May followed shortly by an amplifier failure that occurred on May 6th. After the repair we continued CW operation for a week. Conditioning started at 17 kV (voltage between vanes) and continued up to 63 kV. We were able to achieve up to 65kV however more conditioning time would be needed in order to operate stably. CW operation was stopped in order to continue pulsed beam operations.

The next attempt to return to CW mode operation was made on August 24-25, 2016. During the conditioning, the behavior of "vacuum" was not as stable as the first run. Pressure bursts were observed periodically during power

* Operated by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the United States Department of Energy.
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ramping and increasing the RF field was much more difficult than during the previous run. Additionally, some bursts appeared even without RF power. We also noticed that the output temperature of the left coupler was considerably higher than the right coupler in addition to being higher than the temperatures observed during our May 2016 run. At some moment HV bias current was detected. It increased from burst to burst of pressure. Current can exist even without RF power at RFQ input. It indicated that some resistive deposition appeared at the surface of the ceramic. Resistance was < 1 MOhm (current was > 1mA with bias ~ 0.9 kV). Finally, the ceramic of left RF window was broken and operation stopped. Figure 3 presents the behaviors of main parameters of left coupler in last 5 hours of conditioning in CW mode.

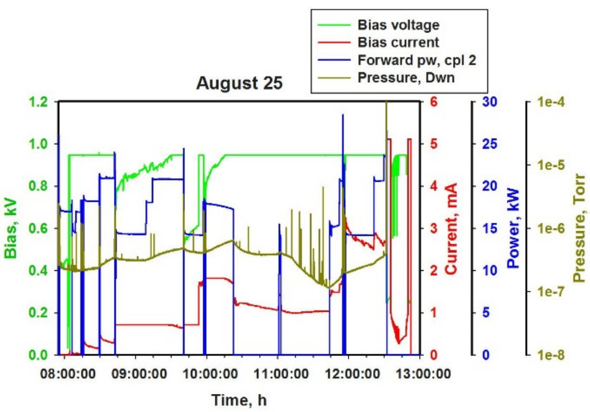

Figure 3: Left coupler. Last 5 hours of conditioning in CW mode. Bias current (red) increased from burst to burst of pressure. Current exist even without RF power (10:30-11:45).

Couplers were removed from the RFQ cavity, disassembled, and the ceramic windows were investigated. Just after disassembling, the resistance of ceramic windows (resistance between outer and inner conductors) were measured at 1 kV (voltage of bias). The broken window showed a resistance of about 700 MOhm, and the unbroken window's resistance was beyond the range of the meter. The total, measured resistance after disassembling was about three orders of magnitude higher than the resistance measured in vacuum. We think the resistance could increase after disassembling because of oxidizing of metal films at the ceramic surfaces. The ceramic surfaces, which were faced to vacuum, showed large areas of grey discoloration. These grey areas can be pure Ti from decomposition of TiN under bombardment from charged particles (electrons). Air sides of ceramics had no signs of discharge, damage or color change. Figure 4 shows the loop antenna after operation and Figure 5 shows the broken ceramics and radial crack in it.

It is not clear whether the crack in the ceramic is the results of multipactor overheating, lack of cooling, initial defect of brazing (window had small leak from the beginning), or some combination of all these reasons. Future tests will hopefully clarify this problem.

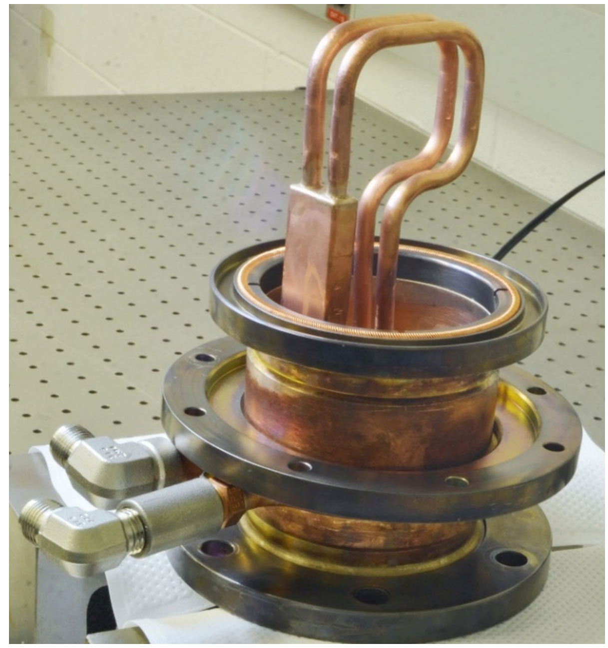

Figure 4: Loop antenna after operation.

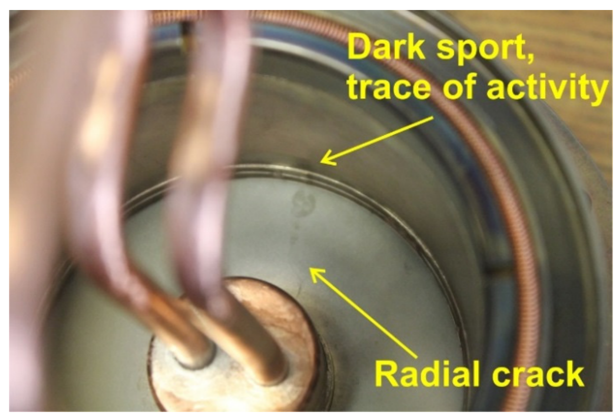

Figure 5: Cracked ceramic of left coupler.

NEW CONFIGURATION

The left coupler failure gives us opportunity to change configuration. The antenna with the broken ceramic window was replaced with new one, and 18 mm spacers were placed between couplers and RFQ body. This reduces coupling and makes the new loop orientations perpendicular to the beamaxis. The new coupler positions and orientations will reduce ohmic losses in the loops by about 15%. Airflow through the antennas will be increased. The new configuration will provide ~ 2g/s of airflow to each coupler (previous configuration provided a maximum flow rate ~ 1g/s to each coupler). Couplers are under test now.

REFERENCES

[1] S. Virostek *et al.*, "Final Design of a CW Radio-Frequency Quadrupole (RFQ) for the Project X Injector Experiment (PXIE)", in *Proc. NAPAC'13*, Pasadena, CA, USA, 2013, p. 1025.

[2] S. Kazakov *et al.*, "Design of RFQ Coupler for PXIE project", in *Proc. IPAC'13*, Shanghai, China, May 2013, WEPFI070, p. 2854.

ISBN 978-3-95450-169-4