

Testing of PIP-II pre-production 650 MHz couplers in warm test stand and in cryomodule

N.Solyak[†], S. Chandrasekaran, S.Kazakov, B.Hanna, J.Helsper, J.Ozelis, A.Sukhanov

FNAL, Batavia, IL 60510, USA

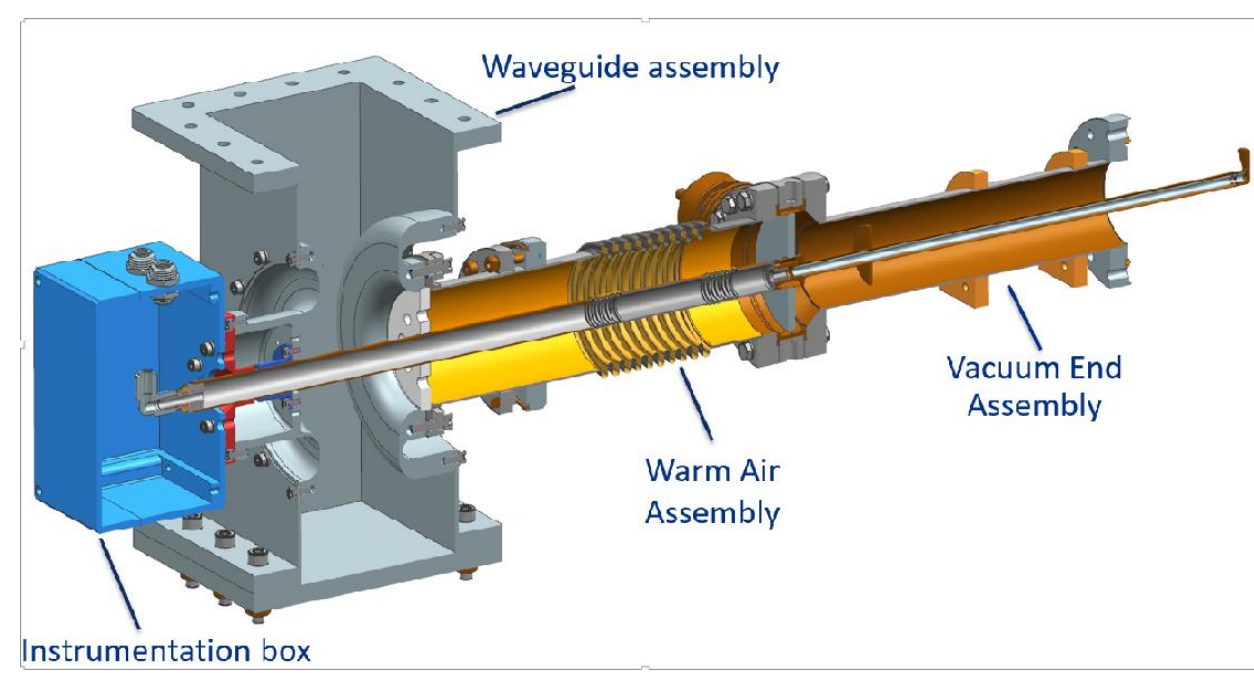


WEPWB096

ABSTRACT

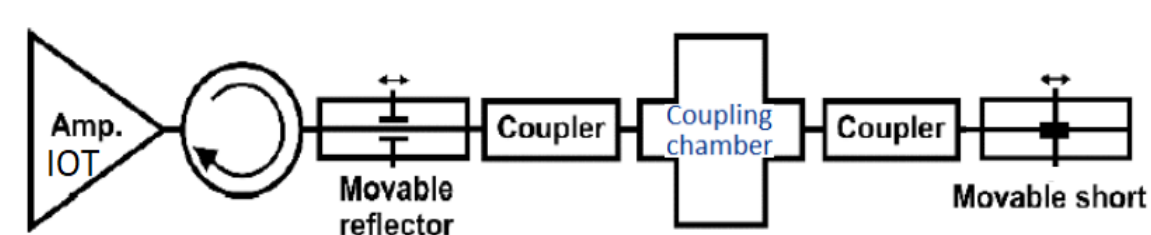
650 MHz fundamental power couplers were developed for PIP-II project to deliver RF power for low-beta and high-beta elliptical cavities. Few prototypes were built and tested and after some modification we built 8 pre-production couplers (with few spares for vacuum side) for HB650 cryomodule. All couplers were successfully tested in pulse mode (up to 100kW) and in CW mode (up to 50kW) in test stand at full reflection at 8 phases. In baseline configuration with DC bias we do not see any multipactoring activity after short processing. We also tested power processing without bias for uncoated and TiN coated ceramic window. Results of these studies presented in this paper. One of the coupler was assembled on LB650 cavity and tested at cryogenic environment in STC cryostat at ~20kW power with full reflection at different reflection phase. We also demonstrated good result from power processing without bias for warm and cold cavity. Six couplers were assembled on HB650 cavities in pre-production cryomodule. Test results from cryomodule qualification is discussing in this paper.

COUPLER RF POWER PROCESSING

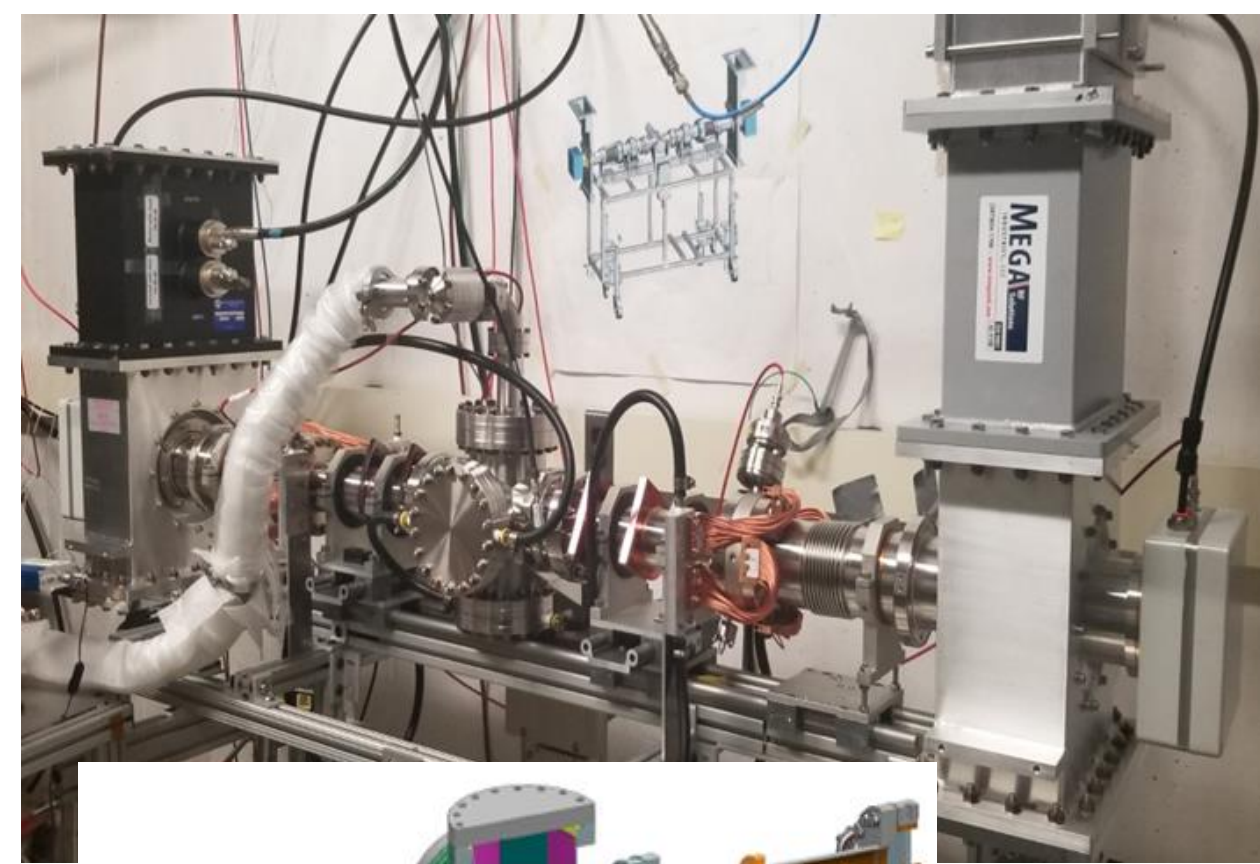


Mechanical design of the pre-production 650MHz coupler. Canon built 11 vacuum assemblies and 8 warm air assemblies:

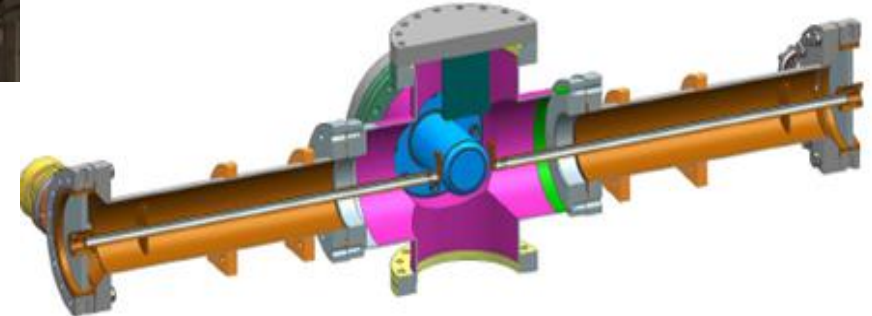
- 10 couplers were tested at RT test stand,
- six of them assembled in ppHB650 and tested
- One tested in STC with LB650 cavity.



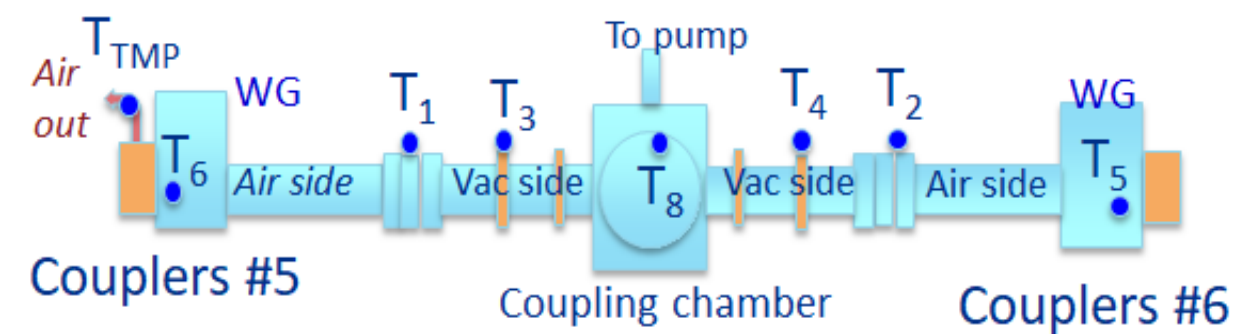
Schematic of RF system in coupler test stand. Resonance conditions between movable reflector and short create allow to get >100kW in SW, using 30kW IOT (gain x (4-6))



Two couplers assembled in test stand. Vacuum coupling chamber (middle) provides capacitive coupling of antennas. Each vacuum part of the coupler have pick-up and vacuum gauge to use for MP diagnostics and RF amplitude near window. Coupler antennas and windows cooled by air flow, copper braids remove heat from window, water cooled sink is modeling CM conditions.



Temperature diagnostics:
We measure temperatures of coupling chamber, window flange, 50K intercept, waveguides and air temperature at the exit of coupler.



Couplers tested in SW regime for 8 reflection phase. For each phase position of short and reflector change to keep system in resonance.

Typical Testing Conditions:

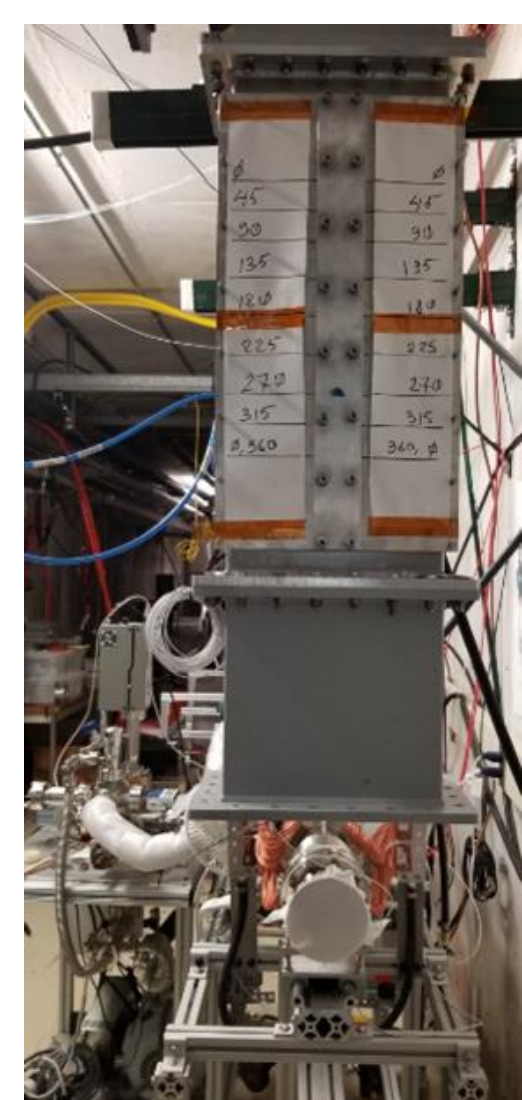
- DC bias 4.5kV on inner conductor (each coupler) - interlock
- Air flow rate 13 SCFM (7.4 g/s) – each antenna - interlock
- Water flow rate - interlock
- Vacuum gauges (both coupler). - interlock 2.E-6 Torr
- Temperature interlocks: T<140F (60K) on ceramic window flange
- Final vacuum after processing <1.e-7 Torr

Short summary of the testing protocol:

- Start with pulse mode: 10, 20, 50, 100, 200, 500 ms: power ramp up to 100kW,
- Switch to CW mode, power up to 50kW, Stay: 1-2hrs to reach equilibrium temp
- In HP tests the power ramping steps were controlled manually to keep vacuum below interlock level (will be automated, script exist and used in earlier tests)

Test without HV bias (coupler#11)

Start with shorter pulses: 10,20,50,100,200,500µs; 1,2,5,10,20,...200,500ms and ramping power up to 100kW. In cw regime max power 50 kW.

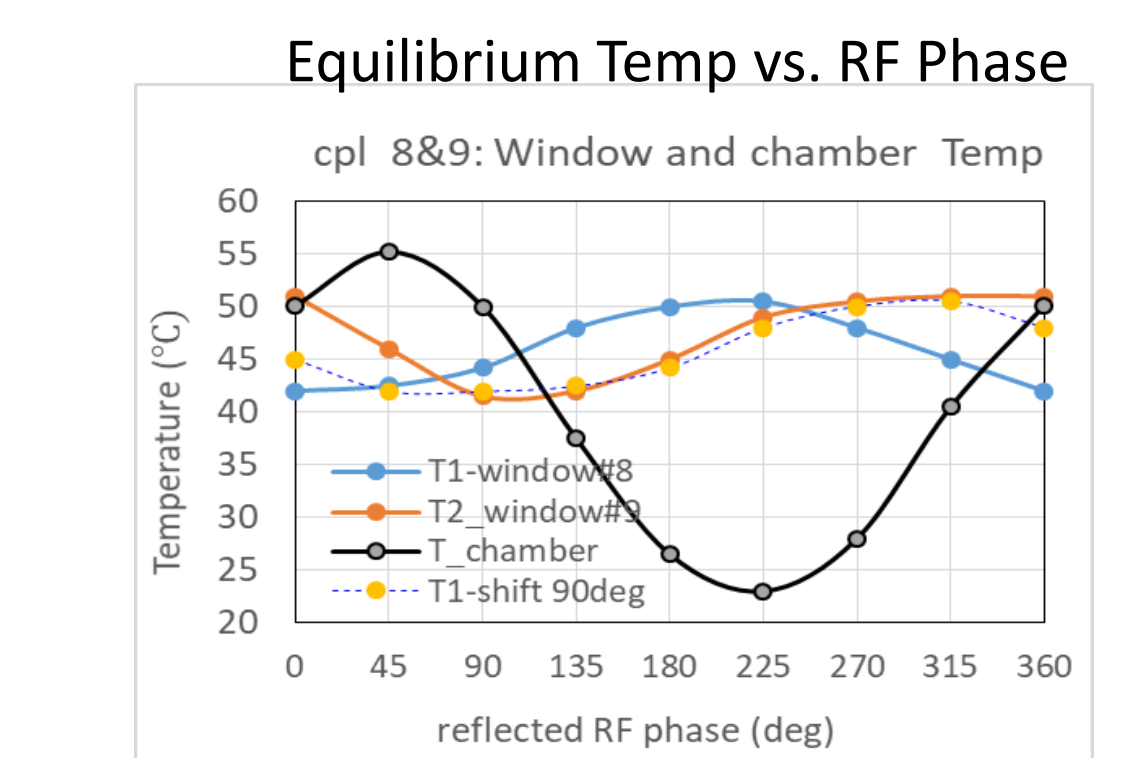
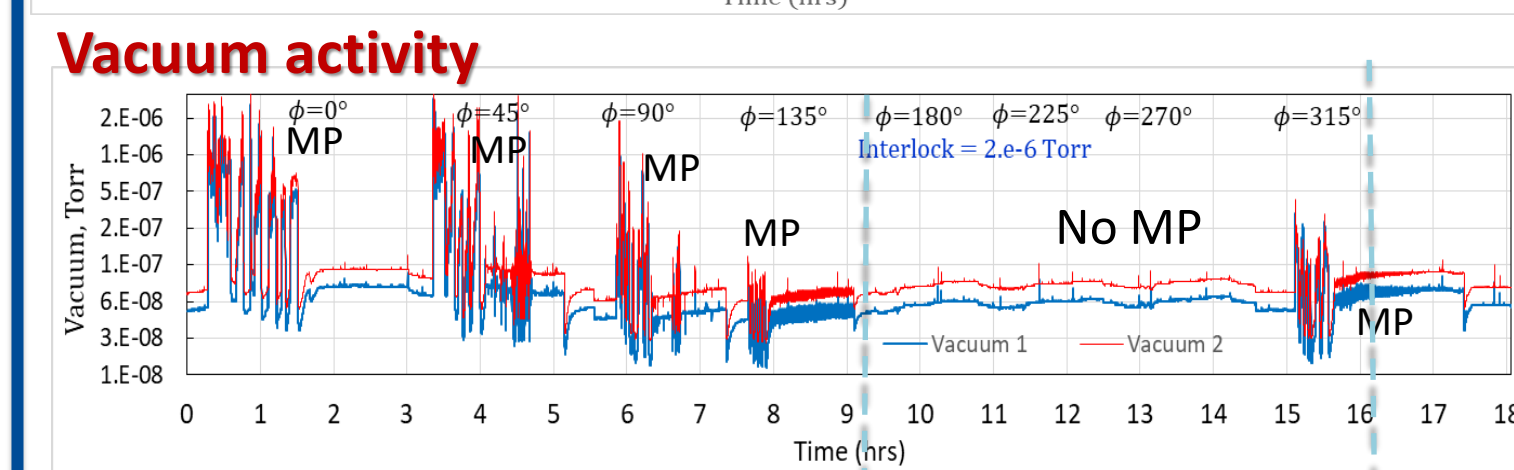
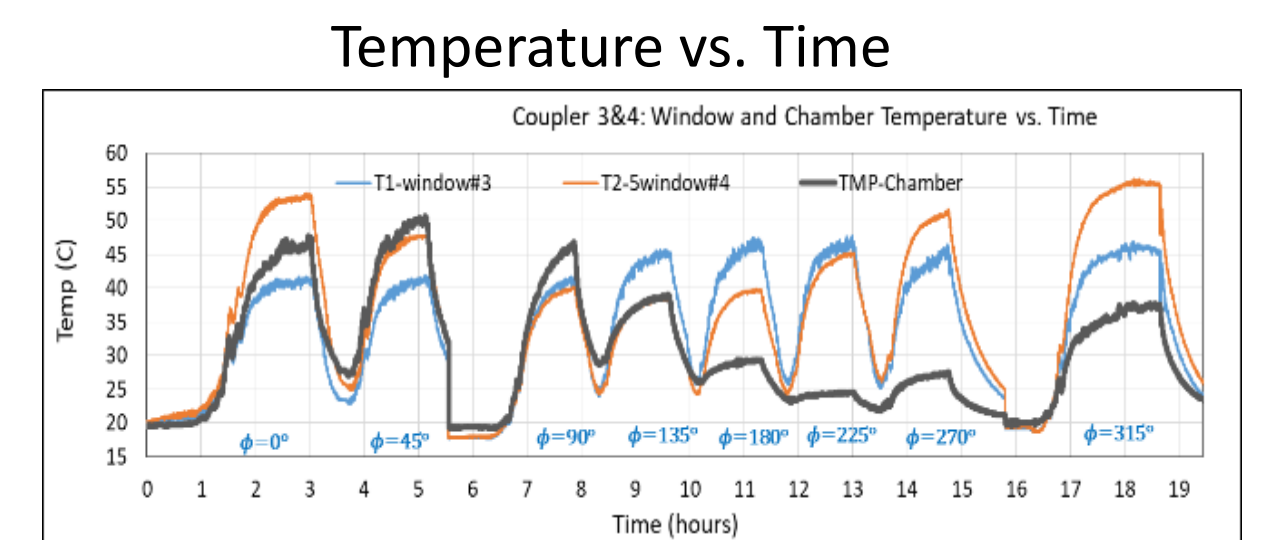
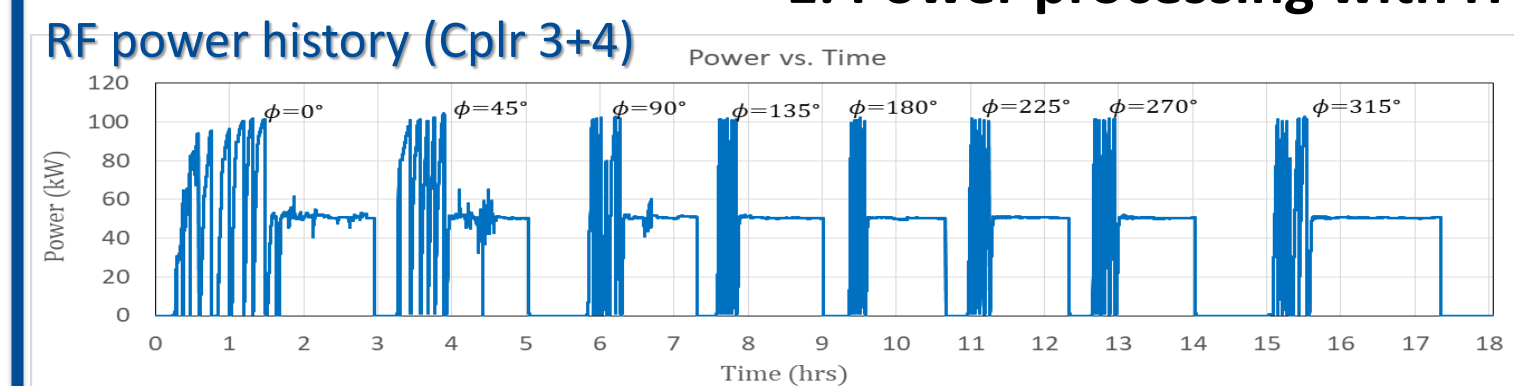


Proton Improvement Plan-II



TEST RESULTS

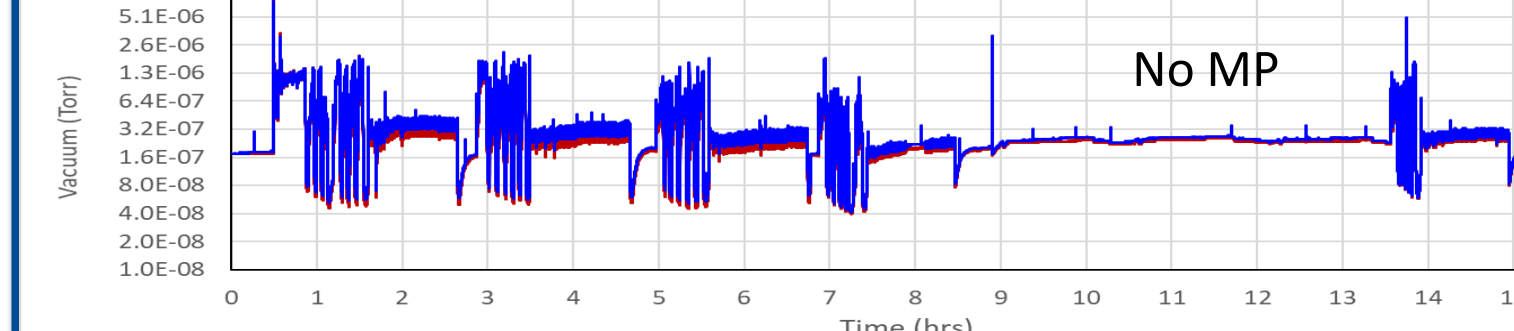
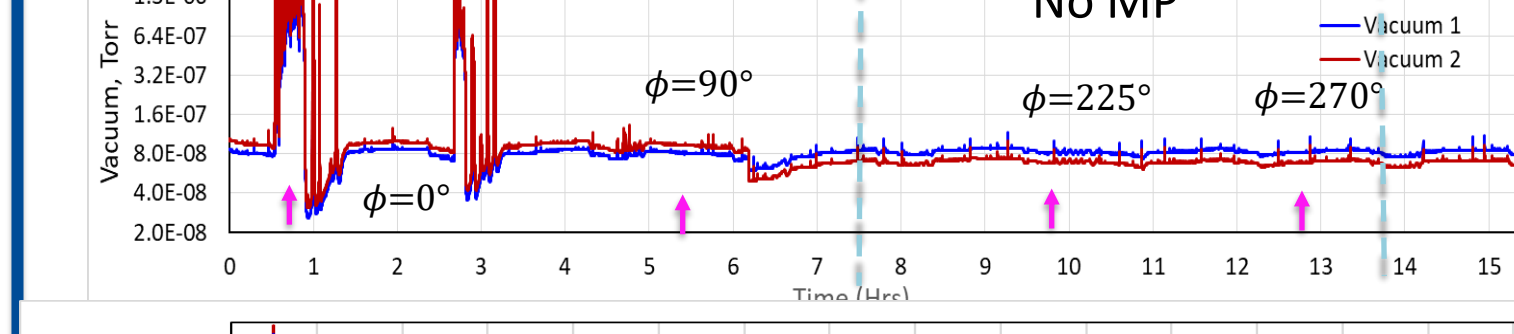
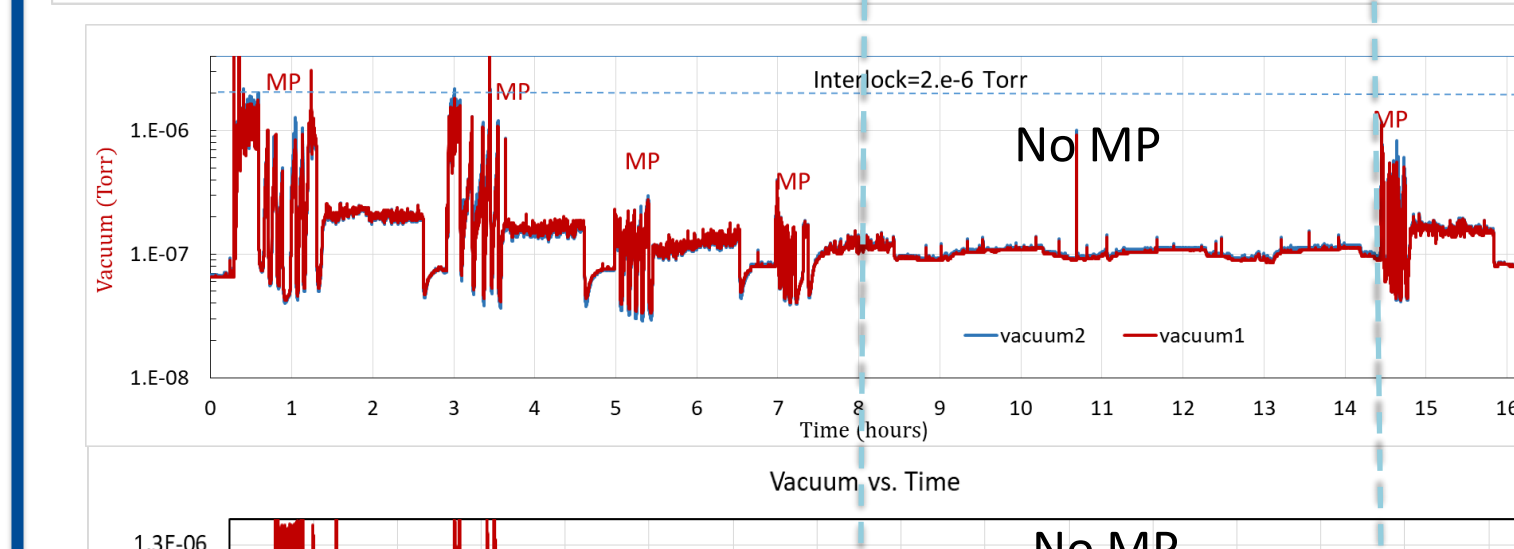
1. Power processing with HV bias (no TiN coating)



Conclusion: All couplers with DC bias met specification requirements. No MP activity up to 50kW CW, full reflection

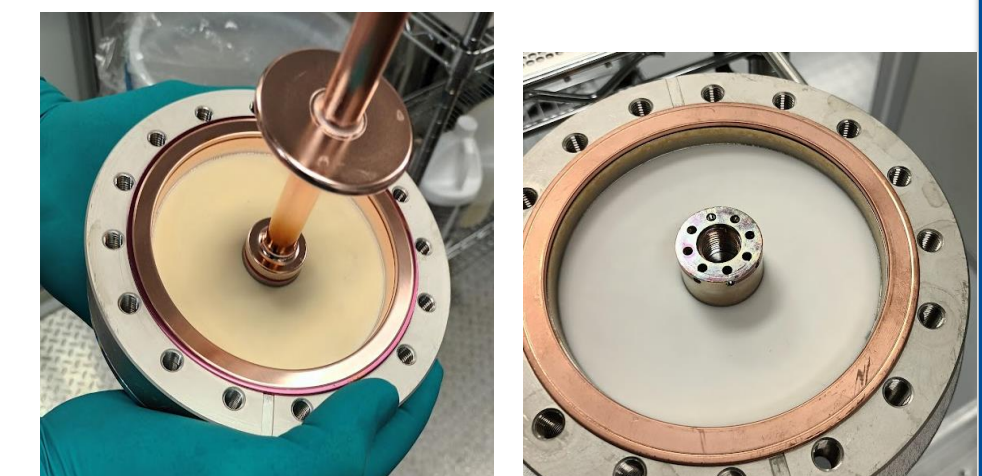
Next test:

TiN coated couplers #7 and #11 re-tested with and w/o bias. Both coupling chambers baked 400C to reduce outgassing and suppress MP.



2. Power processing w/o HV bias (no TiN coating) – couplers 10&11

In pair 10 & 11 coupler 11 was also tested without HV bias for two “bad” phases 0° and 90° and two “good” phases: 225° and 270°. For good phases processing was successfully done in pulse mode up to 100kW and in CW mode up to 50kW. For “bad” phases processing was much more difficult. We achieved 30kW at CW regime after more than 30 hours processing in each bad phase. After processing vacuum part of ceramic was changed color to yellowish.



Vacuum (left) and air side of ceramic (right) after processing w/o HV bias

3. Coupler testing in Spoke Test Cryostat (STC)

One coupler (#8) was assembled on LB650 cavity and tested at STC at warm and cold condition at 28 kW available power. Test result can be summarized as the following:

- With 4.5kV DC bias: no MP activity up to 28kW CW, full reflection (cav ON/OFF resonance)
- Without DC bias:
 - cavity at room temperature; no MP w/o bias
 - Cold cavity OFF resonance: pulses 10Hz (0.01...500ms) and CW-mode up to 28kW; No MP activity after minor processing
 - Cold cavity ON resonance: Pulses 10 Hz (0.01...19ms) up to 28kW. No MP
 - Cold cavity detuned (phase +/- 45°); Pulses (0.01...5ms), 28kW. No MP

Coupler performance in ppHB650 cryomodule

After qualification tests six power couplers were assembled on cavities and installed in ppHB650 cryomodule for testing at cryogenic temperature [5]. To keep temperature of the window flange always above freezing point a few heaters on flange and 4 copper straps are installed between flange and cryostat vessel. Without RF power in coupler the heater power was set to ~15 Watts when cooling air flowing, and ~20 Watts when no cooling air.

All couplers were tested with 4.5kV DC bias at maximum available power 37 kW CW at full reflection (cavity OFF resonance). Air flow kept at ~4 scfm when no RF and ~8.5 scfm when RF. In tests we never saw any MP activity on the cold cathode gauges, no e-probe signals.

SUMMARY

- Couplers 1&2; 3&4; 5&6 8&9 and 10&11 were tested successfully at the test stand with the bias, no MP up to 50kW cw after processing. Pulse processing >50kW helps to clean surface. MP configurations: (phase 0, 45, 90, 135, 315)
- Window flange temperature not exceeds 60°C (stress limitation for ~0.1 Mcycles) for 50kW CW. For operation conditions: P<30kW, air flow 5g/s, expected flange temp < 45°C
- HP processing w/o bias is possible and useful for surface cleaning. HP processing procedure need to be optimized to protect ceramic from contamination: Reduce power to 30kW, eliminate regimes where MP located in window, better baking of chamber and couplers. TiN coating of ceramic may help.
- First STC test of LB650 cavity with coupler is done. Coupler works well up to 30kW available power.
- Six couplers tested in ppHB650 cryomodule, No MP activity, overheating. Studies will continue.

Work supported by Fermi Research Alliance, LLC under Contract No. DEAC02-07CH11359 with the United States Department of Energy



Fermi National Accelerator Laboratory

