MICE RF Module Update

MICE CM42 at RAL, UK

June 22, 2015

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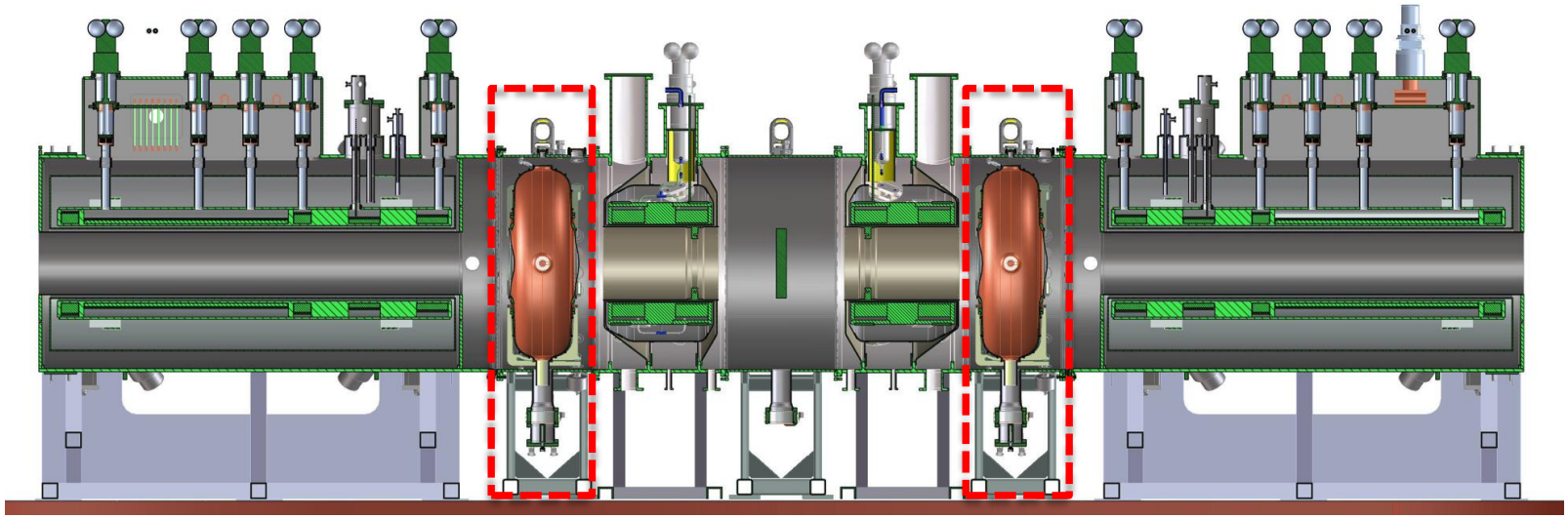
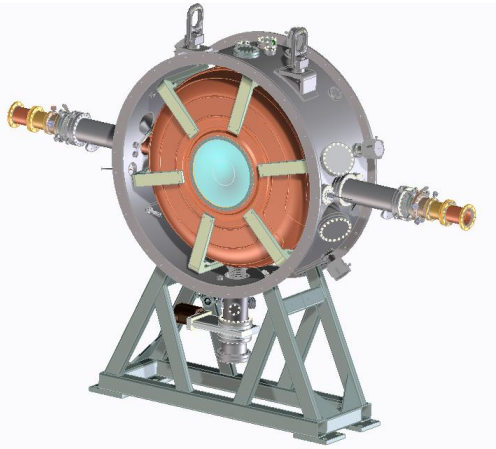
Re-baseline MICE Cooling Channel



- **New MICE cooling channel needs two RF modules**
- **Each MICE RF module has**
  - One 201 MHz RF cavity
  - Two Beryllium windows
  - Two RF power couplers
  - One vacuum vessel hosting the 201 MHz RF cavity
  - Six tuner arms and six actuators
  - Cavity support struts
  - Vacuum pump system and water cooling
  - Diagnostics and bypass lines



Current Status of MICE RF Module

- **Recent MICE 201 MHz RF cavity testing at MTA exceeded/reached required RF gradient**
  - 1.8 MW power in the cavity
  - 3M pulses, no sparks observed
  - Testing with Be windows and external magnetic field
  - High power testing with tuners
- Vacuum vessel nearly ready for fabrication
  - Two design reviews held in the end of January and April 30 & May 1, 2015, respectively
  - Update design and drawing package done
  - RFQ of the RFM vacuum vessel (~ 3 weeks)
- 201 MHz RF cavities ready
  - Four cavities (two spares) EPed completed at LBNL

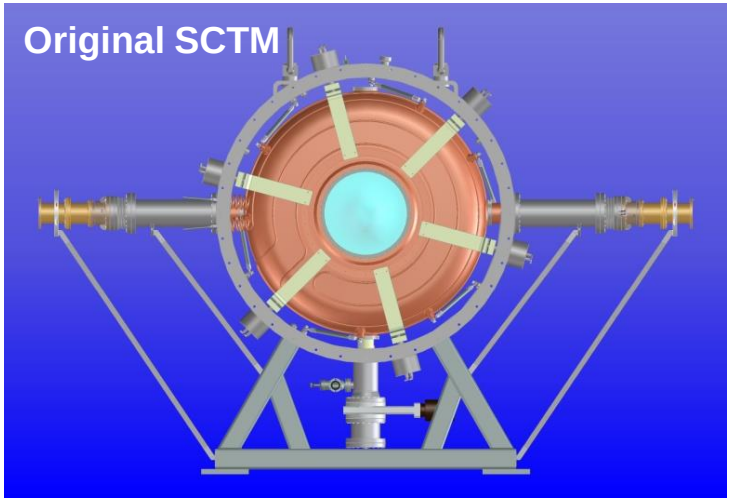
Current Status of MICE RF Module

- RF power coupler fabrication started
  - Updated design to address issues identified at MTA assembly
  - Ceramic RF windows ready and materials ordered
  - Fabrication schedule developed: estimated delivery of the RF couplers ~ end of September 2015
- New tuner actuator design and prototype
  - Functional testing complete
  - Lifetime testing complete
  - Production of the actuators will begin soon
- 25 tuner arms being shipped from University of Miss. to LBNL: will show up at LBNL anytime
- Be windows ready (we have 10 windows!)
  - Will explore the possibility for a destruction test at Materion in Fremont

- **Vacuum system design (protection of Be windows) evolving**
  - Close collaboration with MICE team at RAL, coordinated by Mr. Terry Anderson at Fermilab

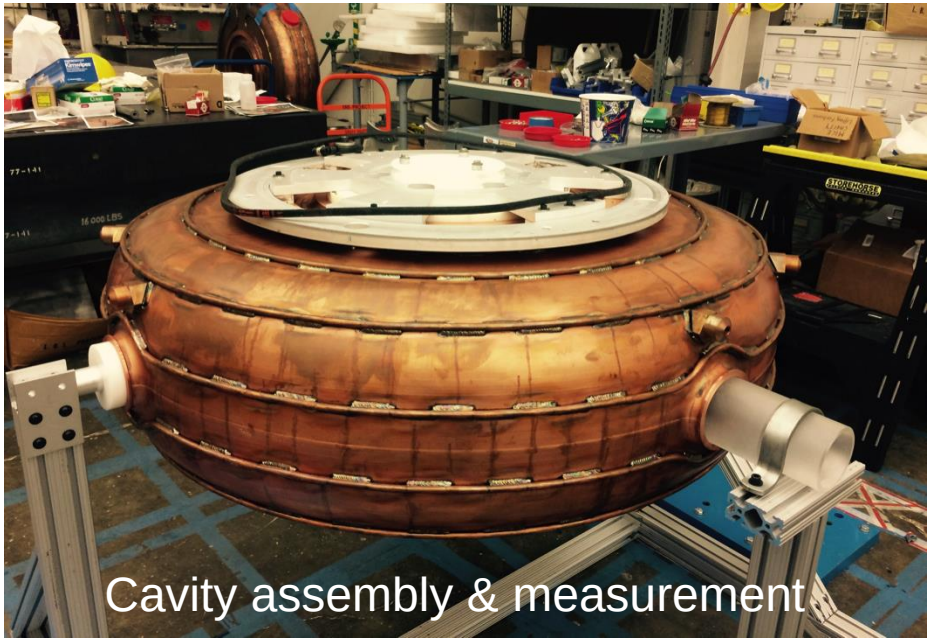
The RF Module

- MICE RF module (RFM) is very similar to the single cavity test module (SCTM) that has been tested under high power RF at MTA, FNAL
  - Integration into MICE cooling channel, including vacuum system, still remains
- Necessary improvement and modification to the RFM & components design made to address issues and experience learned from SCTM at MTA
  - Vacuum issues
    - Modification to the vessel design
    - RF coupler
    - Actuator design
    - Vacuum port and bypass lines
    - Water cooling lines



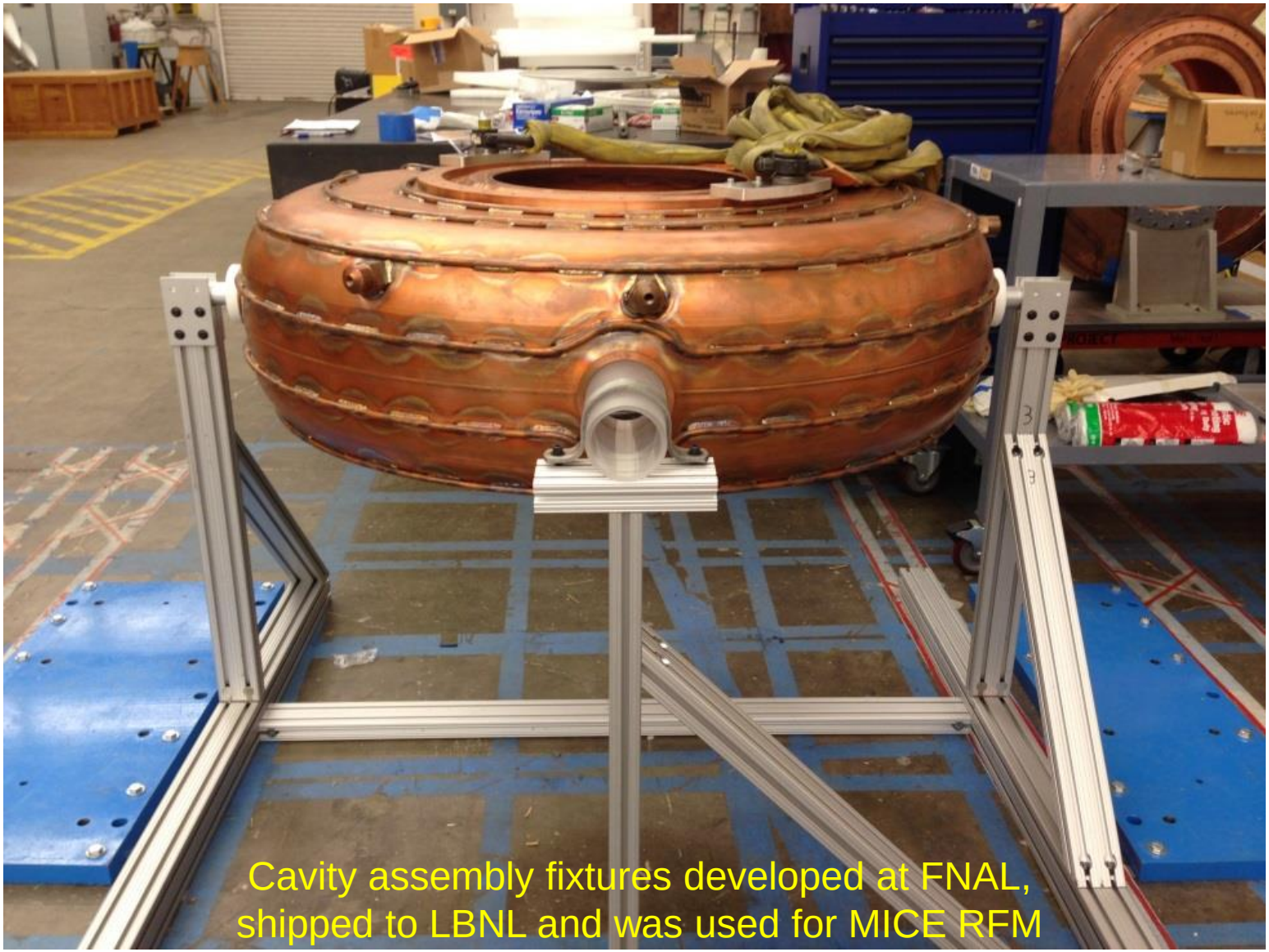
MICE RF Cavity

- Selected four best cavities (two spares) from nine cavity bodies based on inner surface finish & frequency measurements of the cavity bodies with Be windows
- Four cavities have been selected for electro-polished (EP) and completed
- Ten beryllium windows available

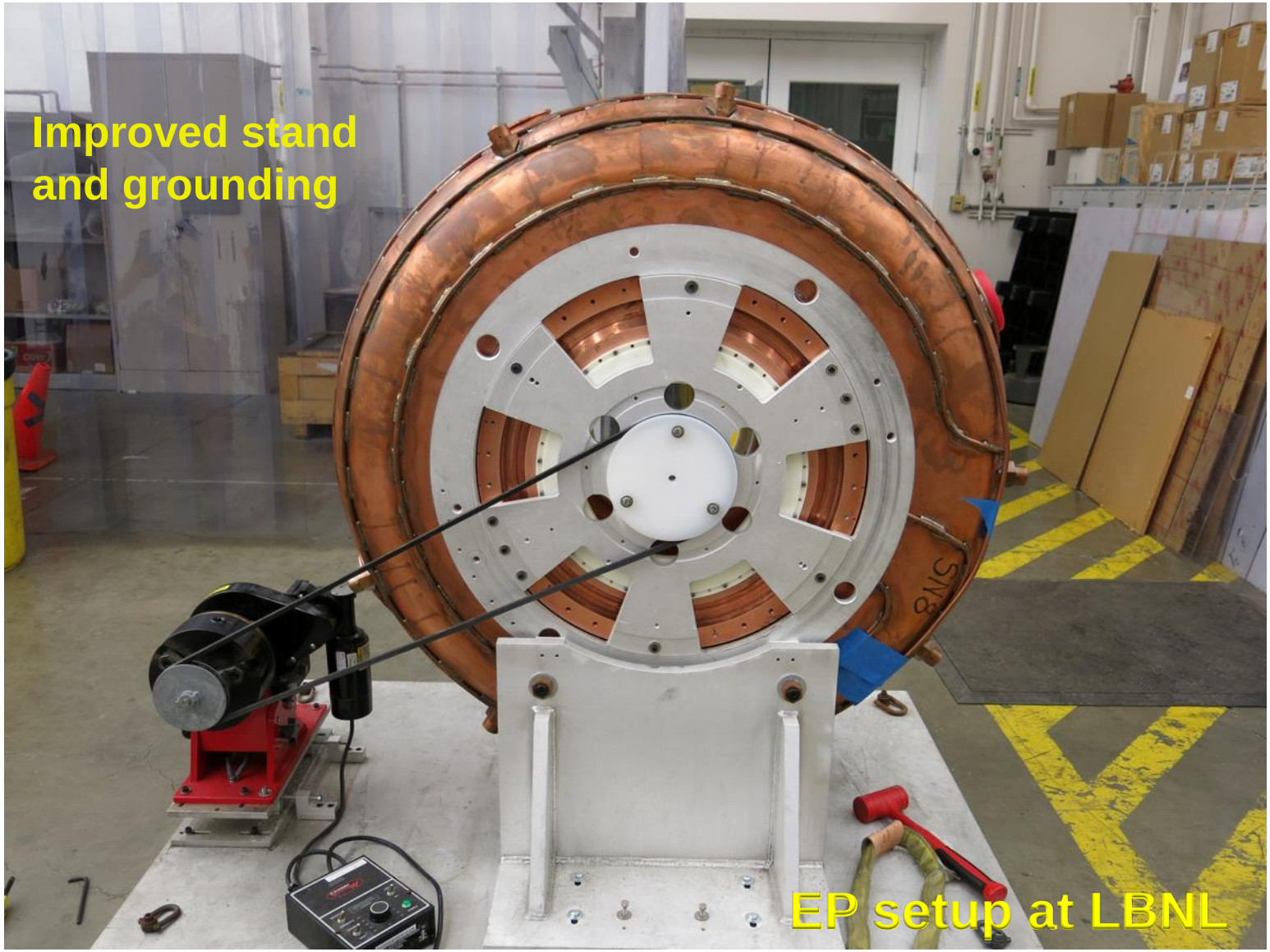

Cavity assembly & measurement


EP setup at LBNL

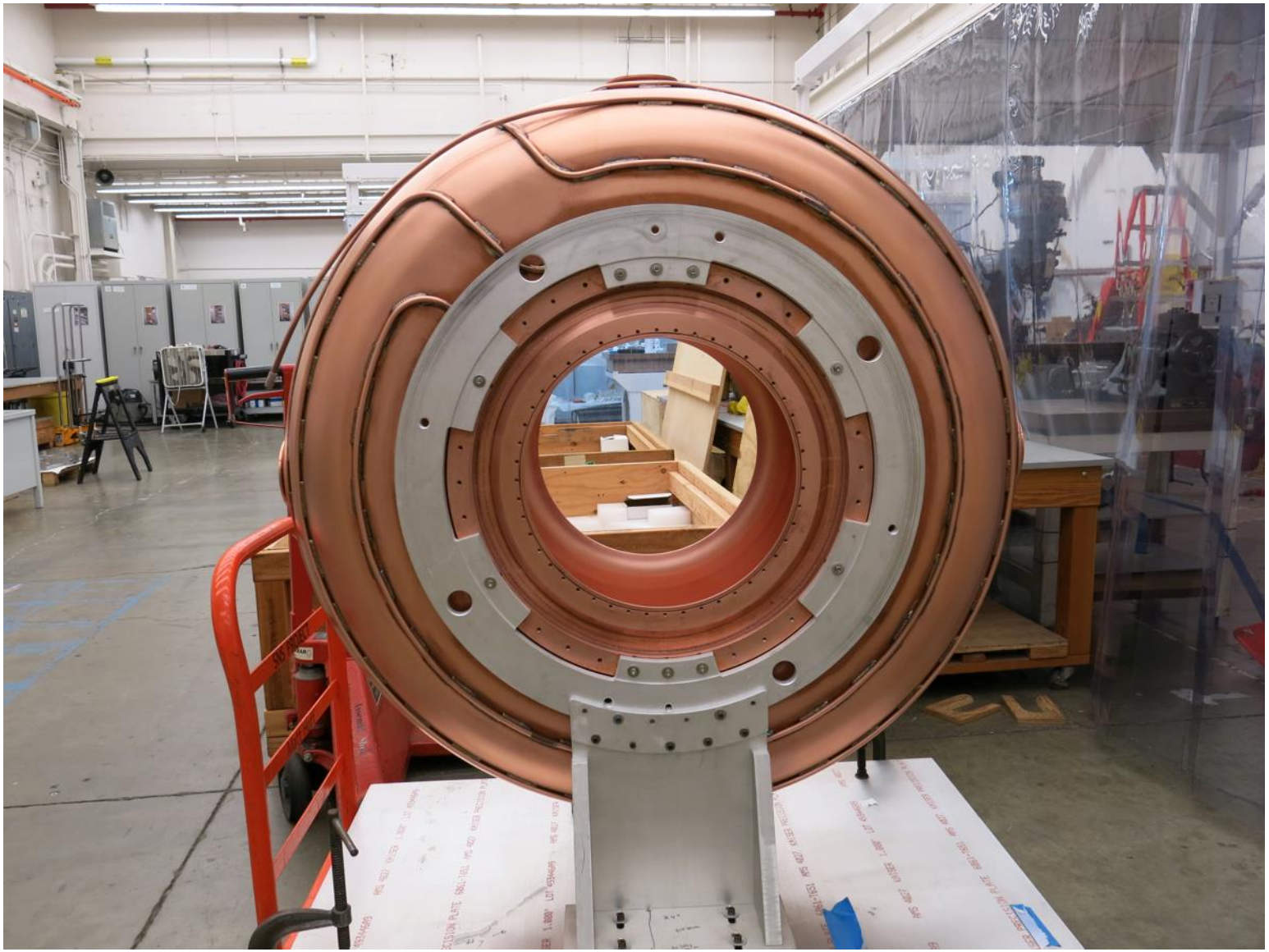
RF Cavity Fixtures



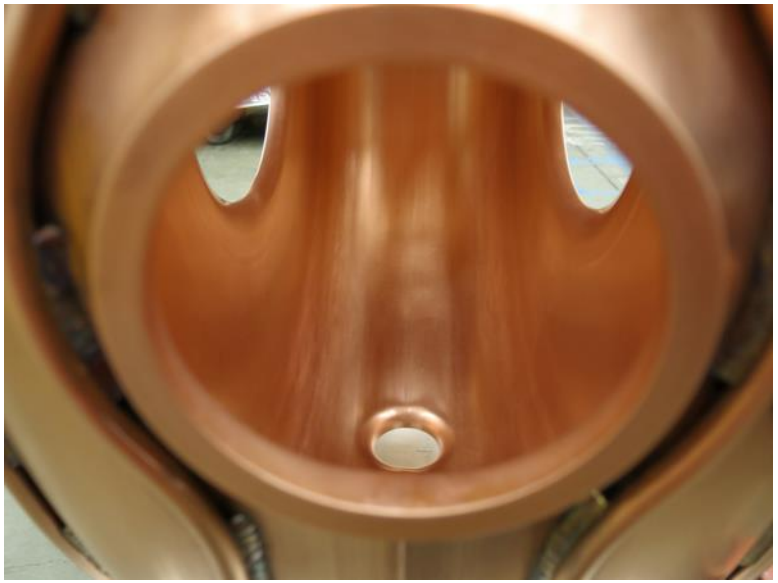
EP Setup at LBNL



The First EPed MICE Production Cavity



Images of Cavity Inner Surface



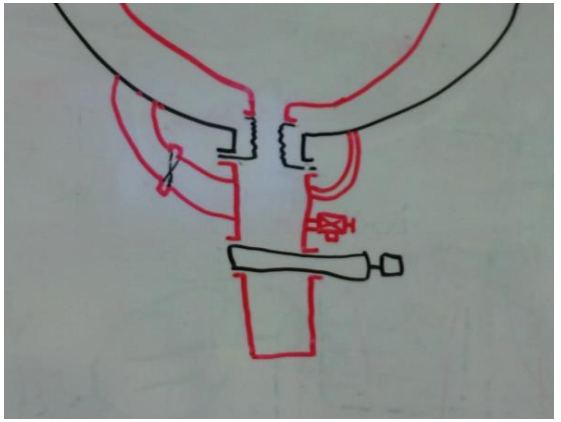
Inner surface finish of the first EPed MICE production cavity at LBNL
(photo taken on 2/21/2015)

Summary of MICE RF Cavities

- Cavity (with beryllium windows) selection complete
  - Four cavities selected (two spares)
  - In combination with different Be windows, additional ~ 100 kHz frequency tuning range
- EP of the four cavities complete and are ready for assembly in early FY16
- RF power coupler design updated
  - Interface with cavity re-designed for easier assembly/tuning
  - Cooling tube slot cover plate to be silver soldered for isolate the cavity vacuum
  - Materials and parts received/ordered
  - Fabrication schedule developed: ~ end of September 2015
  - TiN coating work has begun on the inner surface of the outer coax tube
- Production of actuators
  - Prototype lifetime testing is complete
  - Fabrication starts soon

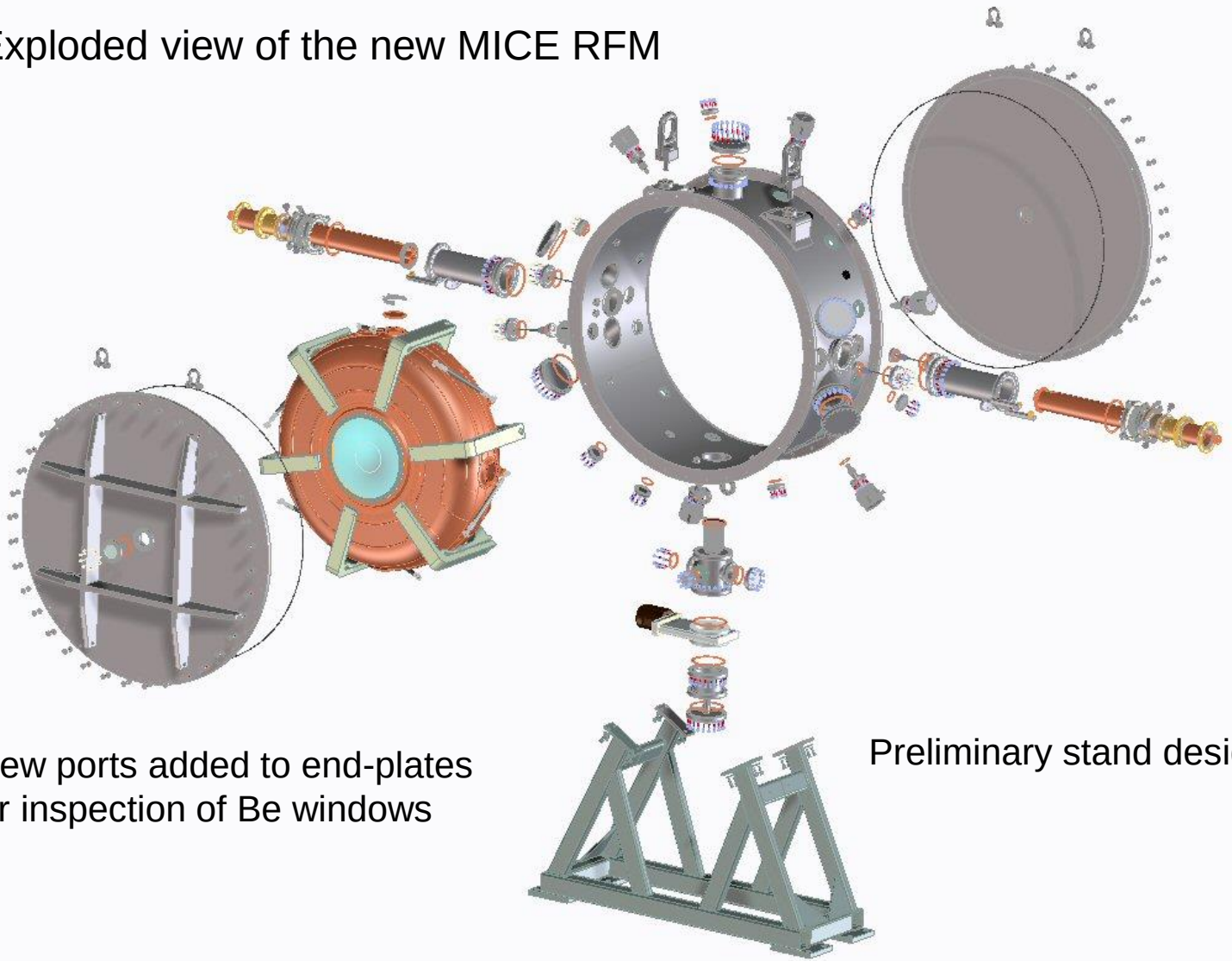
Brief Summary Of Vacuum Vessel Design

- First RFM Vacuum Vessel conceptual design review held at LBNL on Jan. 27-28, 2015
- Second RFM Vacuum Vessel Fabrication Readiness Review held at LBNL on April 30 and May 2015
- **Design requirements/goals**
  - Good vacuum inside RF cavity ~ 10^{-8} Torr
  - Minimal differential force on the beryllium windows
  - Exterior vacuum connecting to the rest of MICE cooling channel with base pressure of ~ 1-3 x 10^{-6} Torr
- **Summary of the new vacuum vessel design**
  - Update of vacuum system calculations
  - Isolate cavity vacuum from the external channel
  - Direct cavity port-pump connection with bellows
  - By pass lines or burst disc/pressure valve to protect Be windows still needs work (cross spool piece in the model – vacuum vessel unaffected)
  - Design complete and ready to produce fabrication drawings



New Vacuum Vessel Design

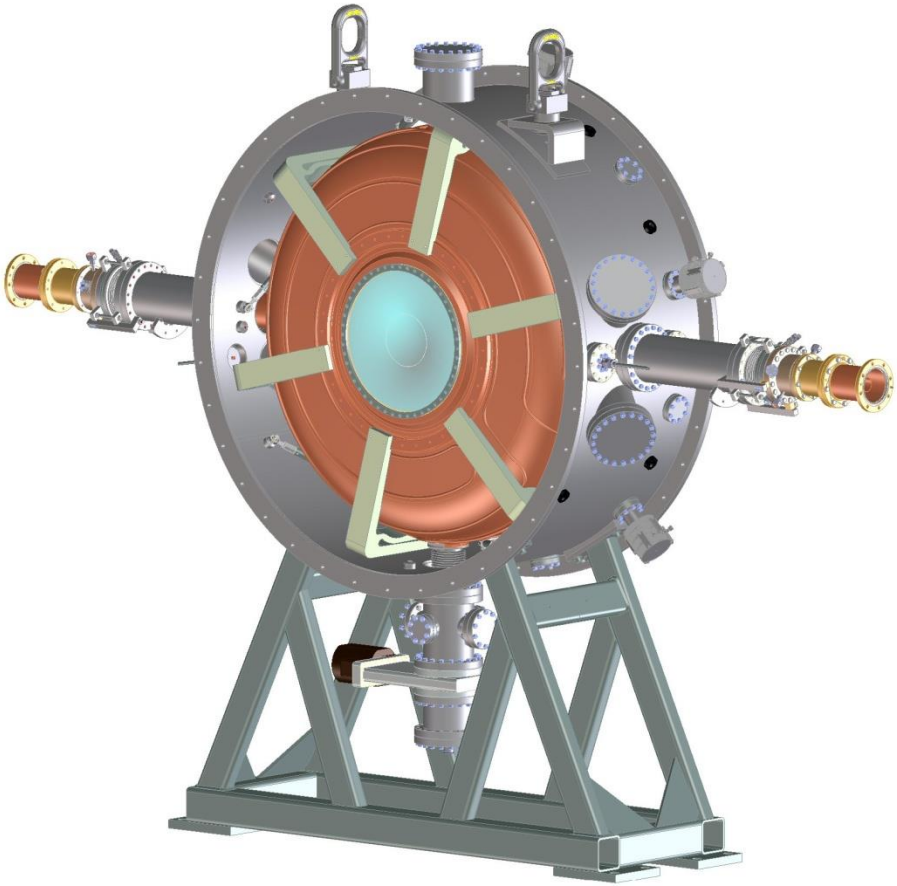
Exploded view of the new MICE RFM



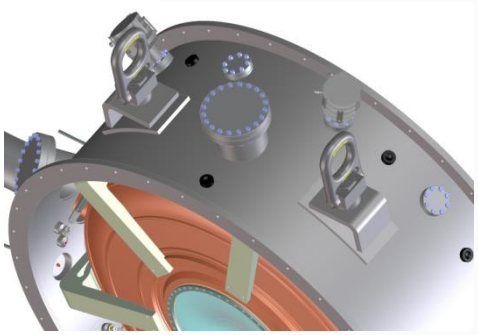
View ports added to end-plates
for inspection of Be windows

Preliminary stand design

The Vacuum Vessel Design



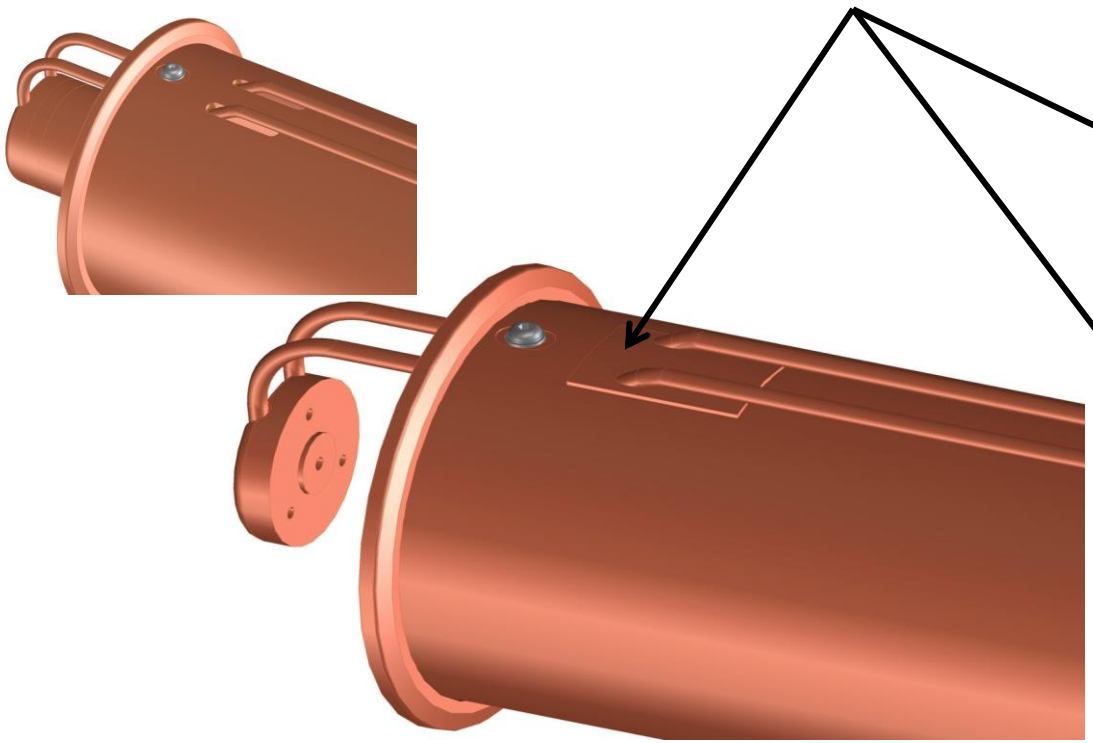
Sectional View of the Vessel

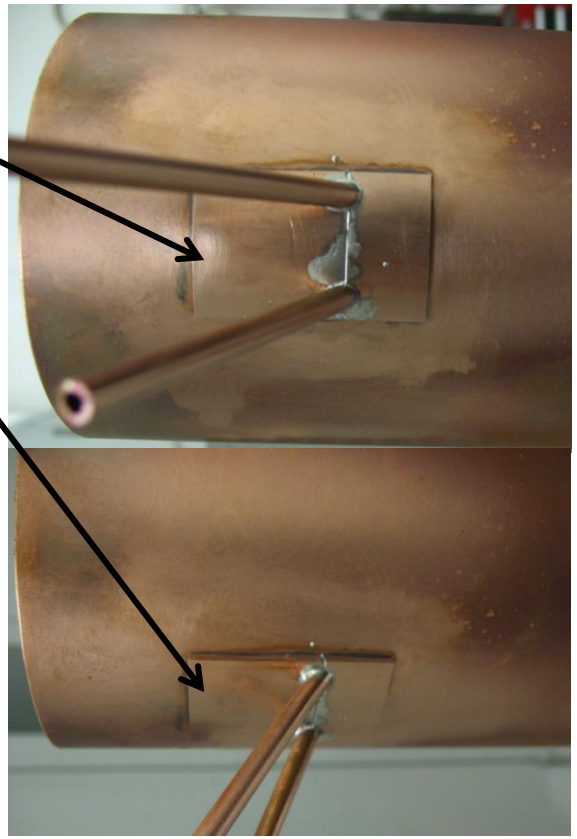


Top port for diagnostics, possibly extra pumping if needed; it will be an 8” bore port

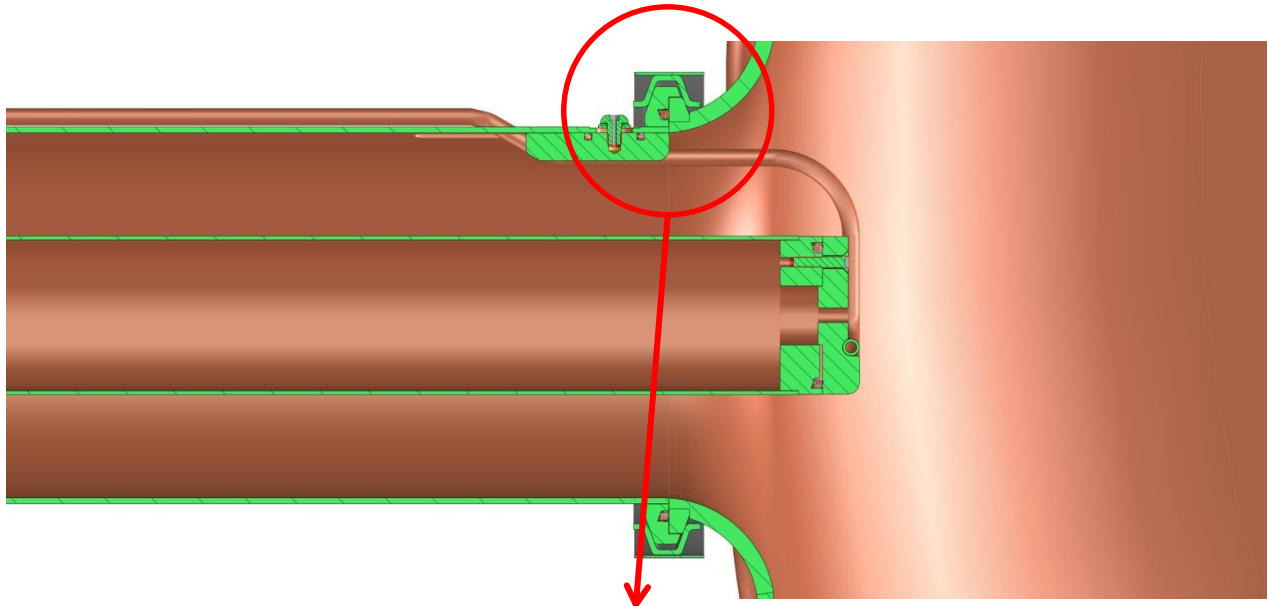
RF Coupler Modification (cont'd)

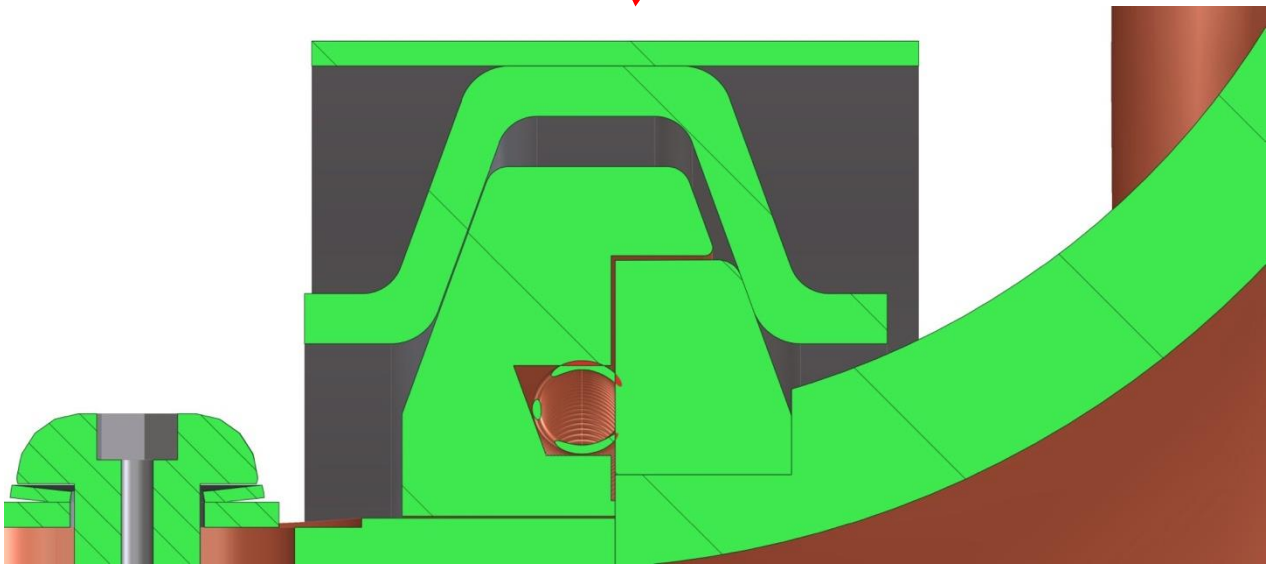
- Once the cooling tubes are in their final position the slot cover plates are pushed into their final position
- The coax tube is preheated and the plates are silver soldered to the coax tube with a reflow process
- Test assembly complete ➔ vacuum leak tight





RF Coupler Modification (cont'd)



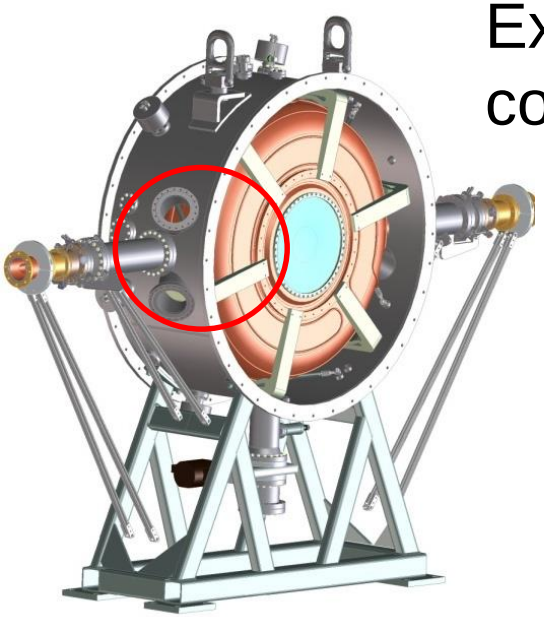


The coupler flange will have a lip to capture the cavity flange

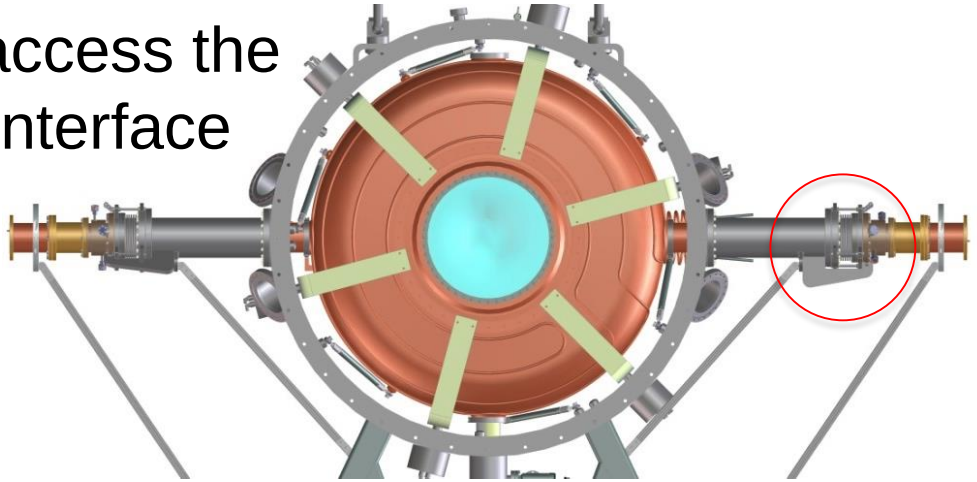
This flange lip will fit over the cavity flange O.D. to provide a connection for rotating the coupler (modification to the vacuum vessel)

The cavity flange remains un-modified

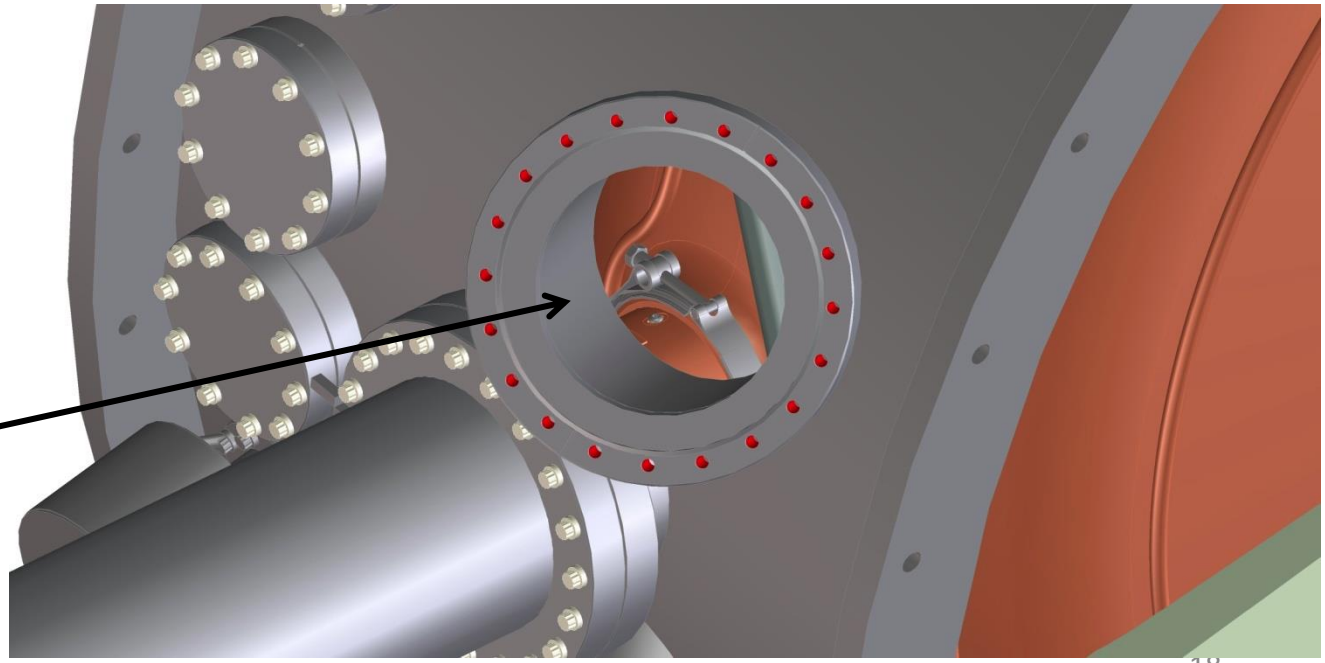
Extra Ports for RF Coupler in Beamline



Extra ports to access the coupler/cavity interface

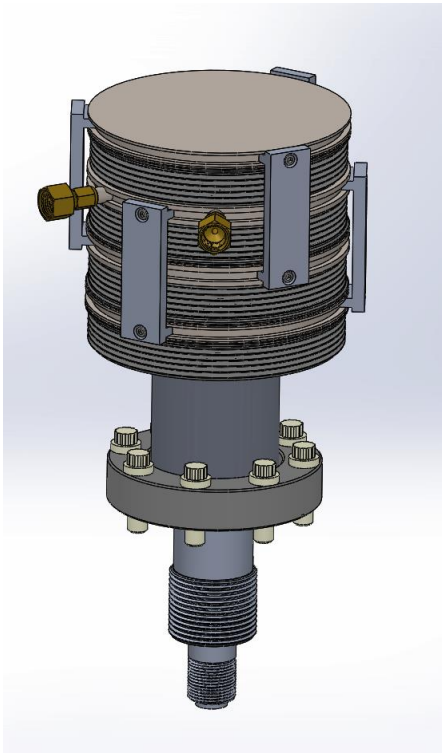


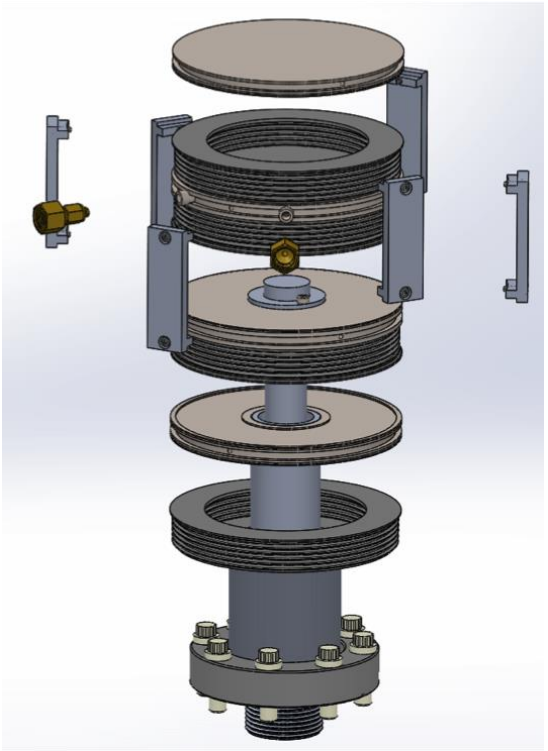
Port will look in from above and below on the coupler to cavity joint

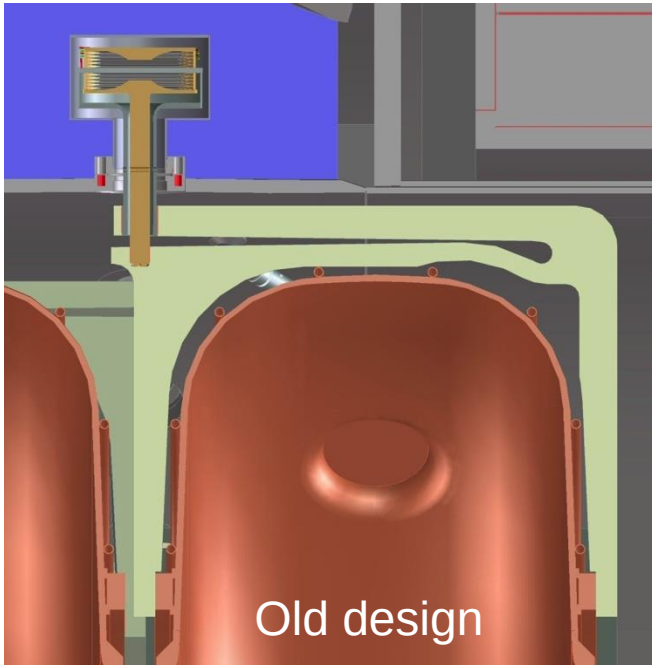


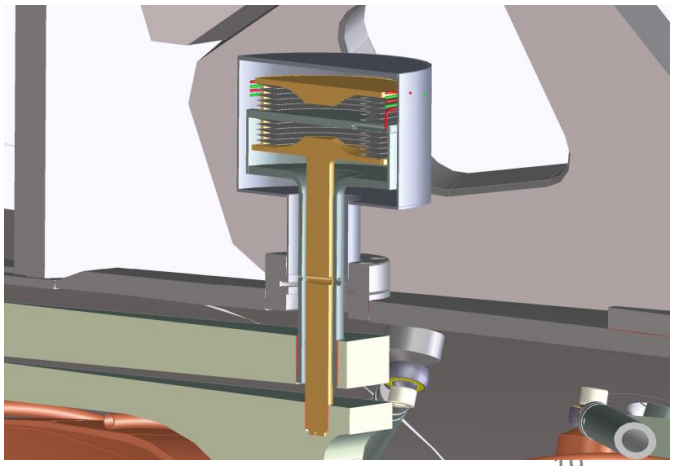
New Actuator Design

- The new design:
  - Re-use bellows we already have
  - Simpler parts to make
  - Easier assembly
  - ➢ More reliable operation
- ○ Functional test complete, lifetime test complete

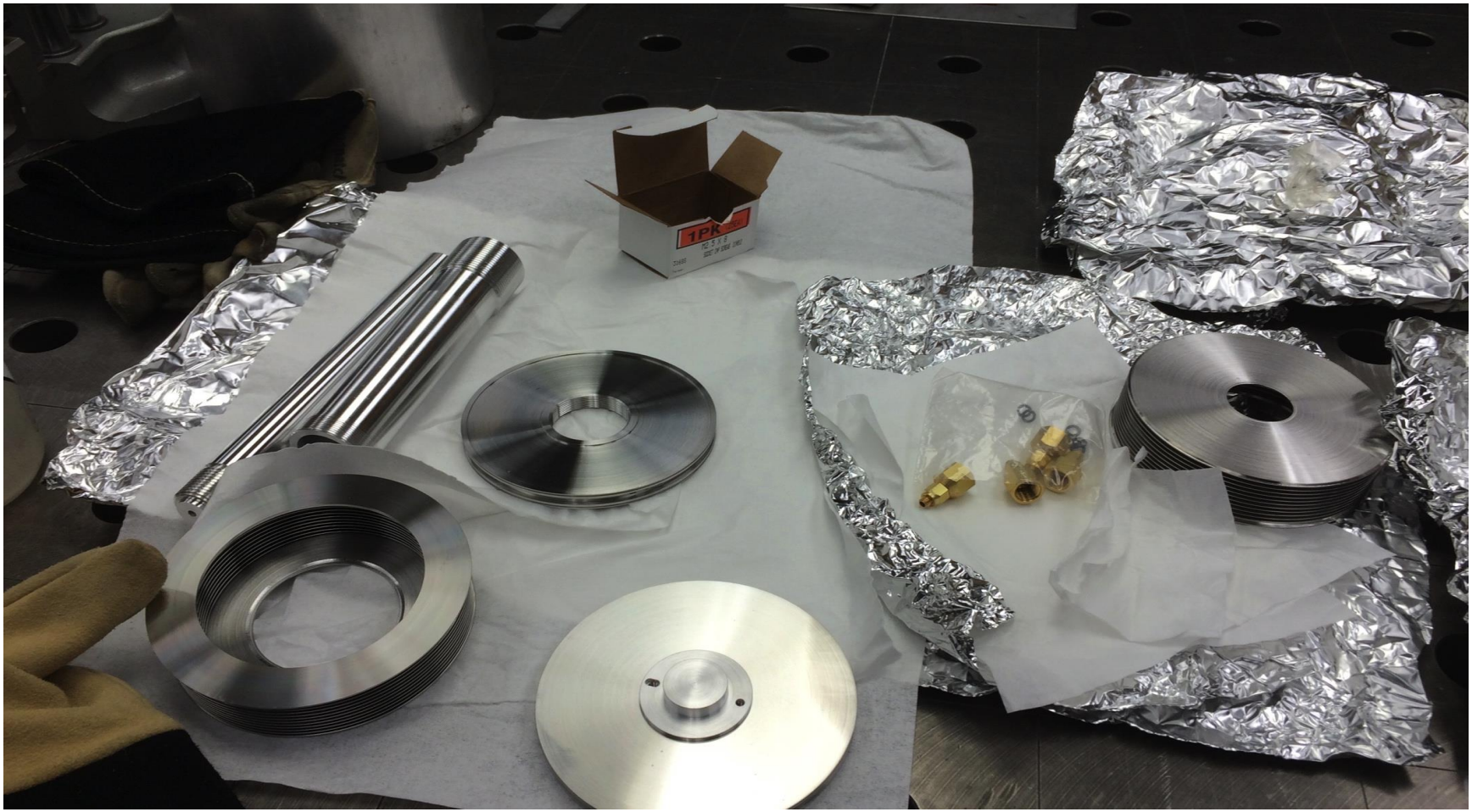






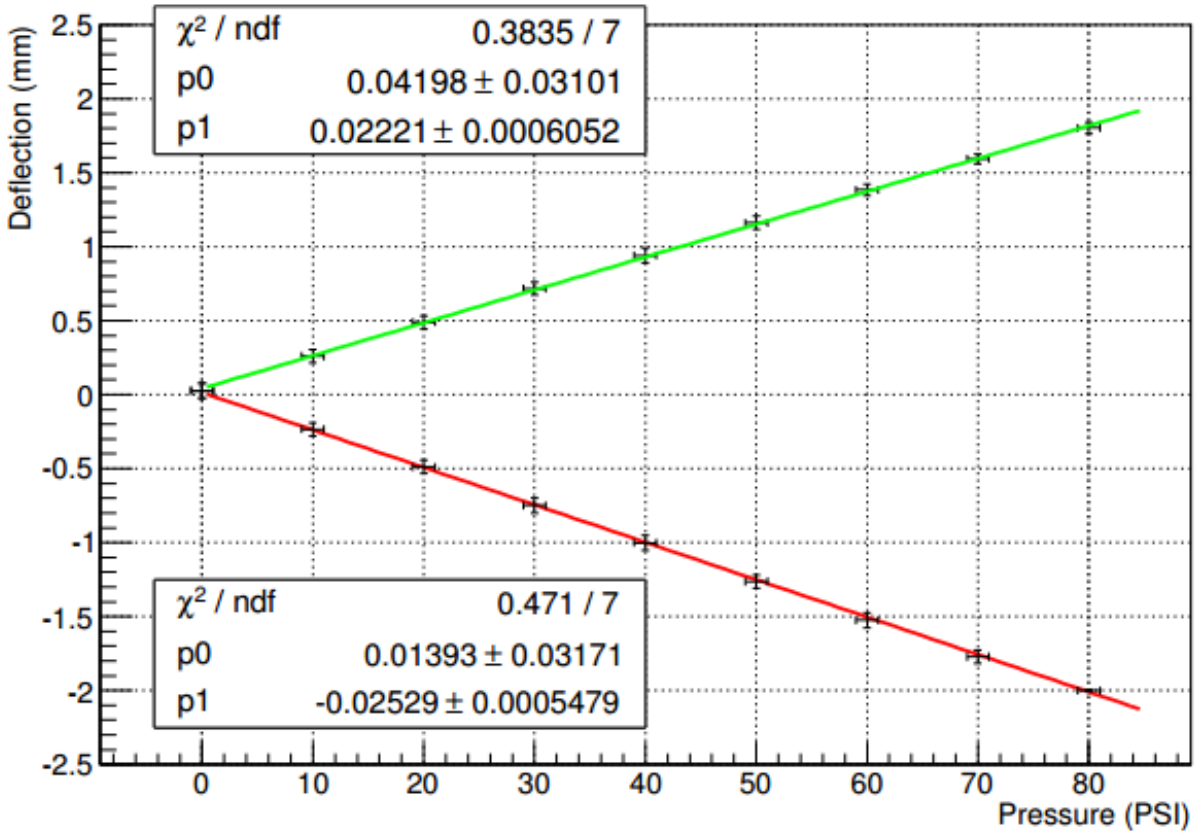


Actuator Parts Before Assembly

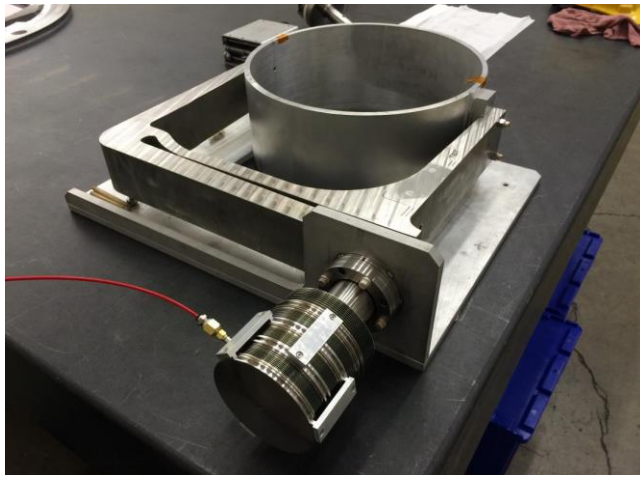


Functional Test of the Actuator

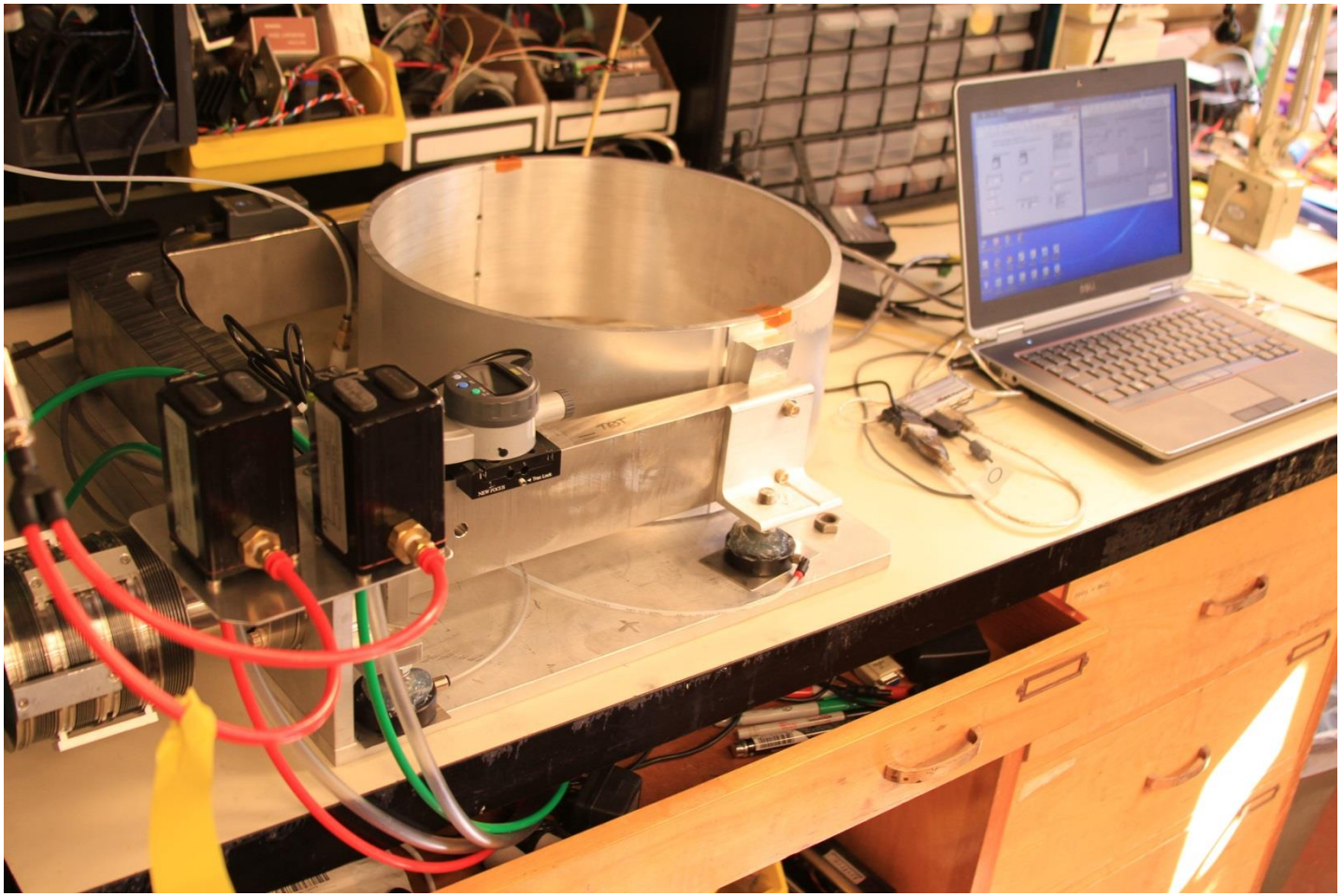
Agree well with the previous tests, lifetime testing started early May, but a leak developed at one of the bellows after 1200 cycles at ± 80 psi (± ~ 200 kHz). A more meaningful and realistic testing plan has been developed/defined and the testing is complete.



The actuator has been repaired: broken bellows has been replaced and welded.



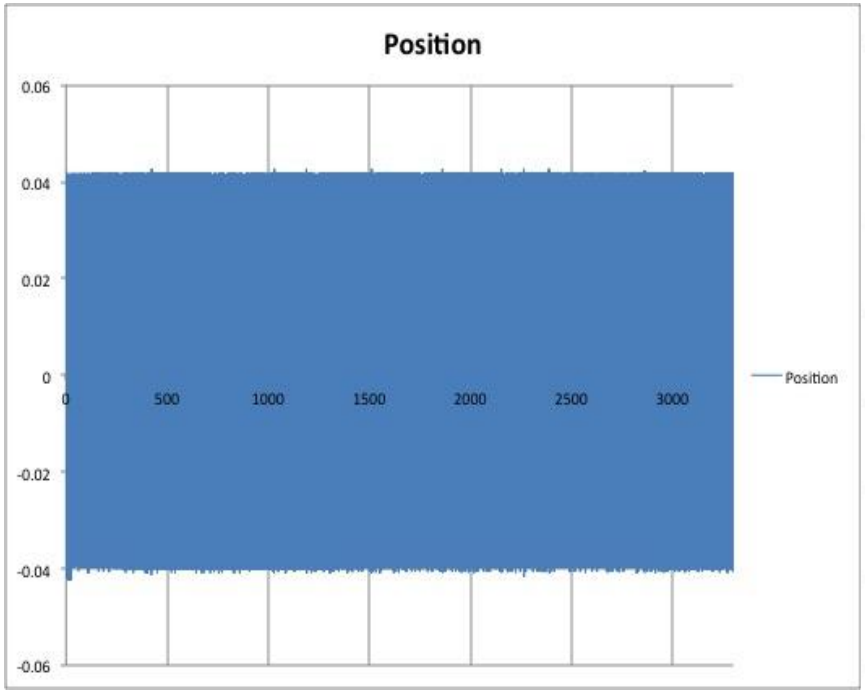
Lifetime Testing Complete



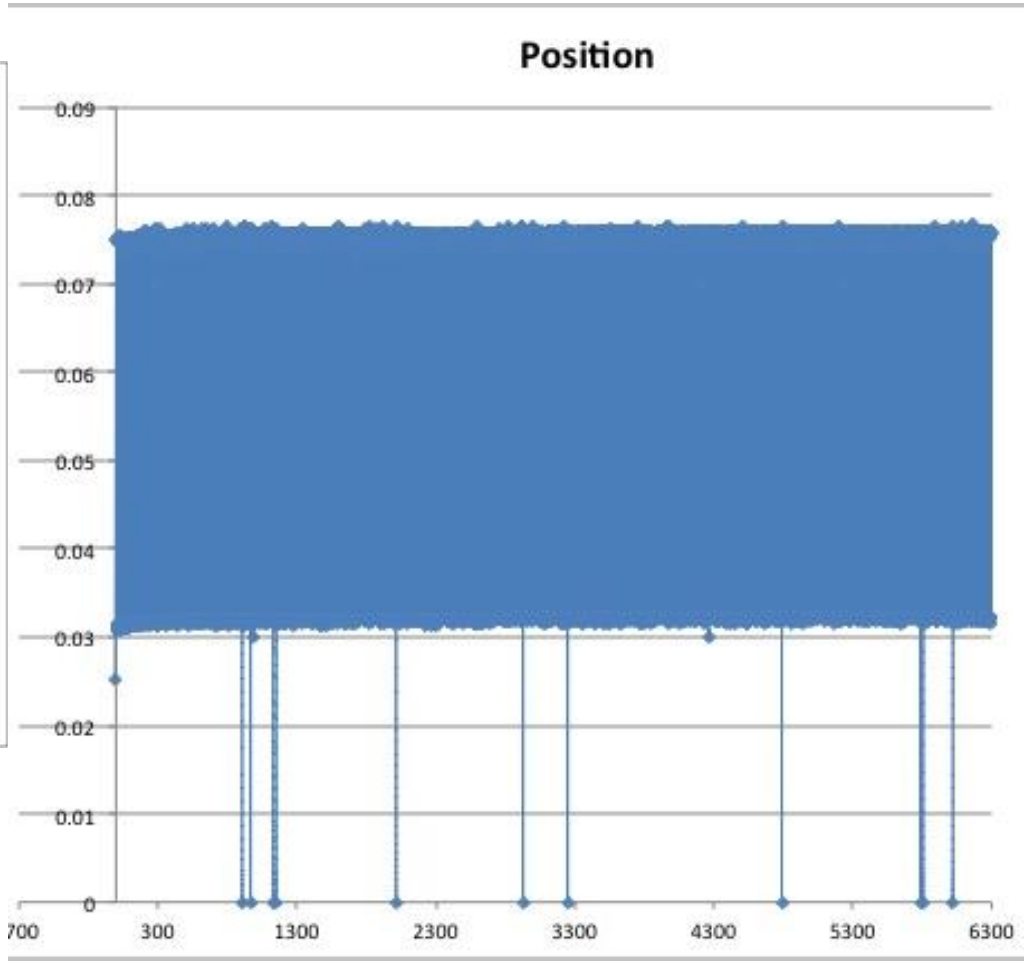
Lifetime Testing of the Actuator

- First round of the actuator testing failed
  - 1,200 cycles at ± 80 psi (~ ± 200 kHz)
  - Vacuum leak developed in one of the bellows
  - Replaced broken bellows with new ones and testing resumed
- 2nd round of testing
  - Plan: ± 20 psi (± 50 kHz) at base pressure of 0, 15 and 30 psi for 10,000 cycles + 40 hours operation
    - Base pressure equivalent to a frequency offset
    - Pressure variation ➔ dynamic tuning
  - All 3 sets of the testing complete
    - Very smooth operation
    - No hysteresis observed
  - The 40 hours lifetime test is complete

Lifetime Testing Results



Base pressure = 0 psi
Dynamic range = ± 20 psi



Base pressure = 15 psi
Dynamic range = ± 20 psi

Summary

- MICE RF module design is complete
- RFM fabrication starts soon after the RFQ process
- Delivery date of two RF modules to RAL:
  - 1st in May and 2nd in June 2016 (details in MICE WBS)
- RF module assembly starts at LBNL in the fall of 2015
  - First two RF power couplers testing at MTA
  - All hardware components must be ready by Oct. 2015
  - Full characterization tests of tuners, low power RF measurement and coupler tuning to be conducted after final assembly
  - Vacuum system testing