

HLRF R&D Towards the TDR

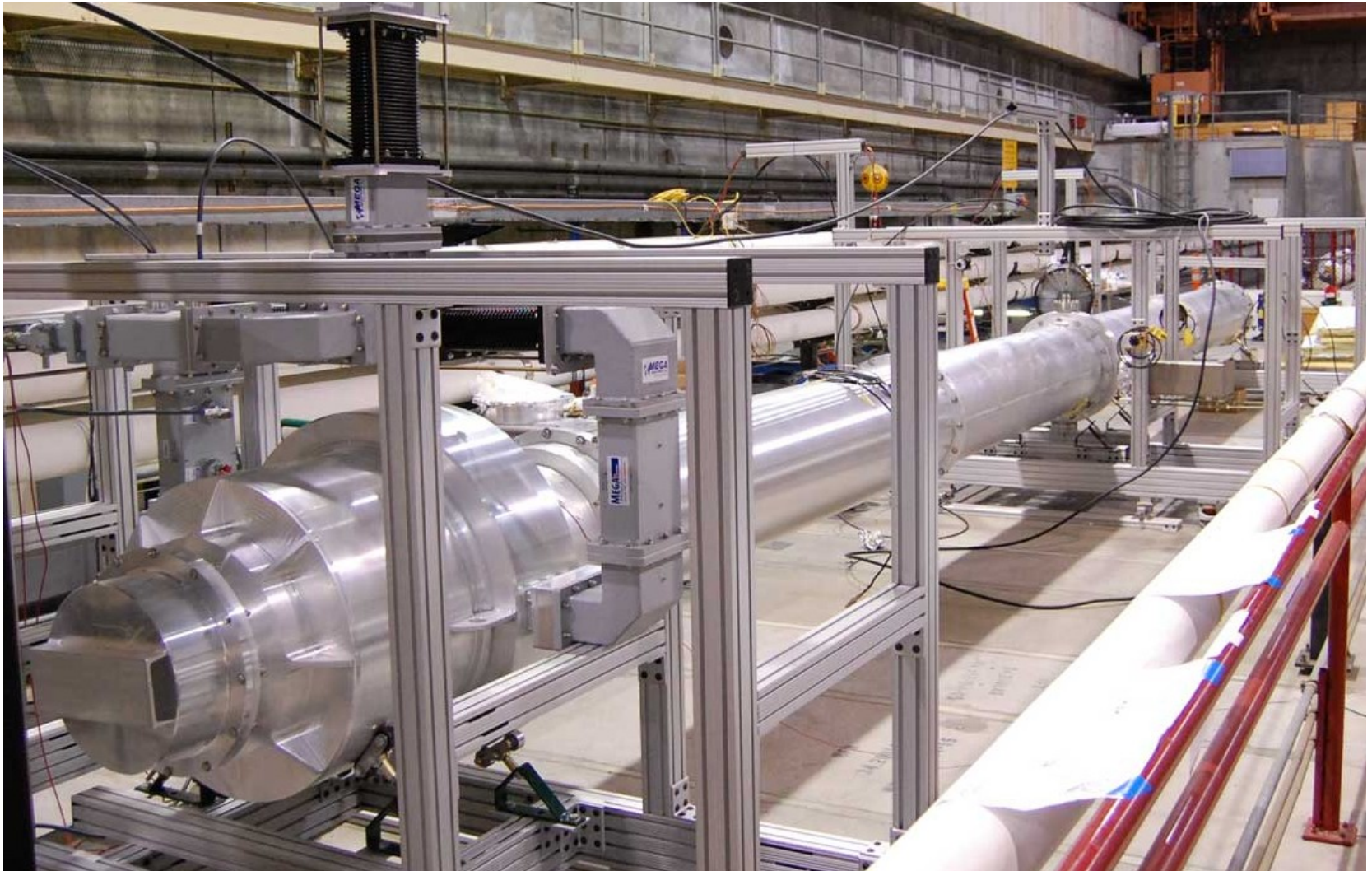
Christopher Nantista

ML-SCRF Webex meeting

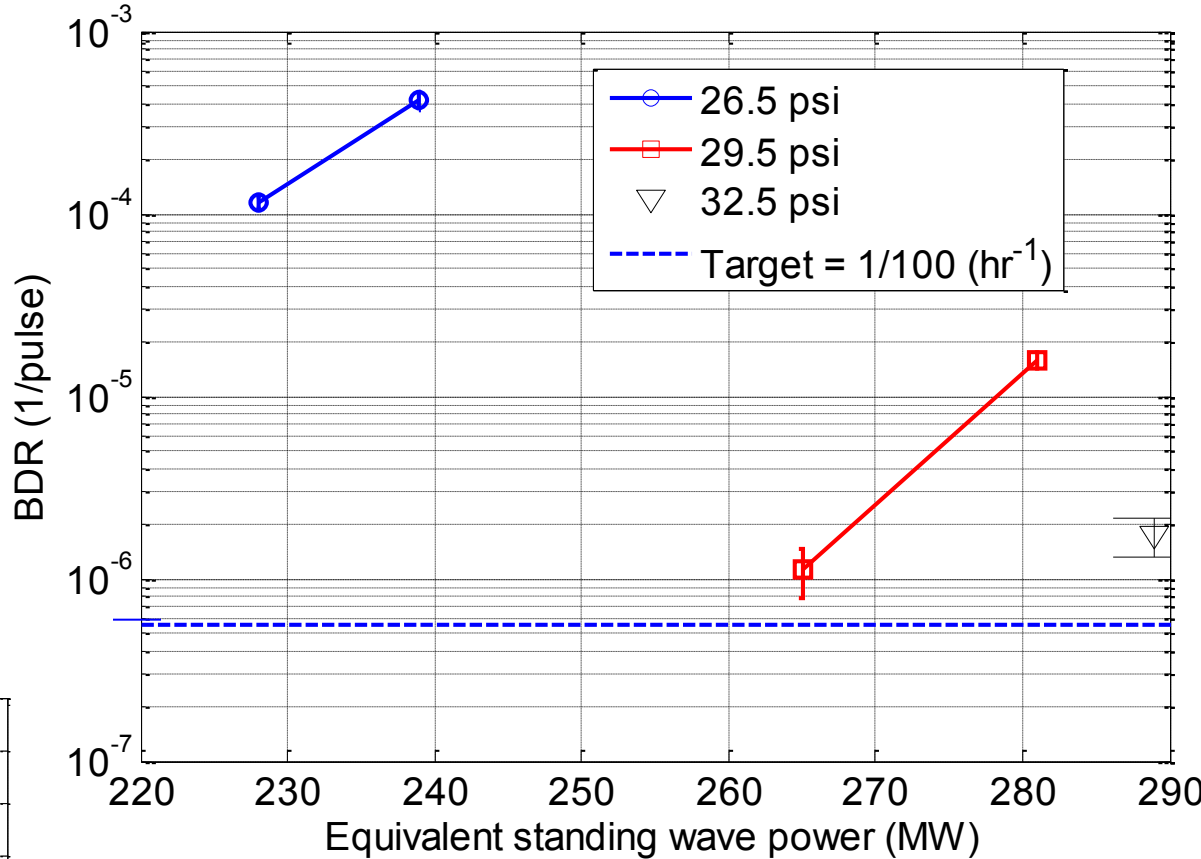
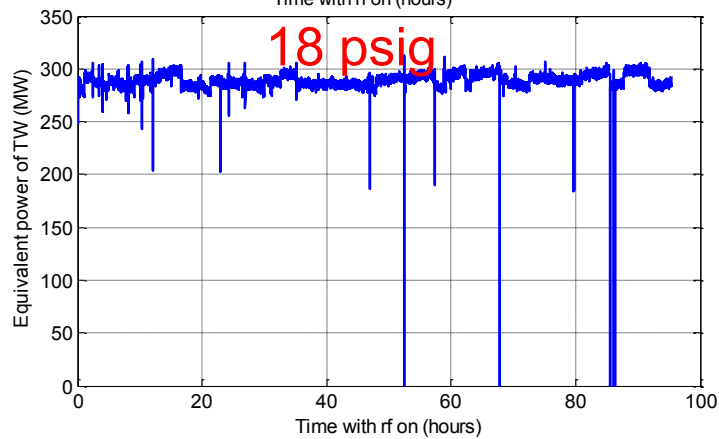
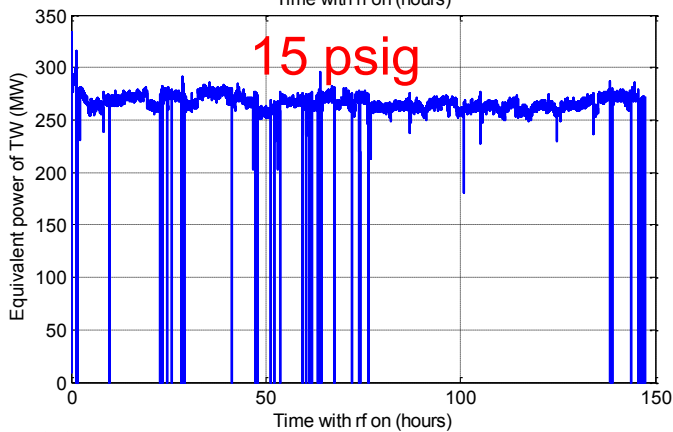
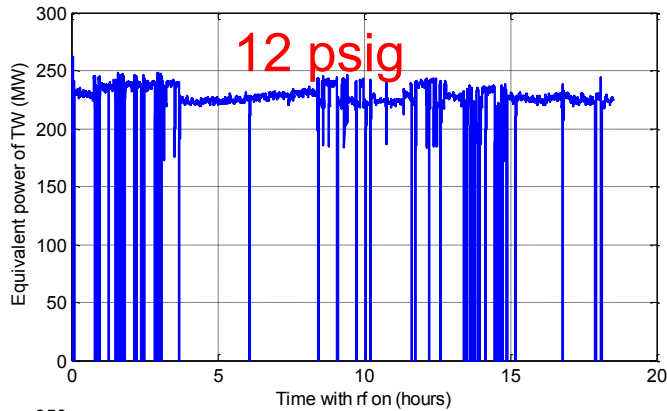
June 29, 2011

Klystron Cluster Scheme Tests

0.48 m diameter, pressurized aluminum pipe resonantly powered to ~ 280 MW
 TE_{01} mode field equivalent in 1 ms pulses @ 5 Hz.



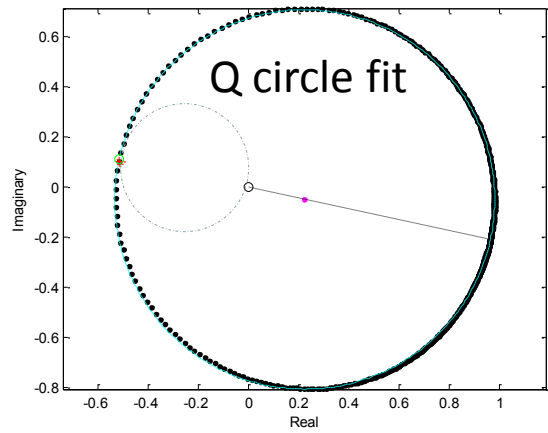
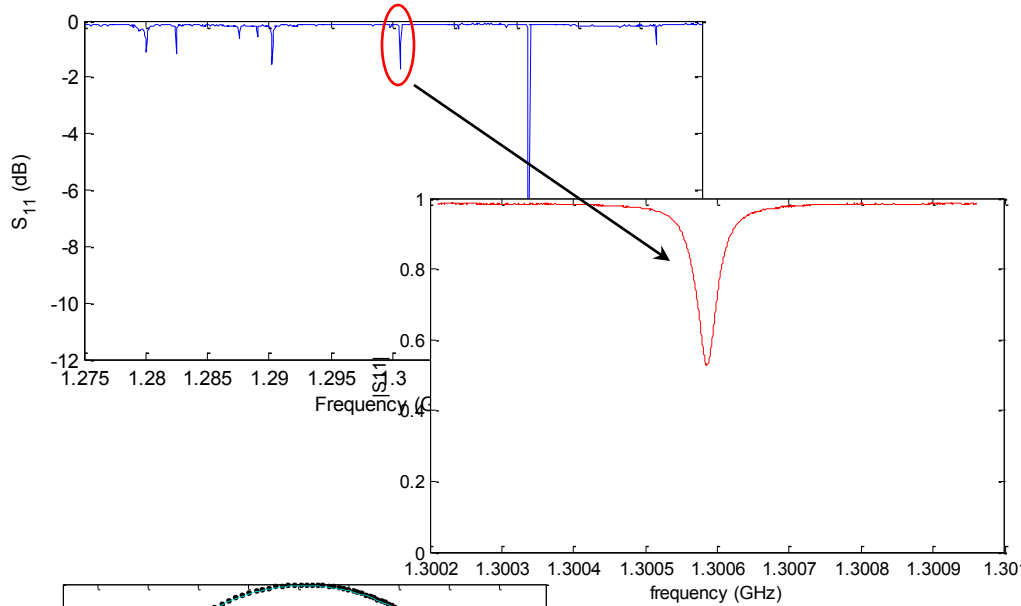
High Power Test History of “Big Pipe”



courtesy of Faya Wang

Resonance Measurement of “Big Pipe”

cold test, unpressurized



$$f_r = 1.300586 \text{ GHz}$$

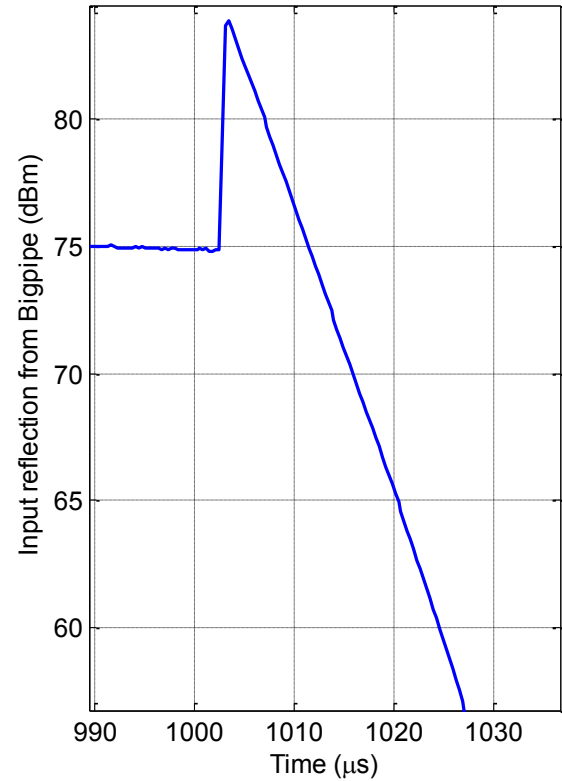
$$Q_L = 33,787$$

$$\beta = 3.3221$$

$$Q_0 = 146,028$$

$$\rightarrow \Delta f_{rFWHM} = 38.5 \text{ kHz}, \quad \tau_c = 2Q_L/\omega = 8.27 \mu\text{s}$$

high power, pressurized



~~B34~~

$$\tau_c = 7.37 \mu\text{s}$$

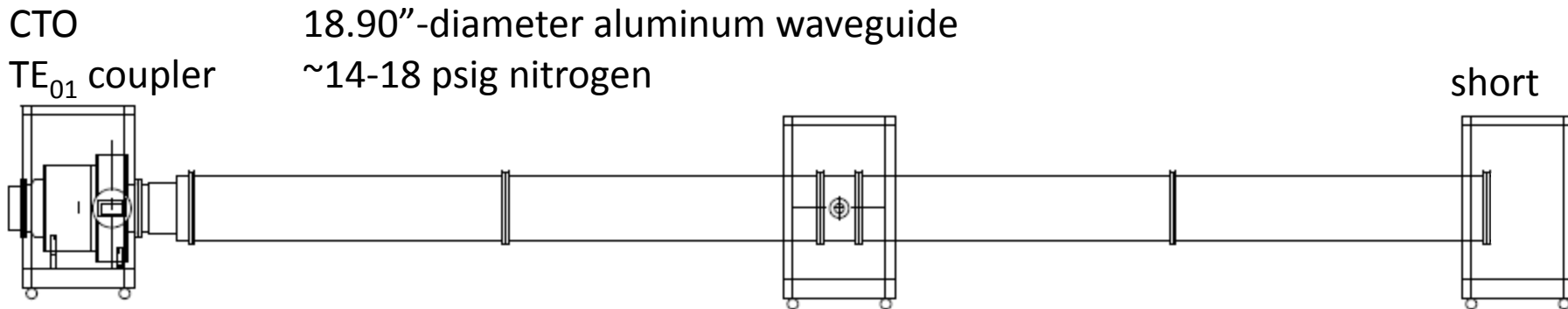
$$Q_L = 30,114$$

$$Q_0 = 133,712$$

$$f = 1300 \sim 1299.4 \text{ MHz}$$

Measured Q_0 is only ~59-65% of theoretical estimate (226,450).

Experimental System

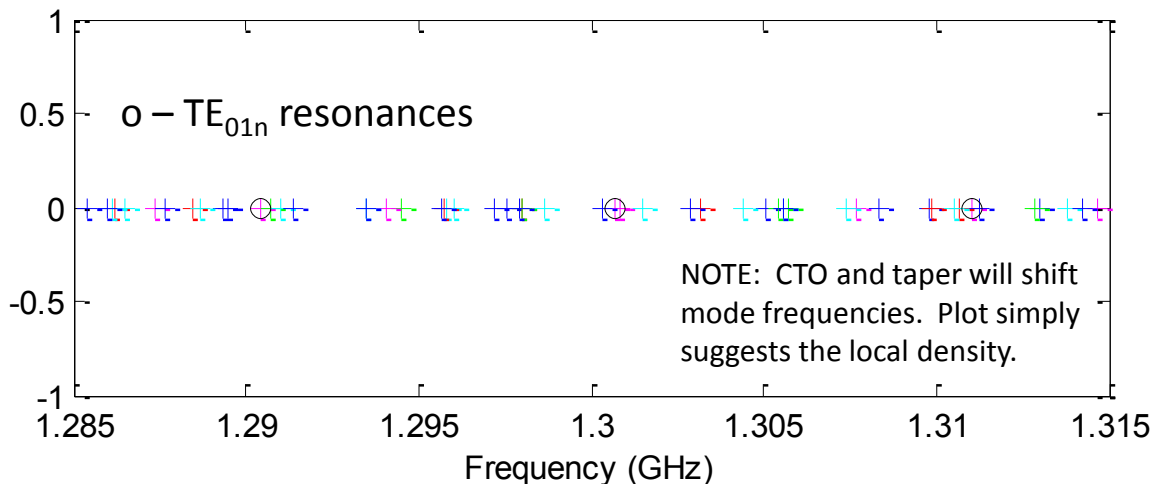


Resonated for ~200 hrs. @ 5Hz, ~1.1 ms
On the order of 600 kW input for ~75 MW traveling waves
w/ finite number of breakdowns

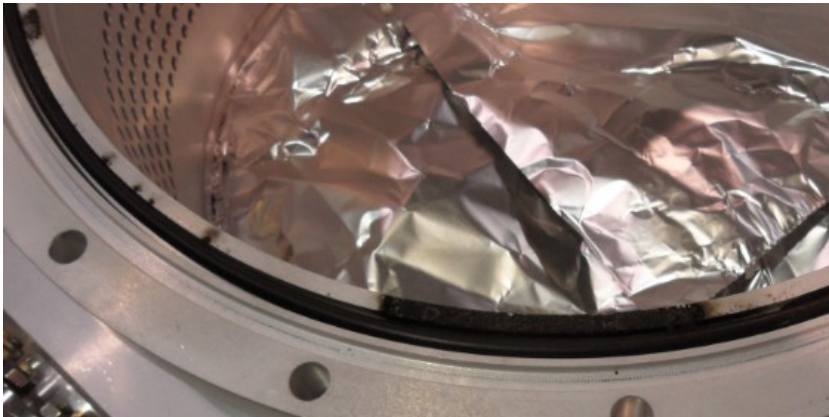
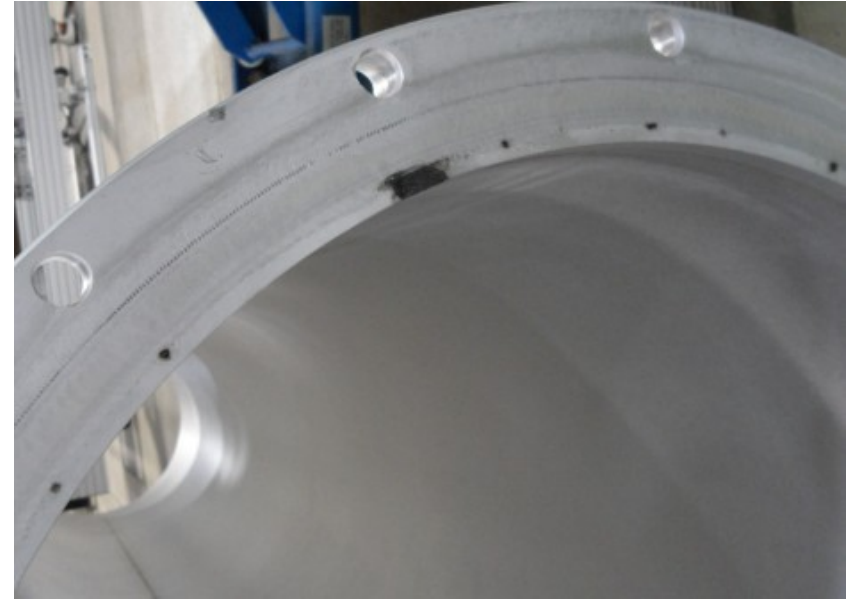
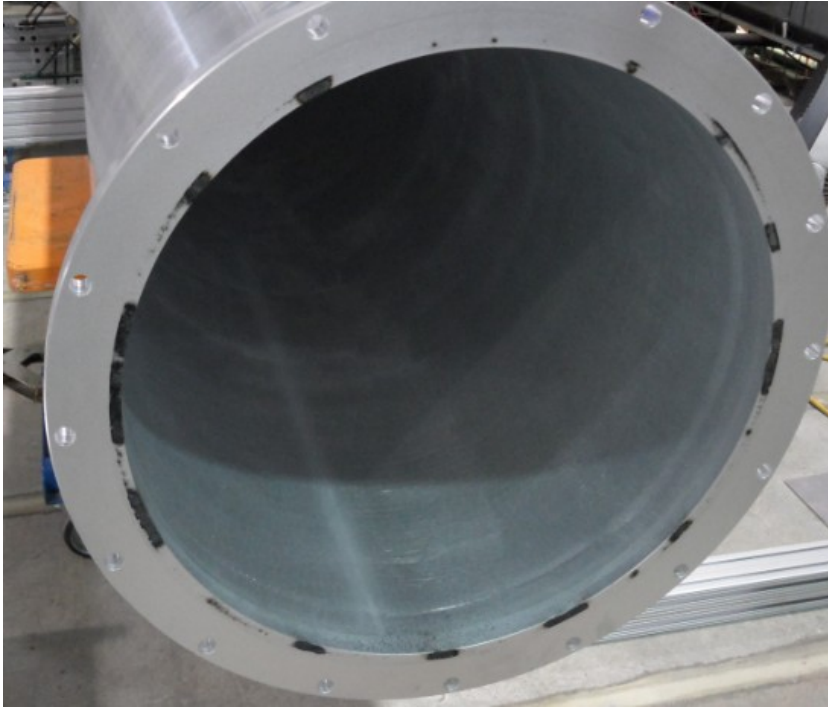
of propagating modes: 21*
highest propagating mode: TE₅₁
highest prop. TM mode: TM₃₁

* including x-polarizations

Theoretical Resonances of 11.8m of WC1890

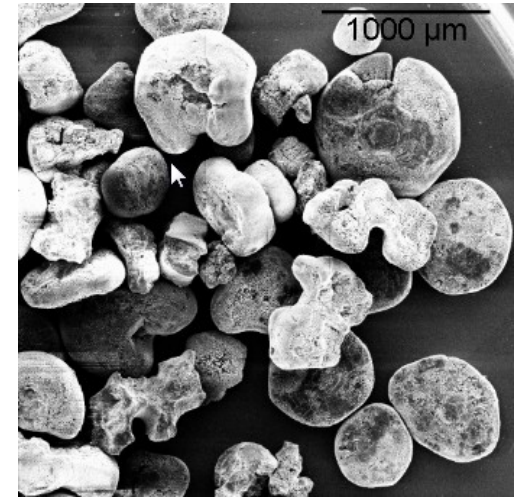
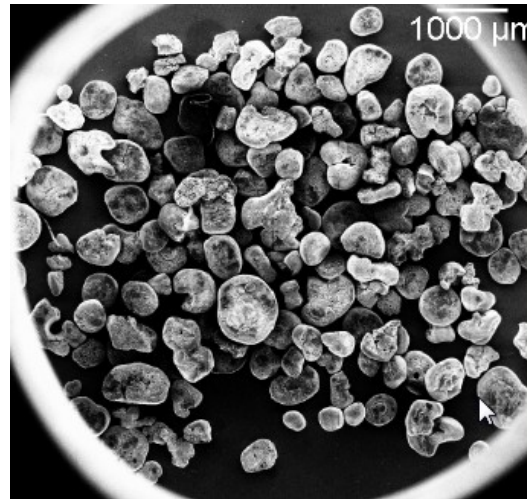
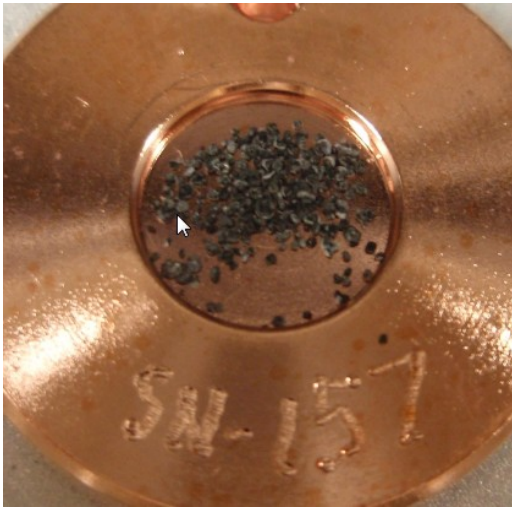


“Scorched” Flange Faces

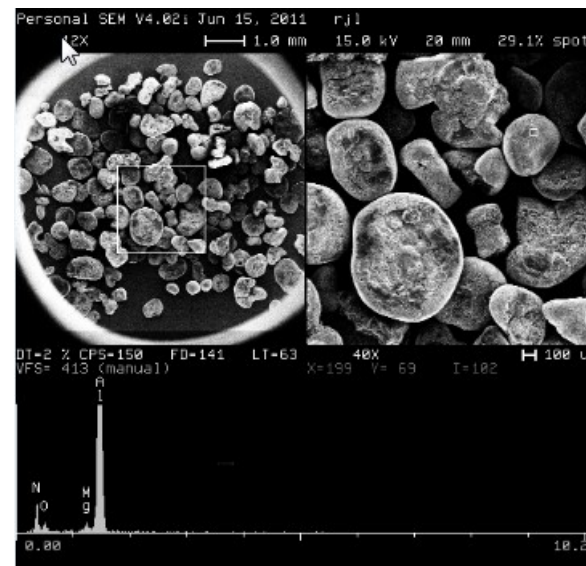
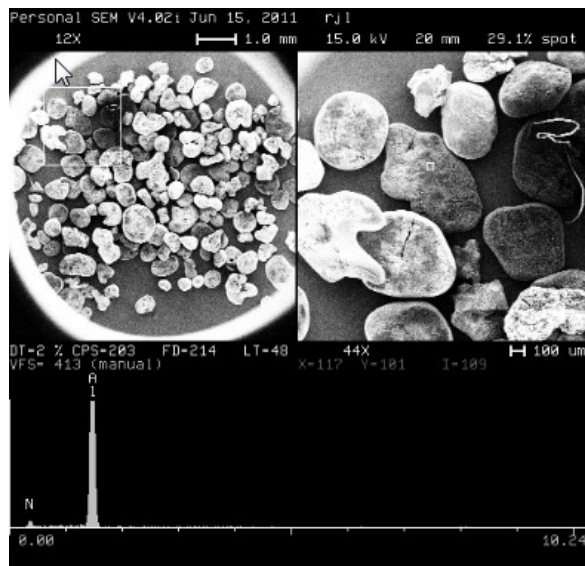


Photos provided by Sam Chu

Flange Crumbs



Images and SEM analysis provided by Lisa Laurent



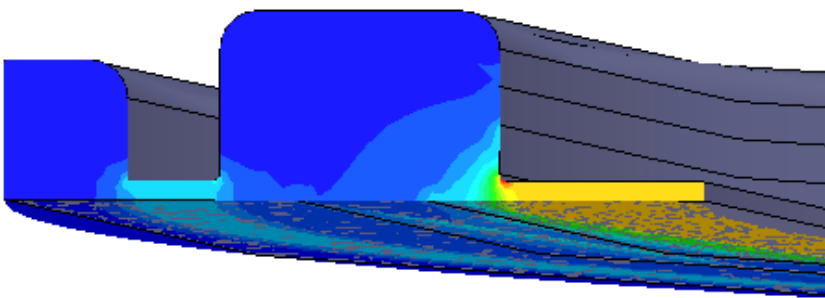
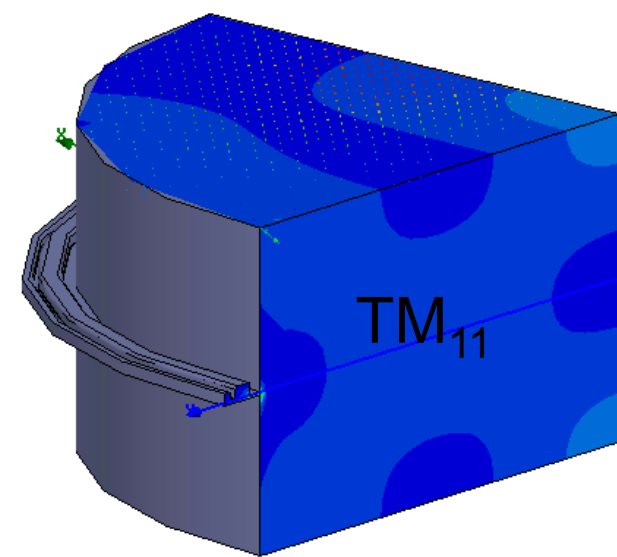
Flange Gap Fields

TE_{01} fields should not extend into a gap between flanges.

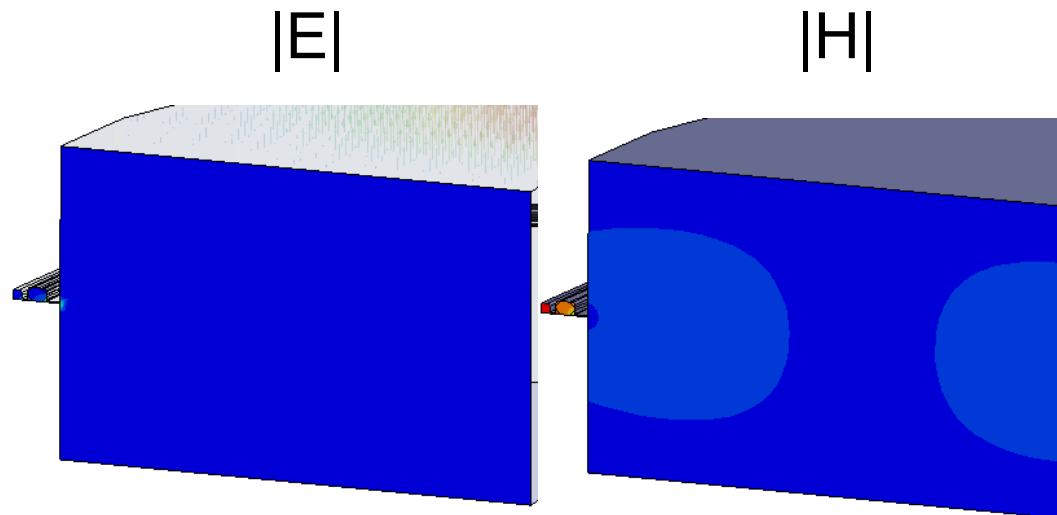
However, fields of parasitic modes will.

Gap modes near operating frequency can be strongly excited by even low levels of parasitic modes.

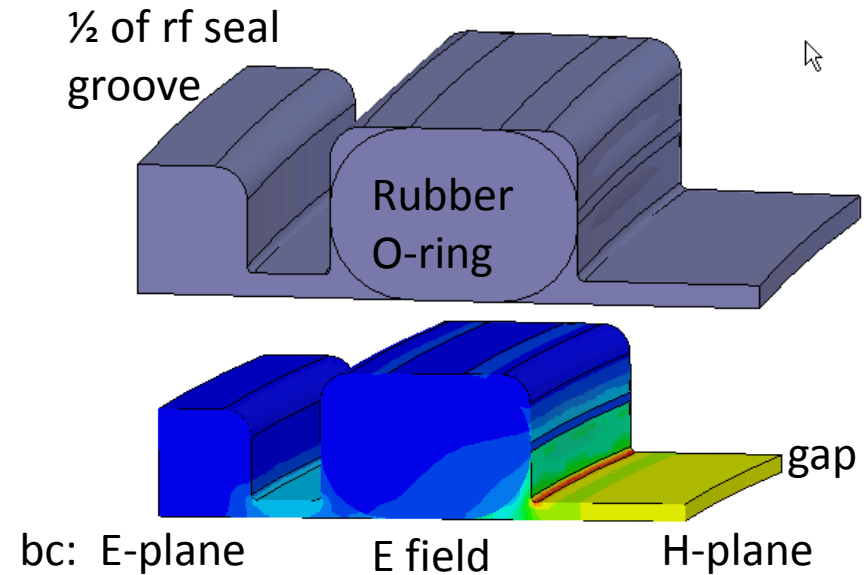
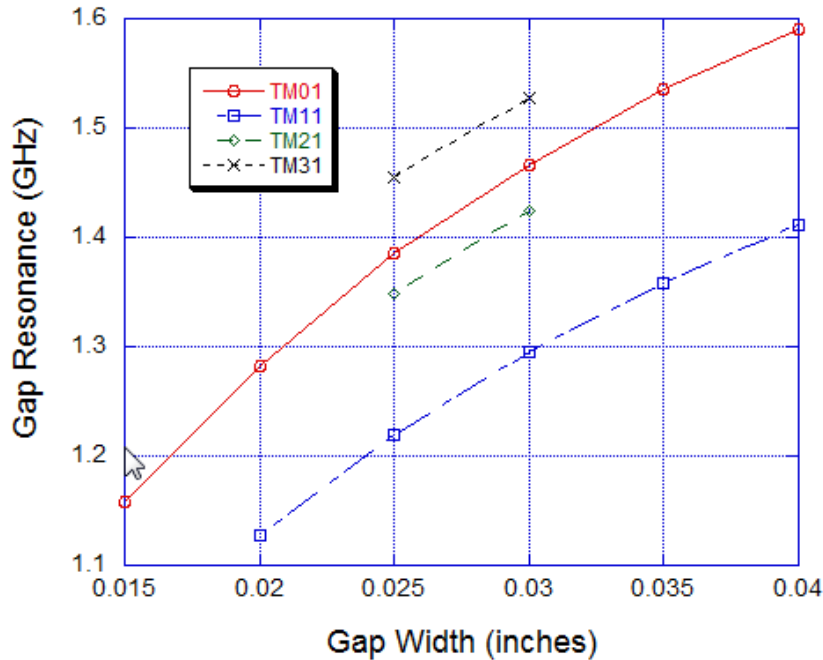
O-ring & rf seal grooves bring flange modes down into range.



TM_{11} 0.025" gap mode:
1.3154 GHz



Flange Mode Gap Dependence

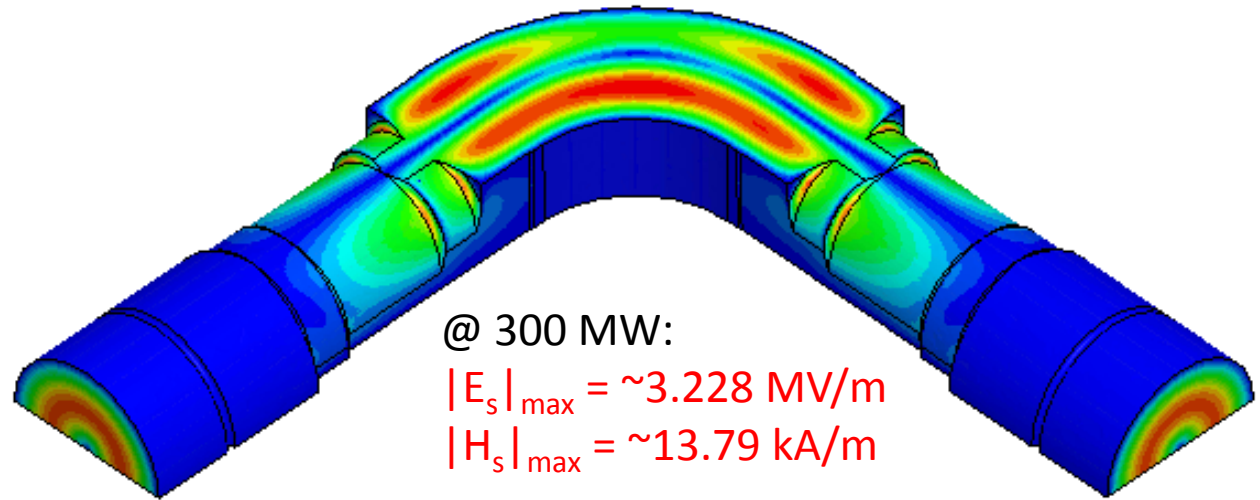


Flanges designed to touch, assuming vacuum, but switch to pressurization could introduce/widen gaps.

At proper spacing, modes cross 1.3 GHz.

SOLUTION: Clean and remachine flanges so as to pre-stress i.d. lip. Retest at high-power and confirm solution before finalizing 80m pipe order. Transmission tests are also planned, as well as inclusion of bend.

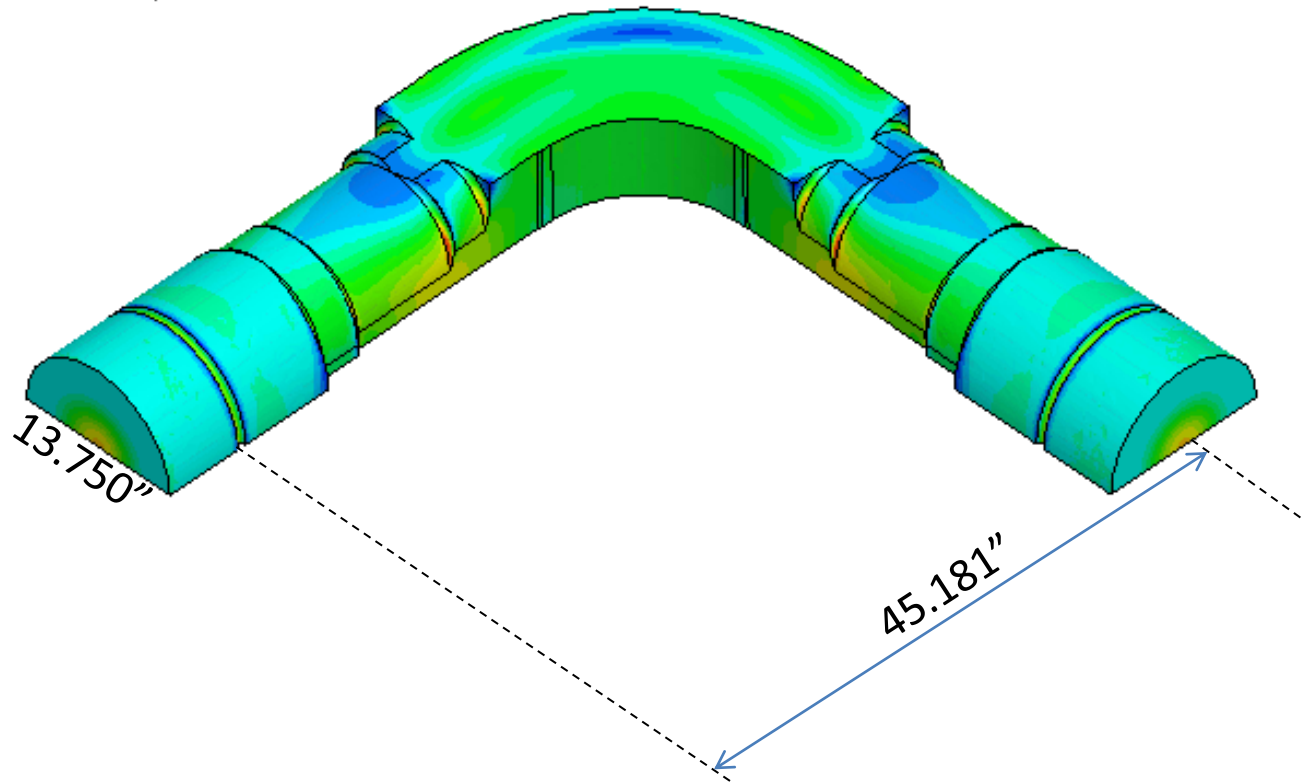
New Step-Taper Bend Design



@ 300 MW:

$$|E_s|_{\max} = \sim 3.228 \text{ MV/m}$$

$$|H_s|_{\max} = \sim 13.79 \text{ kA/m}$$

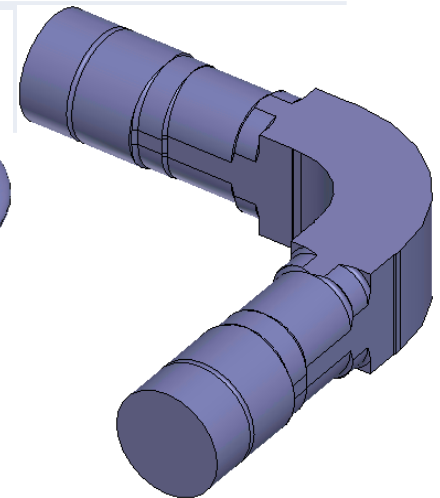
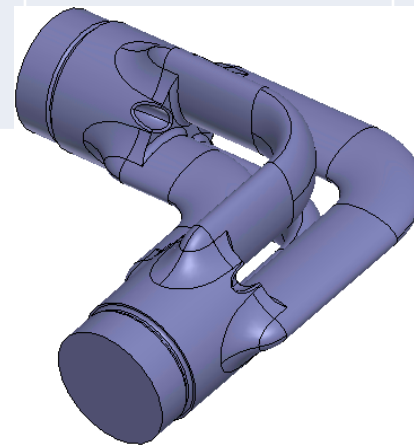
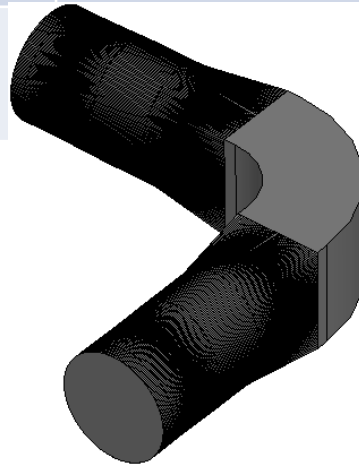


S:1:3	
(0.0071501, -128)	
(0.0015681, 129)	
(0.0074267, 74.5)	
(0.0021001, -170)	
(0.0045811, 31.1)	
(0.001515, -46.4)	
(0.00060334, -75.3)	
(0.99992, 171)	
(0.0025812, -79.7)	
(0.0039367, 10.5)	

Bend Design Comparison

	Taper Bend	4 Channel Bend	Step Taper Bend
axis-face distance (R_{eff})	39.859"	32.873"	45.181"
simulated transmission	99.698%	99.994%	99.9841%
$ E_s _{\text{max}}$ (@300 MW)	3.66 MV/m	3.69 MV/m	3.228 MV/m
$ H_s _{\text{max}}$ (@300 MW)	8.51 kA/m	10.65 kA/m	13.79 kA/m
maximum parasitic mode	-28.1 dB	-51.7 dB	-43.1 dB

mismatch (TE_{01} reflection)

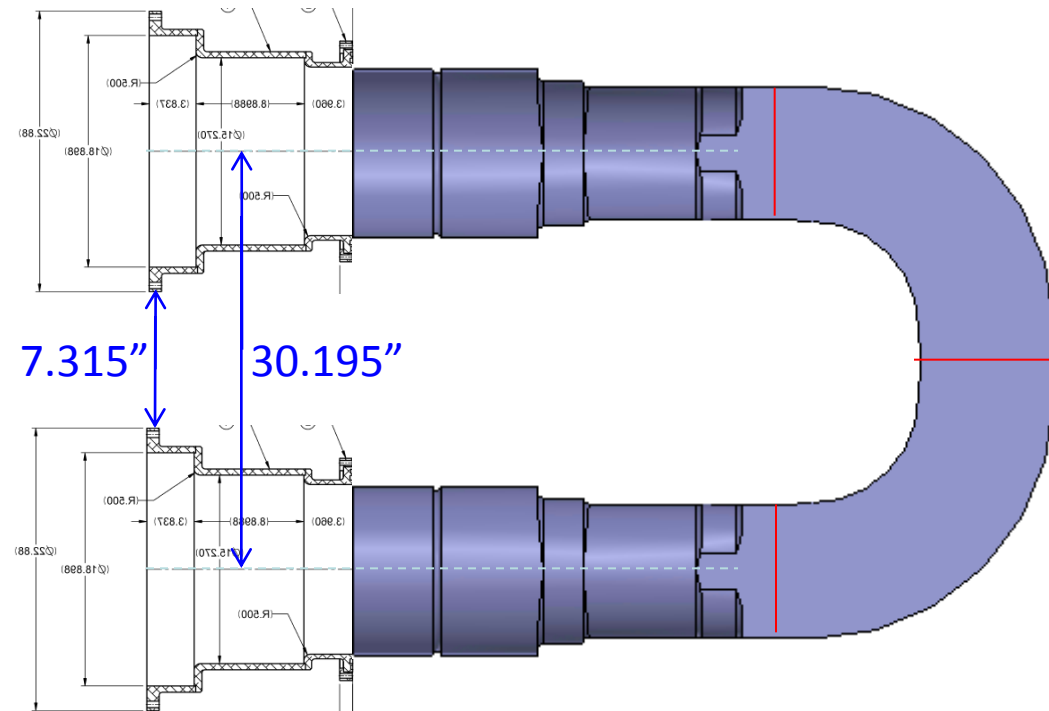
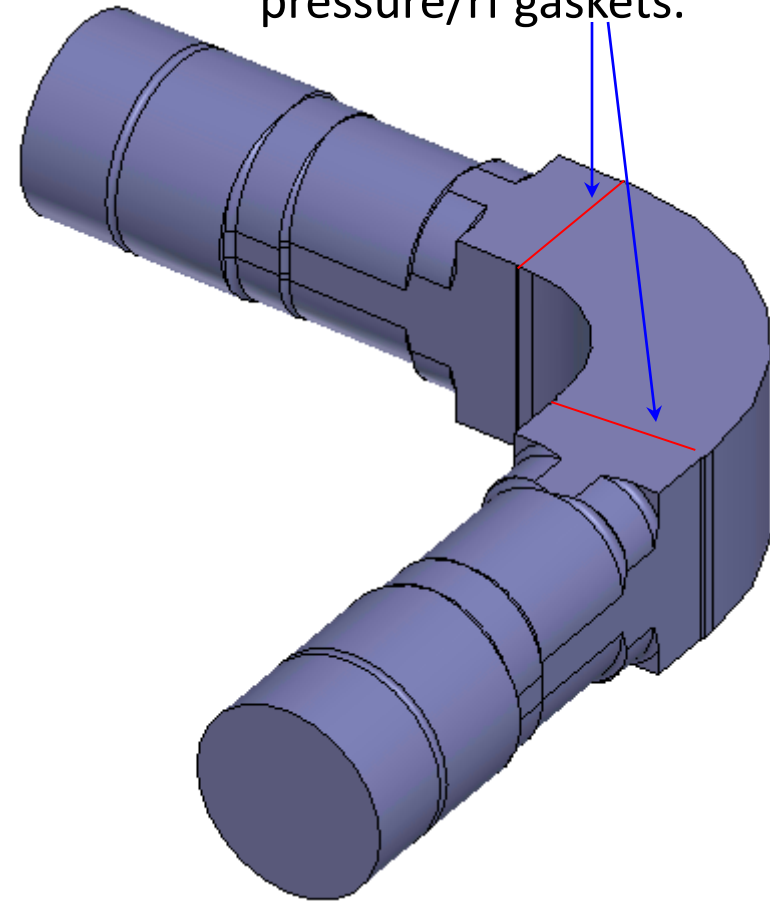


Fabrication

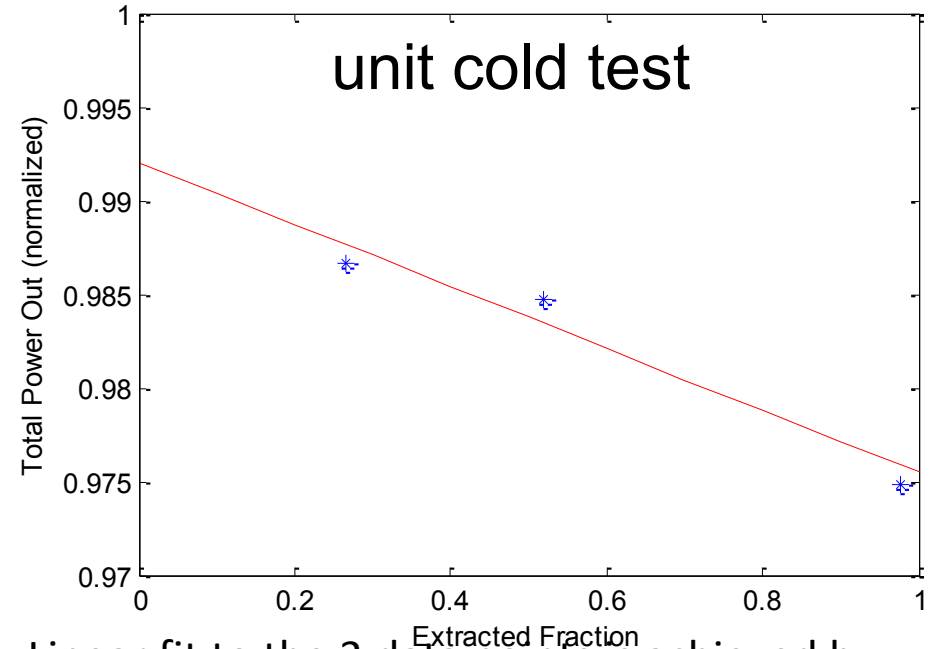
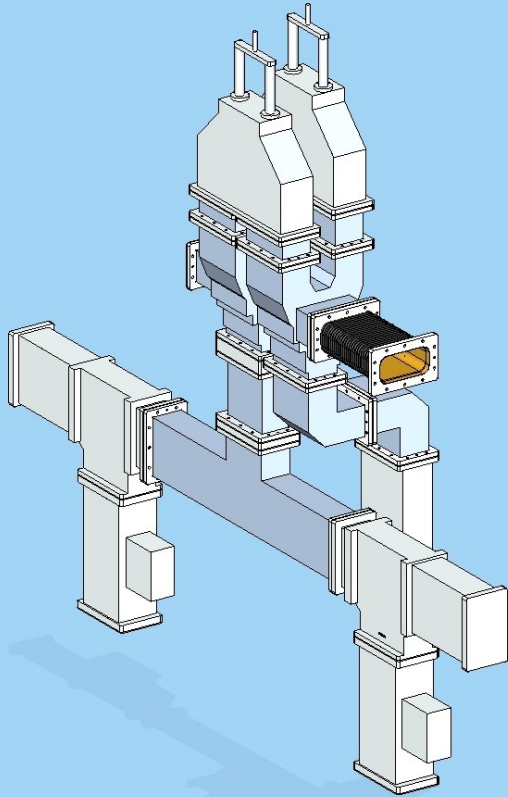
Fabricate in 3 assemblies
(each in multiple parts).

Connect w/ custom
pressure/rf gaskets.

U-bend configuration
for resonant ring.



2nd Local PDS (Power Distribution System) for NML



Linear fit to the 3 data points is achieved by taking losses of $\sim 0.8\%$ for through power and $\sim 2.45\%$ for extracted fraction.

Difference largely attributable to isolators, found in earlier tests to have a transmission loss of $\sim 1.6\%$ (0.07dB).

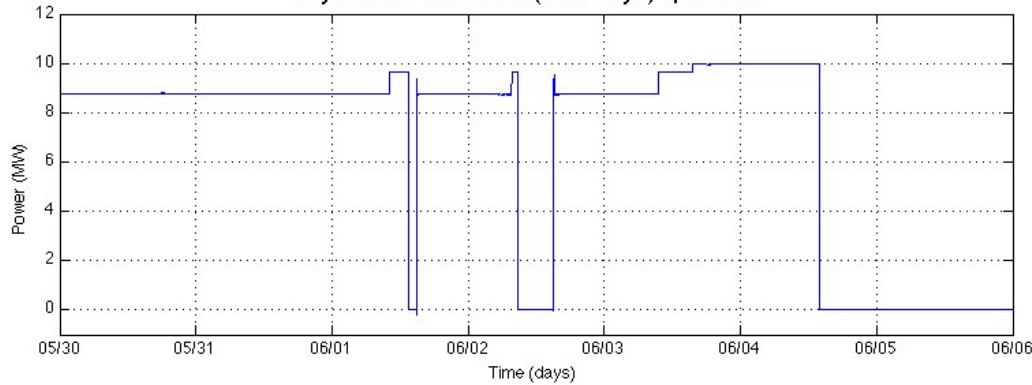
First 2-feed assembly connected to klystron and ready for high-power testing.

Marx Modulator and Toshiba MBK Testing

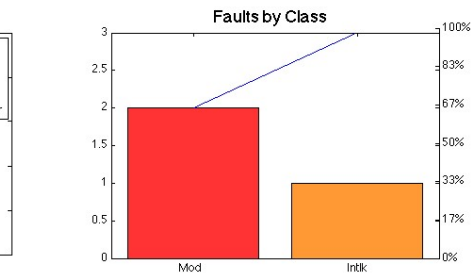
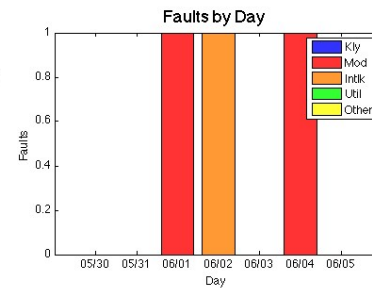
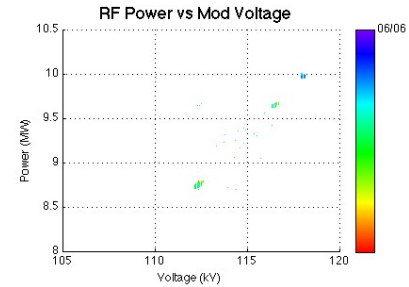
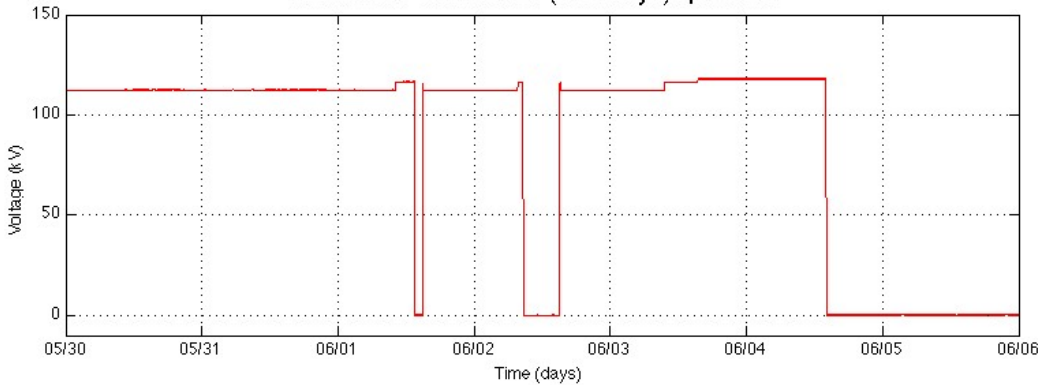
Marx Performance from 05/30/2011 - 06/05/2011

3 total faults: 0 klystron (0.00/day), 2 modulator (0.38/day)

Klystron: 126.3 hours (5.26 days) operation



Modulator: 126.4 hours (5.27 days) operation



Top 5 Faults		
Last event	Count	Description
06/01/2011	1	Modulator current spike
06/04/2011	1	Modulator other/undetermined
06/02/2011	1	Ion pump current
Top 3 events account for 3 faults (100%)		
Color code: Kly Mod Intlk Util Other		

courtesy of Kirk Bertsche