Multimoded RF Systems for Future Linear Colliders

Sami G. Tantawi

Acknowledgment

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K. Ratcliffe and the Vacuum Assembly Team.

We wish to Thank all operators that took shifts 24 hours a day for several months

Outline

- Dualmode resonant delay line pulse compression system for the Next Linear Collider (NLC)
    1. Introduction
    2. Components: design and cold tests
    3. Dualmode Delay Lines: Design and Experimental results
    4. High power experimental results

RF Accelerator Structures needs a short, high power, rf pulse. For example the current NLC design requires a flat-top 396 ns rf pulse with a power level of about 95 MW/m at 11.424 GHz, and a repetition rate of 120 Hz to feed each accelerator structure.

One need to transfer the CW wall plug power to rf pulses with high power and low duty factor. Hence

1. A storage system is needed.
2. A Switch or a switching mechanism is needed to control the charging and discharging of the system.
3. A device to generate the RF power

Storage Systems:

1. Capacitors; i.e. Modulators.

   Switches include pulse forming networks, thyrotrons, IGBTs, and grided guns on microwave tubes.

2. Kinetic energy of an electron beam ; i.e. two beam accelerator,

   Switches include RF beam kickers

3. In the accelerator structure; i.e. super conducting accelerators.

4. *In rf transmission lines and cavities; i.e. rf pulse compression systems.*

   Switches includes rf phase manipulation between rf sources, and solid state switches.

In general most of rf systems, suggested for a linear collider, contains elements from several of the above storage system.

To compare these system one has to consider:

1- Philosophy of the design

- Modularity: one may choose to have a unit that contains one rf source, and compact pulse compression system such as SLED-II
- Flexibility in the operating rf frequency: one may choose Two beam systems
- …..

2- Efficiency

3- Cost

The choice of the system is greatly affected by the available technology of the components.

If one has

1- A really inexpensive efficient rf source

2- A a very efficient and inexpensive modulator system using a very fast switch (such as grided gun on the rf source)

One might use several thousands of these devices to power the main Linac of a collider

However, neither the *inexpensive* rf source nor the *very fast* modulator exist, only ideas at the moment.

The need for RF Pulse compression

1- It is usually easier to build rf sources with low power and long pulse width.
2- Rf sources are expensive, one should get as much energy from them as possible, i.e., the longest possible pulse. One should not let an expensive rf source in an idle mode most of the time.

Hence, rf pulse compression is needed to match the long pulse low power of available rf sources such as klystrons to the high power short pulse needed for the accelerator structure.

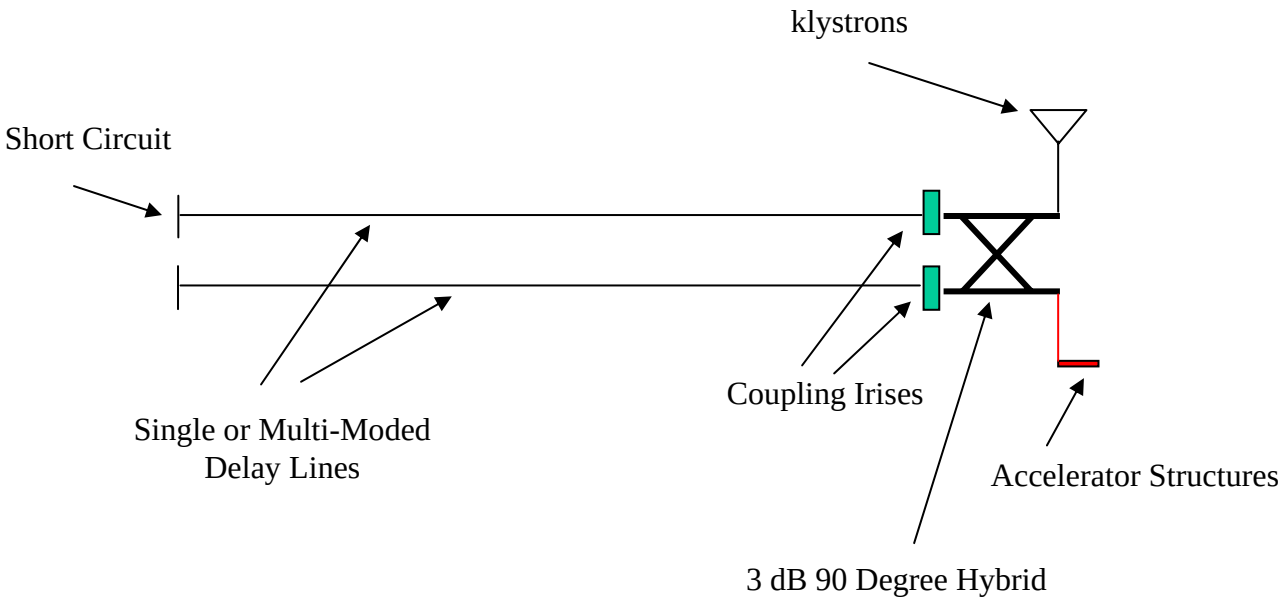
- Pulse Compression should be used with as high of a compression ratio as possible until
    a) The cost of the compression system starts to exceed that of the klystrons and modulator
    b) Or, the available pulse width of the klystrons is exhausted

- The cost of the main linac is directly proportional to the efficiency of the pulse compression system.

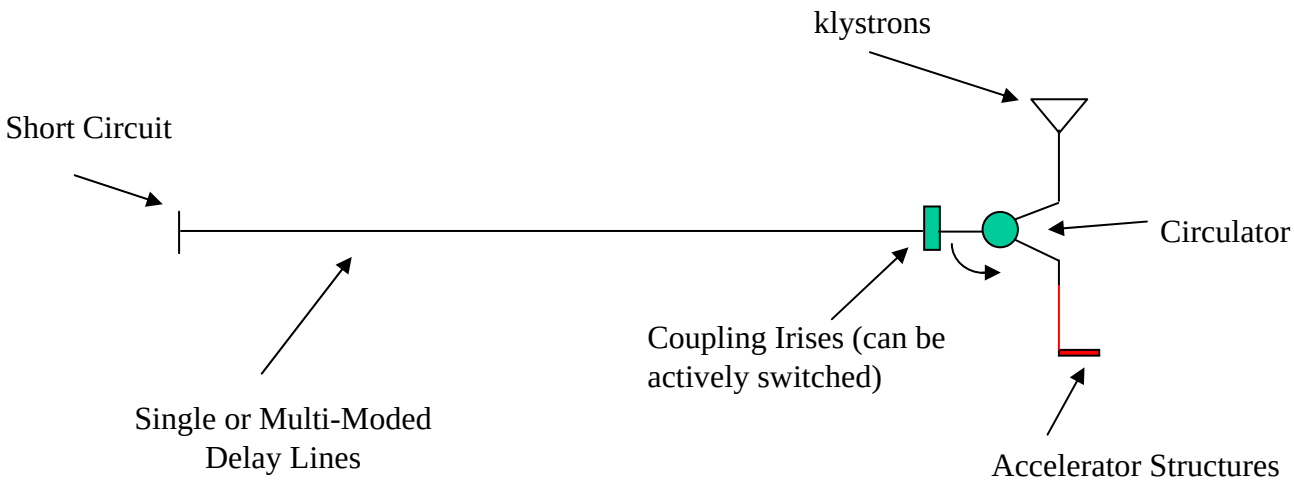
RF Pulse compression for RF Linacs and Colliders

- Resonance Delay Lines (SLED-II)
- Binary Pulse Compression (BPC)
- Delay Line Distribution System (DLDS)

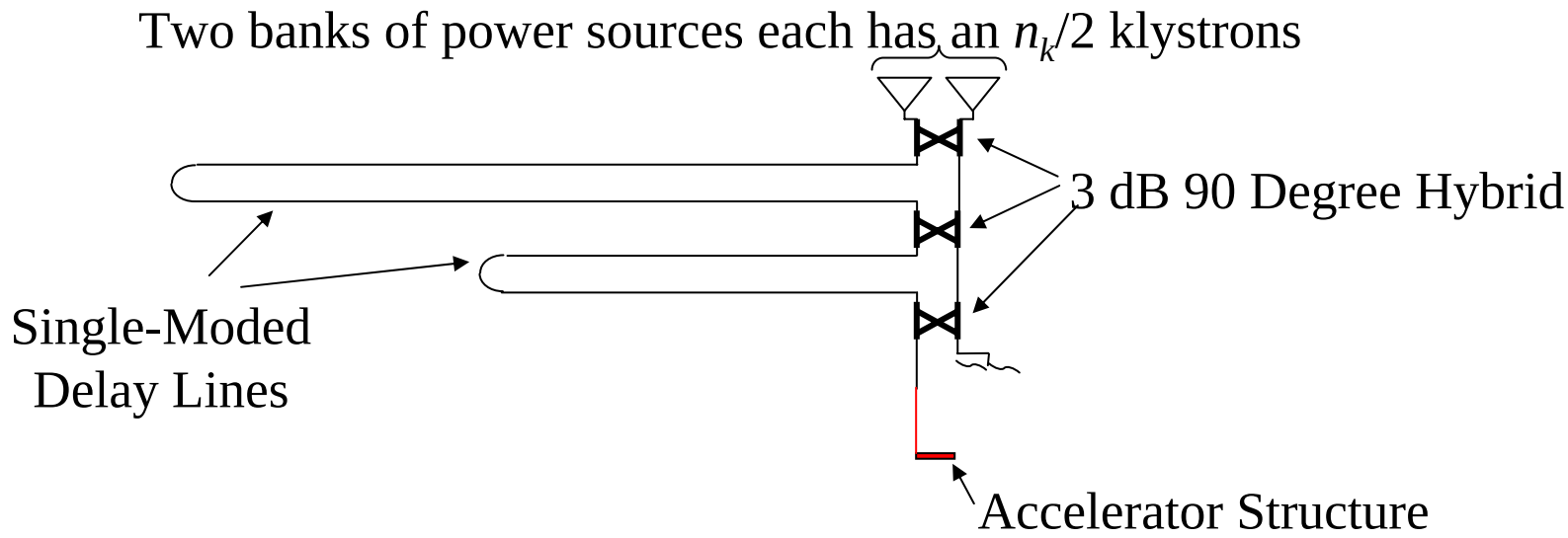
- Two-Stage systems, any combination of two or more of the above systems



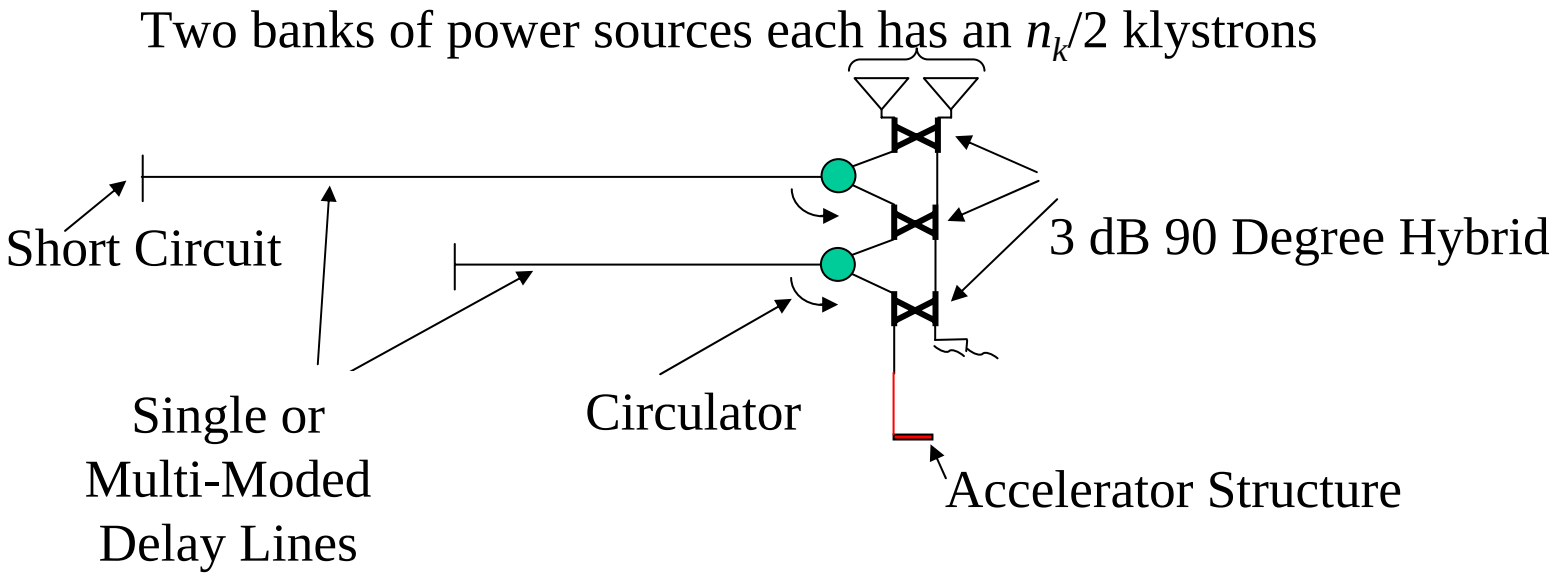
Sled-II Pulse compression system



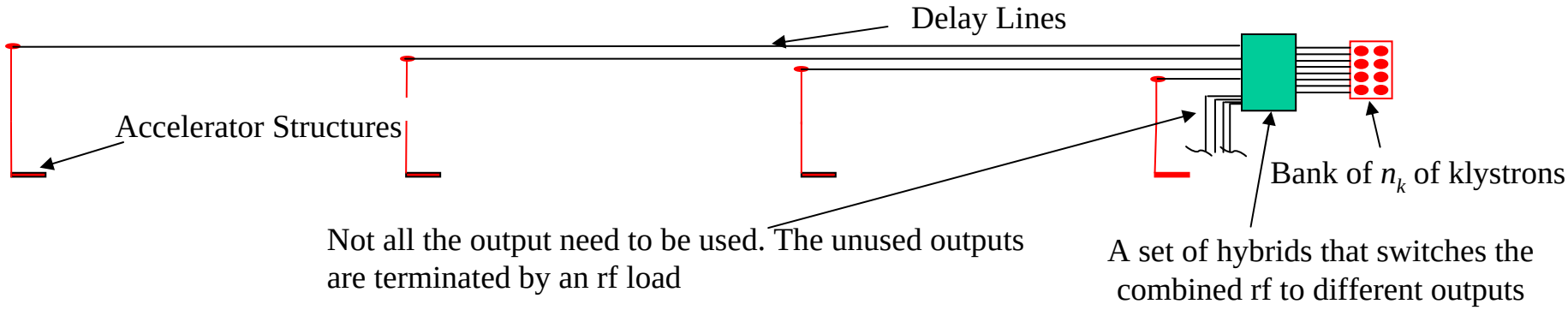
Sled-II pulse compression system with a circulator and active switches



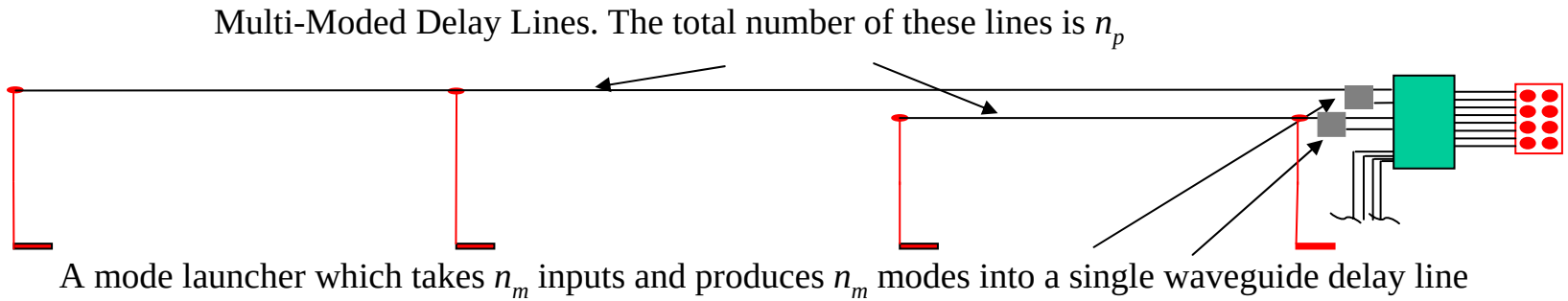
a) Single-moded Binary Pulse Compression



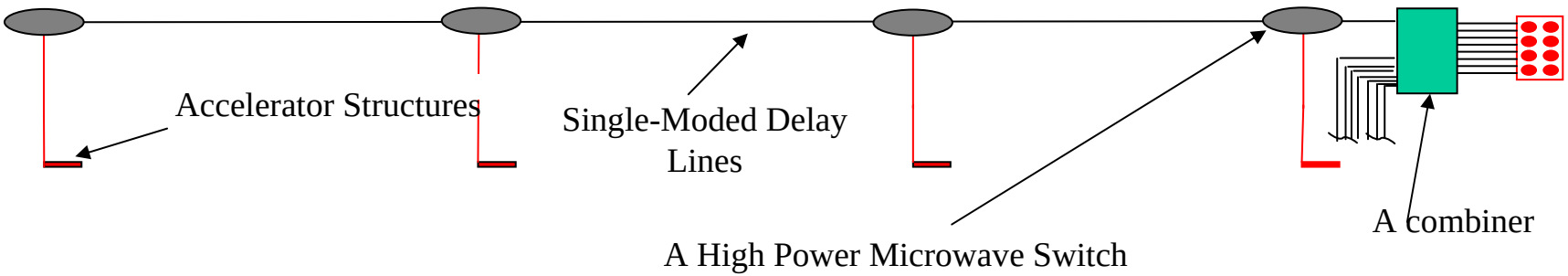
b) Binary pulse compression can have several improvements including the use of a circulator and several modes to reduce the delay line length.



a) A Unit of a Single-Moded DLDS



b) A Unit of a Multi-Moded DLDS



c) A Unit of an Active DLDS

The challenges facing most of these pulse compression system are

1- Compactness, how to produce a storage system which is relatively compact

2- Efficiency, for the resonant delay lines, efficiency could be boosted by an rf switch.

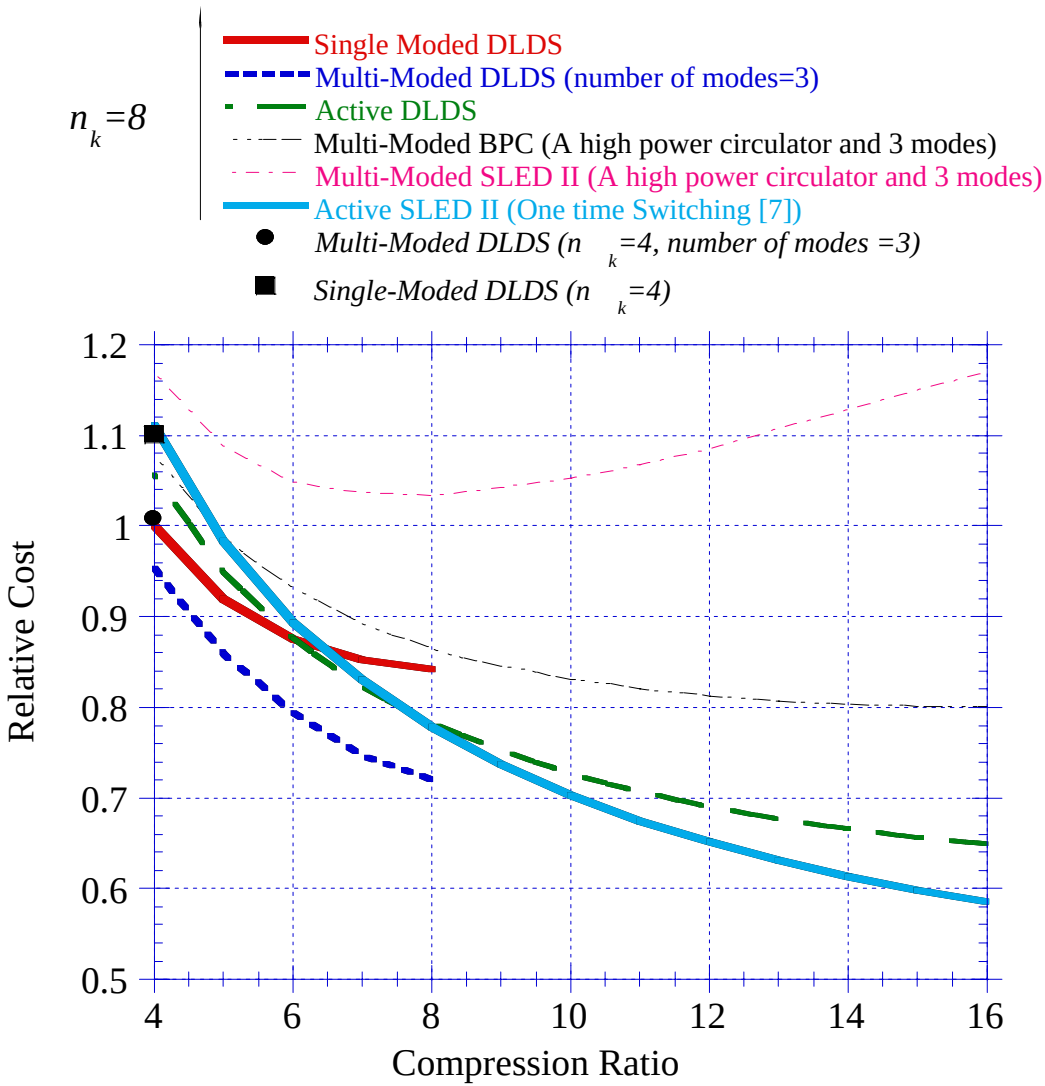
3- Most of these systems could have a more compact topology if one have, a nonreciprocal RF device (circulator), or a switch.

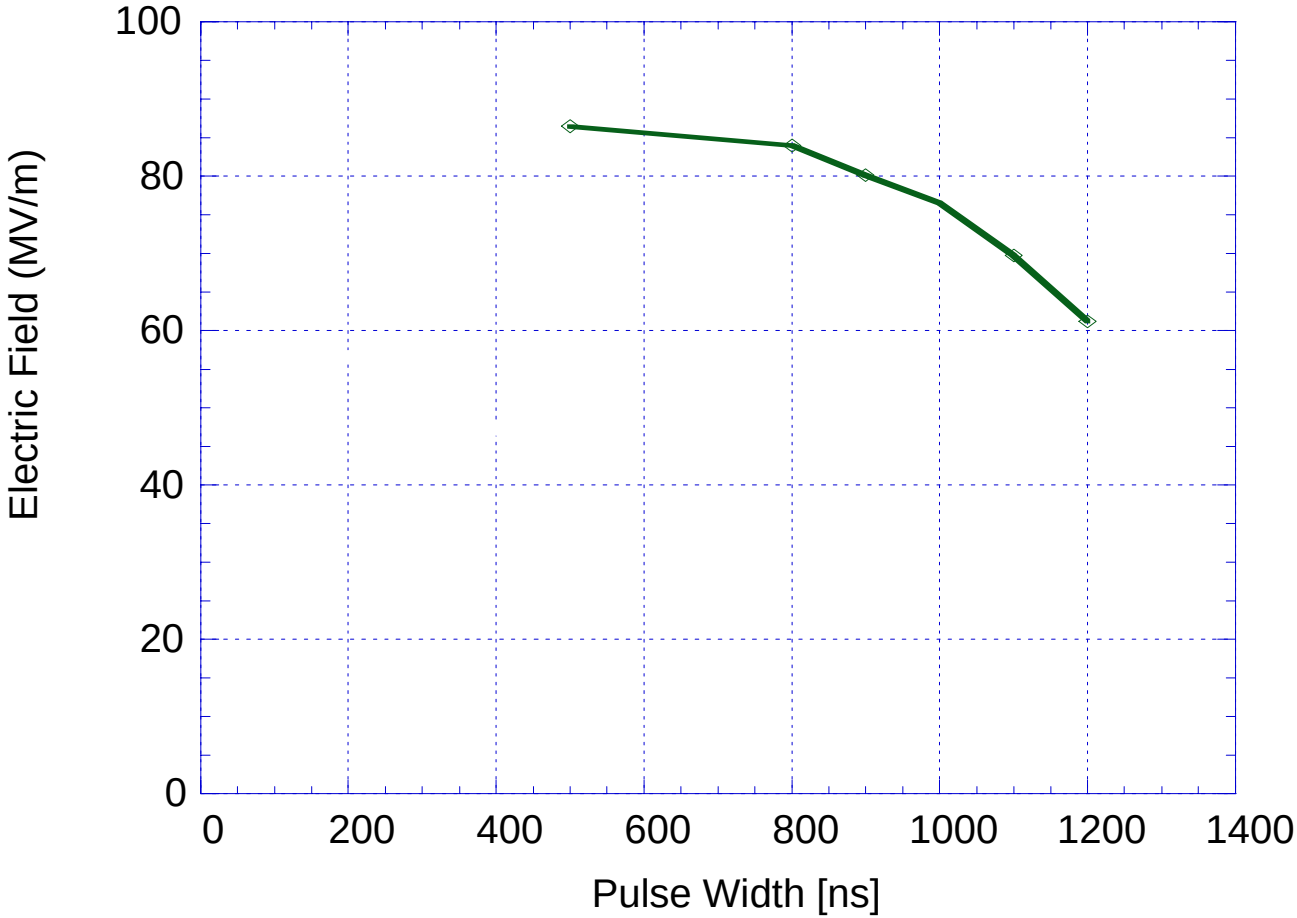
Compactness

•A waveguide near cutoff, hence, a low group velocity. One can use a higher order mode to reduce the losses. A bad idea, dispersion will destroy the pulse shape at a group velocity less than 4.

•Loaded waveguide (slow wave structure). A bad idea because of dispersion and losses.

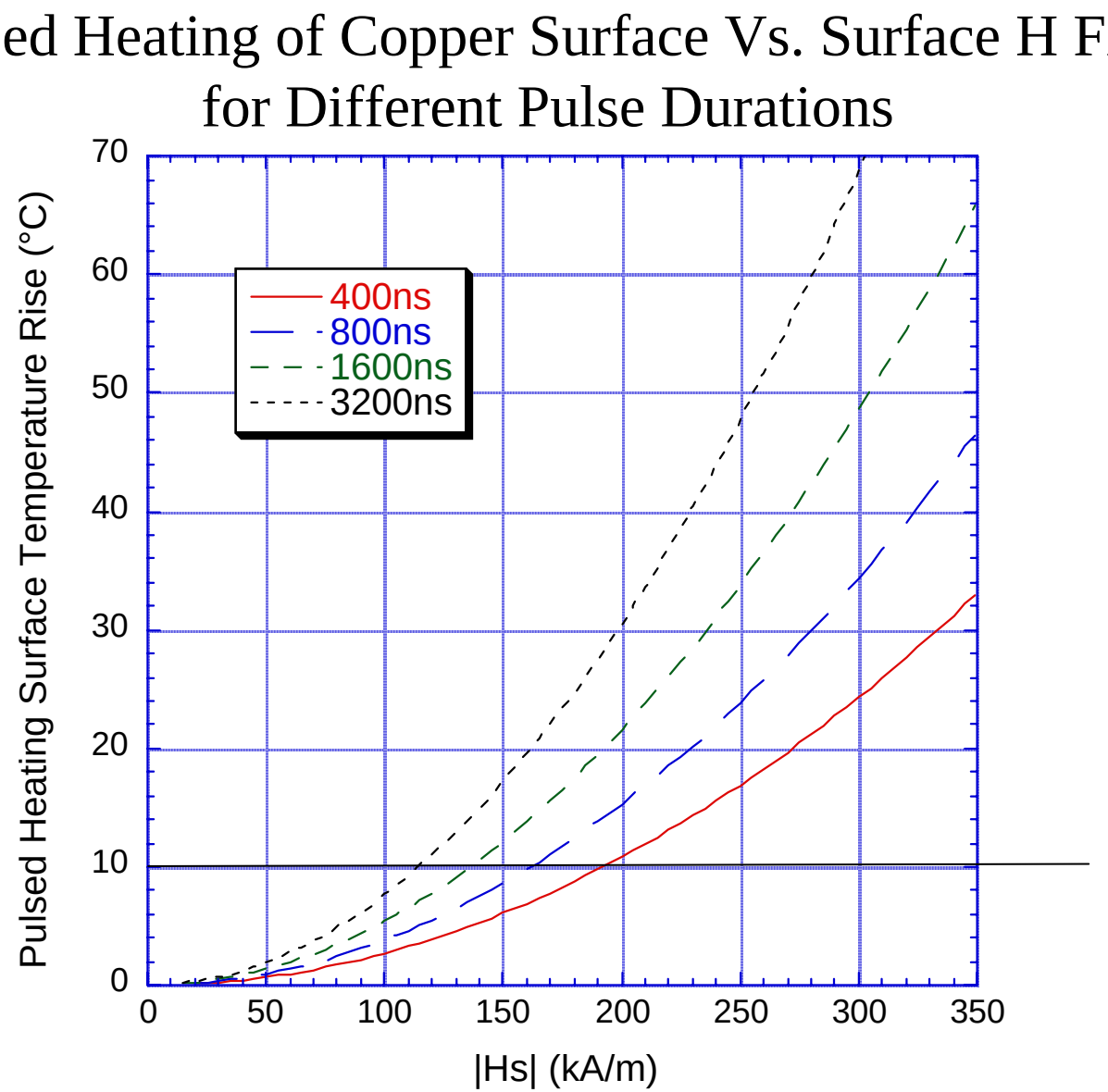
•Multimoded Waveguide, the only good idea with no draw backs. We are using highly overmoded waveguide systems no mater what, using an extra mode, or two, or four, .. Is a bonus.


n_k=8
Single Moded DLDS
Multi-Moded DLDS (number of modes=3)
Active DLDS
Multi-Moded BPC (A high power circulator and 3 modes)
Multi-Moded SLED II (A high power circulator and 3 modes)
Active SLED II (One time Switching [7])
Multi-Moded DLDS (n_k=4, number of modes =3)
Single-Moded DLDS (n_k=4)
Relative Cost
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
4
6
8
10
12
14
16
Compression Ratio

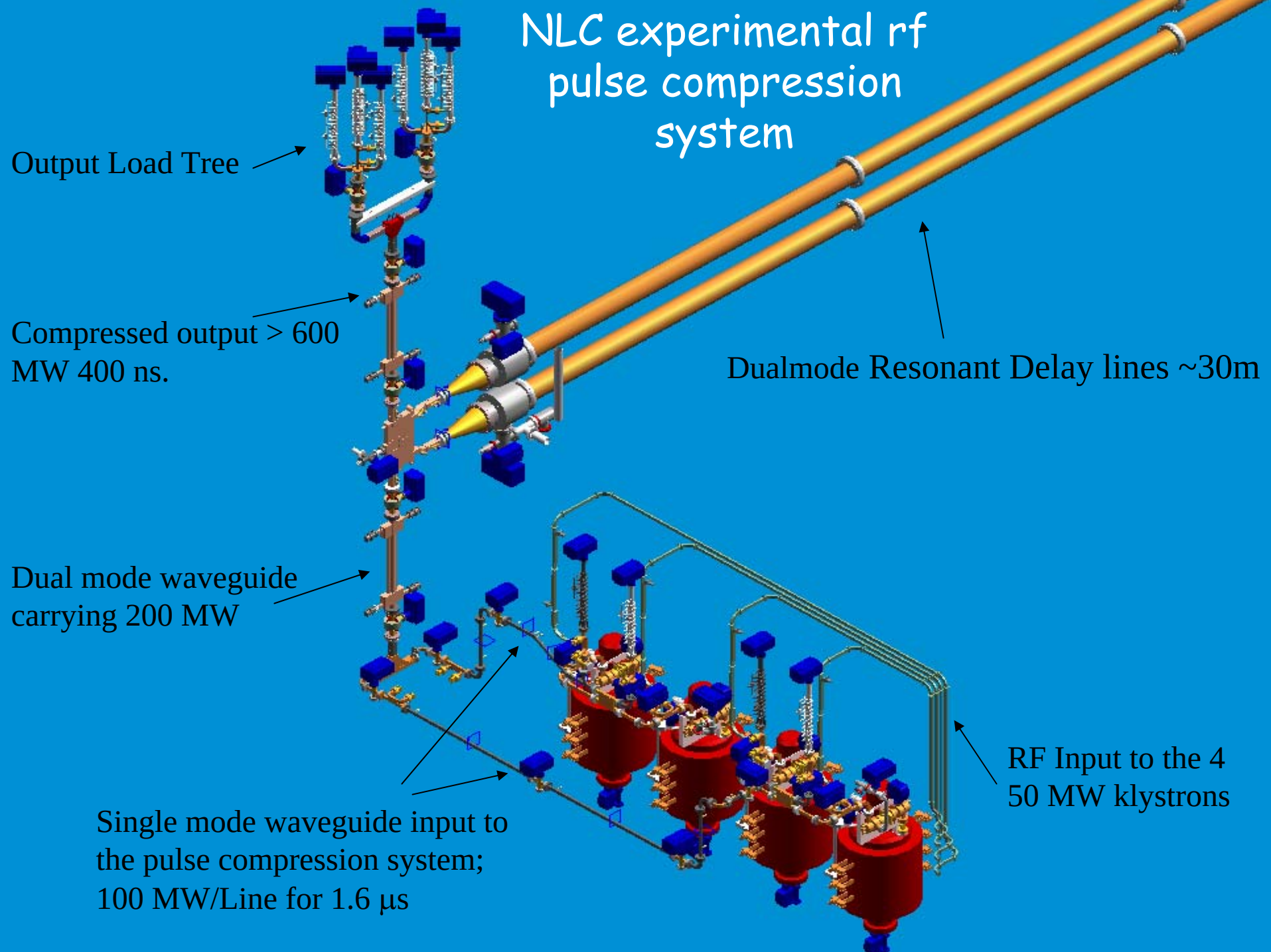


Electric Field breakdown strength in a 16% Group velocity copper waveguide at 11.424 GHz

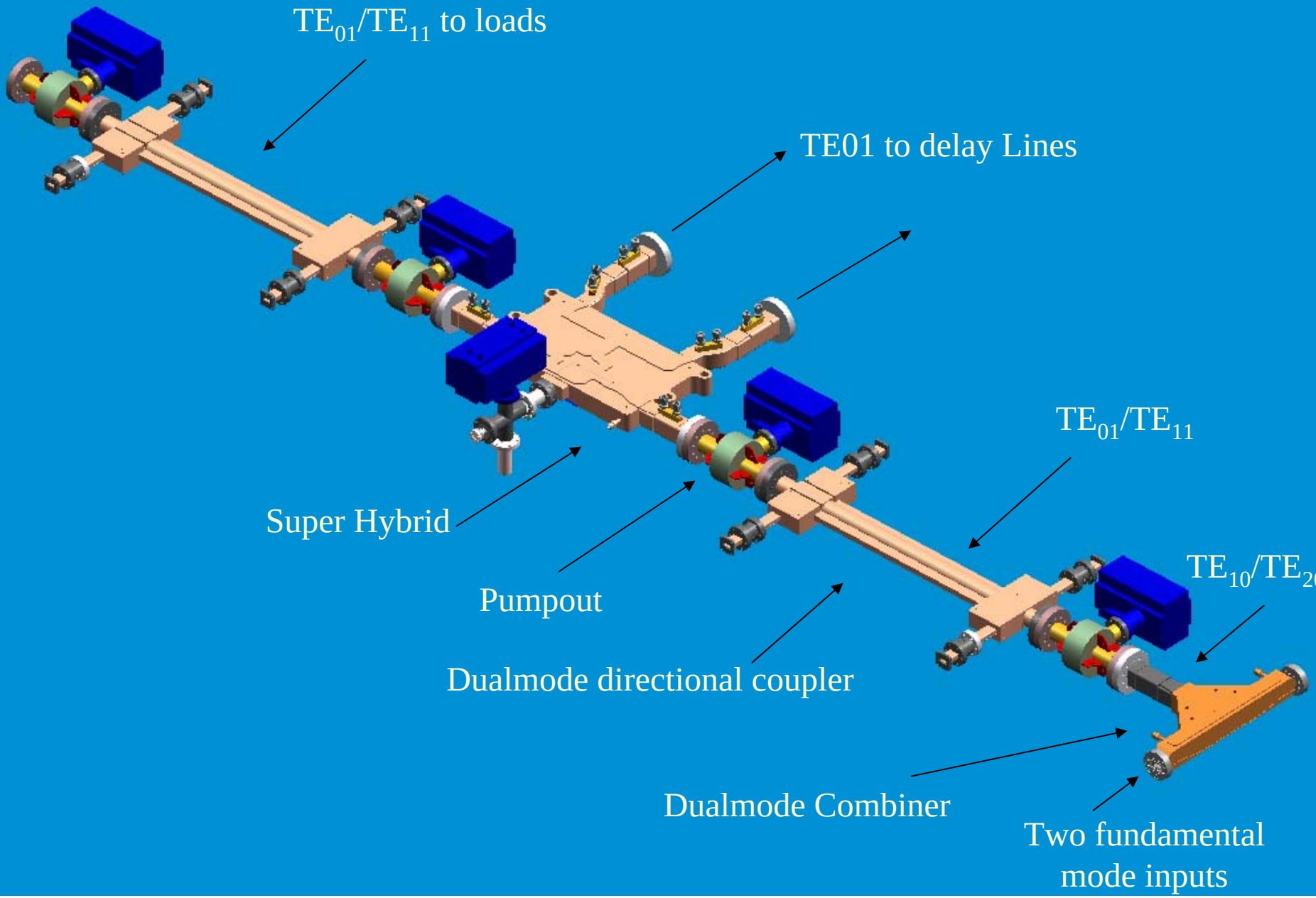
Pulsed Heating



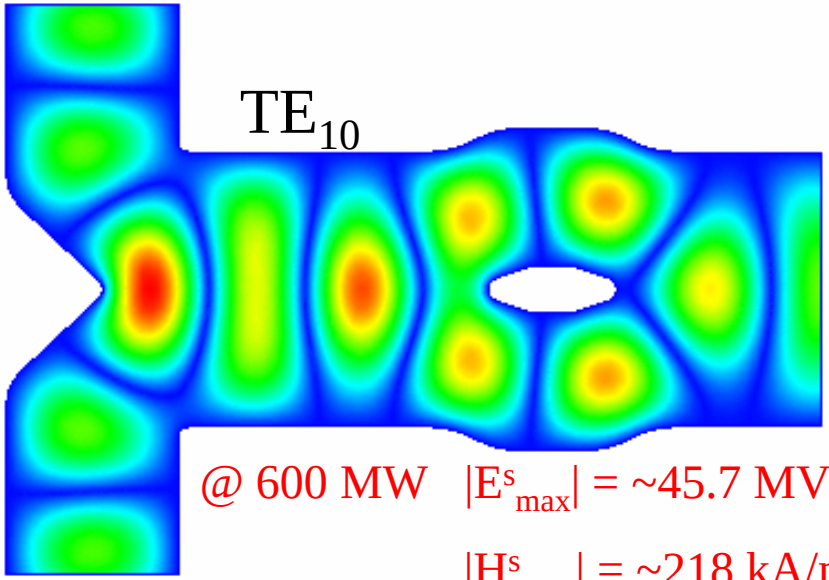
NLC experimental rf pulse compression system



The Head of the pulse compression system

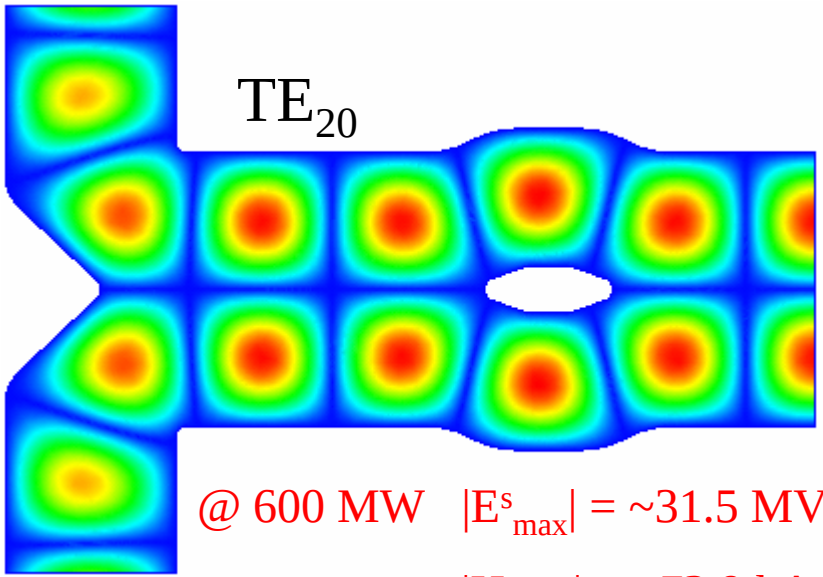


Dual-Mode Combiner



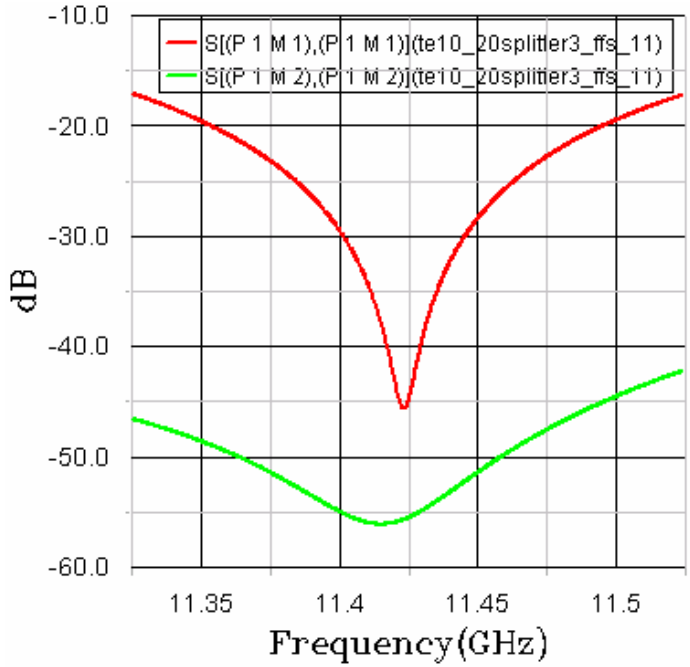
@ 600 MW $|E^s_{max}|$ = ~45.7 MV/m

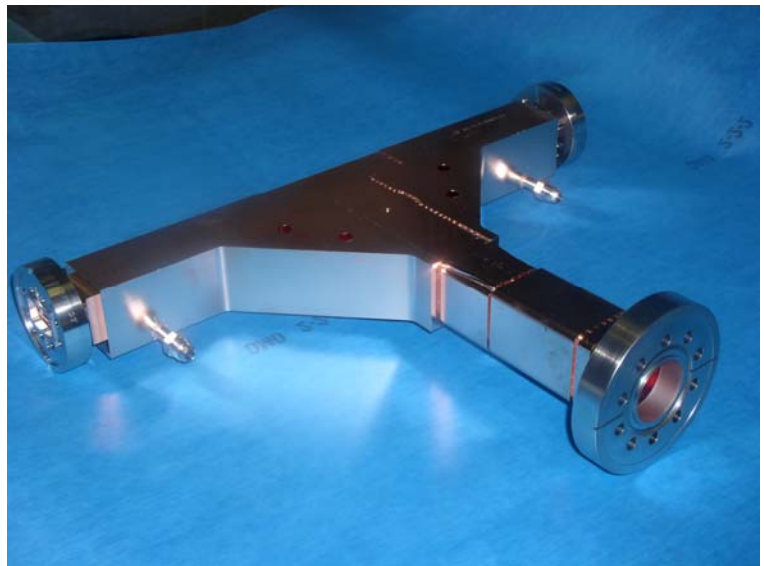
$|H^s_{max}|$ = ~218 kA/m



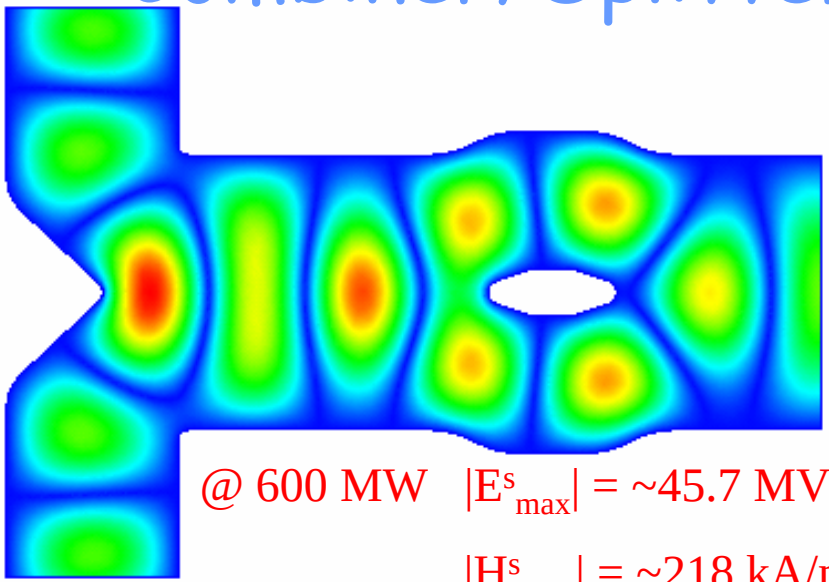
@ 600 MW $|E^s_{max}|$ = ~31.5 MV/m

$|H^s_{max}|$ = ~73.9 kA/m





Dual-Mode Combiner/Splitter



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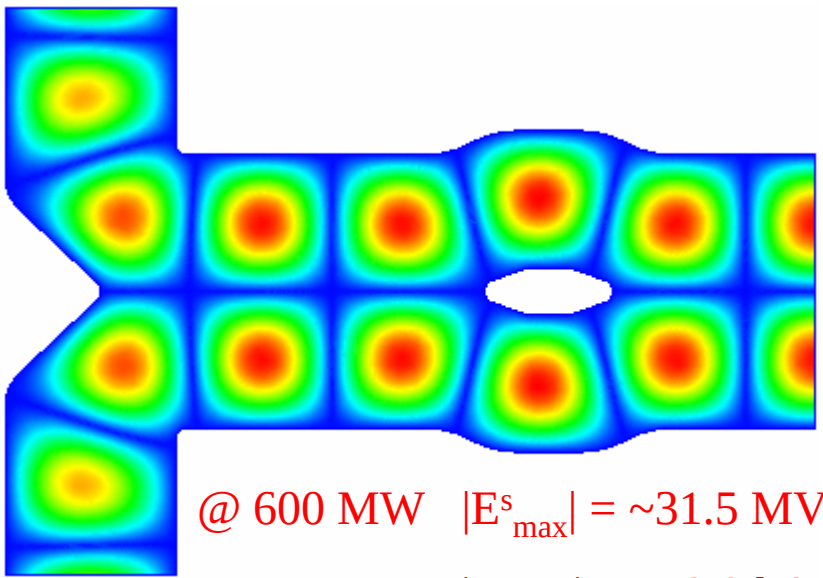

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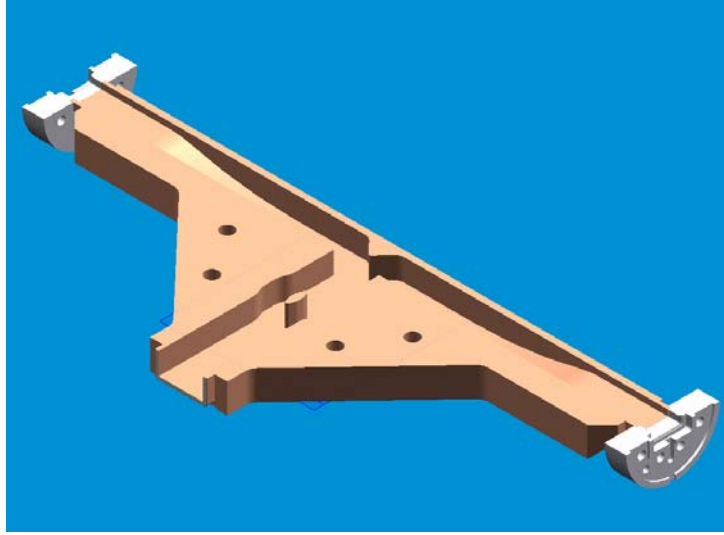
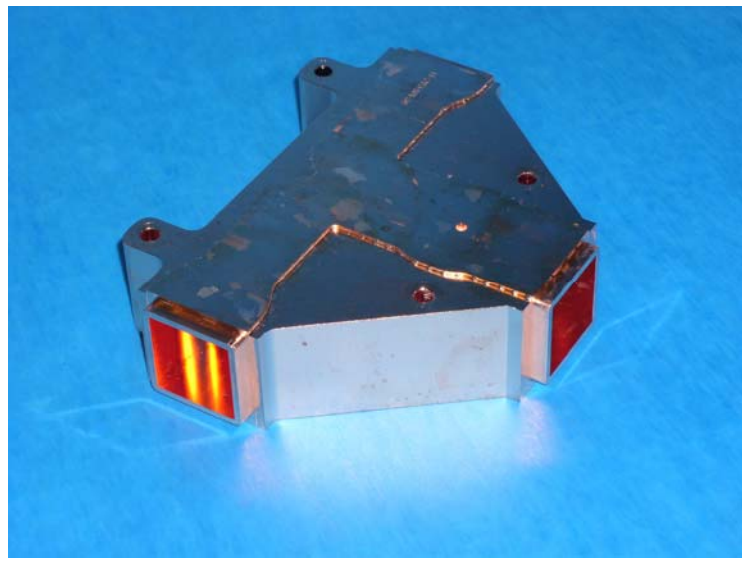
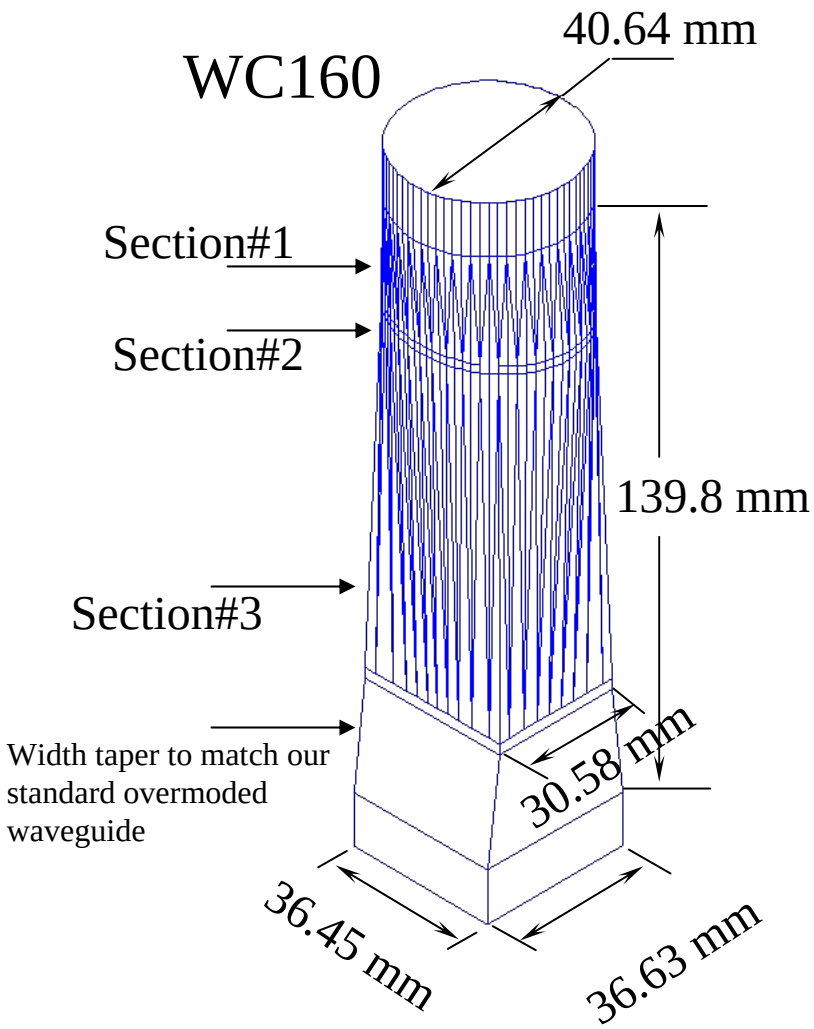
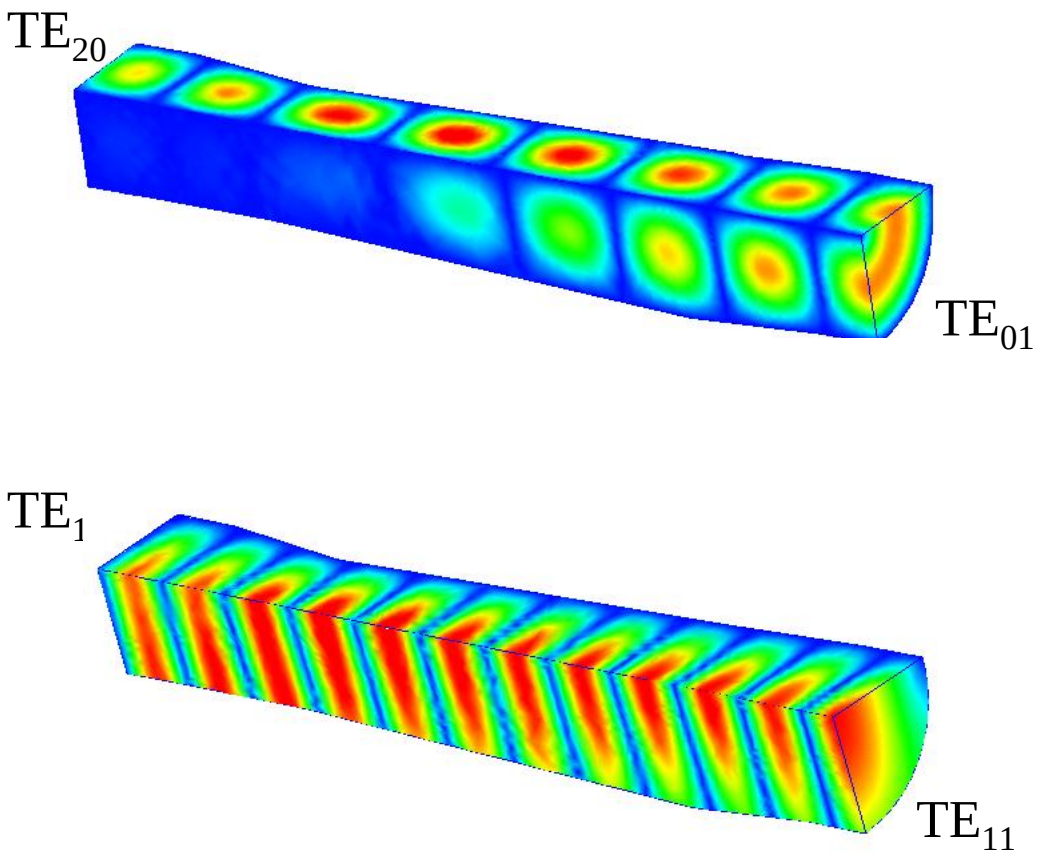
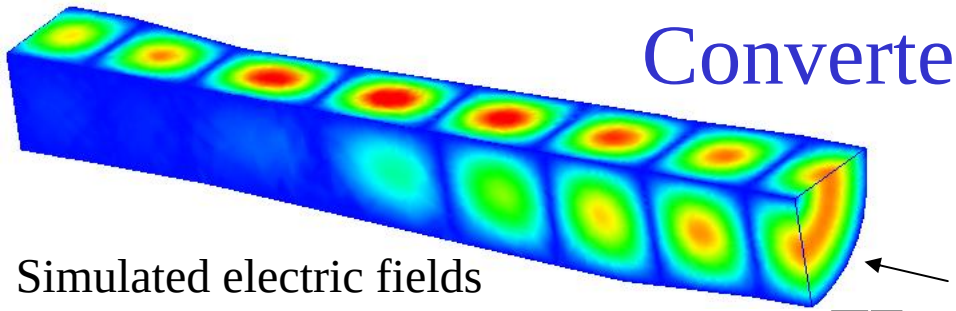




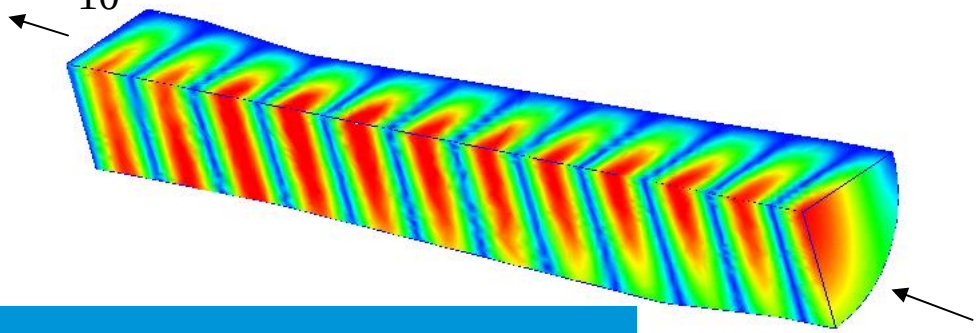

WC160
40.64 mm
Section#1
Section#2
139.8 mm
Section#3
Width taper to match our standard overmoded waveguide
30.58 mm
36.45 mm
36.63 mm

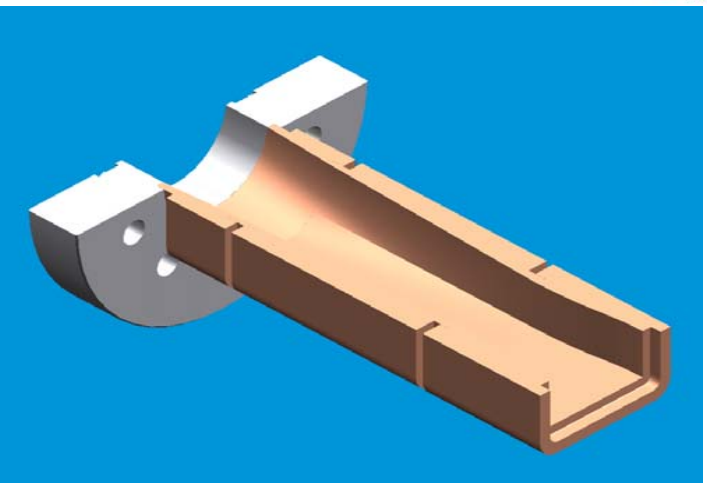

TE_{20}
TE_{01}
TE_{1}
TE_{11}

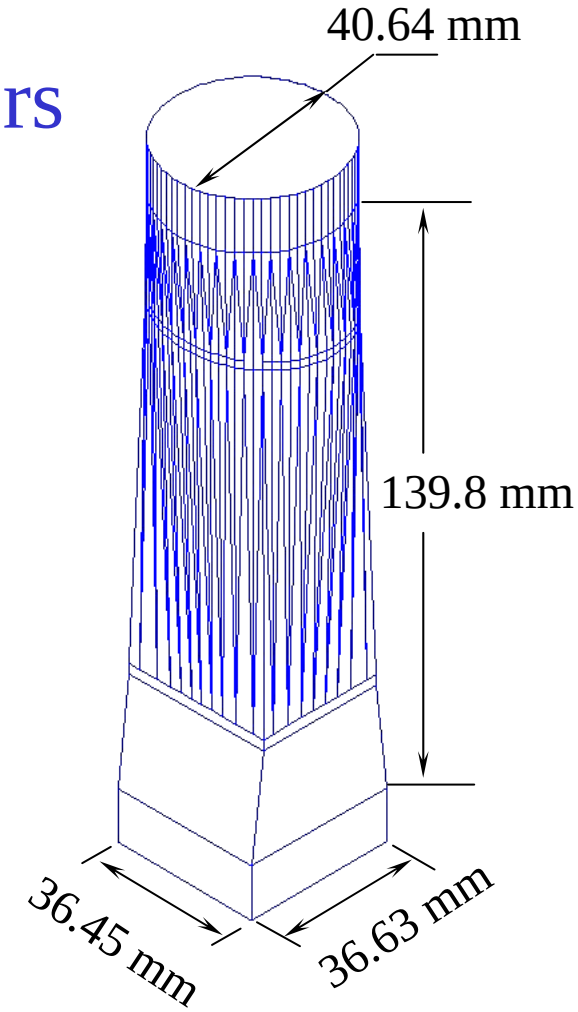
Dual-Moded Rectangular ⟷ Circular Converter/Tapers



Simulated electric fields (HFSS)of the multi-moded circular to rectangular taper

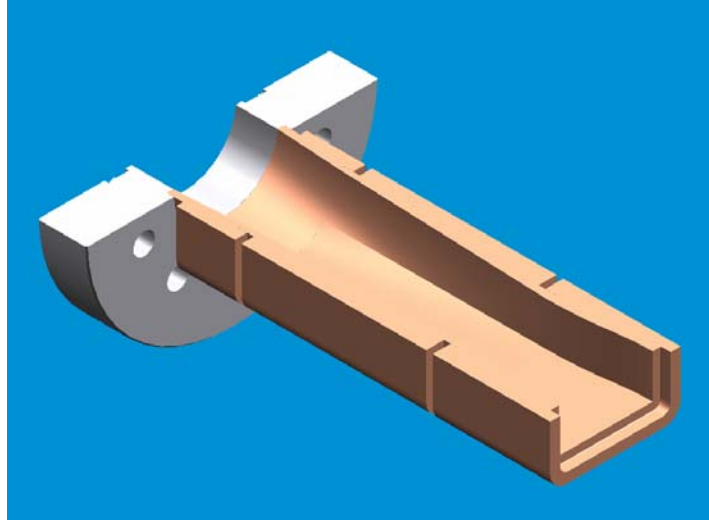




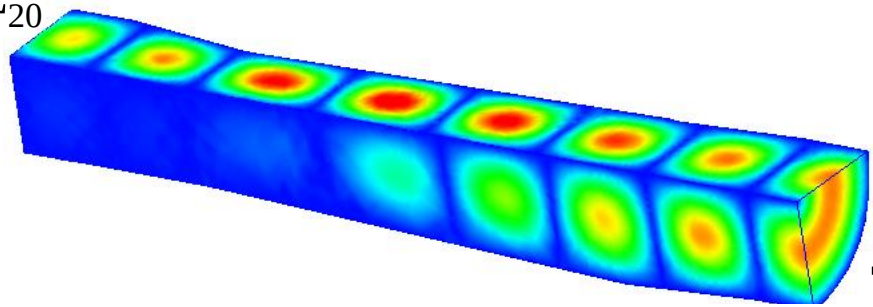


Taper Geometry (Operating Frequency=11.424 GHz)

Dualmode Rectangular-to-Circular Taper

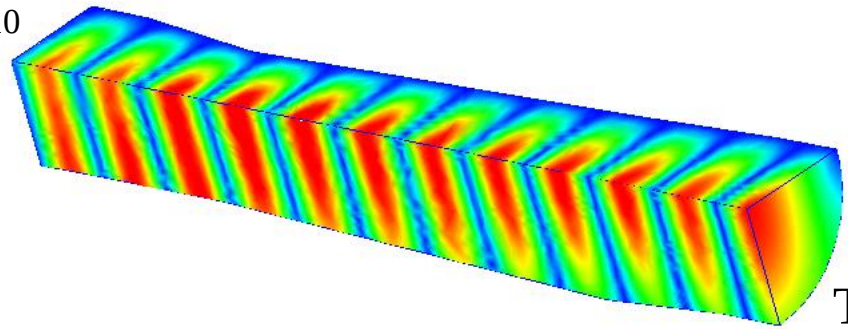


TE_{20}

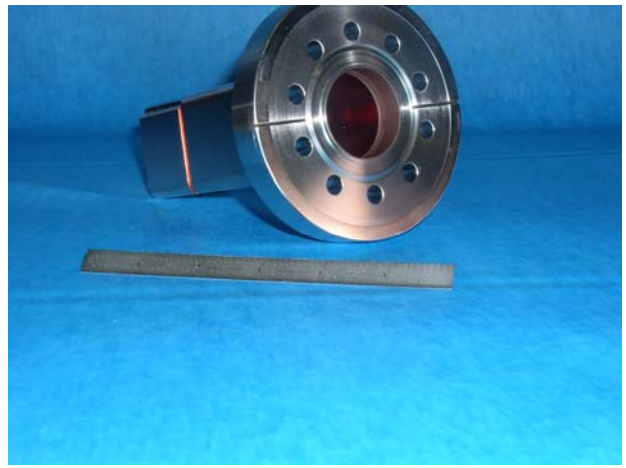


TE_{01}

TE_{10}



TE_{11}

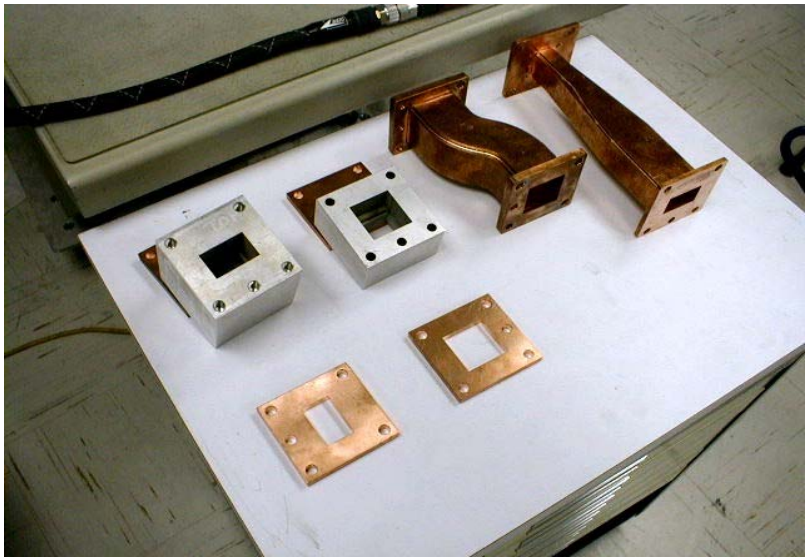


Instrumental components for cold testing of multimode components:

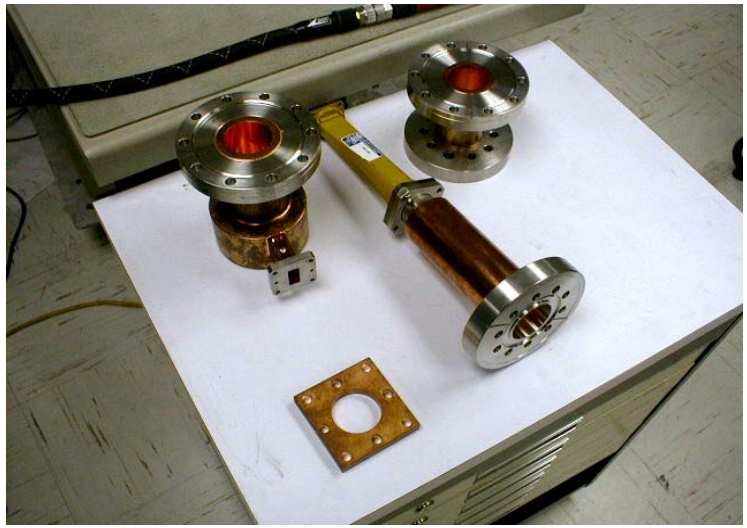
1. TE_{11} Mode launcher
2. TE_{01} Mode launcher
3. Width taper
4. Height taper
5. Small waveguide sections with different lengths at all waveguide cross sections

We followed a strict methodology of designing these instruments. They had to be simulated with at least three different codes and have a performance that is much better than any component that we have. Of course we can only do that because there is no restrictions on field levels.

Cold Test Components/Calibration Standards

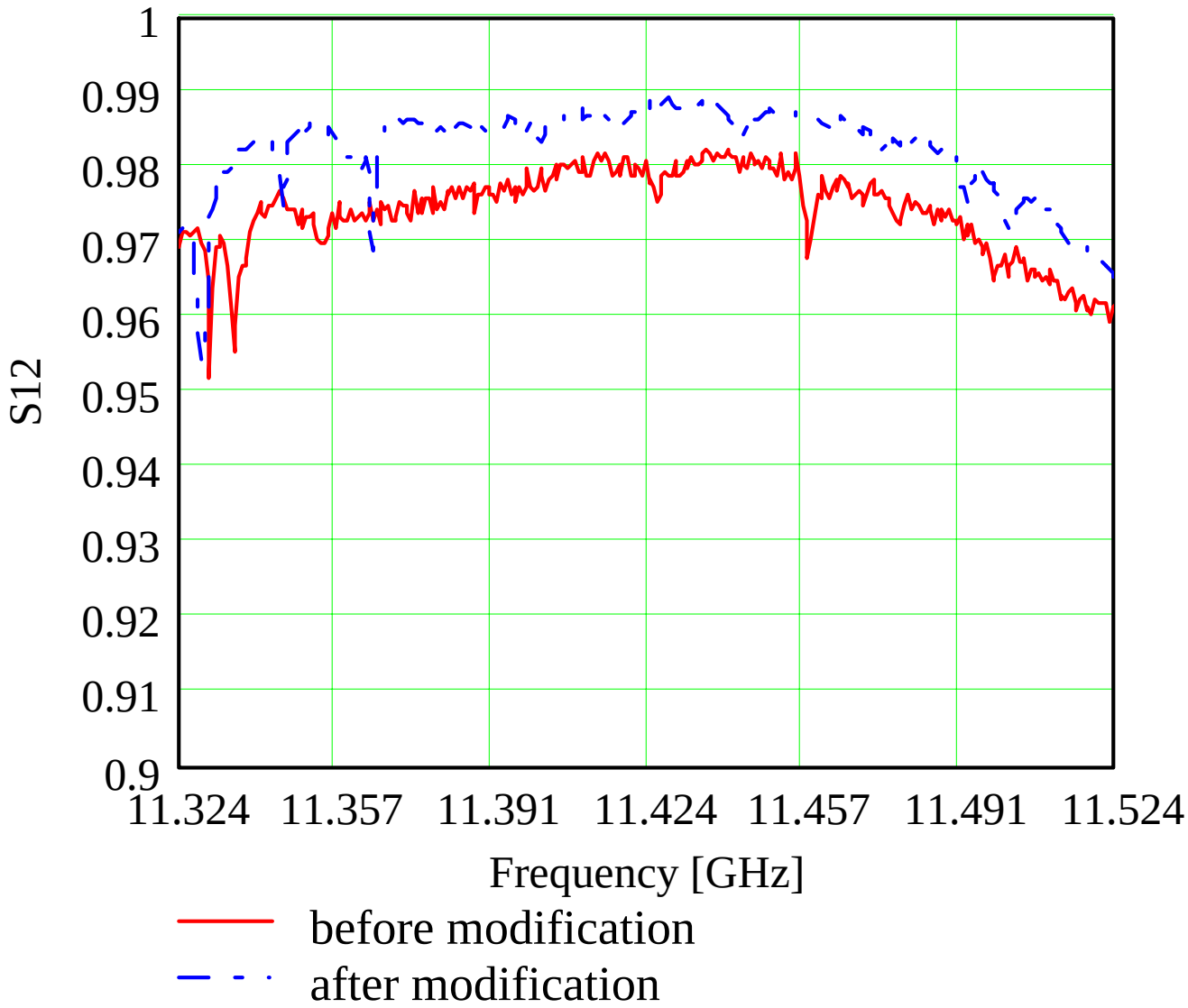


Width Taper, Height Tapers and Jog Mode Converter

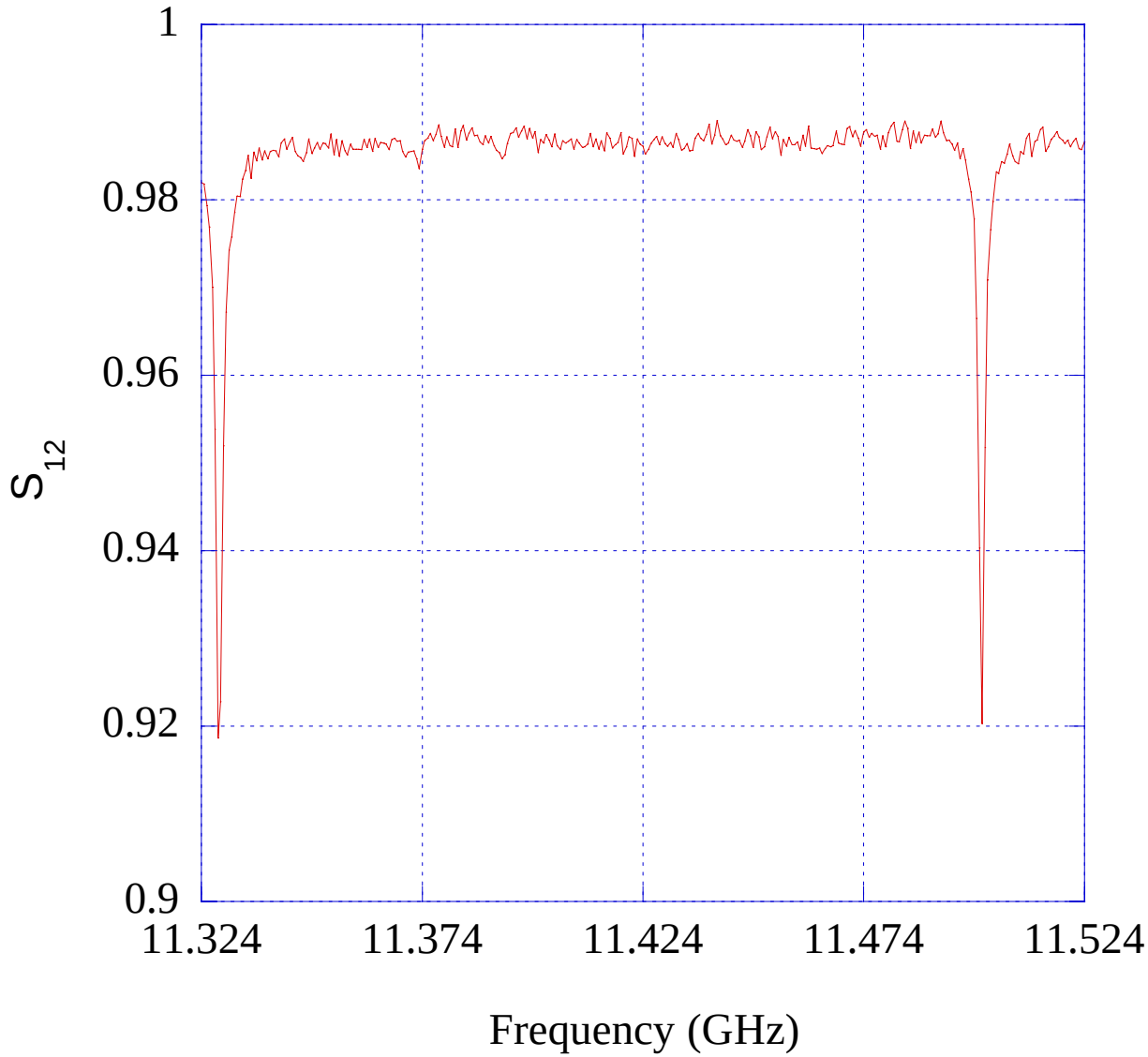


TE_{01} Mode Converter, TE_{11} Mode Converter, and Size Taper

Multimoded Matched Load



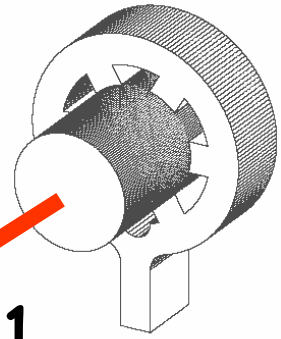
Measured S_{12} between the Rectangular TE_{02} mode and the circular TE_{01} mode. These measurements include the response of mode transducers necessary to launch the modes at both ends of the taper.

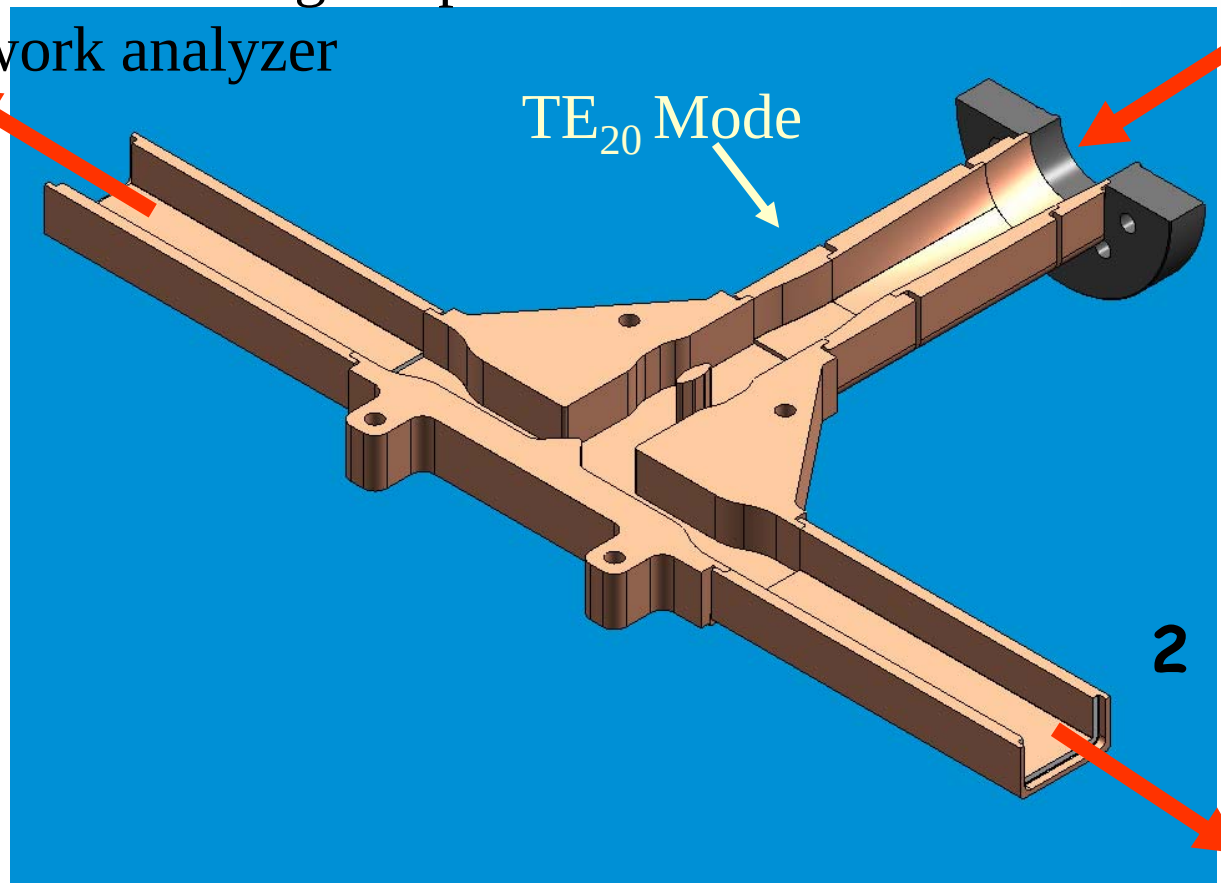


Measured S_{12} between the rectangular TE_{01} mode and the circular TE_{11} mode. These measurements include the response of mode transducers necessary to launch the modes at both ends of the taper.

To instrumental width taper-
To instrumental height taper-
To Network analyzer

TE_{01} Mode launcher

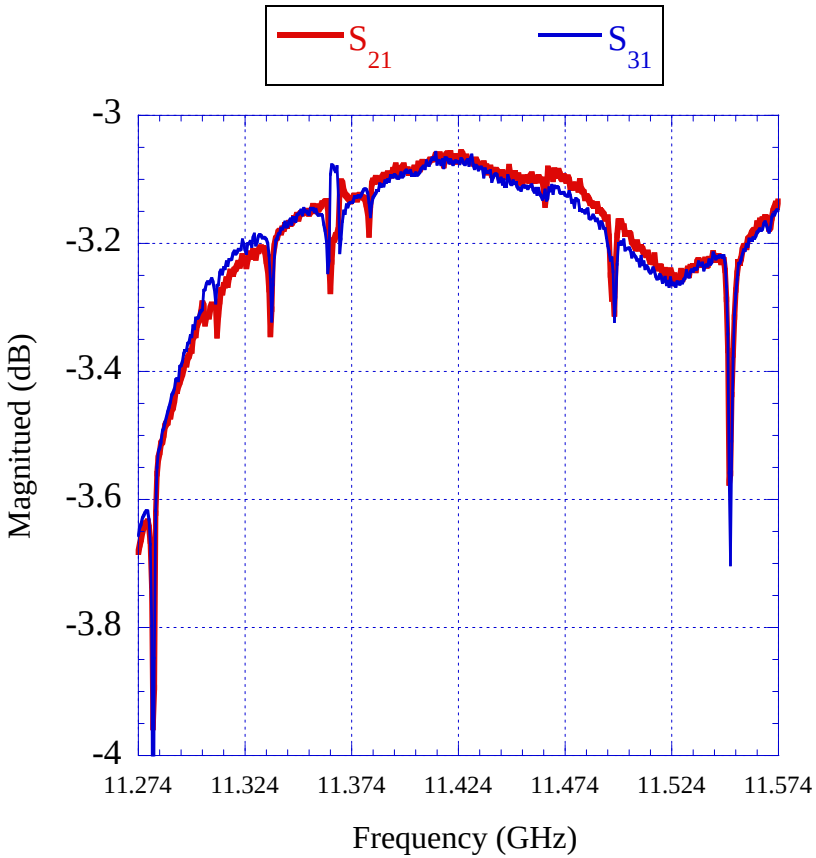


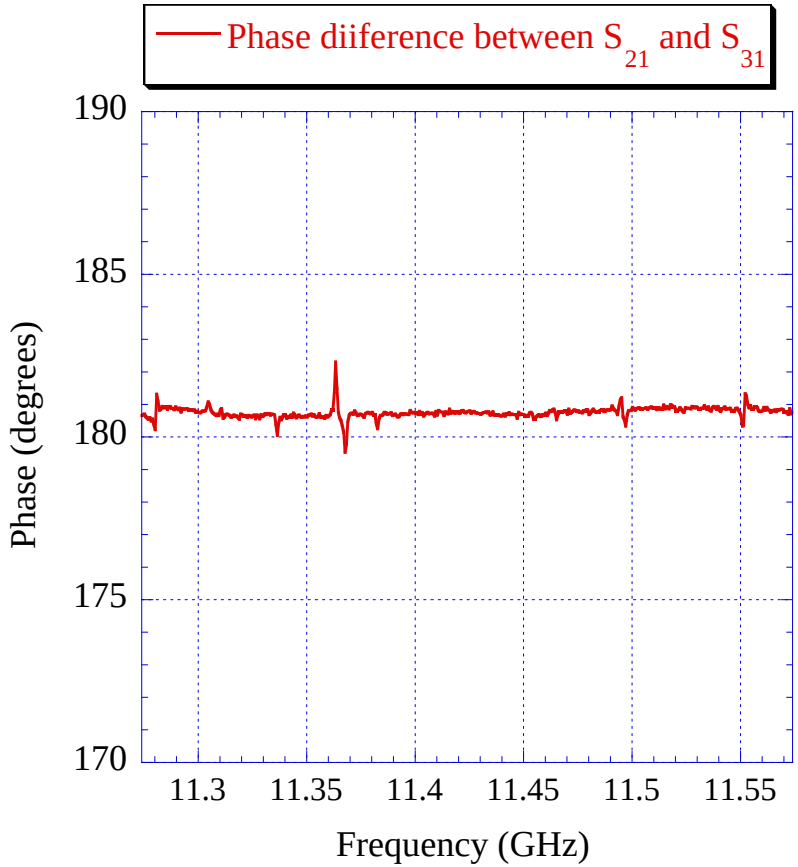


From Network Analyzer

To instrumental width taper-
To instrumental height taper-
To Network analyzer

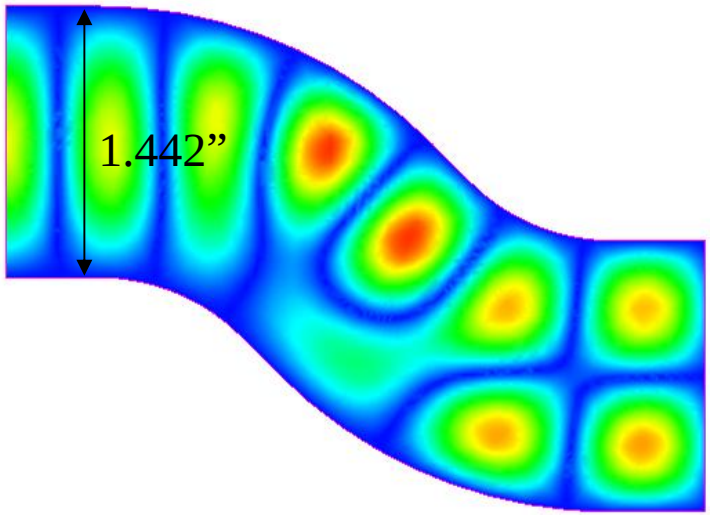
Cold Test Setup for the Splitter and Circular-to-Rectangular Taper

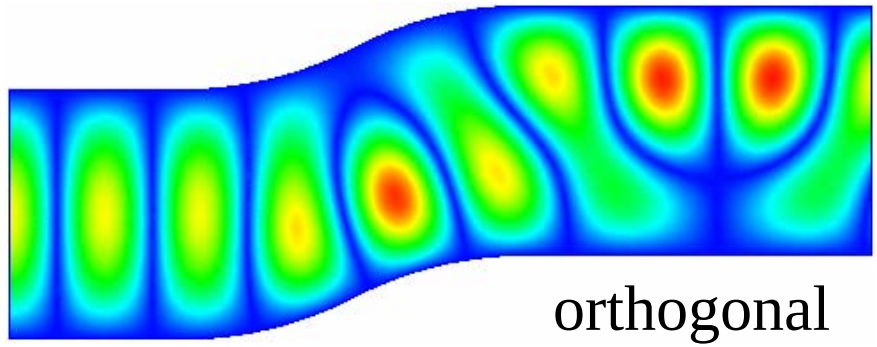




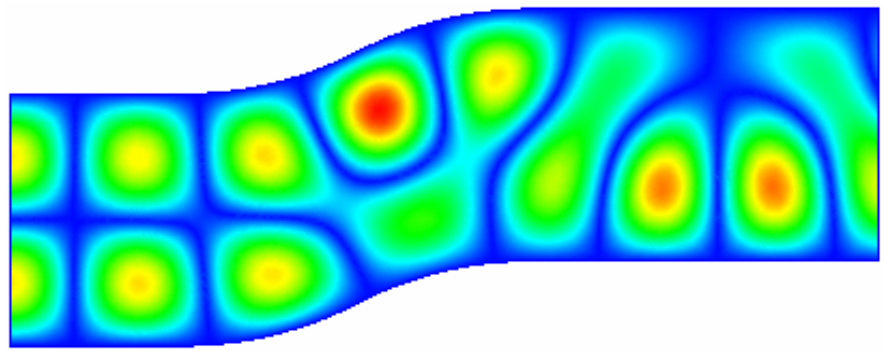
Cold Test Results of:
Splitter-Circular to rectangular taper-Wraparound mode converter-instrumental height taper-instrumental width taper. Total losses at 11.424 GHz =1.3%

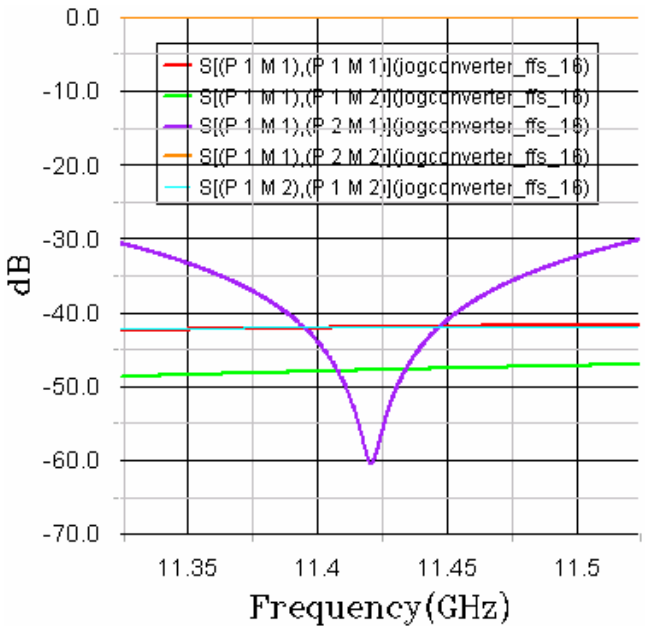
Jog Converter and Mode Mixer





orthogonal
50/50 mixes

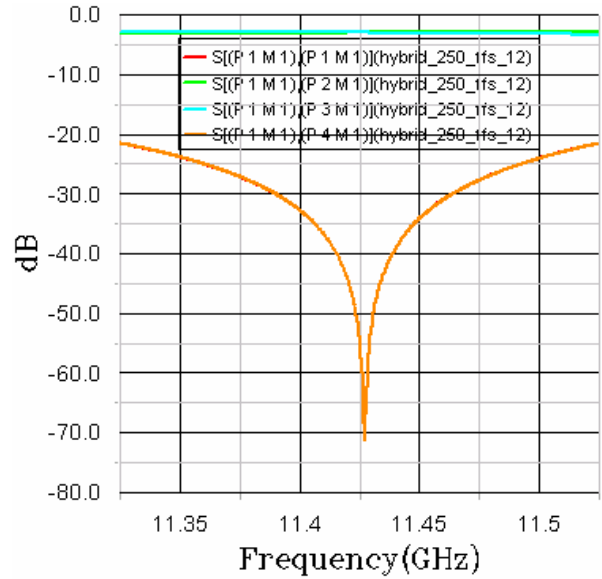




	(P 1 M 1)	(P 1 M 2)	(P 2 M 1)	(P 2 M 2)
(P 1 M 1)	0.0018	0.0048	0.707	0.7072
(P 1 M 2)	0.0048	0.0087	0.7072	0.707
(P 2 M 1)	0.707	0.7072	0.0019	0.0048
(P 2 M 2)	0.7072	0.707	0.0048	0.0087

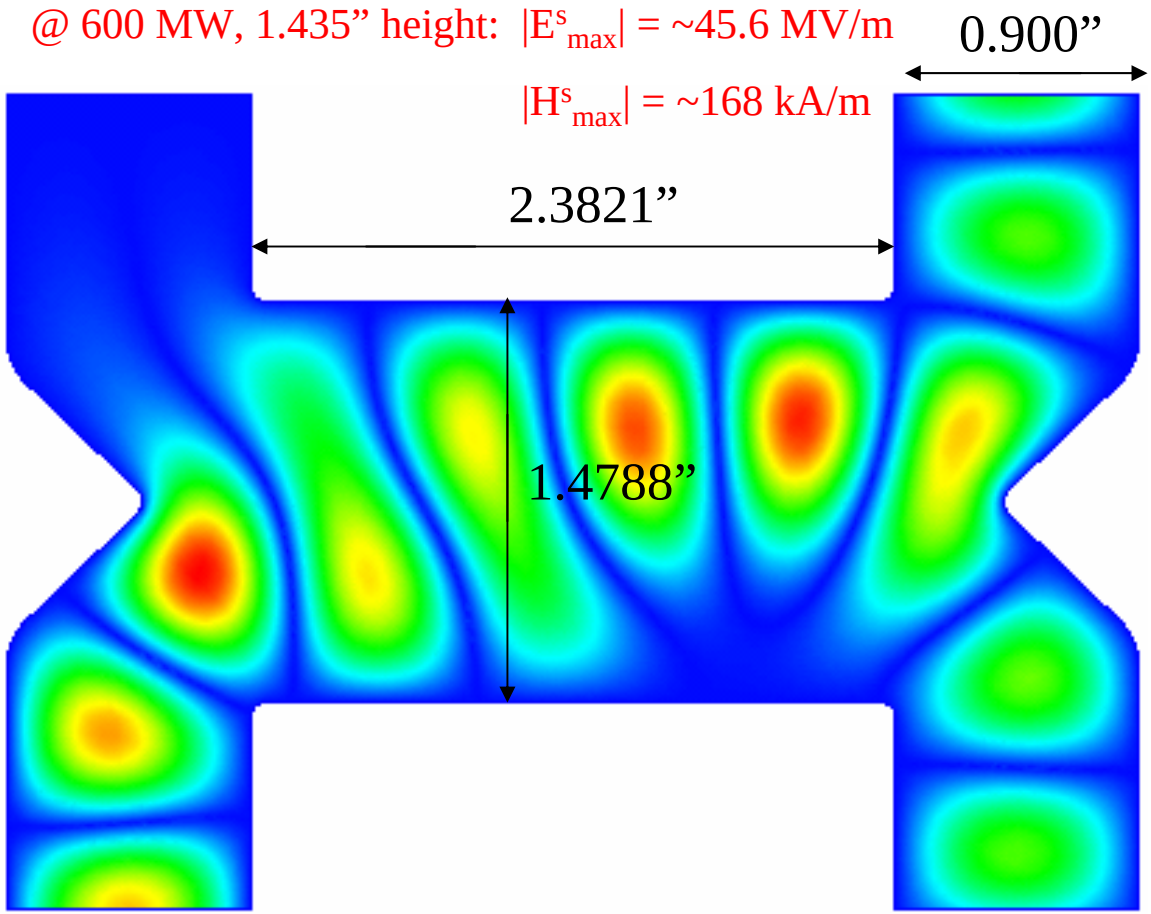
Magic H Hybrid

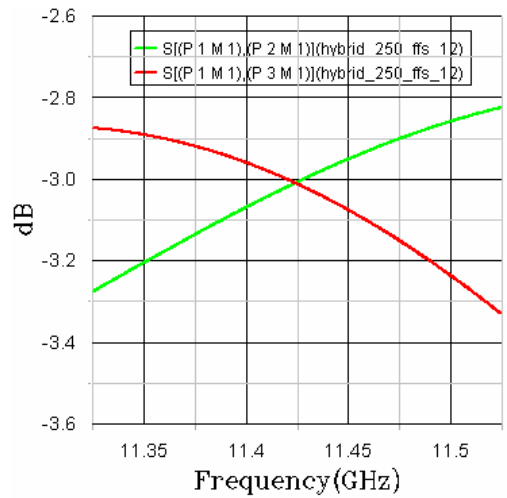
	(P 1 M 1)	(P 2 M 1)	(P 3 M 1)	(P 4 M 1)
(P 1 M 1)	0.0028	0.7071	0.7071	0.0028
(P 2 M 1)	0.7071	0.0028	0.0028	0.7071
(P 3 M 1)	0.7071	0.0028	0.0028	0.7071
(P 4 M 1)	0.0028	0.7071	0.7071	0.0028



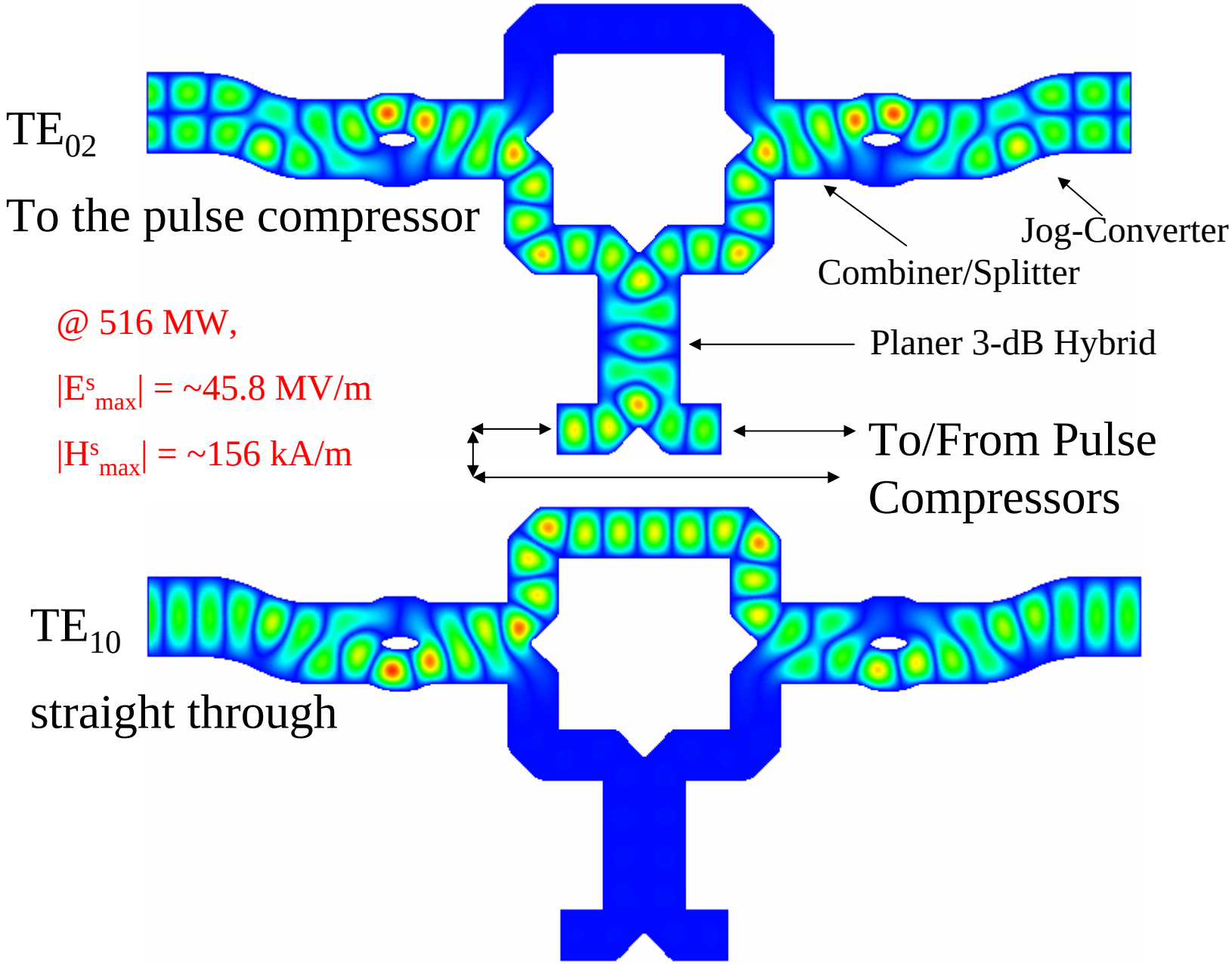
@ 600 MW, 1.435” height: $|E^s_{max}|$ = ~45.6 MV/m

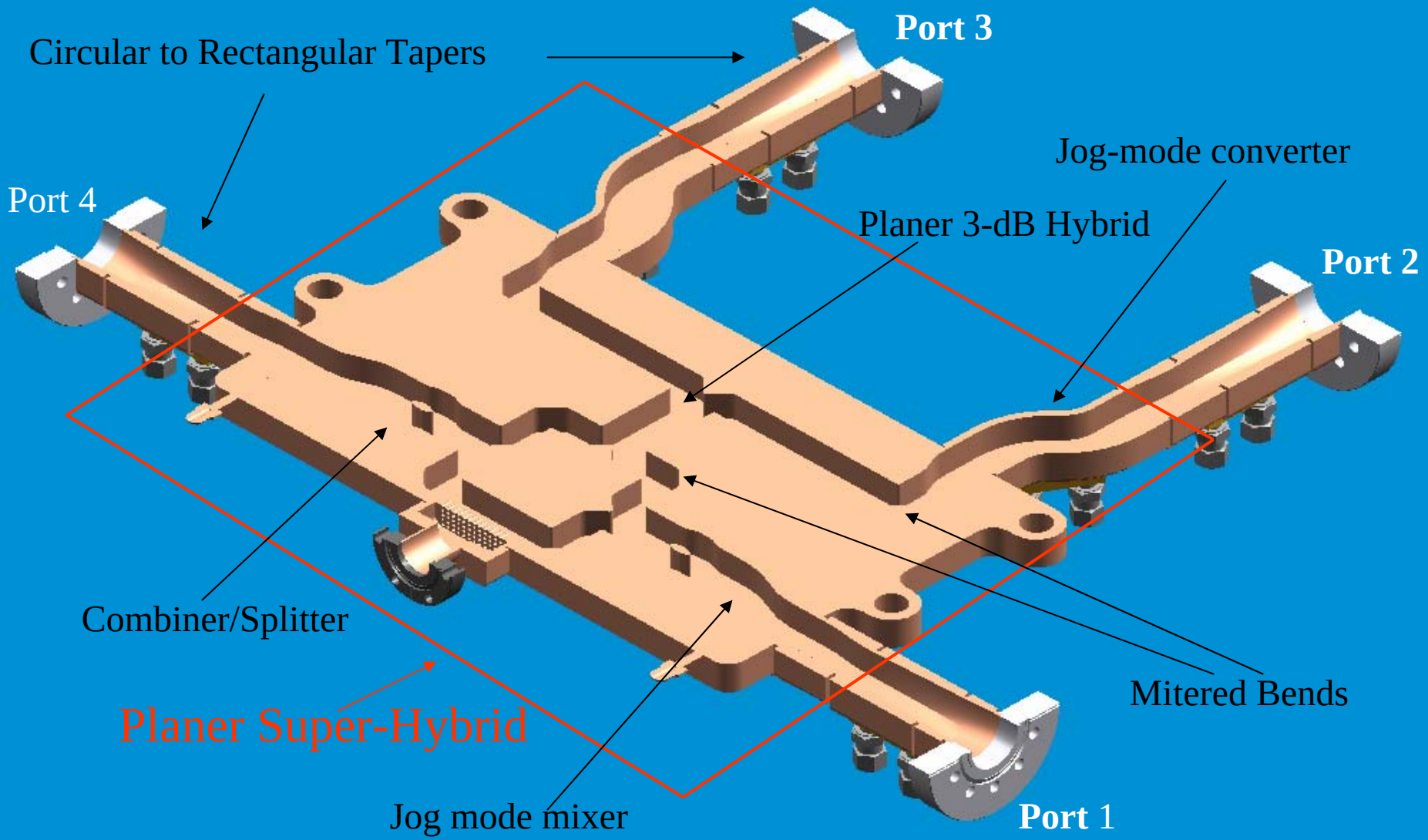
$|H^s_{max}|$ = ~168 kA/m

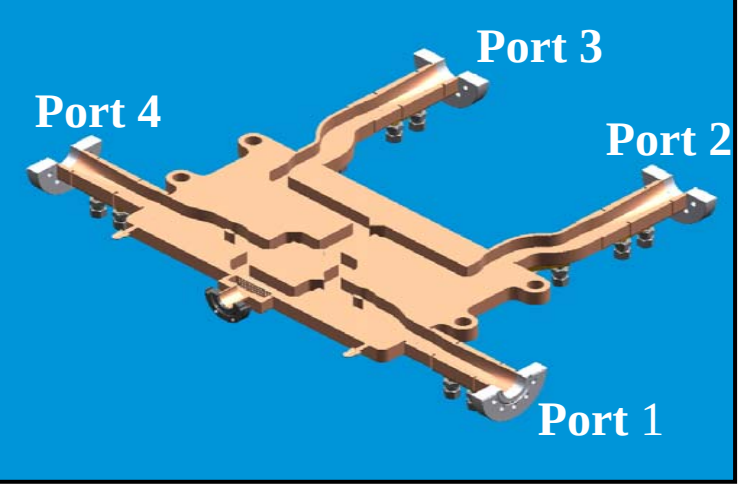




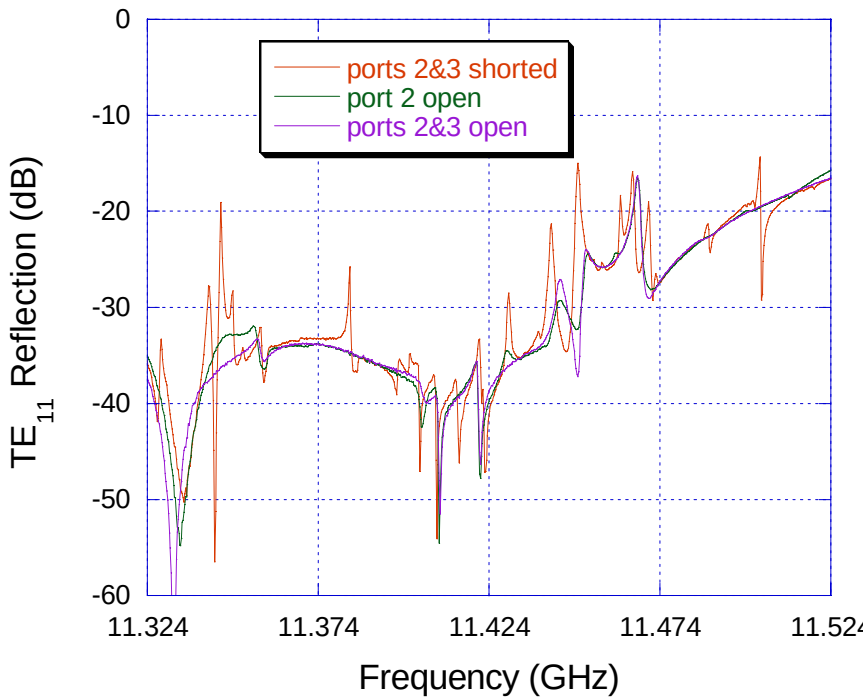
C. Nantista ‘02

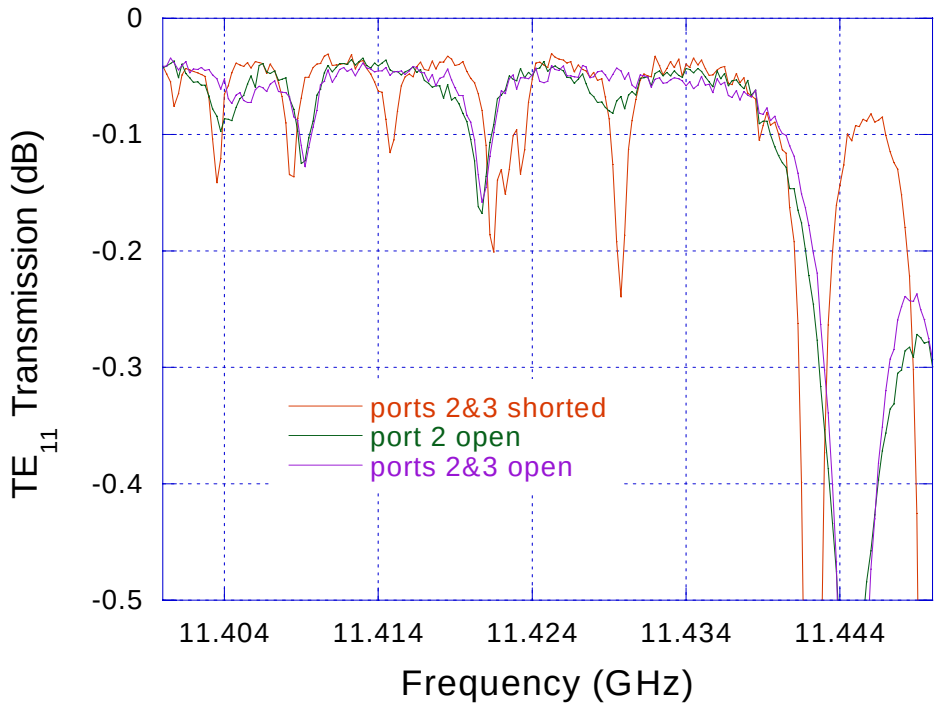

TE_{02}
To the pulse compressor
Jog-Converter
Combiner/Splitter
@ 516 MW,
$|E^s_{max}|$ = ~45.8 MV/m
$|H^s_{max}|$ = ~156 kA/m
Planer 3-dB Hybrid
To/From Pulse Compressors
TE_{10}
straight through

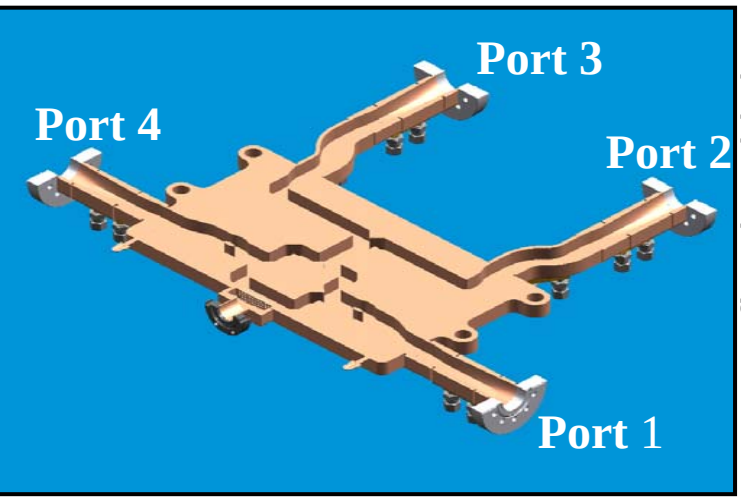

Circular to Rectangular Tapers
Port 3
Port 4
Jog-mode converter
Planer 3-dB Hybrid
Port 2
Combiner/Splitter
Planer Super-Hybrid
Mitered Bends
Jog mode mixer
Port 1

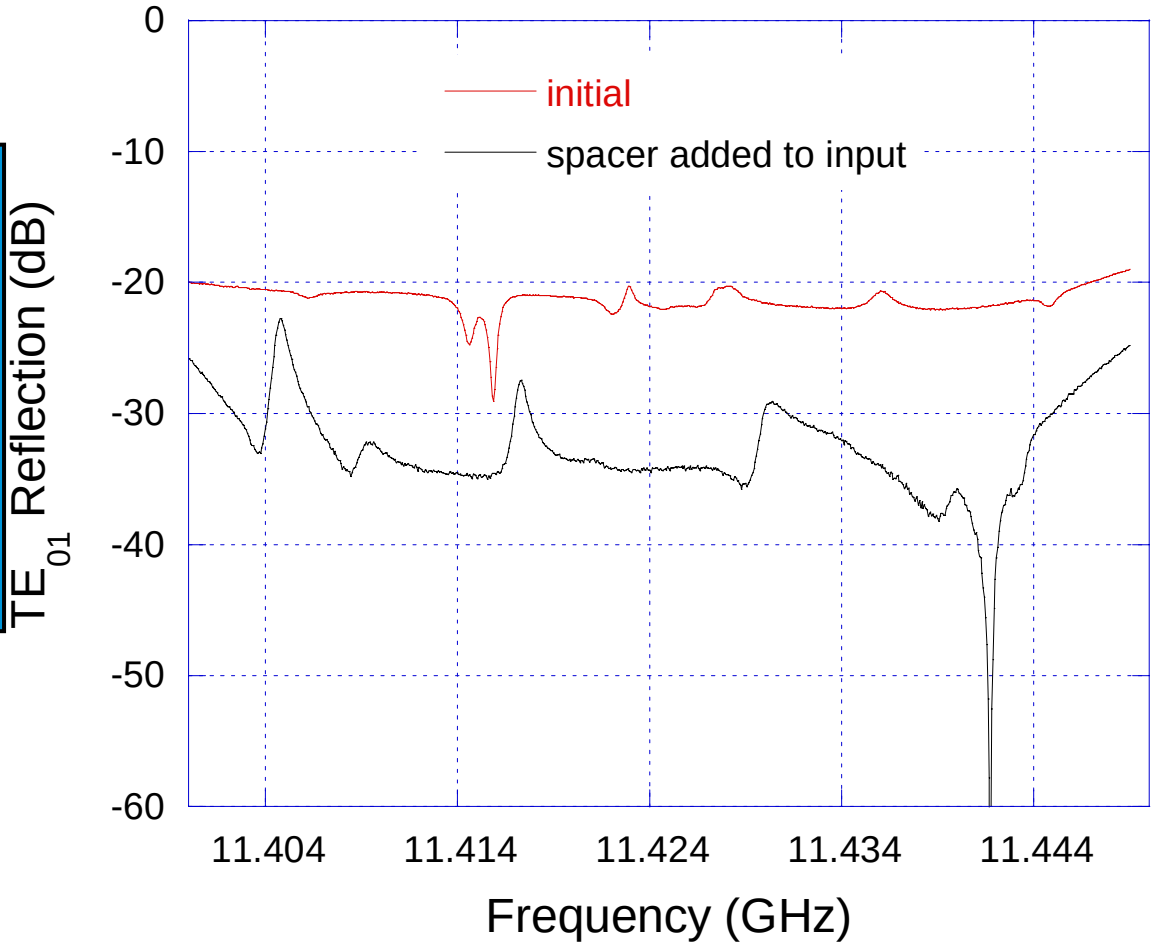


Circular TE_{11} mode transmission and reflection between port 1 and port 4 (S_{41}) for different conditions at port 2 and port 3.

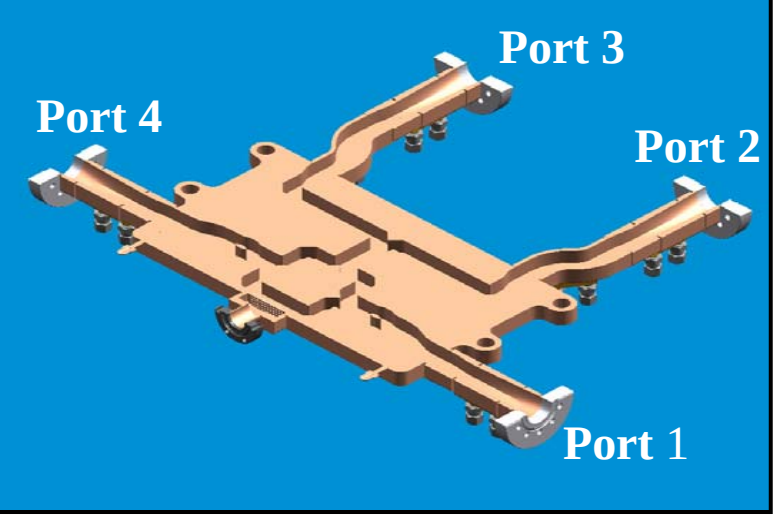




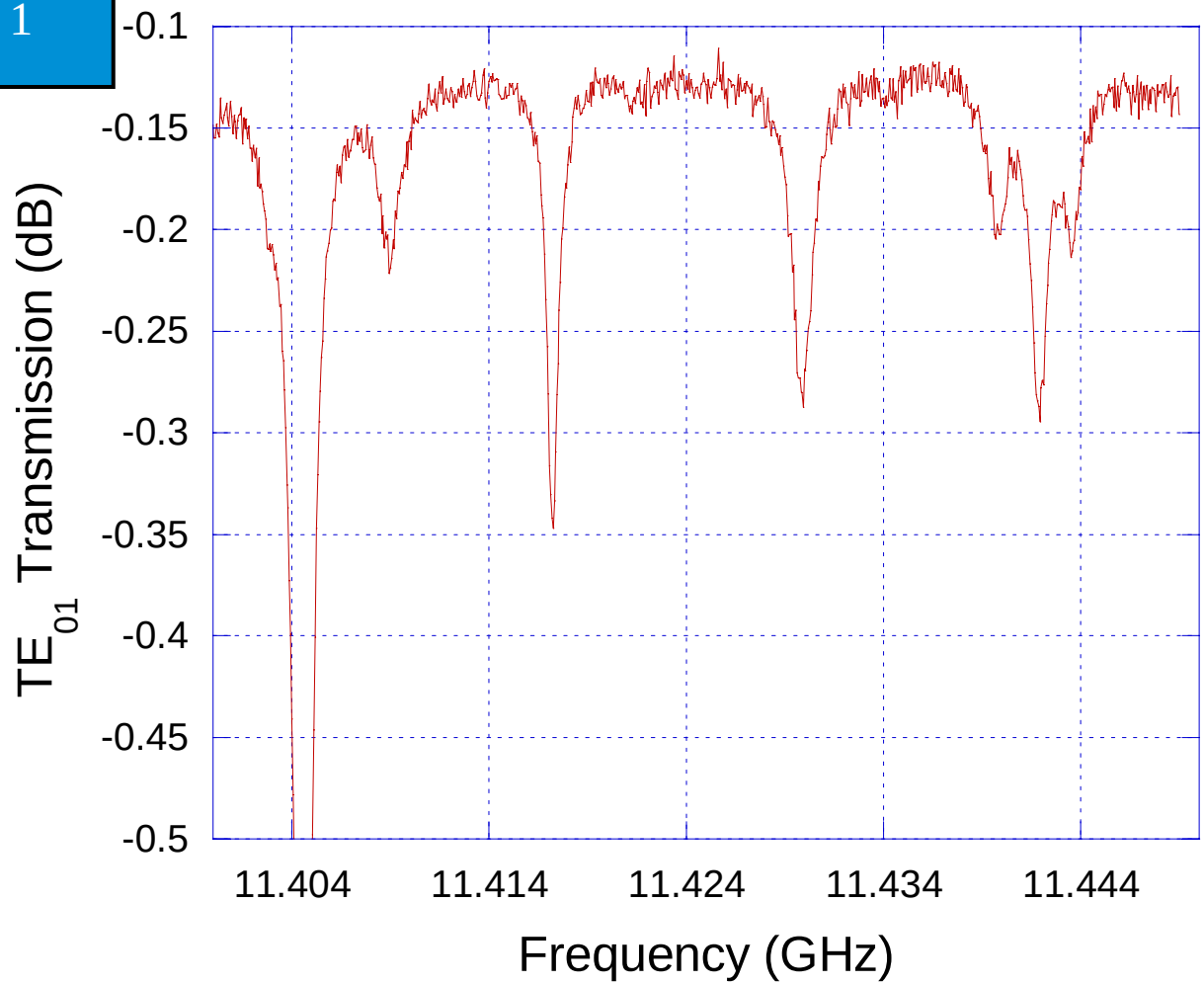


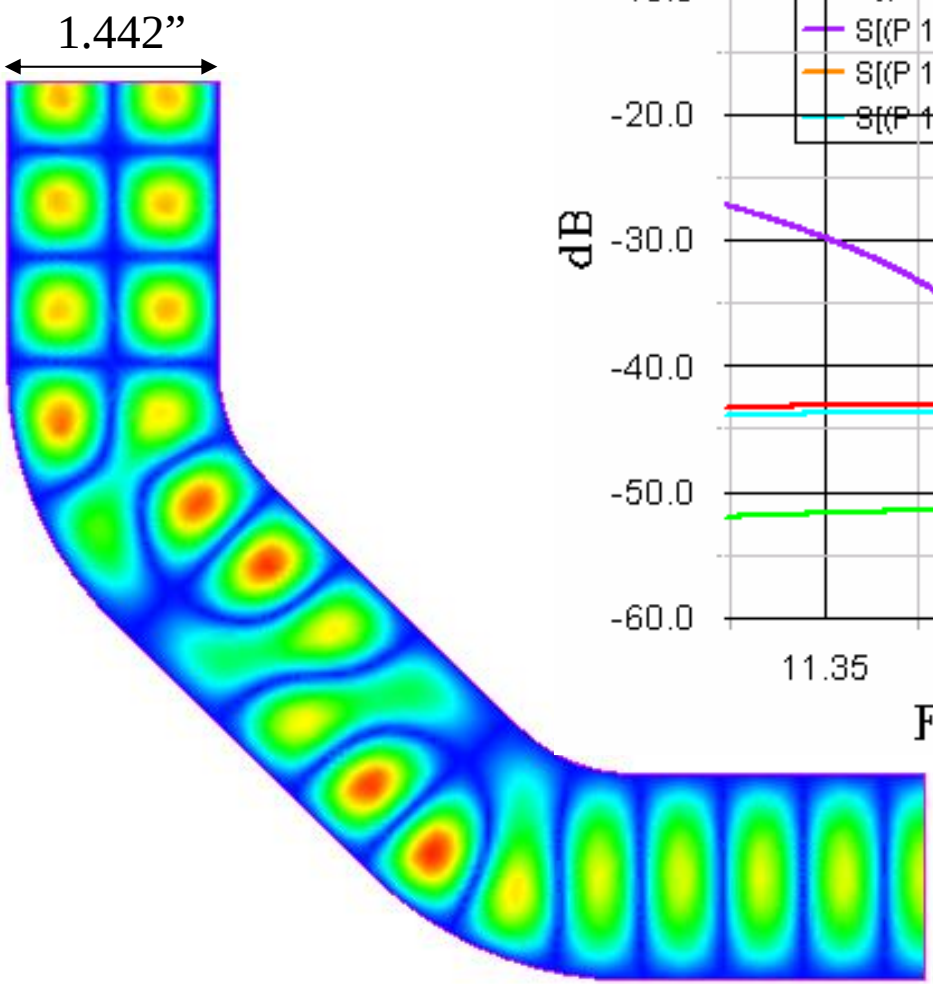


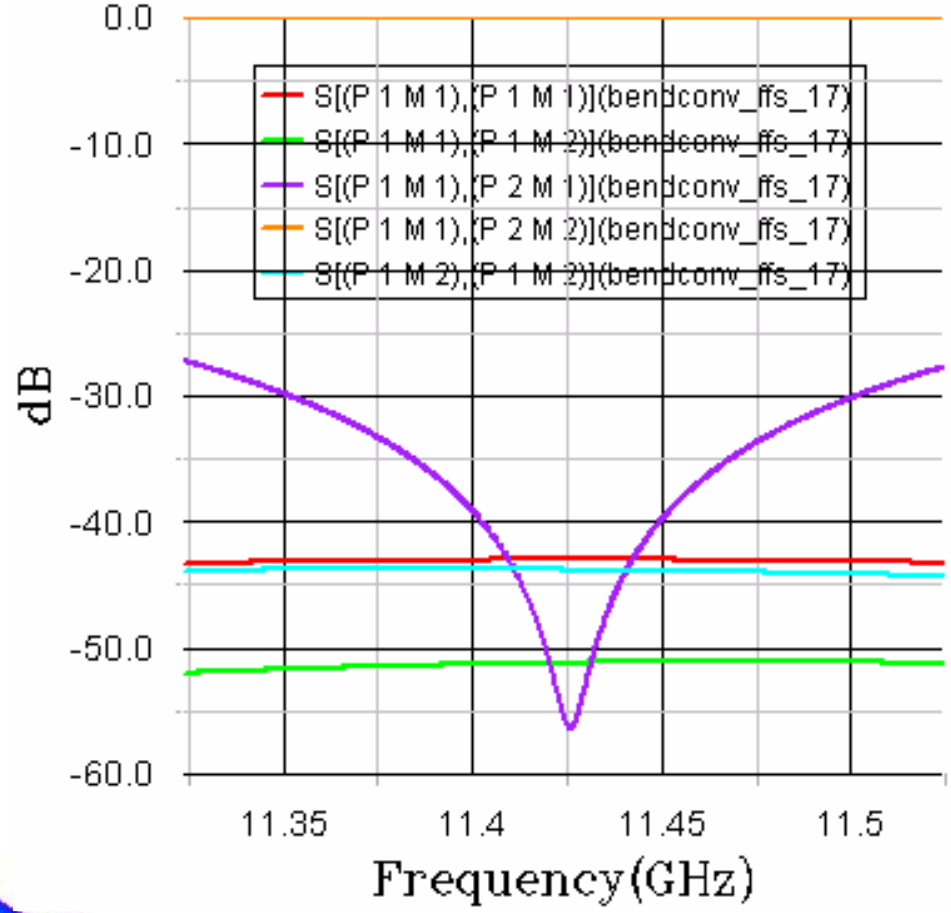
Reflection measurements (S_{11}) for the circular TE_{01} mode from port 1 while shorting both port 2 and port 3 and matching port 4.



Circular TE_{01} mode transmission between port 1 and port 4 (S_{41}) while shorting both port 2 and port 3.





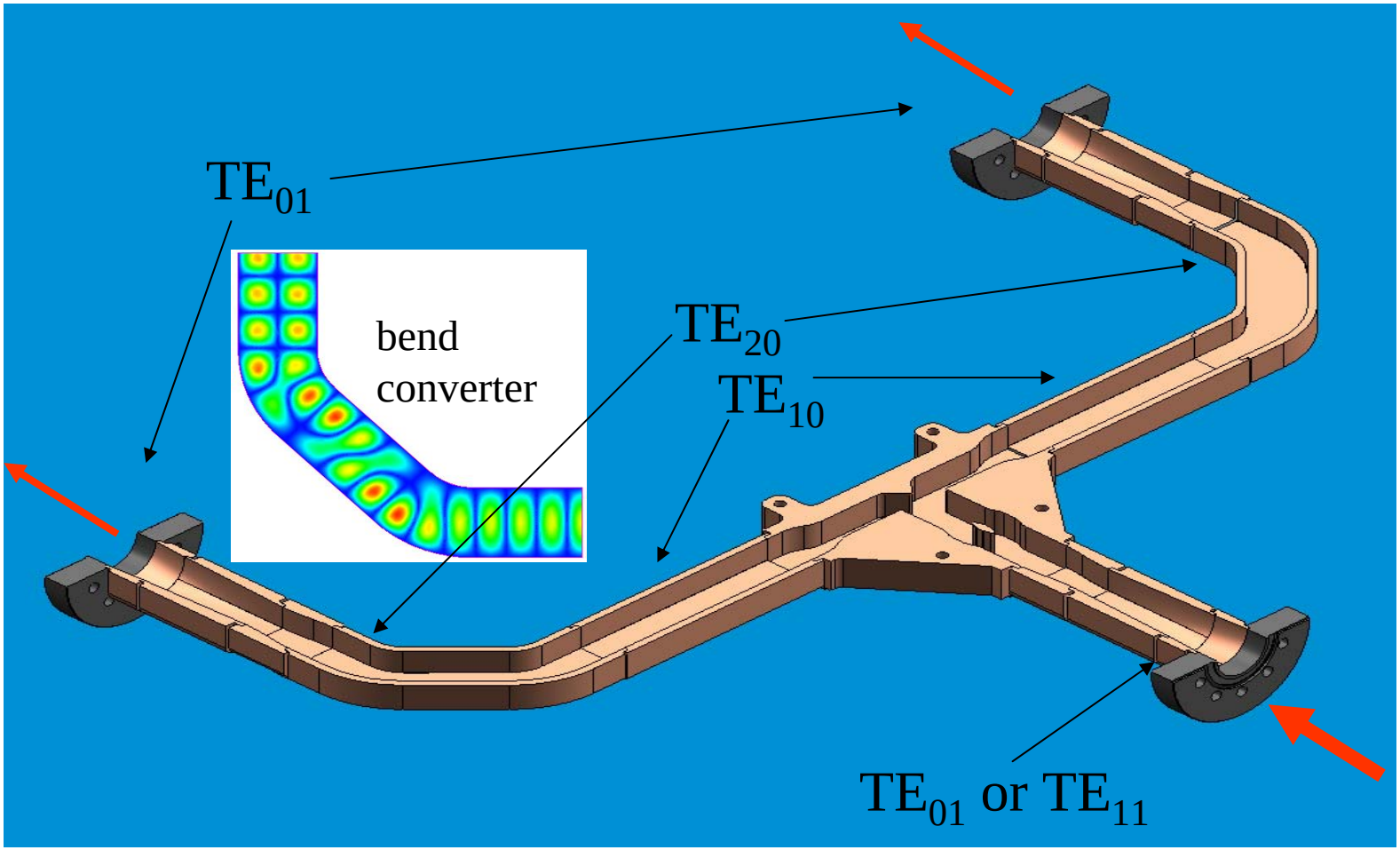


@ 600 MW $|E^s_{max}|$ = ~37.8 MV/m

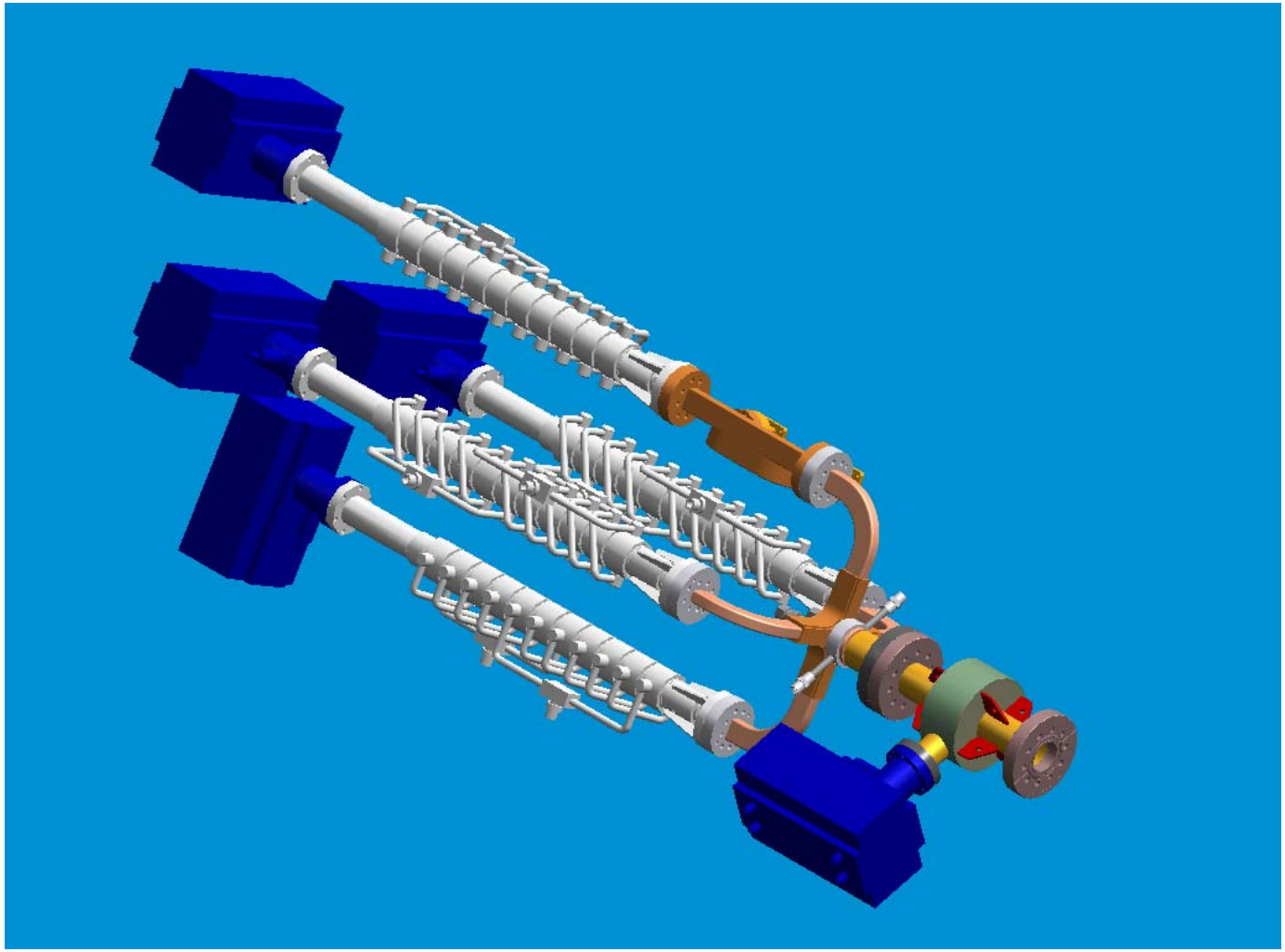
$|H^s_{max}|$ = ~83.8 kA/m

Bend Converter Design

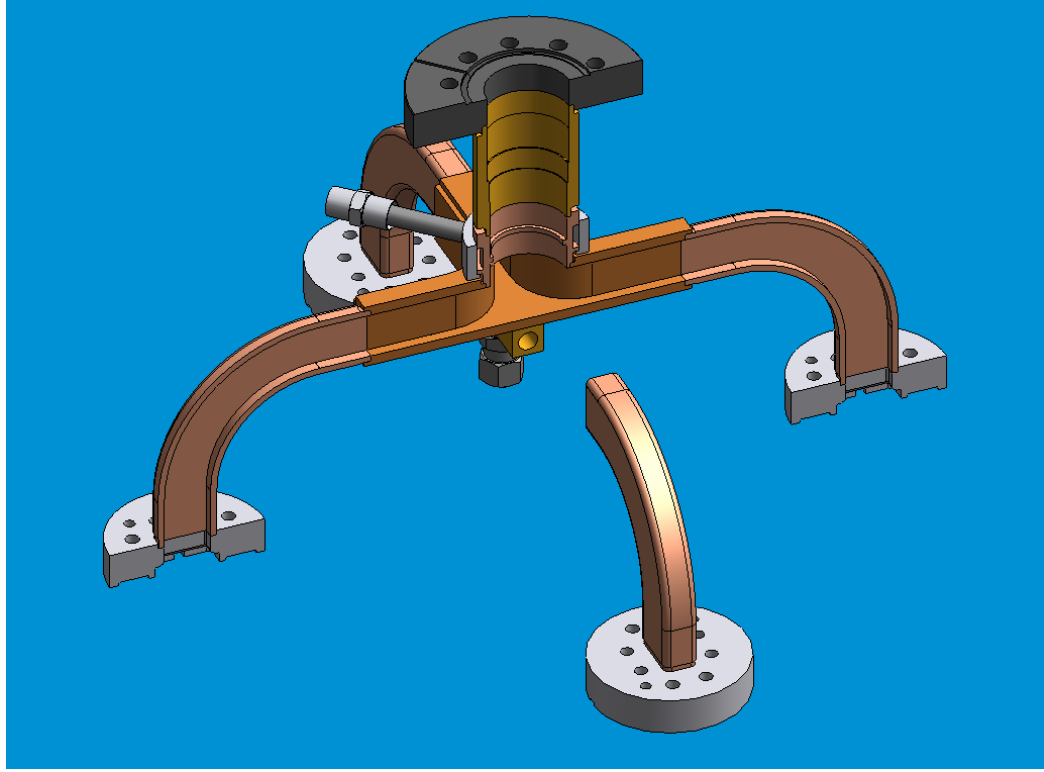
Dual-Mode Splitter



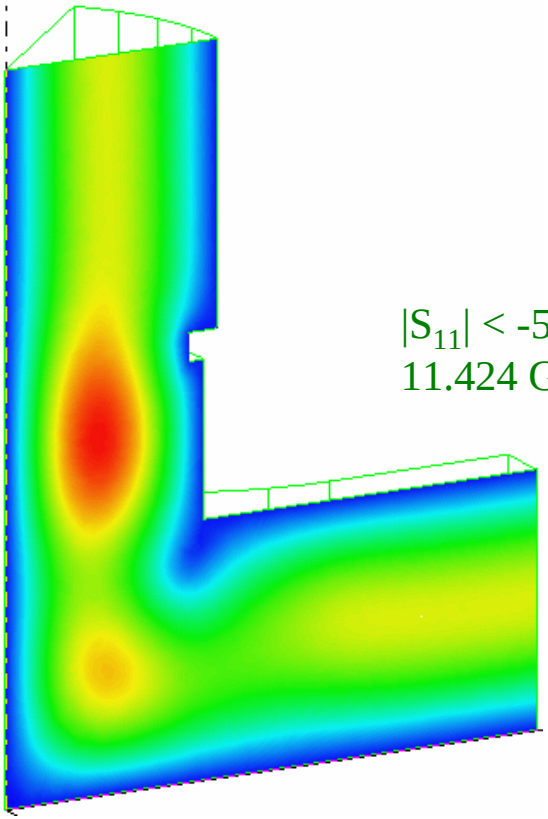
Dualmode Splitter: For either incident mode the power is evenly divided between the two output ports, which launch the TE_{01}.



Load Tree: The input power, carried by the TE_{01} mode, is split 4 ways to be absorbed at the loads



WC160

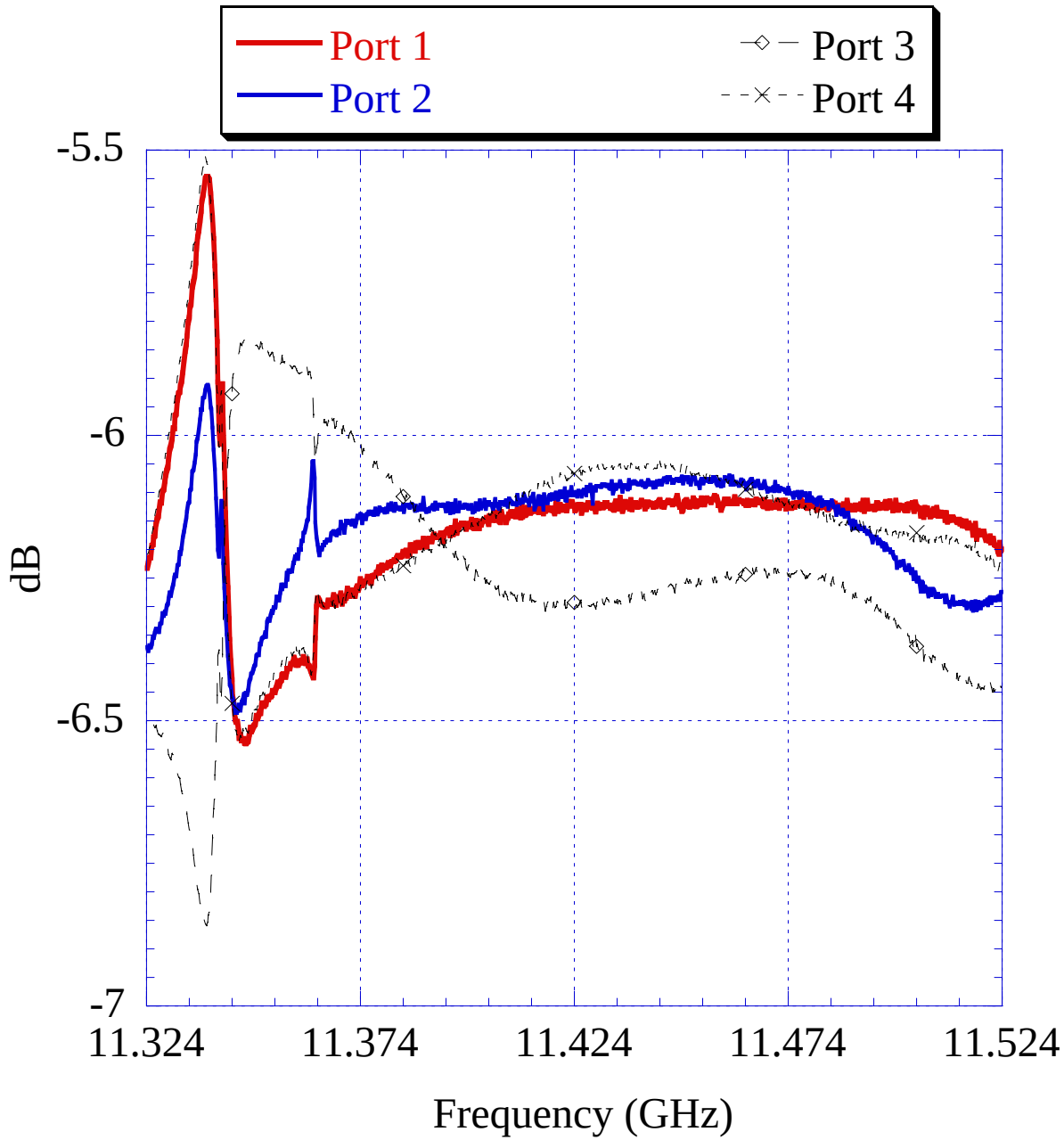


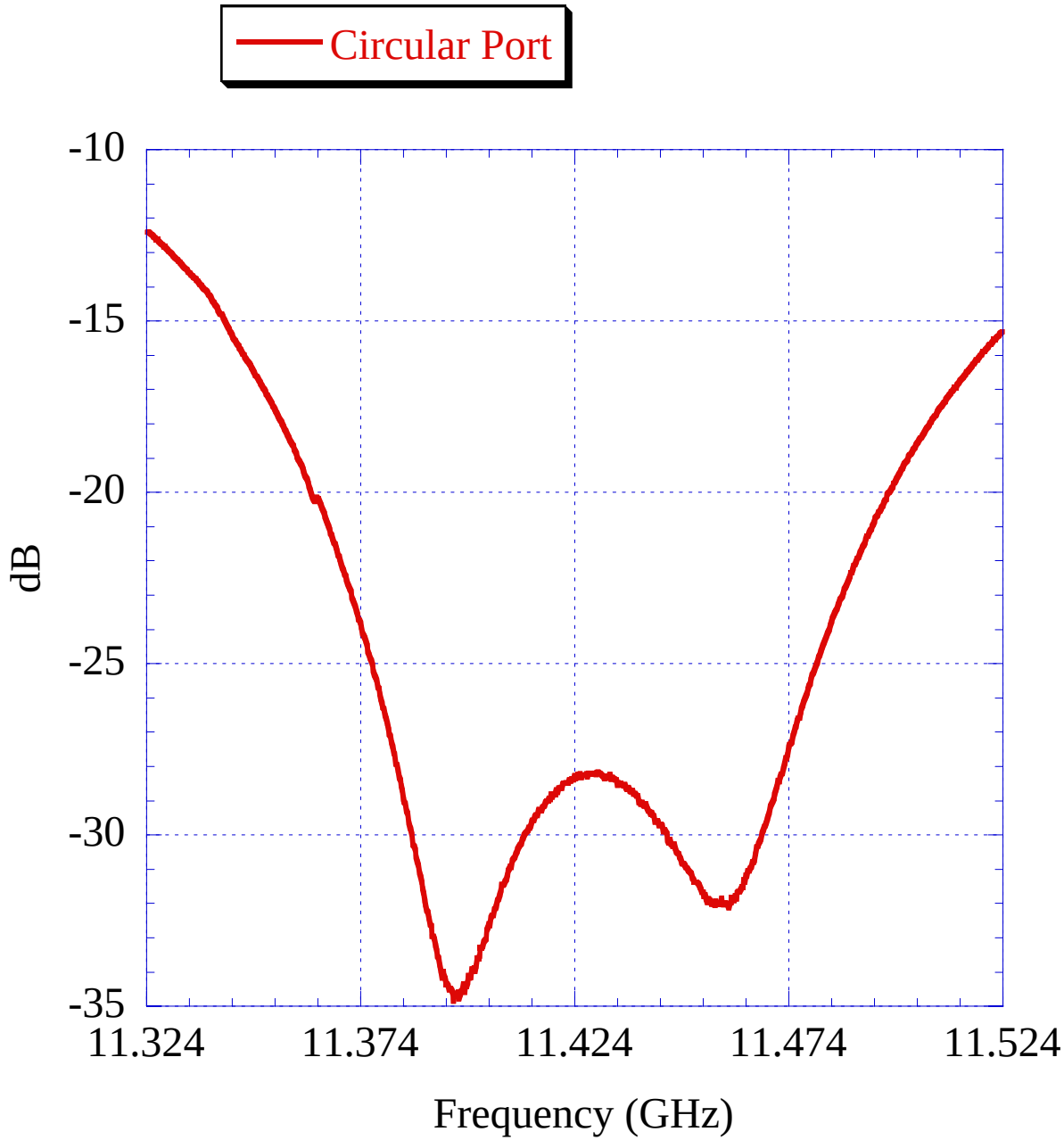
$|S_{11}| < -57$ dB @
11.424 GHz

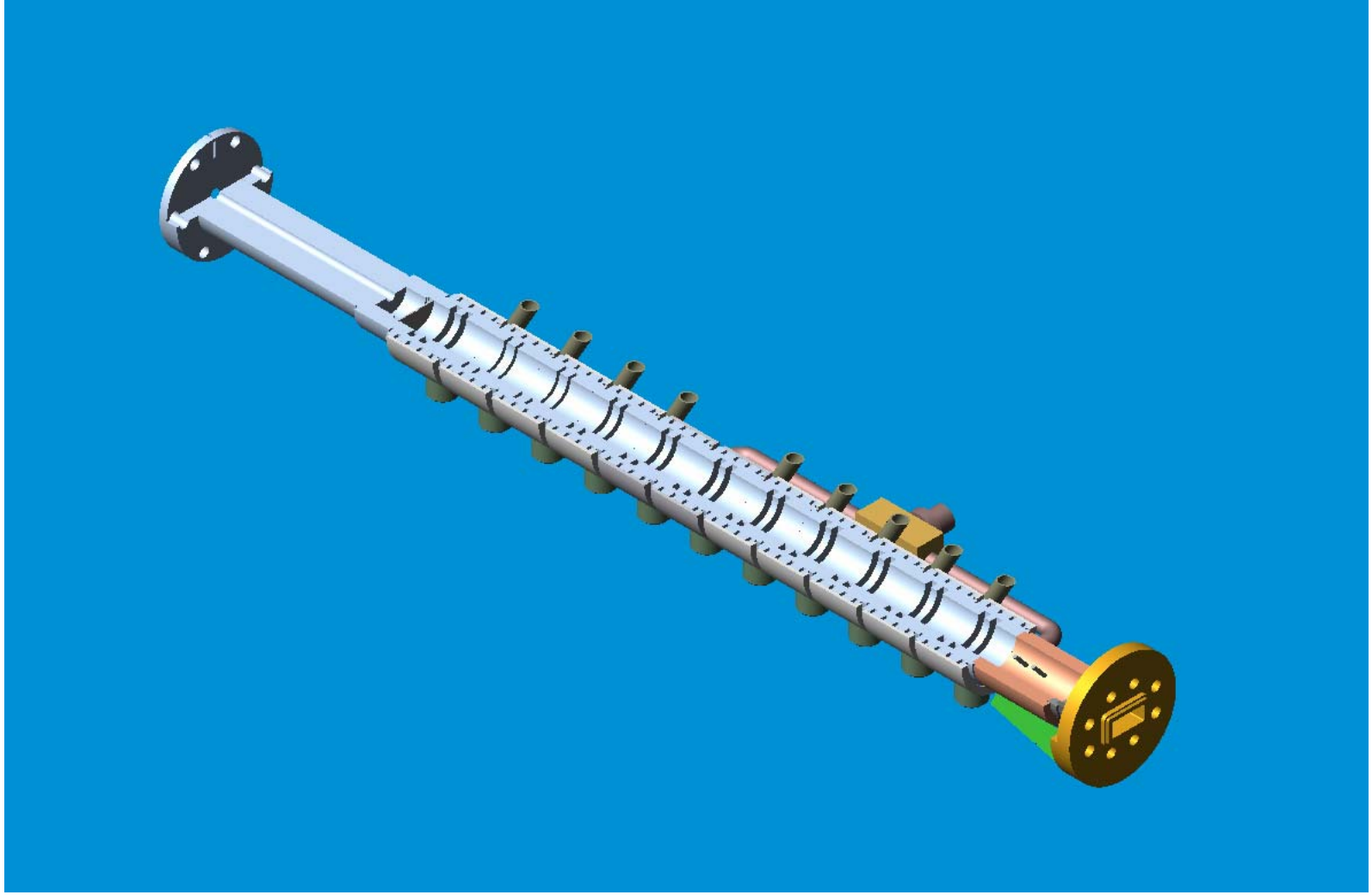
WR90

Four Way Splitter Design

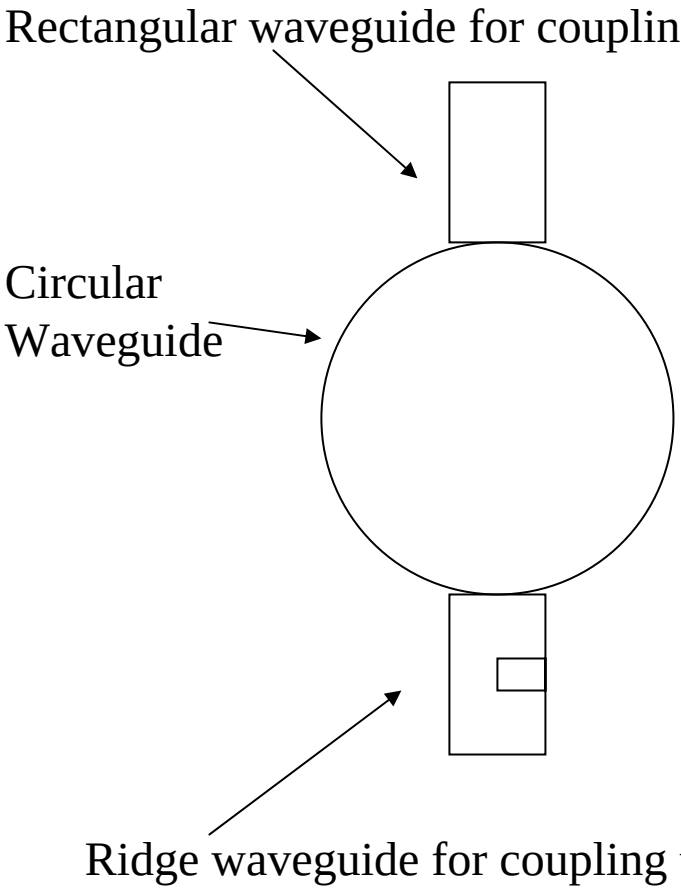
Power Divider

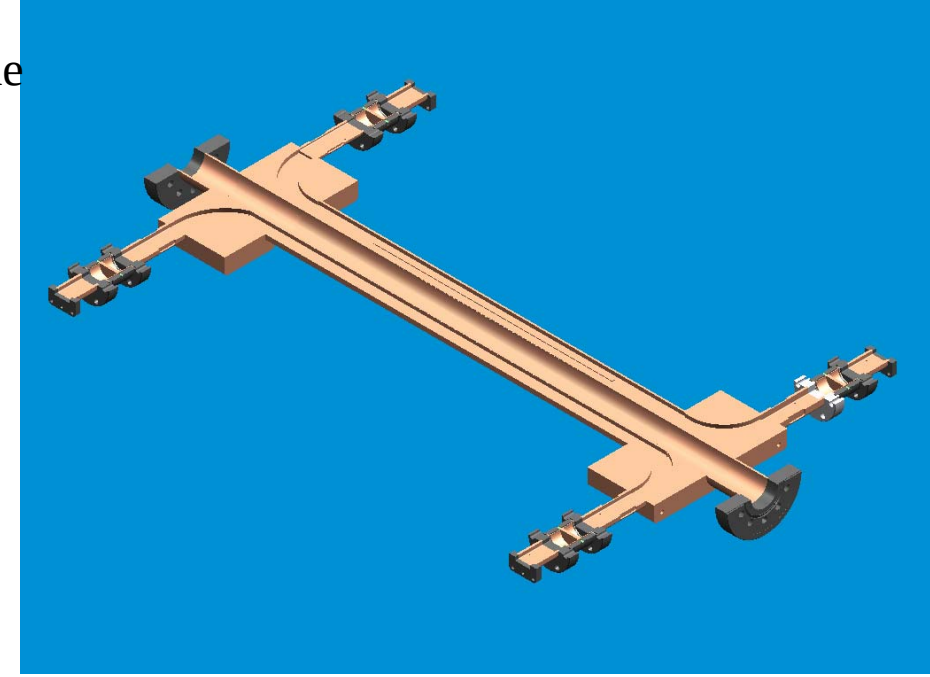



Circular Port
-10
-15
-20
-25
-30
-35
dB
11.324
11.374
11.424
11.474
11.524
Frequency (GHz)



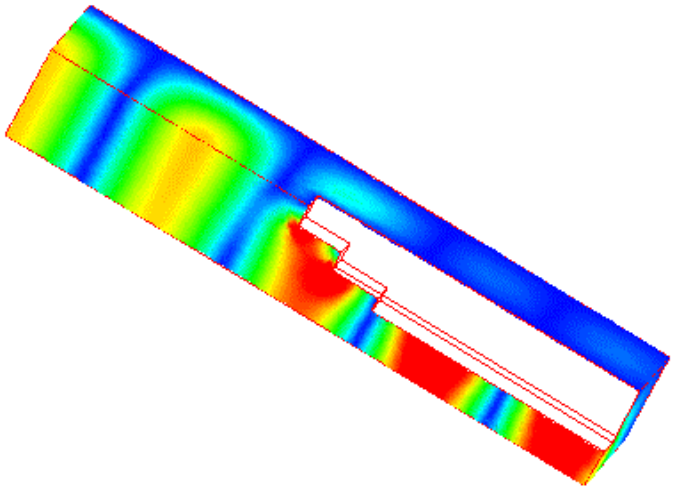
High Power Load Design

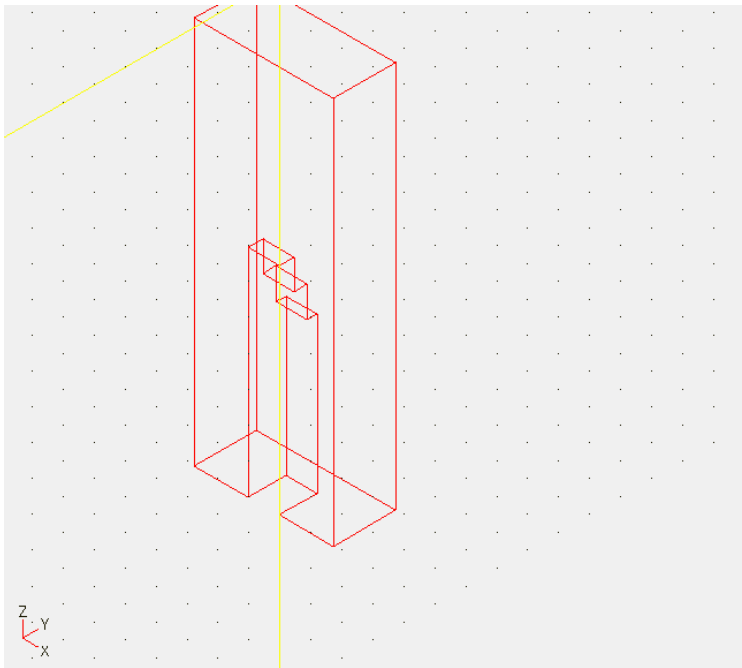


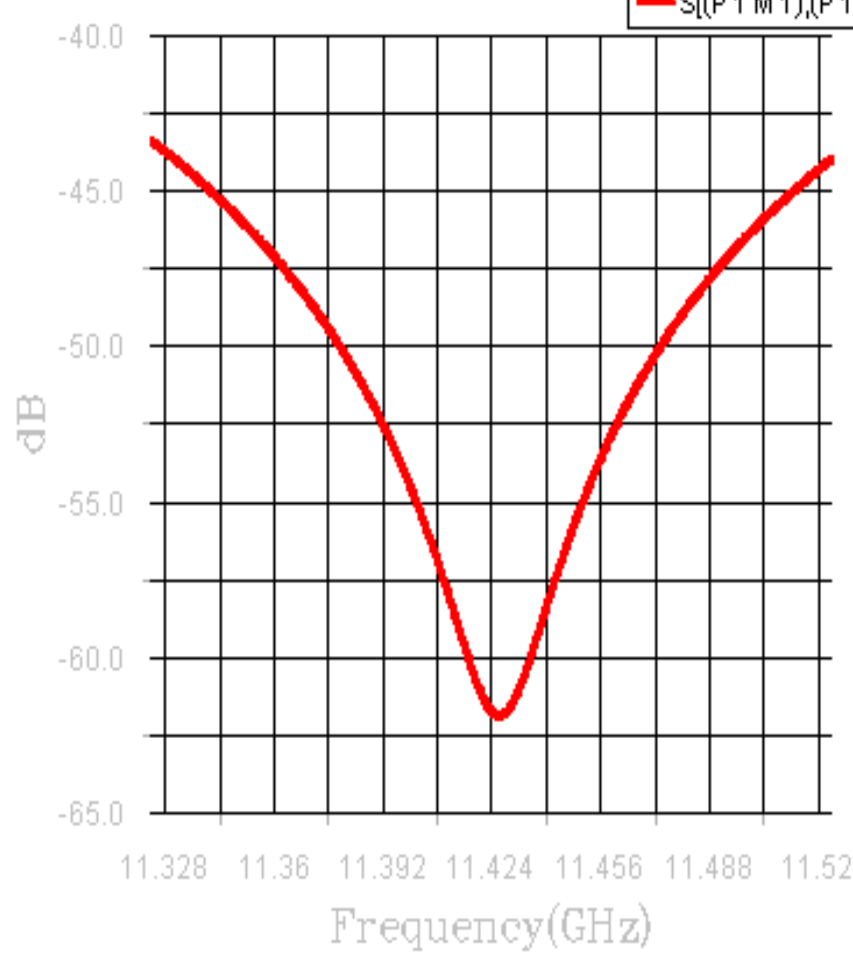


- **The waveguide sizes are chosen to match wavelengths between the circular waveguide modes and side waveguide fundamental mode**
- **The coupling hole pattern represents a Hamming window**

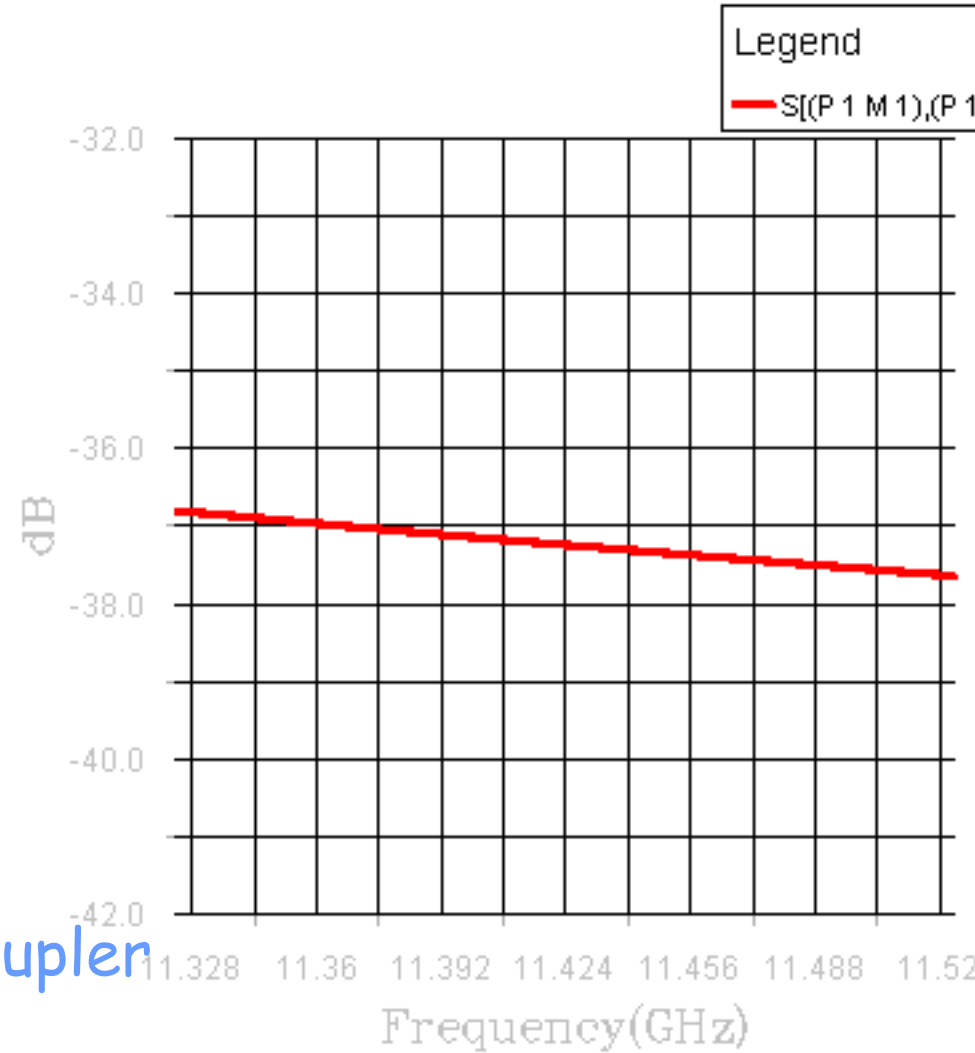
Dual-moded Directional Coupler







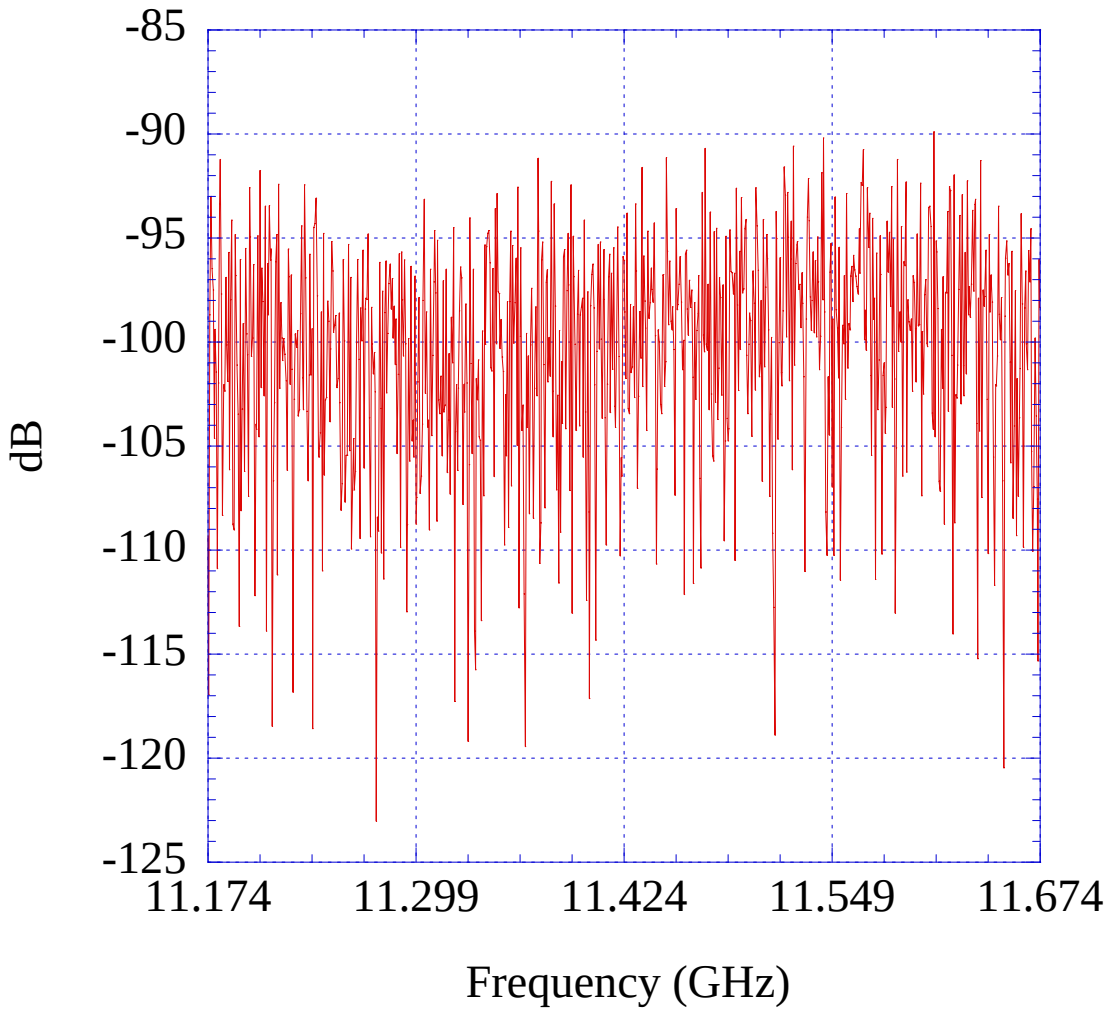
End taper for TE_{11} coupler



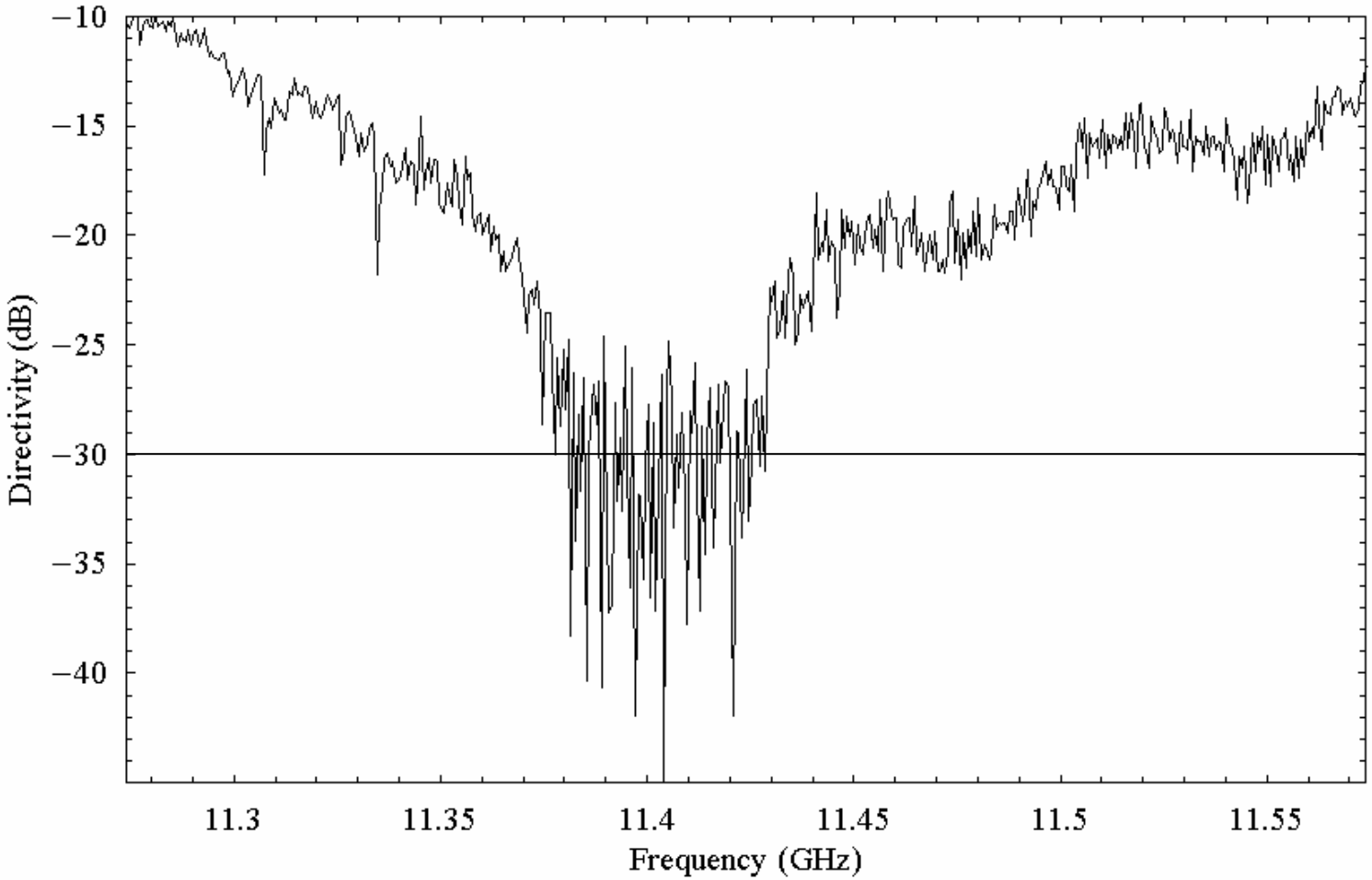
End taper for the TE_{01} coupler

Directional Coupler Cold Test

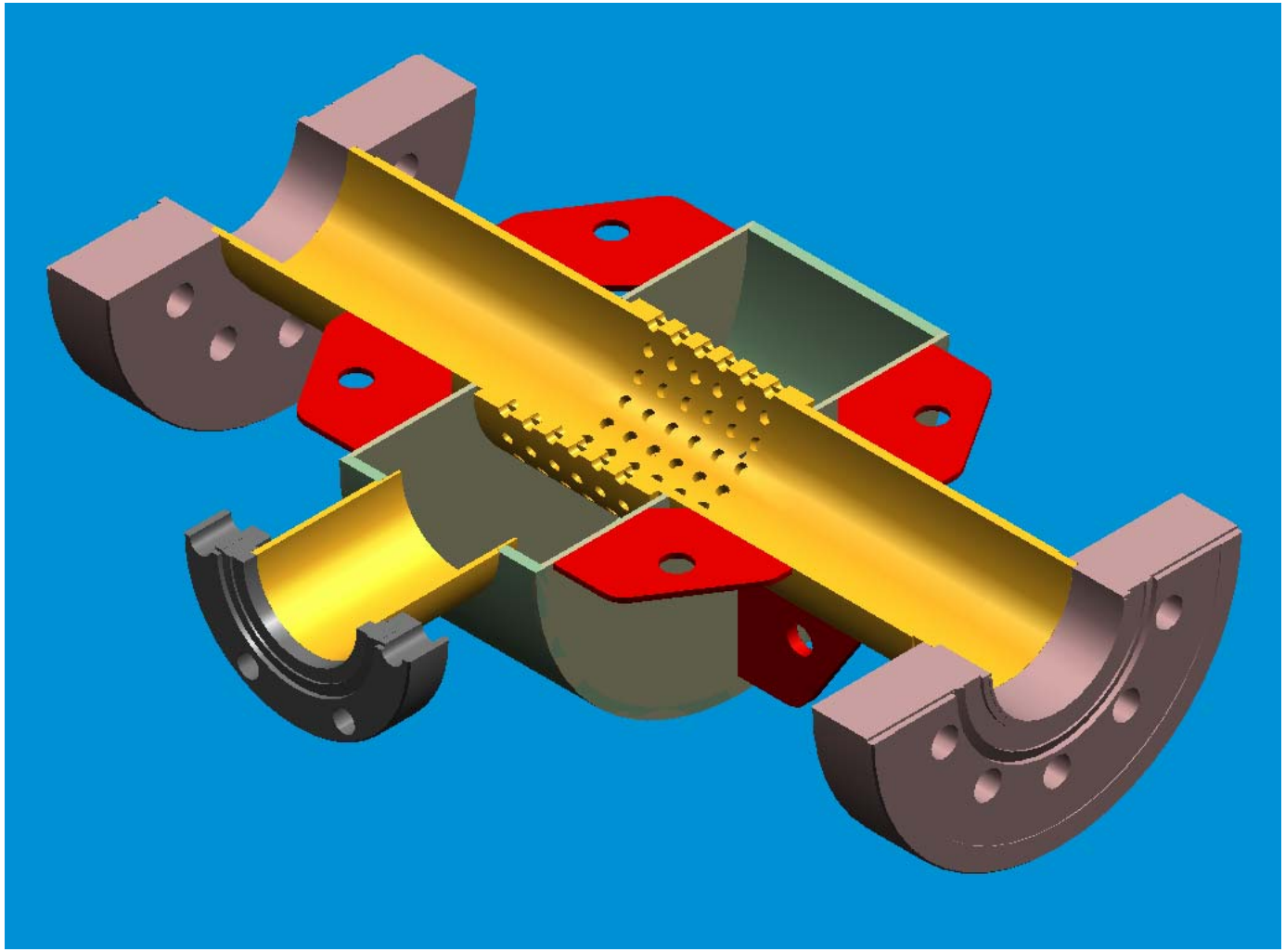
Coupling between the TE_{01} mode and the TE_{11} coupler arm



Since the coupling coefficient for the desired mode is -47 dB, Isolation between coupler arm and the unwanted mode is better than -45 dB.

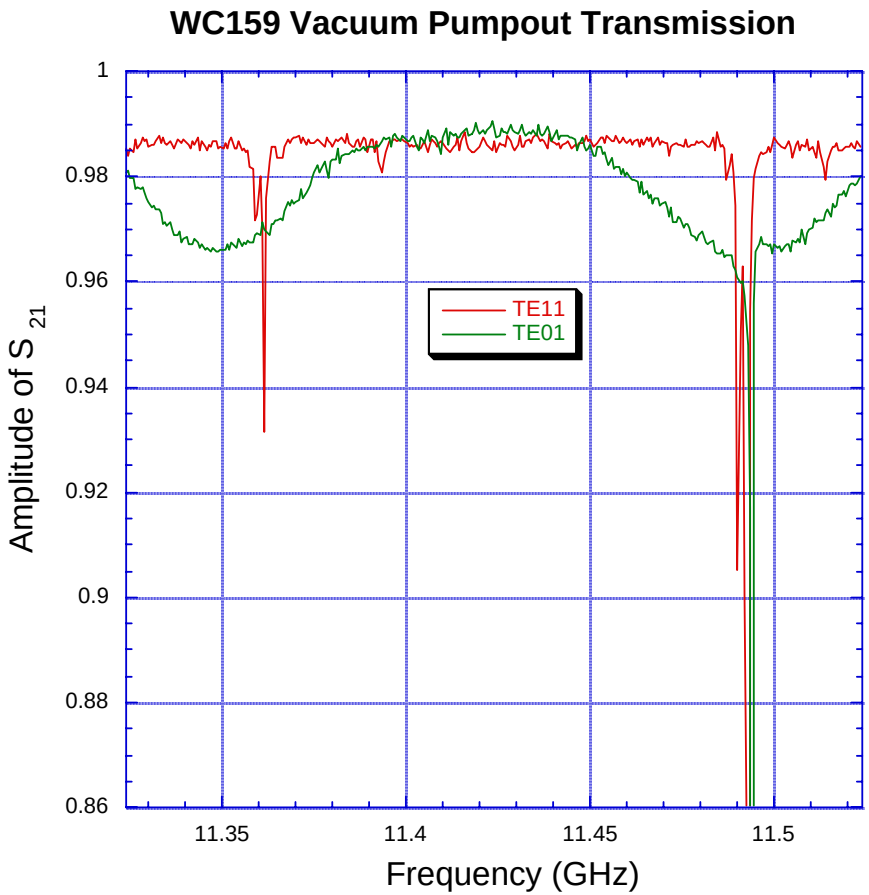


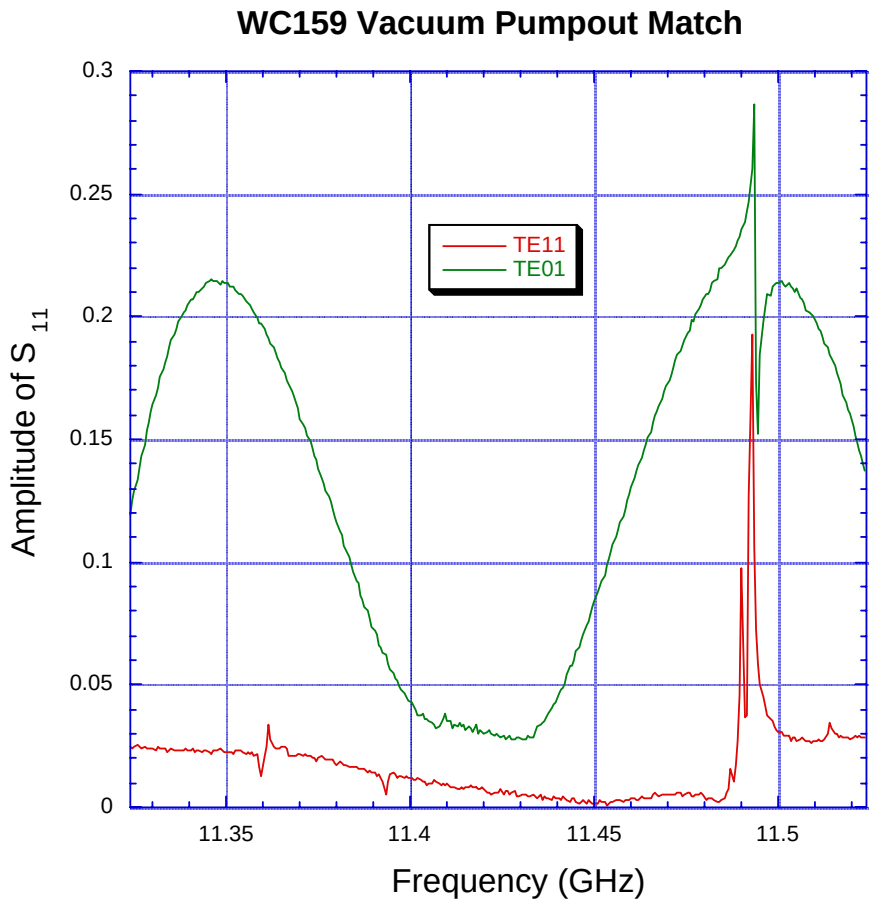
Measured directivity for the TE_{01} Arm

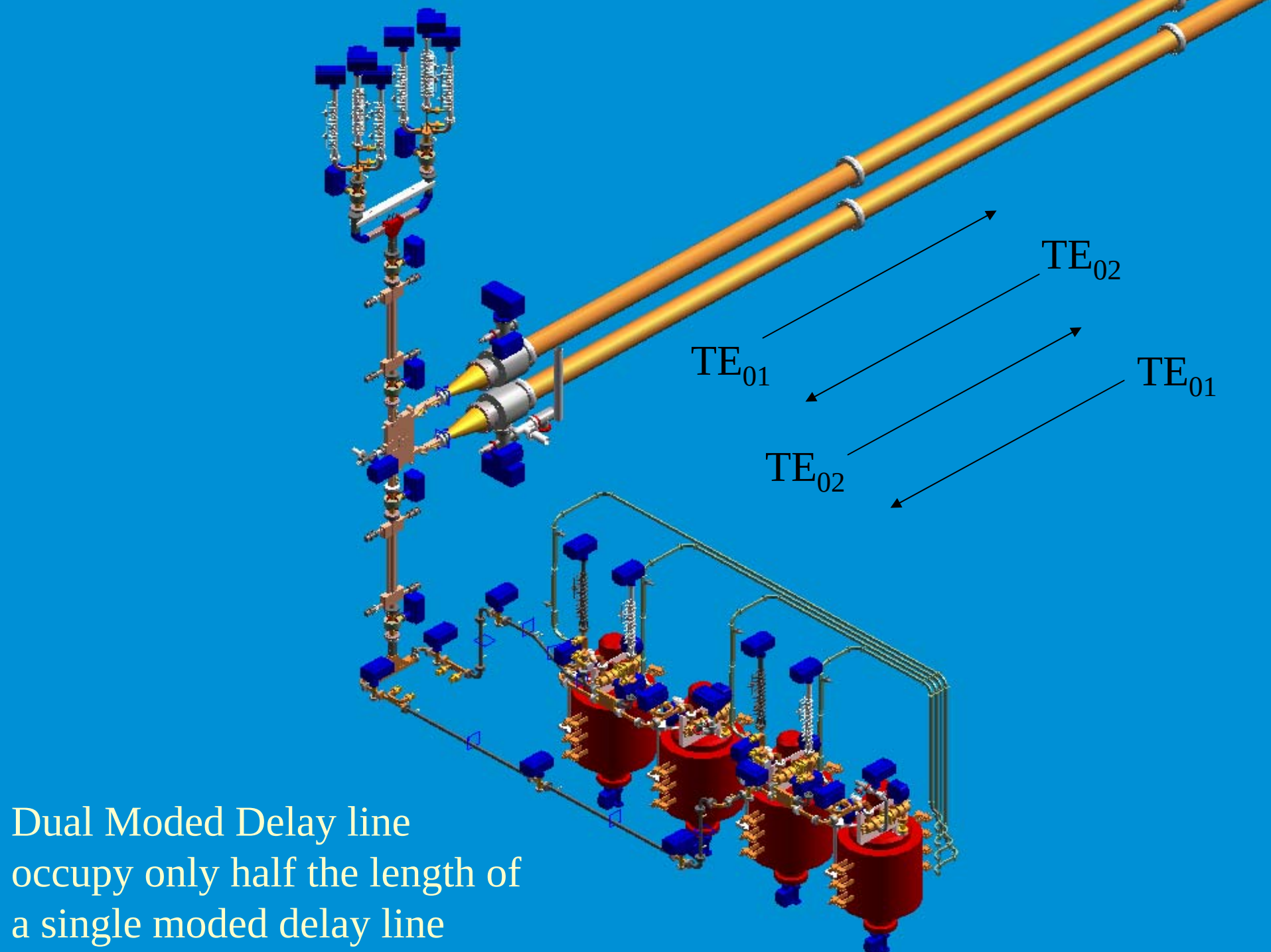


Pumpout design: the set of holes are designed to cancel any coupling or self-coupling for the TE_{01} and the TE_{11}

Vacuum Pumpout Cold Test





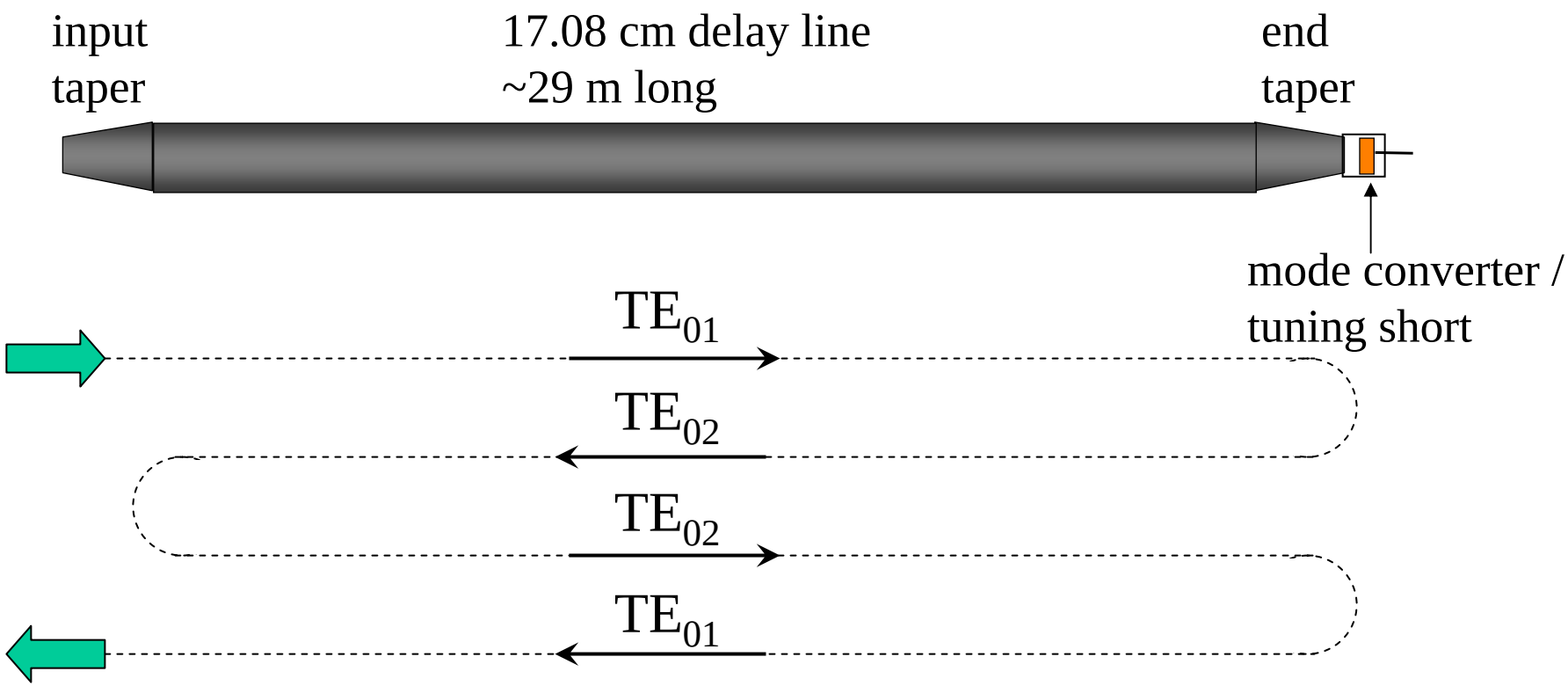


Dual Moded Delay line
occupy only half the length of
a single moded delay line

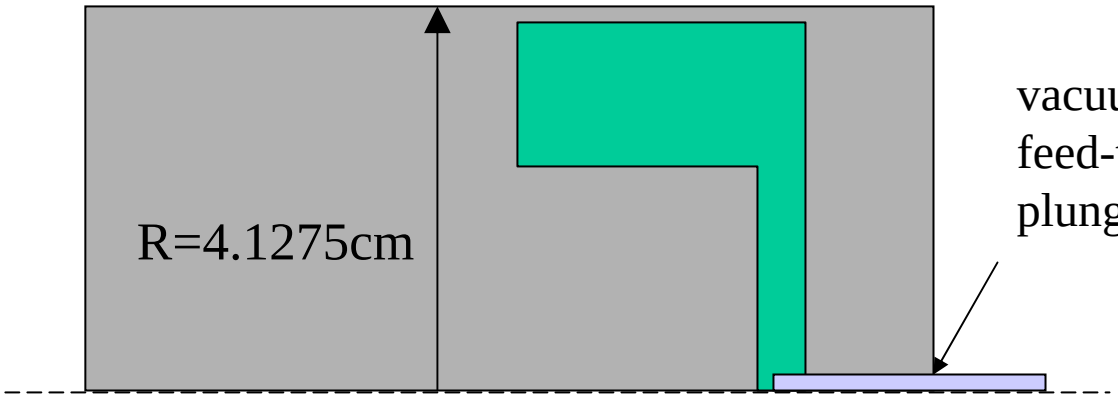
Dual-Moded Delay Line

Dual-moding the delay lines cuts their required length approximately in half.

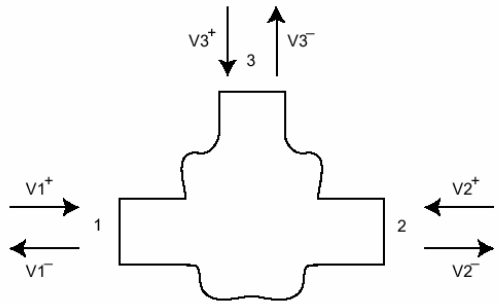
$$L = \frac{T}{2} \frac{v_{g1} v_{g2}}{v_{g1} + v_{g2}}$$



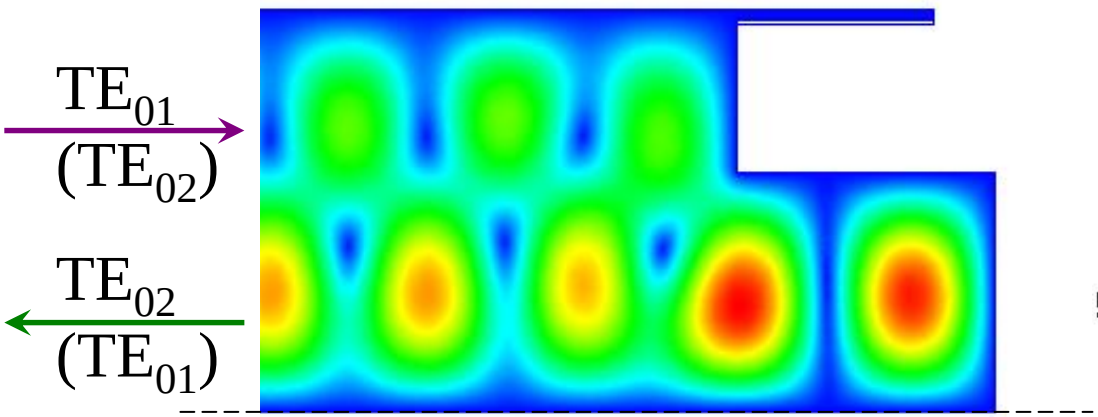
Reflective TE_{01}/TE_{02} Mode Converter

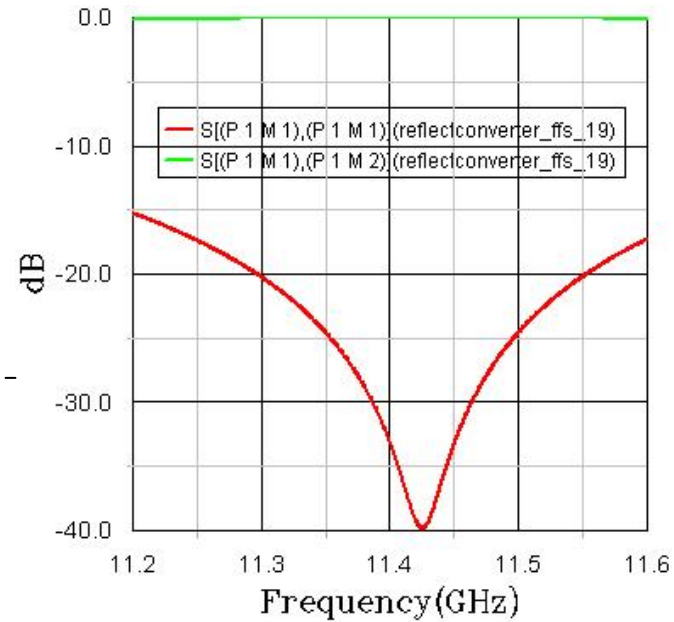


vacuum
feed-througl
plunger



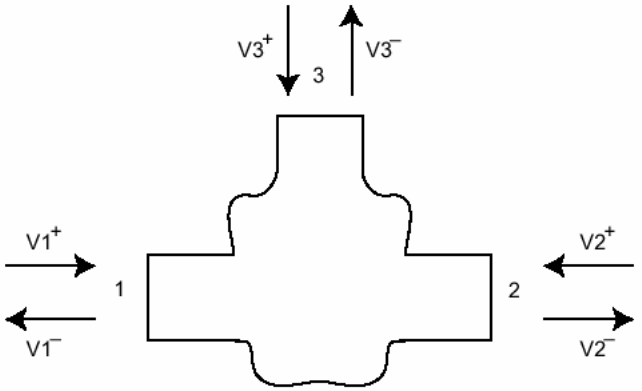
$$\underline{\underline{S}} = \begin{pmatrix} \frac{e^{j\phi} - \cos\theta}{2} & \frac{-e^{j\phi} - \cos\theta}{2} & \frac{\sin\theta}{\sqrt{2}} \\ \frac{-e^{j\phi} - \cos\theta}{2} & \frac{e^{j\phi} - \cos\theta}{2} & \frac{\sin\theta}{\sqrt{2}} \\ \frac{\sin\theta}{\sqrt{2}} & \frac{\sin\theta}{\sqrt{2}} & \cos\theta \end{pmatrix}$$

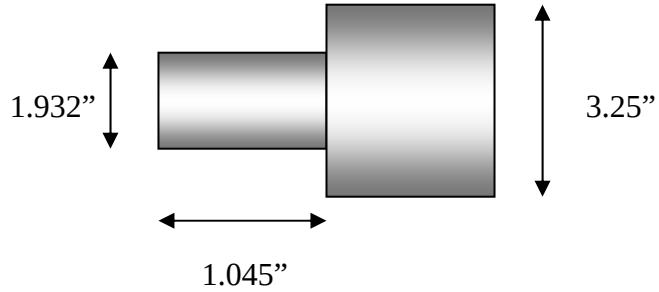




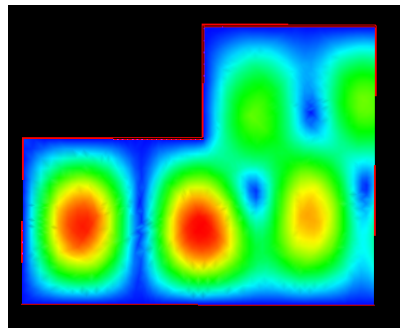
S =

	(P 1 M 1)	(P 1 M 2)
(P 1 M 1)	0.0102	0.9999
(P 1 M 2)	0.9999	0.0102

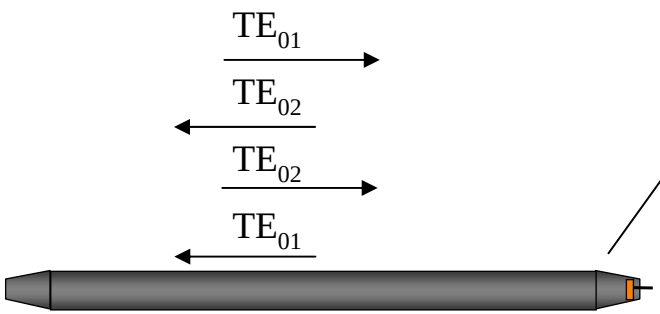




$$\underline{\underline{S}} = \begin{pmatrix} \frac{e^{j\phi} - \cos\theta}{2} & \frac{-e^{j\phi} - \cos\theta}{2} & \frac{\sin\theta}{\sqrt{2}} \\ \frac{-e^{j\phi} - \cos\theta}{2} & \frac{e^{j\phi} - \cos\theta}{2} & \frac{\sin\theta}{\sqrt{2}} \\ \frac{\sin\theta}{\sqrt{2}} & \frac{\sin\theta}{\sqrt{2}} & \cos\theta \end{pmatrix}$$

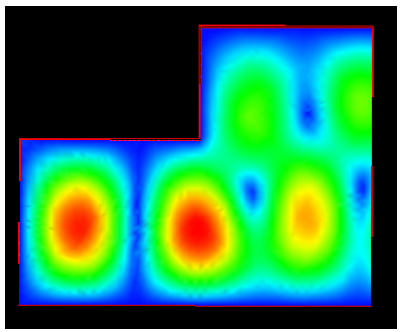


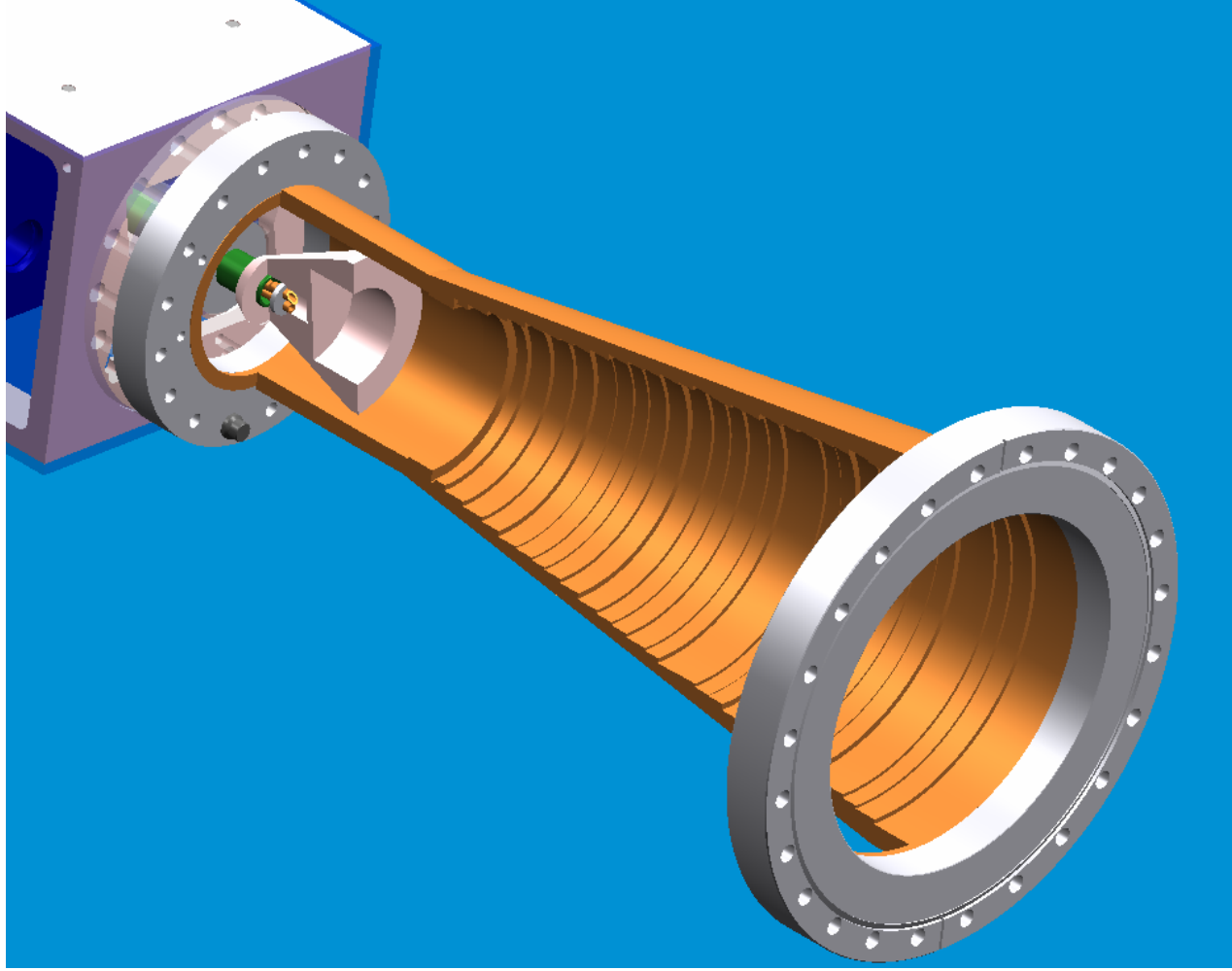
	(P 1 M 1)	(P 1 M 2)
(P 1 M 1)	0.0147	0.9999
(P 1 M 2)	0.9999	0.0147



Field Pattern within the device. Peak field at 300 MW (one device per transmission line) is 26.6 MV/m. This field is in the middle of the small guide.

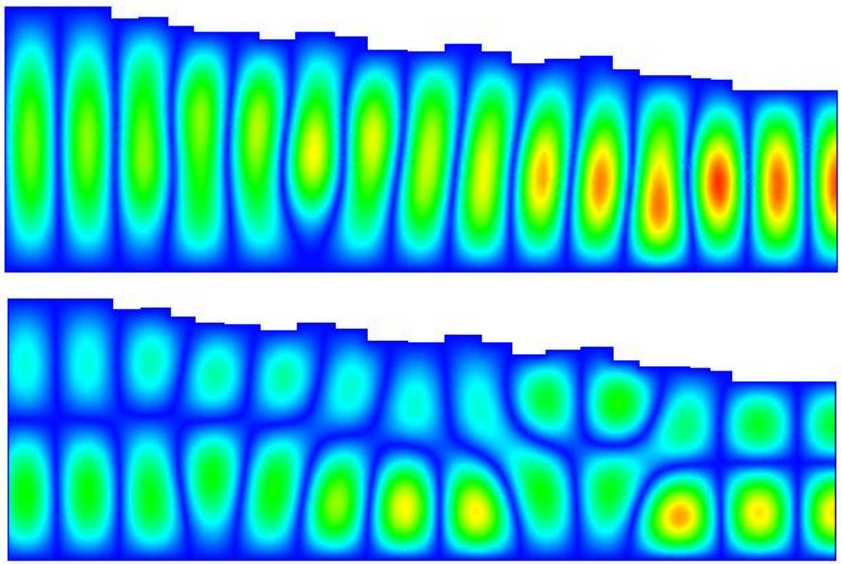
End mode converter simulations

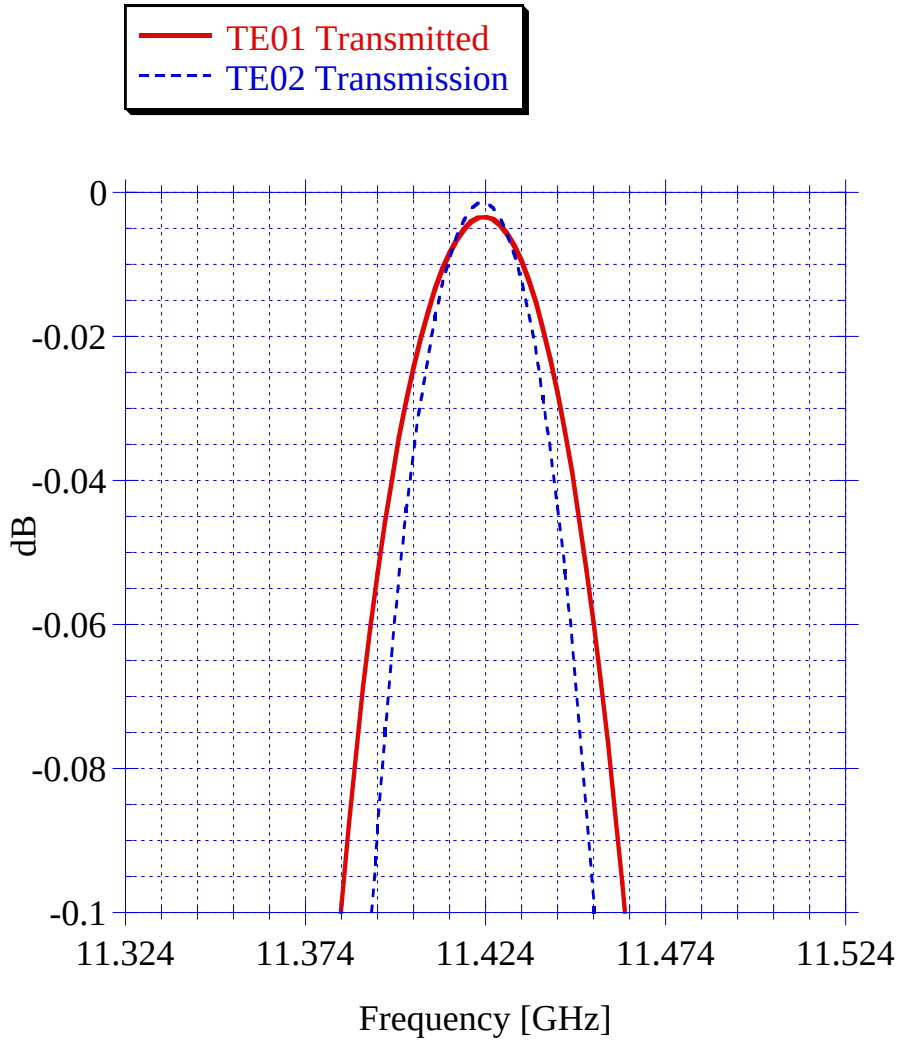




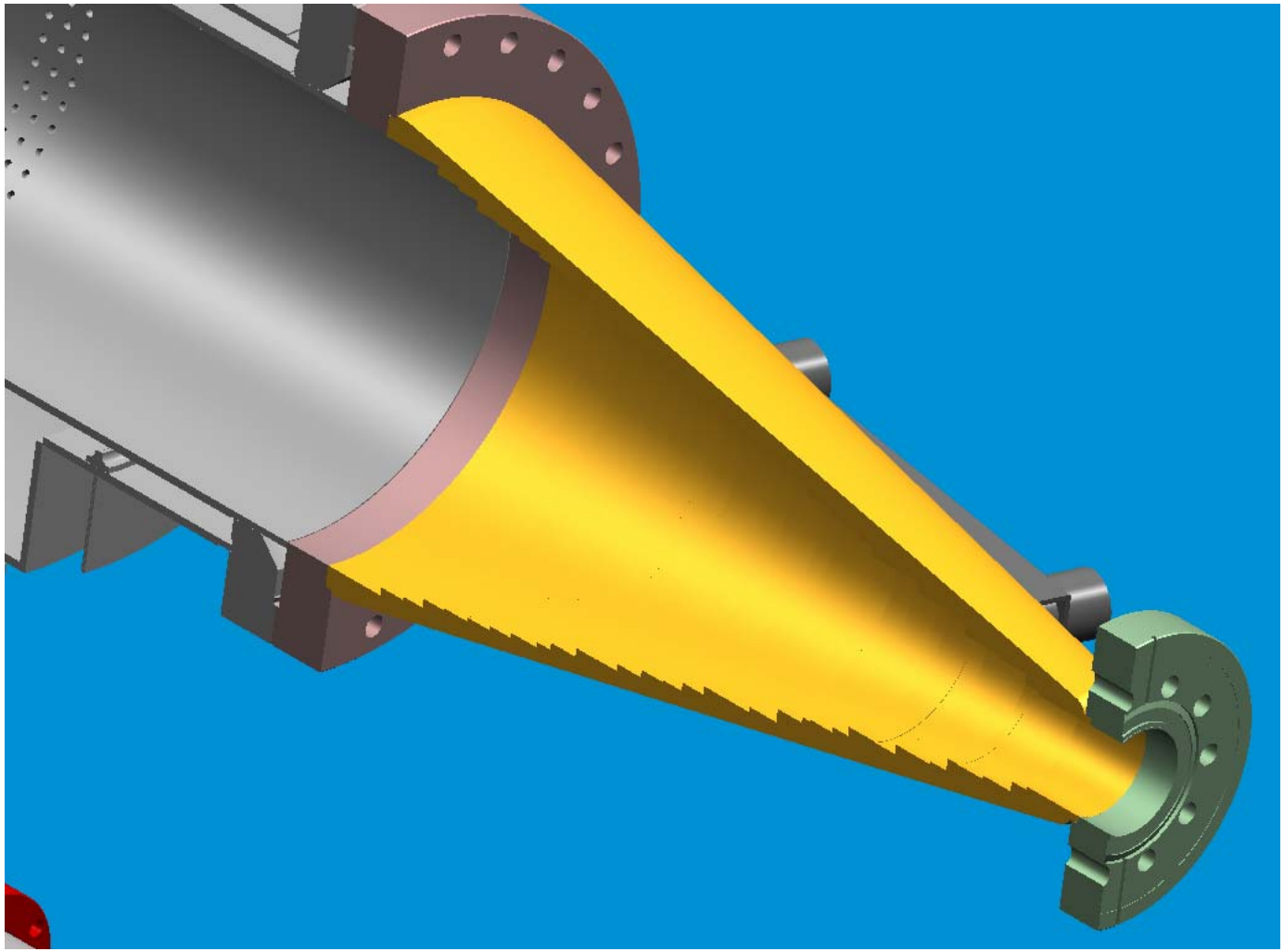
End taper and mode converter

	TE_{01} (P 1 M 1)	TE_{02} (P 1 M 2)
(P 1 M 1)	0.0147	0.9999
(P 1 M 2)	0.9999	0.0147



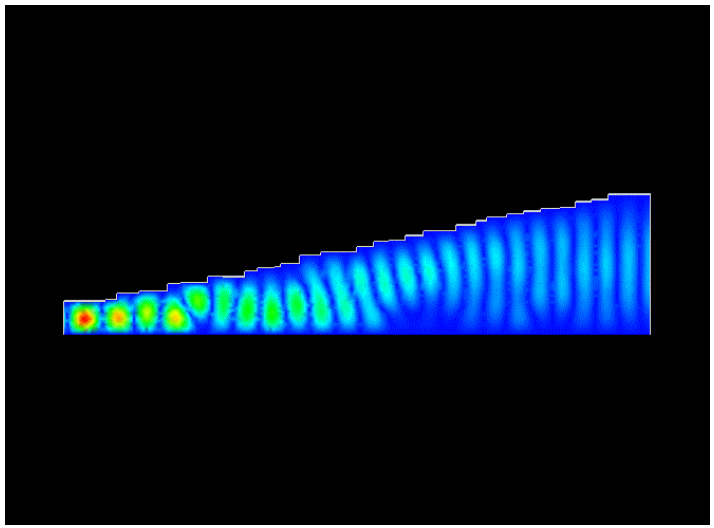


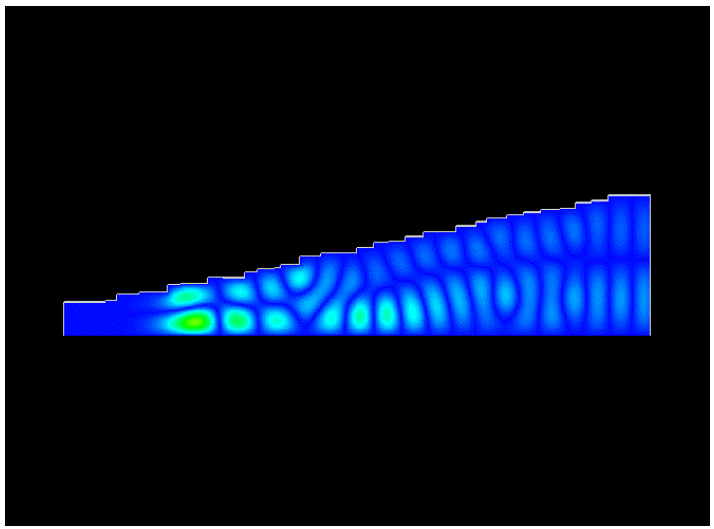
End Taper (before the TE_{01}-TE_{02} Mode converter)

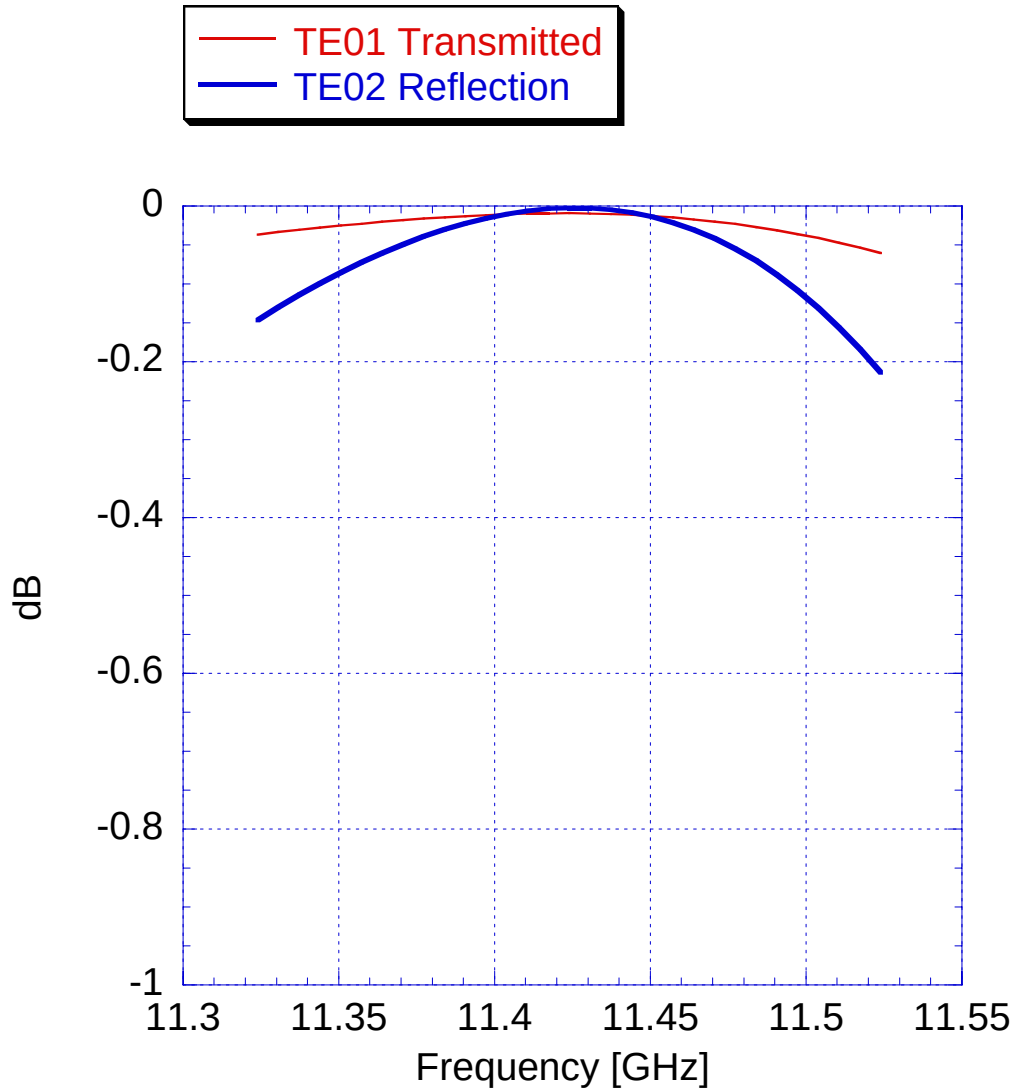


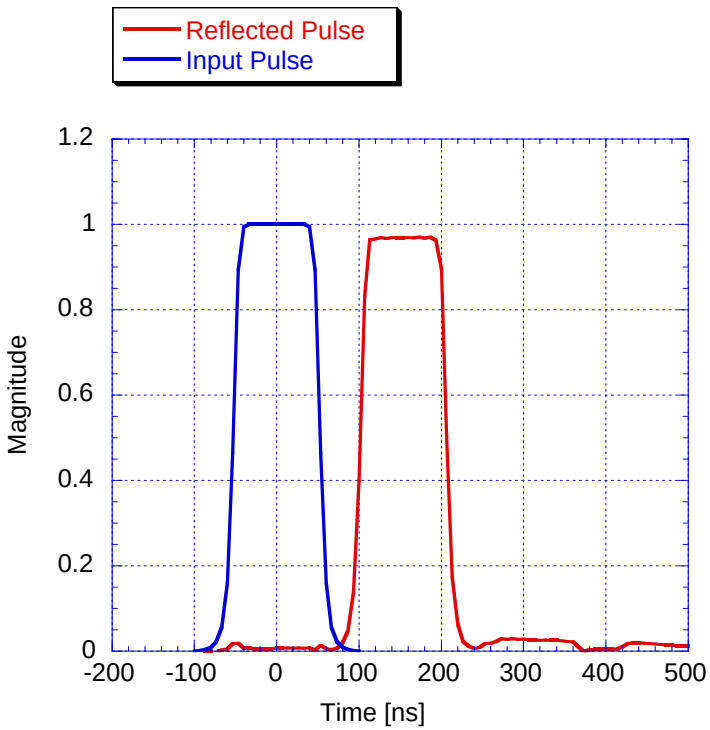
Input taper design

Input Taper for a Dual-Moded System

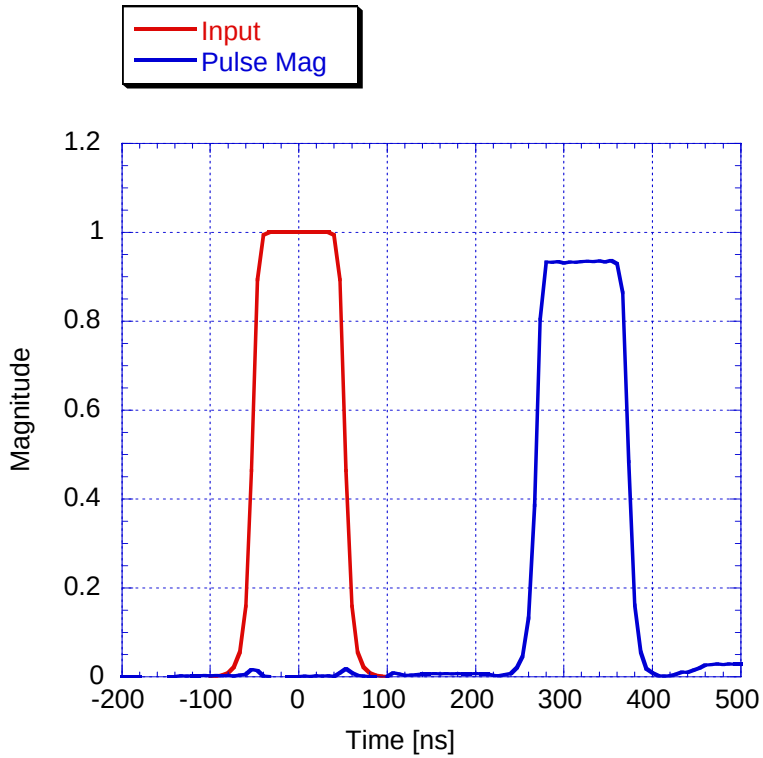




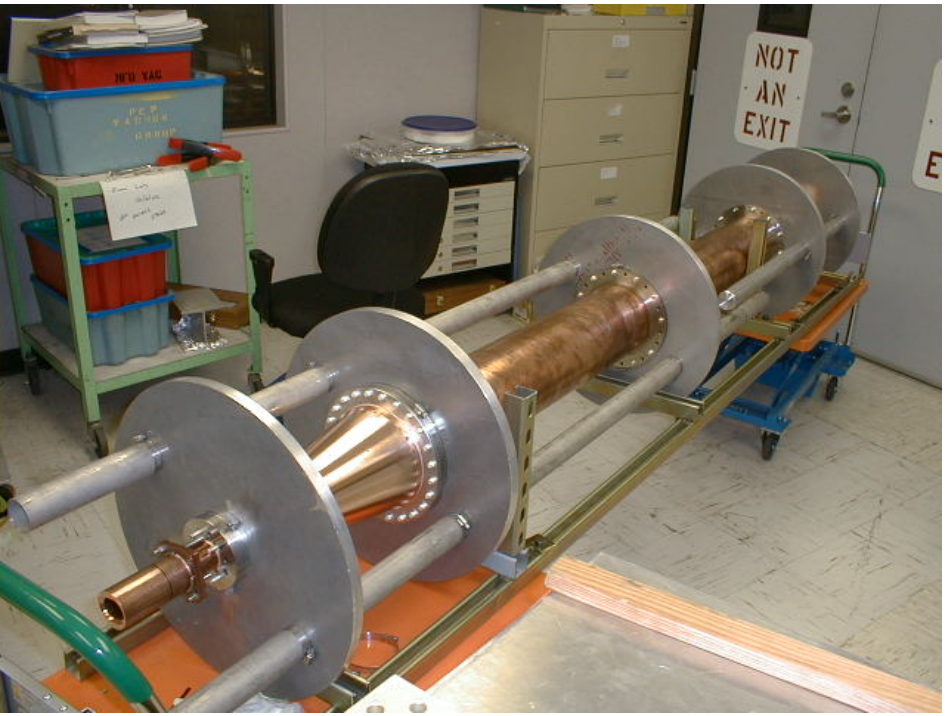




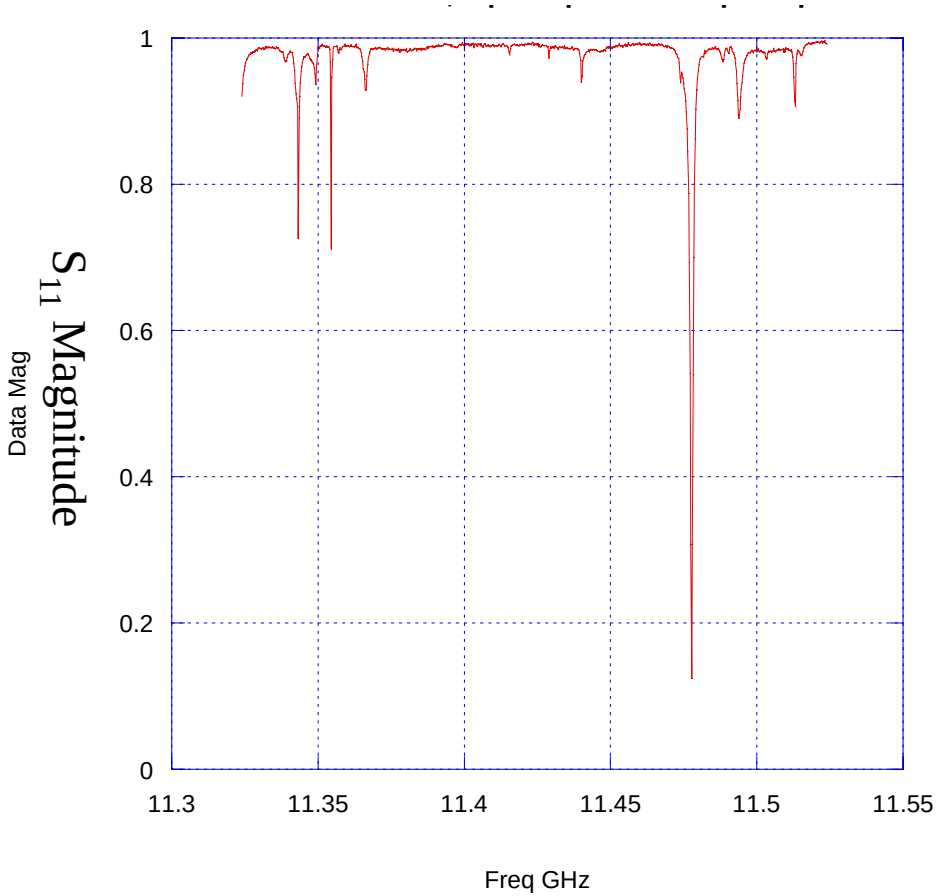
Measured Delay through 75 feet of WC475 waveguide terminated with a flat plate. The round trip delay time is 154 ns

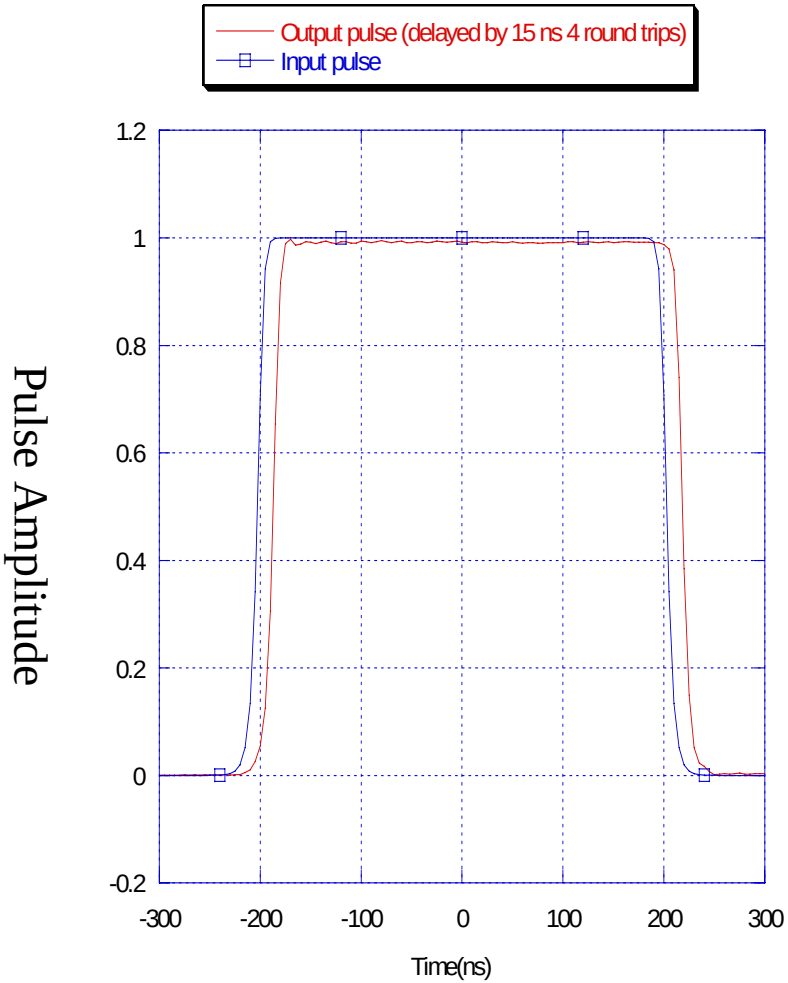


Measured delay through 75 feet of WC475 waveguide terminated with a TE01-TE02 Mode converter. The round trip delay time is 320 ns

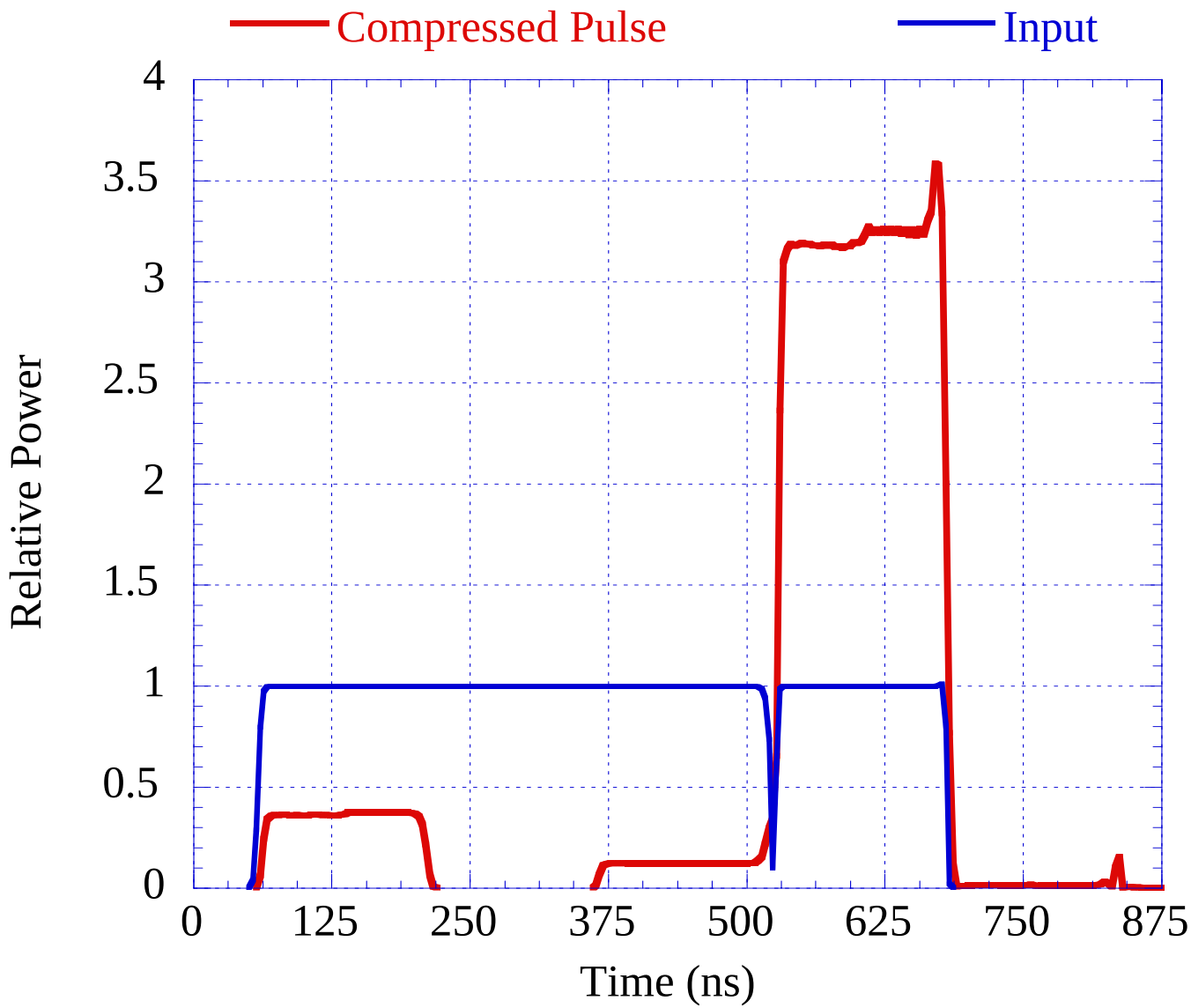


Multimoded Taper Cold Test





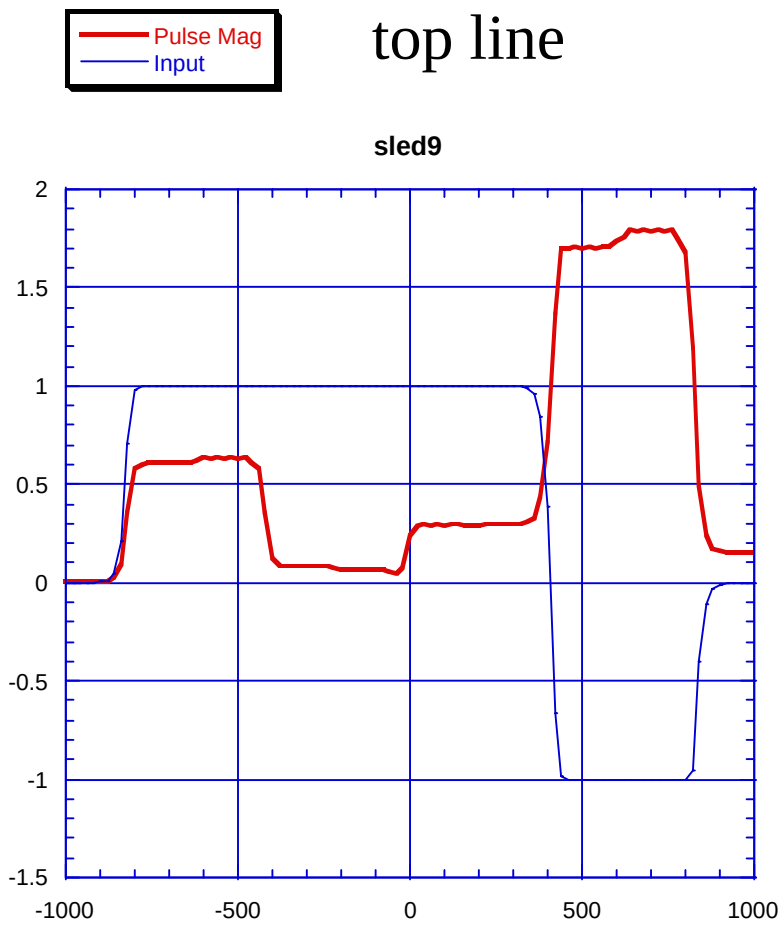
Measured frequency response and constructed time response of the dual-moded taper assembly.



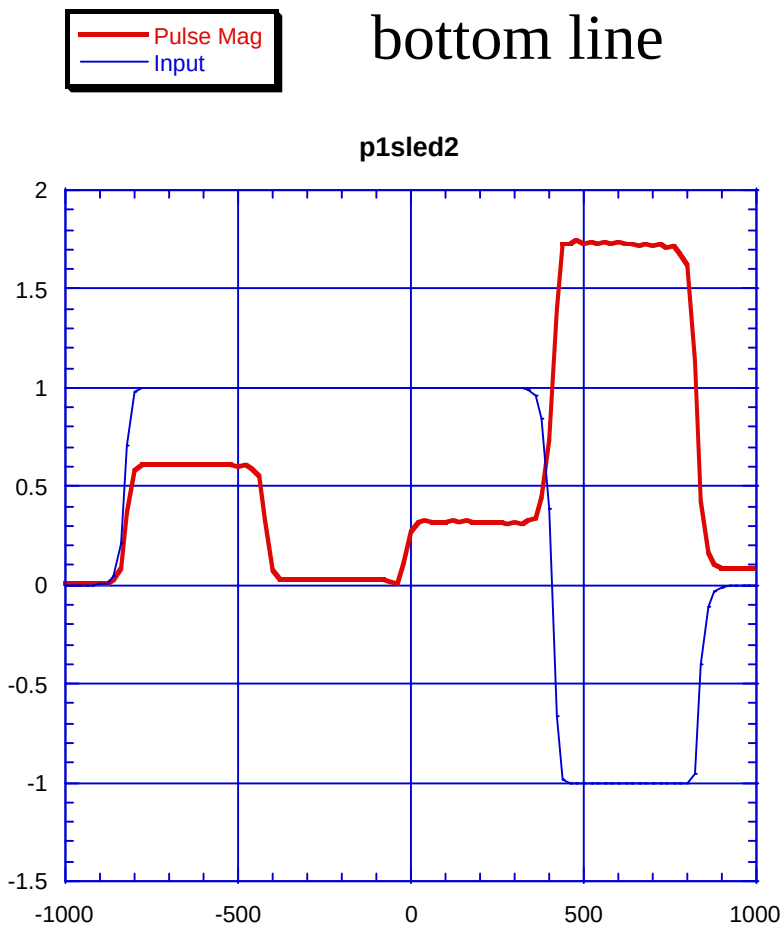
Measured Response of the dual-mode SLED-II Pulse compression system at a compression ratio of 4. Delay line length is ~35 feet. Output pulse width is 150 ns.

Delay Line Cold Tests

Delay Line Cold Tests



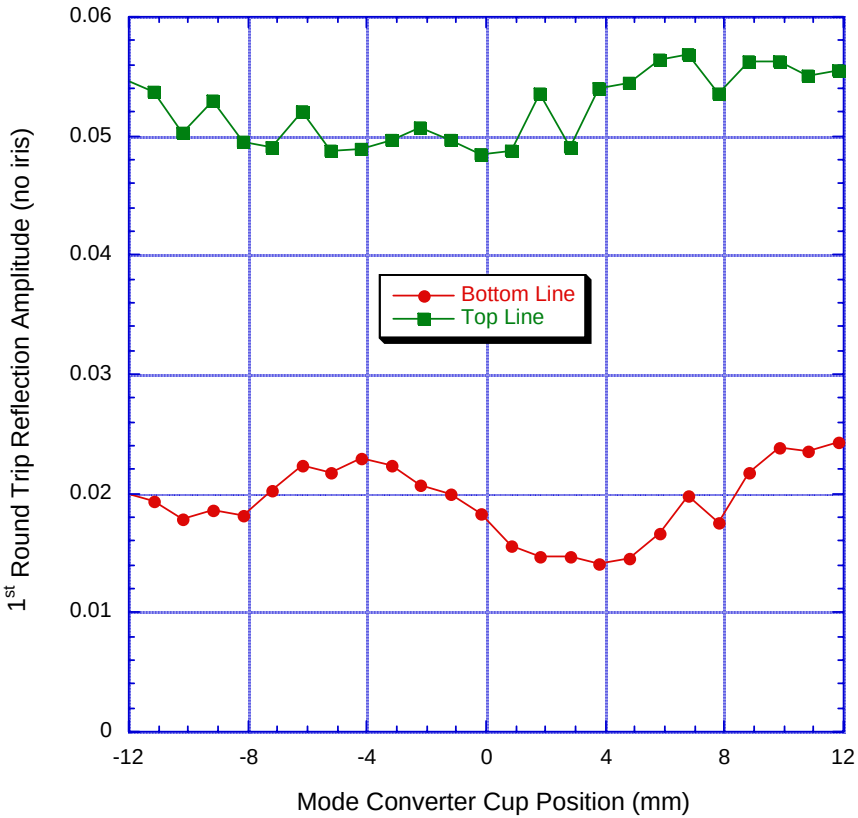
top line

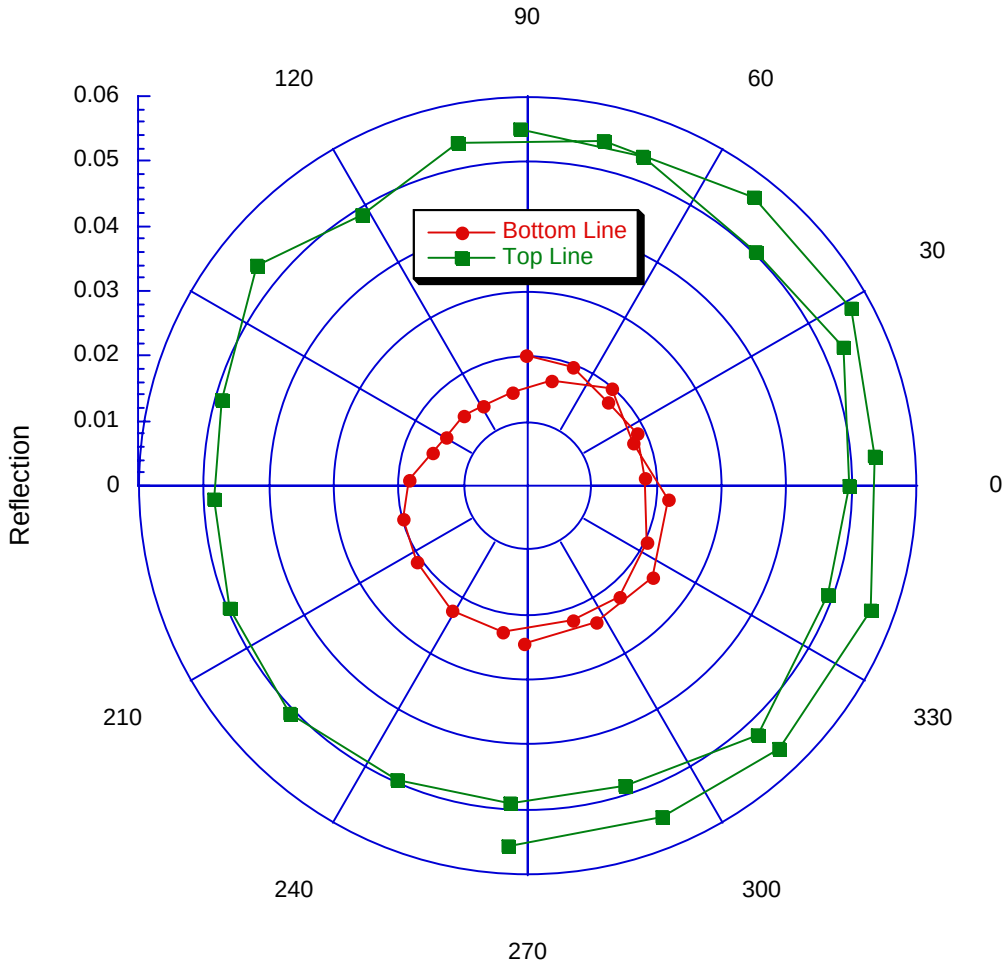


bottom line

Small mid-time-bin steps seen (mode impurity).

Spurious reflection after first round trip (irises removed)





Amplitude oscillation due to interference with slight wrap-around mode launcher mismatch (~-48 dB).

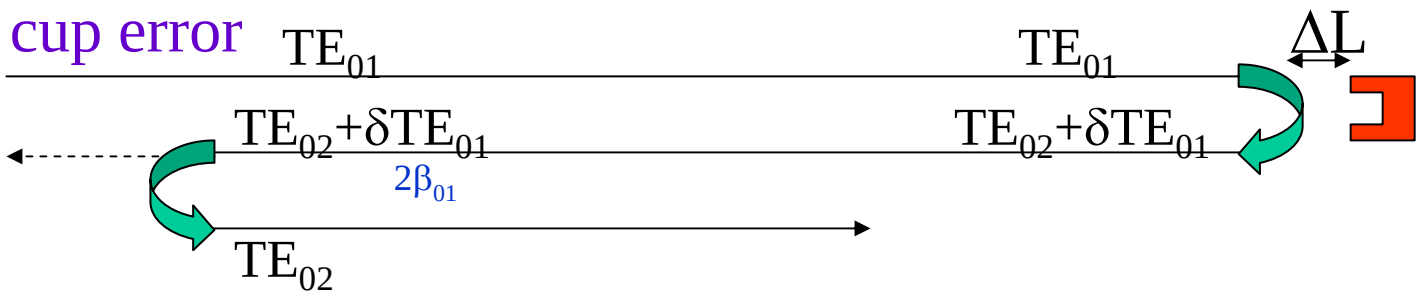
TE01 mode contamination

bottom line: ~-34 dB

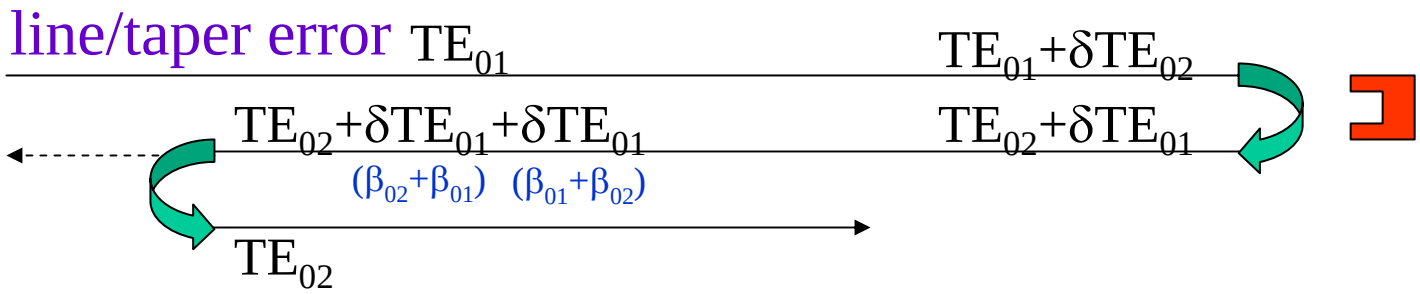
top line: ~-26 dB

Amp. $\Delta\phi/\Delta L$

const. $2\beta_{01}$



const. $(\beta_{01}+\beta_{02})$



The wavelengths for these phase oscillations are 14.2 mm and 16.1 mm, respectively.

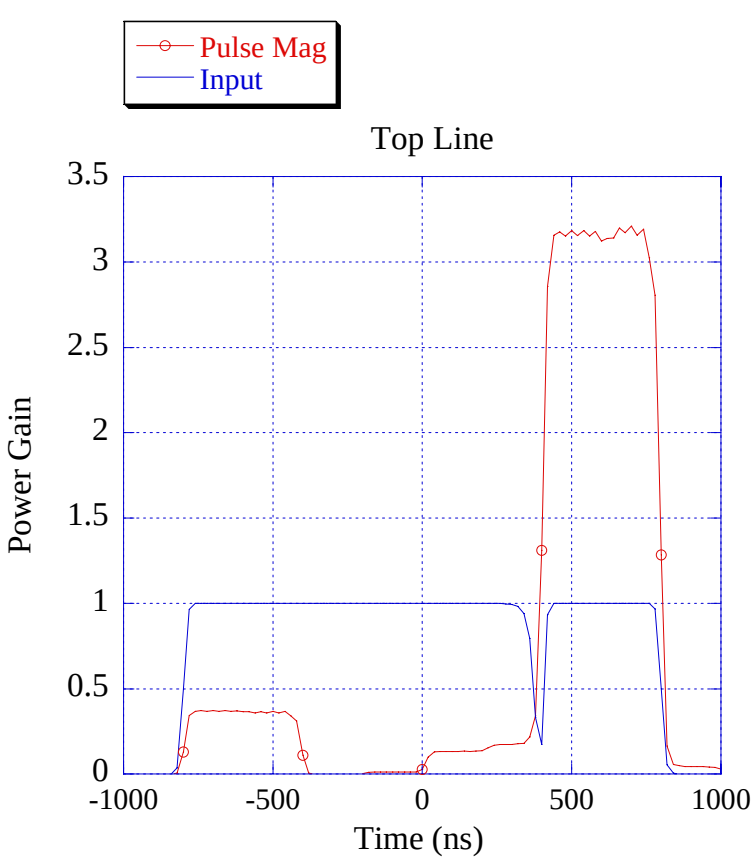
Measurements show a phase cycle over ~ 16 mm, indicating mode contamination predominantly from the delay lines and tapers.

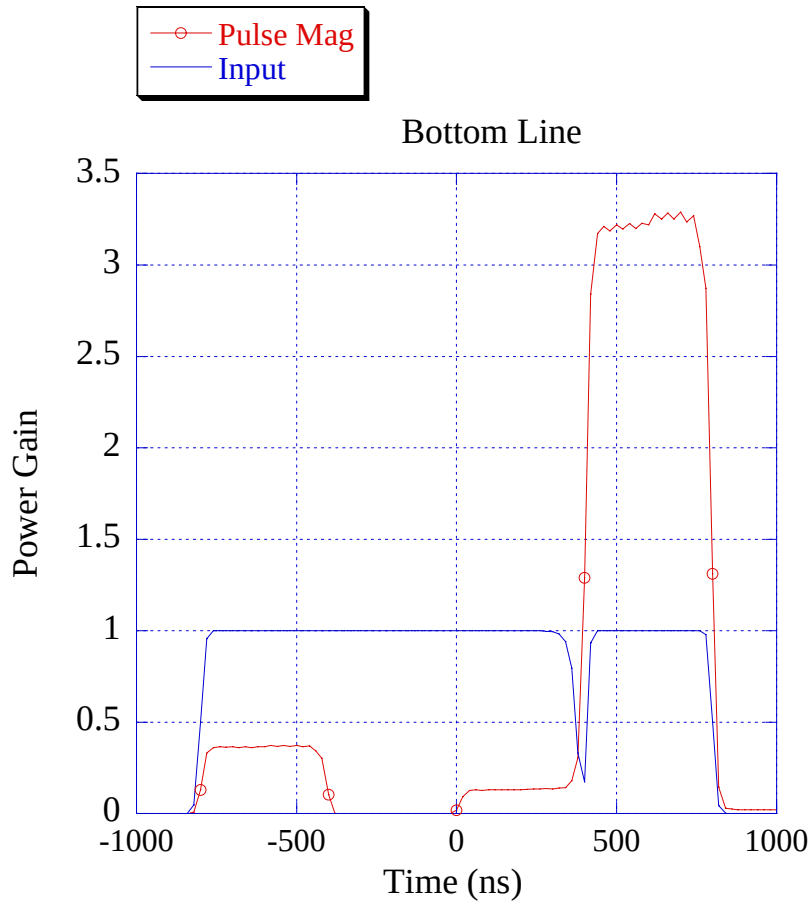
Slight amplitude oscillations reveal a very small fixed mismatch in wrap-around mode launcher.

Non-periodic amplitude change can be attributed to longer range beating between a small cup error contamination and that from the lines/tapers (60.3 mm).

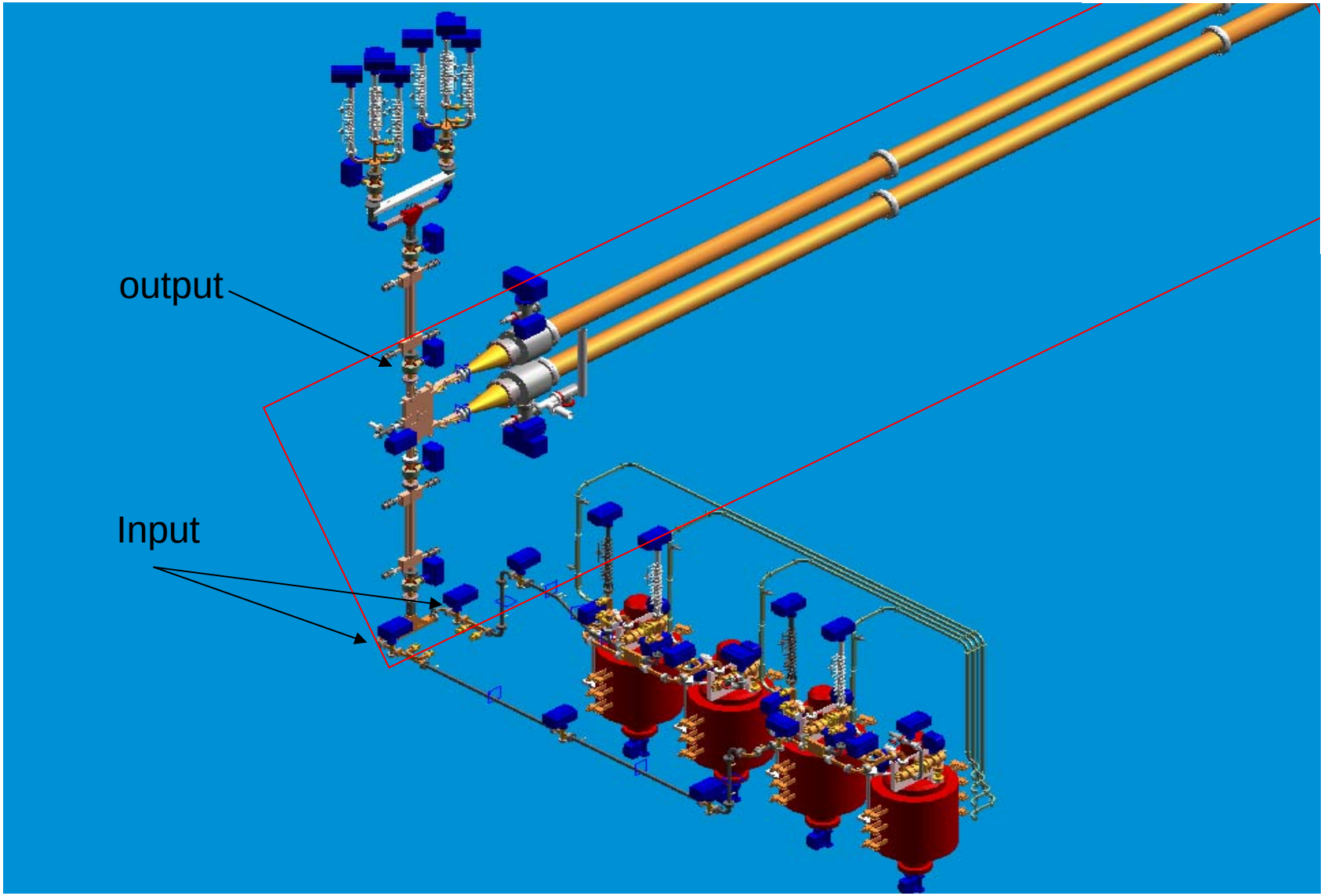
Problem Fixed by:

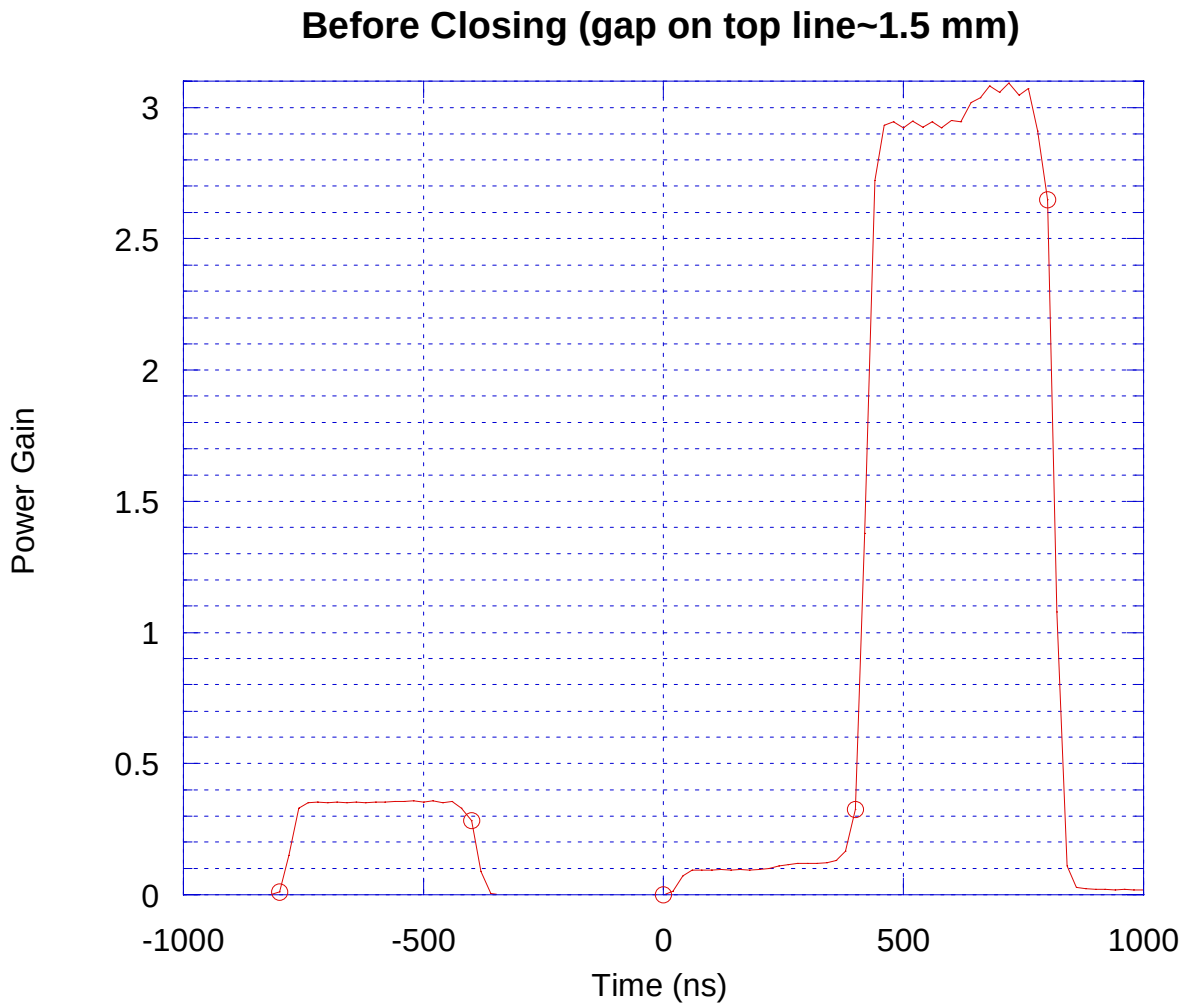
- Permutations of tapers
- Adjusting iris distance
- Choosing good resonant position for tuning plunger (3 within range of motion).

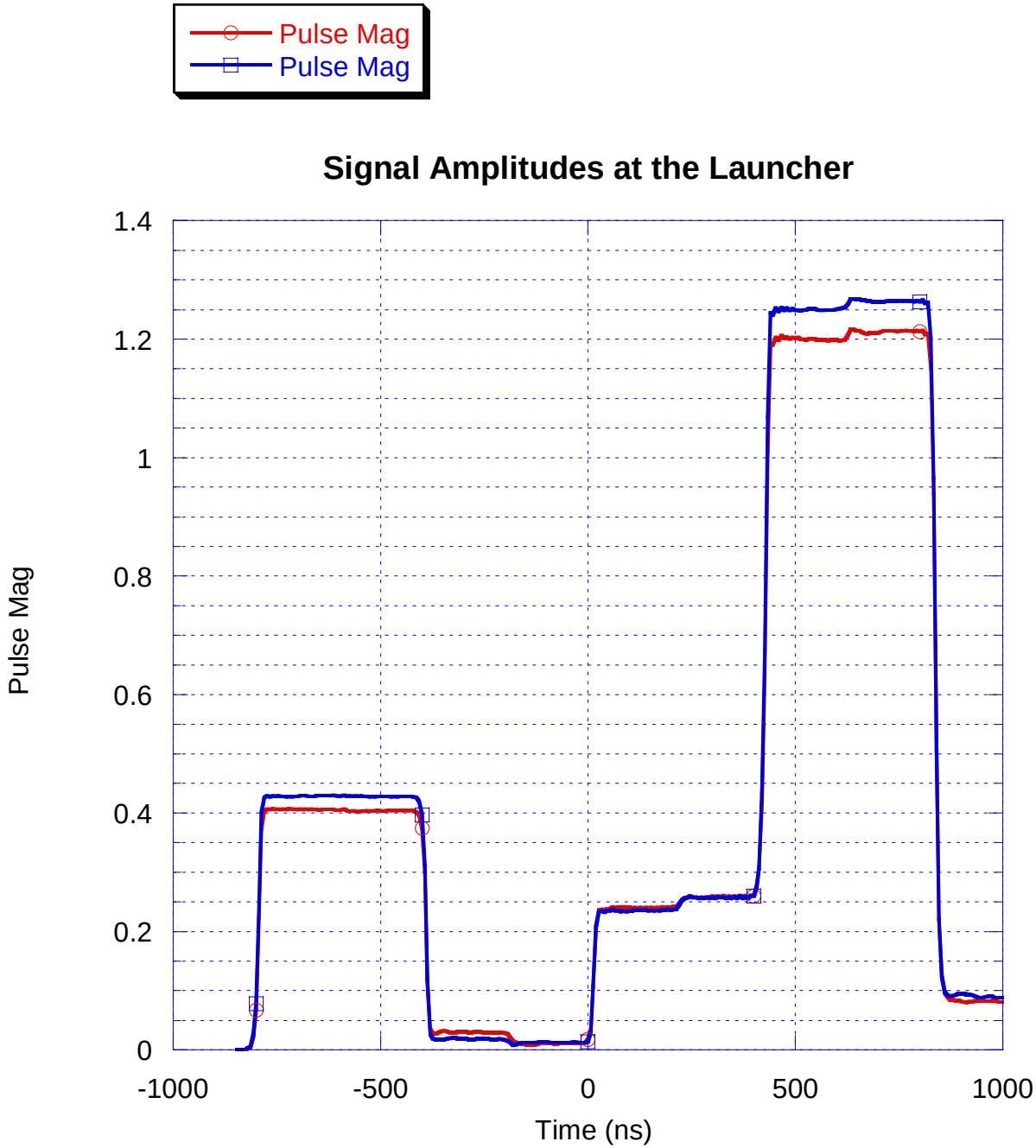


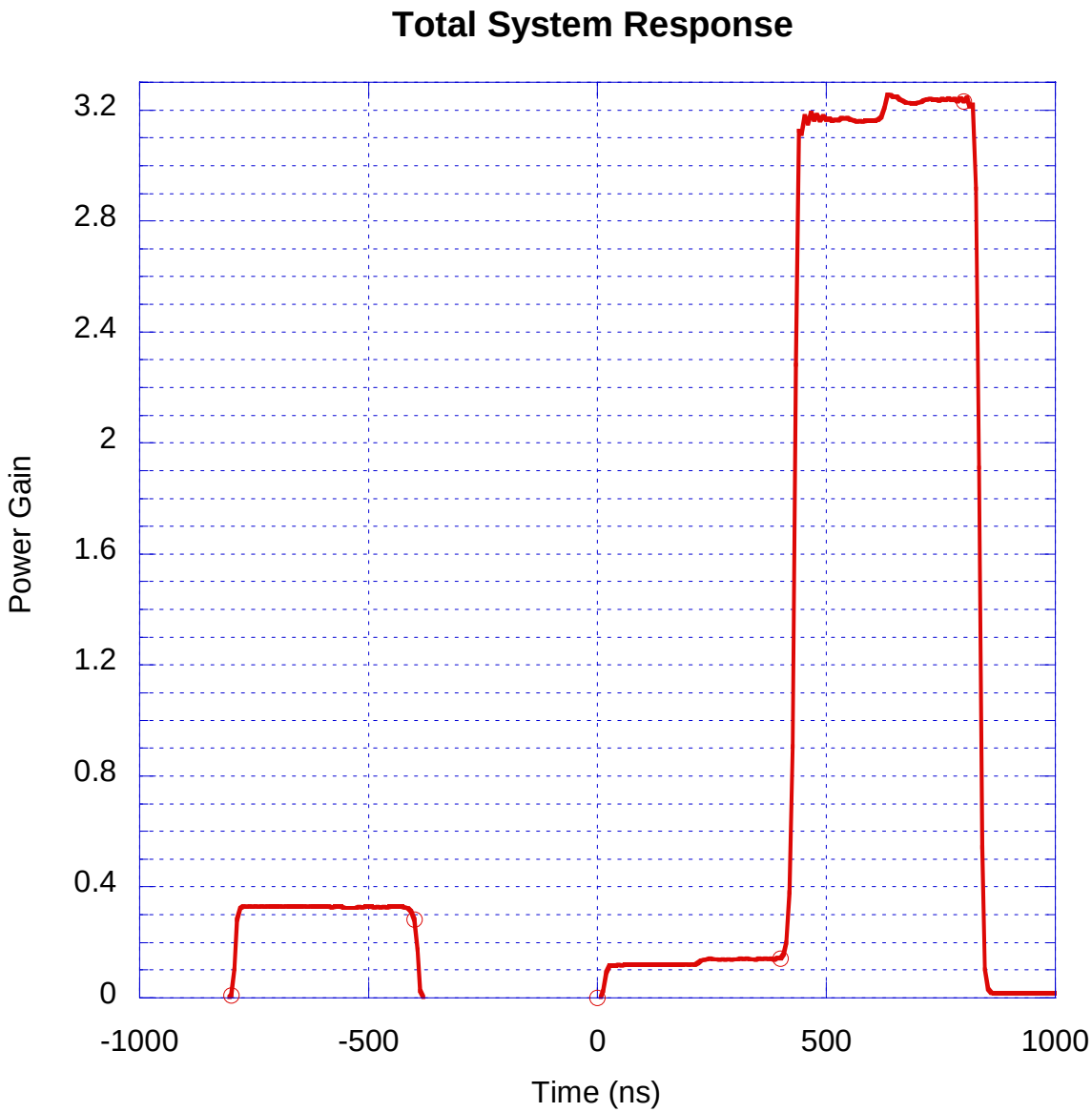


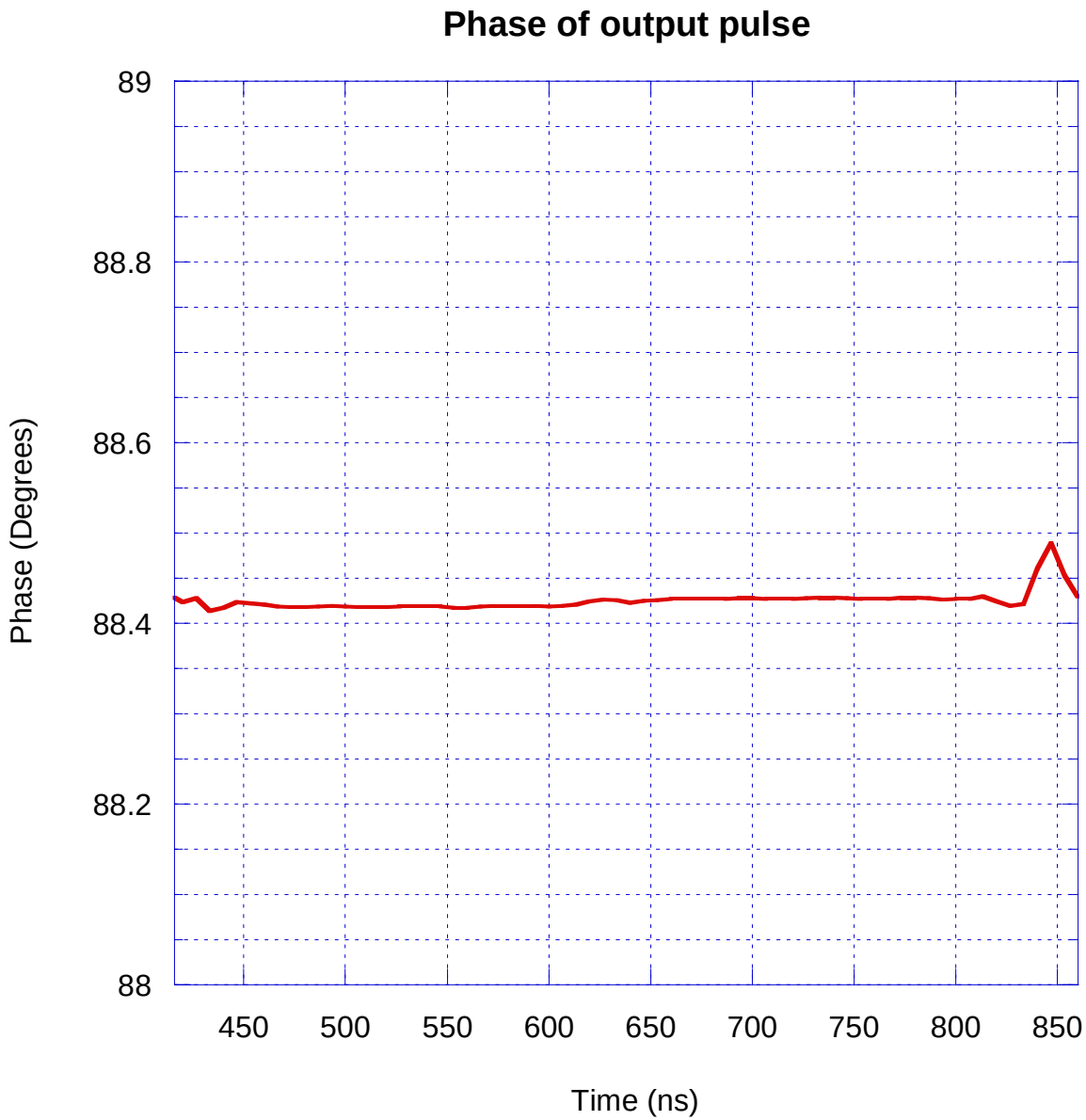
System test (1)

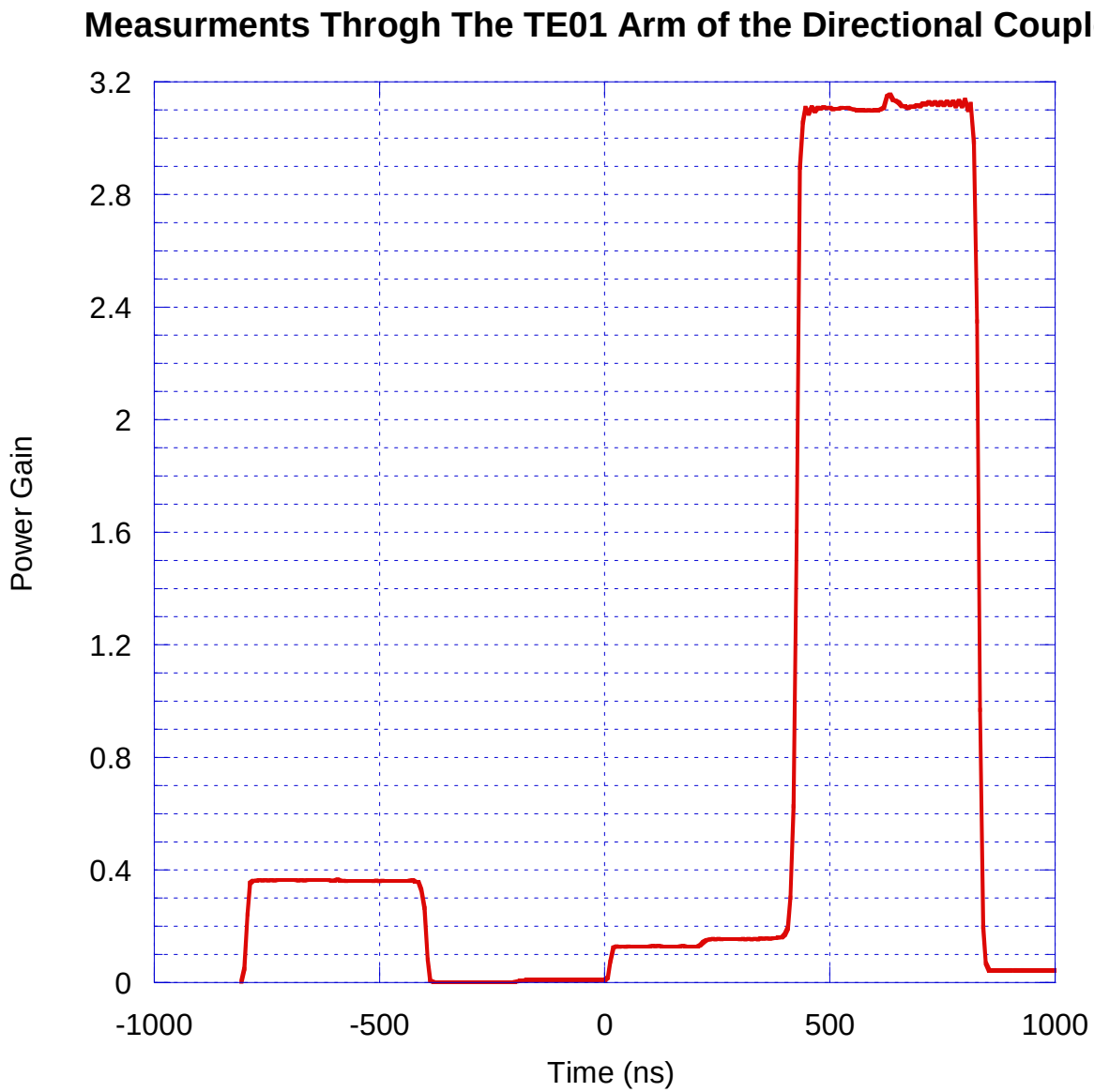


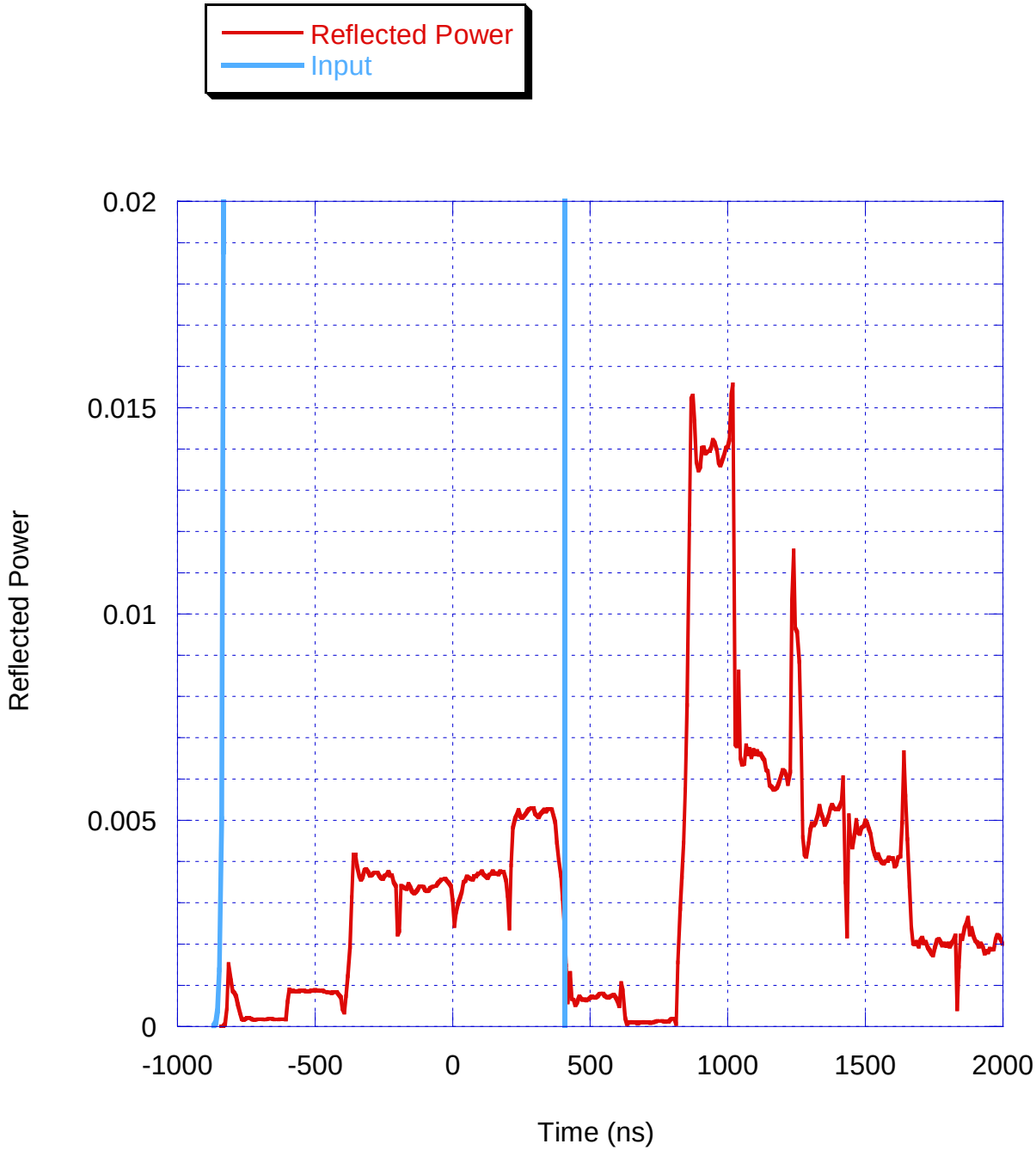

Before Closing (gap on top line~1.5 mm)
Power Gain
3
2.5
2
1.5
1
0.5
0
-1000
-500
0
500
1000
Time (ns)

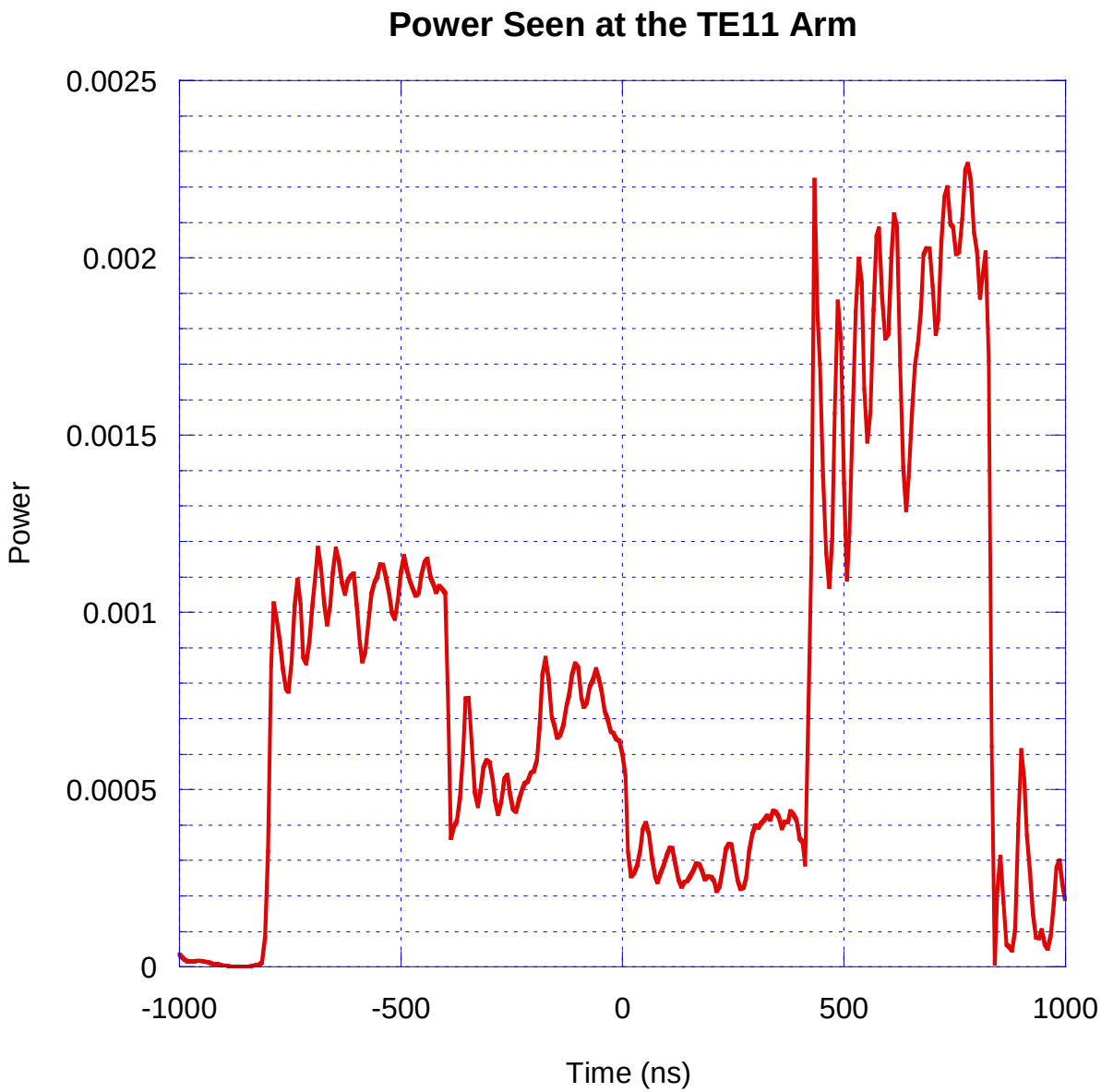

Pulse Mag
Pulse Mag
Signal Amplitudes at the Launcher
Pulse Mag
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-1000
-500
0
500
1000
Time (ns)

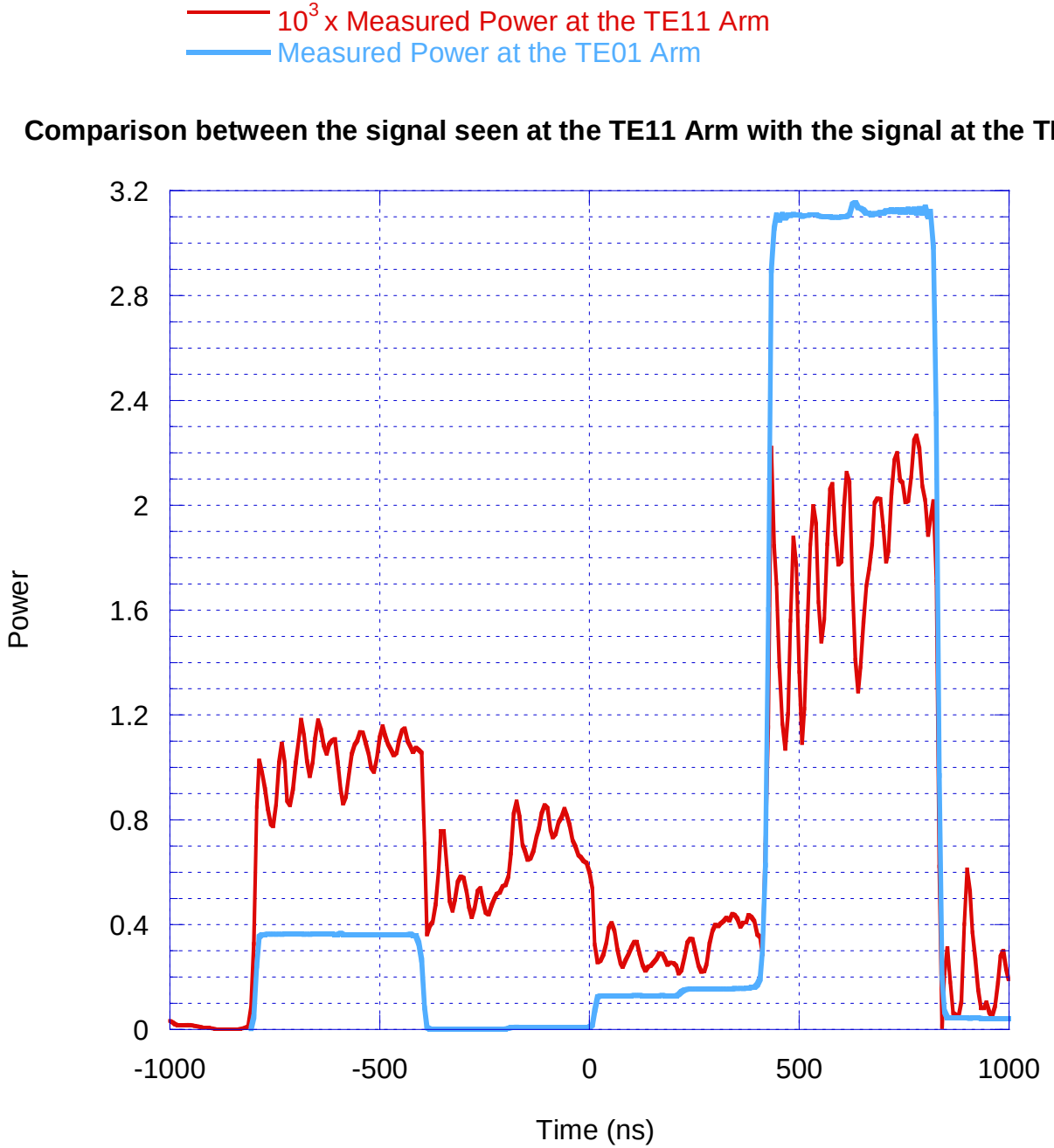

Total System Response
Power Gain
3.2
2.8
2.4
2
1.6
1.2
0.8
0.4
0
-1000
-500
0
500
1000
Time (ns)


Phase of output pulse
89
88.8
88.6
88.4
88.2
88
Phase (Degrees)
450
500
550
600
650
700
750
800
850
Time (ns)

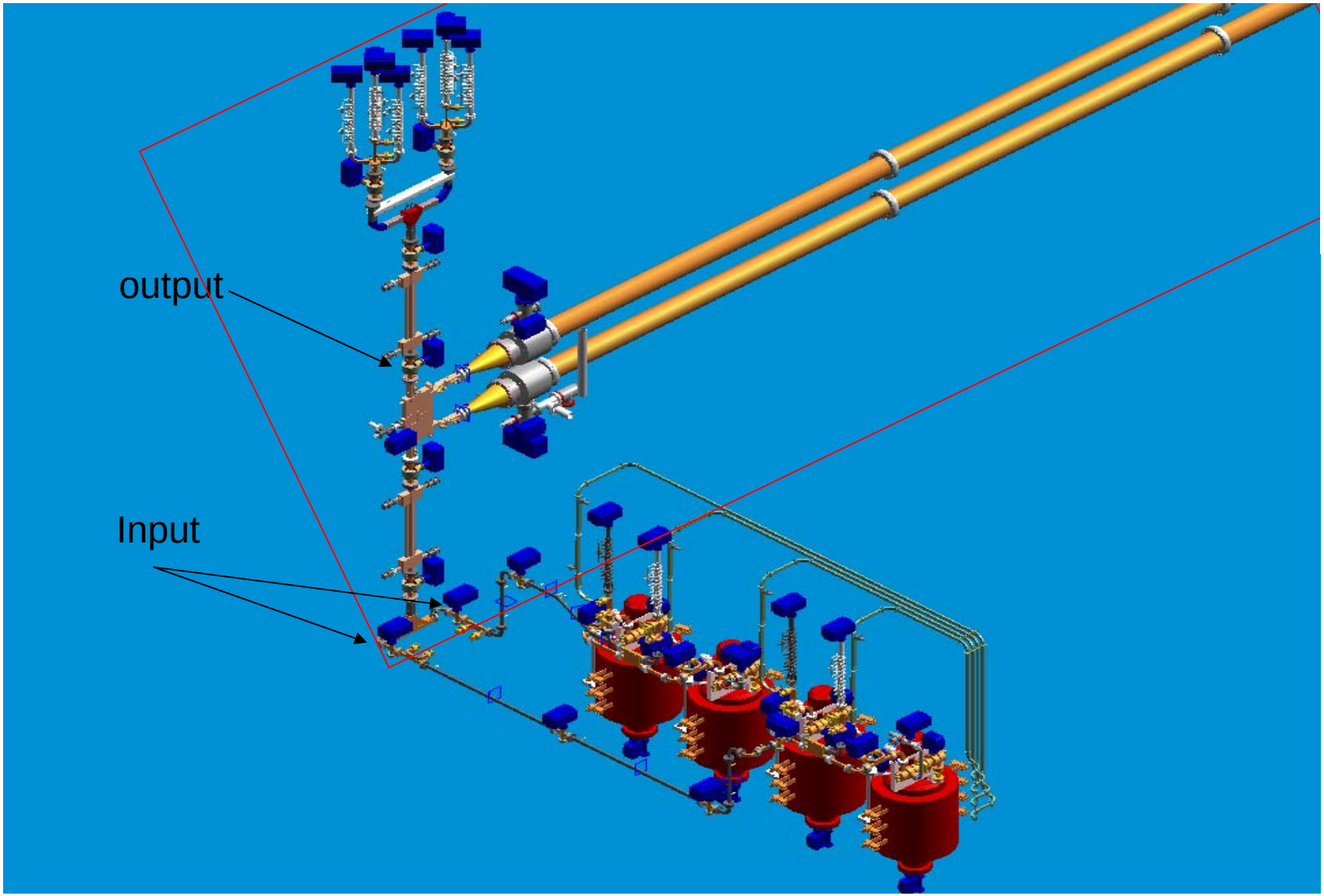

Measurments Throgh The TE01 Arm of the Directional Coupler
Power Gain
3.2
2.8
2.4
2
1.6
1.2
0.8
0.4
0
-1000
-500
0
500
1000
Time (ns)


Reflected Power
Input
0.02
0.015
0.01
0.005
0
Reflected Power
-1000
-500
0
500
1000
1500
2000
Time (ns)

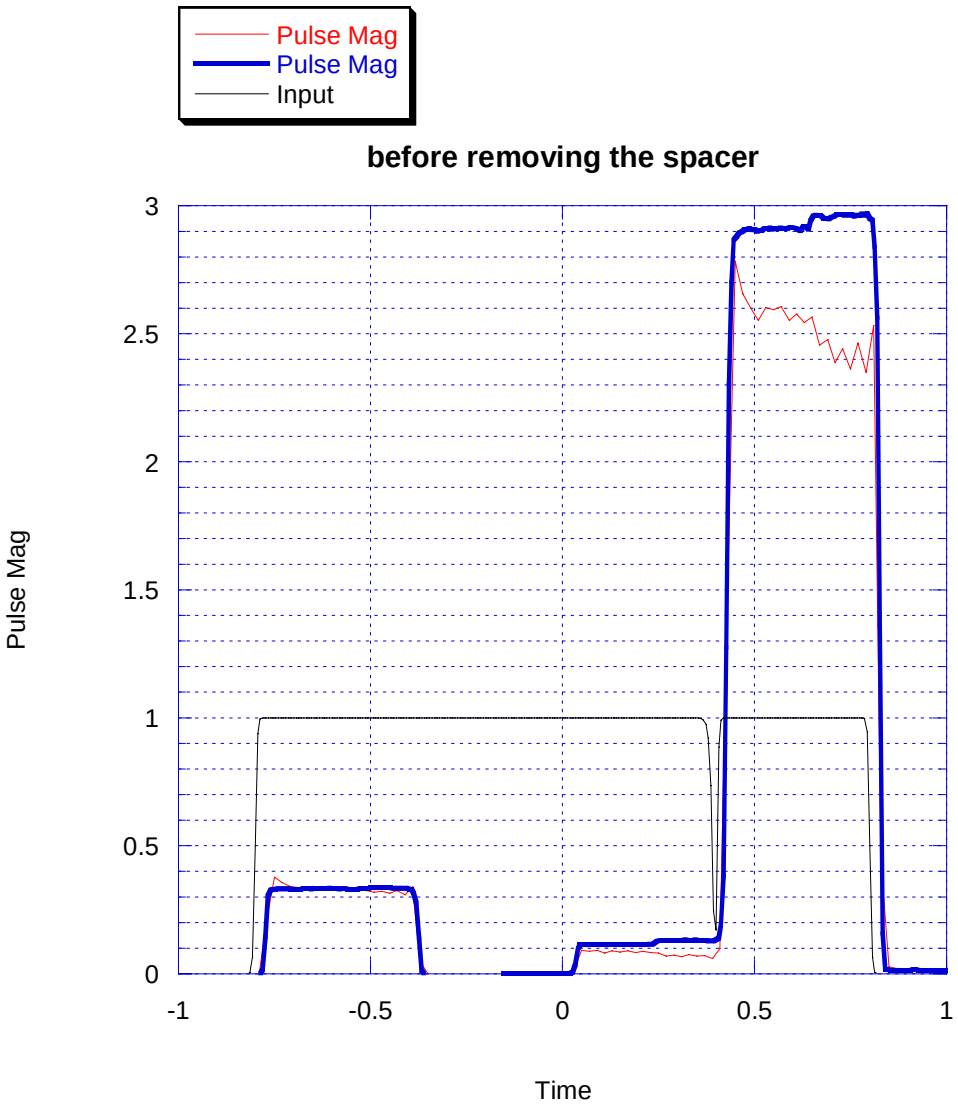

Power Seen at the TE11 Arm
0.0025
0.002
0.0015
0.001
0.0005
0
Power
-1000
-500
0
500
1000
Time (ns)

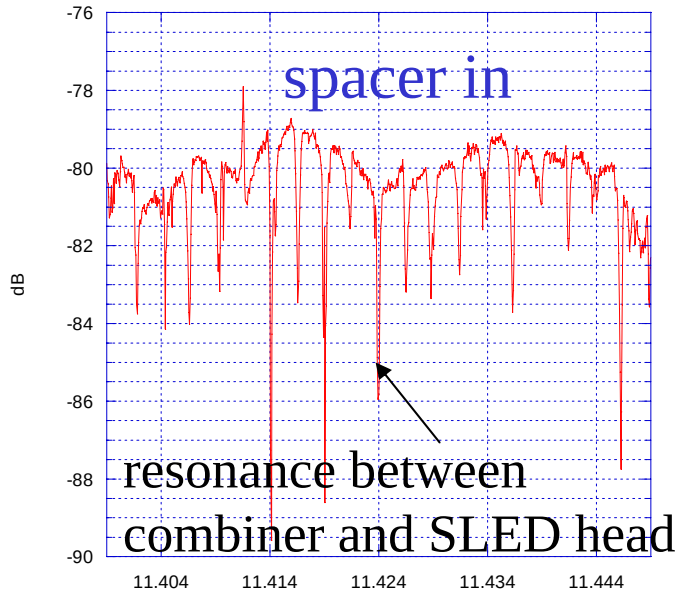

10^3 x Measured Power at the TE11 Arm
Measured Power at the TE01 Arm
Comparison between the signal seen at the TE11 Arm with the signal at the TE01 Arm
Power
3.2
2.8
2.4
2
1.6
1.2
0.8
0.4
0
-1000
-500
0
500
1000
Time (ns)

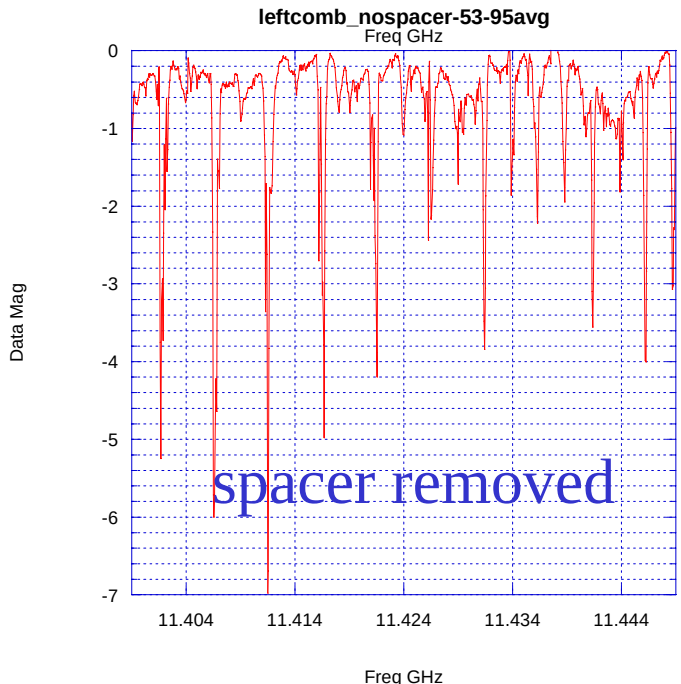
System test (2)

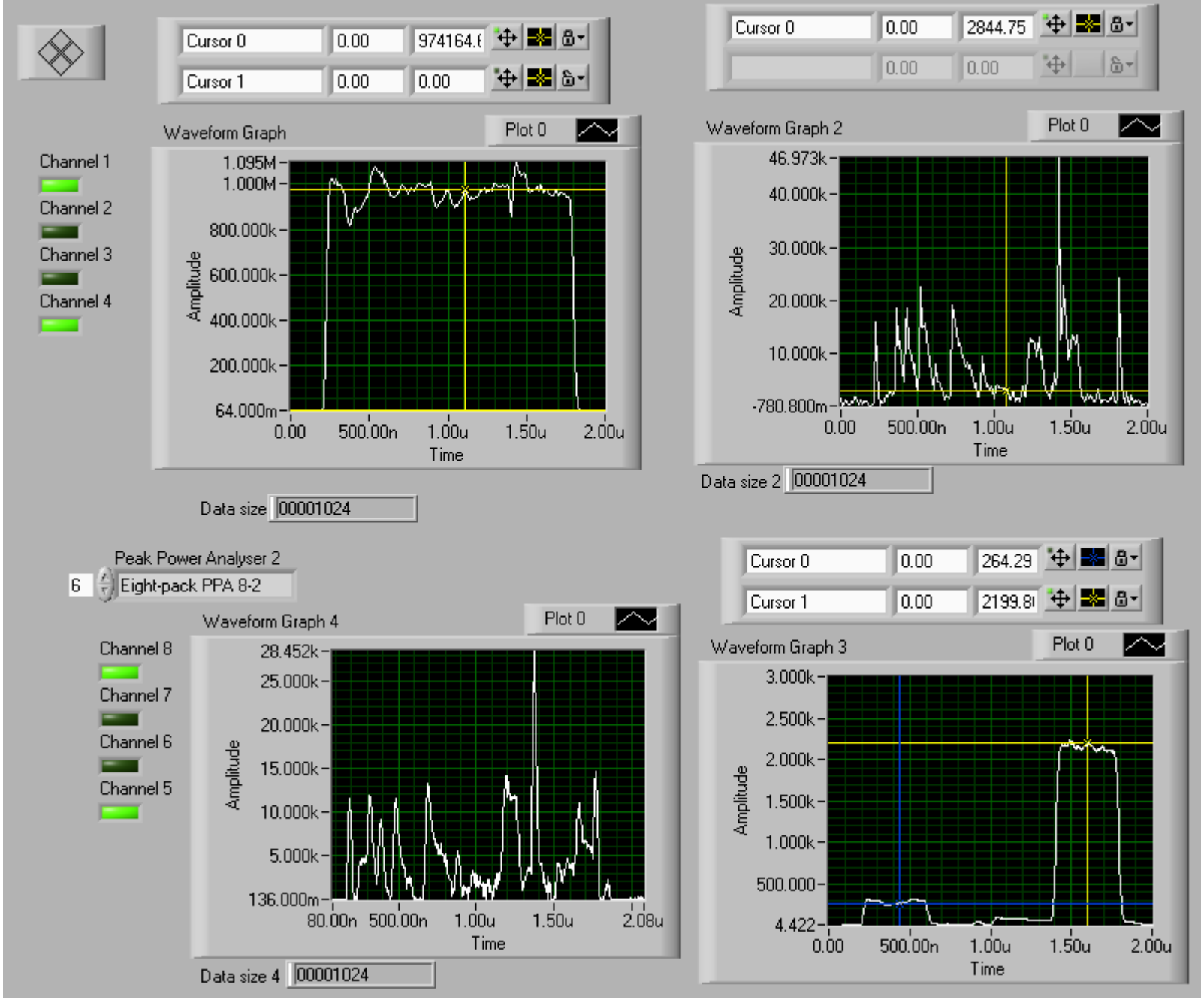


System Cold Tests





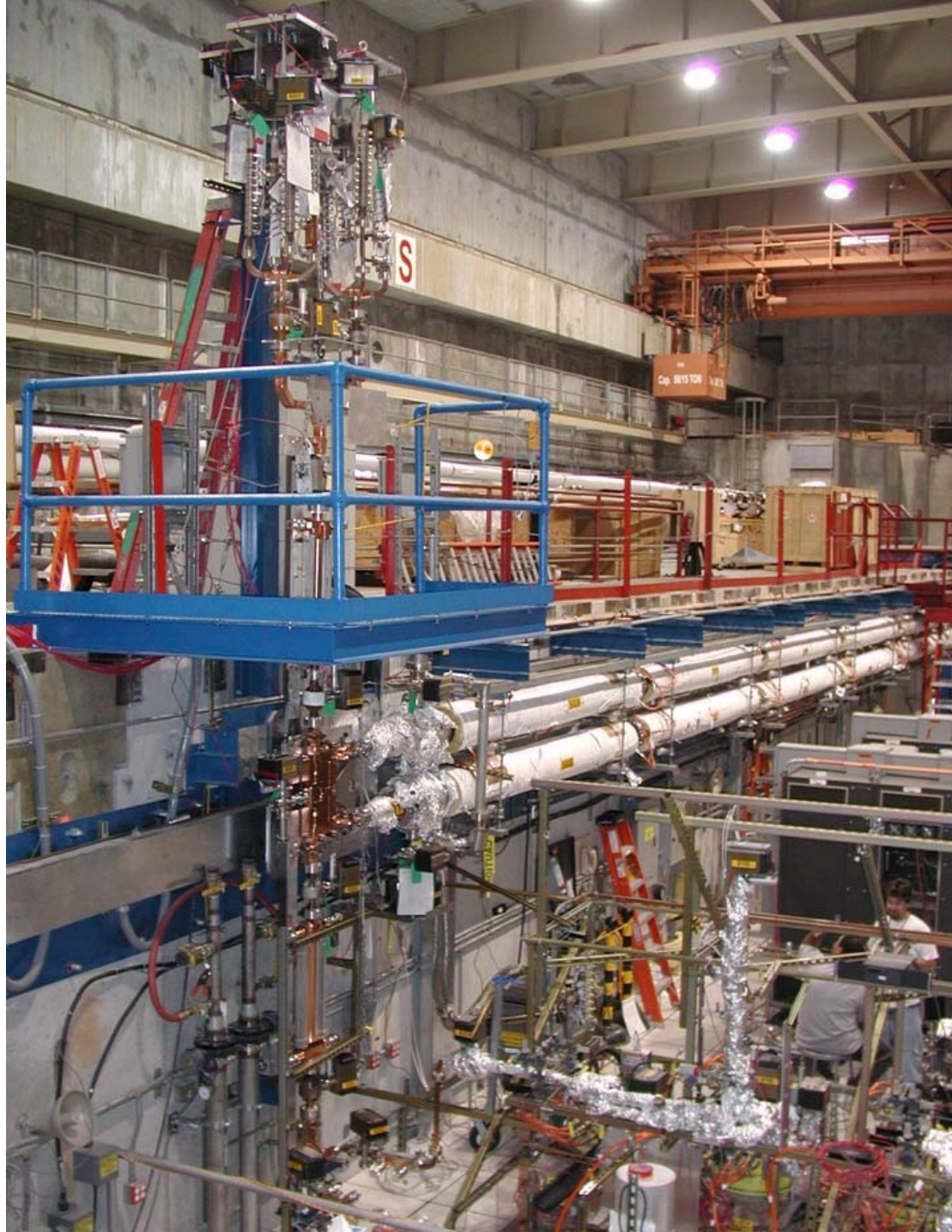




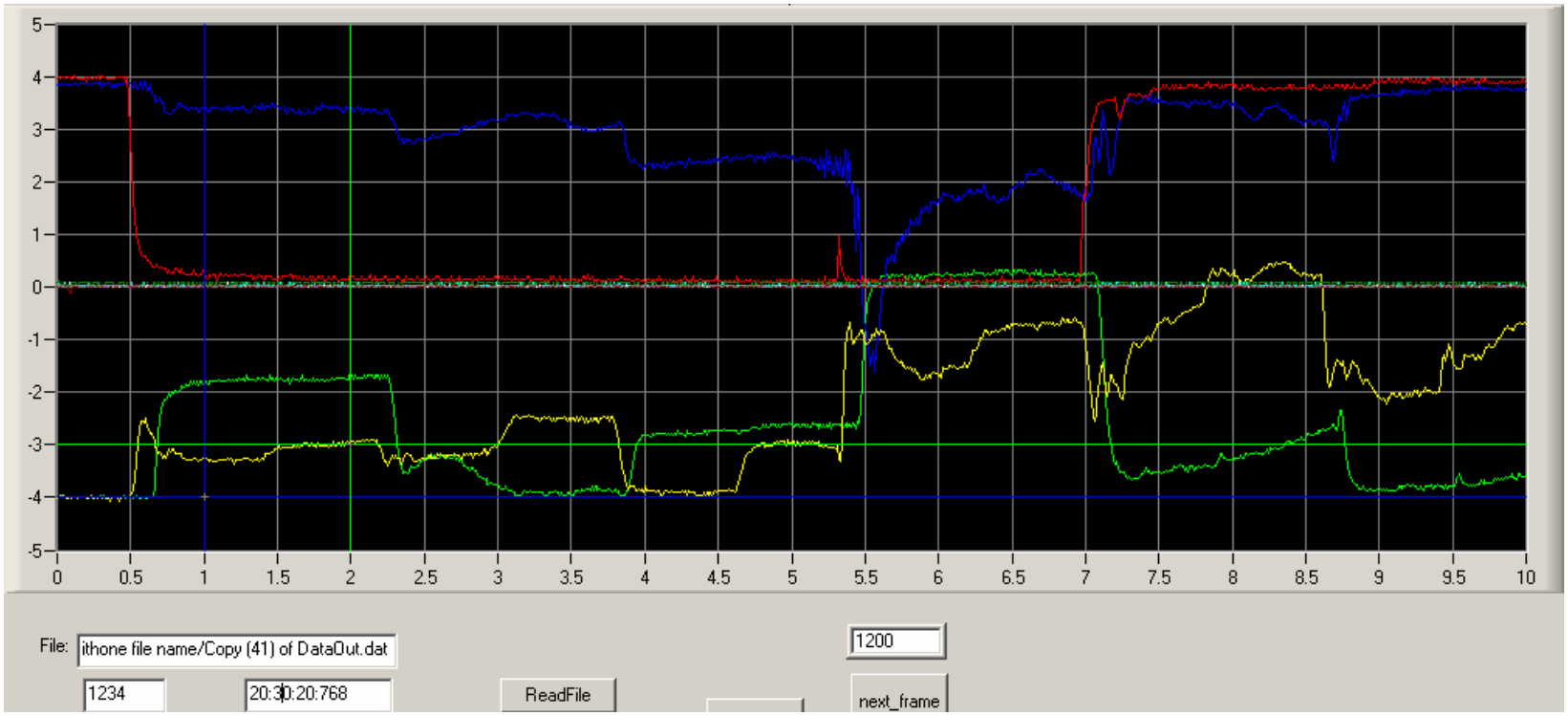
16 steps 2 klystrons

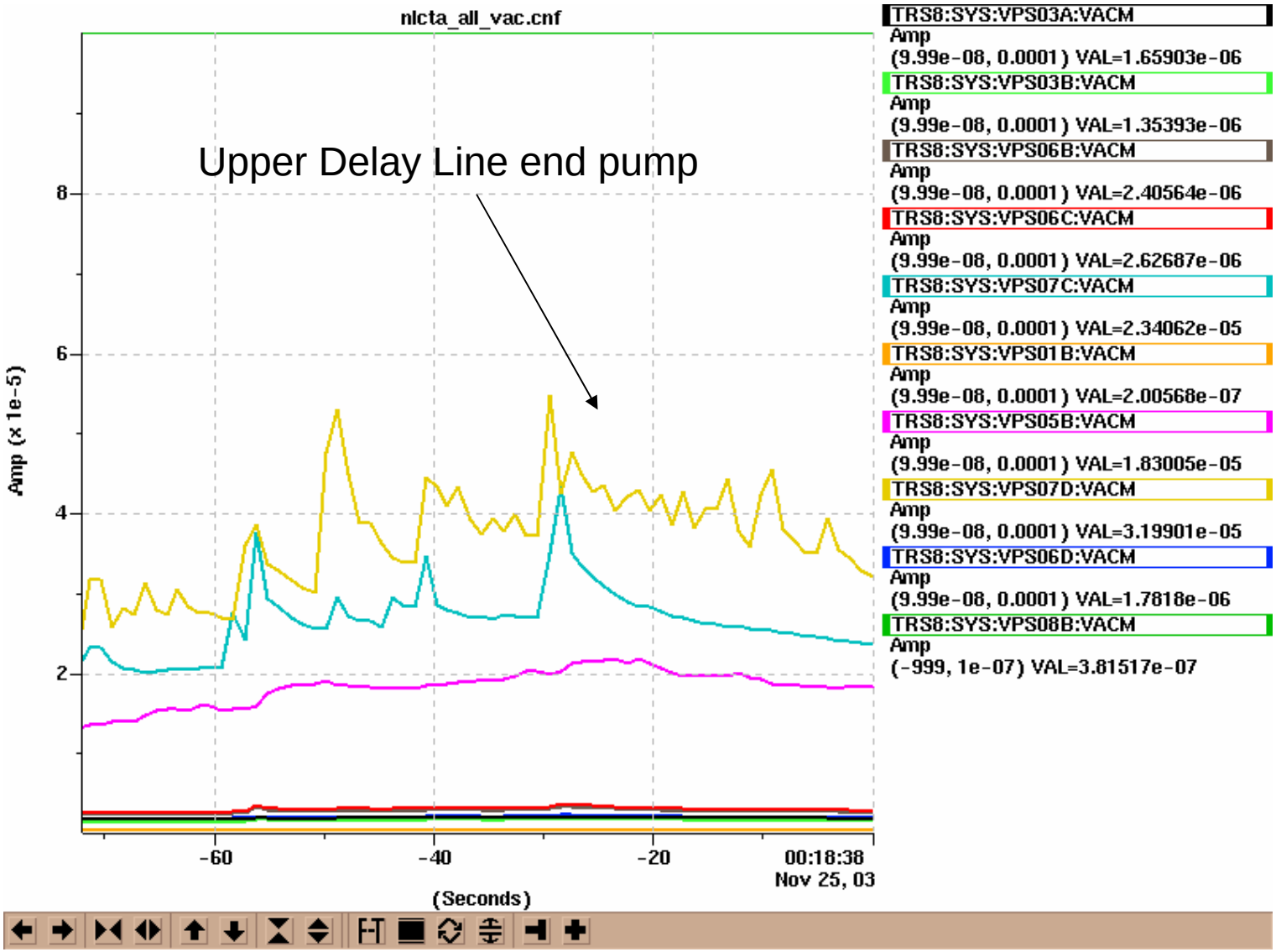
High Power Experiments

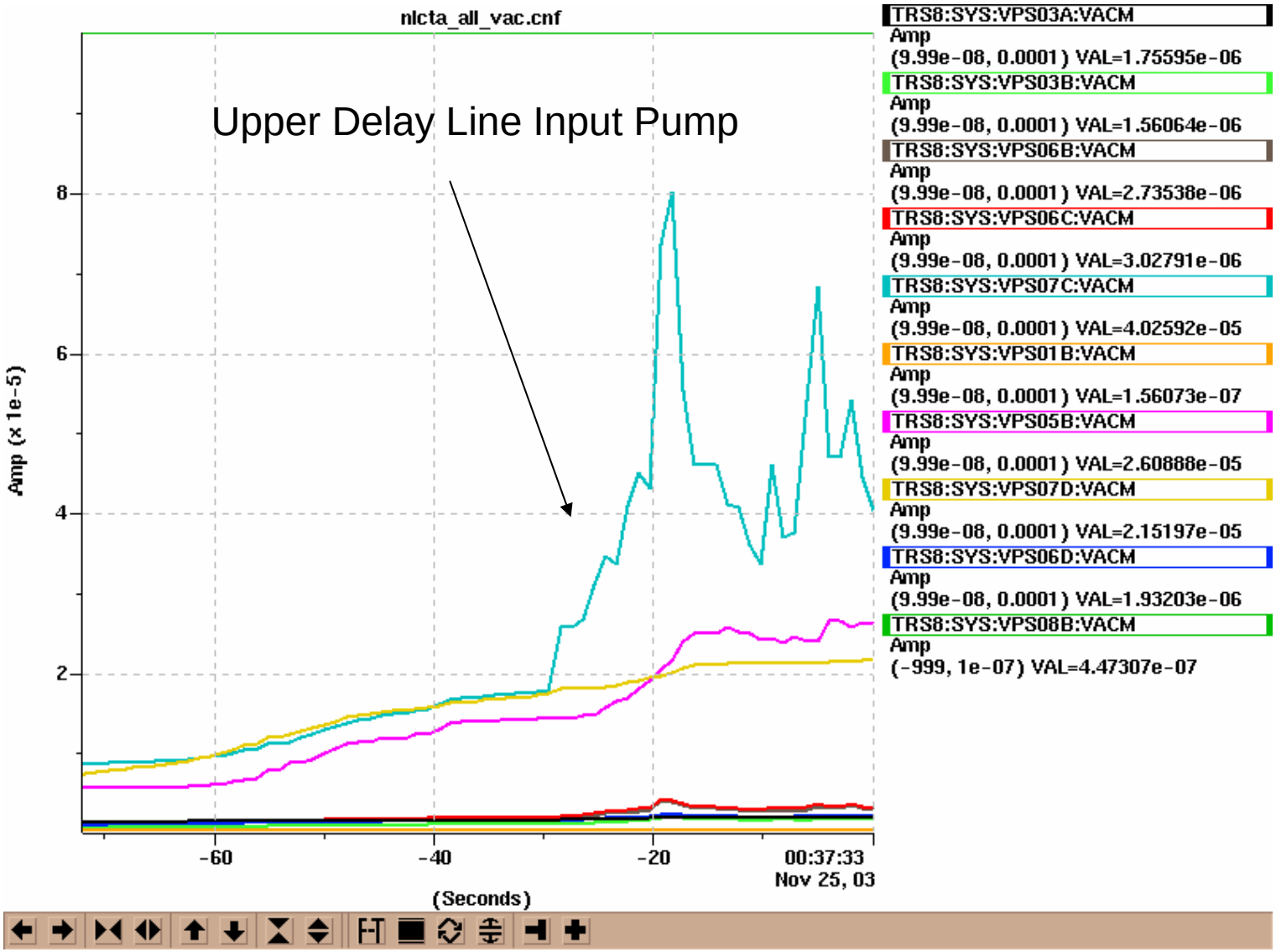
8-Pack Phase 1

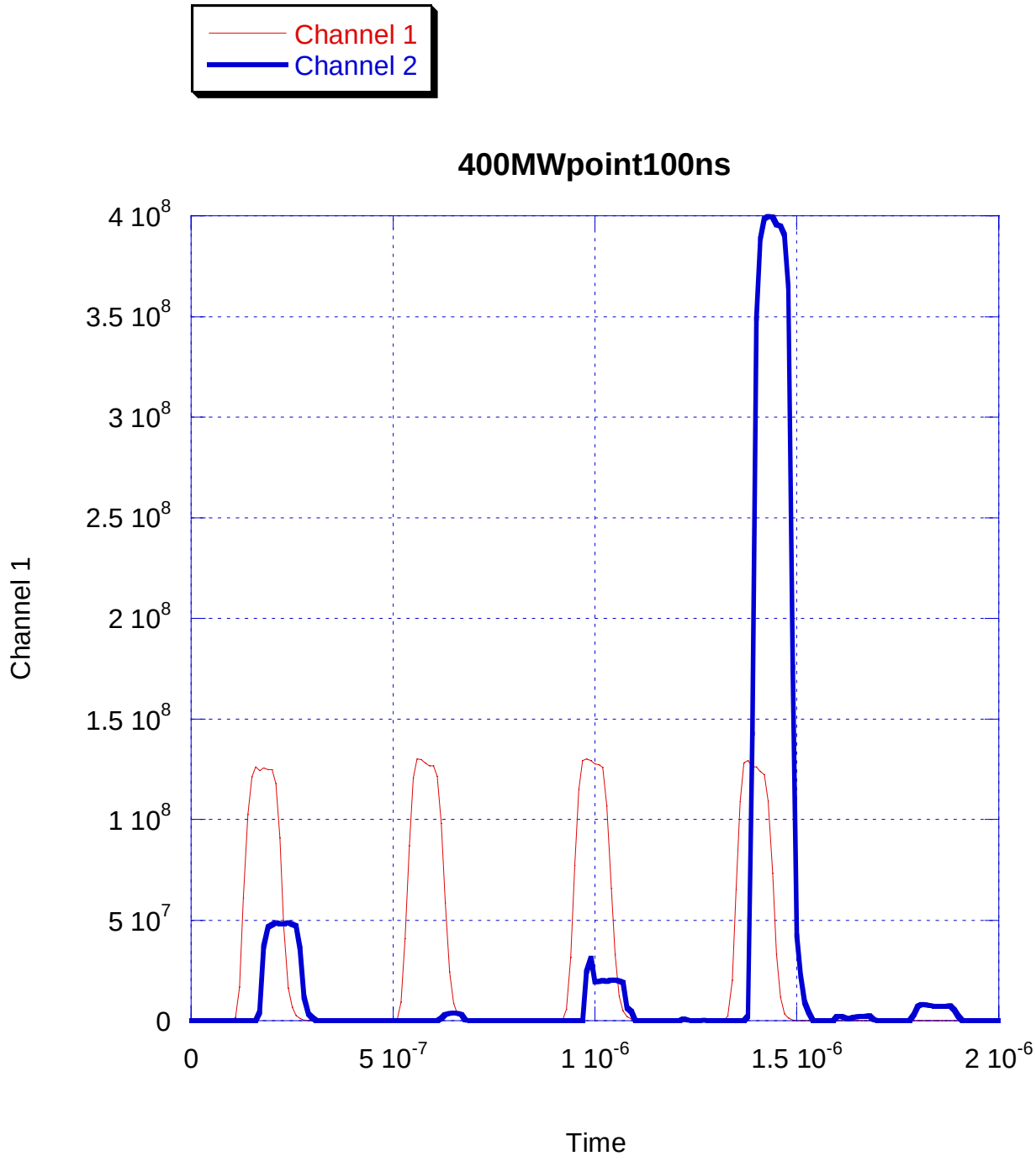


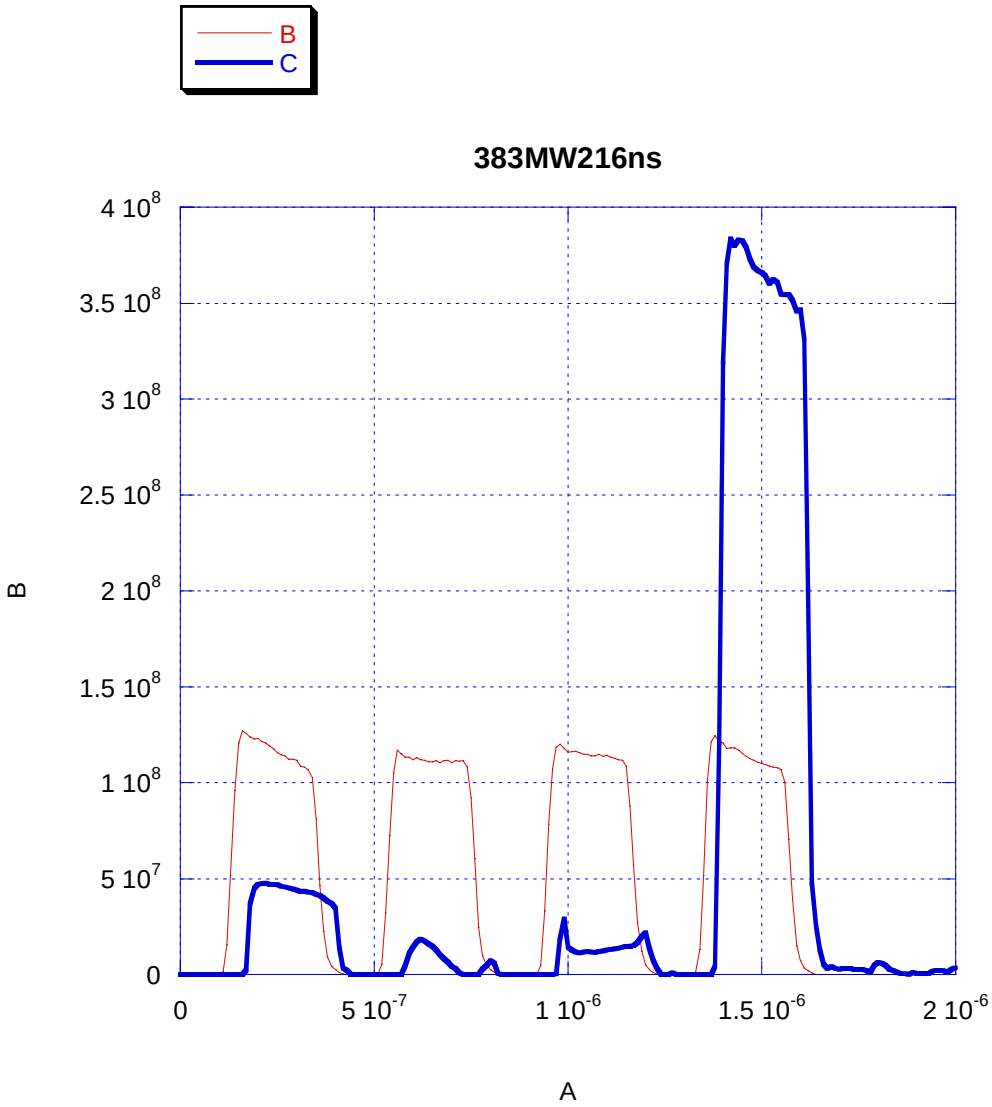
After pulse breakdown
(Loads)

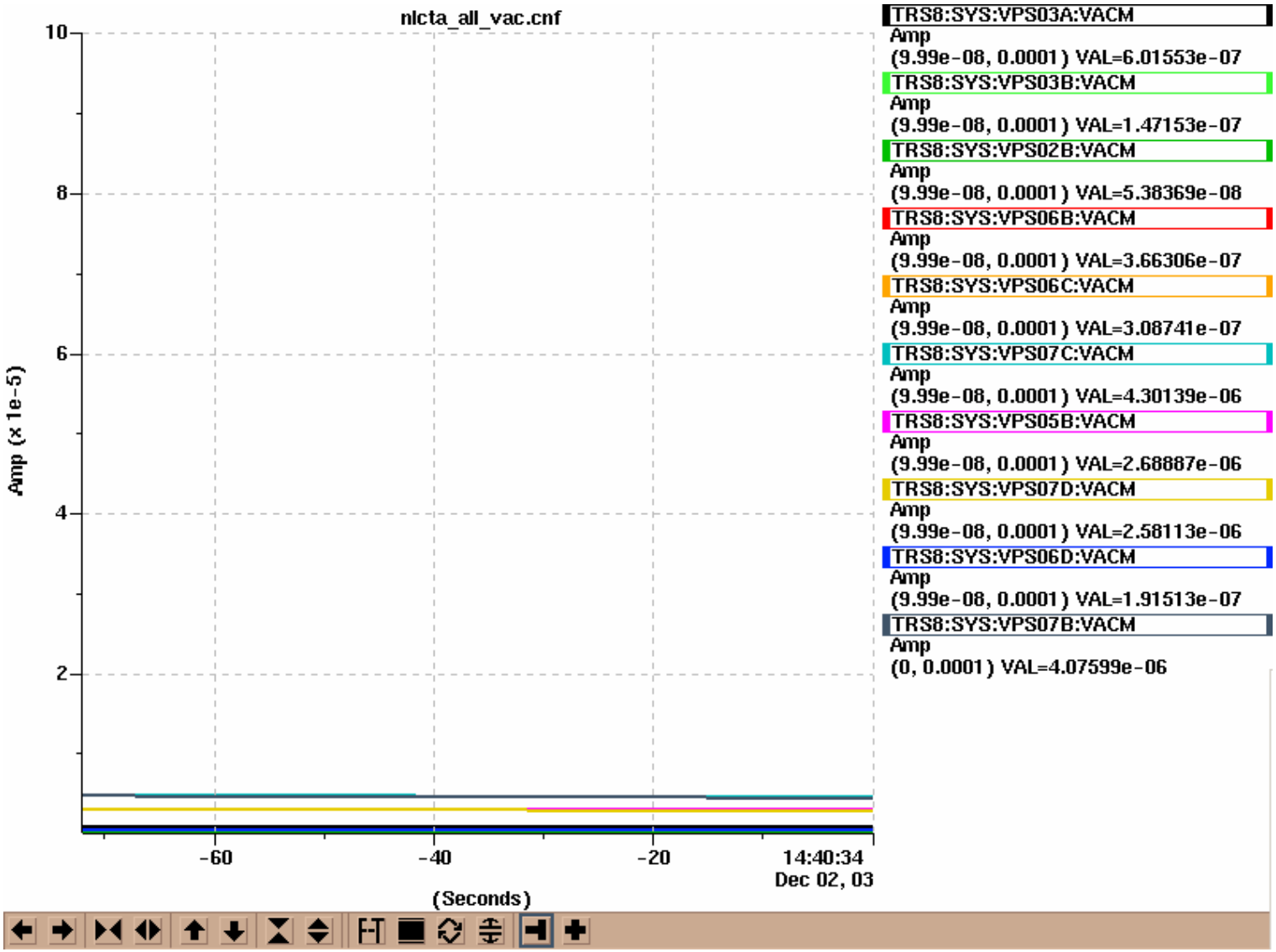



nlcta_all_vac.cnf
Upper Delay Line end pump
Amp (x 1e-5)
8
6
4
2
-60
-40
-20
00:18:38
Nov 25, 03
(Seconds)
TRS8:SYS:VPS03A:VACM
Amp
(9.99e-08, 0.0001) VAL=1.65903e-06
TRS8:SYS:VPS03B:VACM
Amp
(9.99e-08, 0.0001) VAL=1.35393e-06
TRS8:SYS:VPS06B:VACM
Amp
(9.99e-08, 0.0001) VAL=2.40564e-06
TRS8:SYS:VPS06C:VACM
Amp
(9.99e-08, 0.0001) VAL=2.62687e-06
TRS8:SYS:VPS07C:VACM
Amp
(9.99e-08, 0.0001) VAL=2.34062e-05
TRS8:SYS:VPS01B:VACM
Amp
(9.99e-08, 0.0001) VAL=2.00568e-07
TRS8:SYS:VPS05B:VACM
Amp
(9.99e-08, 0.0001) VAL=1.83005e-05
TRS8:SYS:VPS07D:VACM
Amp
(9.99e-08, 0.0001) VAL=3.19901e-05
TRS8:SYS:VPS06D:VACM
Amp
(9.99e-08, 0.0001) VAL=1.7818e-06
TRS8:SYS:VPS08B:VACM
Amp
(-999, 1e-07) VAL=3.81517e-07

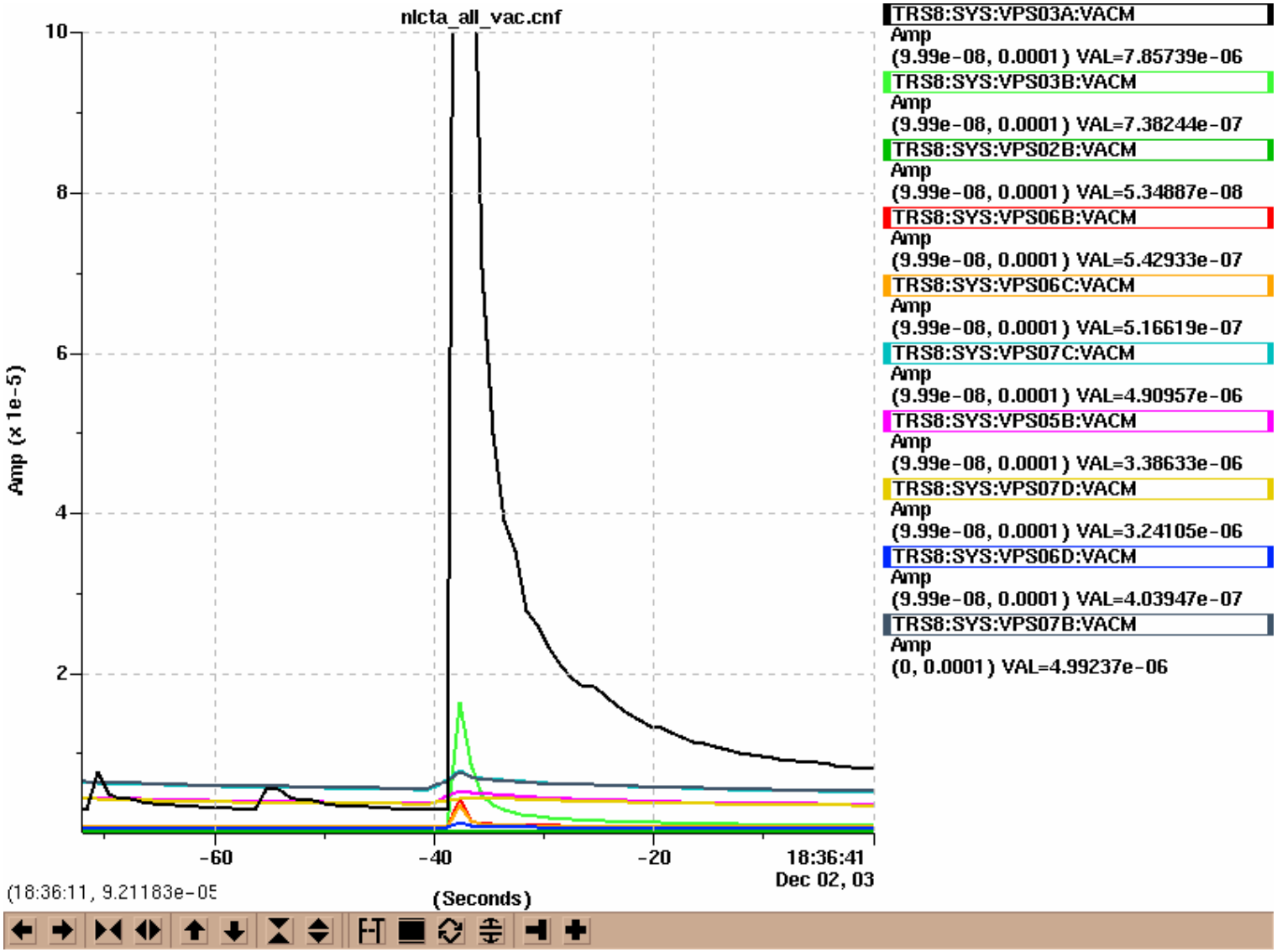

nlcta_all_vac.cnf
Upper Delay Line Input Pump
Amp (x 1e-5)
8
6
4
2
-60
-40
-20
00:37:33
Nov 25, 03
(Seconds)
TRS8:SYS:VPS03A:VACM
Amp
(9.99e-08, 0.0001) VAL=1.75595e-06
TRS8:SYS:VPS03B:VACM
Amp
(9.99e-08, 0.0001) VAL=1.56064e-06
TRS8:SYS:VPS06B:VACM
Amp
(9.99e-08, 0.0001) VAL=2.73538e-06
TRS8:SYS:VPS06C:VACM
Amp
(9.99e-08, 0.0001) VAL=3.02791e-06
TRS8:SYS:VPS07C:VACM
Amp
(9.99e-08, 0.0001) VAL=4.02592e-05
TRS8:SYS:VPS01B:VACM
Amp
(9.99e-08, 0.0001) VAL=1.56073e-07
TRS8:SYS:VPS05B:VACM
Amp
(9.99e-08, 0.0001) VAL=2.60888e-05
TRS8:SYS:VPS07D:VACM
Amp
(9.99e-08, 0.0001) VAL=2.15197e-05
TRS8:SYS:VPS06D:VACM
Amp
(9.99e-08, 0.0001) VAL=1.93203e-06
TRS8:SYS:VPS08B:VACM
Amp
(-999, 1e-07) VAL=4.47307e-07


Channel 1
Channel 2
400MWpoint100ns
4 10^8
3.5 10^8
3 10^8
2.5 10^8
2 10^8
1.5 10^8
1 10^8
5 10^7
0
Channel 1
0
5 10^-7
1 10^-6
1.5 10^-6
2 10^-6
Time


B
C
383MW216ns
4 10^8
3.5 10^8
3 10^8
2.5 10^8
2 10^8
1.5 10^8
1 10^8
5 10^7
0
B
0
5 10^-7
1 10^-6
1.5 10^-6
2 10^-6
A

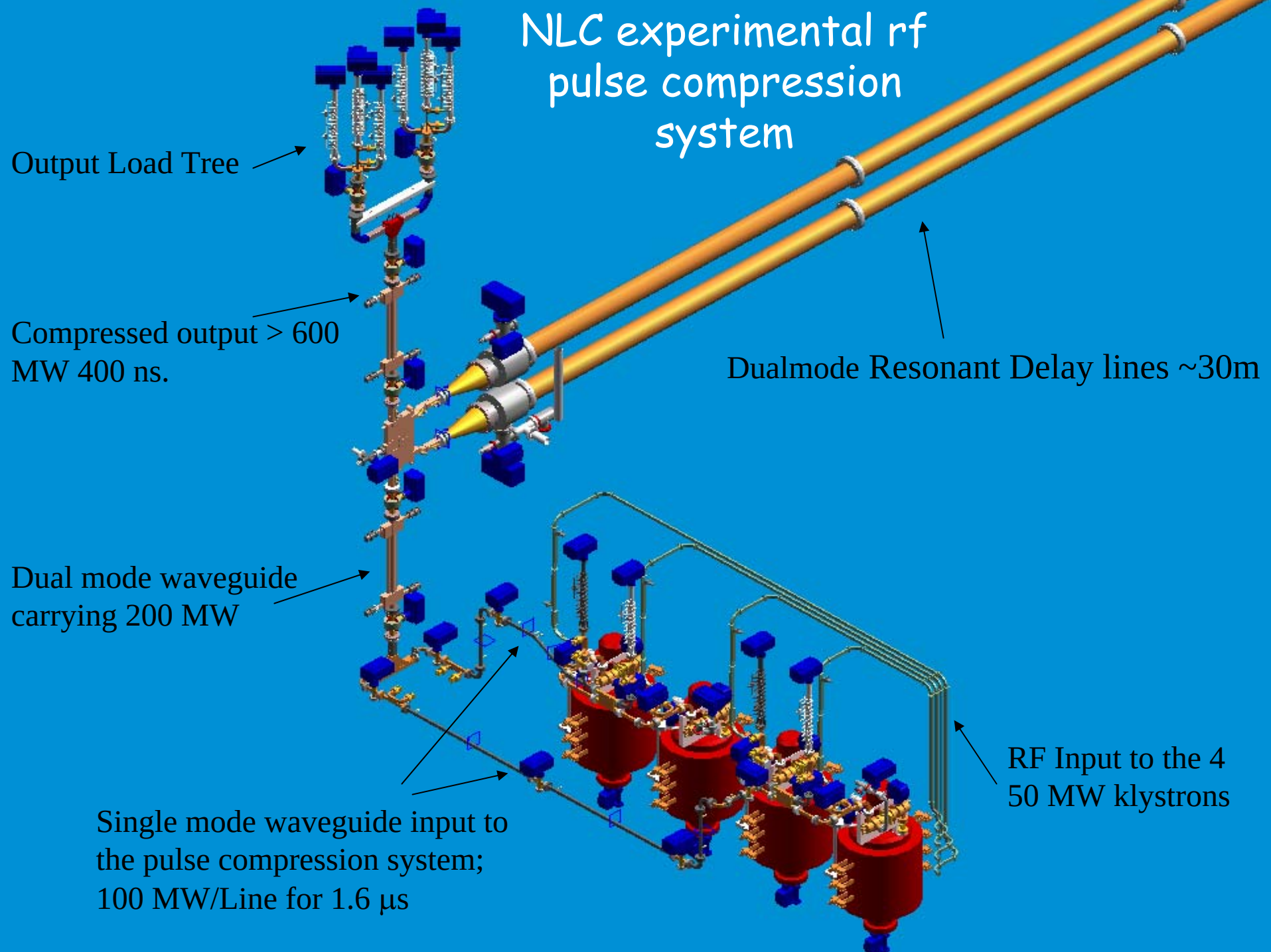

nlcta_all_vac.cnf
10
8
6
4
2
Amp (x 1e-5)
-60
-40
-20
14:40:34
Dec 02, 03
(Seconds)
TRS8:SYS:VPS03A:VACM
Amp
(9.99e-08, 0.0001) VAL=6.01553e-07
TRS8:SYS:VPS03B:VACM
Amp
(9.99e-08, 0.0001) VAL=1.47153e-07
TRS8:SYS:VPS02B:VACM
Amp
(9.99e-08, 0.0001) VAL=5.38369e-08
TRS8:SYS:VPS06B:VACM
Amp
(9.99e-08, 0.0001) VAL=3.66306e-07
TRS8:SYS:VPS06C:VACM
Amp
(9.99e-08, 0.0001) VAL=3.08741e-07
TRS8:SYS:VPS07C:VACM
Amp
(9.99e-08, 0.0001) VAL=4.30139e-06
TRS8:SYS:VPS05B:VACM
Amp
(9.99e-08, 0.0001) VAL=2.68887e-06
TRS8:SYS:VPS07D:VACM
Amp
(9.99e-08, 0.0001) VAL=2.58113e-06
TRS8:SYS:VPS06D:VACM
Amp
(9.99e-08, 0.0001) VAL=1.91513e-07
TRS8:SYS:VPS07B:VACM
Amp
(0, 0.0001) VAL=4.07599e-06

Zero Power


nlcta_all_vac.cnf
Amp (x 1e-5)
10
8
6
4
2
-60
-40
-20
18:36:41
Dec 02, 03
(18:36:11, 9.21183e-05
(Seconds)
TRS8:SYS:VPS03A:VACM
Amp
(9.99e-08, 0.0001) VAL=7.85739e-06
TRS8:SYS:VPS03B:VACM
Amp
(9.99e-08, 0.0001) VAL=7.38244e-07
TRS8:SYS:VPS02B:VACM
Amp
(9.99e-08, 0.0001) VAL=5.34887e-08
TRS8:SYS:VPS06B:VACM
Amp
(9.99e-08, 0.0001) VAL=5.42933e-07
TRS8:SYS:VPS06C:VACM
Amp
(9.99e-08, 0.0001) VAL=5.16619e-07
TRS8:SYS:VPS07C:VACM
Amp
(9.99e-08, 0.0001) VAL=4.90957e-06
TRS8:SYS:VPS05B:VACM
Amp
(9.99e-08, 0.0001) VAL=3.38633e-06
TRS8:SYS:VPS07D:VACM
Amp
(9.99e-08, 0.0001) VAL=3.24105e-06
TRS8:SYS:VPS06D:VACM
Amp
(9.99e-08, 0.0001) VAL=4.03947e-07
TRS8:SYS:VPS07B:VACM
Amp
(0, 0.0001) VAL=4.99237e-06

421 MW 360 ns

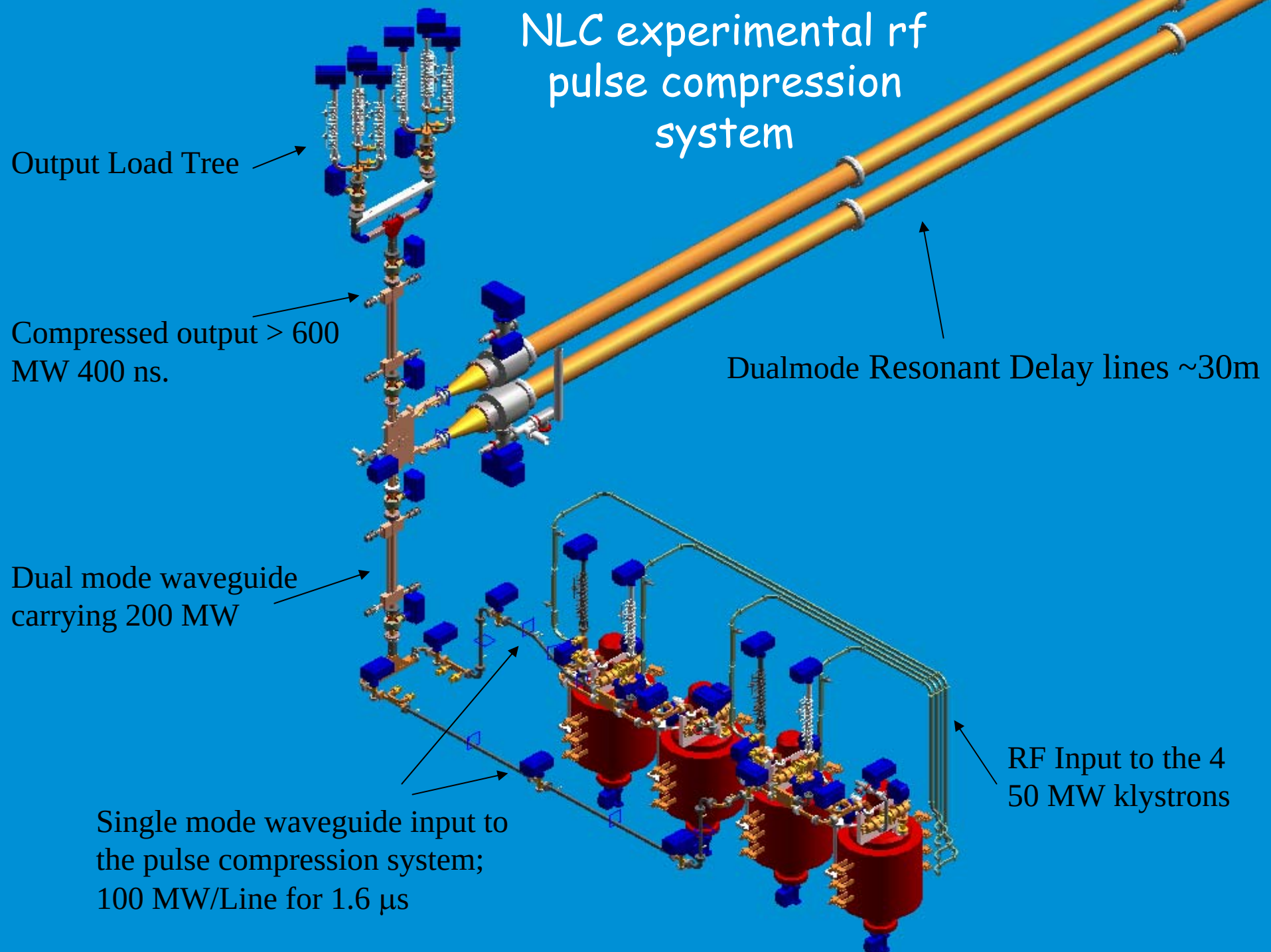
NLC experimental rf pulse compression system



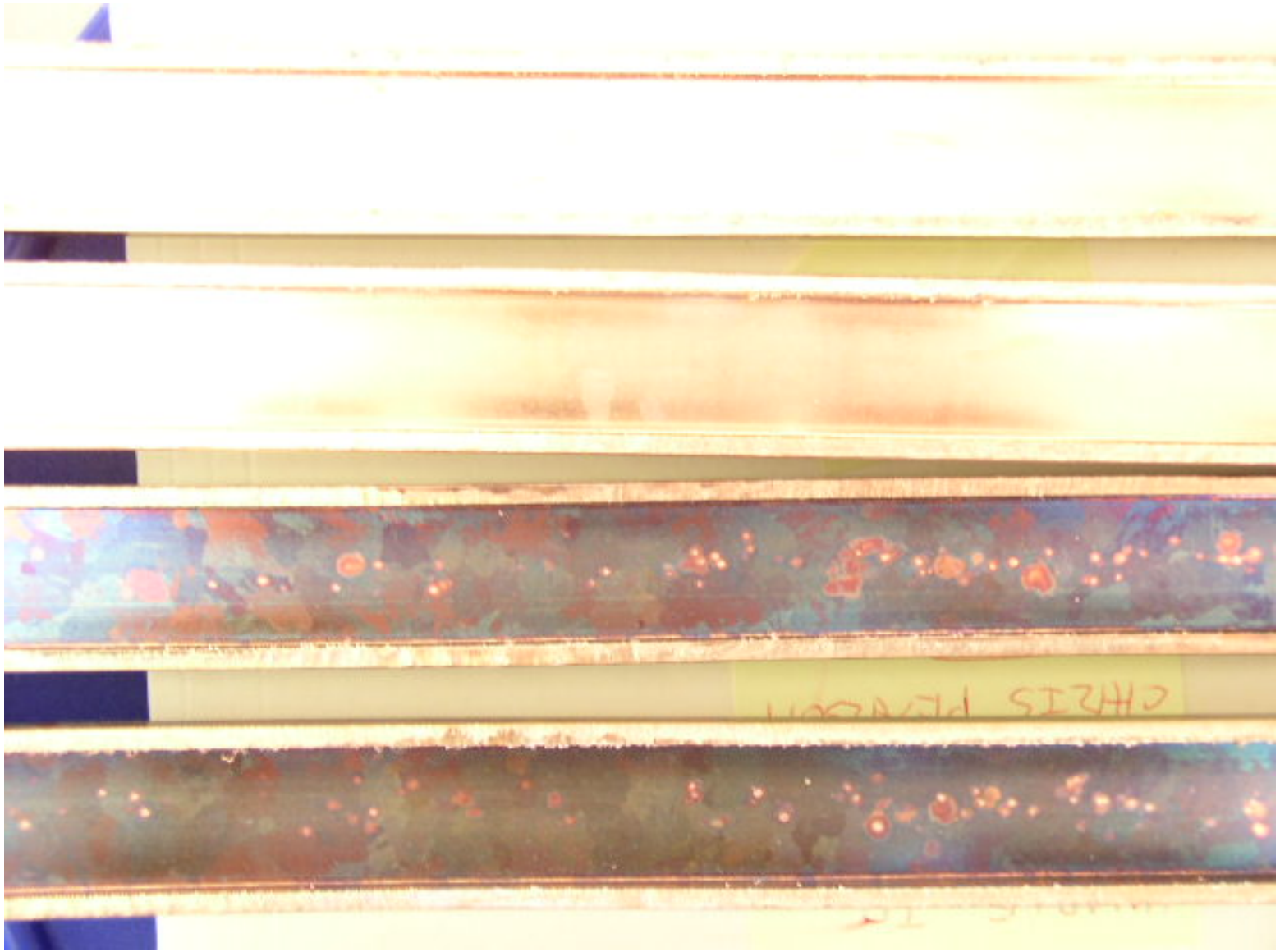
System Modifications

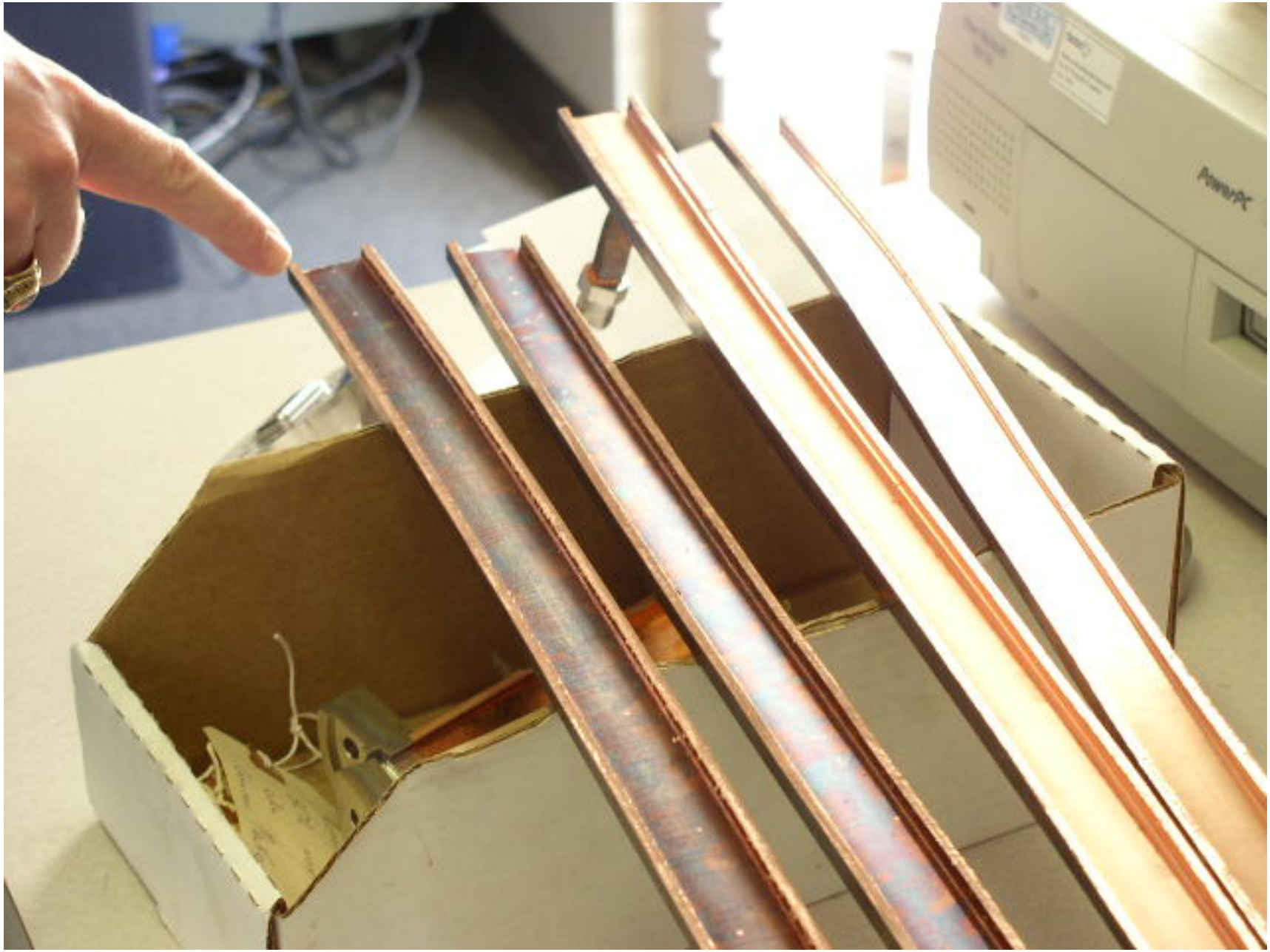
- Replaced a pumpout
- Replaced the whole line of WR90
- Cooled down the WR90 with fans
- *Hard wired* the klystrons driver together

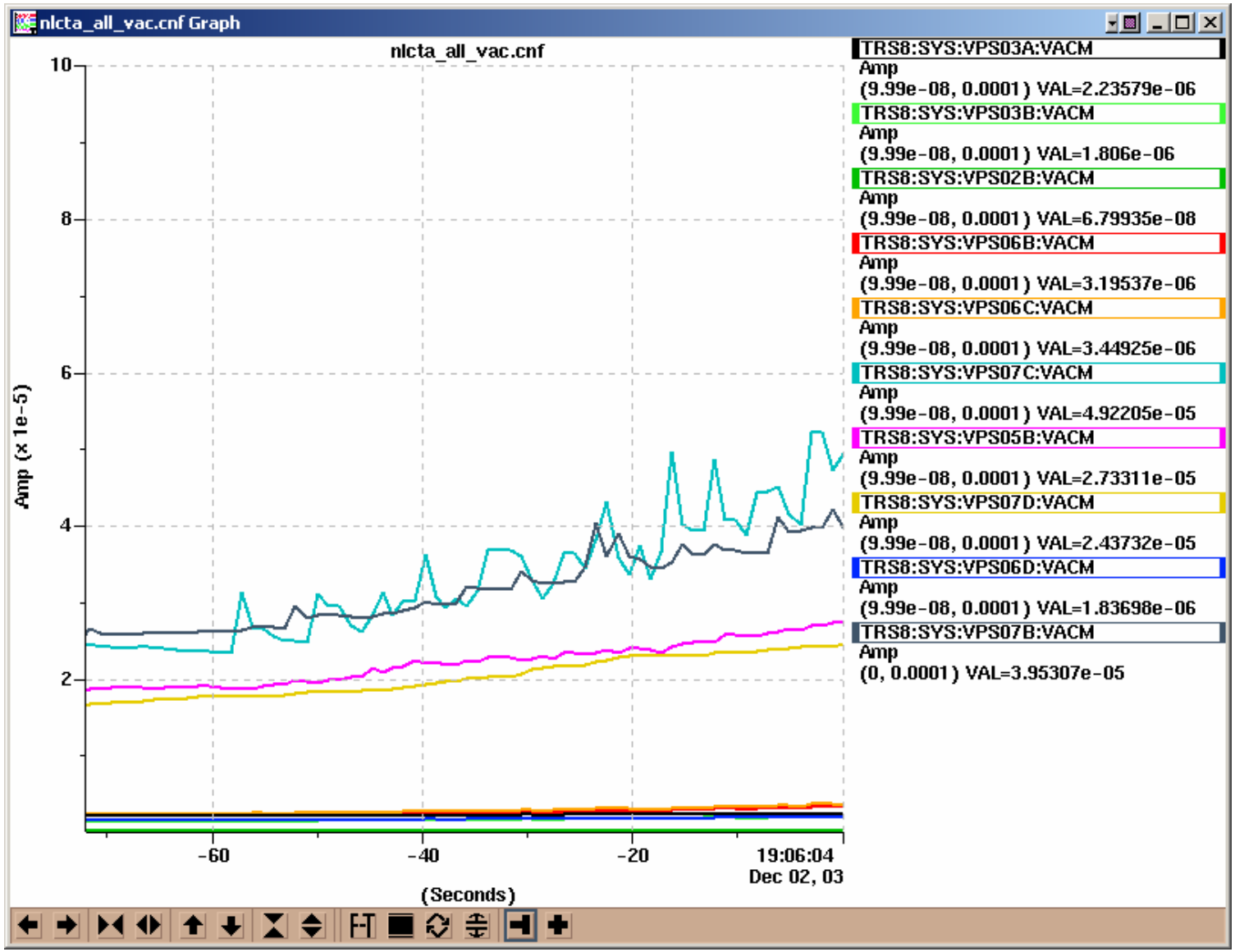
NLC experimental rf pulse compression system



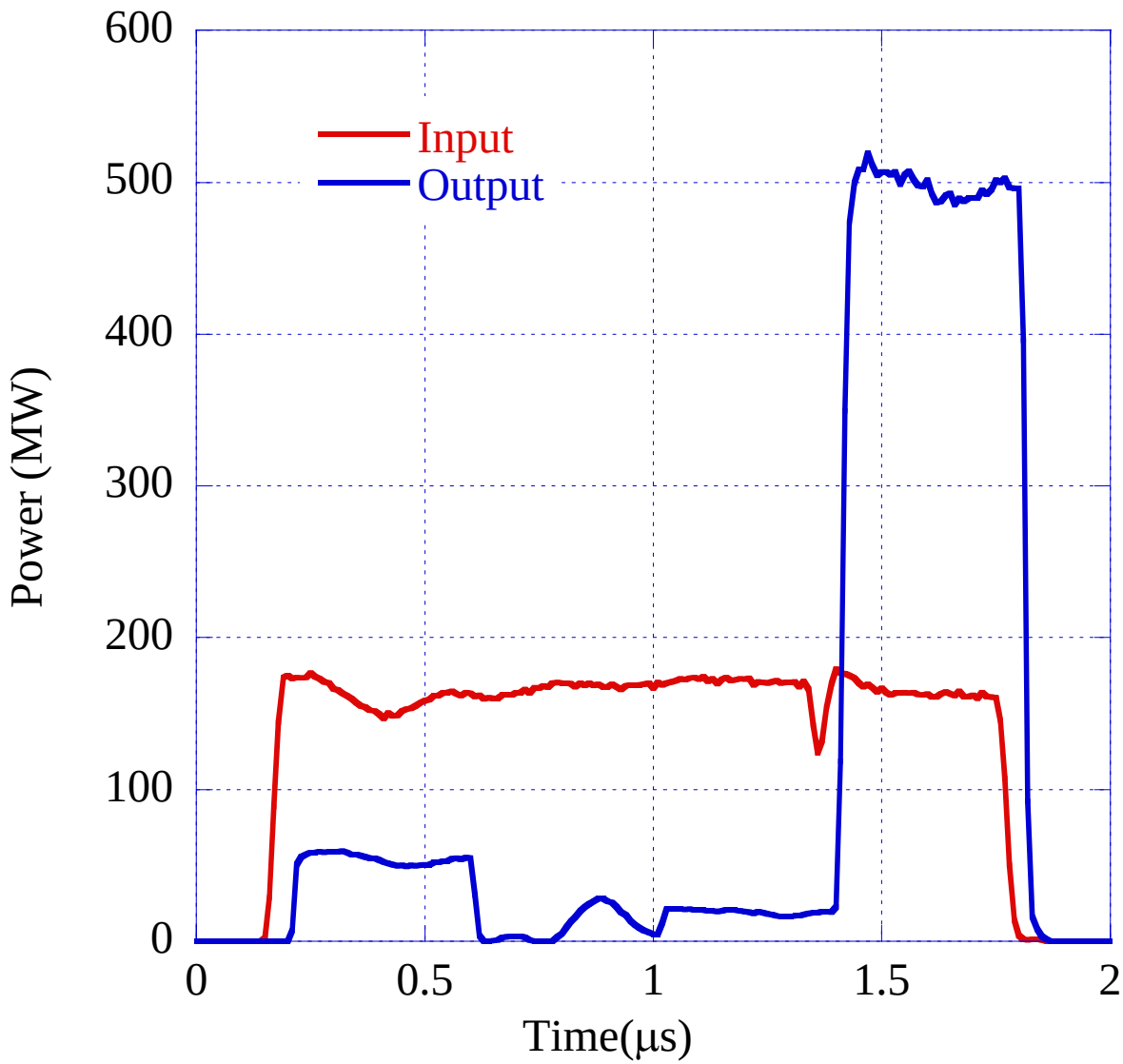
PEPU SW WINDOW TRAVELLER

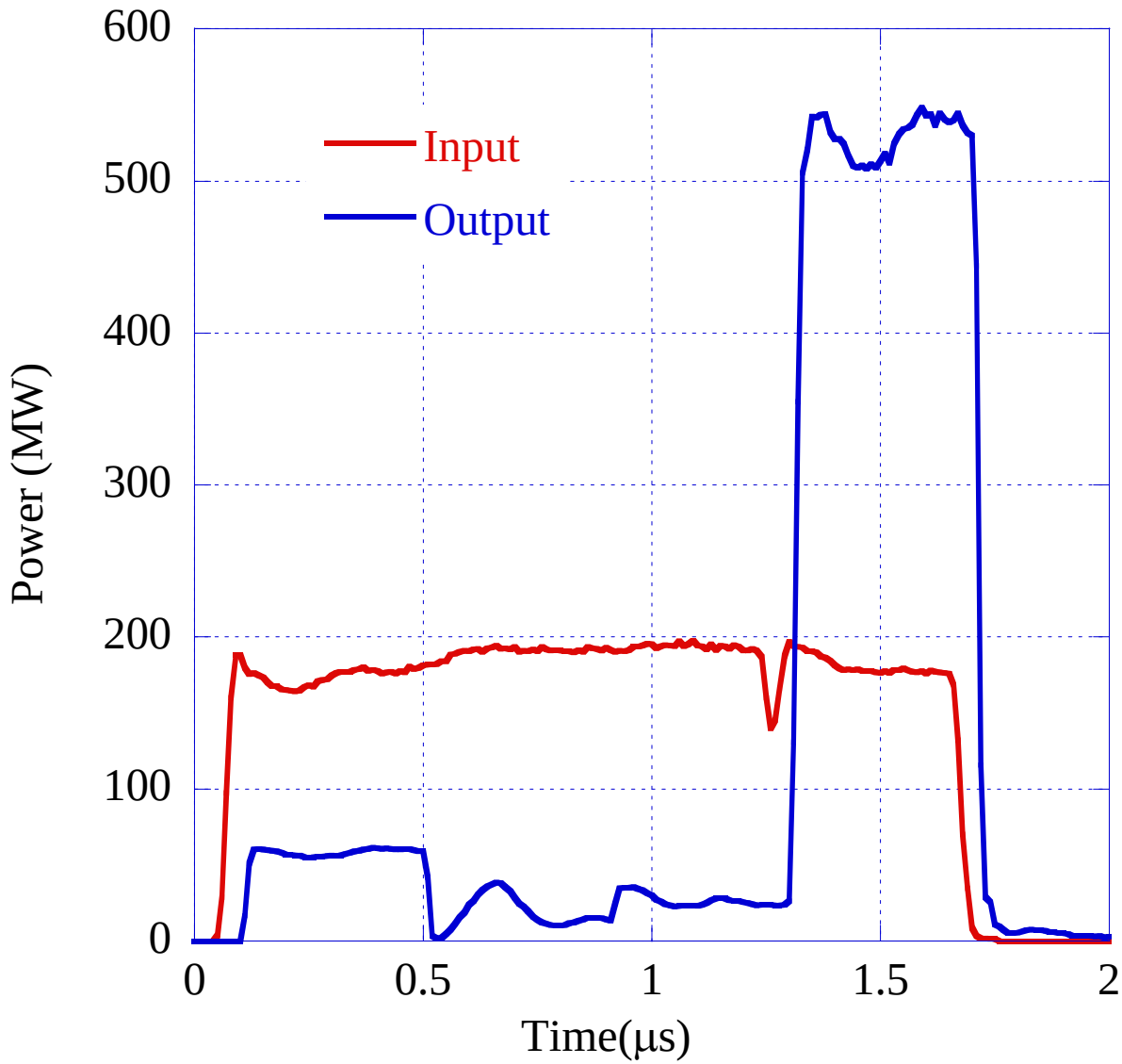


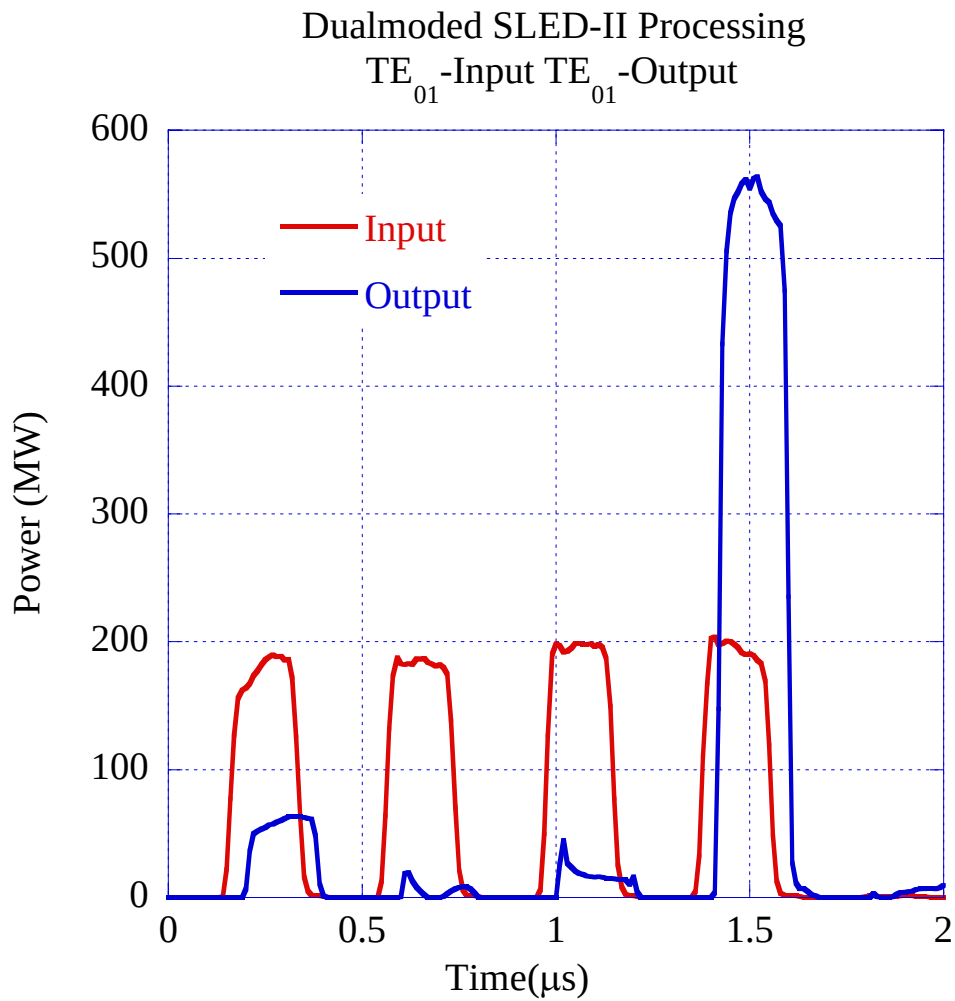


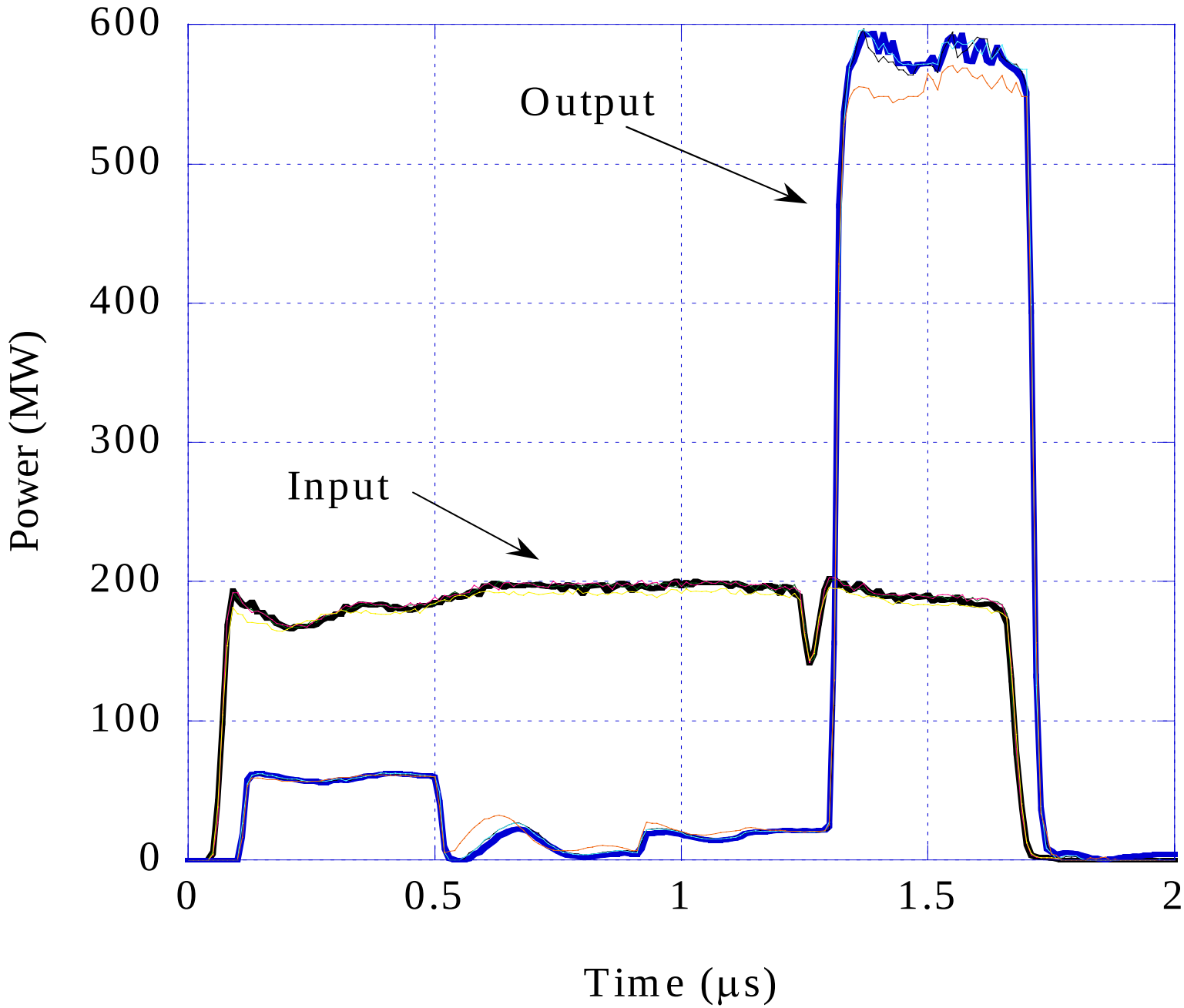

nlcta_all_vac.cnf Graph
nlcta_all_vac.cnf
Amp (x 1e-5)
10
8
6
4
2
-60
-40
-20
19:06:04
Dec 02, 03
(Seconds)
TRS8:SYS:VPS03A:VACM
Amp
(9.99e-08, 0.0001) VAL=2.23579e-06
TRS8:SYS:VPS03B:VACM
Amp
(9.99e-08, 0.0001) VAL=1.806e-06
TRS8:SYS:VPS02B:VACM
Amp
(9.99e-08, 0.0001) VAL=6.79935e-08
TRS8:SYS:VPS06B:VACM
Amp
(9.99e-08, 0.0001) VAL=3.19537e-06
TRS8:SYS:VPS06C:VACM
Amp
(9.99e-08, 0.0001) VAL=3.44925e-06
TRS8:SYS:VPS07C:VACM
Amp
(9.99e-08, 0.0001) VAL=4.92205e-05
TRS8:SYS:VPS05B:VACM
Amp
(9.99e-08, 0.0001) VAL=2.73311e-05
TRS8:SYS:VPS07D:VACM
Amp
(9.99e-08, 0.0001) VAL=2.43732e-05
TRS8:SYS:VPS06D:VACM
Amp
(9.99e-08, 0.0001) VAL=1.83698e-06
TRS8:SYS:VPS07B:VACM
Amp
(0, 0.0001) VAL=3.95307e-05

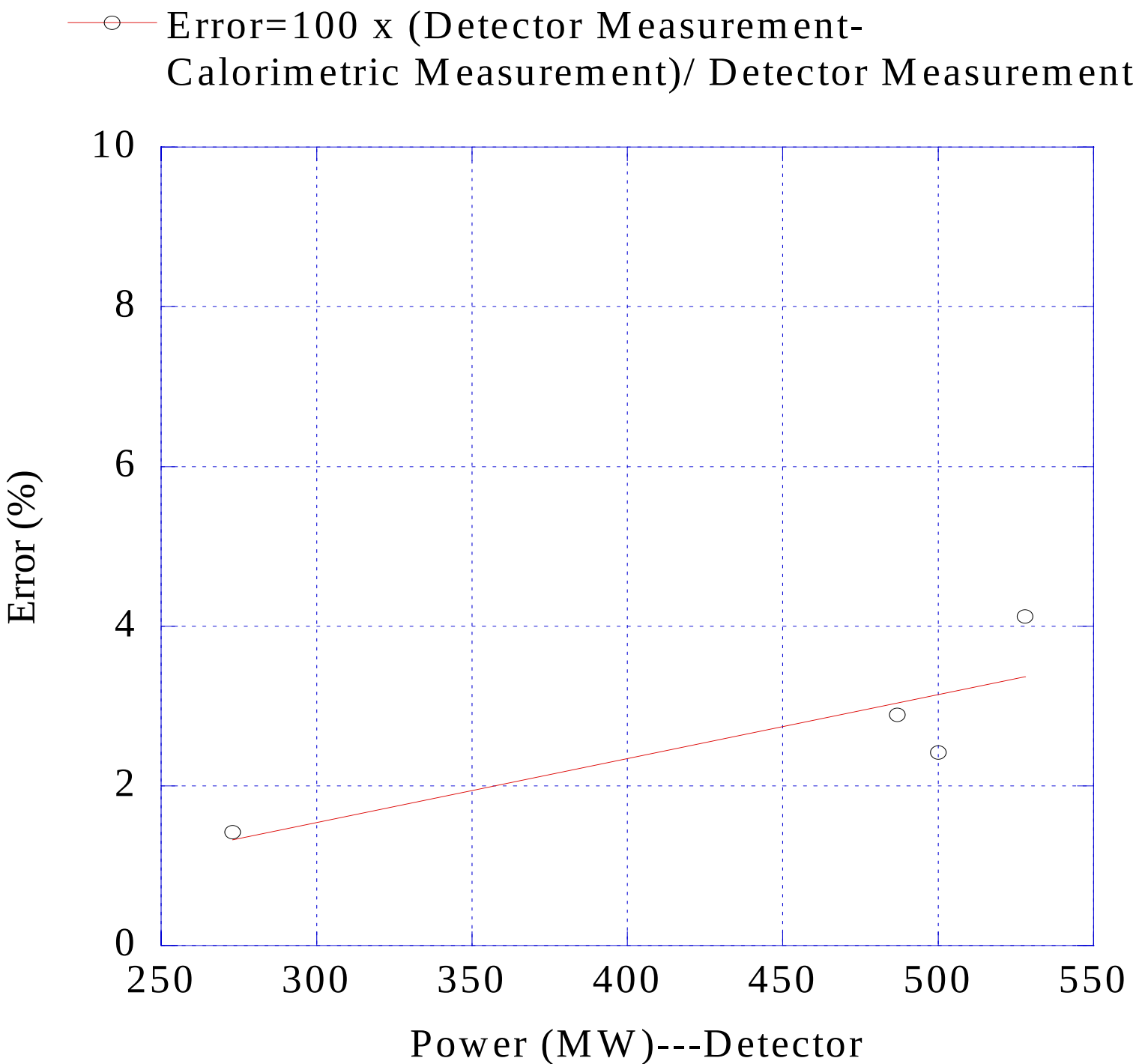
436 MW 360 ns

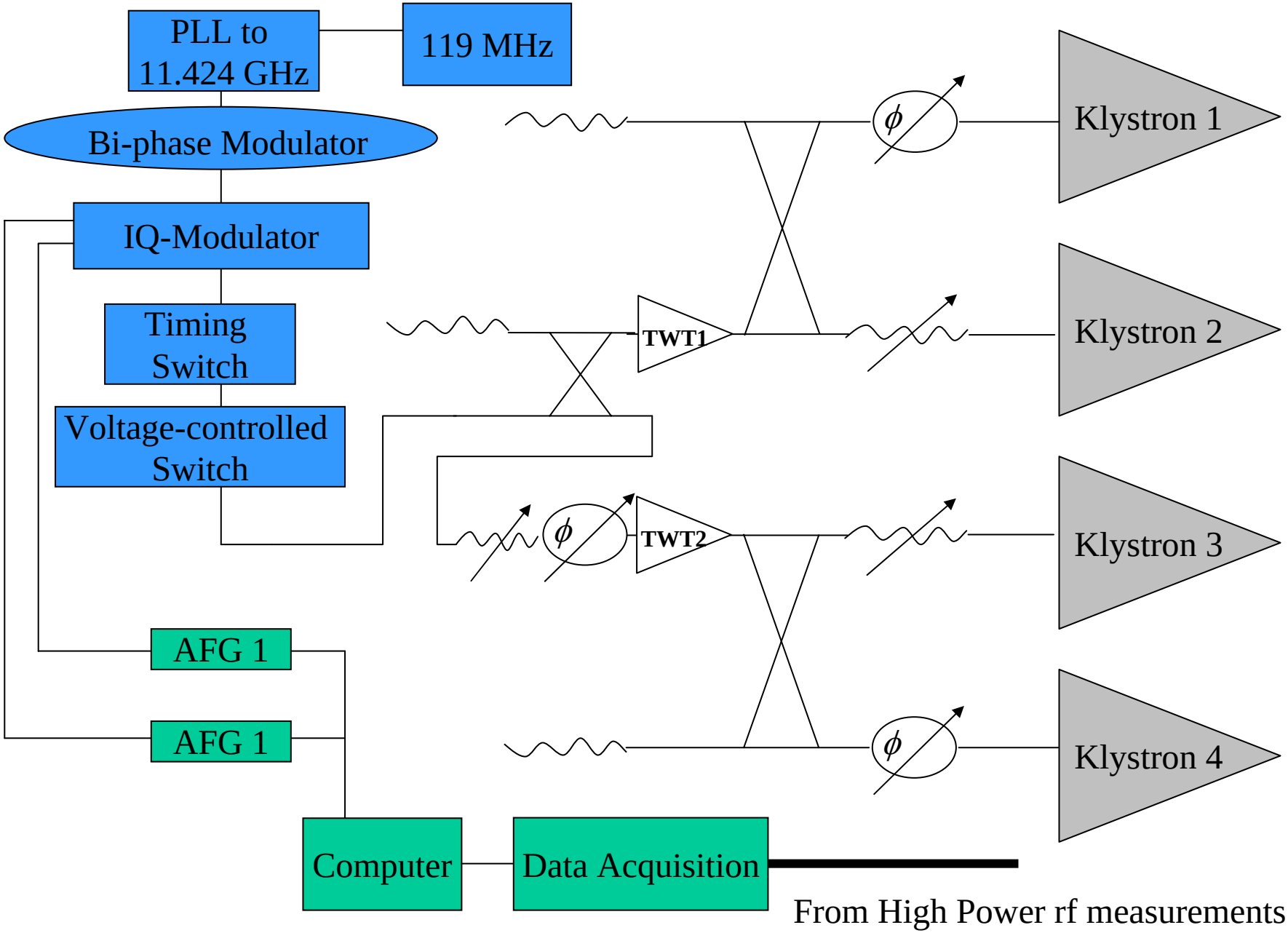

Dualmoded SLED-II Performance
December 4, 2003 11 am
TE01-Input TE01-Output
Input
Output
Power (MW)
Time(μs)
600
500
400
300
200
100
0
0
0.5
1
1.5
2


Dualmoded SLED-II Performance
December 6, 2003 1:00 am
TE01-Input TE01-Output
Input
Output
Power (MW)
600
500
400
300
200
100
0
0
0.5
1
1.5
2
Time(μs)

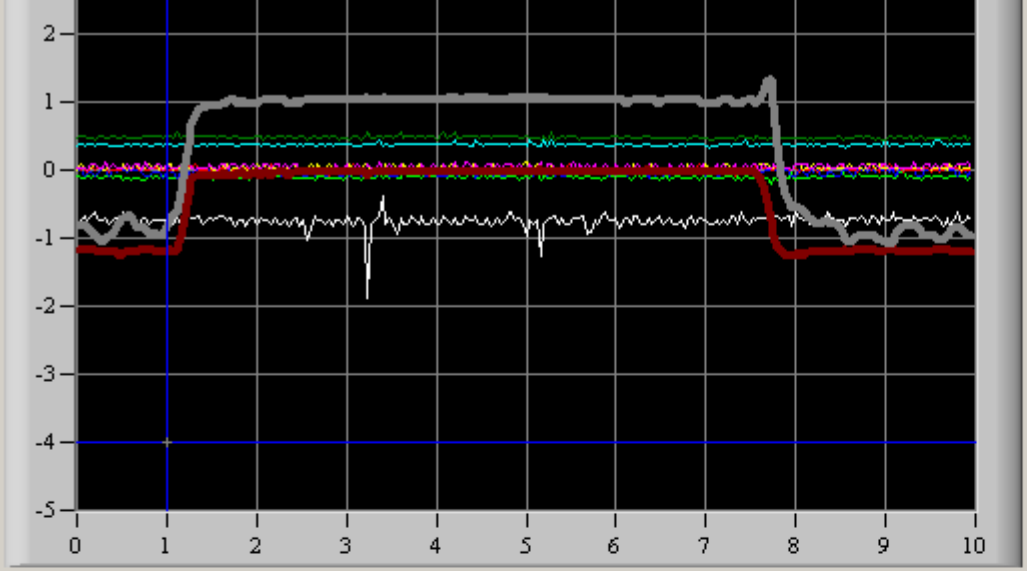

Dualmoded SLED-II Processing
TE01-Input TE01-Output
Input
Output
Power (MW)
Time(μs)
600
500
400
300
200
100
0
0
0.5
1
1.5
2


600
500
400
300
200
100
0
Power (MW)
Output
Input
0
0.5
1
1.5
2
Time (μs)


Error=100 x (Detector Measurement-
Calorimetric Measurement)/ Detector Measurement
10
8
6
4
2
0
Error (%)
250
300
350
400
450
500
550
Power (MW)---Detector



Low-Level RF Architecture



3	0.02	0.000
4	0.2	0.000

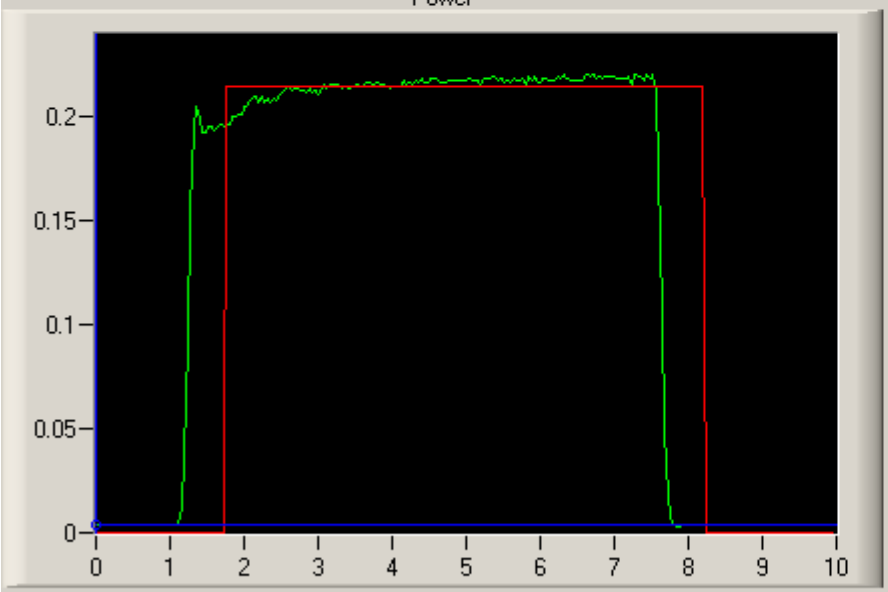
Digitizer#2

Time base 0.000 us/div

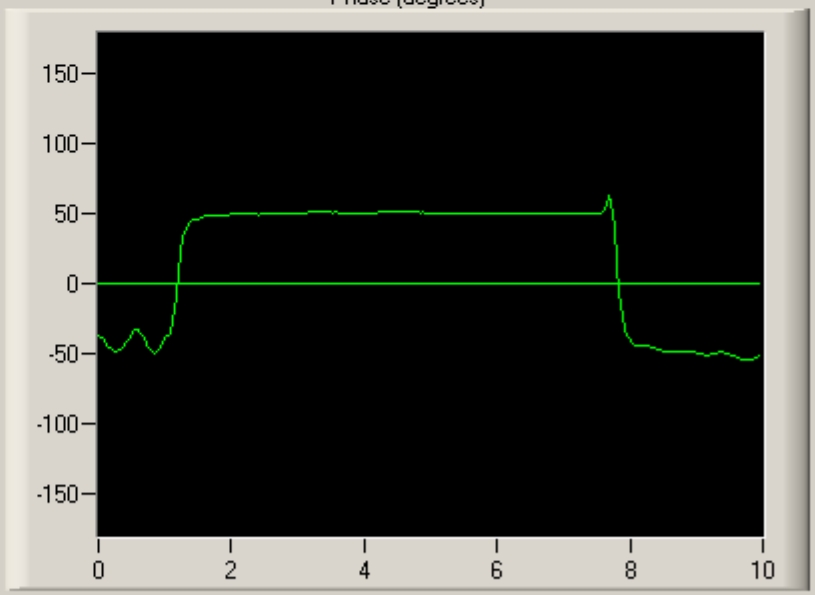
Ch#	V/div	VOffset, V
1	0.01	0.000
2	0.01	0.000
3	0.2	0.030
4	0.2	0.040
5	1	0.200
6	1	0.000

Saving Data

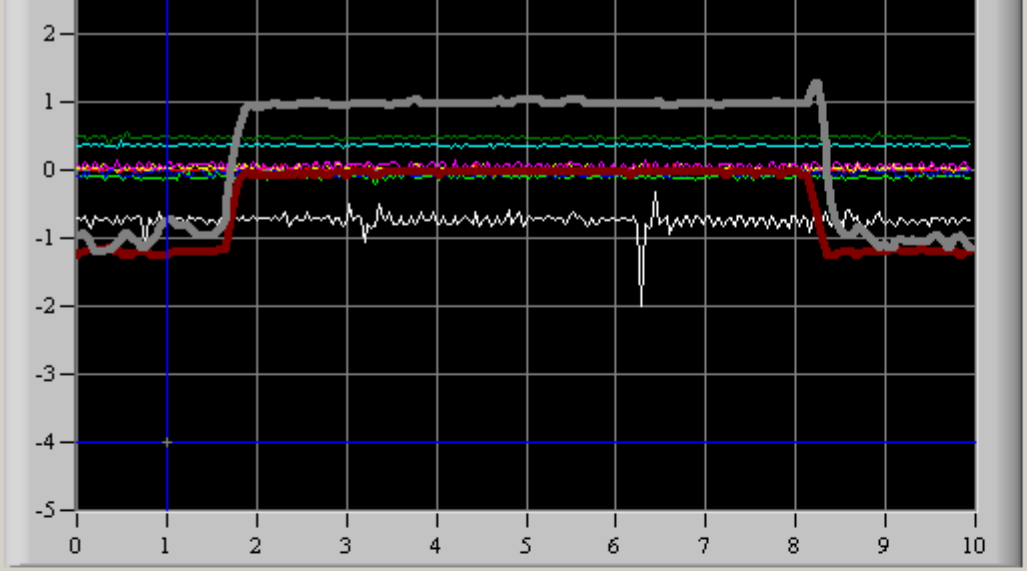
Power



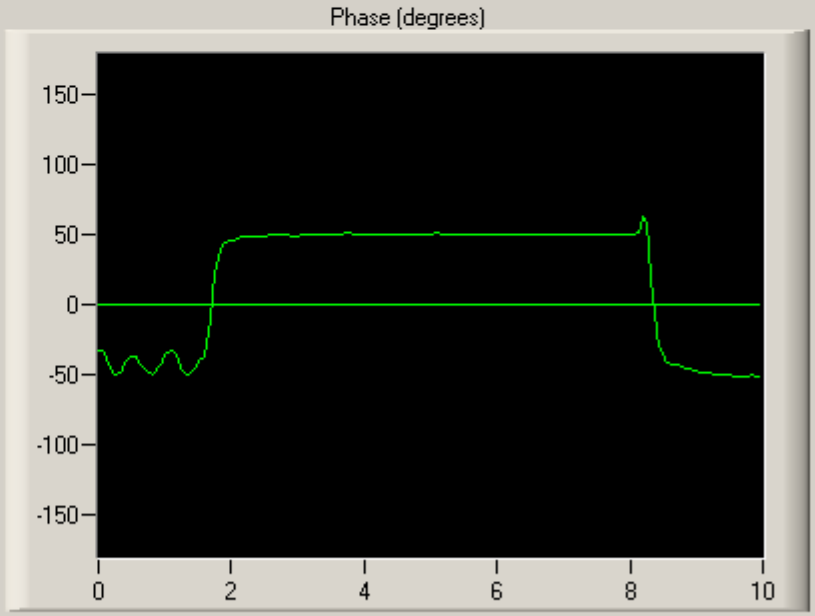
Phase (degrees)



0.00394136429129


2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10

Power
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
6
7
8
9
10


Phase (degrees)
150
100
50
0
-50
-100
-150
0
2
4
6
8
10

3	0.02	0.000
4	0.2	0.000

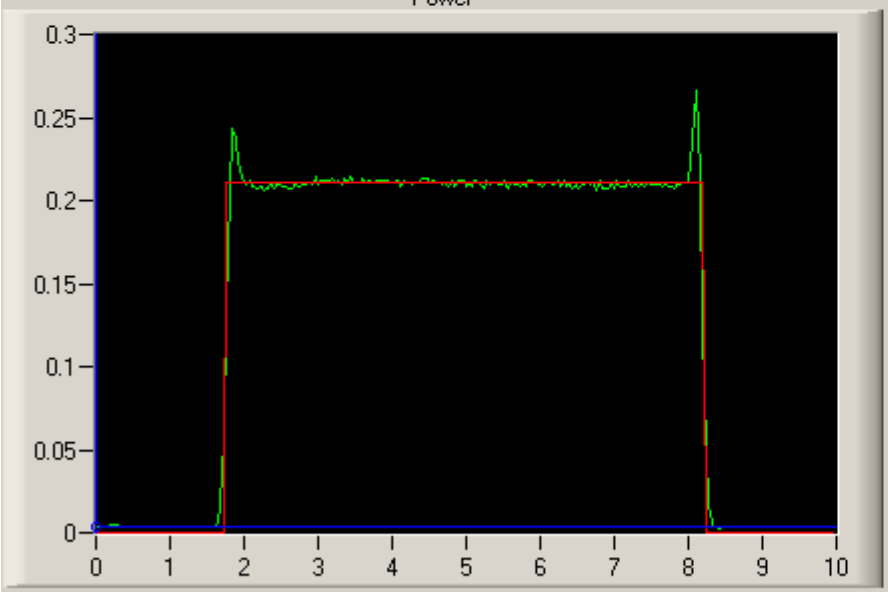
Digitizer#2

Time base 0.000 us/div

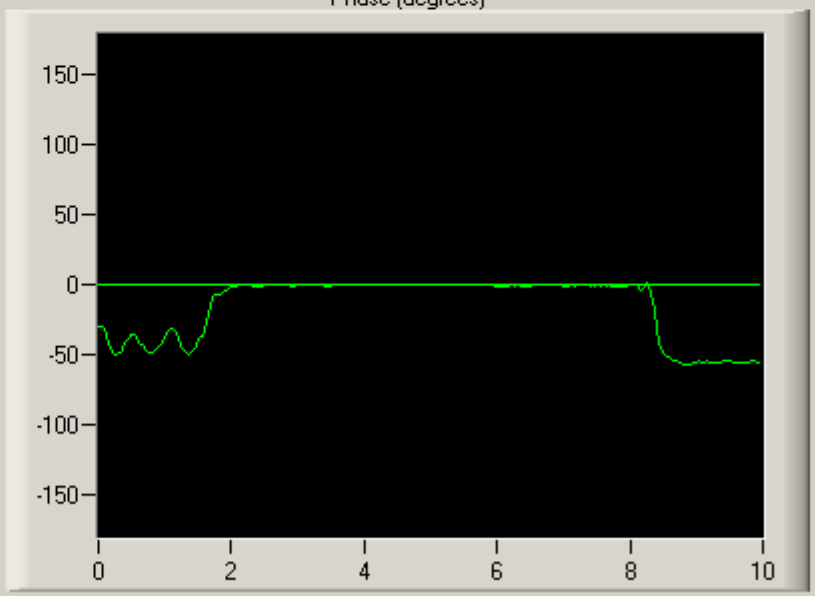
Ch#	V/div	VOffset, V
1	0.01	0.000
2	0.01	0.000
3	0.2	0.030
4	0.2	0.040
5	1	0.200
6	1	0.000

Saving Data

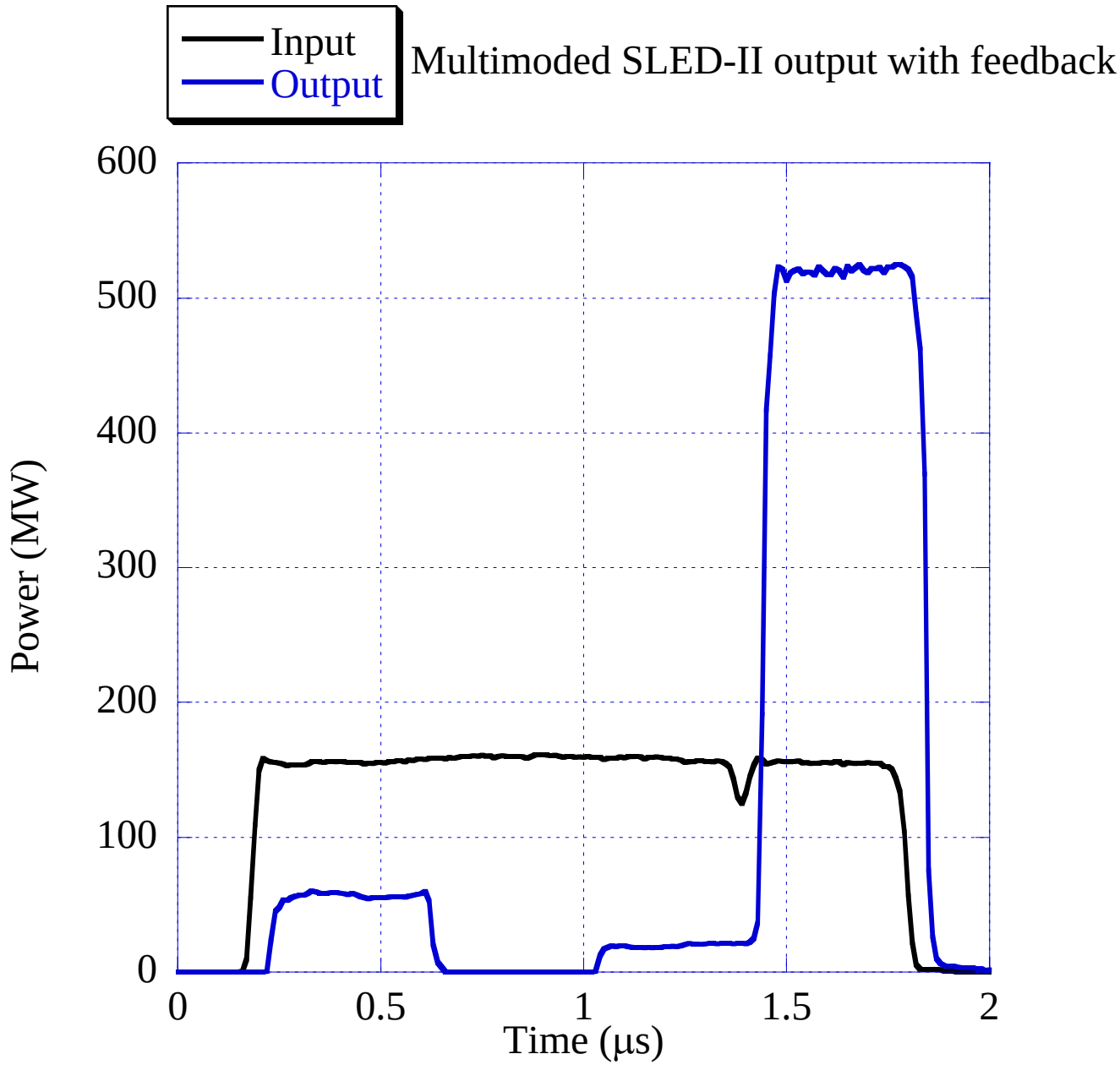
Power



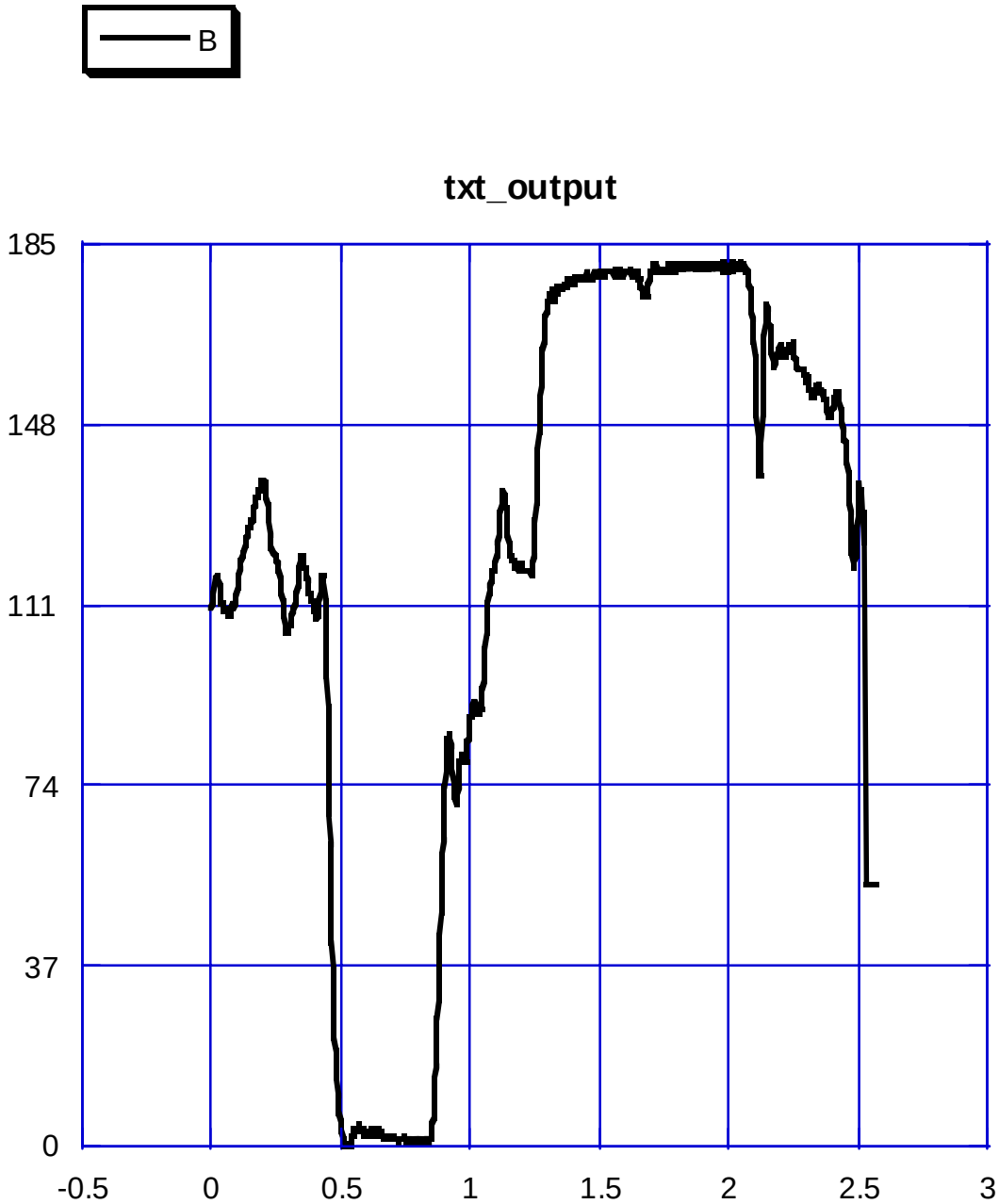
Phase (degrees)

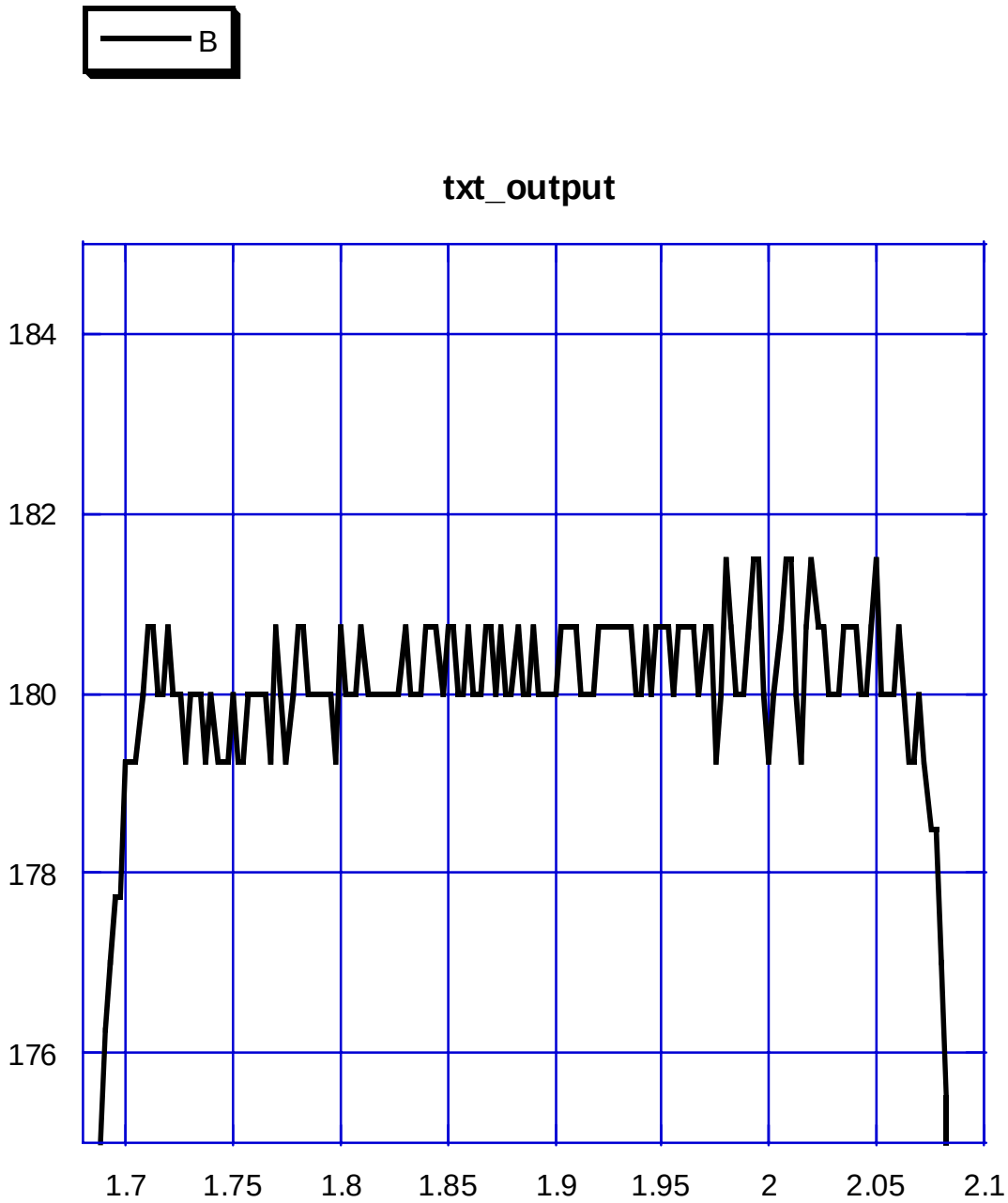


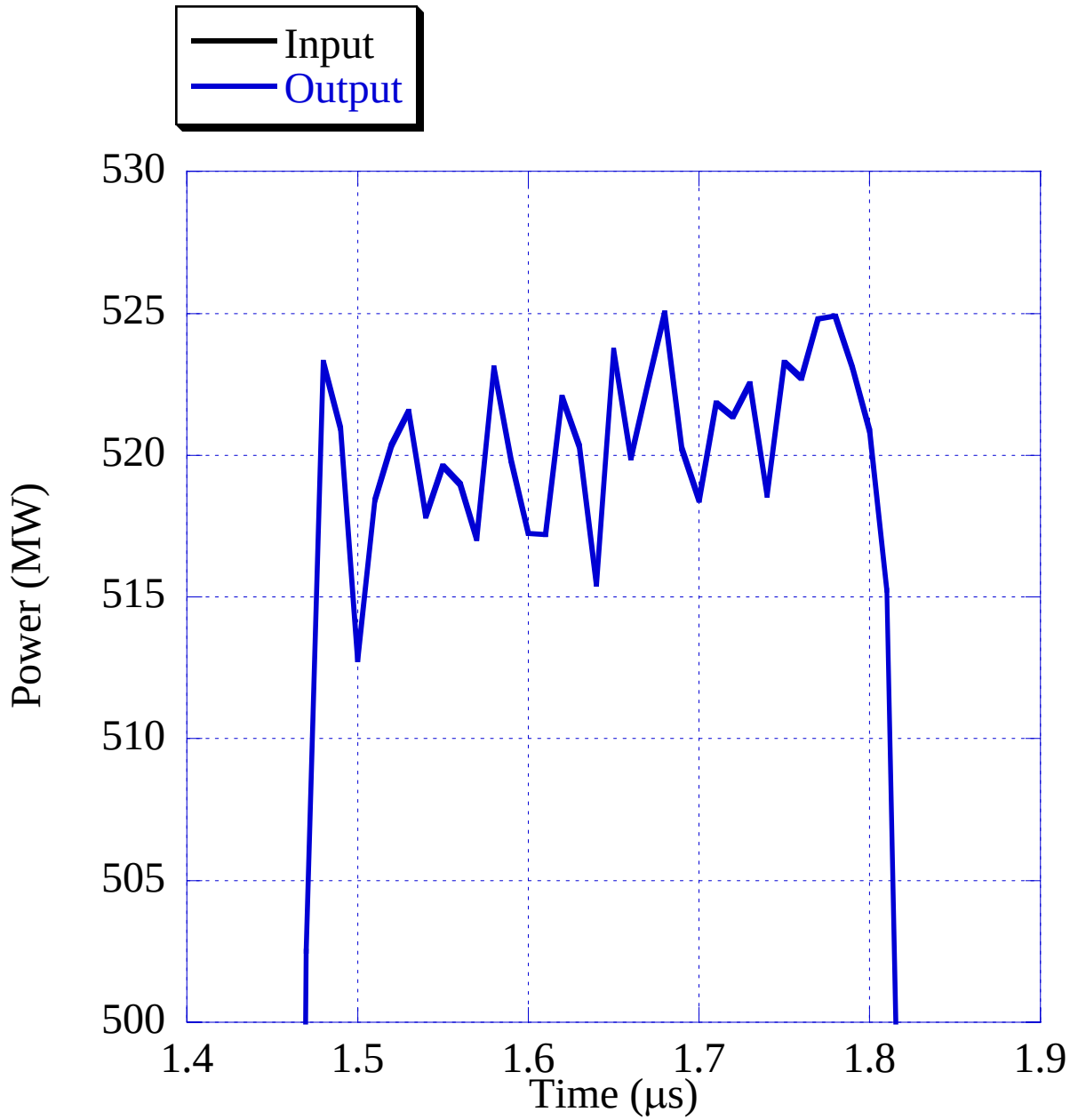
0.00379301656647



Sami Tantawi (1/27/2004)

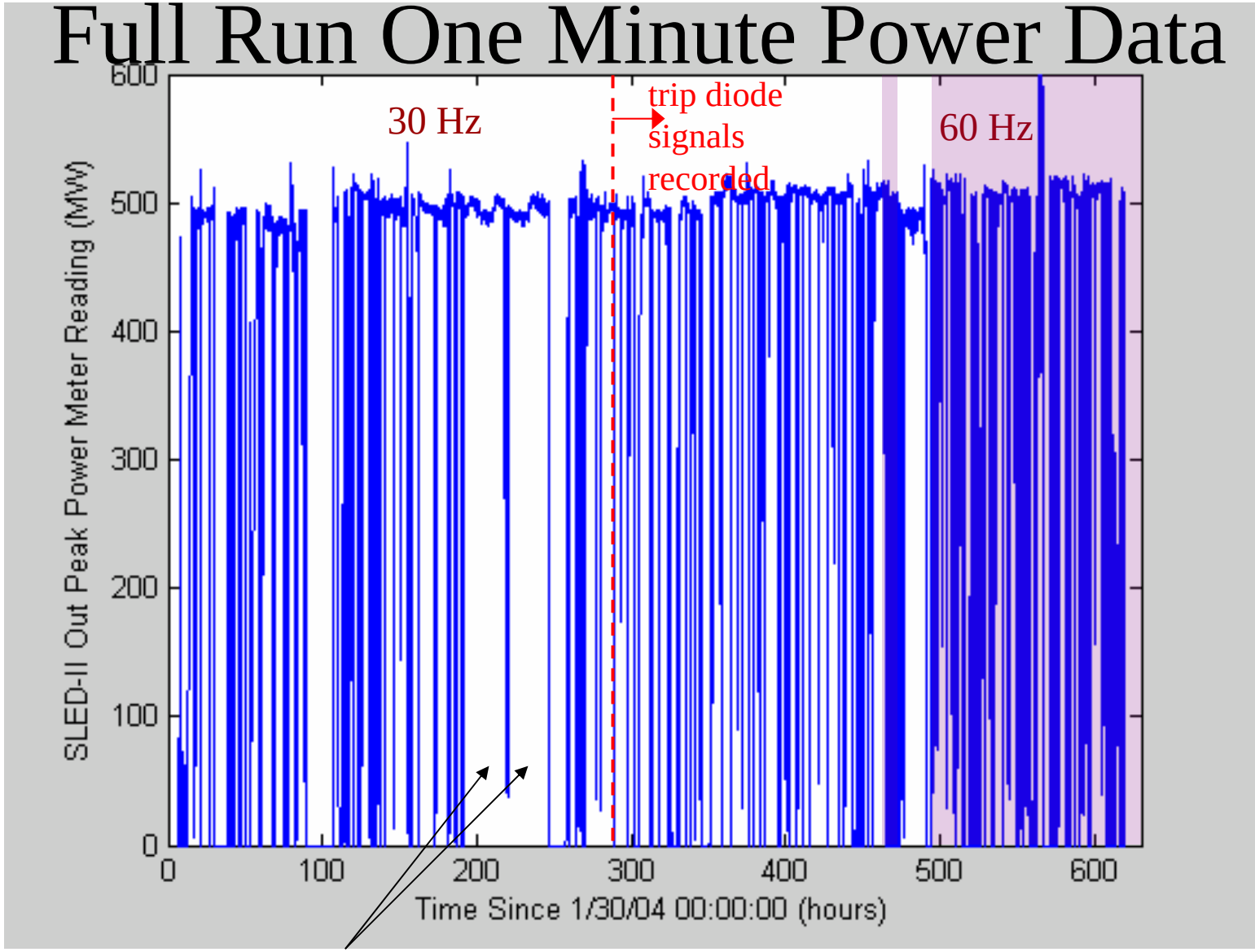

B
txt_output
185
148
111
74
37
0
-0.5
0
0.5
1
1.5
2
2.5
3


B
txt_output
184
182
180
178
176
1.7
1.75
1.8
1.85
1.9
1.95
2
2.05
2.1



Sami Tantawi (1/27/2004)

Full Run One Minute Power Data



Two 26 hrs. gaps w/ no trips.

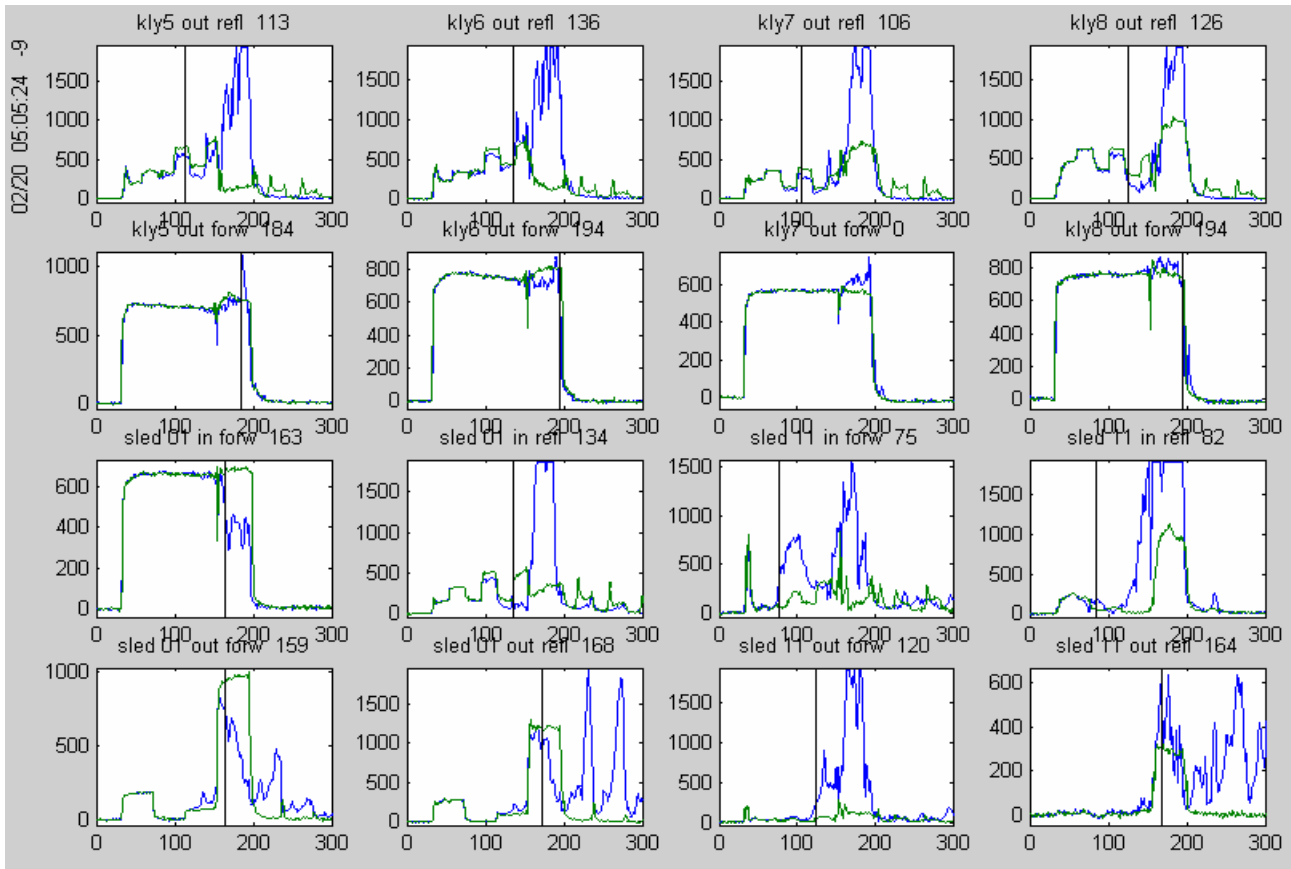
~455.7 hrs. on total w/ ~272 trips*

~357 hrs. @ 30 Hz w/ ~ 156 trips

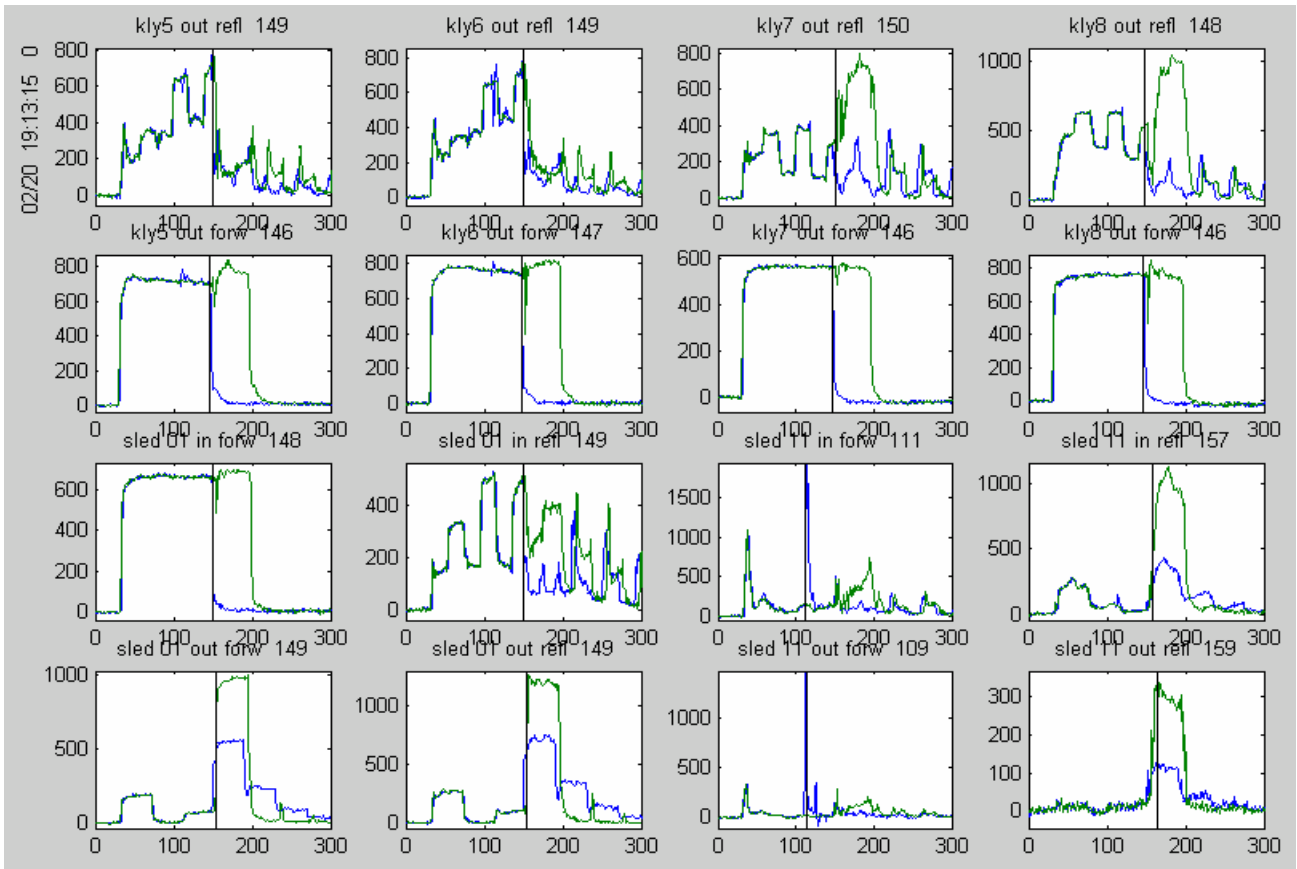
~98.75 hrs. @ 60 Hz w/ ~ 116 trips

*"trips" here includes accidental and deliberate human induced interruption of operation.

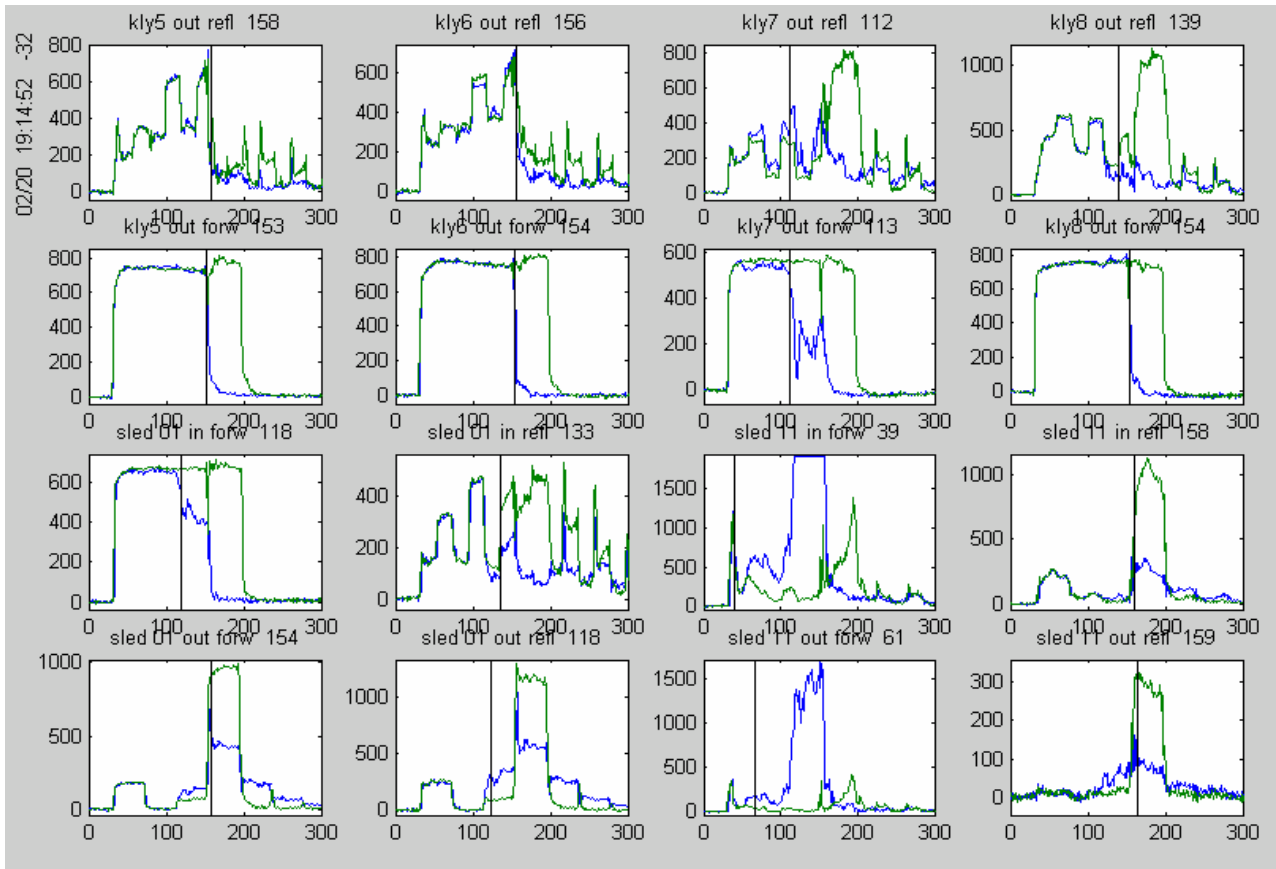
SLED Breakdown Event



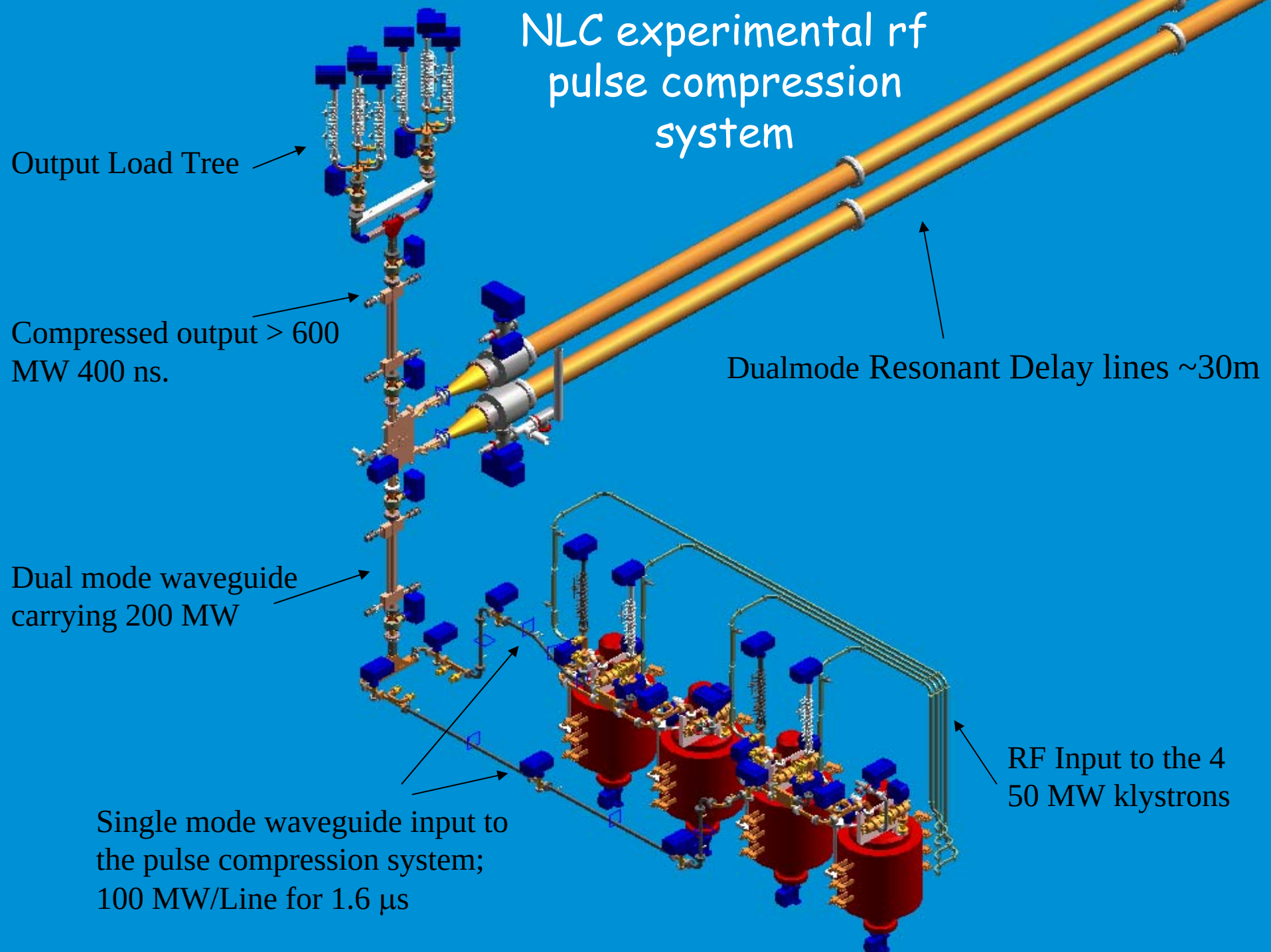
Unclear event



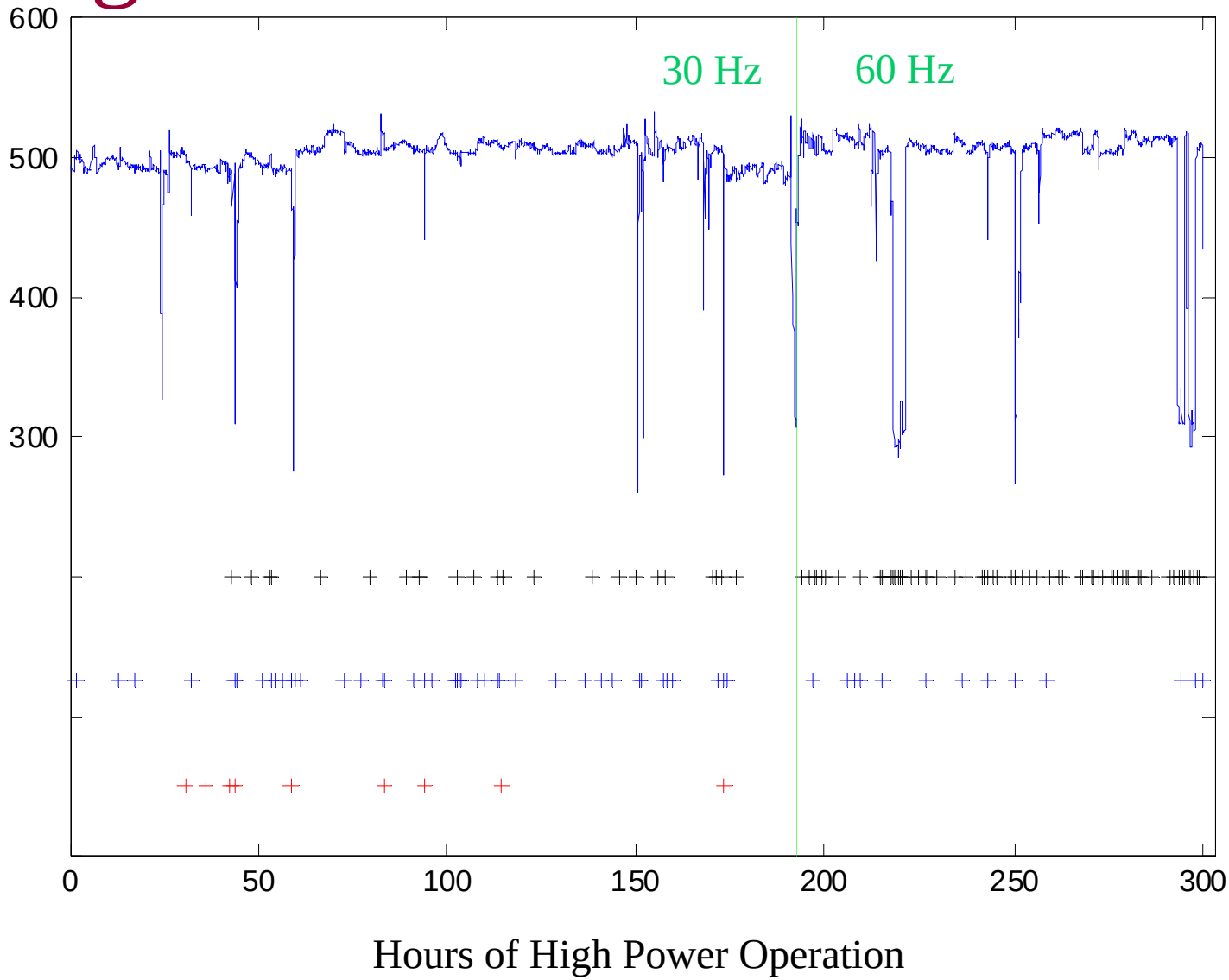
Klystron Breakdown event



NLC experimental rf pulse compression system



Analysis Corrected for SLED Mistuning and Human Interference



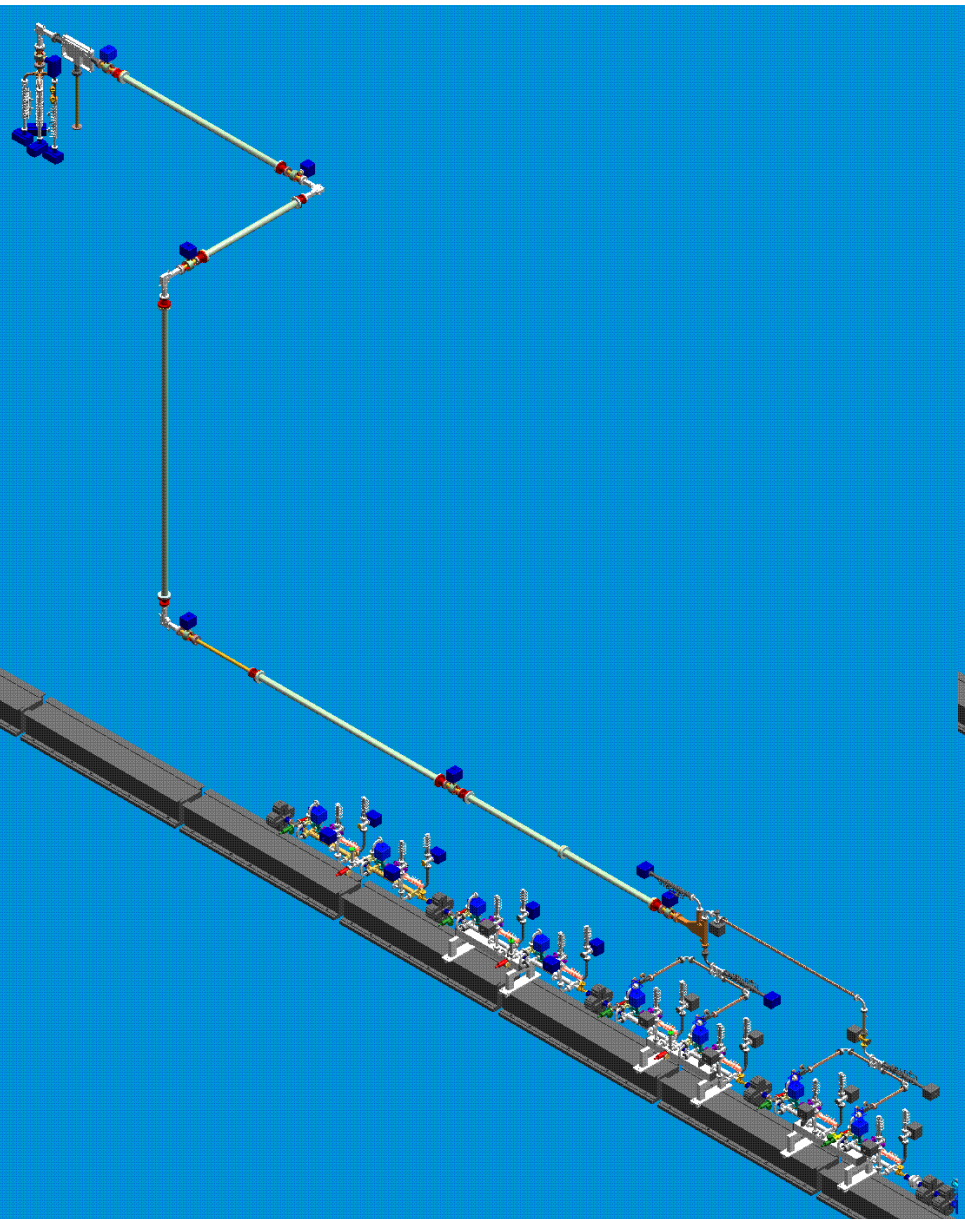
Diode Trip Analysis (Since 2/11)

Out of 211 trips in 365.65 hrs (30Hz equivalent)

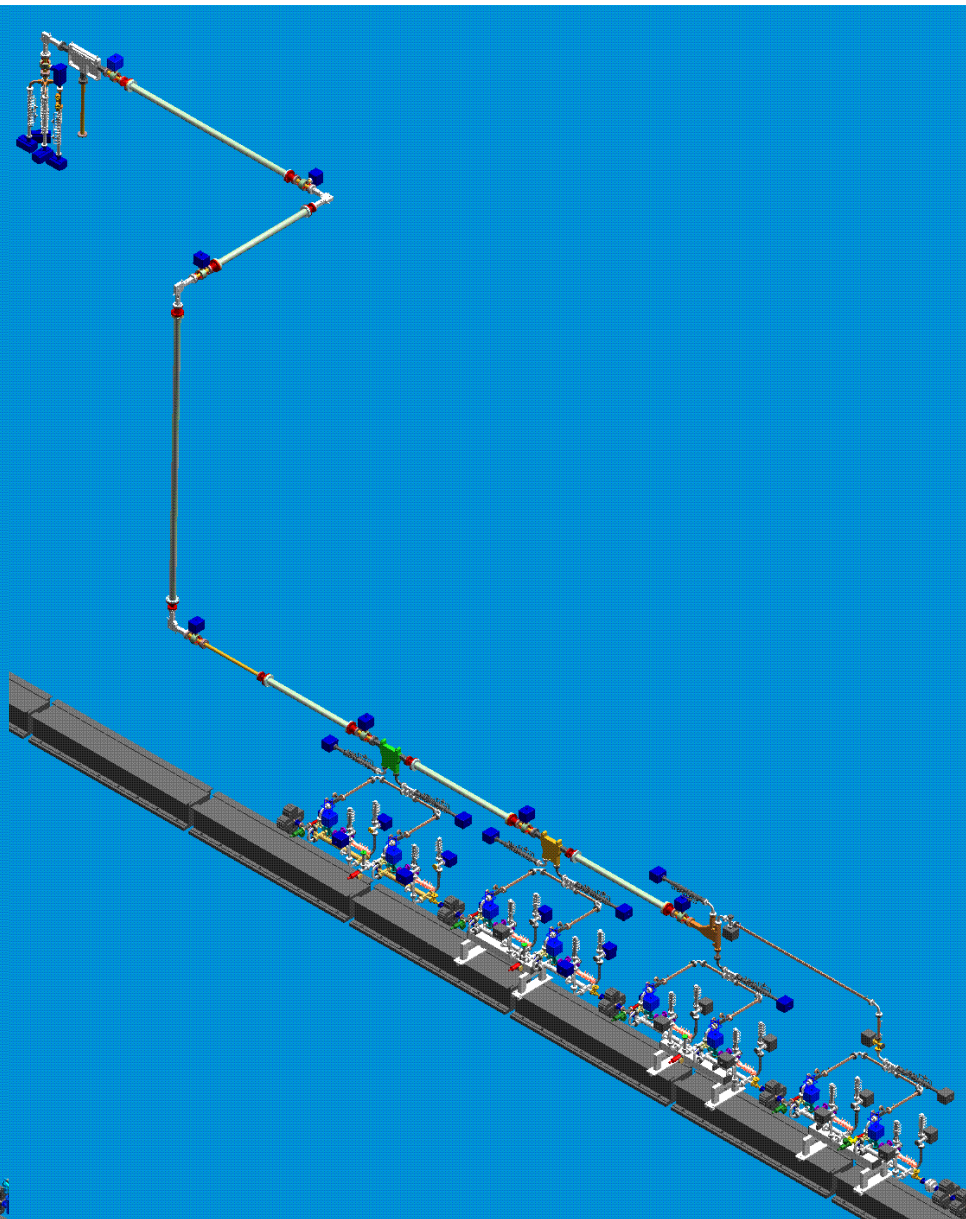
- 29 -SLED or Combiner
- 1 - Klystron 5
- 15 - Klystrons 5&6
- 18 - Klystron 6
- 72 - Klystron 7
- 28 - Klystrons 7&8
- 38 - Klystron 8
- 1 – Loads
- 7 - ?

+ dig. Vac. faults

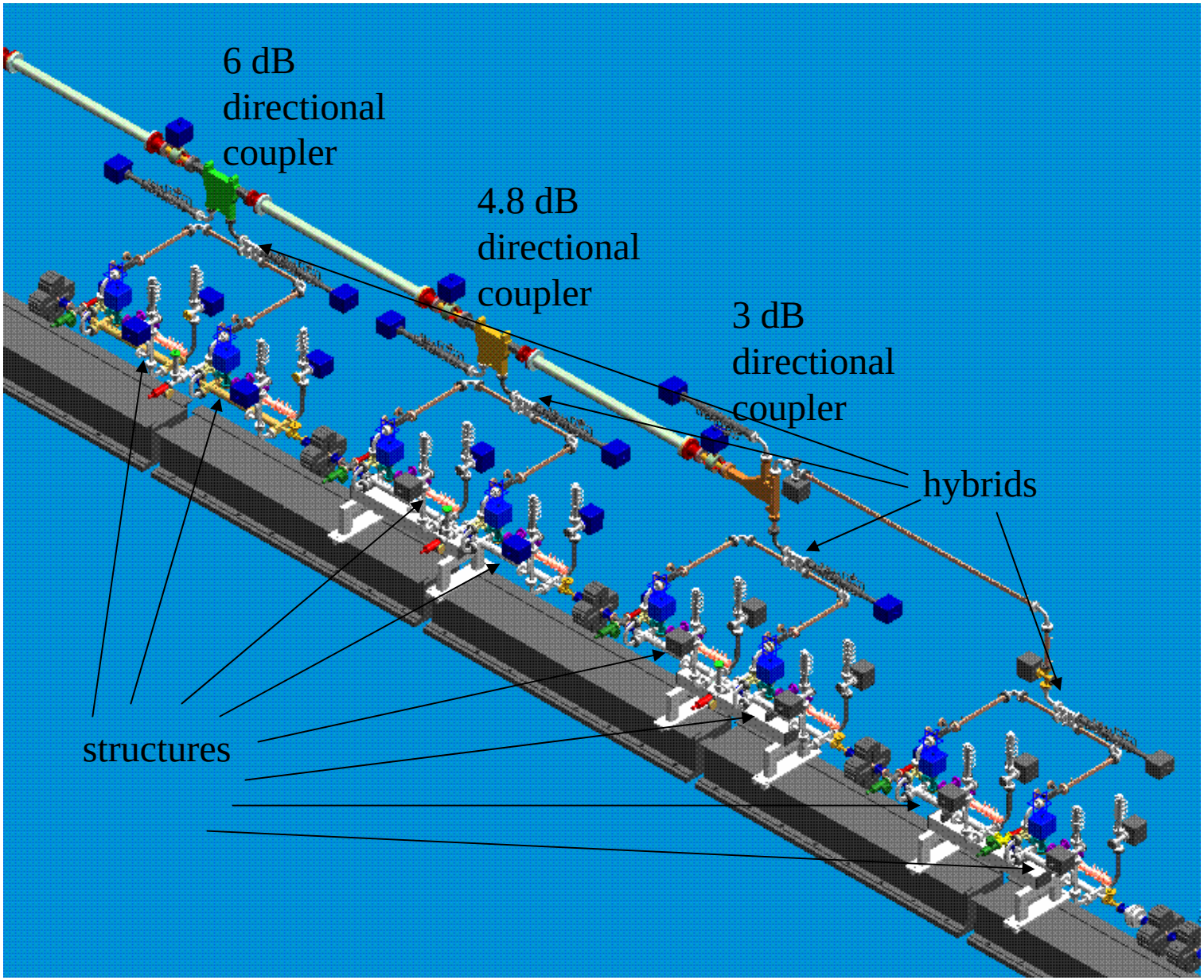
8-Pack Phase 2a



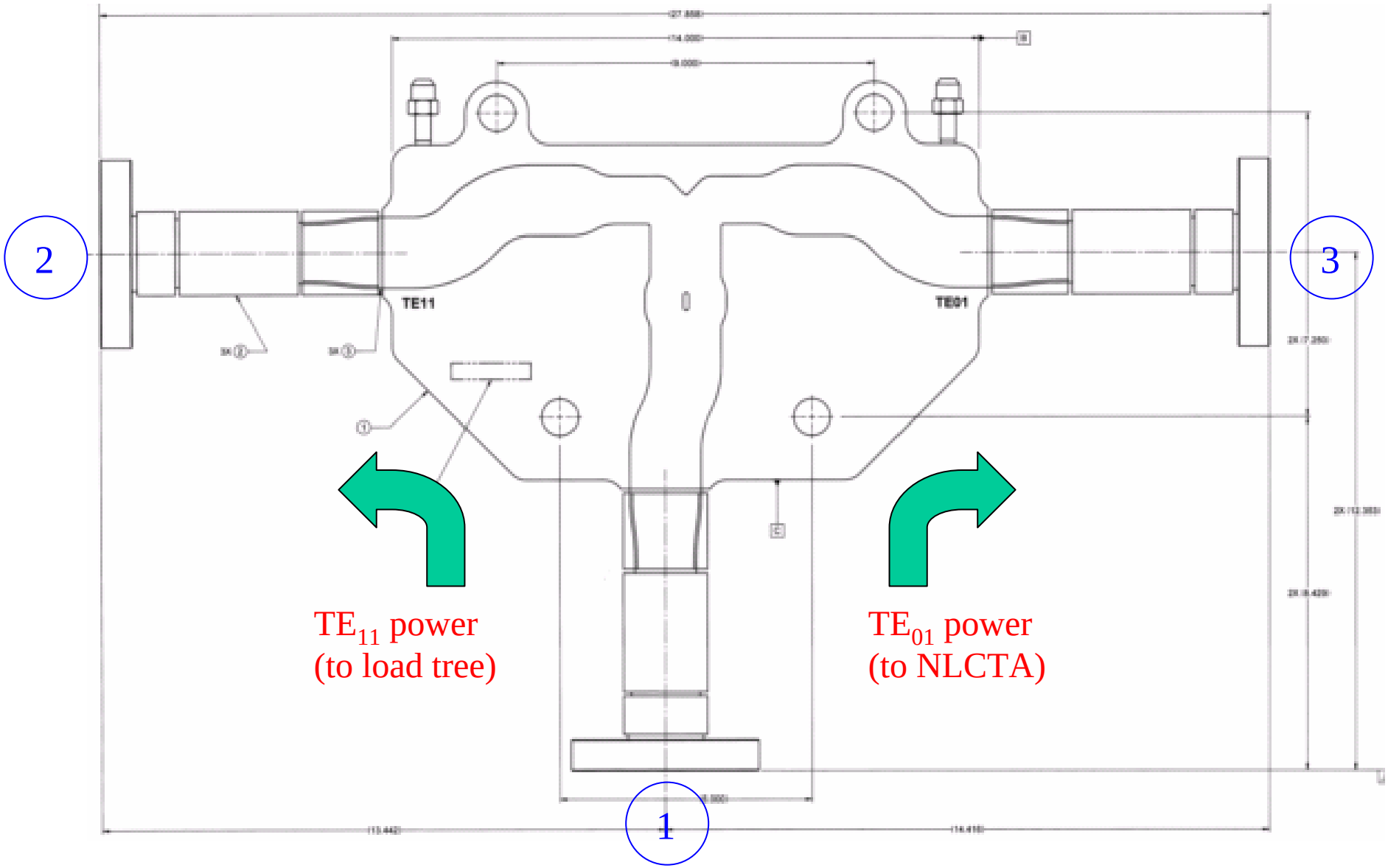
8-Pack Phase 2b



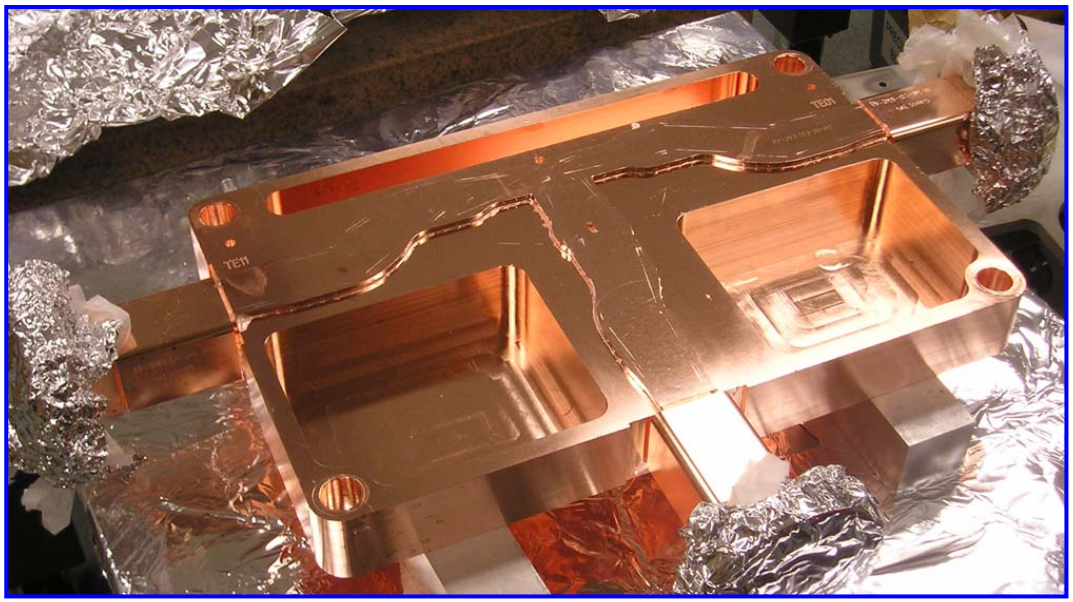
Power Distribution

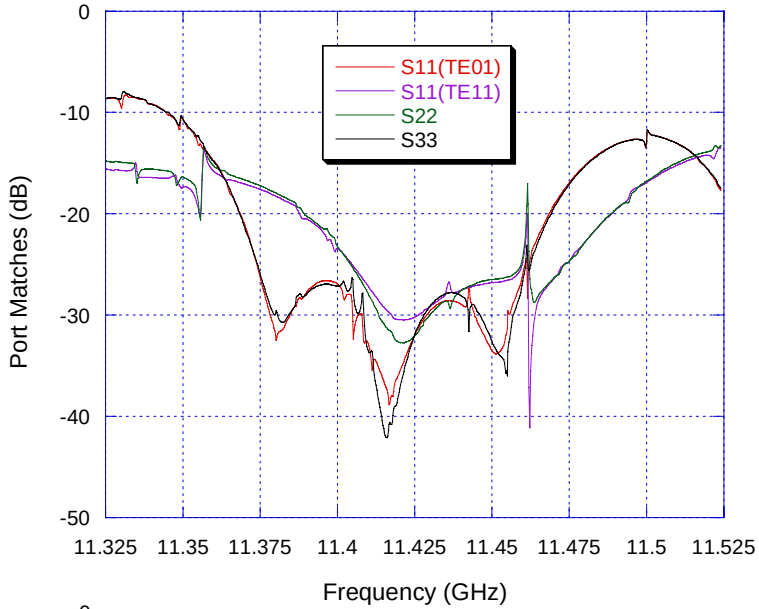


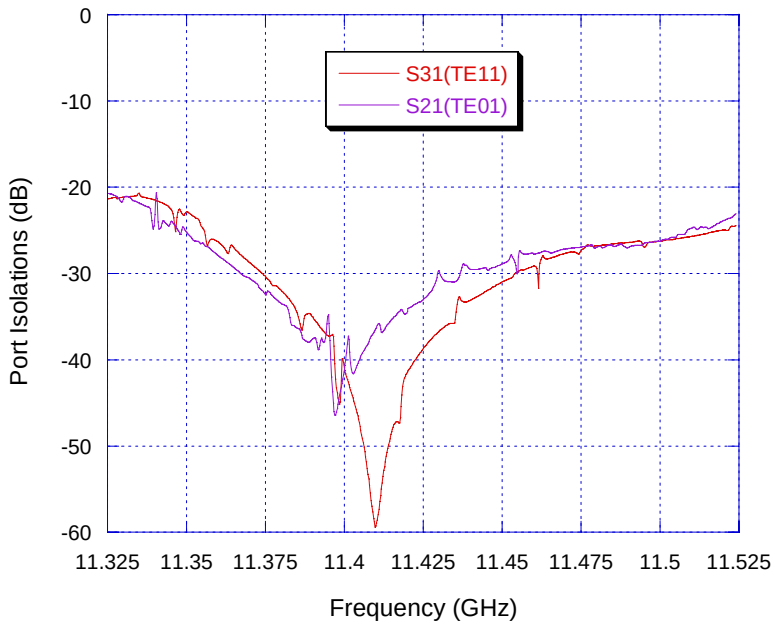
Mode Stripper

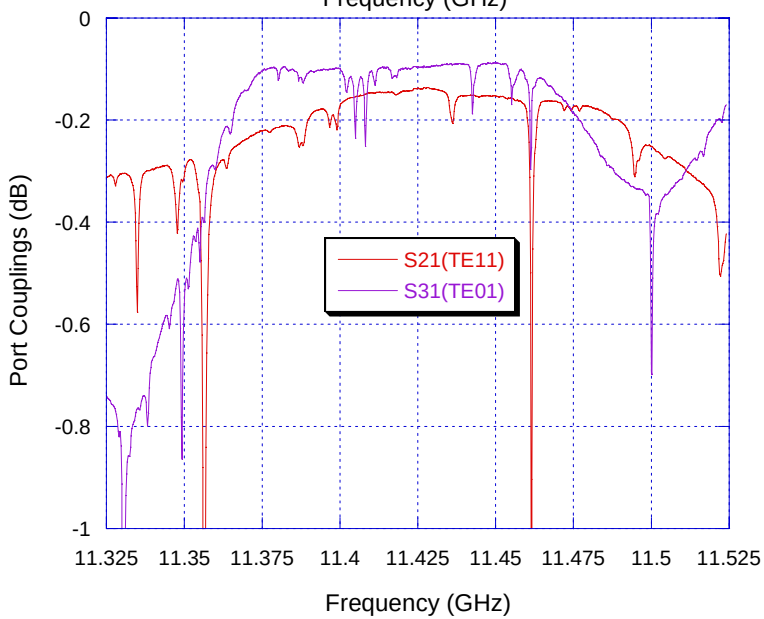


Mode Stripper Cold Test

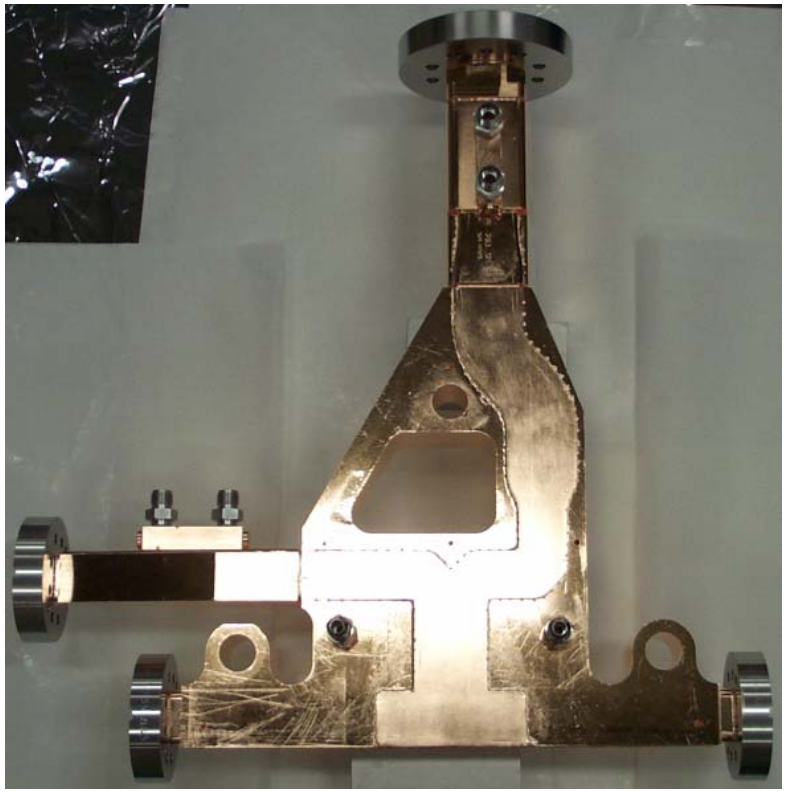


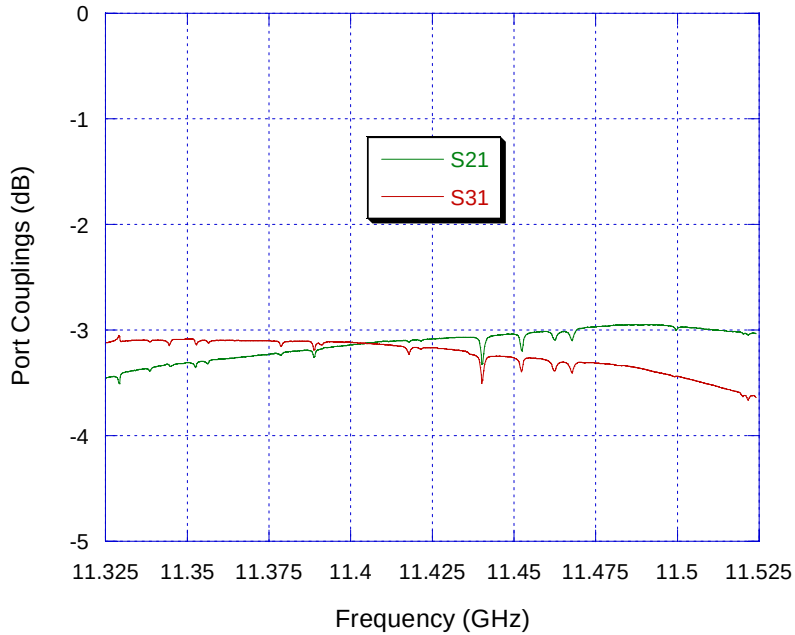


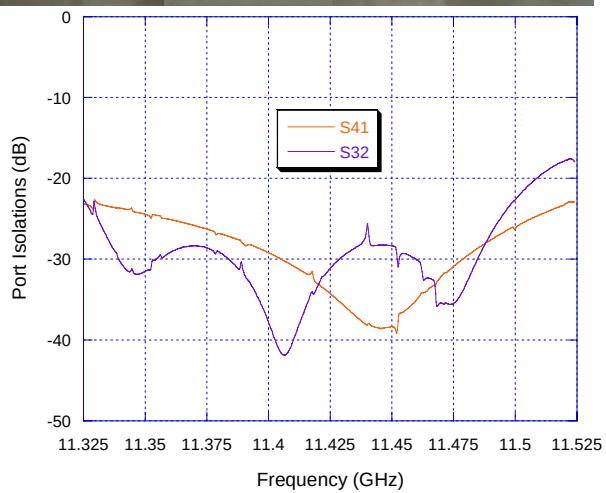


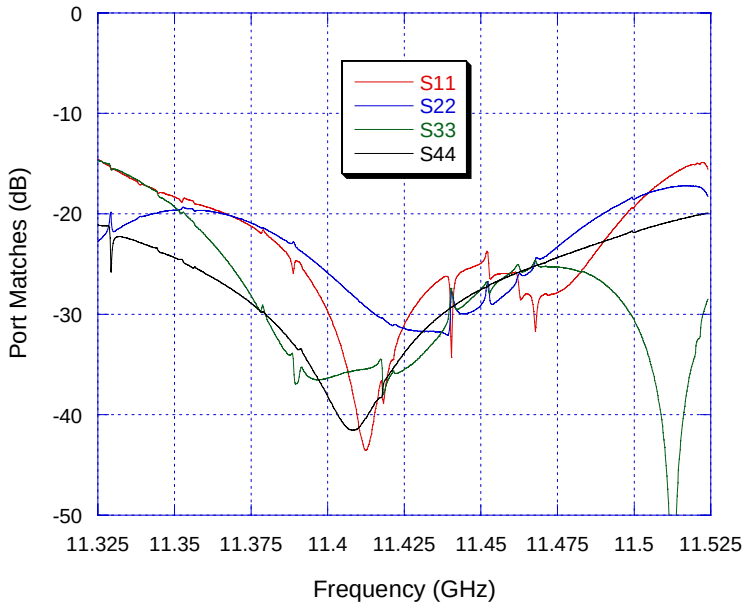


3 dB Directional Coupler Cold Test

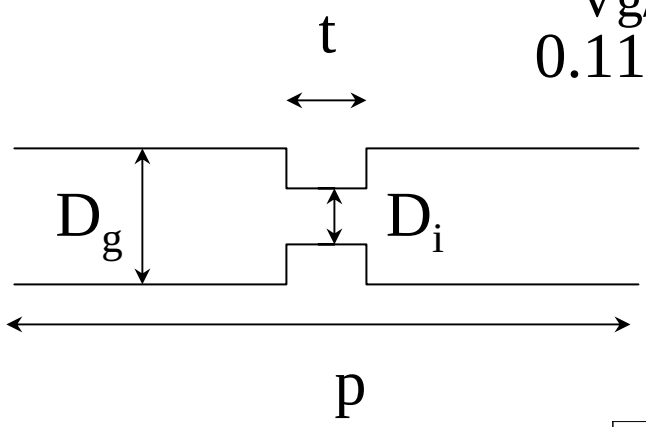




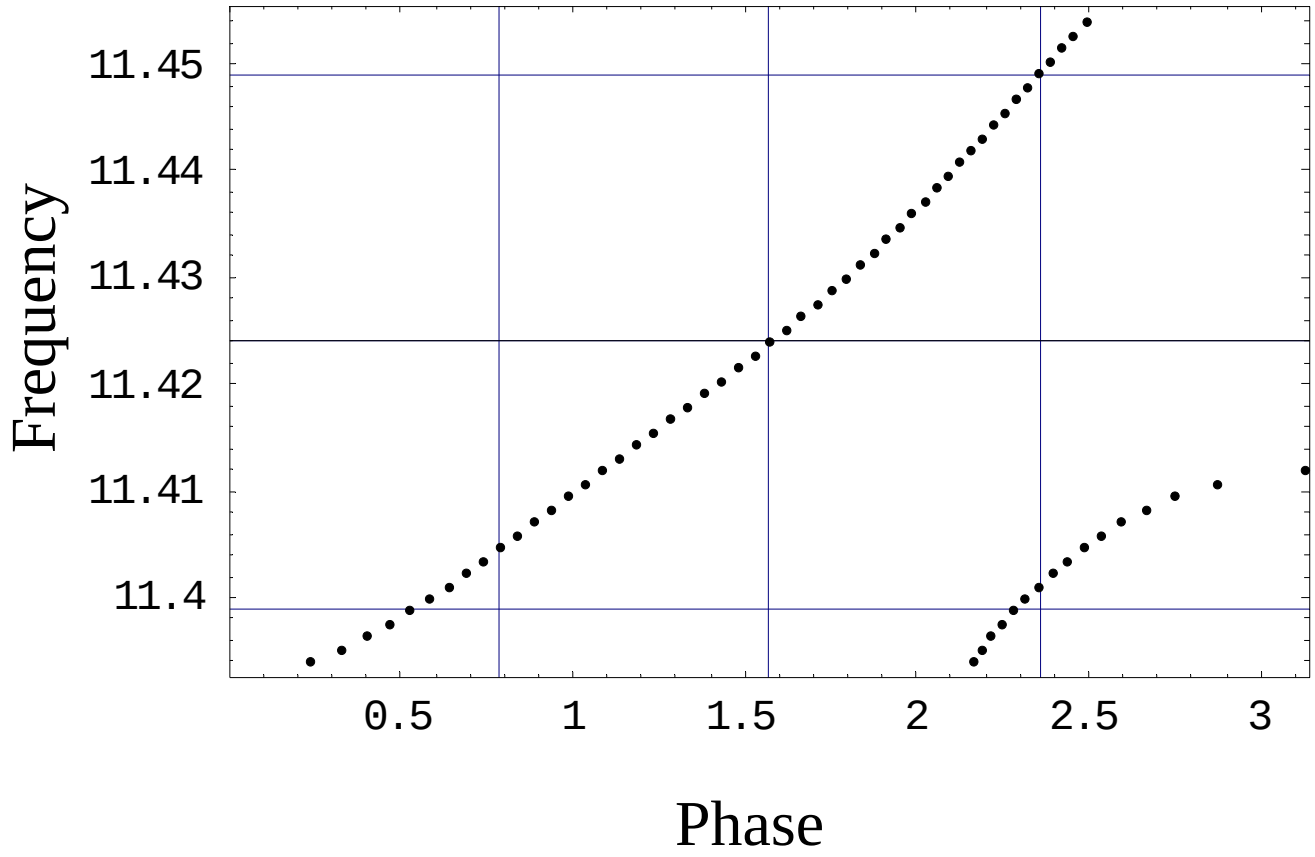




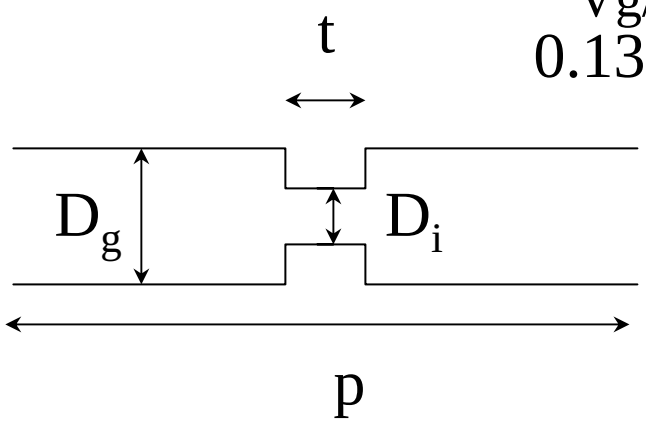
Vg/c	100ns Delay Length (cm)	Losses/100ns (%)
0.119911	359.484	2.78738



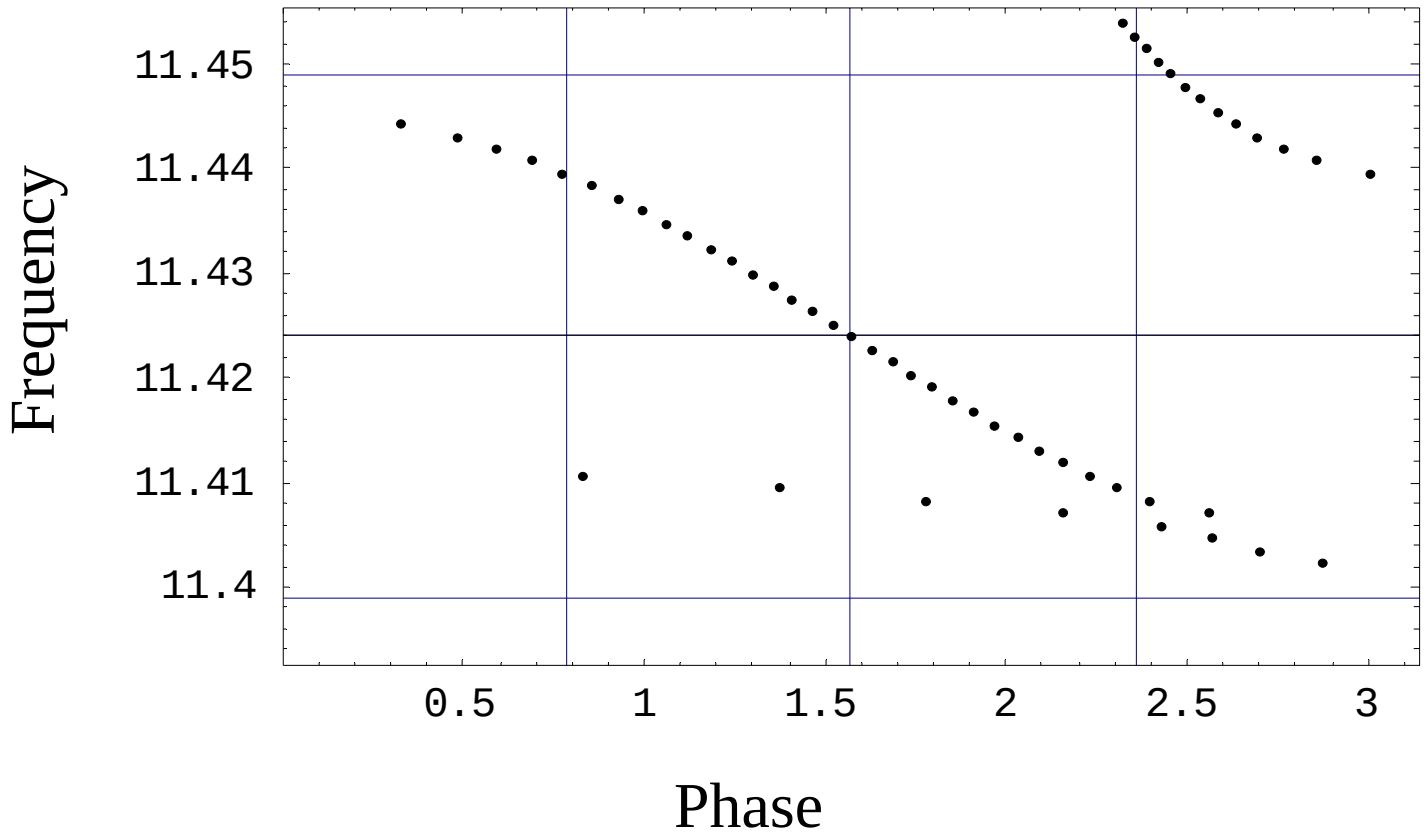
D_g=6.725”
T=0.1”
Di=3”
P=8.500”



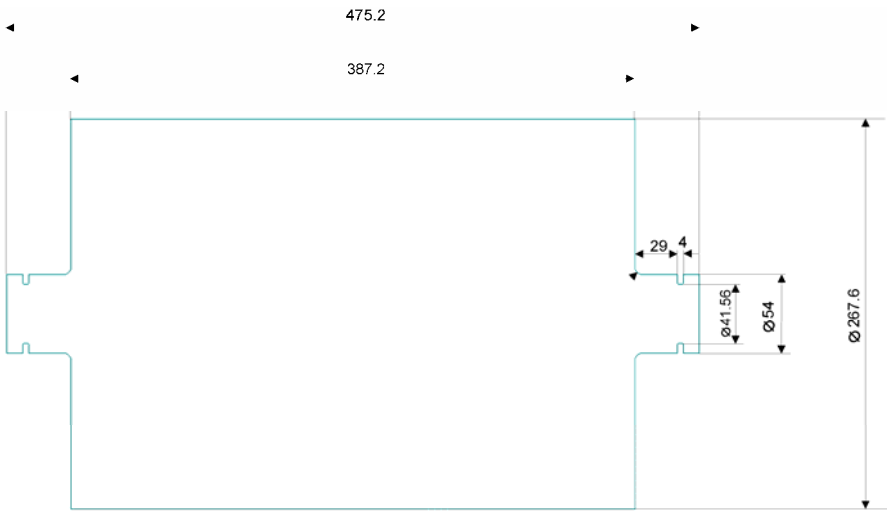
Vg/c	100ns Delay Length (cm)	Losses/100ns (%)
0.13649	409.156	2.35132

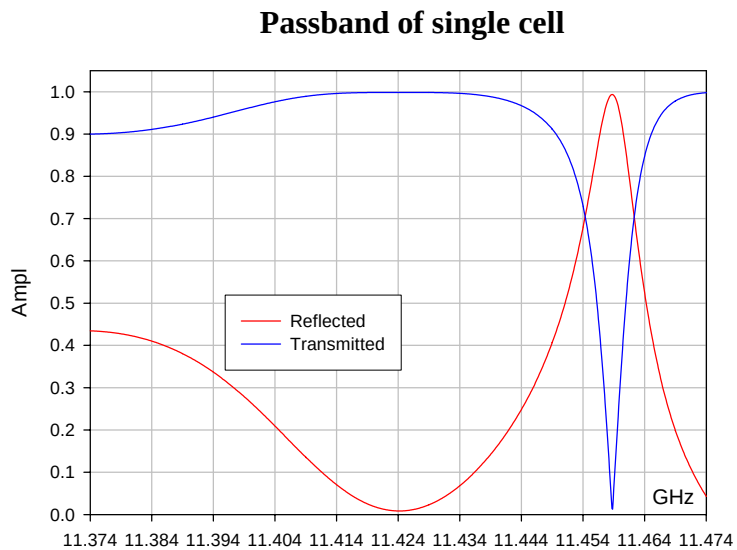


D_g=6.725”
T=0.1”
Di=3”
P=11.5035”



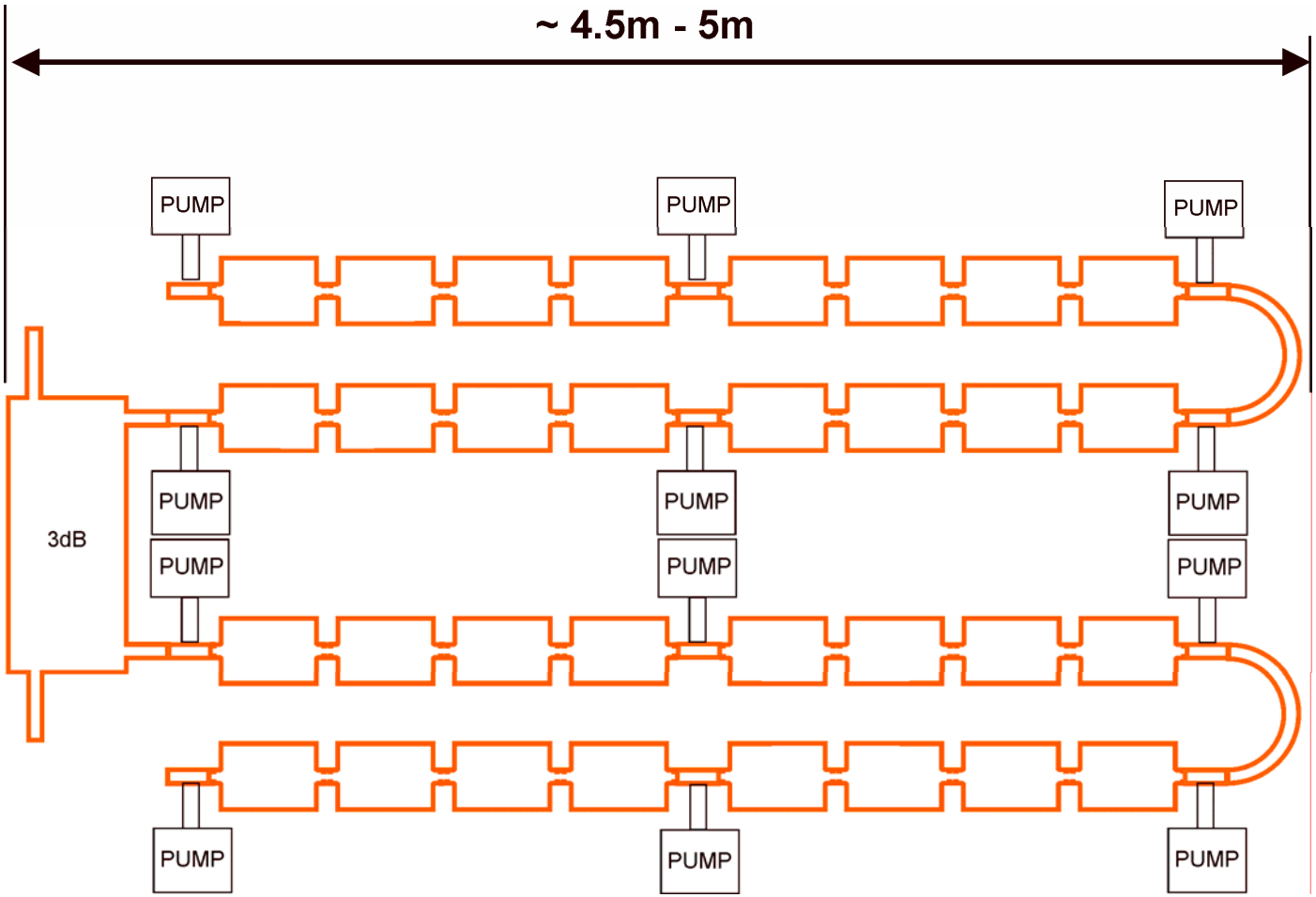
The cell is not matched enough. We can match two cell or structure of several cells by placing the cells at right distance from each to other. But to get more smooth passband is better to match each cell by iris.

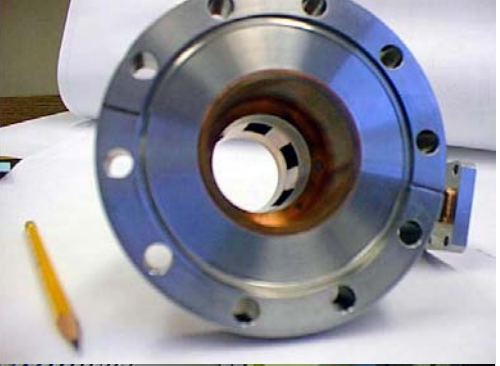


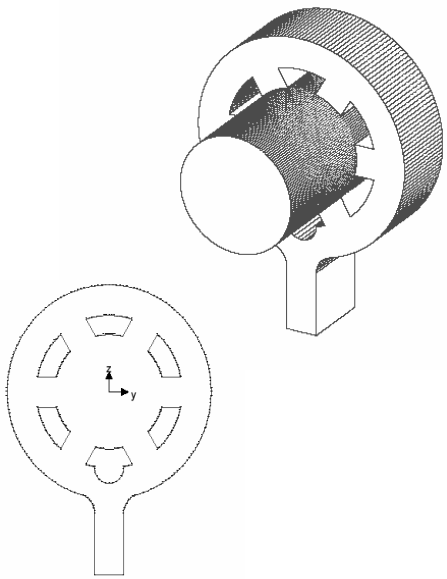


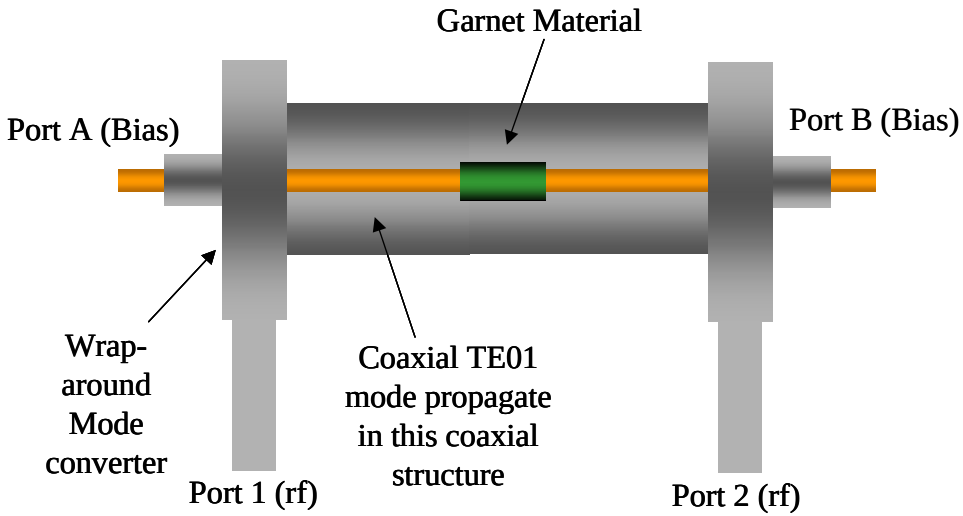
Geometry of cell with matching irises.

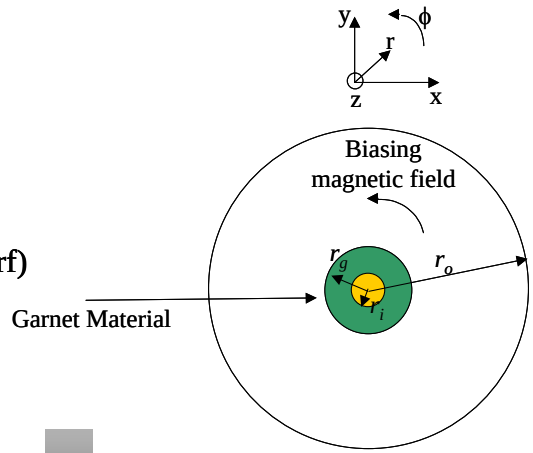
Total length of SLED-II can be not more then 5m

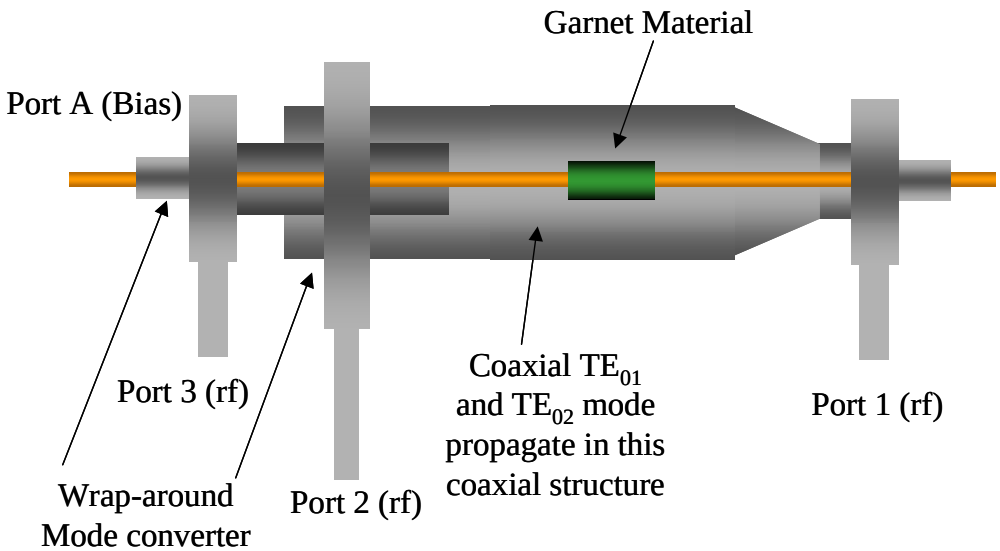












Wrap-Around Mode Converter for Tap-off, and extraction, tested to 470 MW

Conclusion:

- We have introduce a fully dual mode rf system
- We have shown design and experimental data for over moded components that propagates two modes at the same time. These component perform all possible function found in single moded rf systems
- At the operating frequency of 11.424 GHz, the peak electric field is ~49 MV/m (400 ns) and the peak Magnetic field is ~0.17 MA/m (400 ns). This was demonstrated to be low enough for a reliable high power operation of the system.

Conclusion:

- We have introduce a fully dual mode rf system
- We have shown design and experimental data for over moded components that propagates two modes at the same time. These component perform all possible function found in single moded rf systems
- At the operating frequency of 11.424 GHz, the peak electric field is ~49 MV/m (400 ns) and the peak Magnetic field is ~0.17 MA/m (400 ns). This should be low enough for a reliable high power operation of the system (remain to be seen)
- We have invented several new measurement techniques and instrumental components needed for characterizing dual moded rf systems.