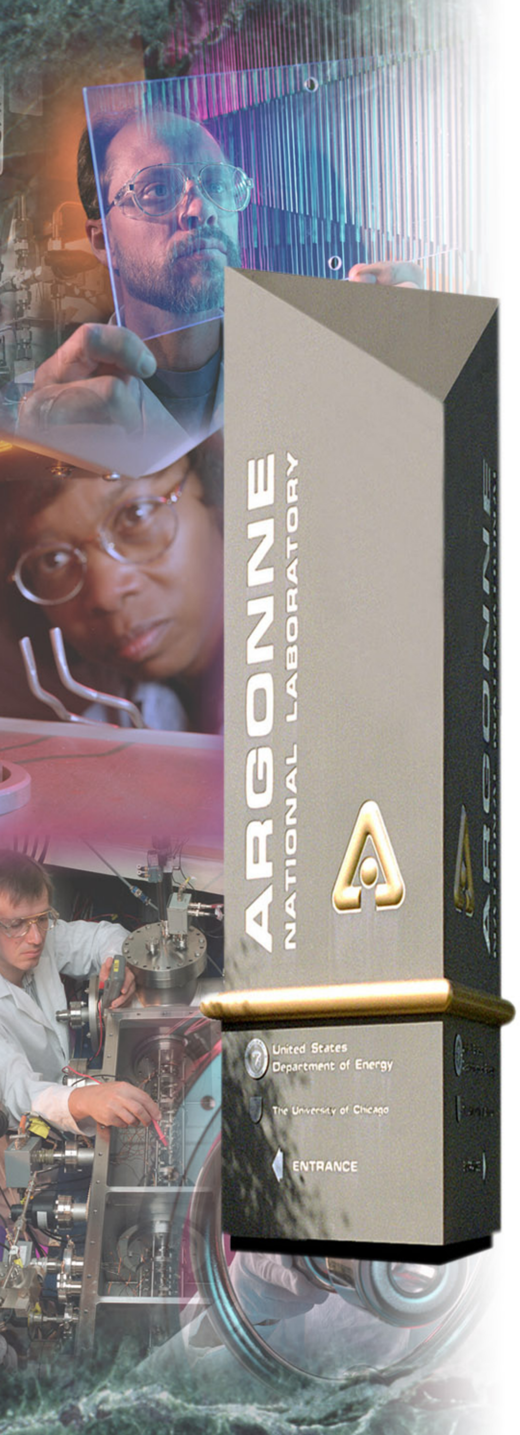

Parameters for the SCRF Deflecting Cavity

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APS/CNM 2005 Users Meeting

Workshop 9: Generation and Use of Short X-ray Pulses at APS

May 6, 2005

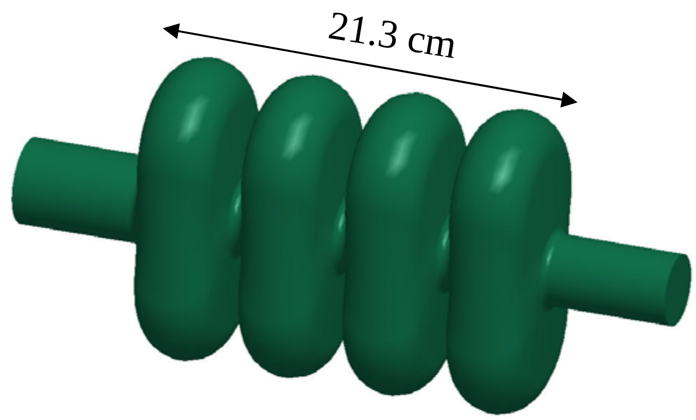
Proposed Deflecting Cavity Design Goals

- Beam dynamic simulations show that 4 MV deflecting voltage at 2.8 GHz creates an x-ray pulse on the order of picoseconds.
- One straight section will be used for deflection and one for recovery. 2.5 m space is available in each section.
- For CW operation, copper cavity is not an option since rf losses are too large and the space is limited.
- SC system would operate at 2 K due to R_{BCS} losses at high frequencies.

Frequency	2.81 GHz
Deflecting Voltage	4 MV
Deflecting Gradient	~ 5 MV/m
Q_o	3×10^9
B_{MAX}	< 100 mT
RF loss at 2 K	< 50 W
HOM: Rt at 100 mA	< 2.5 MΩ/m
HOM: Rs $*f_p$ at 100 mA	< 0.8 MΩ-GHz
Available length	2.5 m

1-cell and 4-Cell Squashed Cavity Designs

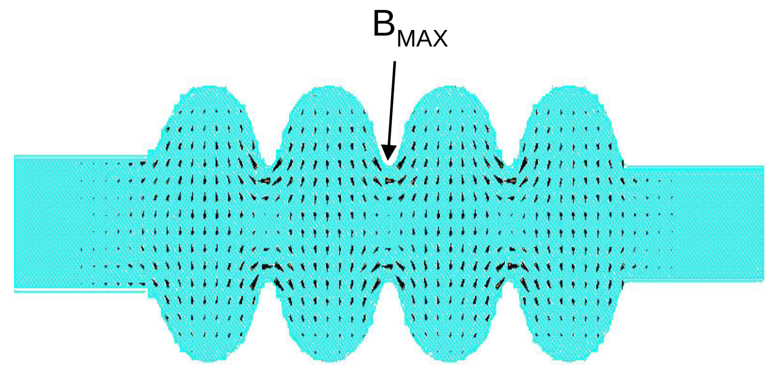
- Squashed-cell shape was used to remove TM_{110} degeneracy.
- Modeled after KEK design (cell aspect ratio ~ 1.8).
- Pi-mode chosen for 4-cell cavity to minimize number of cells. Other modes have better frequency separation.
- 4-cell cavity has 230 mT maximum magnetic field. To ensure $B_{MAX} < 100$ mT, three 4-cell cavities would be required.
- 1-cell cavity has 665 mT maximum magnetic field and would require seven cavities.
- 4-cell cavity has better R_T/Q and will be much more compact than 1-cell cavities.

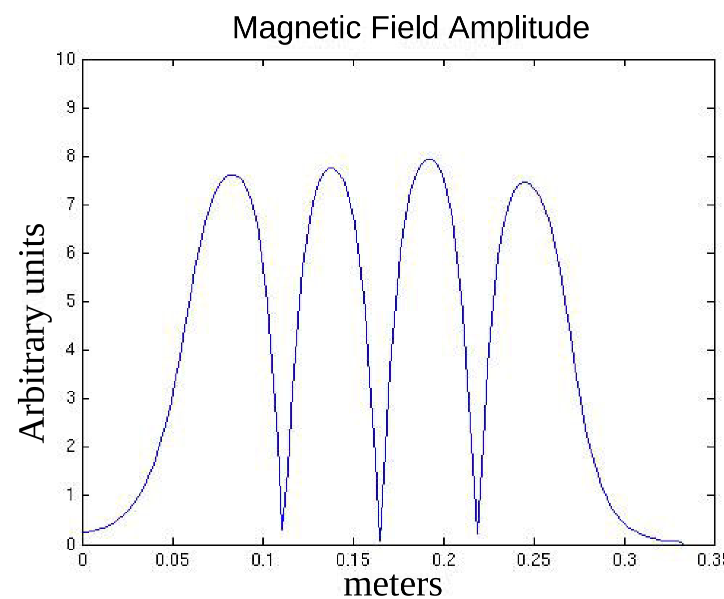


	1-cell	4-cell
Frequency	2.81 GHz	2.81GHz
λ	10.6 cm	10.6 cm
V_T	4 MV	4 MV
Active Cavity Length	5.3 cm	21.3 cm
R_T/Q	53 Ω/m	230 Ω/m
Q	3×10^9	3×10^9
P_L	102 W	25 W
B_{MAX}	665 mT	230 mT
Cell aspect ratio	1.8	1.8

Deflecting Mode Field Optimization

- End cell geometry had been adjusted to improve field uniformity and distribute the maximum surface magnetic fields.
- Electric and magnetic field within each cell uniform to about 5%.
- Peak magnetic field reduced 50% relative to the original cavity shape.
- Further reduction of B_{MAX} may be achieved by optimizing the iris shape.
- Cavity iris in 1-cell cavity was modified to improve B_{MAX} by 5%.
- Additional optimizations may reduce the number of 1-cell cavities or 4-cell cavities required.



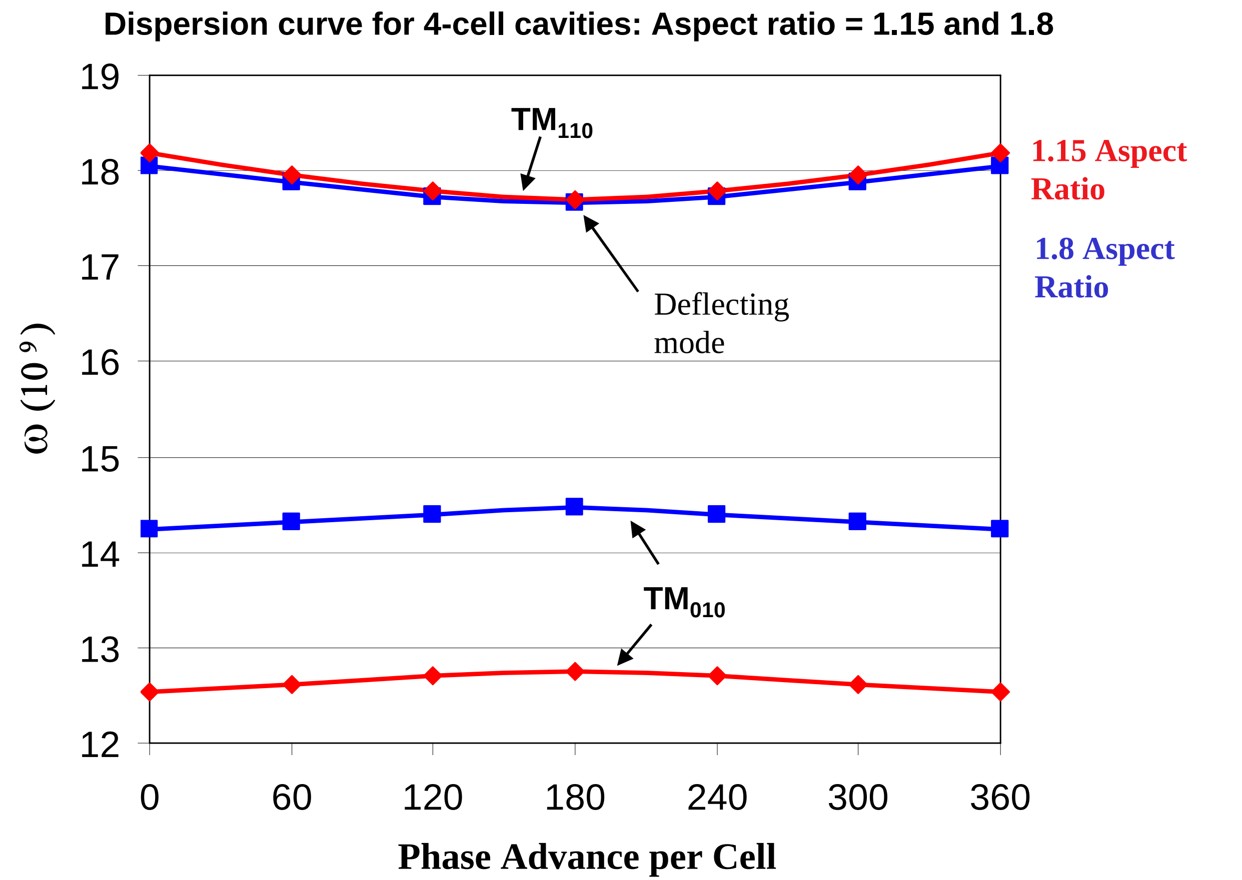


Deflecting magnetic field amplitude along the cavity axis

Mode Separation

- From the dispersion curve, LOMs are ~ 500 MHz from the deflecting mode, while the nearest HOM is 9 MHz apart in the TM_{110} passband. Next HOM passband (TE) is separated by 380 MHz.

- Analysis by ASTec determined a more optimal aspect ratio of 1.15 for mode separation.
- Separation from the LOMs was 800 MHz and 14 MHz in the TM_{11} passband for a 4-cell cavity.
- Passband proximity to the “degenerate” TM_{11} passband only 180 MHz.



Parasitic Modes

- Stability criterion in the APS storage ring for the longitudinal modes is $f_p * R_s < 0.8$ MΩ – GHz
- The transverse shunt impedance R_T is calculated using Panofsky - Wenzel's theorem. The stability criterion at the APS is R_T=2.5 MΩ/m.

$$R_T = \frac{k}{2} \frac{\left| \int E_Z(r_0) e^{jkz} dz \right|^2}{(kr_0)^2 P_{loss}}$$

Freq (GHz)	Type*	Q (10^9)	R_s (Ω) (10^9)	R_T (Ω) (10^9)
2.266	M	5.5	260	-----
2.279	M	5.6	25	-----
2.290	M	5.5	440	-----
2.302	M	5.5	1,300	-----
2.812	D	4.7	-----	32,400
2.821	D	4.8	-----	94.5
2.846	D	4.9	-----	56.6
2.873	D	5.0	-----	63.2

4-cell Cavity

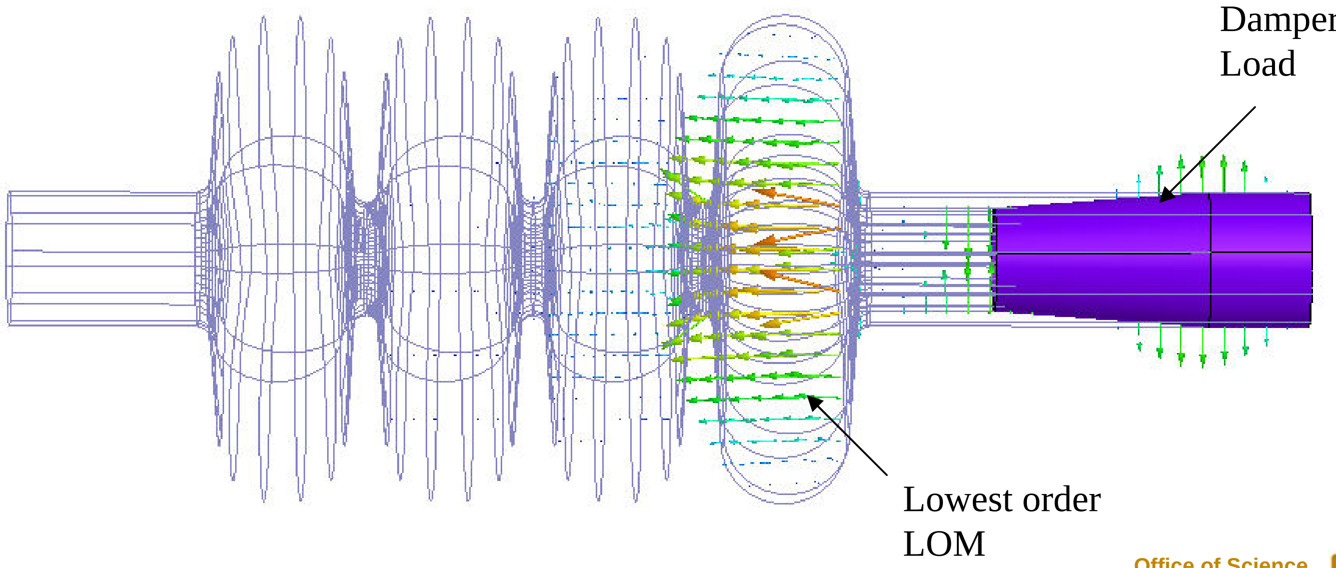
Freq (GHz)	Q (10^9)	R_s (Ω) (10^9)	R_T (Ω) (10^9)
2.278	5.1	98	-----
2.813	4.9	-----	7,700
3.363	3.6	-----	70.7
3.511	3.9	-----	73.5
3.743	3.1	-----	78.4
3.826	4.4	428	-----

1-cell Cavity

*M-Monopole, D-Dipole

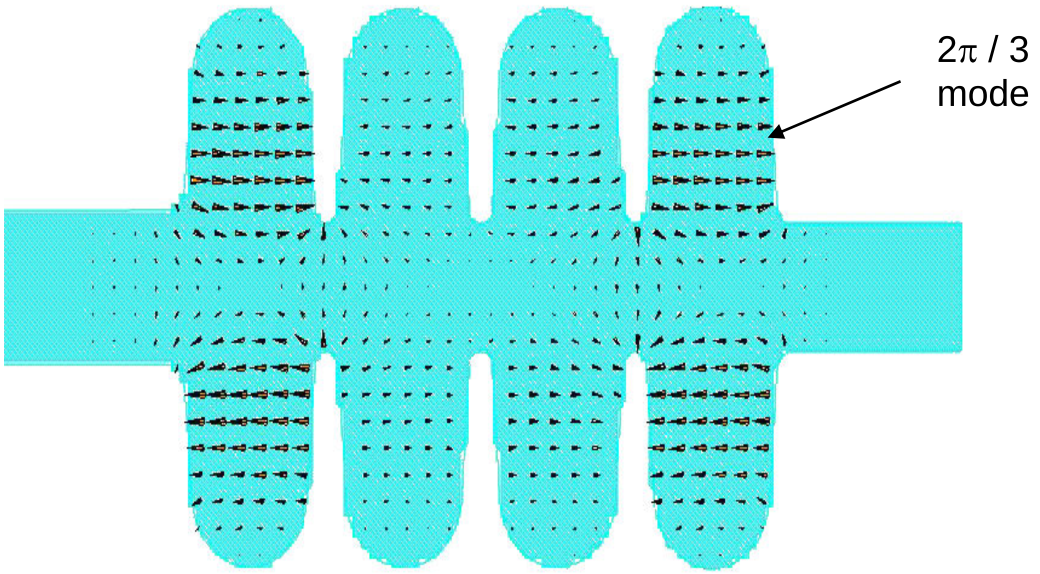
Parasitic Mode Damping

- HOMs pass through enlarged beam pipe to an external damper.
- LOMs are ‘trapped’ modes and are extracted using KEK-type SC coaxial beam pipe inserted into the cavity.
- Coaxial beam pipe is inserted into outermost cell on one side of the cavity. Extracting LOMs from internal cells and at the opposite end of cavity is problematic.
- Thickness of coax sleeve is 5 mm allowing a 2 mm channel for refrigerant assuming 1.5 mm niobium thickness.
- Coax OD to beam pipe separation is 5 mm. Requires strict alignment and will have limited power handling capabilities.



HOM Dipole Mode Damping

- Field profiles are very similar to the deflecting mode.
- The frequency separation of nearest HOM is ~ 9MHz, so damping of this 2π / 3 mode may cause excessive deQing of the deflecting mode
- Instability calculations showed that strong damping is required.
- Rejection filter would need to be lossless and have very small bandwidth.

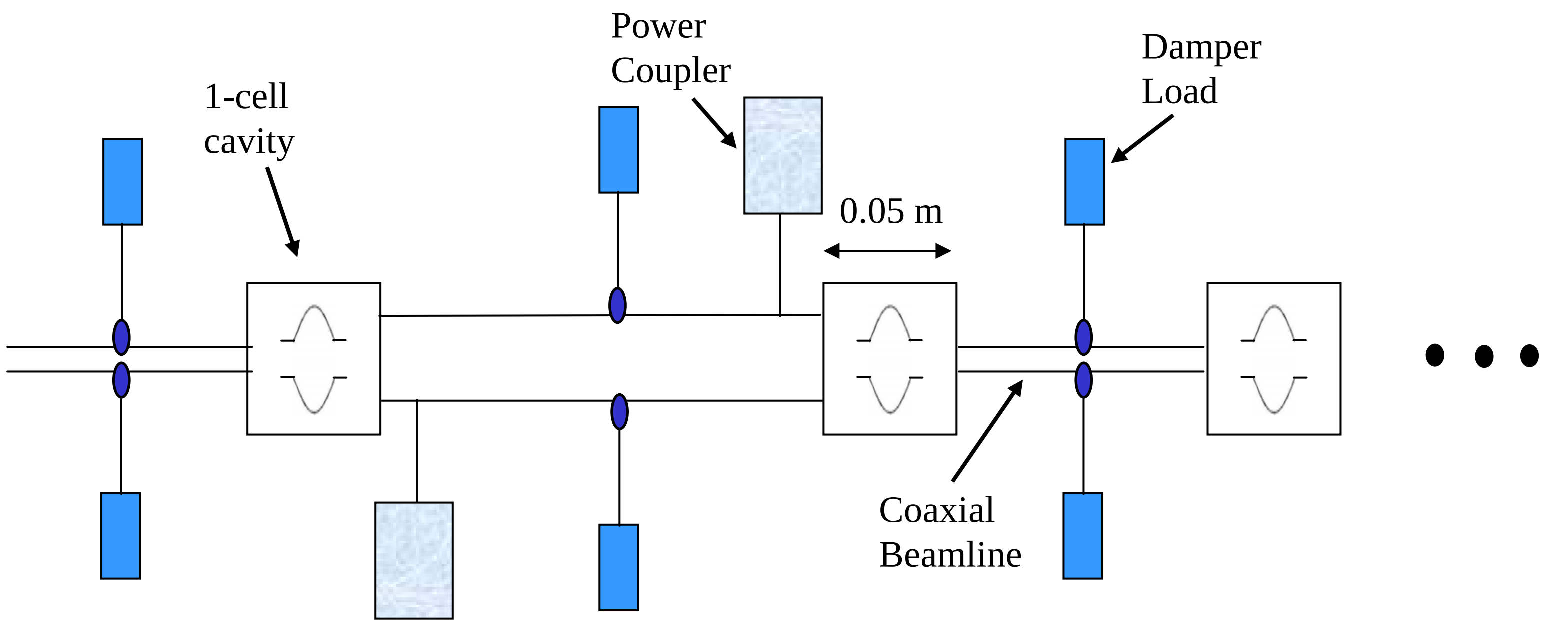


Dipole Mode E-Field Profile

Deflecting Cavity Parameters

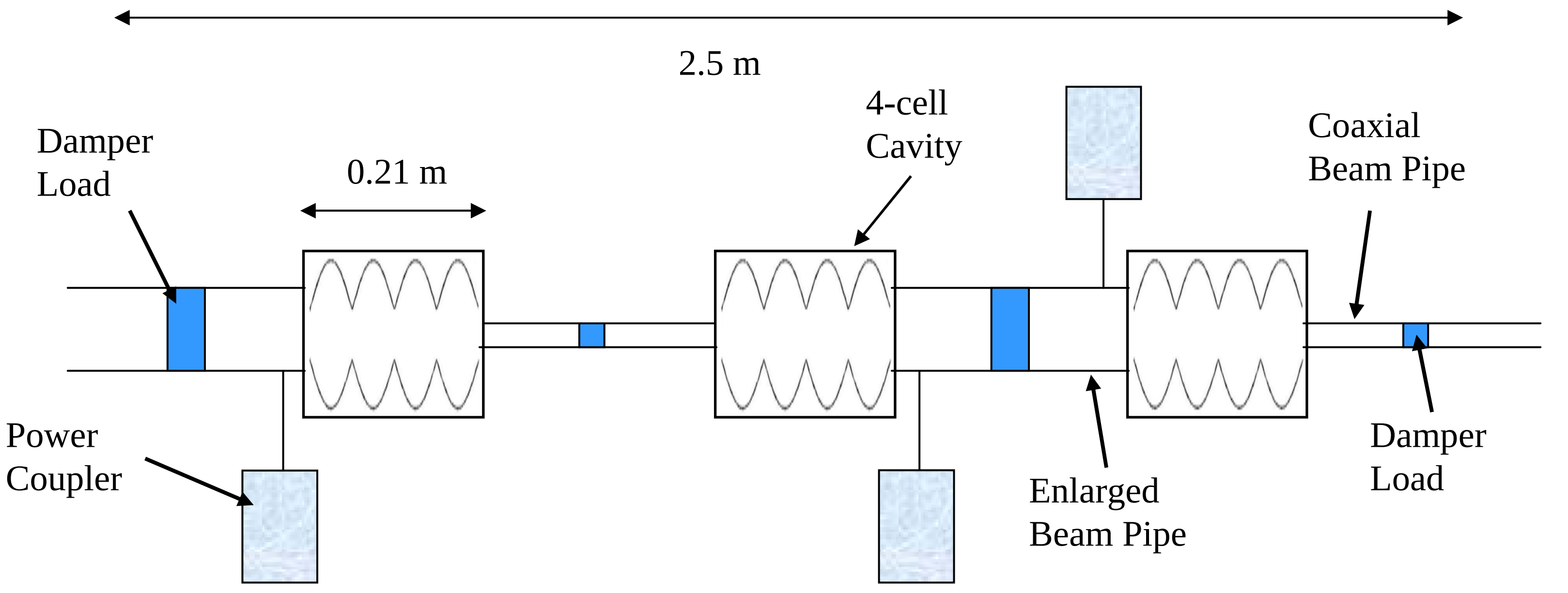
	1-cell	4-cell	
Frequency	2.81	2.81	GHz
No. of cavities	7	3	
Phase advance	----	180	Deg
Cavity radius	7.8	7.8	cm
Iris radius	---	1.8	cm
Beam pipe radius	2.1 / 1.8	2.1 / 1.8	cm
Deflecting voltage	4	4	MV
Deflecting gradient	10.7	6.25	MV/m
Q_o	3×10^9	3×10^9	
R_T/Q	52 * 7	220 * 3	Ω
Active cavity length	5.3 * 7	21.3 * 3	cm
B_{MAX}	95	80	mT
P_{beam} with 1mm offset	~25	~25	kW
RF loss at 2 K	15	10	W

APS 1-cell configuration



- Seven 1-cell cavities are required. One cryomodule would be used for all cavities.
- Cavities would require 0.053 meters / each or 0.37 meters / total.
- HOM and LOM power would be extracted from beamline and transmitted to remote loads.
- 2.1 meters available for seven power couplers, HOM / LOM pickups to loads, and rf separation to minimize coupling.

APS 4-Cell Configuration



- Three (possibly two) 4-cell cavities would require 0.6 meters.
- If one cryomodule is used, 1.9 meters would be available for three power couplers, etc.
- If dampers can not be located remotely (such as from the coaxial beam pipe), space would be required in the beamline for the room temperature loads and for thermal transitions. Separate cryomodules would be needed for each cavity.

Summary

- 1-cell cavities simplify HOM / LOM damping, but require more space.
- 4-cell cavities require much more difficult damping strategy.
- Transmitting HOM's to remote loads would alleviate space requirements.
- Optimization of the cavities is necessary to reduce B_{MAX}.
- Further HOM / LOM instability analysis is required to determine damping requirements.
- Physical HOM / LOM removal from the cavity requires further investigation esp., coaxial damper design and rejection of crabbing mode.