APS Accelerator and ID R&D

Efim Gluskin

Accelerator Systems Division

Advanced Photon Source

APS, ESRF, SPring-8 Meeting

March 18, 2008

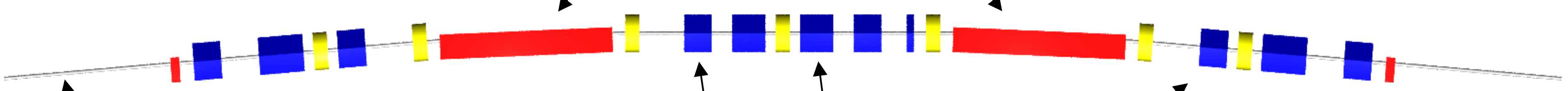
Advanced Photon Source, Argonne

Outline

- APS x-ray source upgrade
- Short x-ray pulses project
- Superconducting undulator

Triple-Bend Design (APS1nm)

APS now: 3.1nm emittance



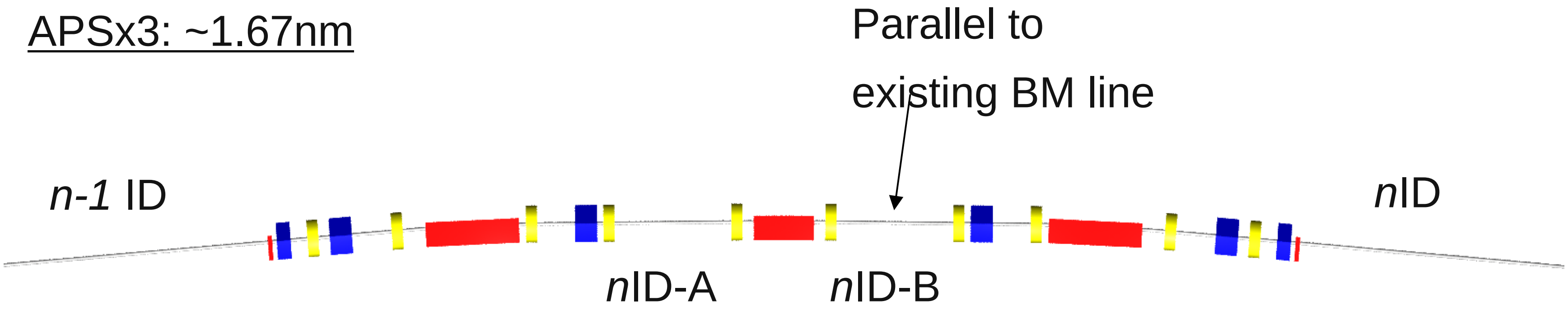
Possible upgrade: 1nm emittance

Thanks to L. Emery for help with figures.

Another Option: APSx3

- This is an evolution of the 1nm lattice
- Offers three times as many ID beamlines
- Could provide a three-pole wiggler for beamlines that still want bending-magnet-like source
- Downside: Emittance doesn't improve much

<u>APSx3: ~1.67nm</u>



2.1m magnet-to-magnet
in new straight sections.

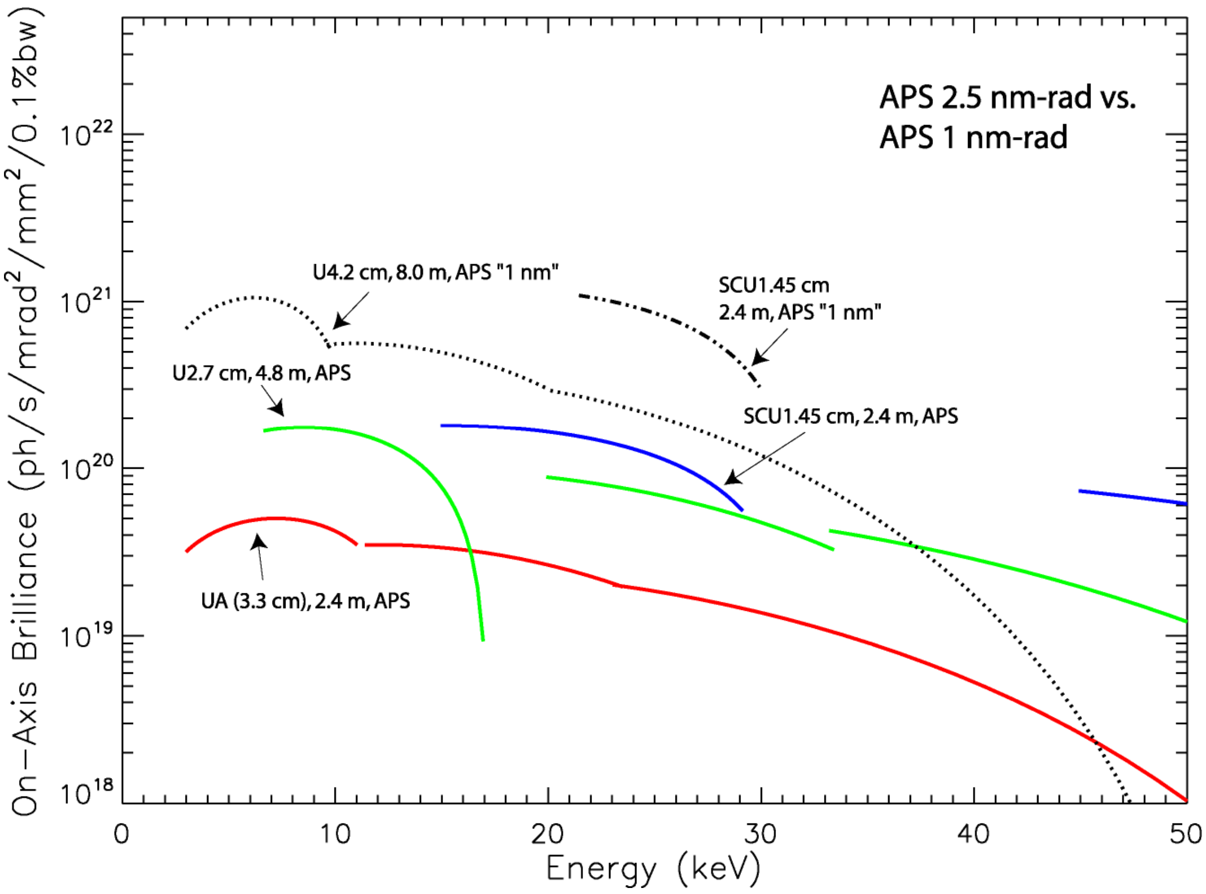
Thanks to L. Emery for help with figures.

Source Parameters Compared to APS Now

Case	*# of Sectors*	*x rms (microns)*	*x' rms (microrad)*	*y rms (microns)*	*y' rms (microrad)*
Today	40	275	11.4	8.5	3
APS 1nm	40	~120	~10	~7	~1
APSx3	40	~120	~14	~13	~1

- Upgraded ring would run at 200 mA, 7 GeV
- Insertion devices would be customized to, e.g., maximize brightness consistent with power limitations of front ends.

On-Axis Brilliance Tuning Curves for The APS 1 nm-rad Lattice



- Beam Energy 7.0 GeV
- Beam Current 100 mA (APS), 200 mA (APS 1 nm-rad), Coupling 1.0%

An "Outfield" ERL Option (G. Decker[1])

- Advantages
  - Linac points away from APS[2] to give straight-ahead FEL hall[3]
  - Beam goes first into new, emittance-preserving turn-around arc[4]
  - Avoids wetlands etc. by using narrow corridor for linac and return line
- Issues
  - Big and expensive
  - Turn-around should be *bigger* than shown
  - Beam goes wrong way around the APS in this sketch (readily fixed)
  - No space for really long undulators.

[1]G. Decker, "APS Upgrade External ERL Option," 9/27/06.

[2]M. Borland, "ERL Upgrade Options and Possible Performance," 9/18/06.

[3]M. Borland, "Can APS Compete with the Next Generation?", May 2002.

[4]M. Borland, OAG-TN-2006-031, 8/16/06.

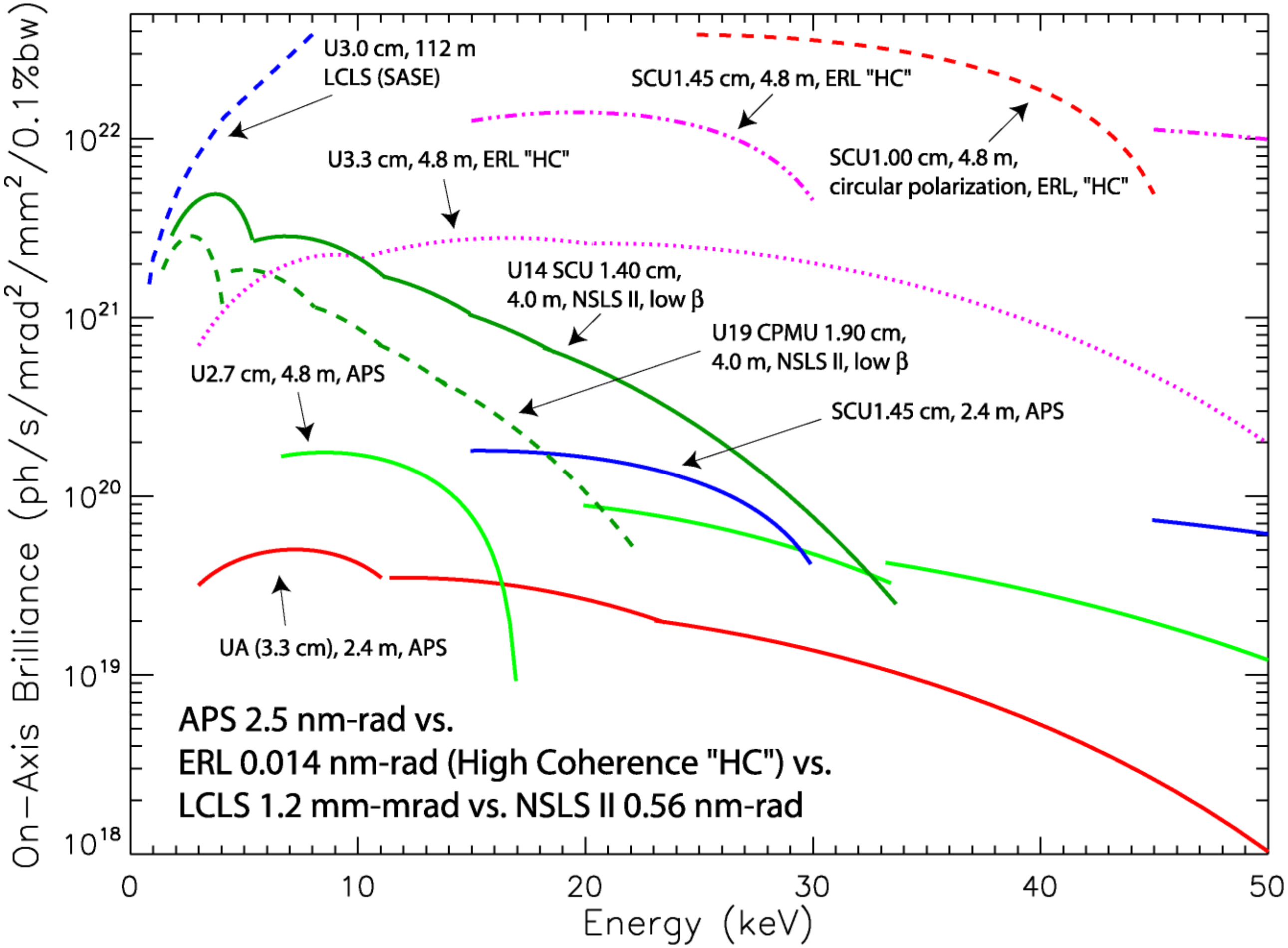
APS ERL Parameters (Scaled to 7 GeV from Cornell ERL*)

	APS now	ERL High flux	High coherence	Ultrashort pulse
Average current (mA)	100	100	25	1
Repetition rate (MHz)	0.3~352	1300	1300	1
Bunch charge (nC)	0.3~60	0.077	0.019	1
Emittance (nm)	3.1 x 0.025	0.022 x 0.022	0.006 x 0.006	0.37 x 0.37
Rms bunch length (ps)	20 ~ 70	2	2	0.1
Rms momentum spread (%)	0.1	0.02	0.02	0.3

- Promise of very high brightness
  - Extremely low emittance, equal in both planes
  - Very low energy spread
- Current from 25 to 100 mA with ultra-low emittance, ps pulses
- Option for less current with high charge, fs pulses.

*G. Hoffstaetter, FLS 2006 Workshop, DESY.

On-axis Brilliance Tuning Curves for Current APS Lattice vs. ERL High-coherence Mode vs. LCLS vs. NSLS II



- Beam energy: 7.0 GeV (APS), 4.3 – 13.6 GeV (LCLS), 3.0 GeV (NSLS II)
- Beam current: 100 mA (APS), 25 mA (ERL High Coherence "HC"), 500 mA (NSLS II)

APS ERL R&D

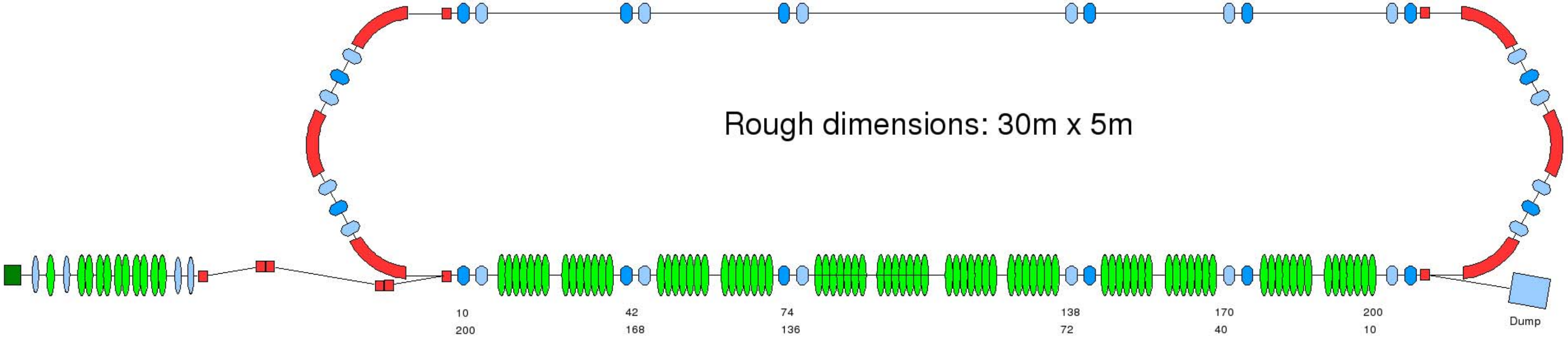
- Four critical areas for ERL R&D
  - Reduction of cryogenic load and resultant reduction of wall plug power requirements
  - Reliable production of ultra-bright, high-average-current electron beams with availability comparable to present-day storage rings
  - Preservation and delivery to users of ultra-low emittance, stable, high-average-current beams
  - Control of beam losses, to protect both personnel and equipment

A Need for a Test Facility

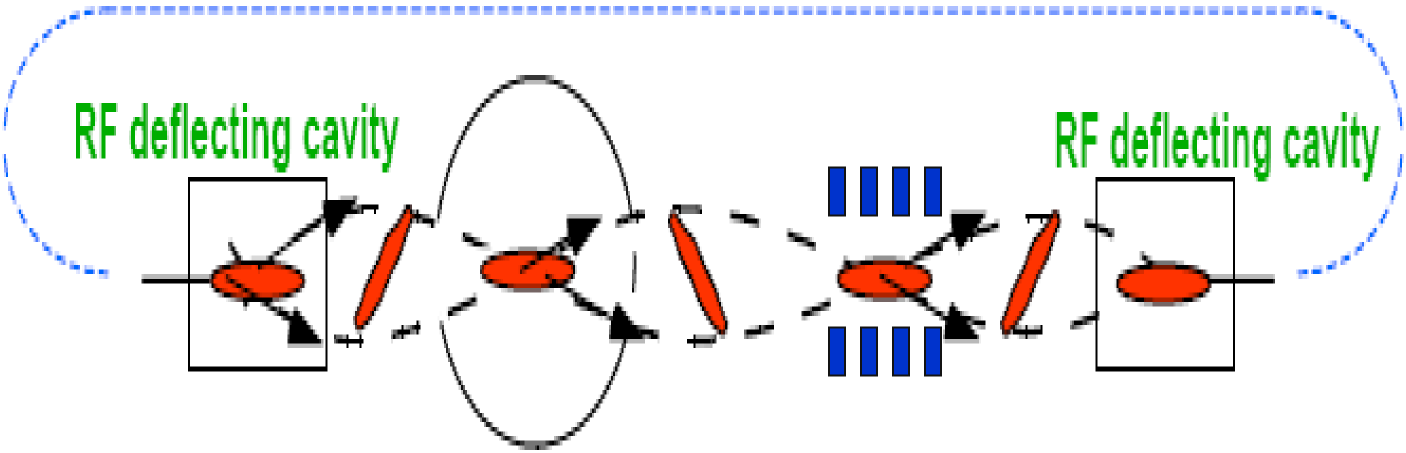
- There is a definite need for a beam test facility to test and characterize components of a the full-size APS ERL
- This can be accomplished with a moderate electron beam energy (~200 MeV) and a low average current (~ 20 mA)
- The purpose of such facility is to characterize and understand issues such as:
  - Electron source
  - Injection scheme
  - Merger
  - Beam transport at injection energy
  - Ultra-low emittance beams generation and preservation
  - Power handling capabilities of the injector linac (FPC performance)
  - System integration
  - Experience with SRF operation
  - Operational reliability

Proposed ERL Test Facility

- APS supports building a ~20 mA, ~200 MeV ERL test facility
  - Test predictions related to beam quality and its preservation up to relativistic energies
  - Assess performance and reliability of rf cavities, dampers, and control systems in a realistic high-current environment
  - Investigate beam loss and collimation in an experimental setting
  - Develop high-precision, high-rate diagnostics
  - Address integration issues
- APS is eager to be the host or a strong partner in this endeavor



Crabbing Scheme†

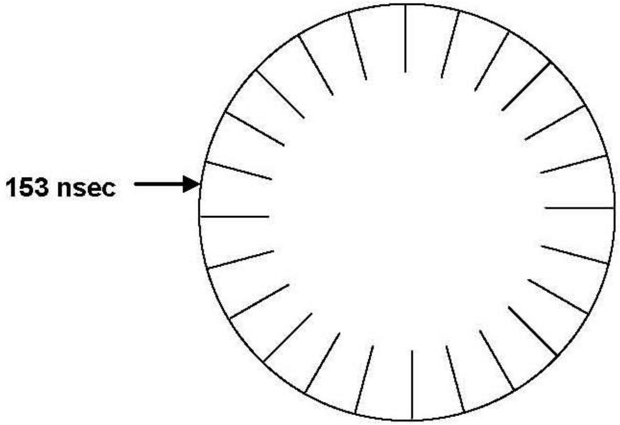


- Deflecting cavity introduces angle-time correlation into the electron bunch "crabbing" the beam. B_x kicks head and tail of the bunch in opposite directions in the vertical plane.
- Electron oscillate along the orbit
- Bunch evolution through the lattice results in electrons and photons correlated with vertical momentum along the bunch length
- Second cavity at nπ phase cancels "kick"; rest of the storage ring unaffected

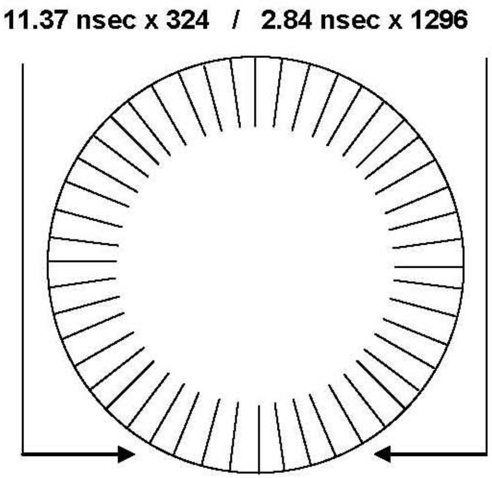
†A. Zholents, P. Heimann, M. Zolotorev, J. Byrd, NIM A 425(1999), 385

APS operating modes, 100 mA

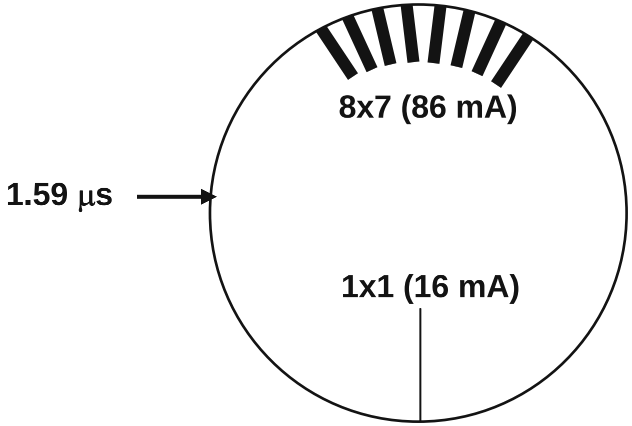
Singlet **24**



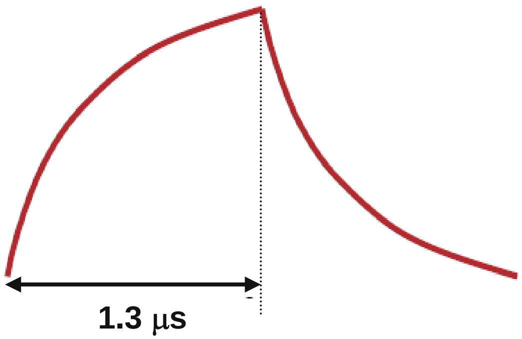
Multi bunch **324 / 1296**



Hybrid with singlet **1 + 8*7**



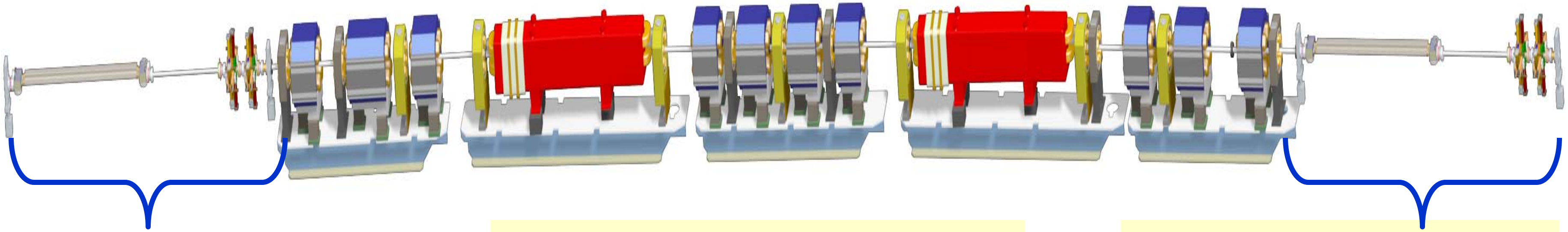
Deflecting cavity rf voltage



Rise/fall times limited by crab cavity fill time (~800ns)

Courtesy: J. Carwardine

Two-Sector Layout[1]



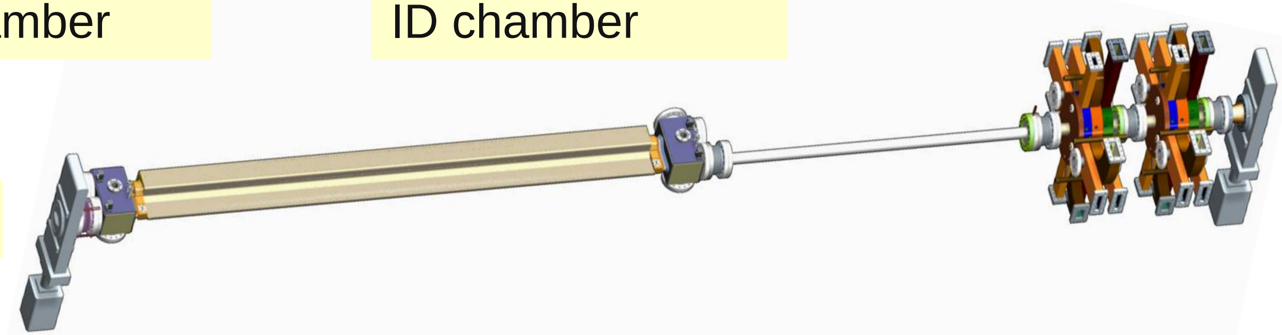
Sector 6, section 6

Sector 7, Girder 1 thru 5

Sector 7, section 6

Upstream end
ID chamber

Downstream end
ID chamber



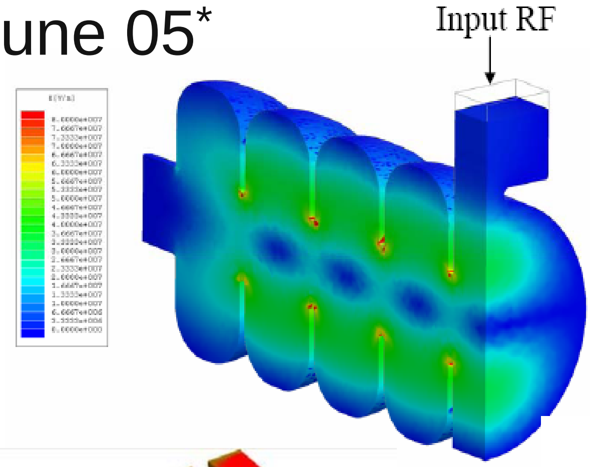
Gate valve

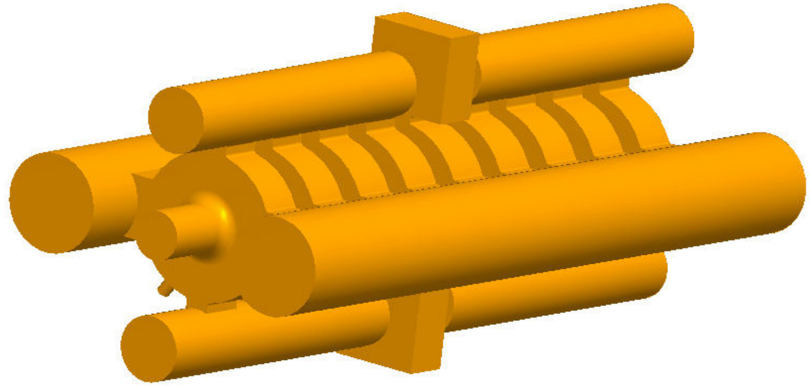
Gate valve

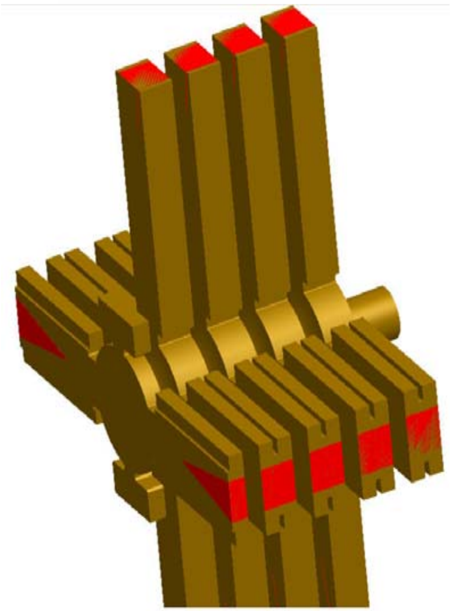
[1] Courtesy: L. Morrison

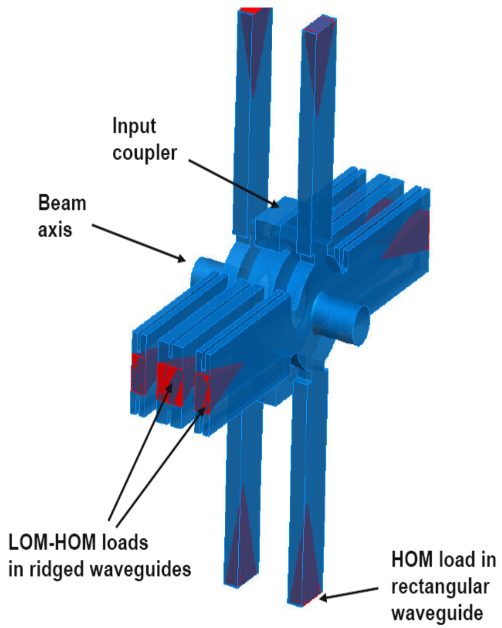
Cavity Design Evolution

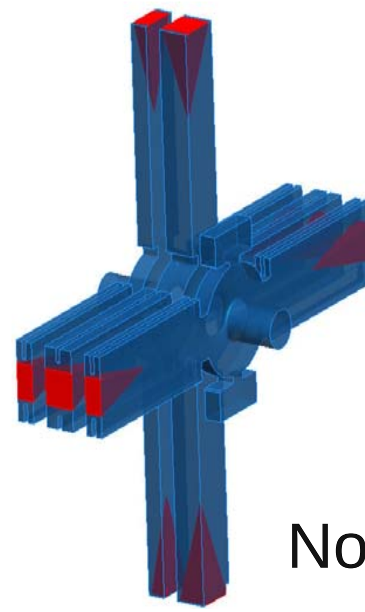
June 05*







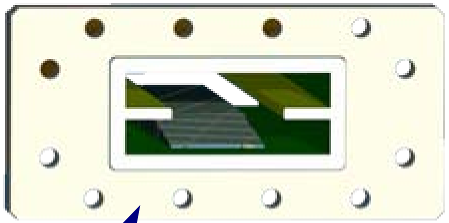


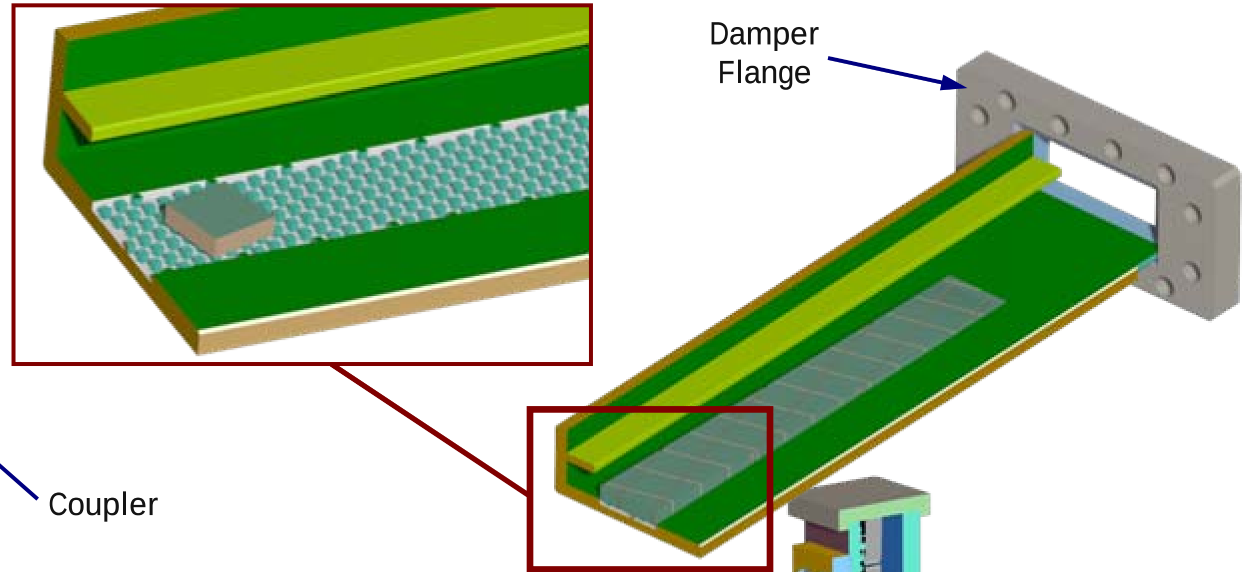


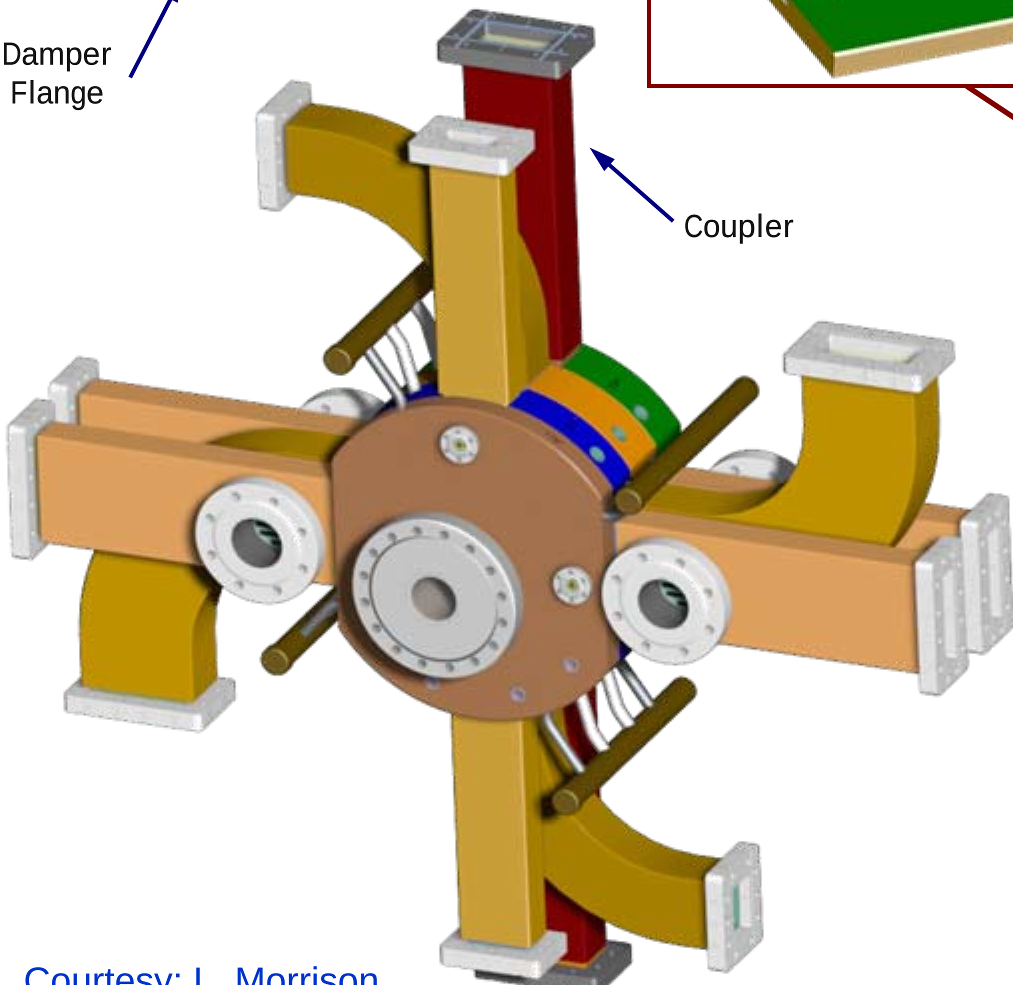
Nov 07**

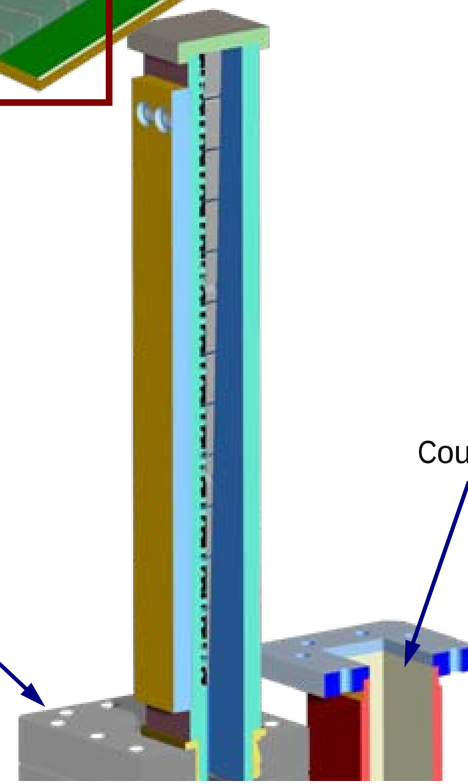
* V. Dolgashev, SLAC

** V. Dolgashev, SLAC, G. Waldschmidt, A. Nassiri





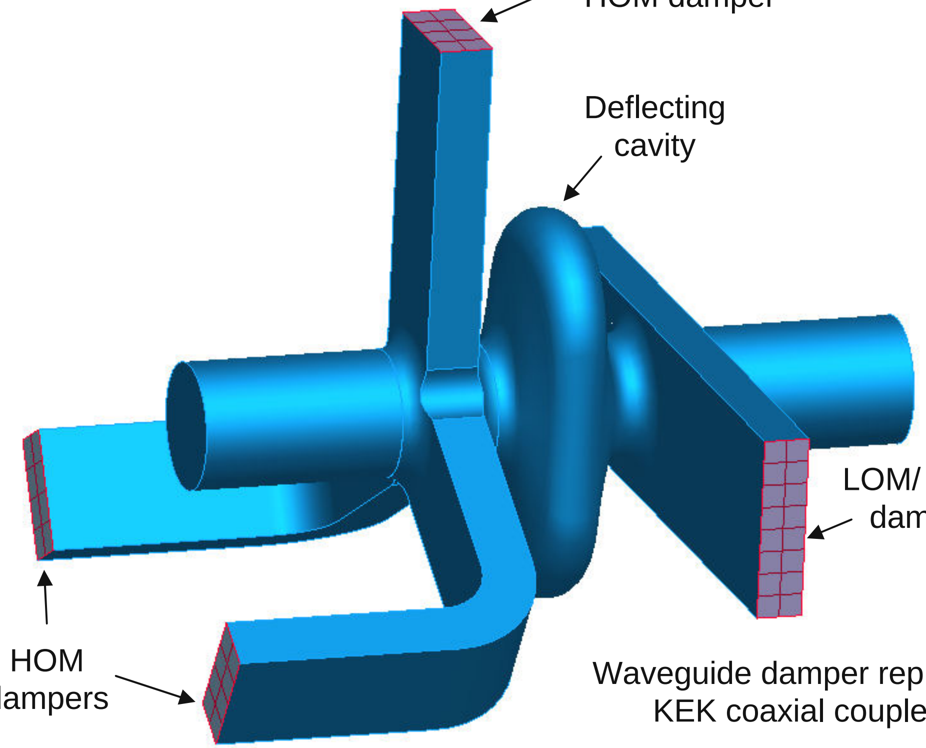




Courtesy: L. Morrison

APS 2.8 GHz Single-Cell Deflecting Cavity

Frequency (GHz)	2.815
Deflecting Voltage	4 MV * 2
Qo (2K)	$3.8 * 10^9$
G	235
R_T / Q (Ω/m)	37.2
Beam radius	2.5 cm
No. Cavities	12 * 2
Operation	CW
Beam Current (mA)	100
E_{sp}/V_{defl} (1/m)	83.5
B_{sp}/V_{defl} (mT/MV)	244.1



Compact single-cell cavity / damper assembly

SCID ACTIVITIES

- Nb_3Sn conductor and undulator model current density and magnetic field studies
- Fabrication and yoke studies.
- Magnetic measurements.
- Cryogenic studies.
- R&D on wire insulation.
- LDRD supported helical undulator studies.

Status of SCID developments

- SCID R&D Program using Nb_3Sn wire is progressing well. Required current densities have been demonstrated on 10 to 20 period models at three different laboratories.
- More than one fabrication technique will work and a few are being tested. We will soon (a few months) be able to choose the technique easiest for manufacture and best able to meet the field requirements.
- A full-scale, 2.4-m long model will be fabricated in-house and tested in a vertical dewar (available at Fermilab).
- Magnet measurement techniques will also be tested soon at the APS and NHMFL.
- Helical undulator models have been built and successfully tested. The results are encouraging and could have important applications in future accelerator projects (ERL, FEL, ILC). This program is an LDRD funded program.