General Overview of the Advanced Light Source: A soft x-ray/VUV facility

Tuesday 23 Nov 2010 at 13:10 (00h50')

In this talk, a general overview of the Advanced Light Source (ALS) will be presented. The ALS is a third generation light source optimized for soft x-ray/ VUV science. Beamline 10.0.1 of the ALS is a good example of a VUV/EUV beamline. A detailed description of this beamline will be presented. This high resolution beamline splits in three branches serving two very different communities. One branch is dedicated to photoemission studies of highly correlated materials (solid state physics) and the other two branches are dedicated to photoionization/photoexcitation studies of atomos, molecules and clusters in gas phase. Recent research highlights conducted in all three branches will be presented in a second talk.

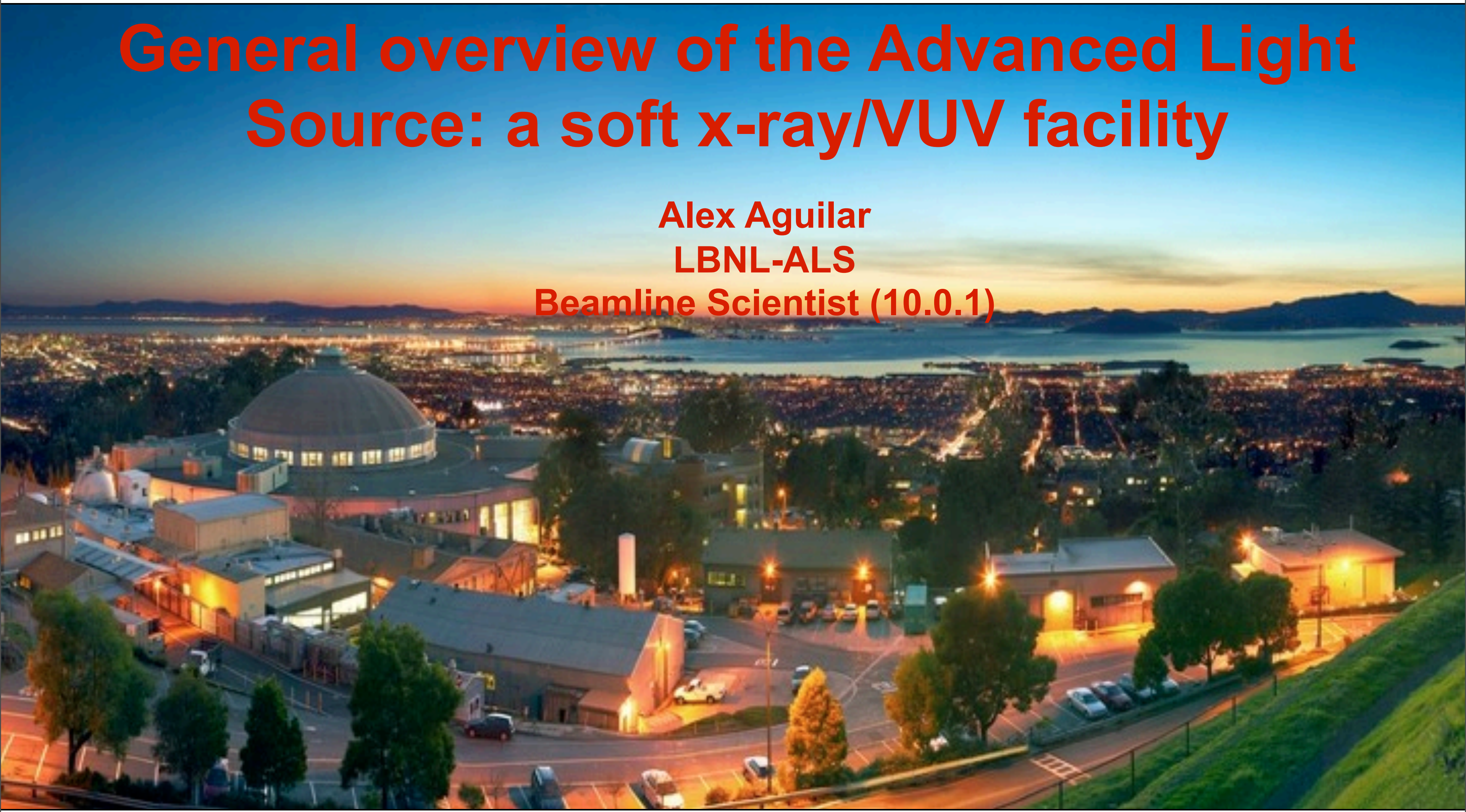
Primary authors : Dr. AGUILAR, Alejandro (LBNL-ALS)

Co-authors :

Presenter : Dr. AGUILAR, Alejandro (LBNL-ALS)

General overview of the Advanced Light Source: a soft x-ray/VUV facility

Alex Aguilar
LBNL-ALS
Beamline Scientist (10.0.1)



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- Bend magnets and Super-bend magnets
- Insertion Devices
  - In Vacuum
  - EPU and QEPU
- Top-Off mode
- Future upgrades
- Beamline 10.0.1
- Summary

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For more information, contact

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A little bit of history…

Original building completed in 1942.

Designed by Arthur Brown, Jr. (designer of the Coit Tower in San Francisco).

Was built to house Berkeley Lab's namesake E. O. Lawrence's 184-inch cyclotron (Nobel Prize in 1939).

Today, the expanded building houses the Advanced Light Source (ALS), a third-generation synchrotron and national user facility.

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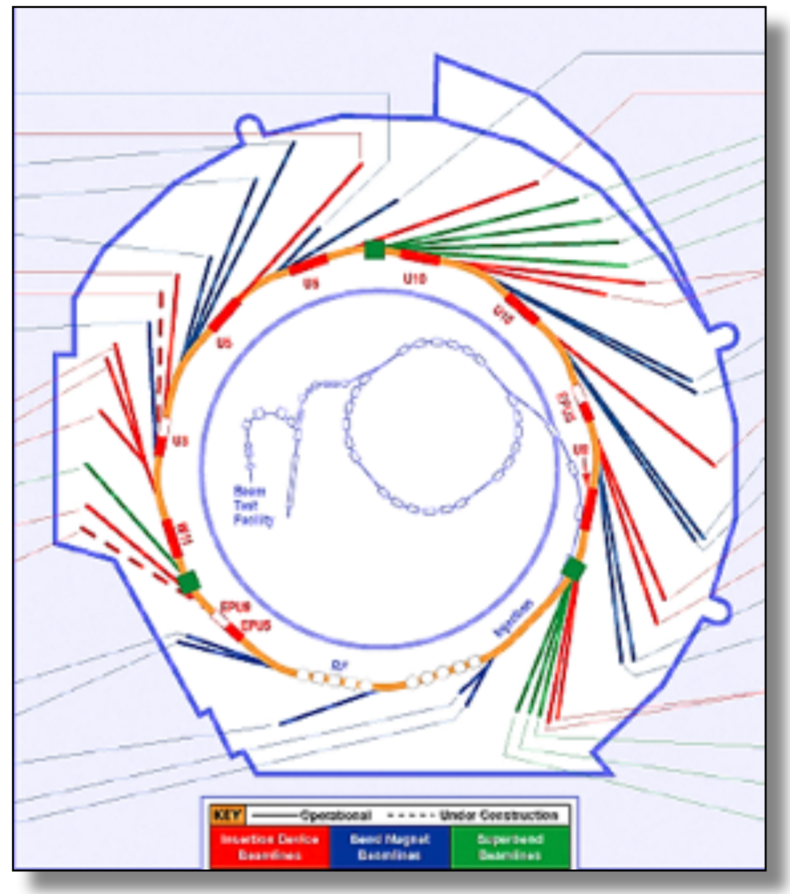
The Advanced Light Source

Lawrence Berkeley National Lab

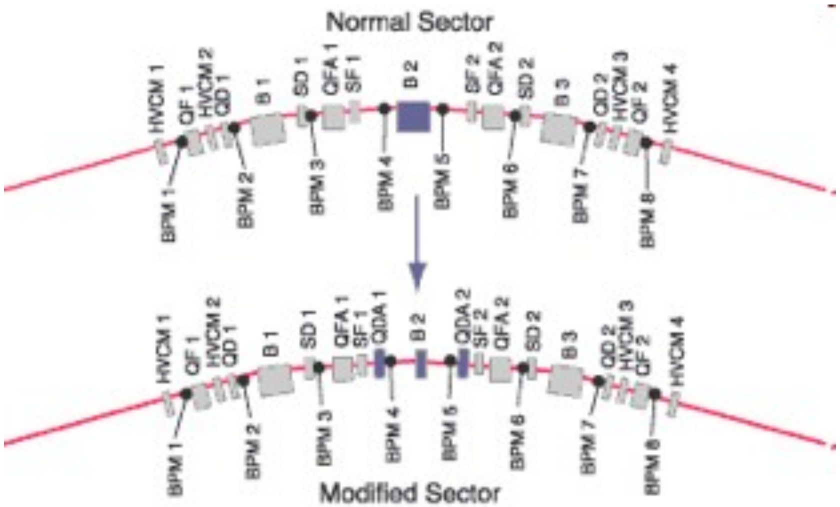
- 3rd generation synchrotron light source
- Commissioned in 1993, $99.5 million
  - Operating budget $25 million
  - 1500 users
- Present (2010)
  - Operating budget $52 million
  - 2800 users
- 1.9 GeV, 0.5 A electron storage ring
- 40 operating beam lines
- 50 possible beam lines

Storage ring parameters

Electron beam energy	1.9 GeV
Injection energy	1.0-1.9 GeV
Beam current	500 mA in multi-bunch
Filling pattern	256-320 bunches; possibility of one or two 5-6 mA "camshaft"
Bunch spacing: multi-bunch	2 ns
Bunch spacing: 2-bunches	328 ns
Circumference	196.8 m
Straight sections	12
Insertion devices	11
Beam sizein streight sections (multi-bunch)	310 μm horiz. x 16 μm vert.



ALS storage ring lattice



12 straight sections

- 12 arc-shaped sections
    - Bend magnets (B),
    - Quadrupoles (QFA, QDA, QF, and QD)
    - Sextupoles (SF and SD).
- Three of the arc sections contain superconducting bend magnets (superbends).

Bending magnets and superbend magnets

9 Bending magnets feeding 19 beamlines

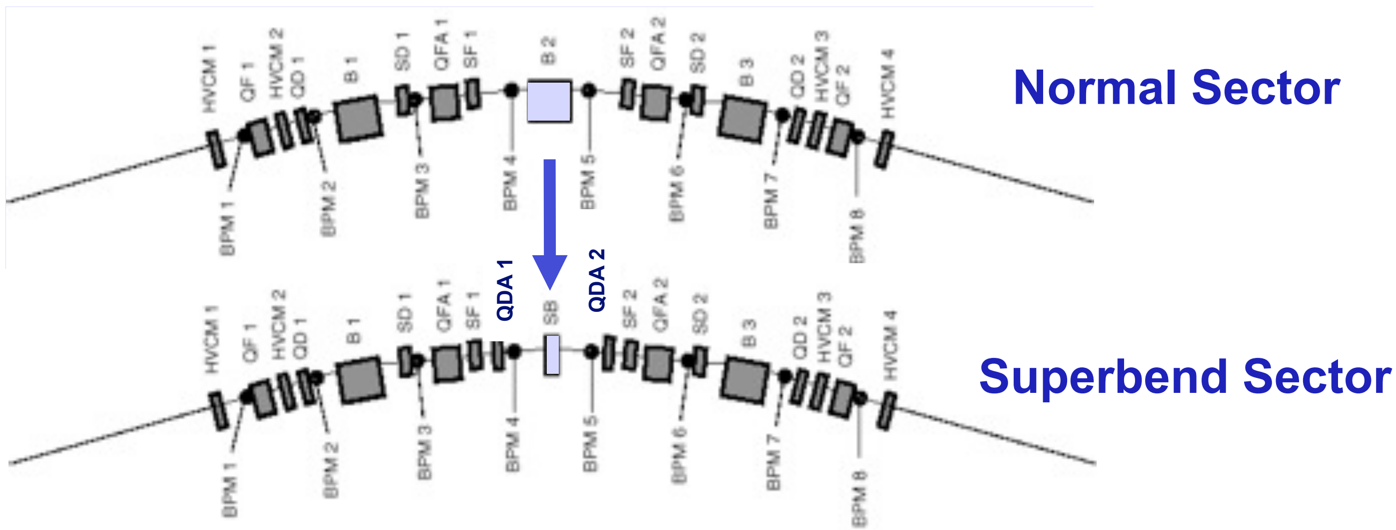
Infrared (IR) Spectroscopy	X-Ray Tomography
X-Ray Microscopy	Magnetic Spectroscopy
Materials Science	Diagnostic Beamlines
Atomic and Molecular Physics	Chemical Sciences
X-Ray Fluorescence Microprobe	Small Molecule Crystallography
EUV Lithography Mask Inspection	MicroXAS

3 Super-bend magnets feeding 8 beamlines

Protein Crystallography	Tomography
High Pressure	X-Ray Micro-diffraction

What is a super-bend magnet and what is it for?

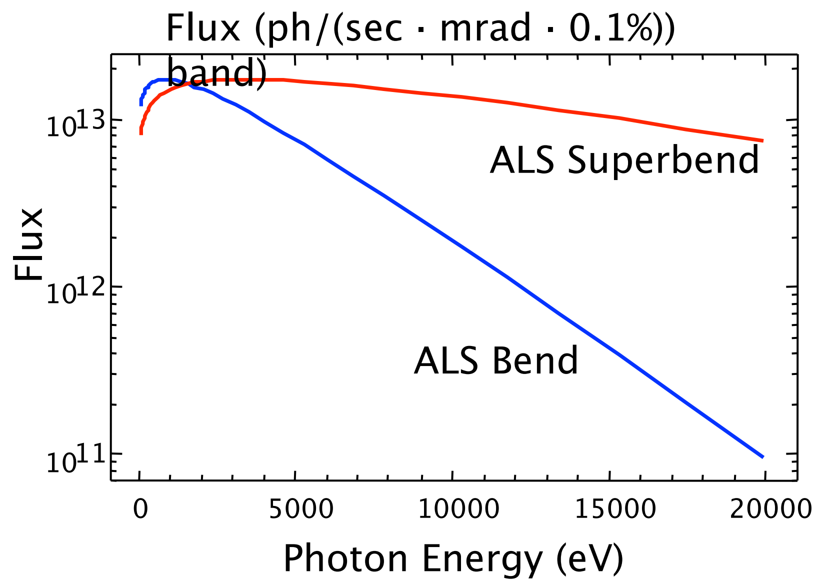
- Expand the capability and capacity of the facility to serve the Hard X-ray community
- Do not compromise the ability of the facility to serve the UV and Soft X-ray community

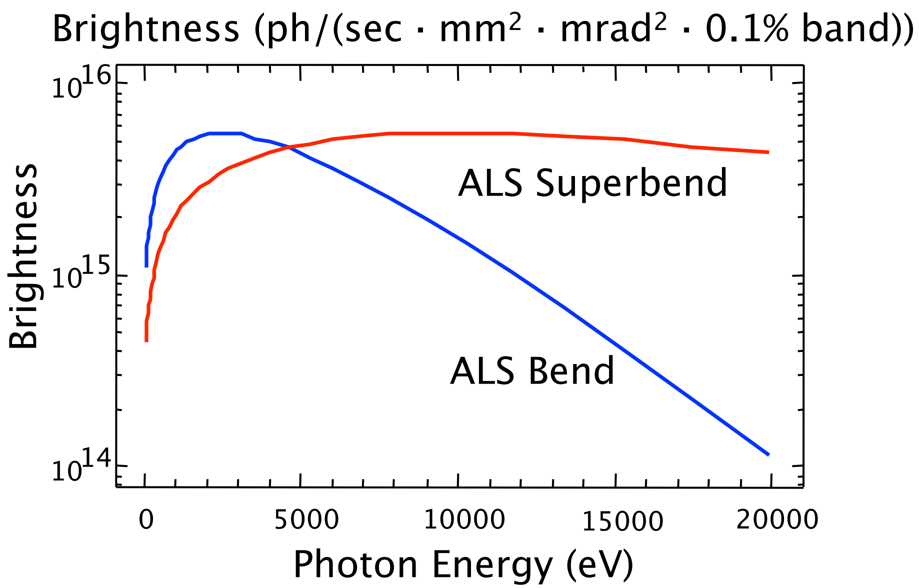


Solution

- In 3 of the 12 ALS sectors, replace an existing 1.3 Tesla bending magnet with a 5 Tesla bending magnet

Super-bend magnets vs. Bend magnet





- Excellent source of hard X-rays — up to 40 keV
  - Well suited for protein crystallography and other hard X-ray applications
    - Small beamsize in the center bend (σ_x = 100 μm) is a good match for many crystals
- High Capacity
  - 3 Superbends yield up to 12 beamlines without using any straight sections

Installing the first Superbend (Aug. 21, 2001)

Insertion Devices

1 Wiggler (11.4-cm-period) feeding 3 beamlines

Protein Crystallography

4 Elliptical Polarization Undulators. 3 are 5-cm-period and 1 is a 9-cm-period

Magnetic Spectroscopy	Molecular Environmental Science
High Resolution spectroscopy of complex materials	Photoemission electron microscope and Soft X-ray scattering

7 Undulators. 2 (U3), 2 (U5), 1 (U8) and 2 (U10)

Ultrafast/Femtosecond Dynamics	Surface, Materials Science
Chemical Dynamics	Diffraction Imaging
Correlated Materials	Atomic and Molecular Physics
EUV testing and interferometry	ARPS

New Insertion Devices

Quasiperiodic Ellipically Polarizing ID
(MERLIN)

In-Vacuum ID
(Femtoslicing)

Ellipically Polarizing ID
(PEEM-III)

In-Vacuum Insertion Device

S. Marks et al.

Specifications
Magnetic gap 5.5 mm
Period 30 mm
No. periods 48
B_o 1.45 T

Smallest ID Gap

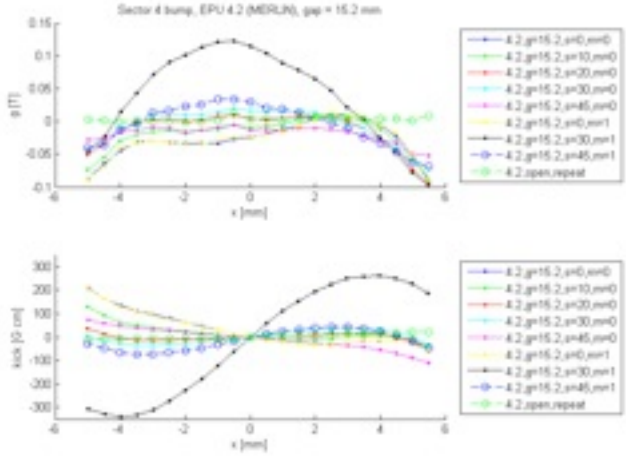
Poster

MERLIN QEPU

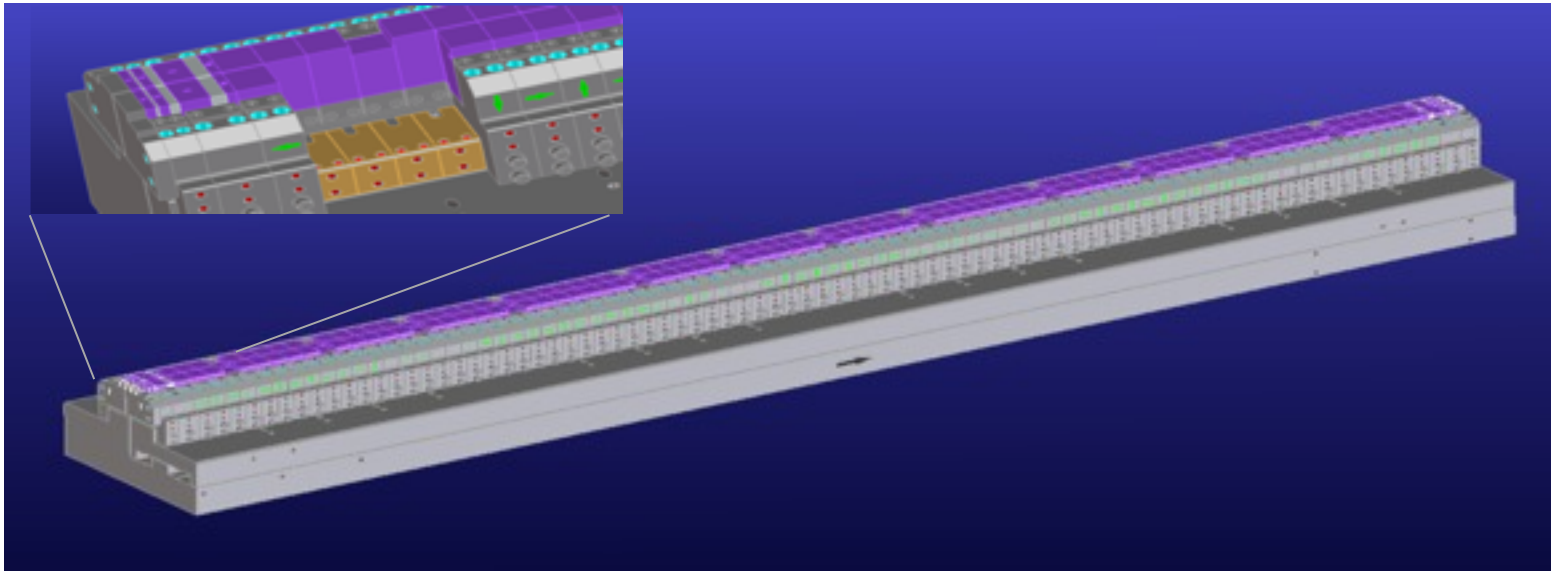
- Installed in Fall/Winter 2007
- Commissioned in January 2008
- First Light in February 2008

Initial Shimming Results are Very Encouraging

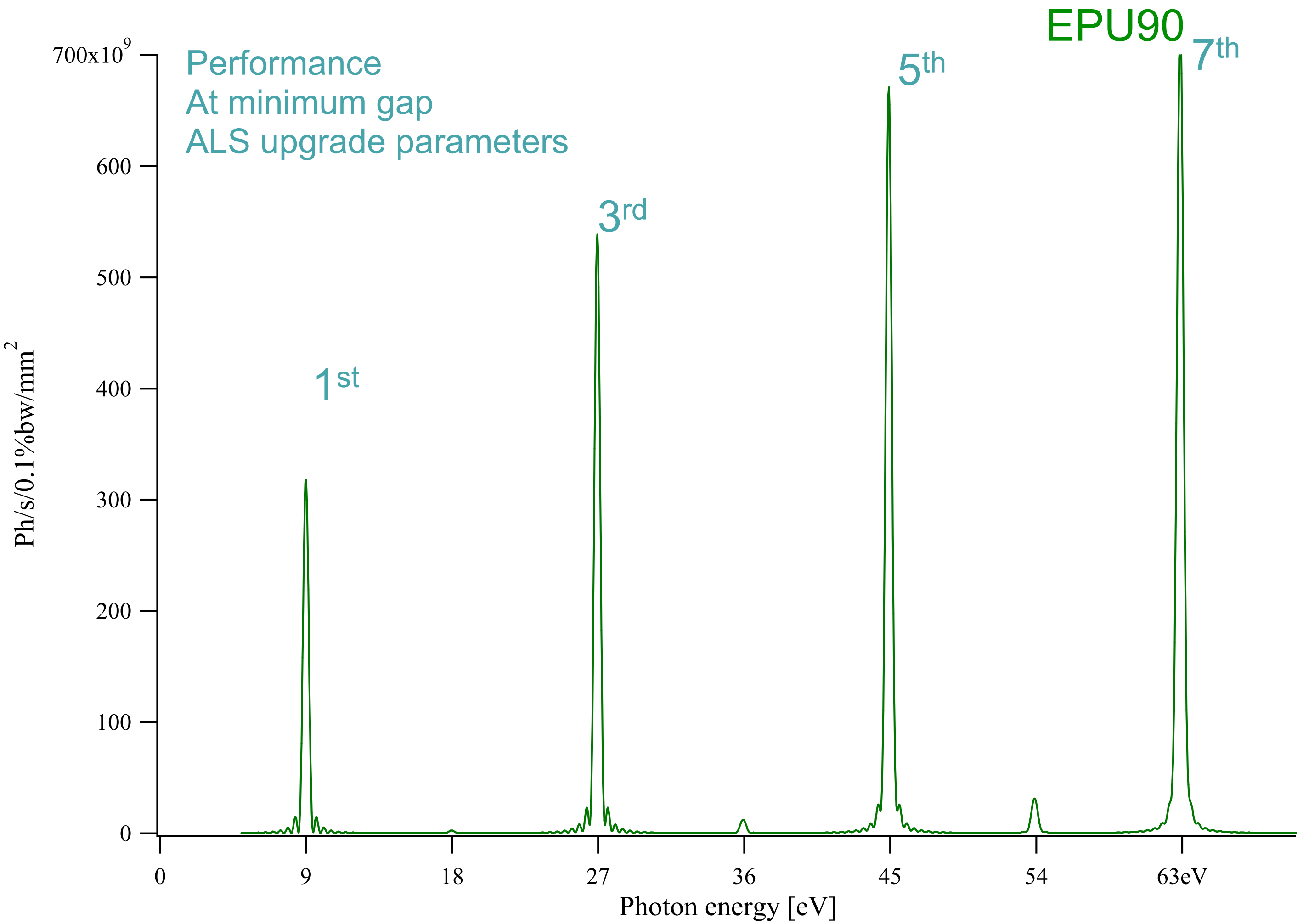
- Dynamic Multipole Shimming Close to Optimal



- # Why a Quasi periodic Undulator (QEPU)
  - For low-energy undulators, the inability of monochrometers to distinguish integral multiples of the fundamental can result in unwanted excitations of electron states.
  - A QEPU is an efficient yet simple scheme is proposed that reduces the photon flux at integer multiples of the fundamental

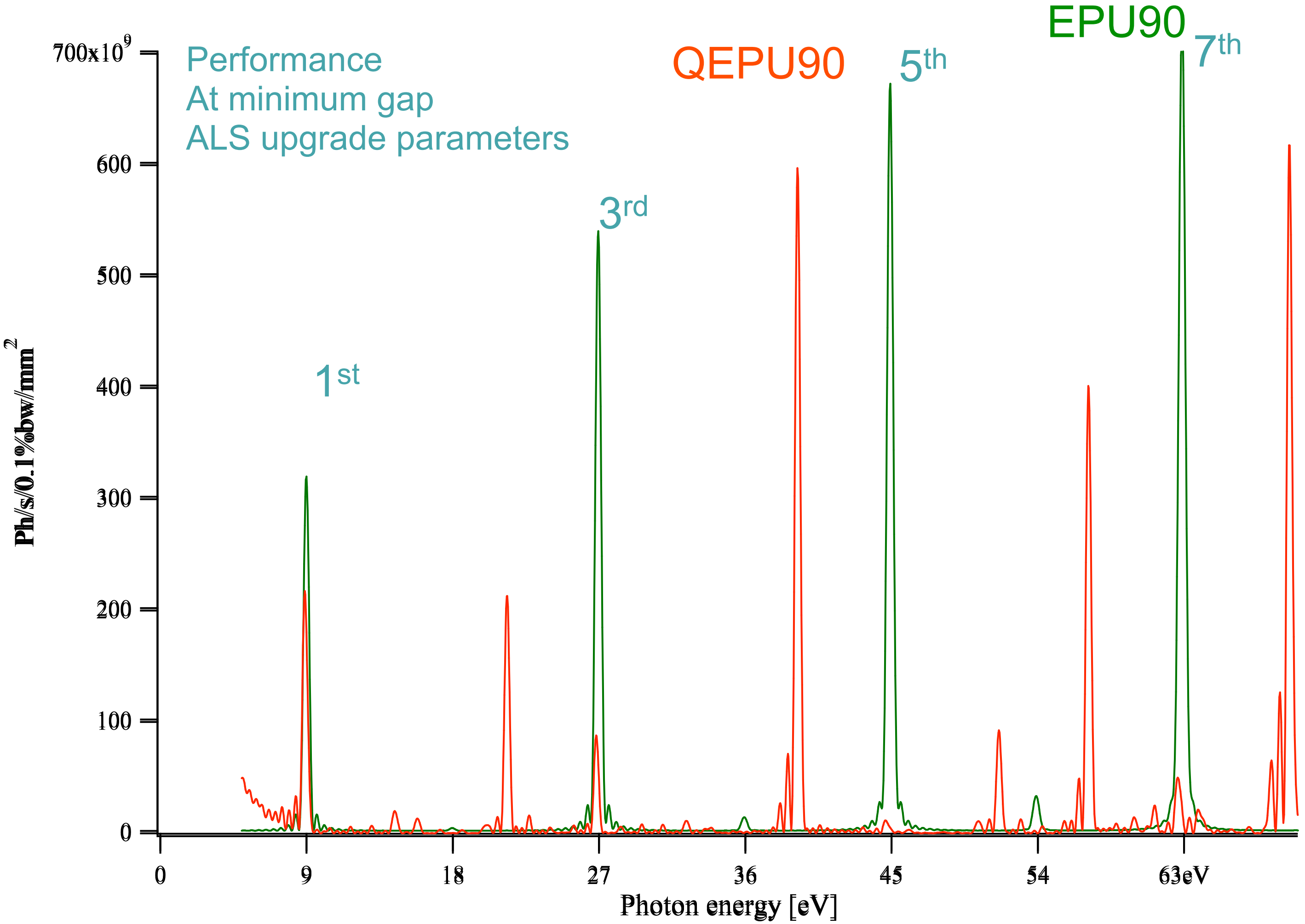


MERLIN Quasi-periodic Undulator (QEPU) Reduces Flux in Higher Harmonics



R. Schlueter, S. Prestemon, S. Marks

MERLIN Quasi-periodic Undulator (QEPU) Reduces Flux in Higher Harmonics



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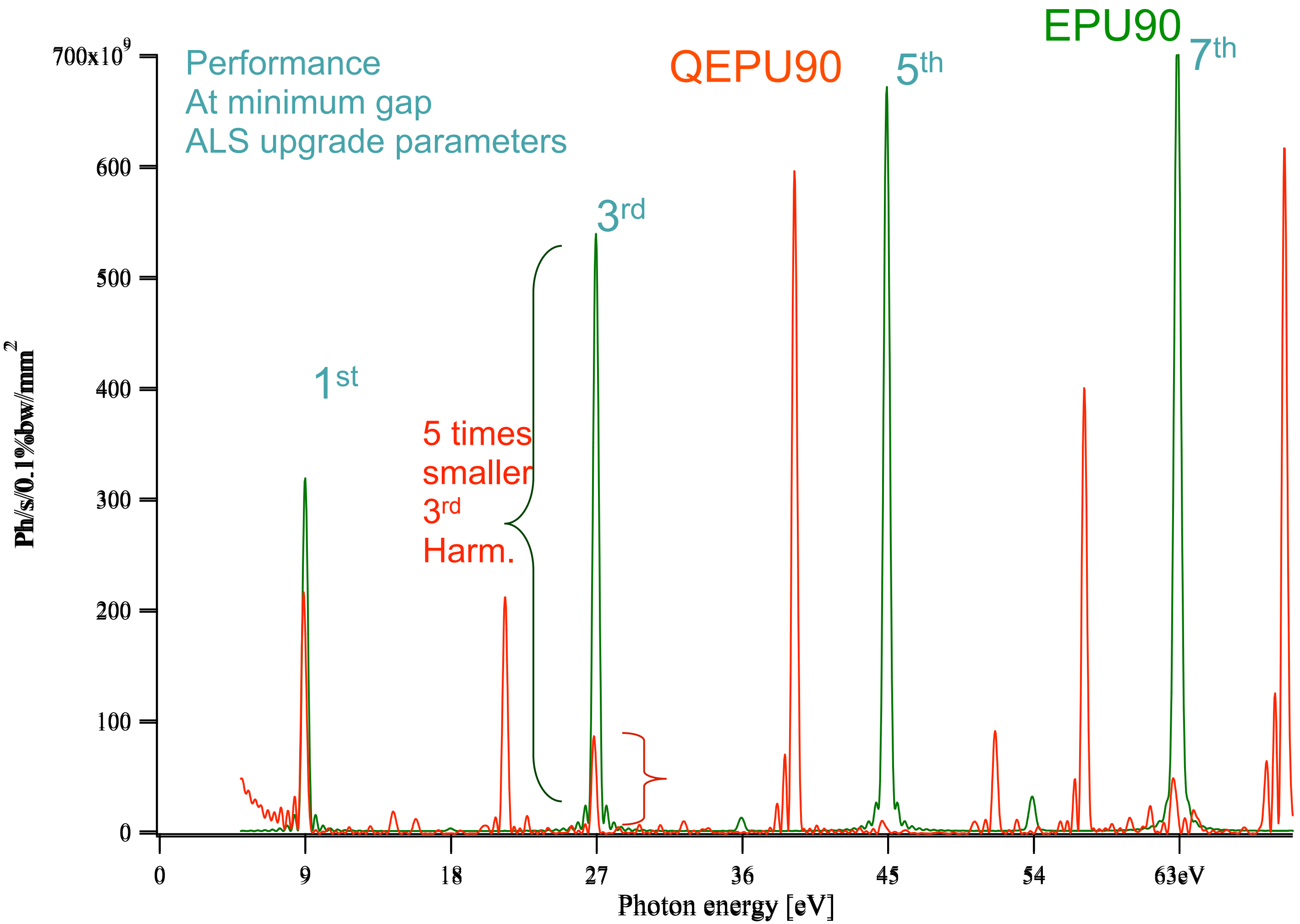

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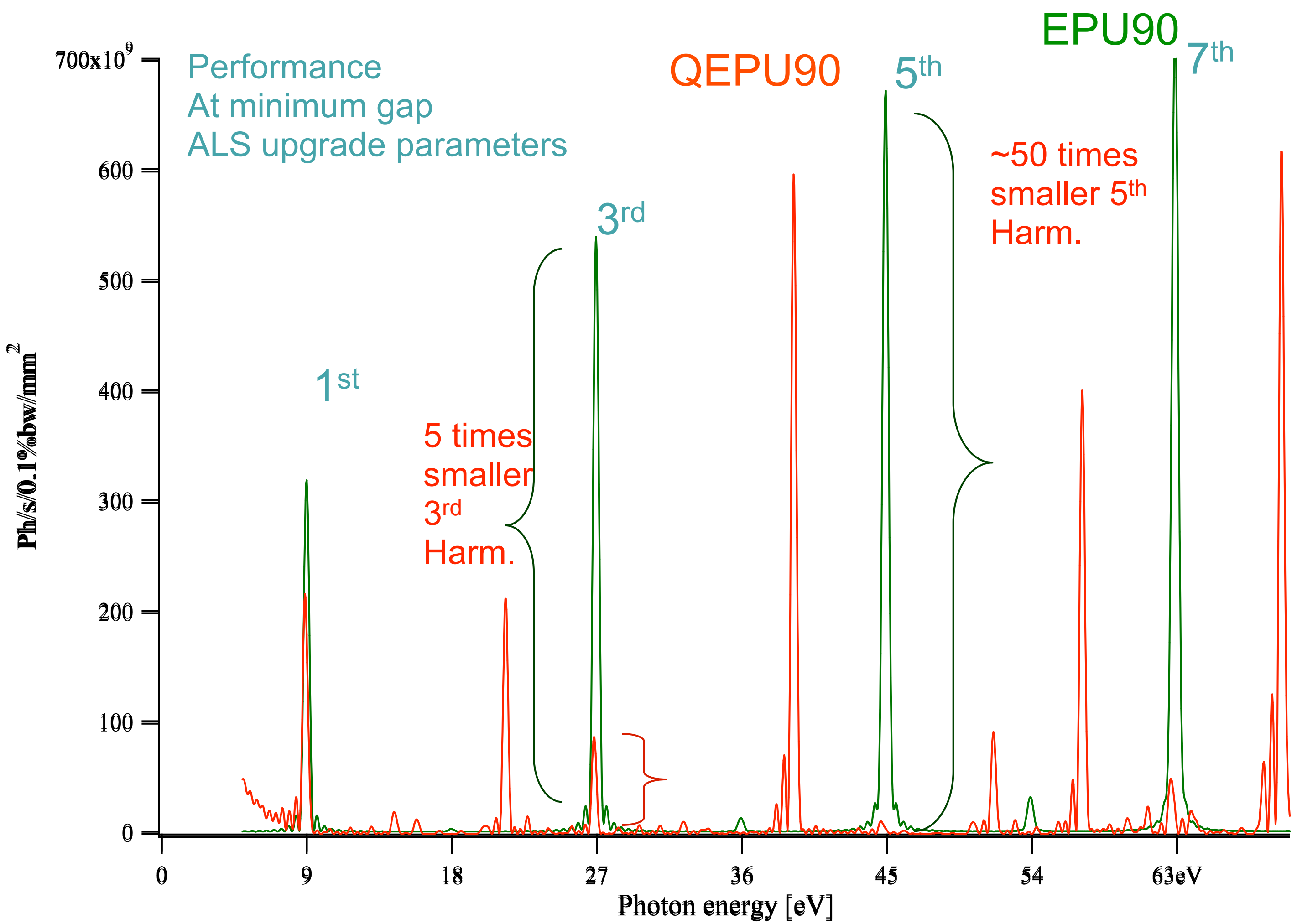

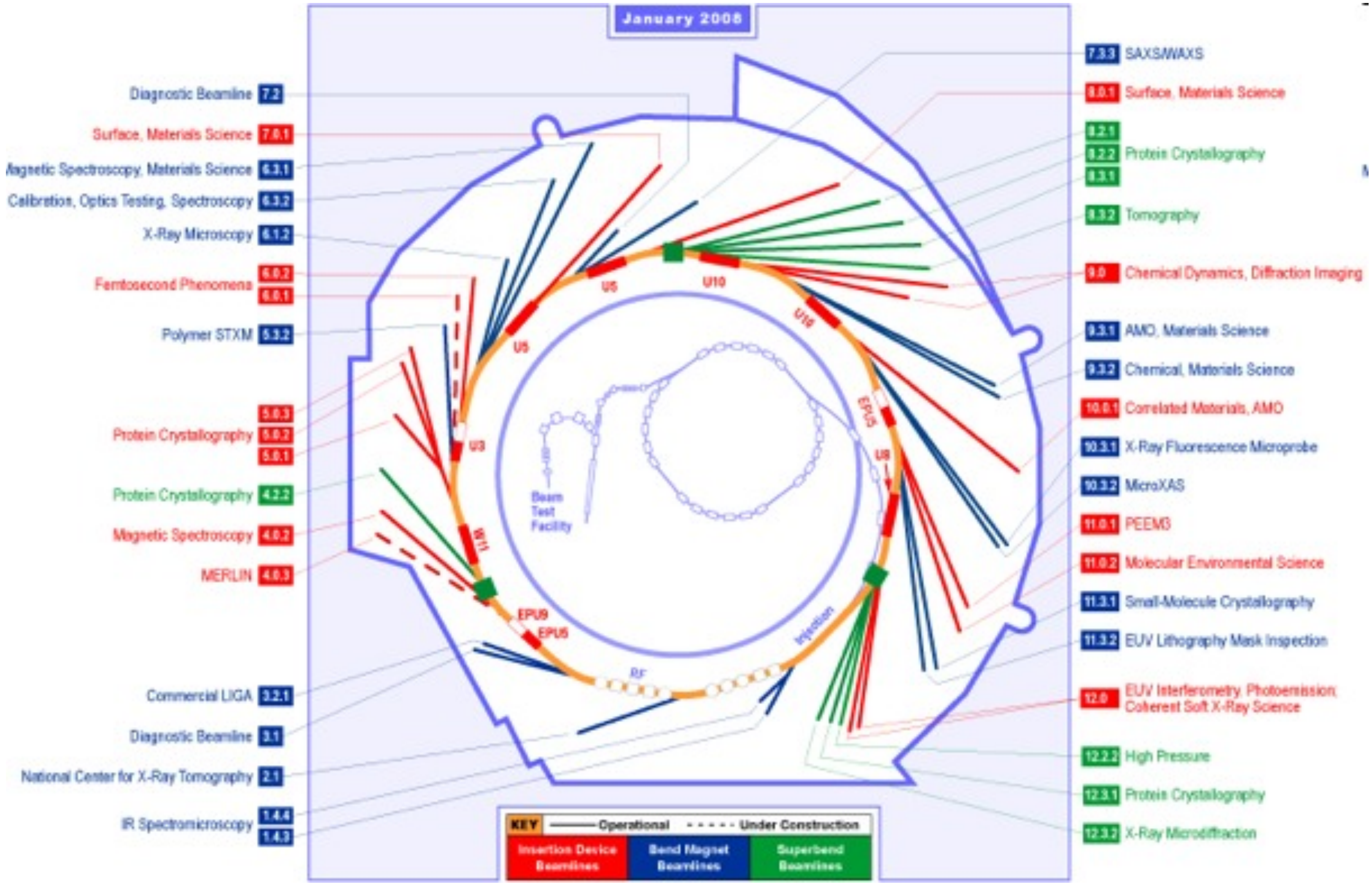

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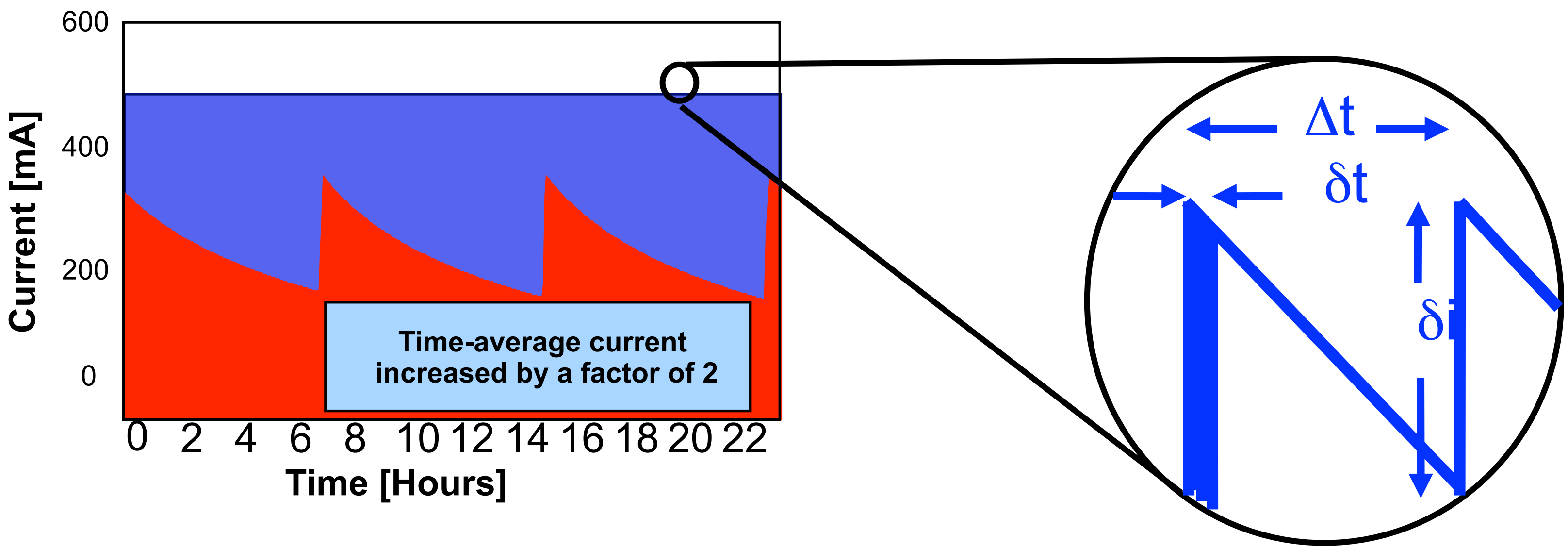
Top-off mode

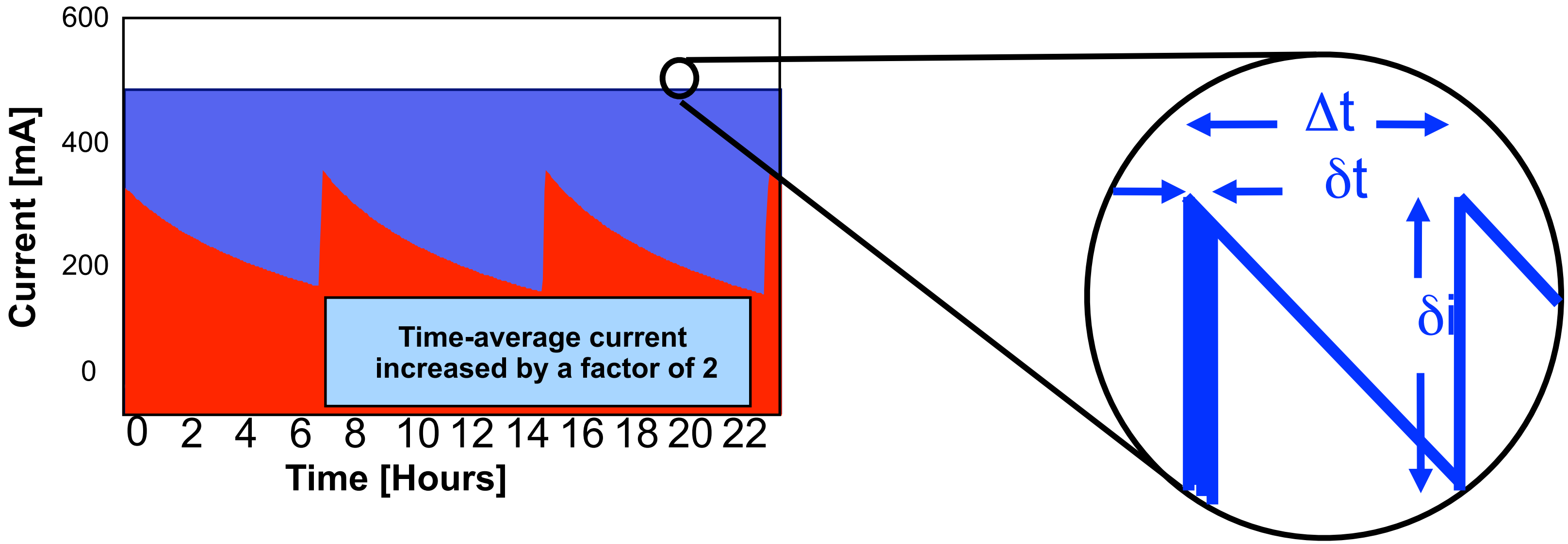


coupling	δi	Δt	σ_h	σ_v	$\sigma`_h$	$\sigma`_v$
After Top-off	**1.5mA**	**32.0s**	**298μm**	**8μm**	**22μrad**	**3μrad**

In top-off mode the plan is to run with

- 2 times higher time averaged current
- smaller vertical beam size – less than half the present size

Top-off mode



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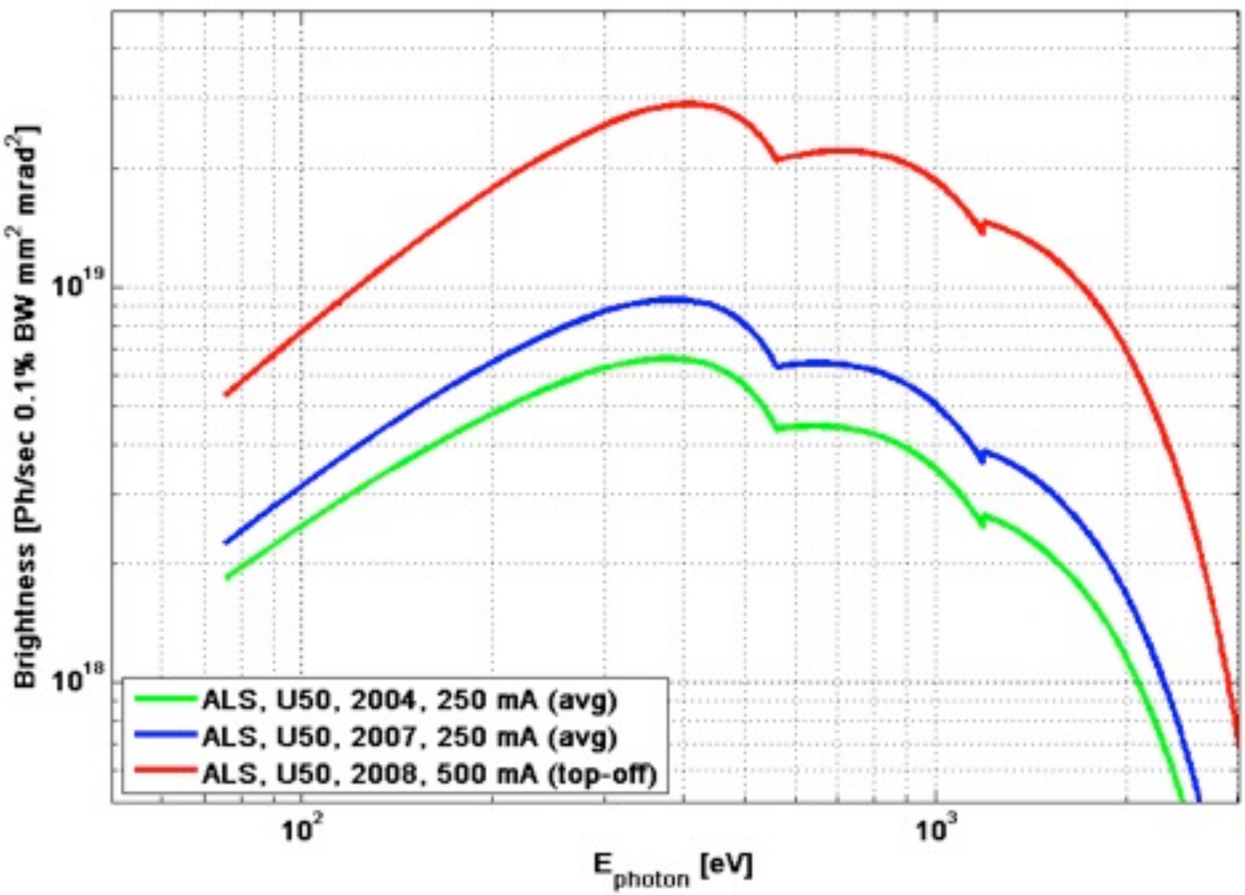
After Top-off	**1.5mA 32.0s 298μm 8μm 22μrad 3μrad**

In top-off mode the plan is to run with

- 2 times higher time averaged current
- smaller vertical beam size – less than half the present size

Top-off mode has opened the door to large increases in brightness and improvements in beam stability

Brightness Before and After Top-off



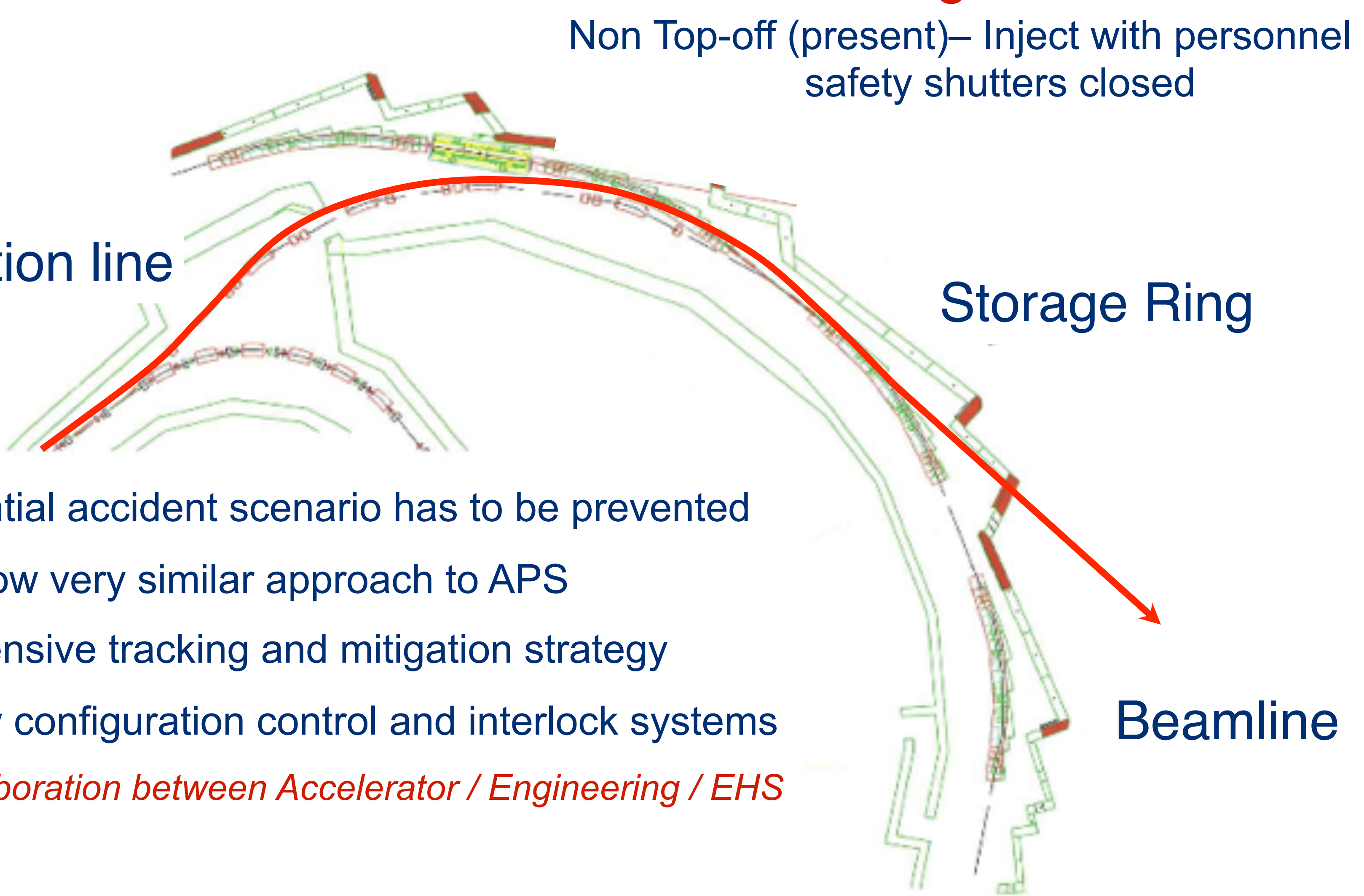
Before and After operation in Top-off mode

Before Top-Off	After Top-Off

• Injection at 1.5 GeV and then ramp
• Inject with insertion devices open
• Average beam current was 250 mA
• Vertical emittance was 150 pm rad
• Lifetime was 8 hours at 400 mA
• Injection period every 2 to 8 hours
  – 1 Hz injection for 4 minutes
    • From 200 to 400 mA
• Photon shutters were closed during injection
	• Full energy injection (1.9 GeV)
	• Inject with insertion devices closed
	• Average beam current is 500 mA
	• Vertical emittance is 30 pm rad
	• Lifetime is about 3 hours at 500 mA
	• Injection period about every 30 seconds
	  – 1 pulse
	    • From 498.5 to 500 mA
	• Photon shutters remain open during injection

Top-off Radiation Issues/challenges

Injected e- beam cannot exit the shielding



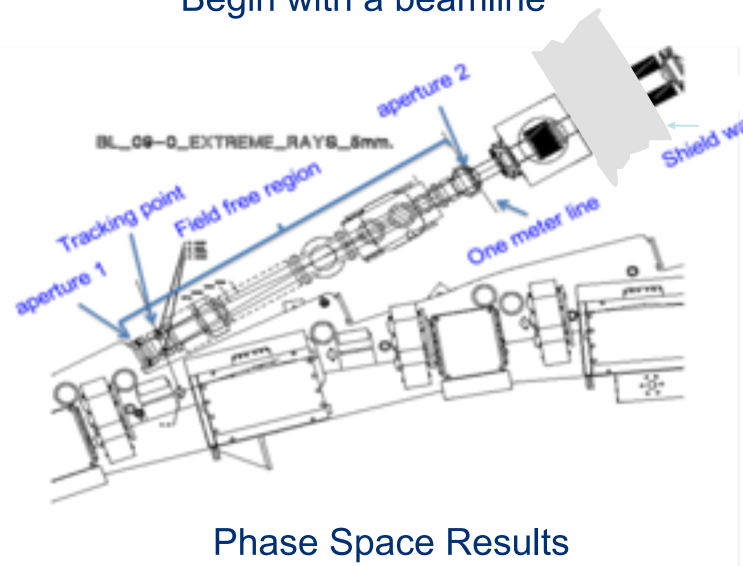
This potential accident scenario has to be prevented

- Follow very similar approach to APS
- Extensive tracking and mitigation strategy
- New configuration control and interlock systems

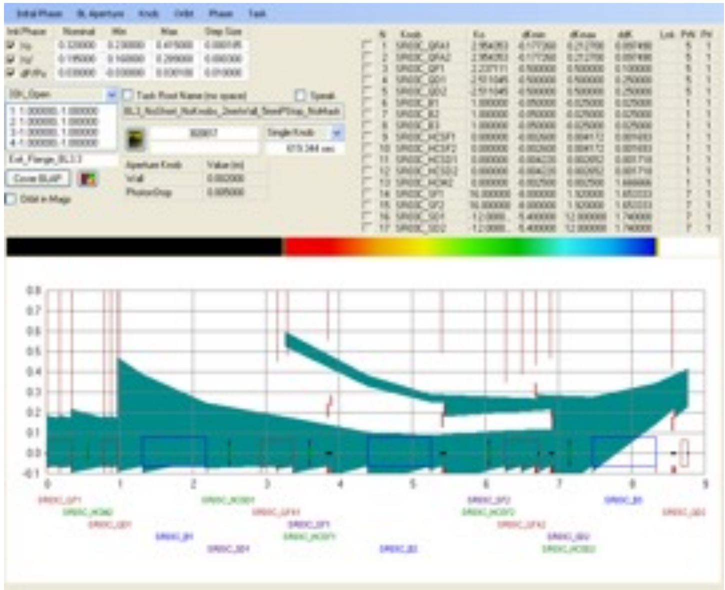
Large collaboration between Accelerator / Engineering / EHS Staff

From Tracking to Requirements

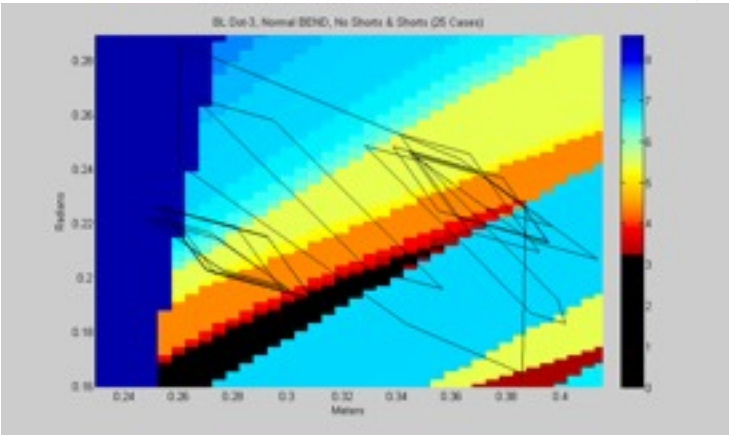
Begin with a beamline



Backtracking Simulator



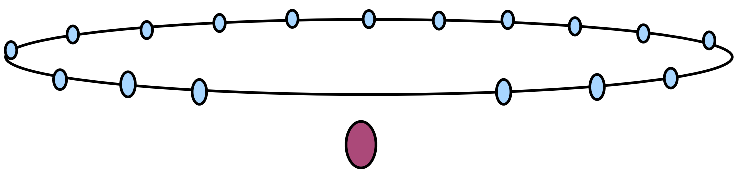
Phase Space Results



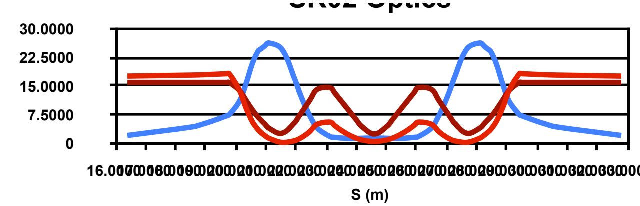
Mitigation : Interlocks and aperture

Some upcoming upgrades at the ALS

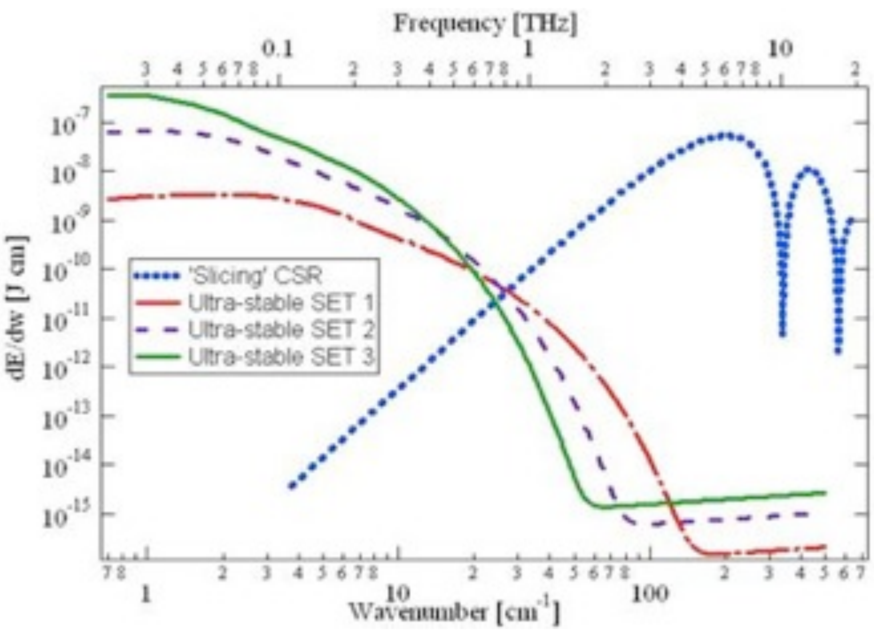
Flexible Bunch Frequency



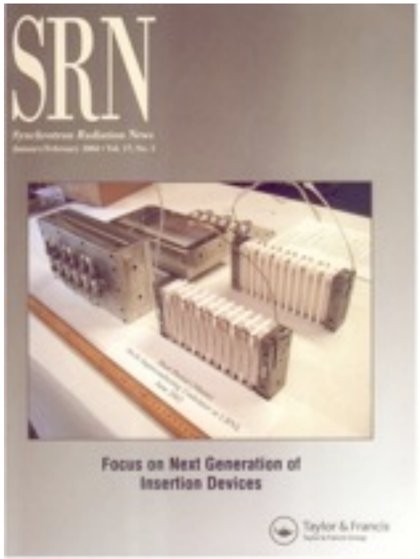
High Brightness Lattices



Terahertz

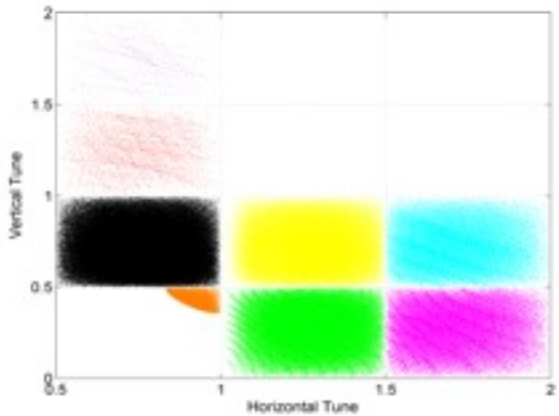


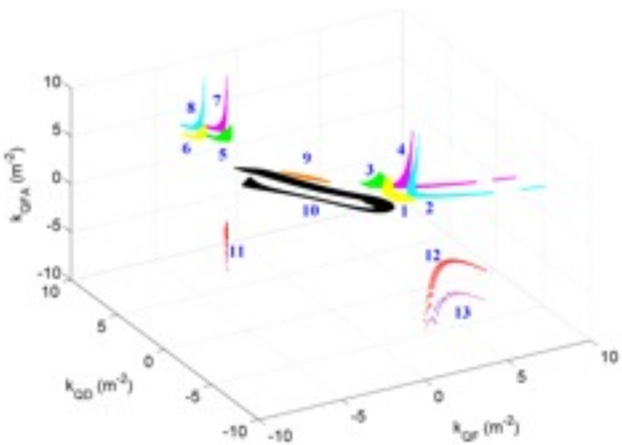
Superconducting IDs



Optimized Lattice Settings

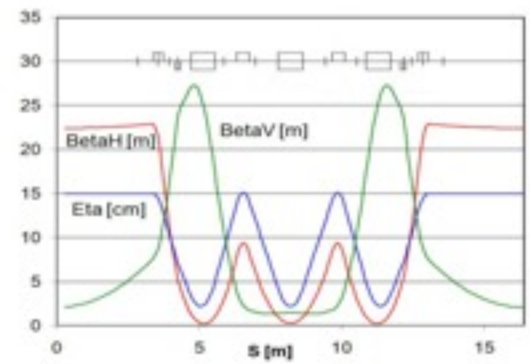
Global Lattice Exploration

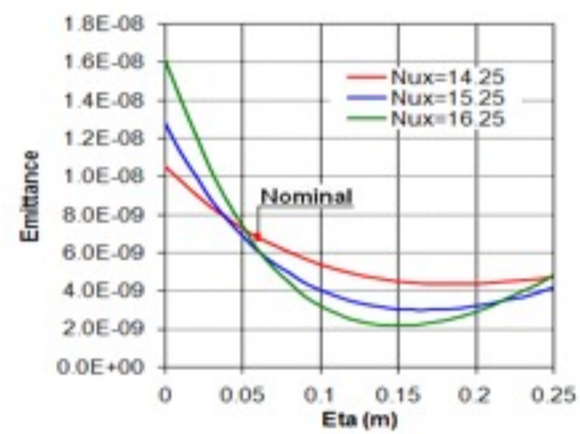




D. Robin, W. Wan, F. Sannibale, V. Suller,
Phys. Rev. ST Accel. Beams 11, 024002 (2008)

Ultralow Emittance Lattice



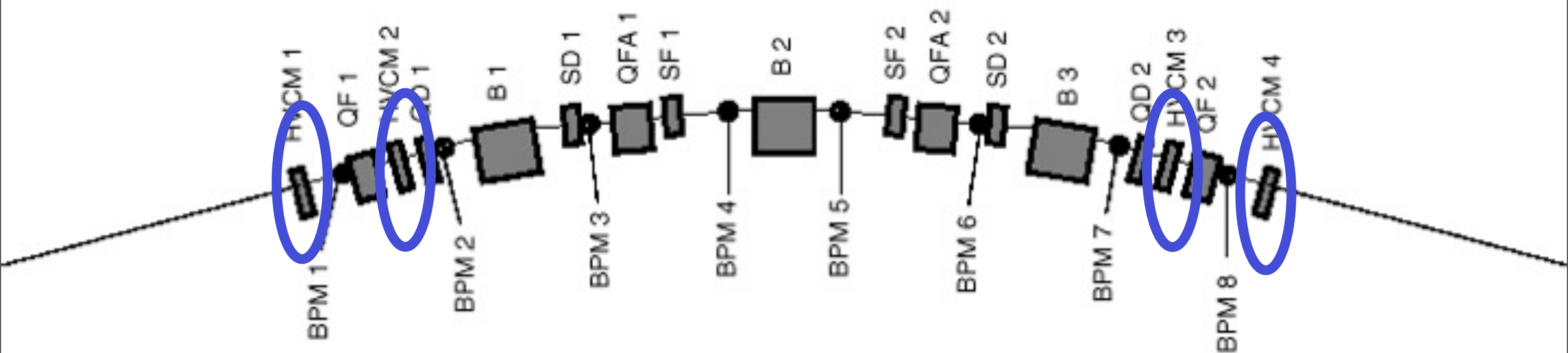


H. Nishimura, et al, *2007 Particle* Accelerator Conference, Particle (2007)

Poster

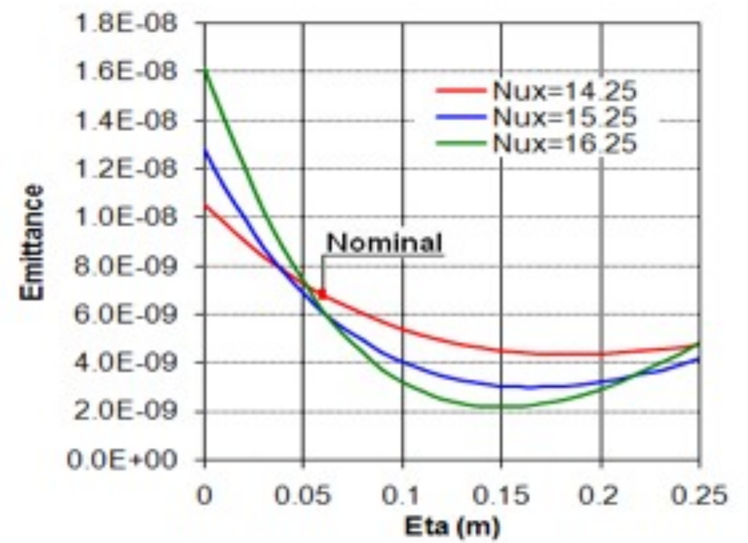
Ultralow Emittance Lattice

Install New Sextupoles



- Horizontal emittance is reduced to 1/3 from 6.3 nm rad to 2.2 nm rad
- Brightness is inversely proportional to emittance

Emittance would be as low as any existing light source



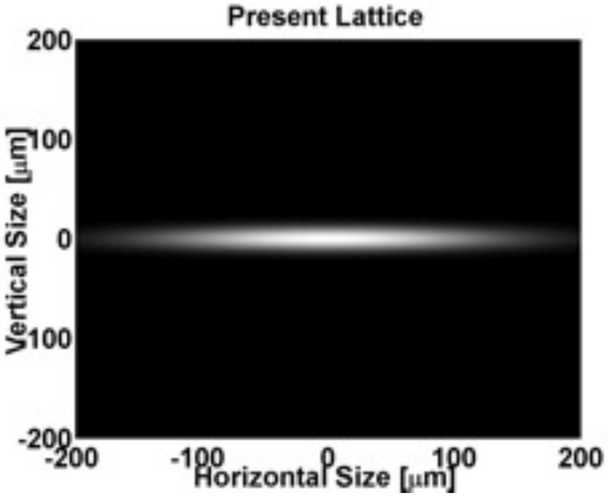
Modest Lattice Upgrade with Big Benefits

- ***Brightness***
  - ***More than 3 times the brightness for central bend and Superbend beamlines***
  - ***Up to 2 times (with more speculative lattices even more) the brightness for soft x-ray beamlines***

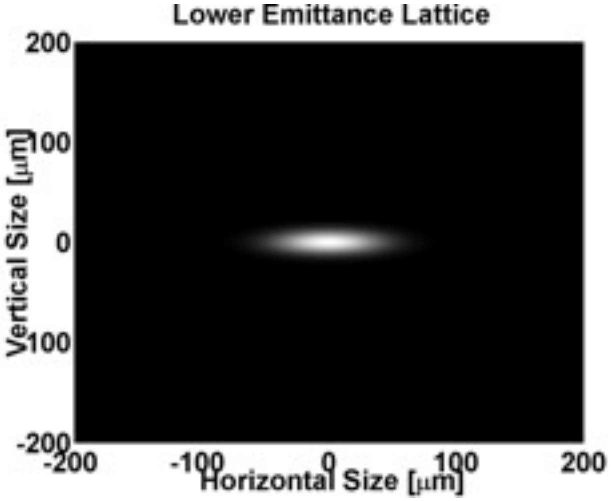
- *Additional Benefits : Short Pulses*
  - *500 MHz picosecond pulses at reduced currents*
  - *Coherent Terahertz Radiation*

Superbend Beamsize

Horizontal Beamsize at Superbends reduced to 30%



223 microns (FWHM)



68 microns (FWHM)

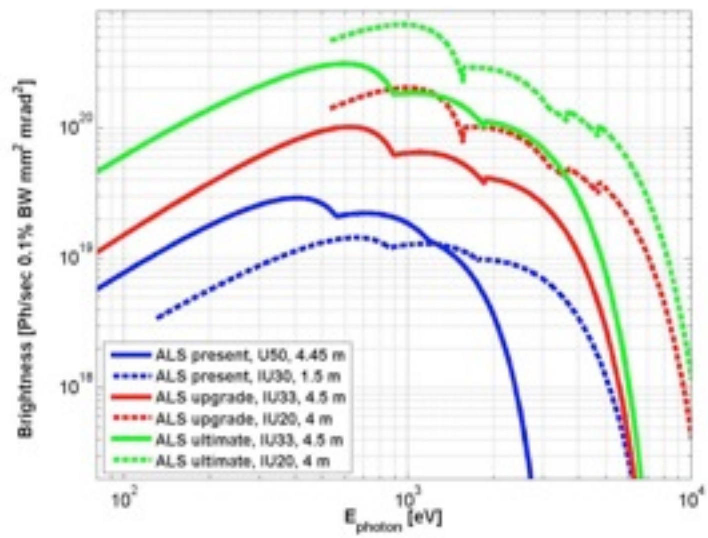
New sextupoles = increasing the brightness

Led by Christoph Steier and Arnaud Madur

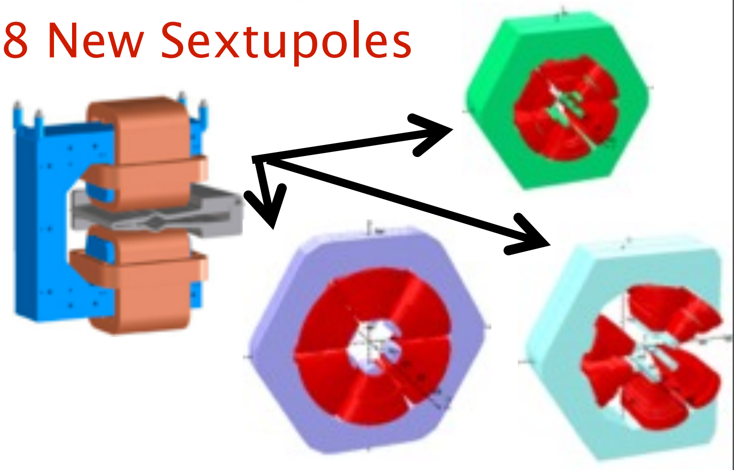
- Horizontal emittance is reduced by factor of 3 to 2.2 nm rad

Of existing light sources, only PETRA-III has a lower emittance

- Brightness is inversely proportional to emittance
- Project received funding in summer 2009
- Passed comprehensive project review
- Close to awarding contract for magnets
- On track for completion of project by end of FY13



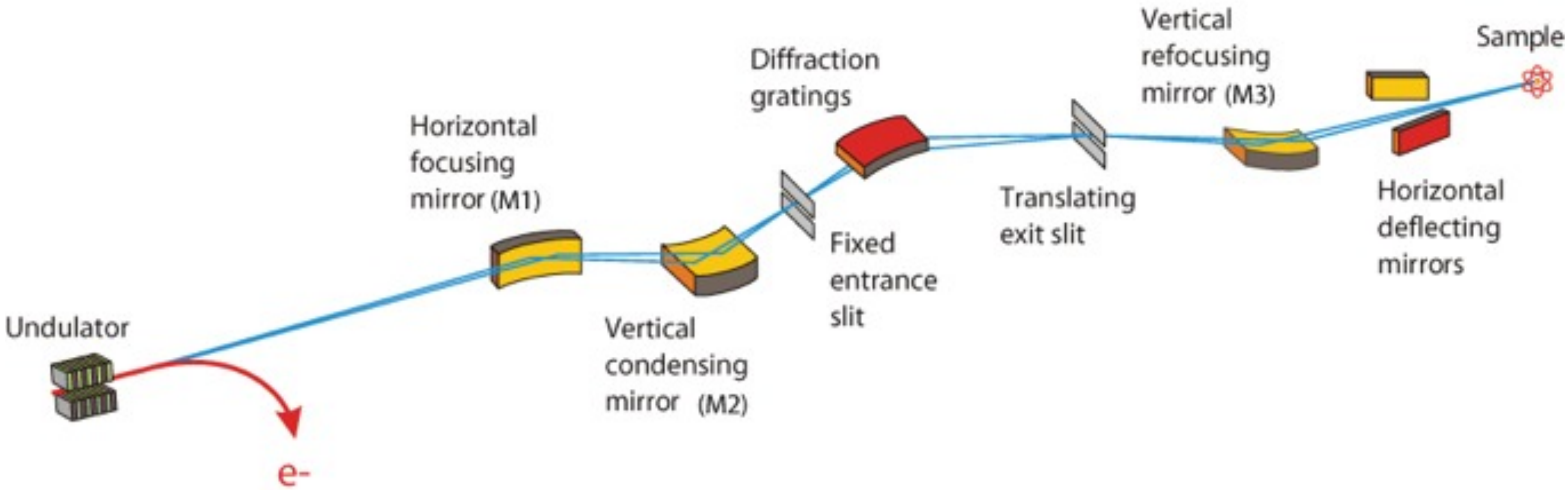
48 New Sextupoles

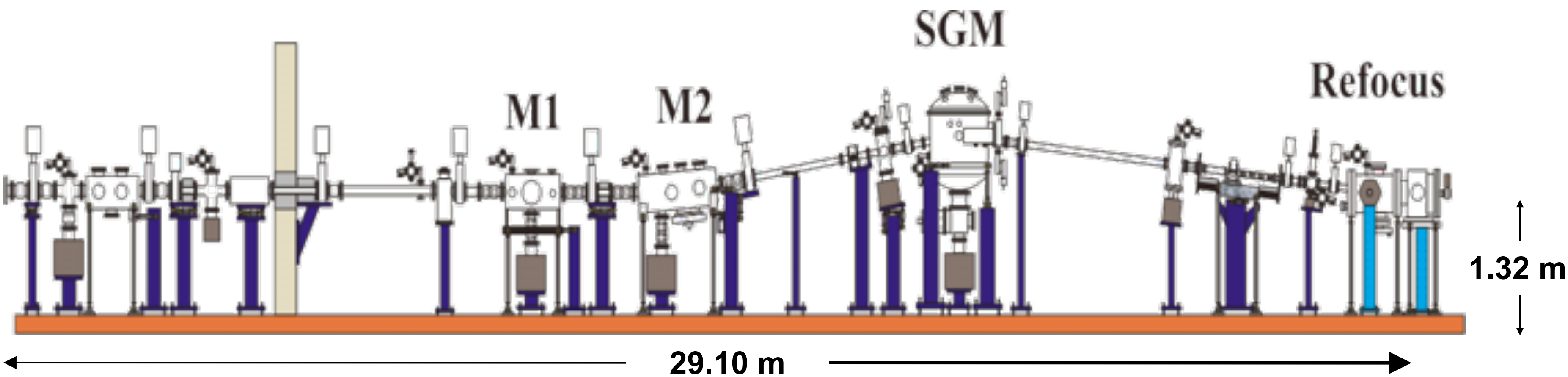


$5.8M (ARRA)funding from BES

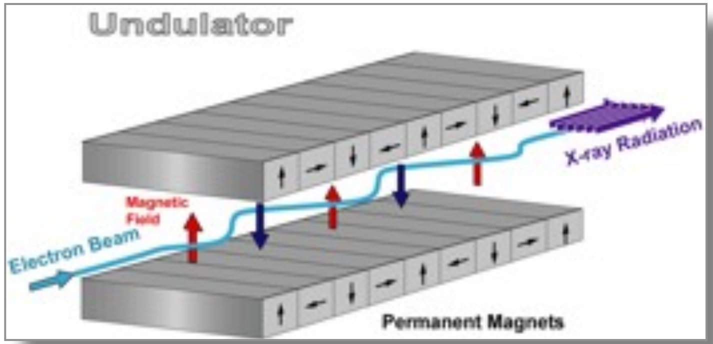
H. Nishimura, et al.- Proceedings of the 2007 PAC Co

Schematic Drawing of Beamline 10.0.1





Beamline 10.0.1

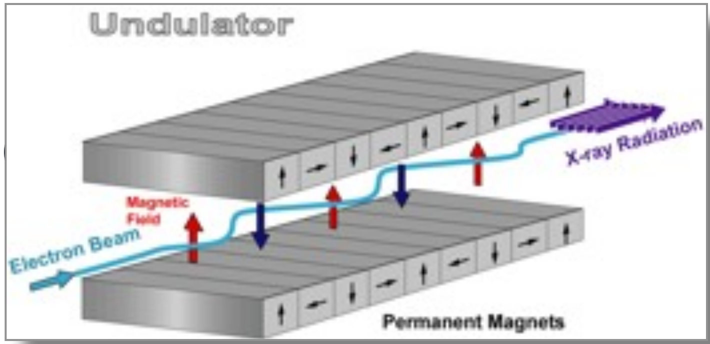


www-xfel.spring8.or.jp/cband/j/Undulator.htm

Beamline 10.0.1

U10 Undulator

- 10.0 cm period, 43 periods
- 12 – 1500 eV energy range (@ 1.9



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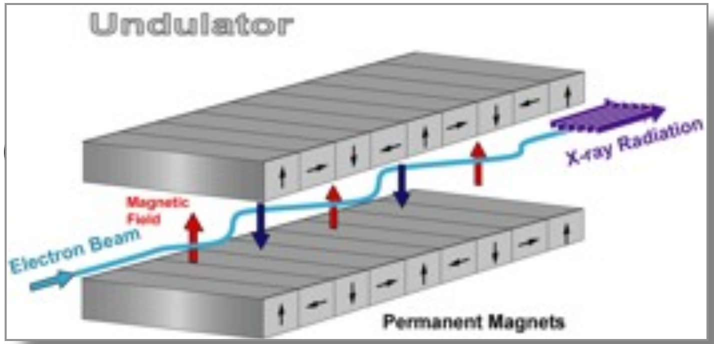

www-xfel.spring8.or.jp/cband/j/Undulator.htm

Spherical Grating Monochromator

Beamline 10.0.1

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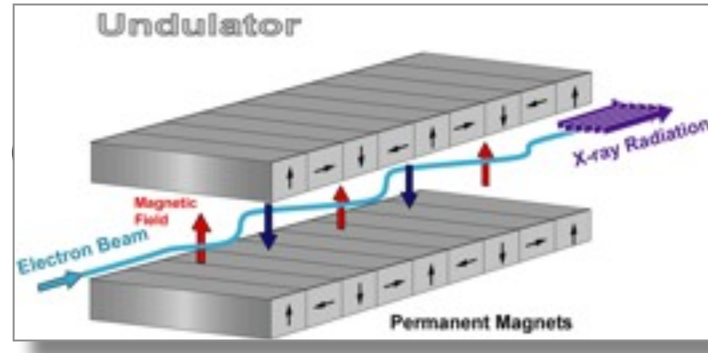

www-xfel.spring8.or.jp/cband/j/Undulator.htm

<u>Spherical Grating Monochromator</u>

- 3 gratings: 380, 925, and 2100 lines/mm

Beamline 10.0.1

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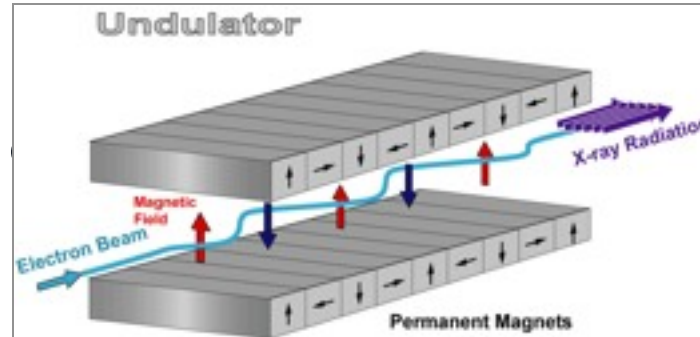
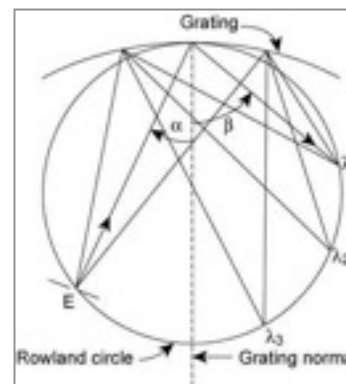


www–xfel.spring8.or.jp/cband/j/Undulator.htm

Spherical Grating Monochromator

- 3 gratings: 380, 925, and 2100 lines/mm
- 17 – 340 eV energy range

Grating	**Ruling** (lines/mm)	**Energy Range** (eV)
Low	380	17 – 75
Medium	925	40 – 170
High	2100	100 – 340



Characteristics of Beamline 10.0.1

Energy range	17 eV to 350 eV (73 nm to 5 nm) 11 eV to 350 eV (future) (112 nm to 5 nm)
Photon flux	From 10^{12} to 10^{14} photons/s depending upon resolution
Resolving power ($E/\Delta E$)	From 10,000 to 65,000

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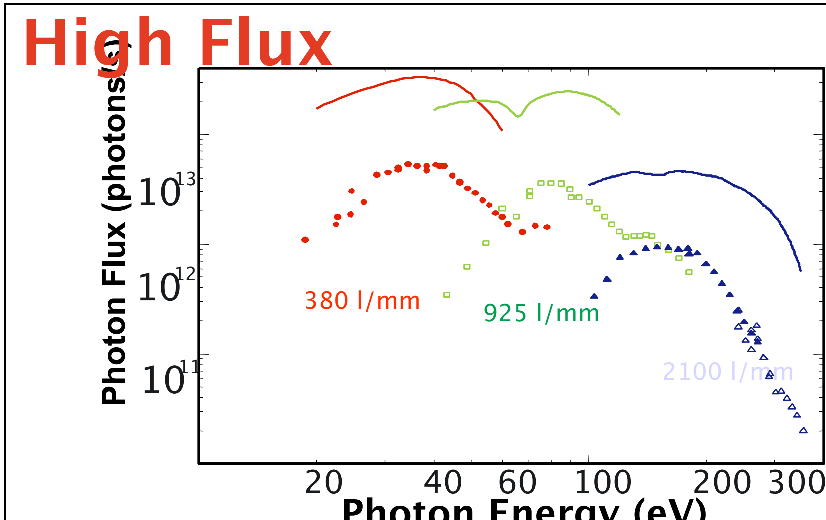
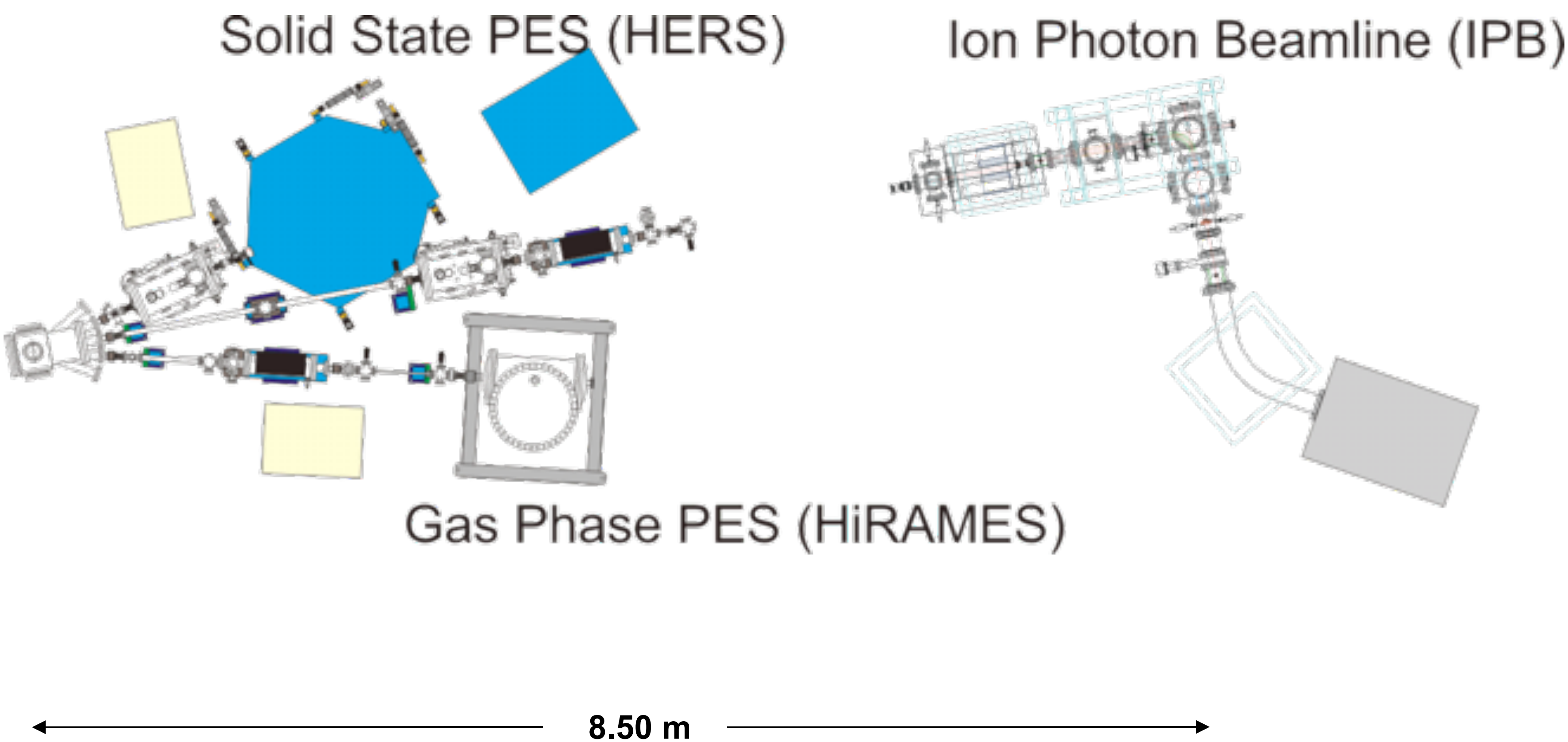
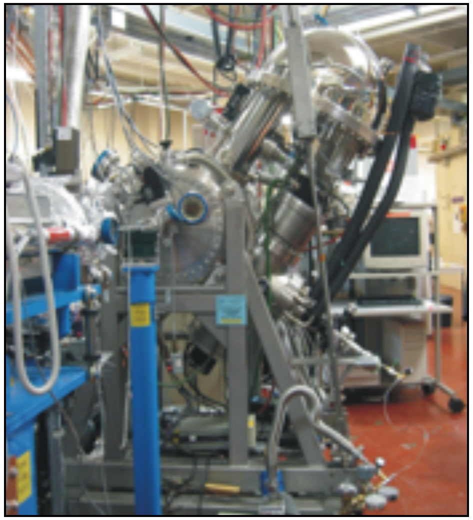


Three Branch Lines (2 for AMO)

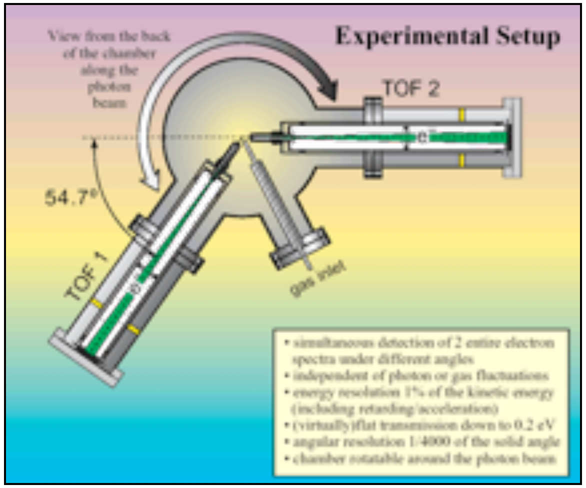


Some of the AMO endstations

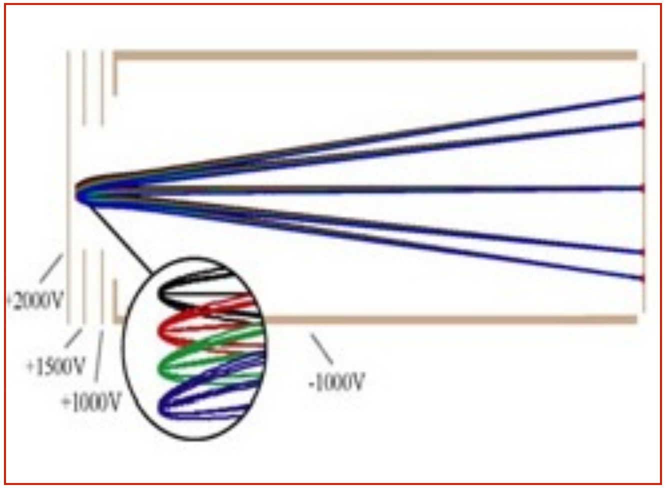
High Resolution e- Spectrometer



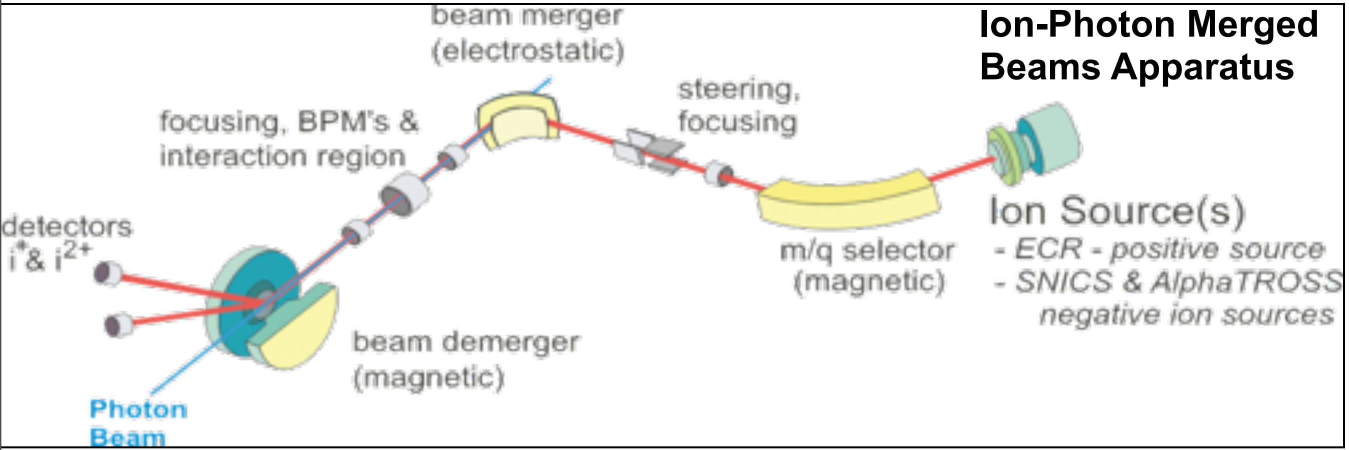
Angle-resolved photoelectron spectroscopy

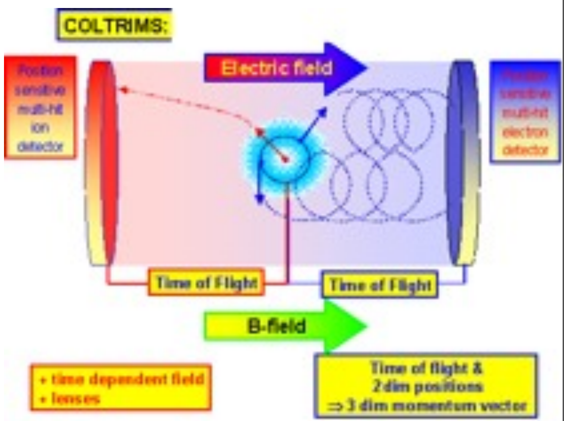


Velocity Map Imaging



Ion-Photon Merged Beams Apparatus





Take home message and questions

- ALS is a mature 3rd generation light source that stays competitive by constantly having important up-grades.
- Plans to “split” the undulator or beamline 10.

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- Building and operating a beamline in an existing ring for few years?
- Heavy ion storage ring? (non in the US or the Americas)

Gracias por su atención

LAWRENCE BERKELEY NATIONAL LABORATORY

November 9, 2010 *Alejandro Aguilar* II Mexican Workshop on Accelerator Physics: A Light Source

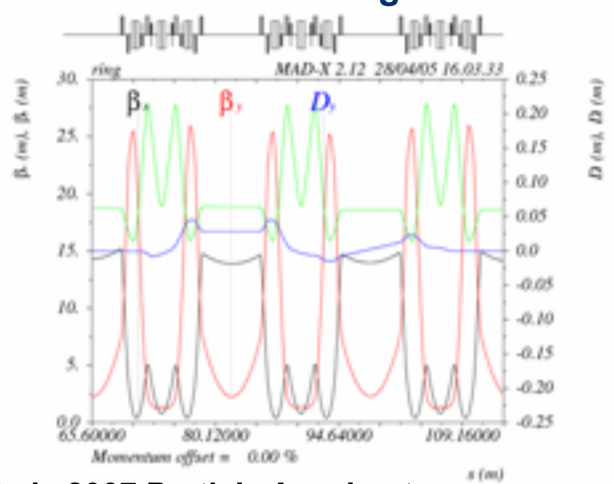
Status of New IDs

- 5 cm EPU (PEEM3)
  - Similar to 3 others that had been installed in the ring already
  - First shimmed for dynamic multipoles
- In-Vacuum ID (Femtoslicing)
  - First in-vacuum device
  - Smallest gap (5mm vacuum)
    - Next smallest gap is 9mm
  - New Lattice for Femtoslicing
    - 12 skew quadrupoles added
- 9 cm QEPU (MERLIN)

  Most challenging device to be installed
  - First quasiperiodic EPU
  - First large period EPU
  - Compensation for

EPU shimming

New Femtoslicing Lattice



C. Steier et al., 2007 Particle Accelerator Conference, Albuquerque, New Mexico, June 2007

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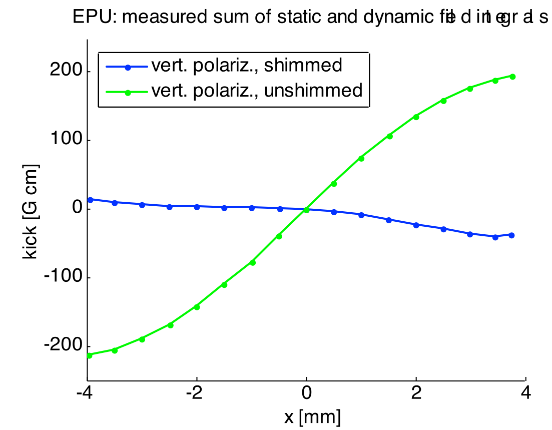
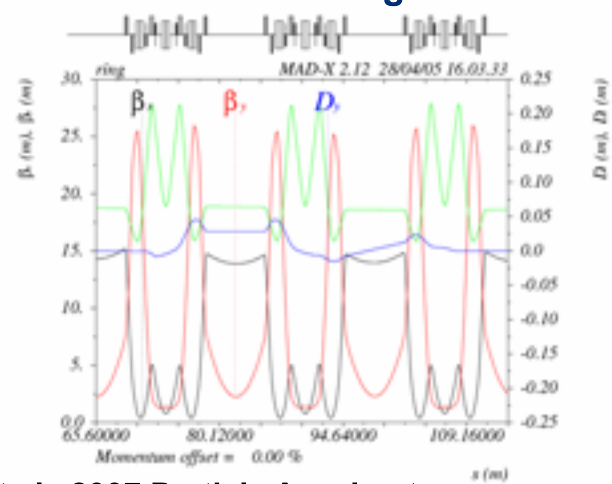


New Femtoslicing Lattice



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