Particle Accelerator Conference 2011

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Status of the ALS Upgrade

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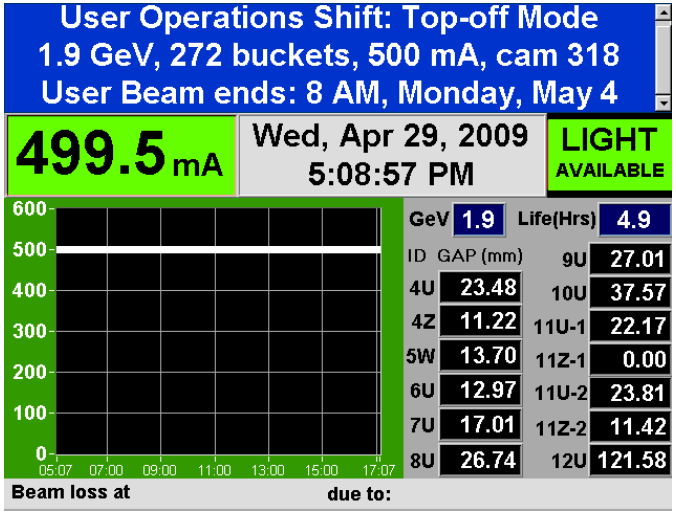
Outline

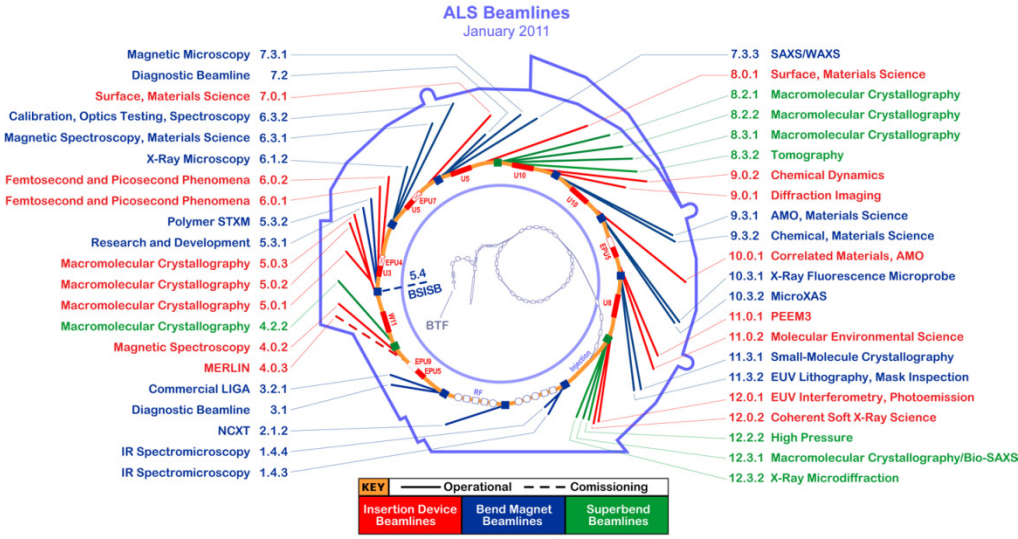
- Introduction
  - The Advanced Light Source
  - Current Performance: Emittance/Brightness
- Strategic Plan
  - Accelerator Upgrades/Improvements
- Brightness Upgrade
  - Hardware
  - Lattice and Optimization
- Summary

ALS Parameters and Beamlines

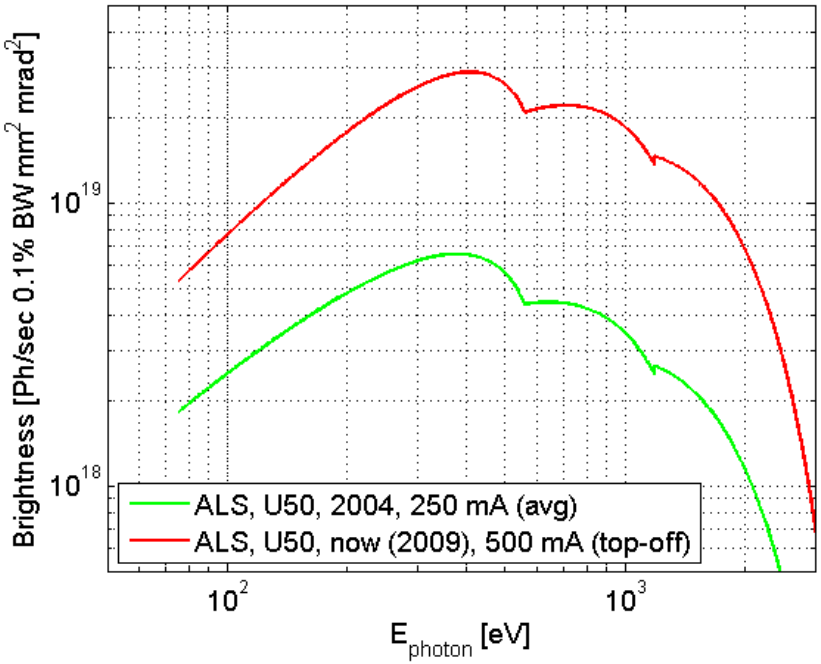
Beam Energy	1.9 GeV
Circumference	196.8 m
RF frequency	499.642 MHz
Harmonic #	328
Beam current (top-off)	500 mA multibunch 36 mA two-bunch
Nat. emittance	6.3 nm (future 2.2 nm)
Vert. Emittance	25 – 50 pm (user ops), 4-5 pm (dedicated AP)
Energy spread	0.097%
Refill period	Top-off every 30-60 s (current stability 0.3%)
User Beamlines	>40 simultaneous (11 insertion devices)

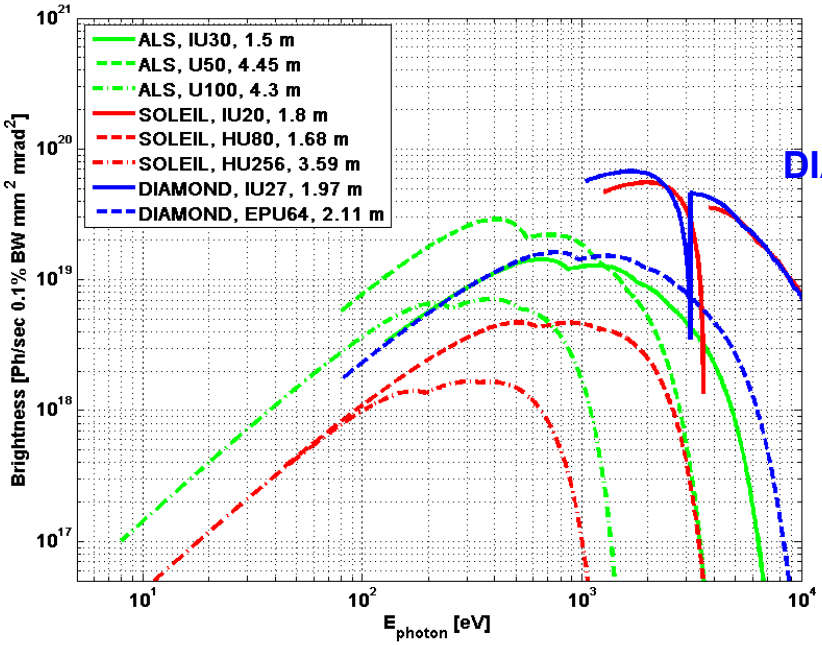
jc/ALSaerial/11-96





ALS Brightness (since 2009)





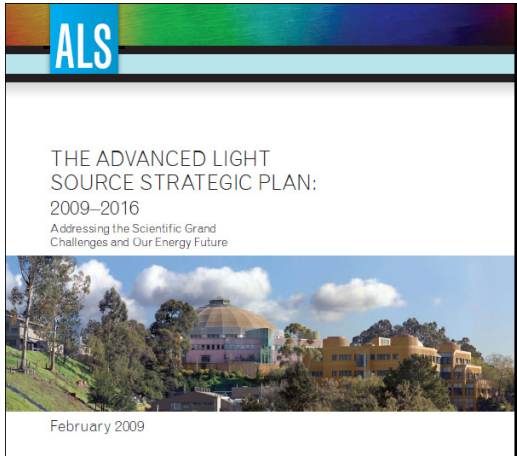
ALS
SOLEIL
DIAMOND

- Recent Top-off upgrade provided factor of 3-10 improvement in brightness for undulator and (super-) bend users
- Now, the ALS compares favorably with the newest light sources below 1 keV photon energy

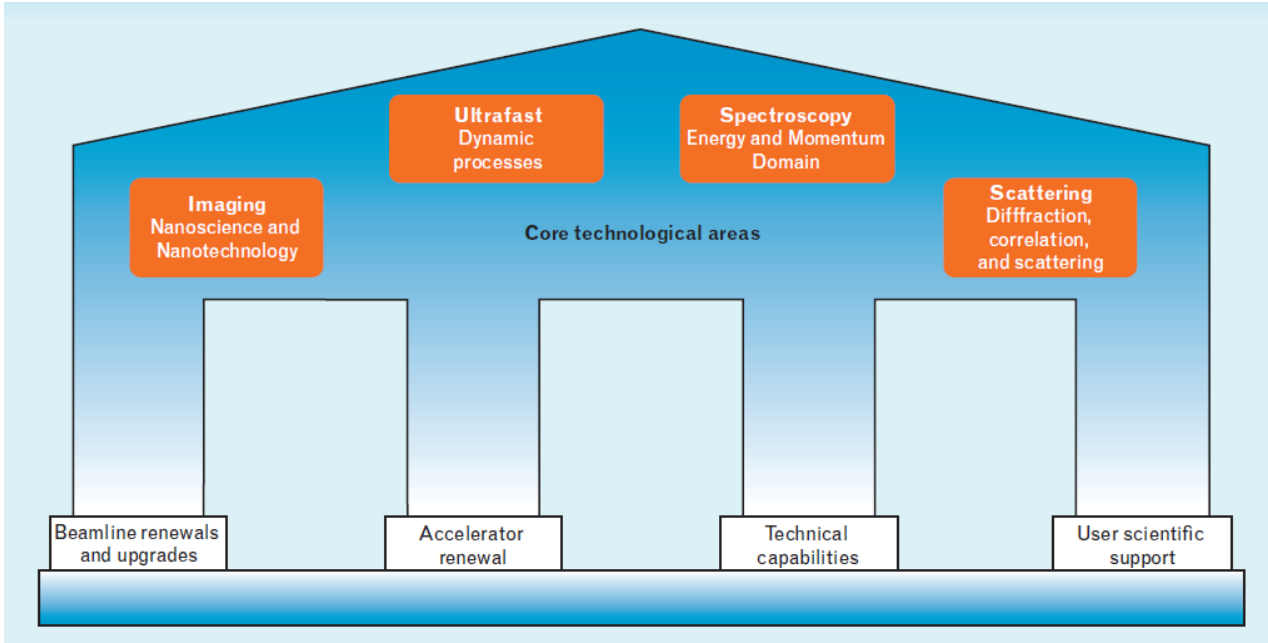
ALS Strategic Plan

- **ALS (since 1993) has been extremely successful in (soft) x-ray science**

- **Newer Facilities provide potentially better performance and better tools**



→ ALS strategic plan to maintain leadership by renewing infrastructure, upgrading existing and developing new instrumentation, and better support of user science.



Accelerator Upgrades

- ALS strategic plan contains several components relating to the accelerator
  - Higher (horizontal) Brightness
  - New Operational Modes
  - Improved Photon Beam Stability
  - Improved Reliability
  - New Insertion Device (R+D)

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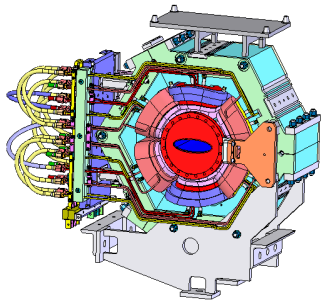

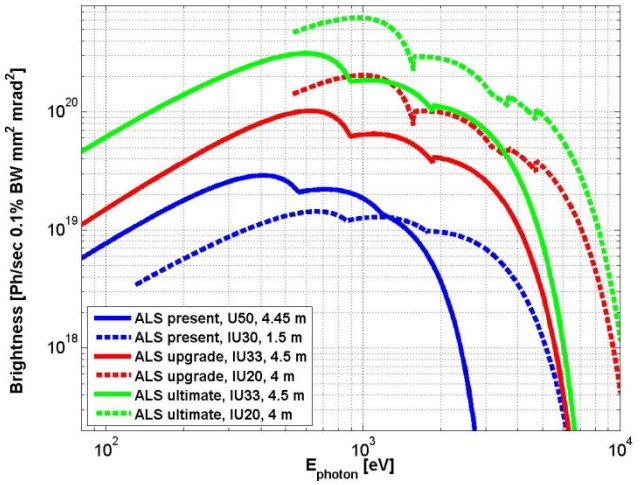

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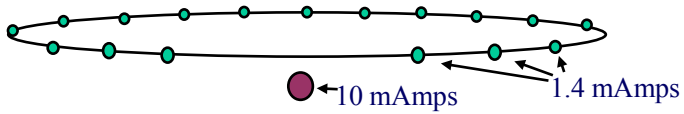
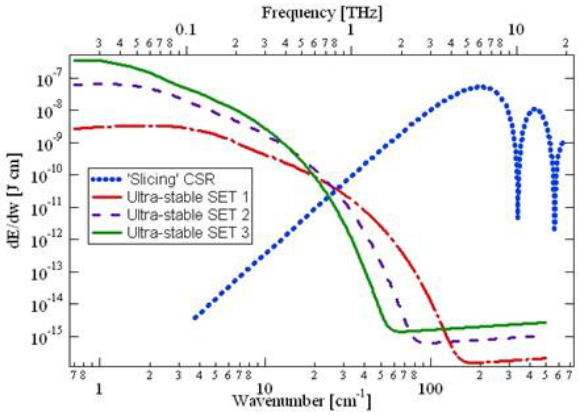
Tailored Bunch Operation



Terahertz



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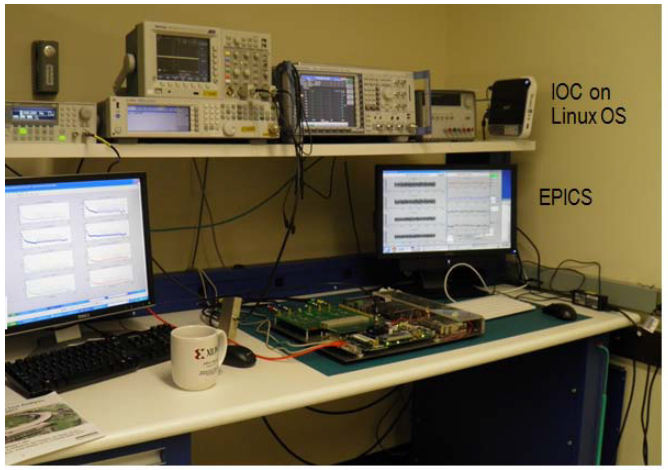

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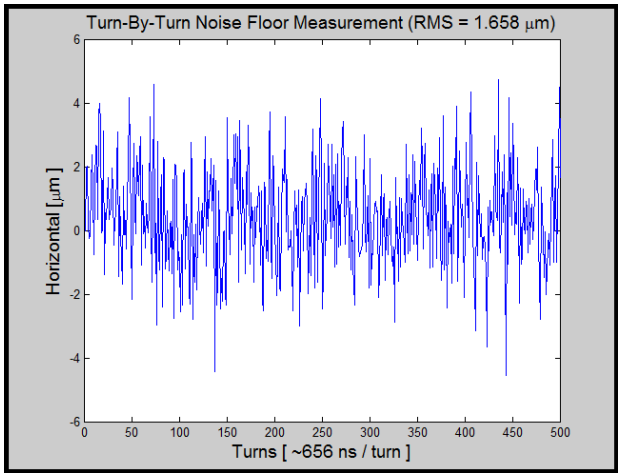
BROOKHAVEN SCIENCE ASSOCIATES



MOP211

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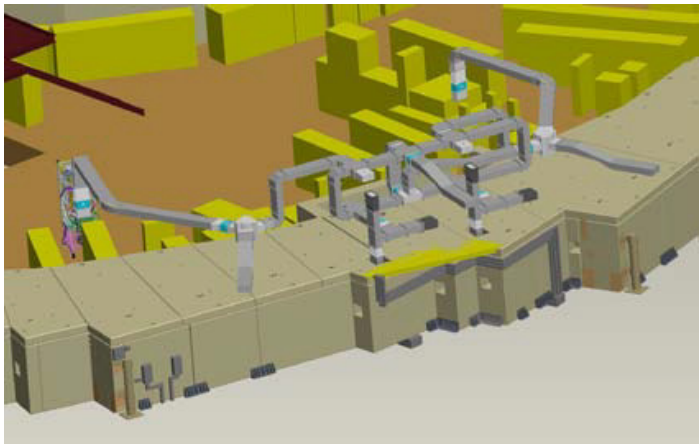

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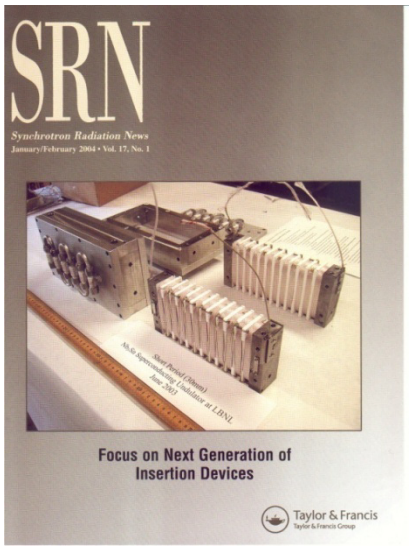
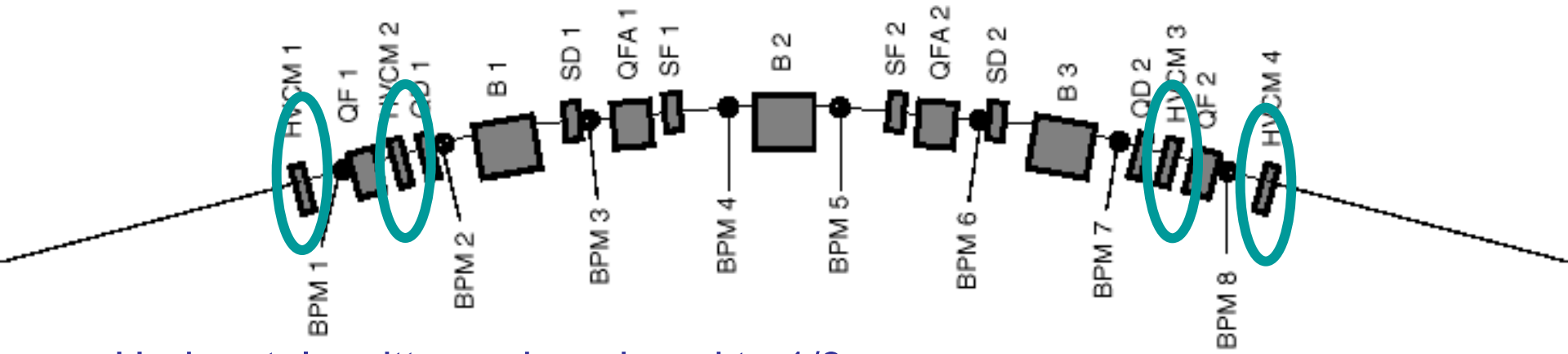


TUP249

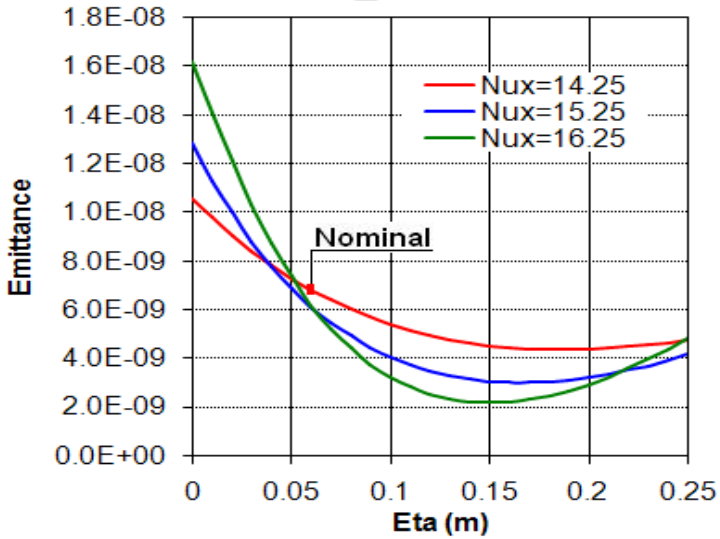
ALS Lattice Upgrade Project

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
- Idea in 2004, on backburner during top-off upgrade, funding in 2009, completion planned for 2012

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



H. Nishimura, et al.– Proceedings of the 2007 PAC Conf

C. Steier, et al., NIM A, DOI: 10.1016/j.nima.2010.11.077.

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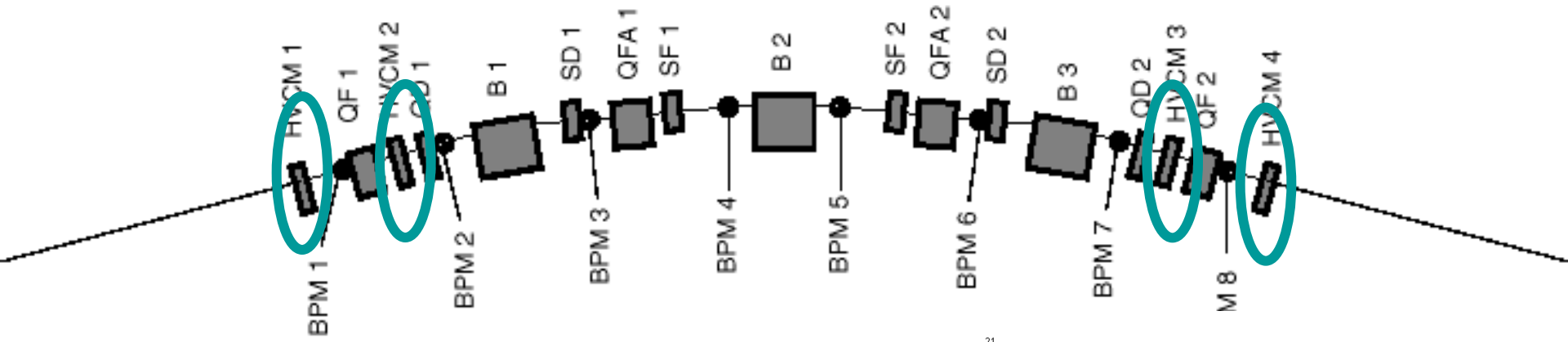

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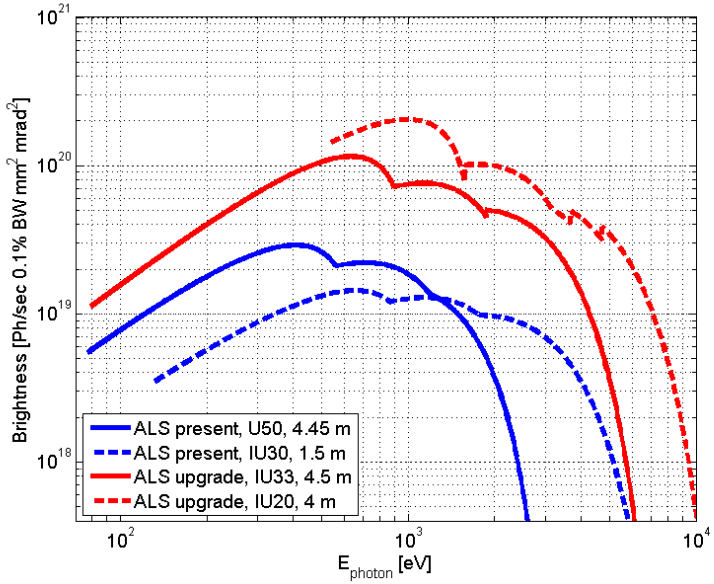

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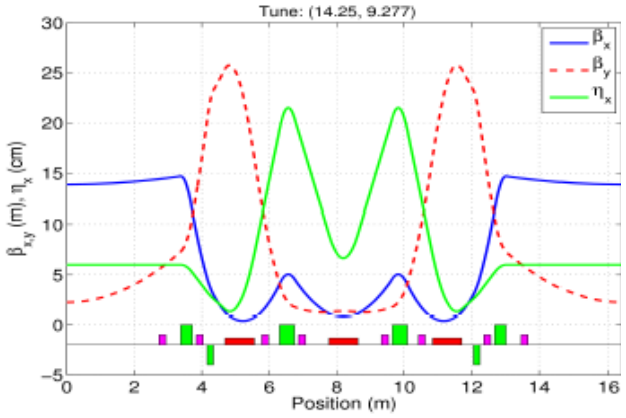
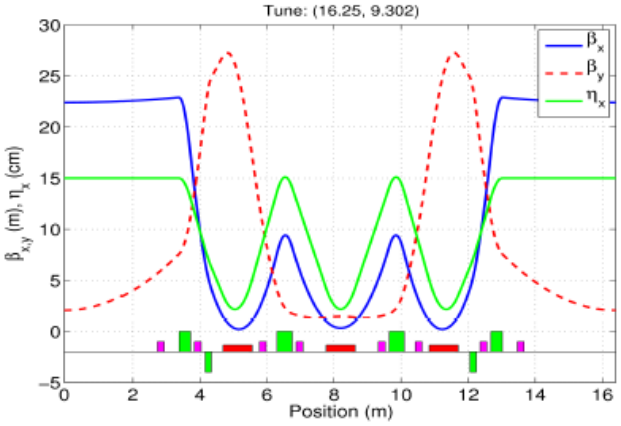
Lattices for ALS upgrade

Current Lattice

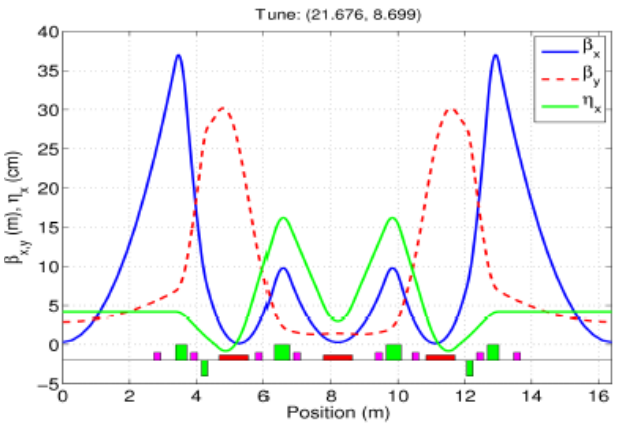


New Large β_x Lattice



Baseline upgrade (large-beta)

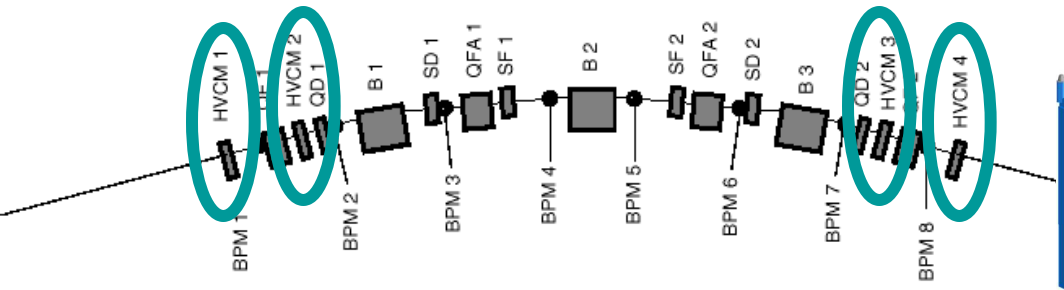
New Small β_x Lattice

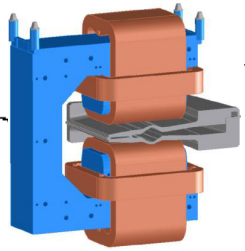


Ultimate upgrade (small-beta)

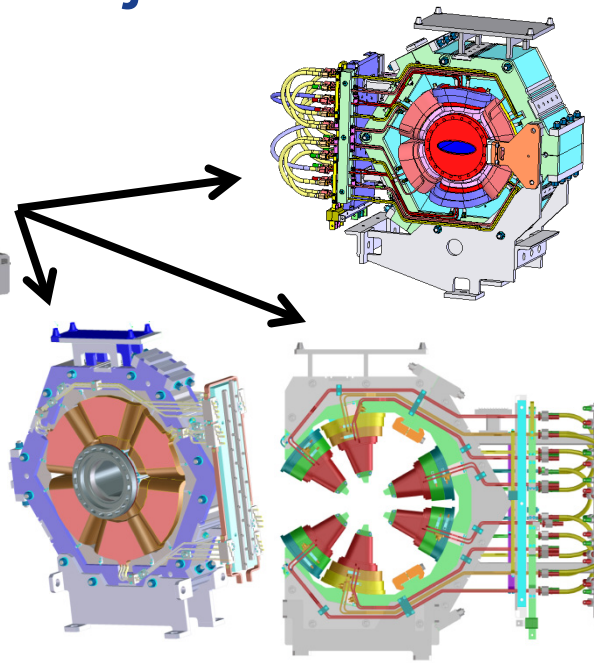
- There are several possible lattices with ~2 nm rad emittance
  - 3x smaller than the nominal ALS (~6.3 nmrad)
- Large β_x lattice optimizes brightness for the central bends
- Small β_x lattice would optimize brightness for the insertion devices

ALS Brightness Upgrade Project





Existing Correctors

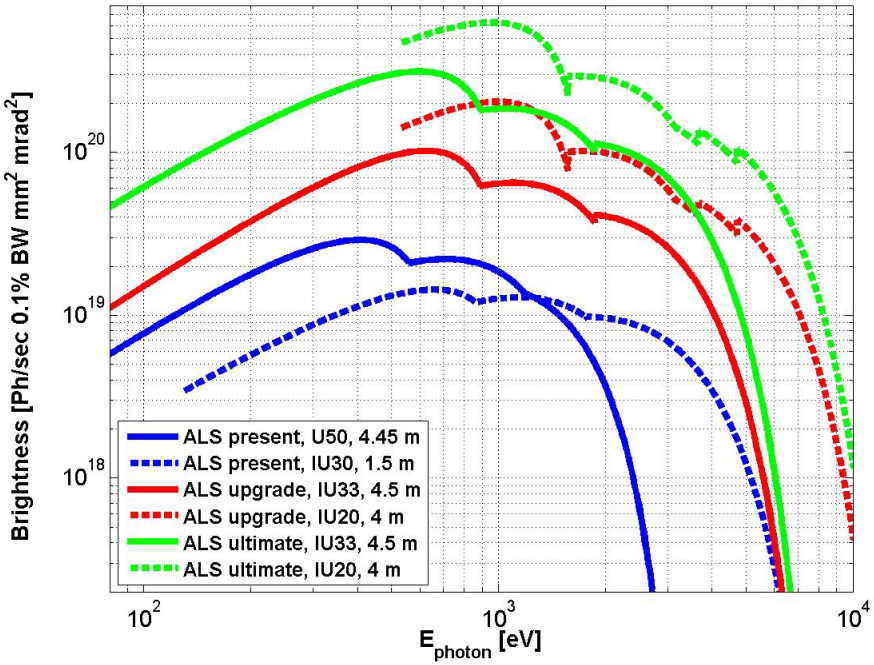


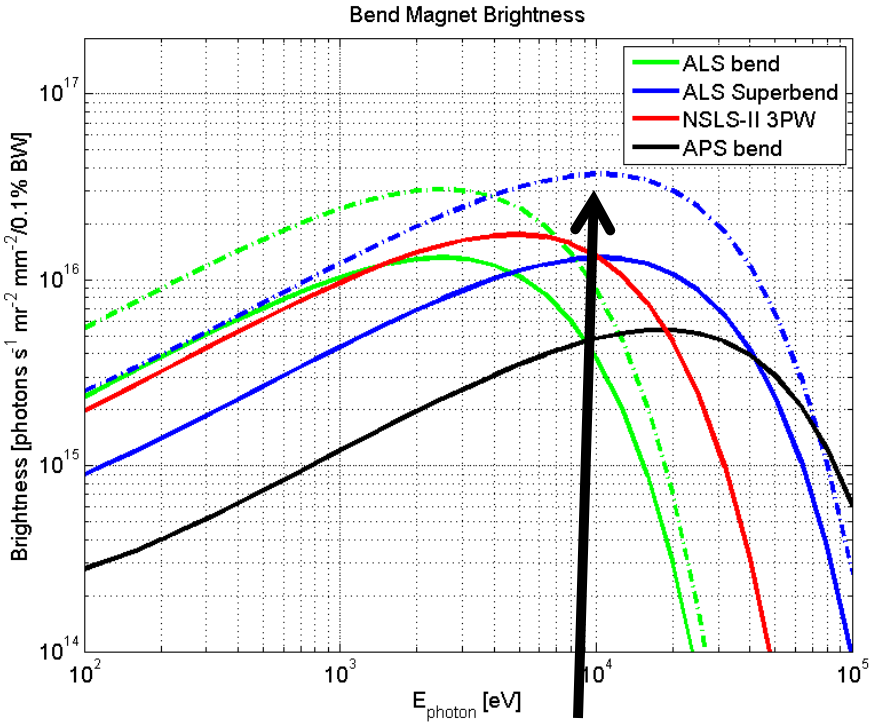
Sextupole / Corrector Multimagnets

- Install 48 New Multi-magnets (Sextupoles/correctors/skew quadrupoles)
- Project received funding in summer 2009
- Passed comprehensive project review (12/09)
- Awarded magnet contract (9/10)
- Passed a detailed design review (3/11)
- On track for completion of project by end of FY13 (early completion planned for 2012)

C. Steier, et al., NIM A, DOI: 10.1016/j.nima.2010.11.077.

Brightness Improvement





Existing lattice with existing insertion devices

Large β_x lattice with conventional long IDs

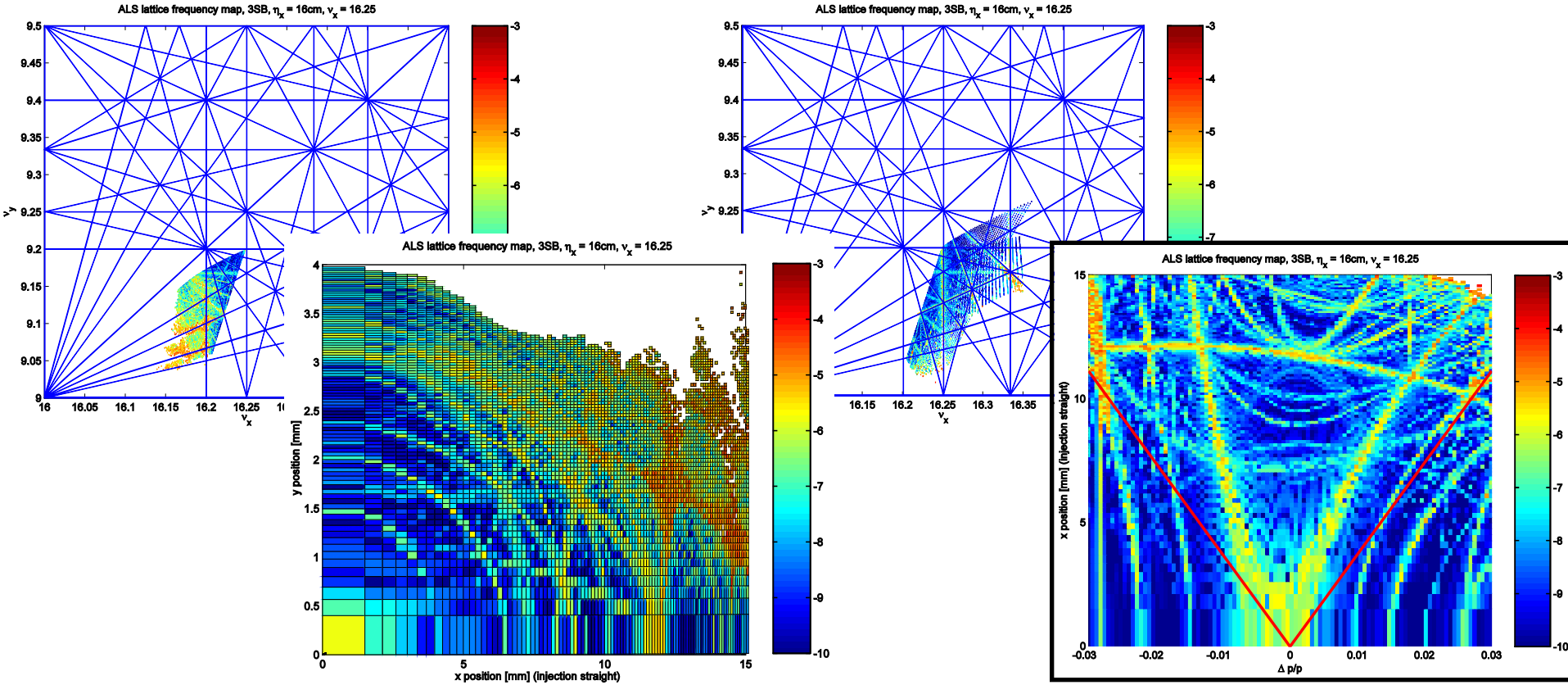
Small β_x lattice with conventional long IDs

ALS ultimate case requires further upgrades beyond the baseline of this project and physics studies are incomplete – not sure, yet, whether fully feasible.

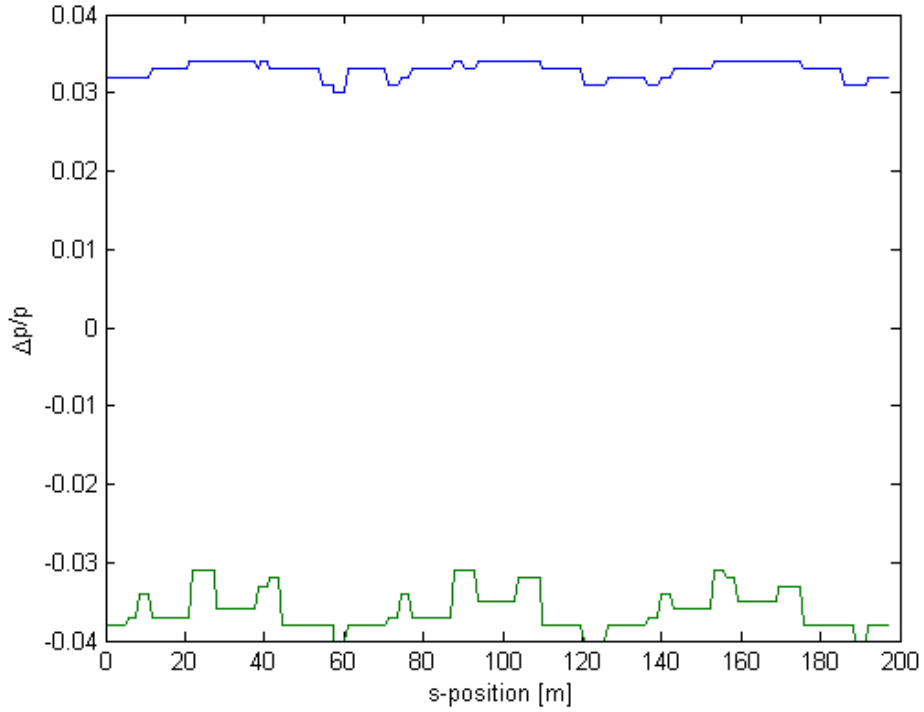
Because of simultaneously small beta function in both planes in center bend magnet at ALS, (super)bend sources provide higher brightness than bending magnets at other 3rd generation sources – very good match to diffraction ellipse.

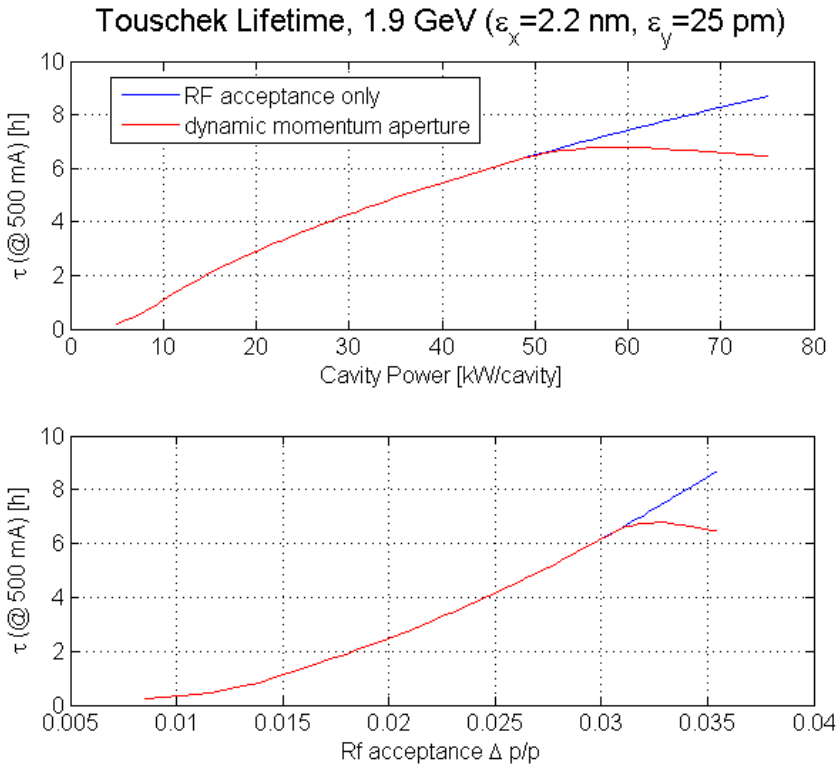
Results of Dynamics Optimization for ALS Upgrade

- Dynamic aperture is large (larger than current lattice)
- Smaller H function in the arc results in larger momentum acceptance
- H function in the straight smaller than in the arc: wiggler and other IDs reduce emittance further



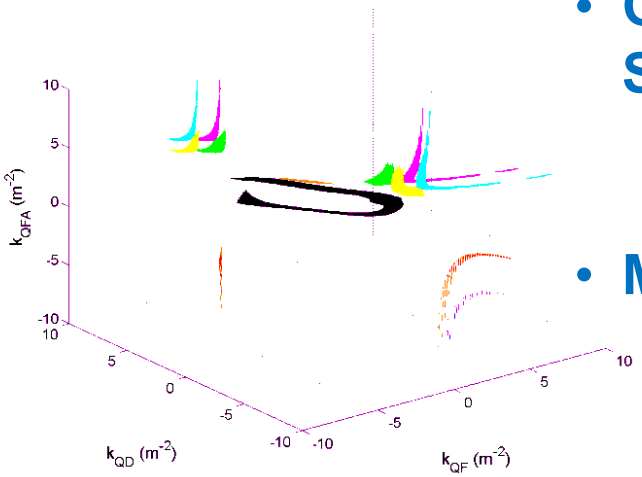
Touschek Lifetime of Upgrade

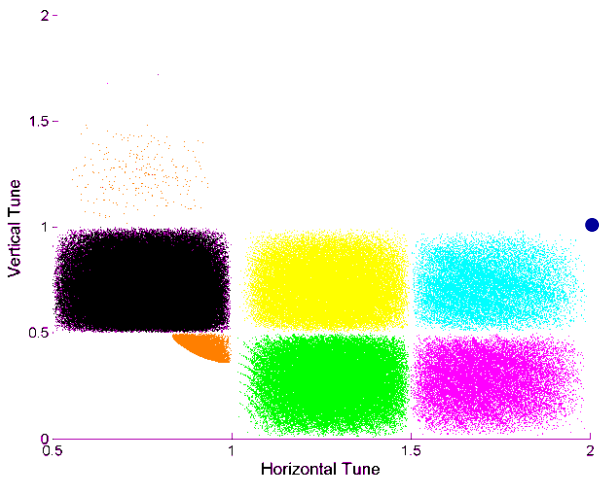




- Dynamic Momentum Aperture larger,
- Touschek Lifetime longer than present lattice

Lattice optimization

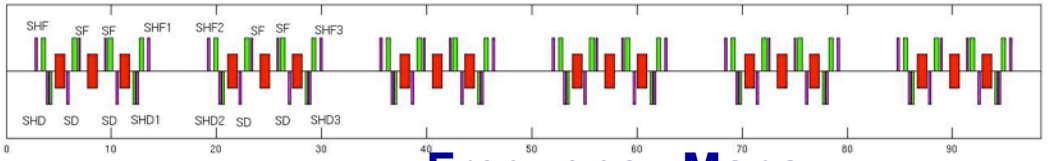




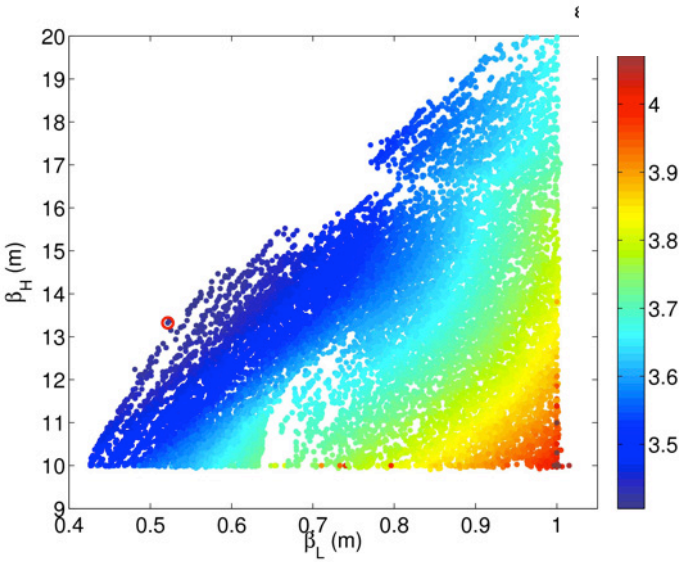
- **GLASS – Global Analysis of All Stable Solutions**
  - Tool to look for optimum lattice solution for highly periodic lattices (few parameters)
- **MOGA – Multi Objective Genetic Algorithms**
  - Usefulness for accelerators first demonstrated for photo injectors (Bazarov et al./Cornell)
  - Optimum solution with moderate computation time for larger dimensional parameter spaces
  - Integrated optimization of linear+nonlinear lattice possible
- **Frequency Maps (quantitative diffusion rates)**
  - In use for years for studies of global dynamics (simulation and measurement).
  - Can also be used as merit function (e.g. for MOGA)

One High β-Straight Lattice

Optimization with 7 quadrupoles and 10 sextupoles

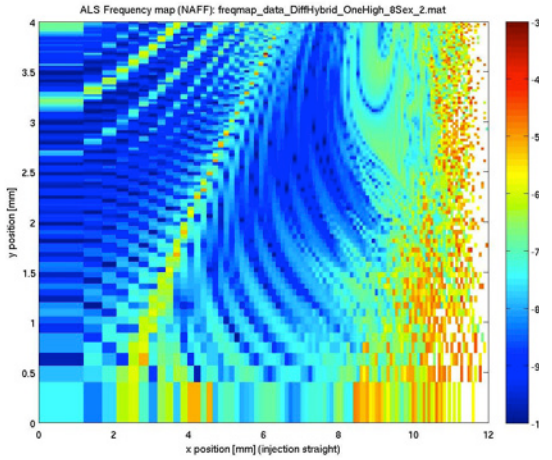


Emittance / β Tradeoffs



Frequency Maps

Amplitude Space



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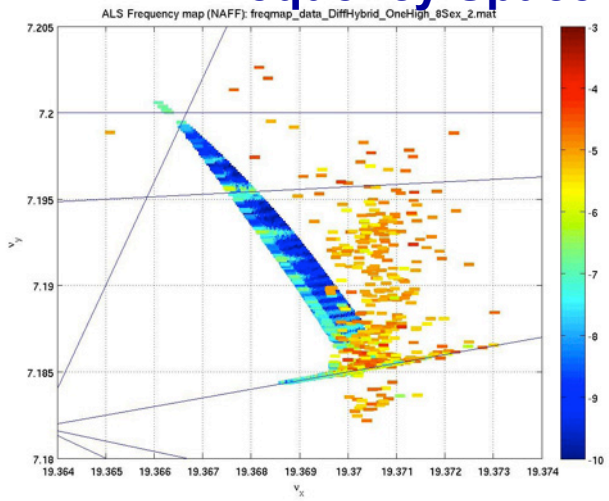

TUODN4, WEP031

- **Finding interesting solutions that may be compatible with the present injection scheme**
- **More work to be done on finding solutions with lower sextupole strengths**

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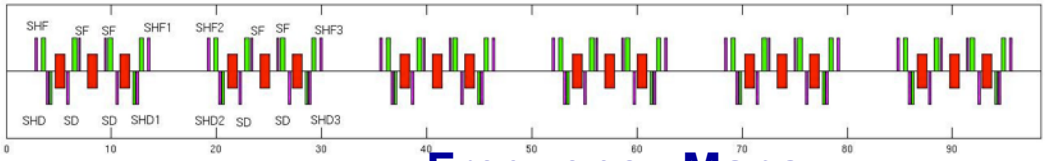

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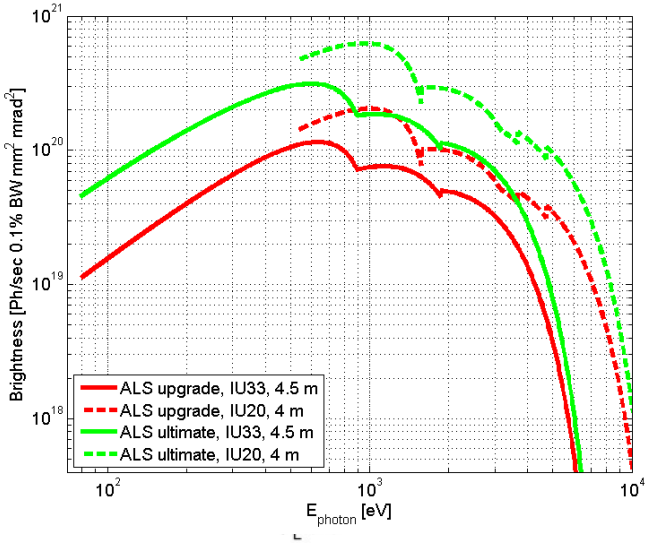

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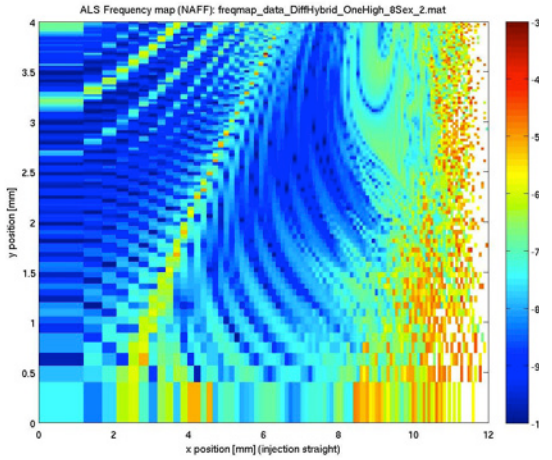

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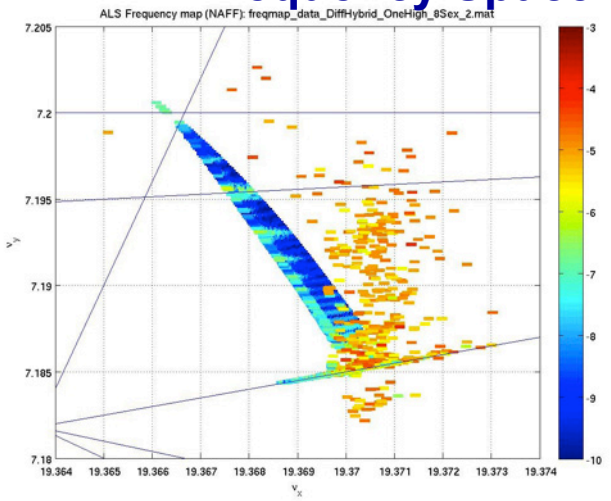

TUODN4, WEP031

- **Finding interesting solutions that may be compatible with the present injection scheme**
- **More work to be done on finding solutions with lower sextupole strengths**

Summary

- ALS at 18 years of age still has significant upgrade potential
- ALS strategic plan includes new beamlines, accelerator upgrades, infrastructure upgrades, user/science support
- ALS Brightness Upgrade
  - Will provide significant brightness increase for users in cost effective way (2012/2013)
  - If low beta function lattices can be made to work, average brightness of up to 10^{21} is possible at ALS