NSLS Upgrade Concept

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Particle Accelerator Conference

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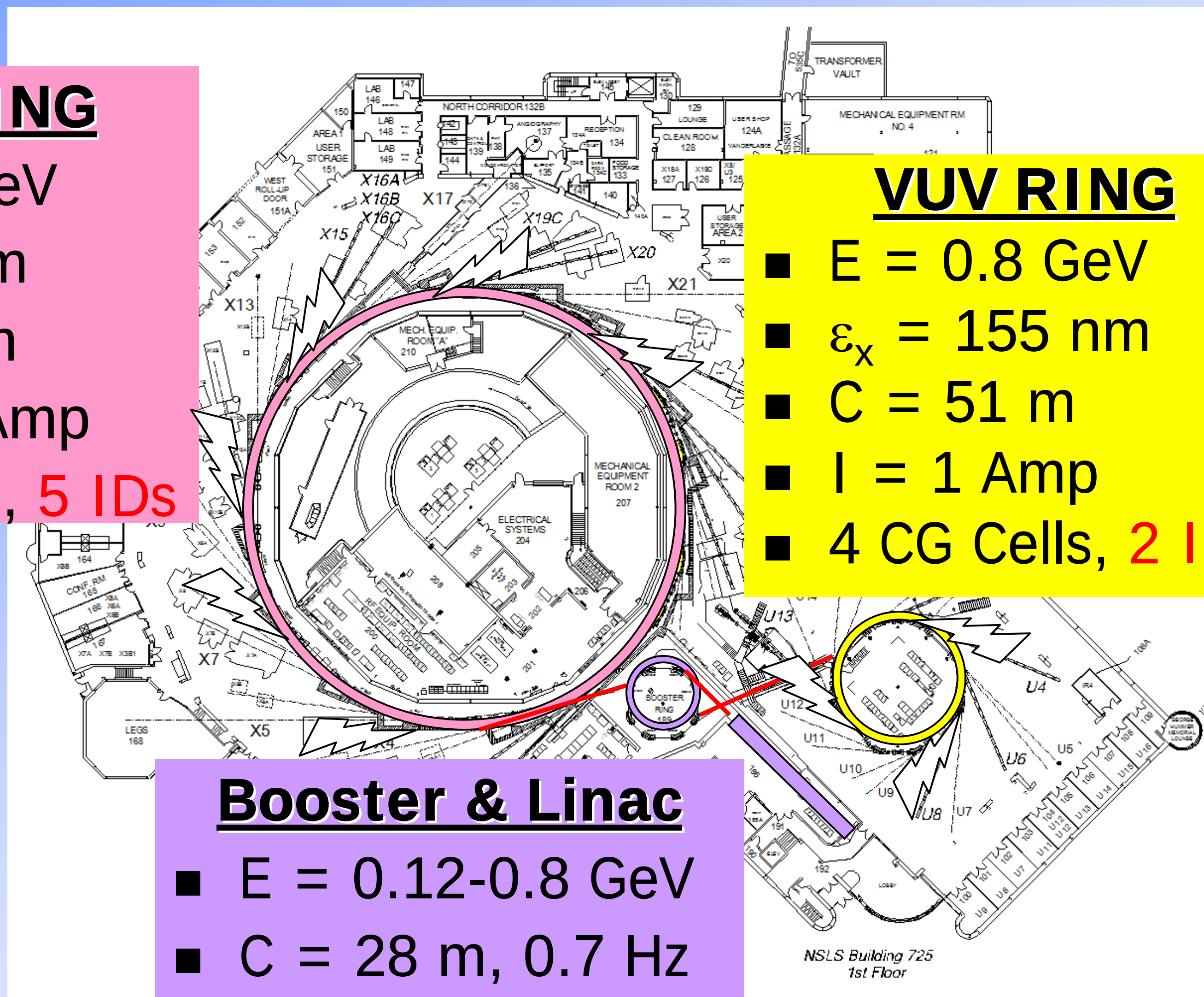
Outline

- NSLS Today
- Motivation & Goals
- Upgrade Concept
- Accelerator R&D Issues
- Concluding Remarks

NSLS Accelerators Today



XRAY RING

- E = 2.8 GeV
- ε_x = 60 nm
- C = 170 m
- I = 0.28 Amp
- 8 CG Cells, 5 IDs

VUV RING

- E = 0.8 GeV
- ε_x = 155 nm
- C = 51 m
- I = 1 Amp
- 4 CG Cells, 2 IDs

Booster & Linac

- E = 0.12-0.8 GeV
- C = 28 m, 0.7 Hz
- I = 0.01 Amp

Upgrade Motivation and Goals

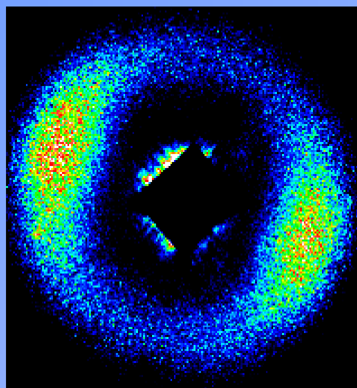
Background:

- The two rings at the NSLS are entering their 3rd decade of dedicated operation for 2500 users!
- Brighter sources exist in the USA and abroad; in fact with the SPEAR3 upgrade we are the least bright in USA
- Bulk of the light source users reside in 5-20 keV
- Brightness is the driver but average current / flux users are important as well

Goals:

- 10^3 increase in undulator brightness in the 5-20 keV range
- without a significant reduction in flux
- increase the insertion device capacity from 5 to ~20,
- all done for a reasonable cost -> circumference & energy

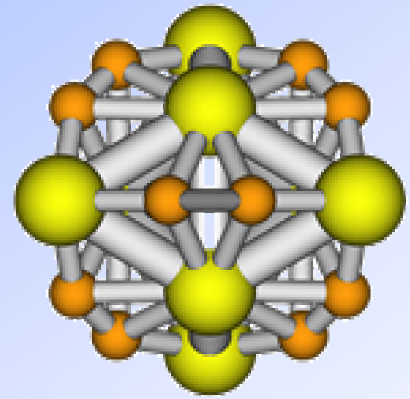
Science Case: Nano-Sciences



Nano Magnetism

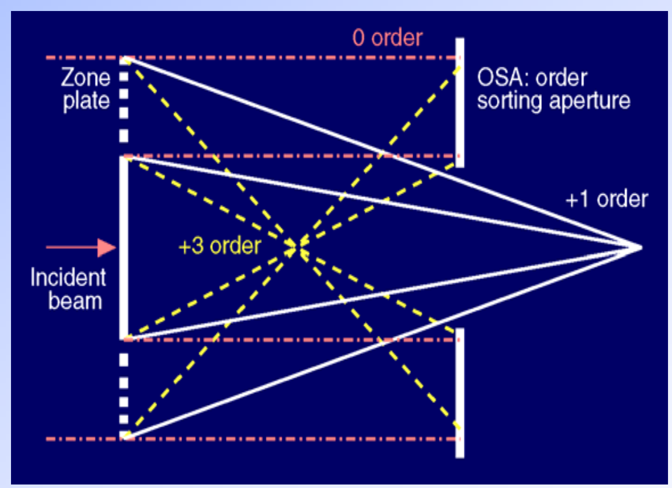
X-rays ~ 10 nm

Brightness driven exps!



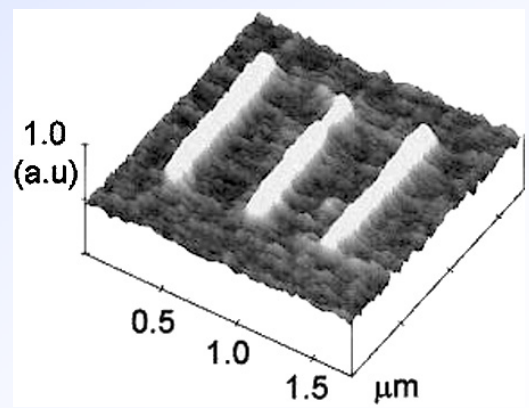
Chemical Catalysis

Cu Interconnect Chip



Zone Plate Optics

Piezo-Electric Sensor



Upgrade Scope

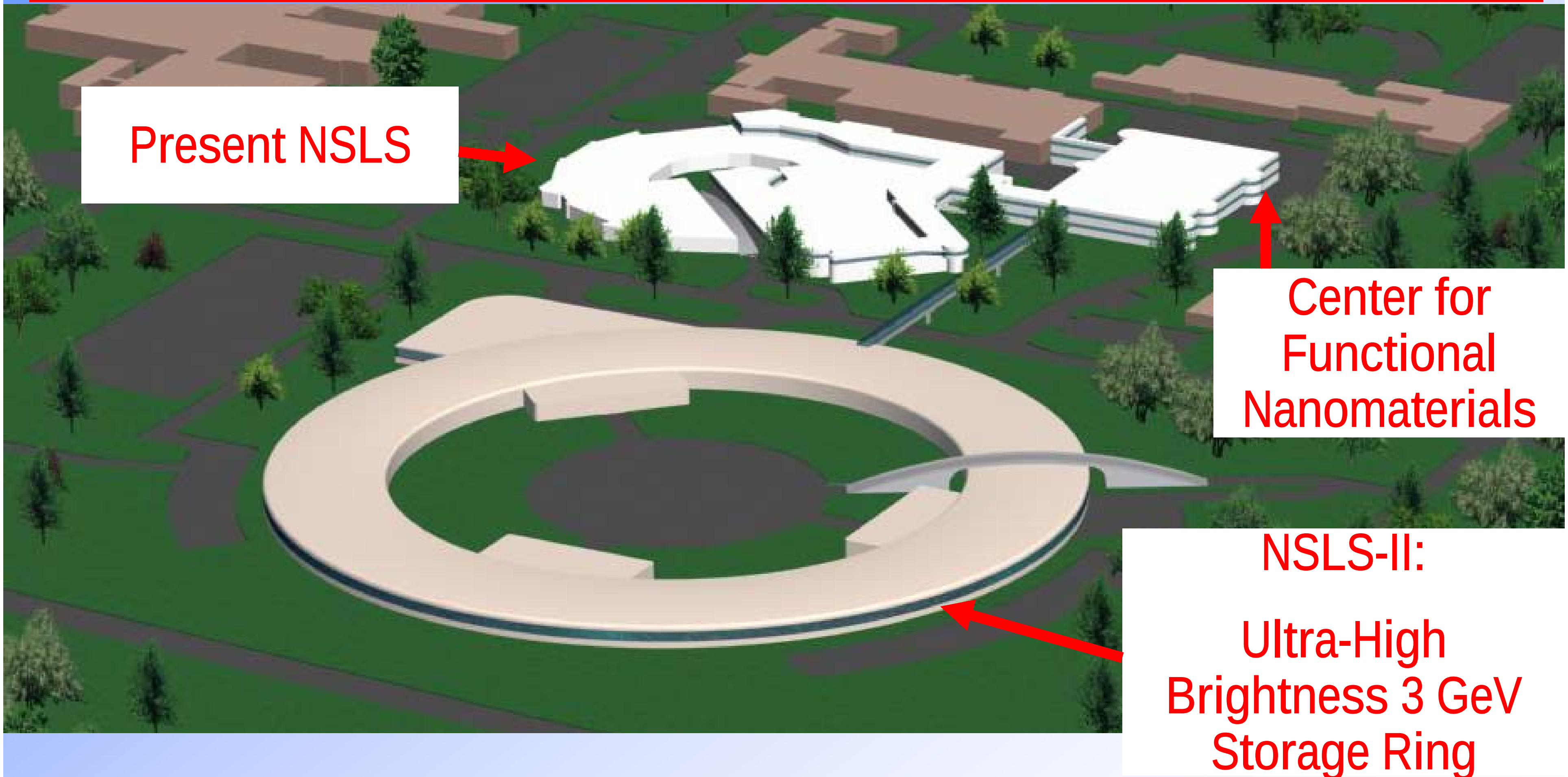
- We considered multiple possibilities:
  - ❑ **New Electron Storage Ring**
  - ❑ **Free Electron Lasers**
  - ❑ **Refurbished Existing Accelerators**
  - ❑ **Energy Recovery Linac Upgrade Option**

- Proposal submitted to BESAC

- BESAC report Feb 2003:

> Recognizing the continued need for 3rd generation X-ray sources, we recommend that NSLS and BES formulate a plan for a 3rd generation ring

Layout


Present NSLS
Center for Functional Nanomaterials
NSLS-II:
Ultra-High Brightness 3 GeV Storage Ring

LS Storage Ring Design Algorithm

0.5 A

2-2.5 m

$$B \propto \frac{I\,L_u}{(\varepsilon_{Ex} \oplus \varepsilon_{Lx})(\varepsilon_{Ey} \oplus \varepsilon_{Ly})}$$

1-2 nm

$\lambda/4\pi$

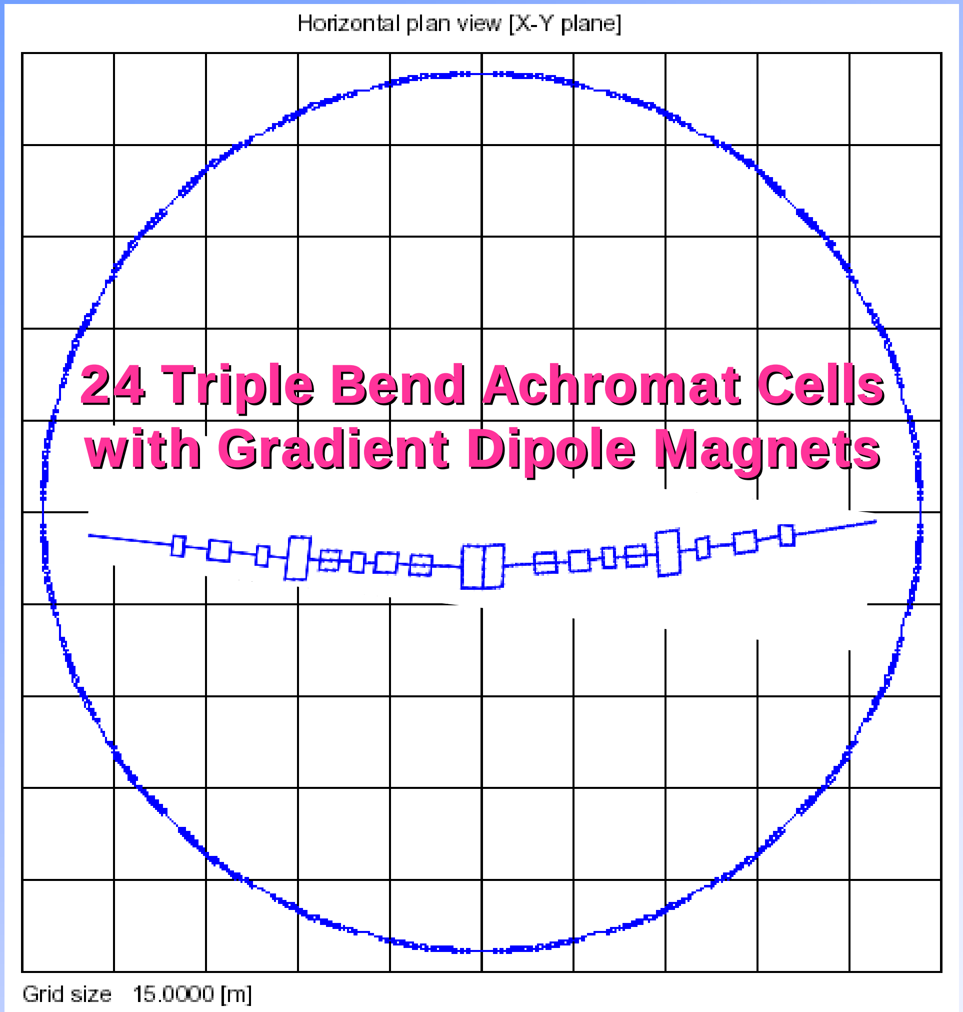
Lattice Optics: Layout lattice to meet user specs: $\varepsilon \sim \gamma^2\,\theta^3$

Tracking for Dynamic Aperture: Low ε implies small η requiring strong sextupoles

Collective Effects & Lifetime: IBS, top off, instabilities, etc.

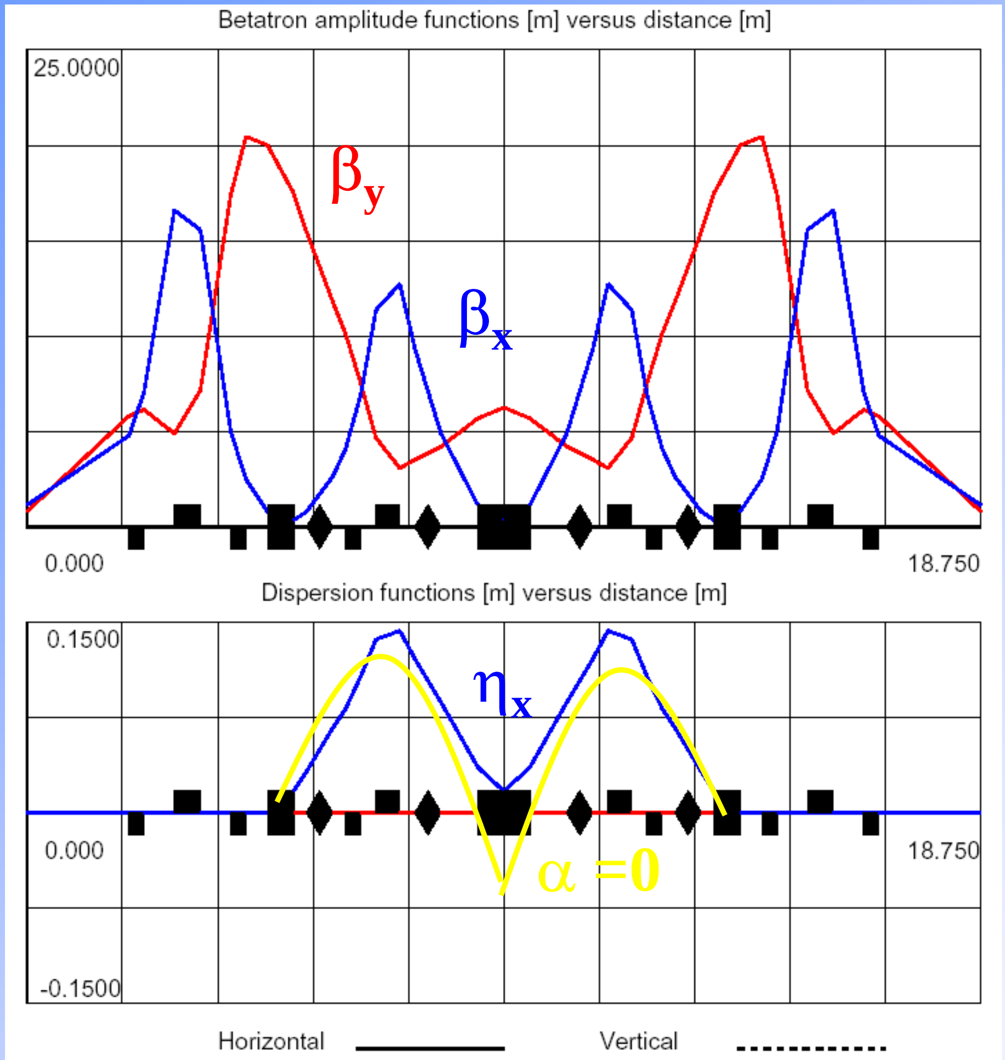
Cost Analysis

Candidate Lattice: High Brightness Electron Storage Ring



- $E = 3$ GeV
- $C = 523$ m
- $\varepsilon_x = 1.5$ nm (Ach, no ID)
- $\alpha = 1.9 \times 10^{-4}$
- $\sigma_E = 9.5 \times 10^{-4}$
- $L_{ss} = 4$ m
- $\xi_x, \xi_y = -90, -30$
- B, B' = 1.3 T, 3 T/m

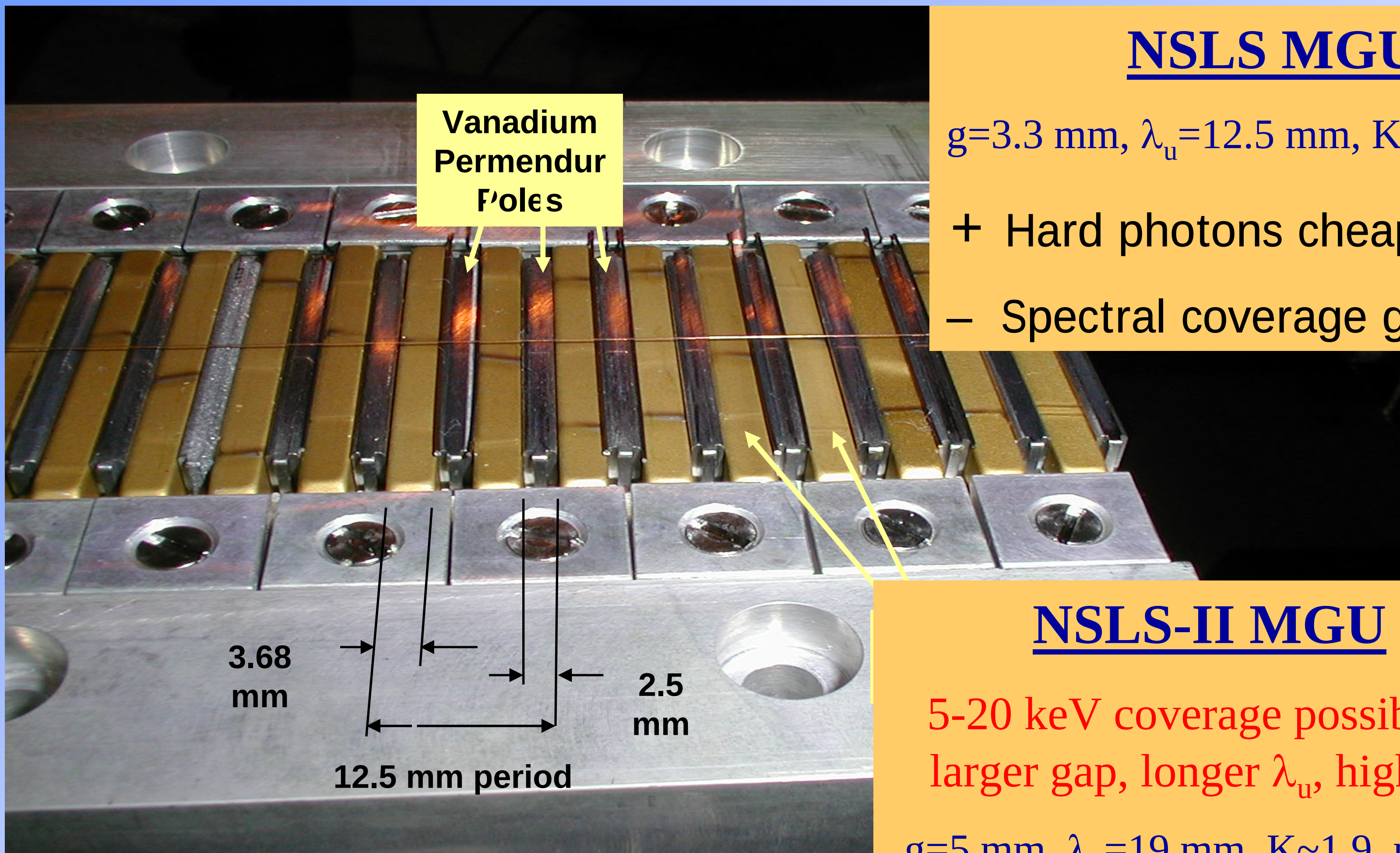
TBA Twiss Parameters



Lattice Characteristics

- TBA with gradient dipole for low ε
- TBA for ERL option
  - Achromatic, tunable α
  - Isochronous, α = 0
- Low β_y for small gap IDs
- ID triplet for tunability
- Space for harm. sexts
- Decoupled $\beta_{x,y}$ for $\xi_{x,y}$ correction

Permanent Magnet In-Vacuum Undulators



NSLS MGU

g=3.3 mm, λ_u=12.5 mm, K~1, n=1-5

+ Hard photons cheap

– Spectral coverage gaps

NSLS-II MGU

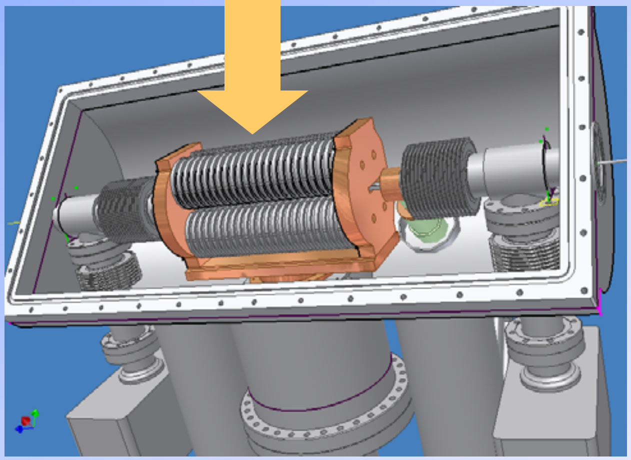
5-20 keV coverage possible at larger gap, longer λ_u, higher n

g=5 mm, λ_u=19 mm, K~1.9, n=3-11

Superconducting Mini Gap Undulators

<u>Why SCU?</u>

- Short-period (~ 1 cm) is a must to generate <u>tunable</u>, multi-keV photons in medium-energy rings
- Higher fields, higher K (>2.2), full tuning range (3:1) attainable only with SC technology



NSLS SCU cryo-cooler design

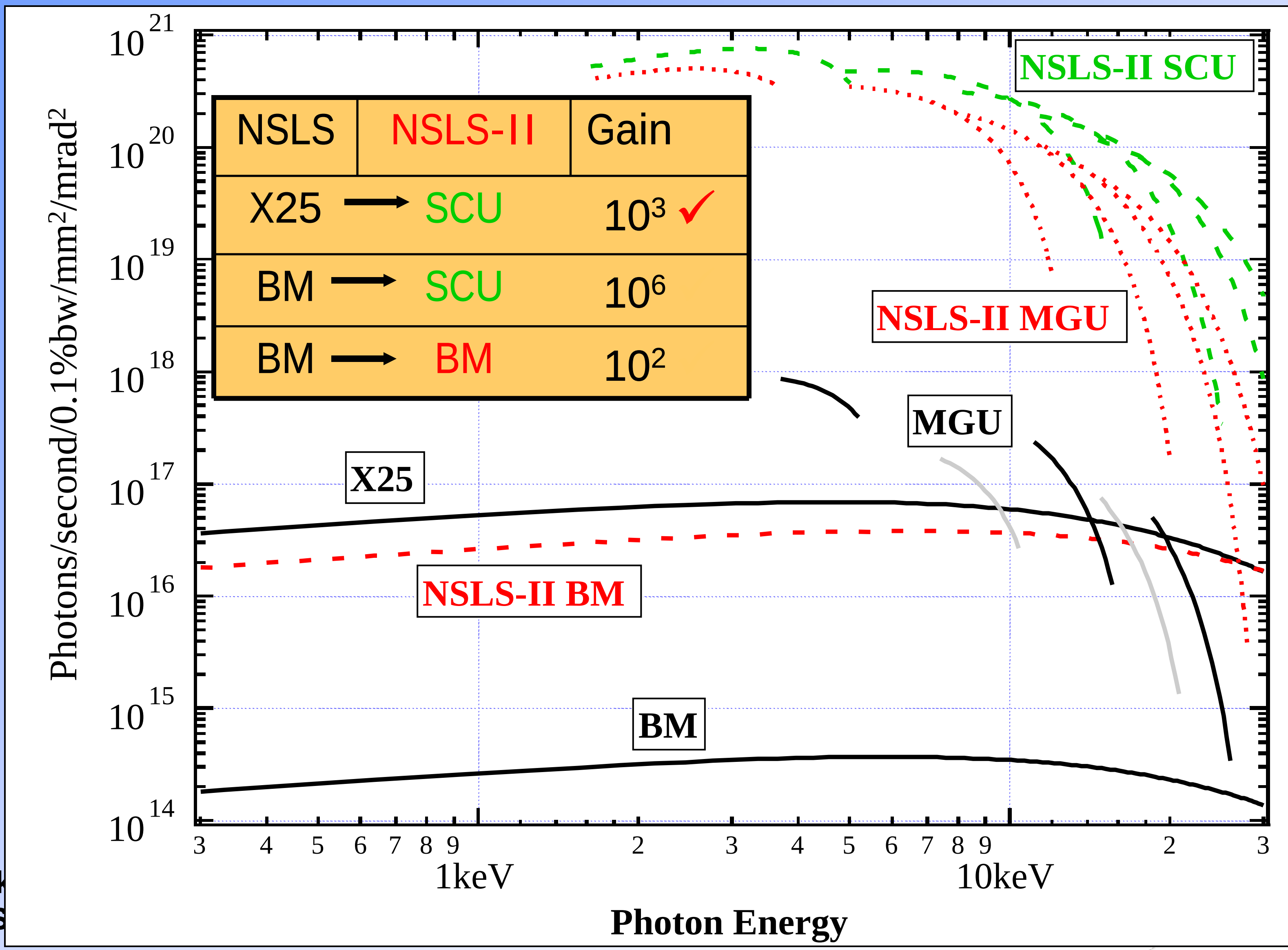
<u>Will it be there?</u>

- NSLS pioneered PM MGUs.
- NSLS and BNL SC Magnet Division are setting up a SCU testing facility.
- NSLS joined SLAC, ALS & APS in collaboration in SCU R&D.
- Parallel R&D efforts in Europe (ANKA, ACCEL) may lead to commercial sources of SCUs.
- ⇒Confidence in availability of SCU in time for NSLS Upgrade.

<u>NSLS-II SCU</u>

g=5 mm, λ_u=15 mm, K~2.2, n=1-11

Brightness


NSLS | NSLS-II | Gain
X25 → SCU 10^3 ✓
BM → SCU 10^6
BM → BM 10^2
NSLS-II SCU
NSLS-II MGU
MGU
X25
NSLS-II BM
BM
Photons/second/0.1%bw/mm2/mrad2
10^21
10^20
10^19
10^18
10^17
10^16
10^15
10^14
3 4 5 6 7 8 9 2 3 4 5 6 7 8 9 2 3
1keV
10keV
Photon Energy

RF System Choice

SPECS

830 kW with IDs (470 w/o)

2.8 MV @ 3% height

500 MHz SC RF

+ Higher V/cavity saves space: 2-3 CESR cavities enough
+ No HOMs ⇒ no bunch-bunch feedbacks or detuning tricks
+ Fewer cavities ⇒ lower Z_{BB}
+ Coll. effects, lifetime, ID heat...
+ Demonstrated reliability
+ Commercially available
+ Trend for modern LS (SRRC, CLS, Diamond, Soleil, ...)

53 MHz NC RF

- Low gradient: 7 NSLS type cavities are needed
+ Best for high single bunch charge (>100ma)

Preliminary Parameters

Nominal Energy	3 GeV
Circumference	523 m
Number of periods	24 TBA
Max. ID Length	4 m
Bend Radius	7.64 m
Natural Emittance	1.5 nm
Betatron Coupling	0.5% (DL @ 1 Å)
Momentum Compaction	0.000187
Tunes H/V	36.38/13.72
Energy Spread	0.095%
RF Frequency	500 MHz
Natural Bunch Length (rms)	13 ps @ 3% rf bucket
Maximum Current	500 mA

Collective Effects & Lifetime

- **Single Bunch Instabilities**
  - Longitudinal Microwave: O.K. for $|Z/n|<0.1\ \Omega$
  - Transverse (TMCI, MW): R&D Issue
- **Couple Bunch Instabilities**
  - Resistive Wall: O.K. for SCU, feedback for MGU?
  - From Cavity HOM: O.K. due to SCRF
- **Intra-Beam Scattering**: O.K., only few % ε blow-up
- **Gas Scattering Lifetime:** O.K., elastic/inelastic >10hrs
- **Touschek Lifetime:** down to 2 hrs, O.K. with top-off?

Storage Ring R&D Issues

Our storage ring design/optimization is a work in progress:

- What does it really take to reach 1 nm? Size, lattice, cost…
  - Existence proof: ESRF (3.75 nm @ 6 GeV)
    measured ~1 nm @ 3 GeV (L. Farvacque, 2002)
  - Could this be done at lower circumference and higher current?
  - **Dynamic aperture tracking underway**: harmonic sextupoles, tune shift with amplitude, off energy, etc.
- Lifetime and top off injection
- Collective effects for small gap IDs, small α, etc.
- Magnets: gradient dipoles, strong sextupoles, etc.
- Booster design
- Accommodating IR users...

Closing Remarks & Outlook

Motivation: increased capacity & brightness

Goals: ~20 ID straights, ~10^3 gain in brightness

Concept: 3 GeV ultra-low emittance ring,
many small gap (SC?) undulators

Outlook:

- Encouragement from BESAC in Feb. 2003 ✓
- Continue with ring/booster/undulator designs
- Machine advisory committee
- User workshops and refinements of the science case in Fall 2003

We are very enthusiastic about this project!

Acknowledgements

- Many thanks to my colleagues on the NSLS scientific & technical staff for their contributions to the NSLS Upgrade.