EMITTANCE REDUCTION METHODS FOR NSLS-II

Weiming Guo
NSLS-II
LER workshop, Oct. 3, 2011 16:30-16:45

U.S. DEPARTMENT OF ENERGY

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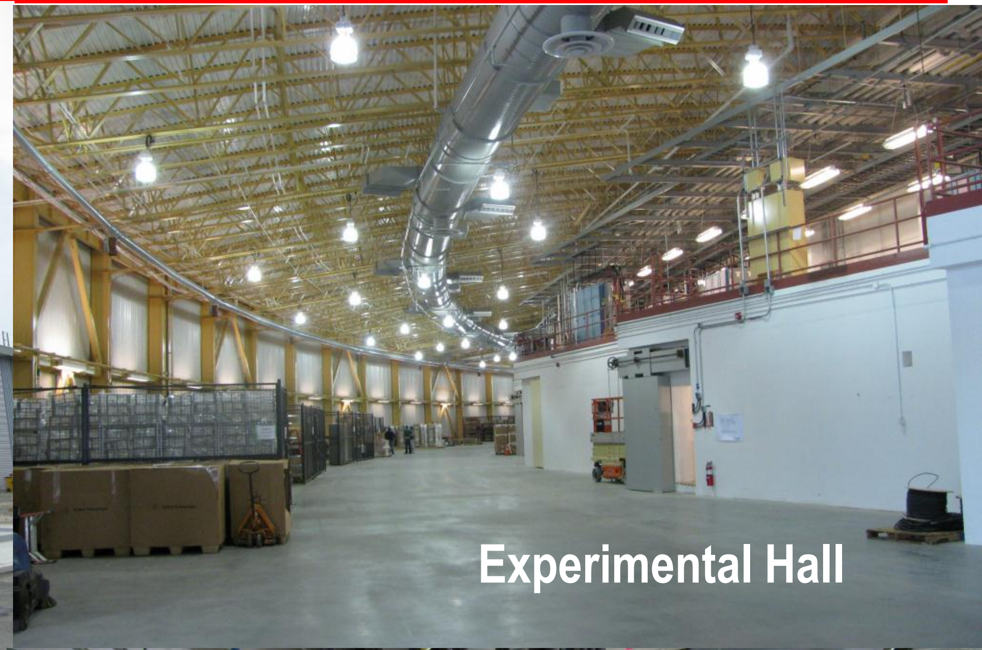
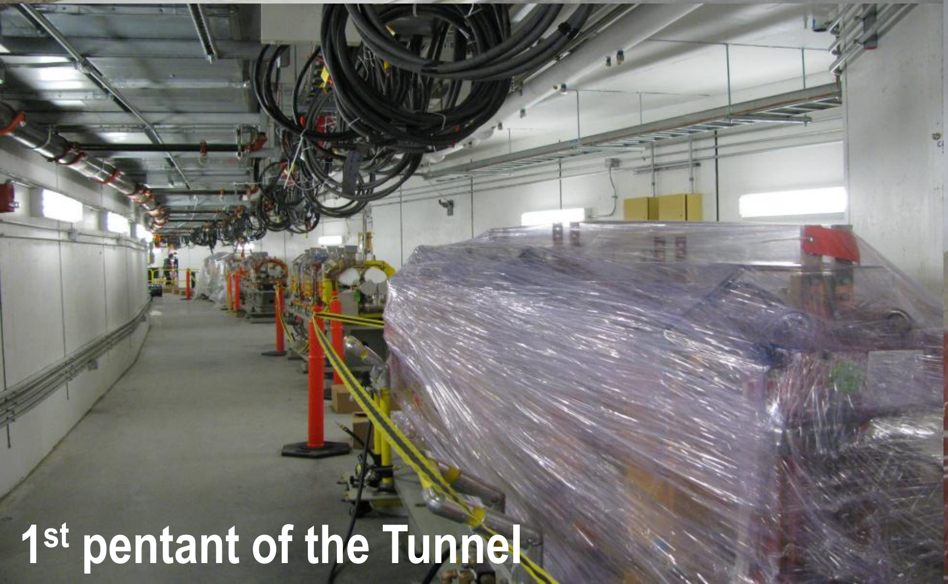
Outline

- Update on the NSLS-II construction
- What is new in the design
- Emittance reduction approach: damping wiggler
- Second approach: damping partition

Building and Installed Girders

Front Entrance


Experimental Hall


1st pentant of the Tunnel

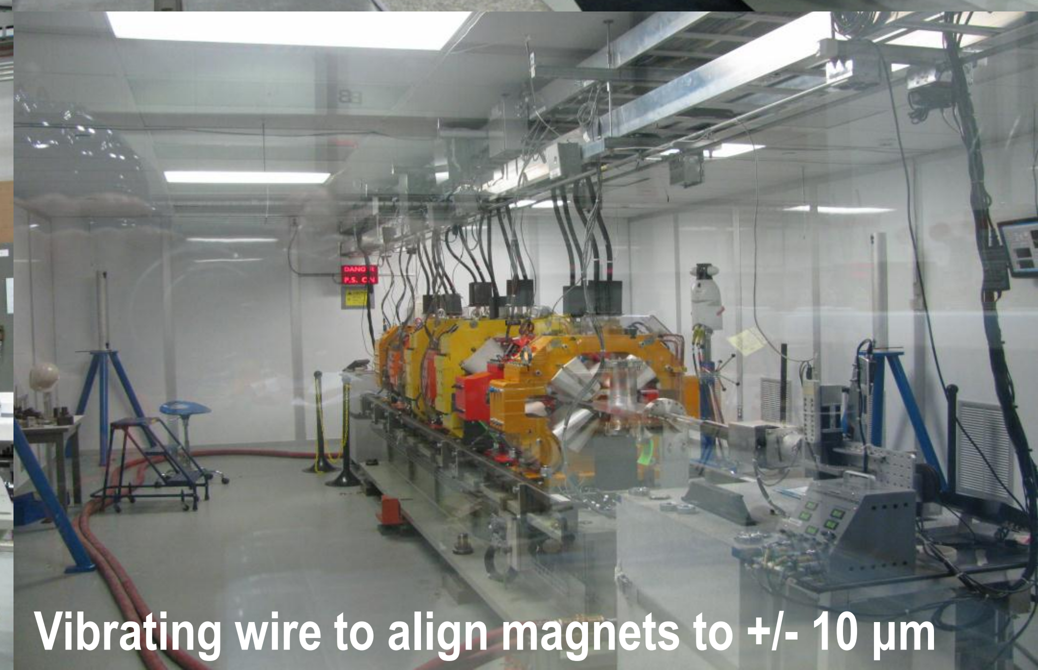

4 girders installed

Magnets and Alignment


Magnet storage


Dipole measurement setup


Pre-alignment using laser trackers

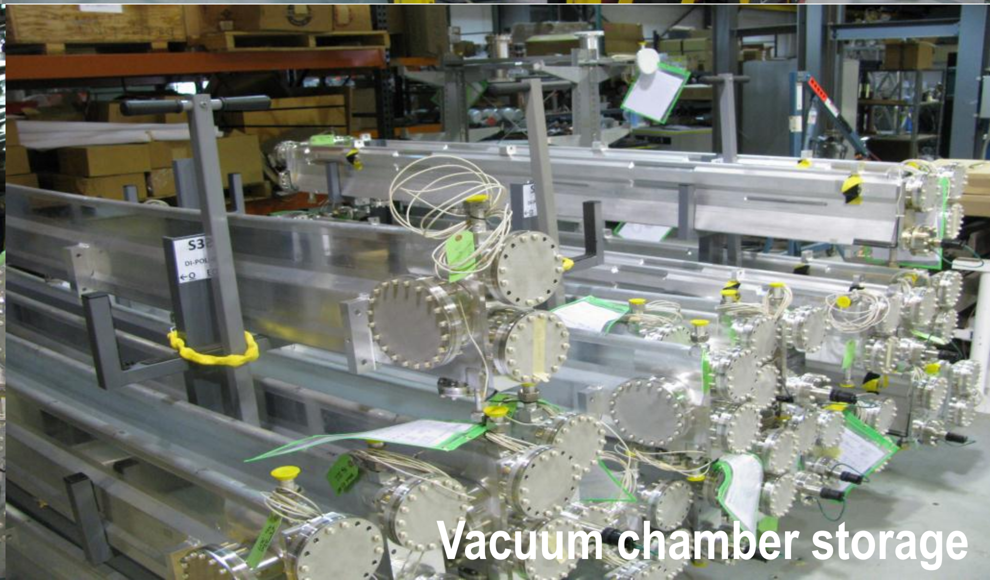

Vibrating wire to align magnets to +/- 10 μm

Vacuum Chamber

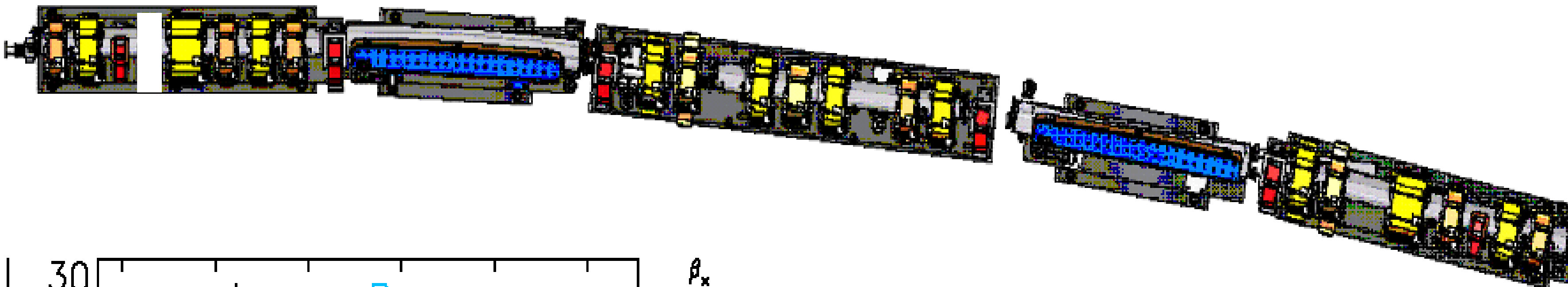
Vacuum Chamber measurement

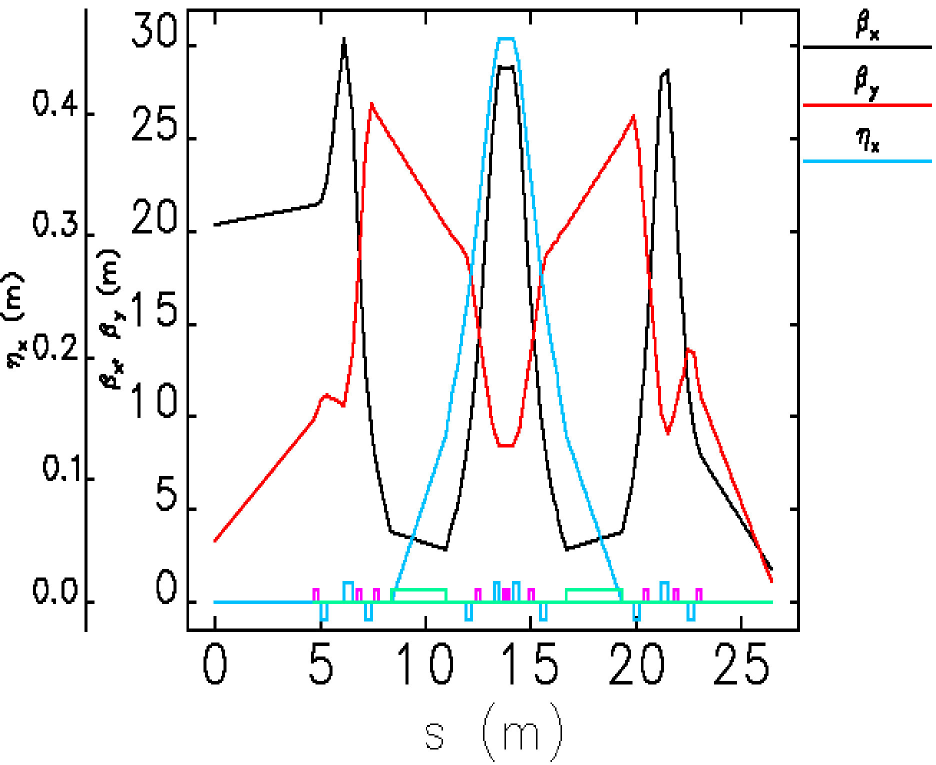
Vacuum chamber baking


Vacuum chamber storage


Vacuum chamber storage

Lattice Functions for One Cell





Dipole: 2, 1 ps

Quad: 10, 8 families, indep. powered

Sext: 10, 10 families, 1 ps for 1 family

H/V slow correctors: 6, 2 per girder

H/V Fast correctors: 3

BPMs: 6, 2 per girder

Requirements on nonlinear dynamics:

15 mm injection, +/-2.5% momentum

Some Recent 3rd Generation Light Sources

	Energy (GeV)	Emit. (nm-rad)	Beam Size σ_x/σ_y (μm)	Circum. (m) (μm)	Num. of straights	Current (mA)	Bunch length (mm)	Charge per bunch (nC)
SOLEIL	2.75	3.74	205 / 9	354	16	500	7.5	1.0
SSRF	3.5	3.9	155 / 10	432	20	300	4	0.6
DIAMOND	3	2.7	120 / 36	562	24	300	2.8	0.6
Max-4	3	0.25	47 / 6	528	20	500	50	5
NSLS-II	3	**1**	45 / 3	**792**	30	500	4.4	1.0

Lattice Design Evolution

- The magnet separation is standardized to 17.5 cm to save space

  Magnet interference is negligible due to the ~7 cm bore aperture;

  The space is slightly tight for BPM installation, but is manageable.

- The 3 chromatic sextupoles are placed asymmetrically to provide an extra nonlinear chromatic knob

  The three knobs can be used to correct $\xi_x^{(1)}$, $\xi_y^{(1)}$ and $\xi_x^{(2)}$

- Only one type of combined function magnet: corrector + skew quadrupole, to eliminate field Errors

  Pure dipole, quadrupole, sextupole, h/v corrector, fast corrector

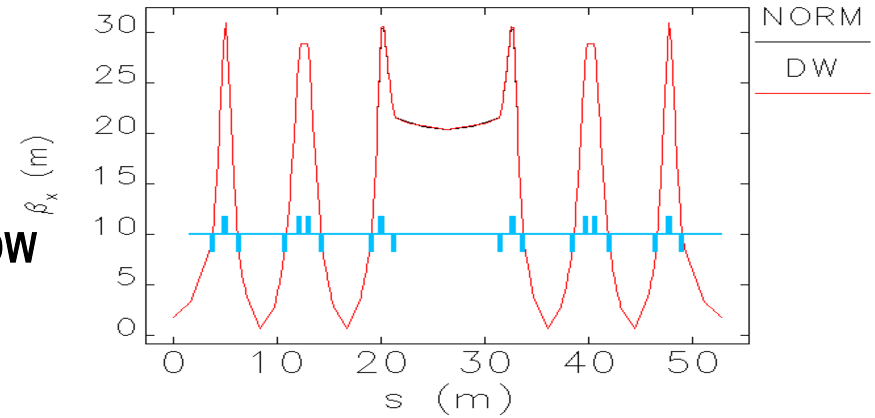
- Magnet fabrication and alignment deploy the state-of-the-art technology to ensure good performance

  The harmonics are specified to be a few units (10^{-4} at r=25mm); pole precision is ~10 μm after EDMing; every magnet is measured using rotating coil, and shimmed if necessary;
  the magnet will be aligned to +/- 30 μm using the vibration wire technique and laser trackers;
  the magnets at the peak dispersion location have larger aperture to provide larger good-field region (30mm).

The Damping Wigglers Approach

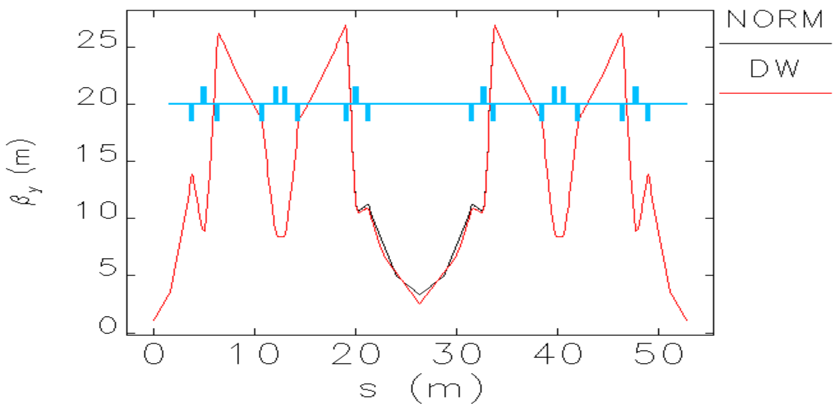
Cons and Pros:

- **Weak dipole (0.4T) to enhance the damping wiggler effect**
- **Long dipole(2.62m) increases the circumference, and contributes to the large peak beta function and large linear chromaticity**
- **Straights are needed for damping wigglers, even though DW can be used as radiation sources**
- **IDs also reduces emittance significantly**
- **Momentum spread of the bare lattice is small (5×10^{-4})**



Linear matching and nonlinear optimization

- **Three quadrupole families in the long straight are used to match the lattice ($\alpha_x=0$, $\alpha_y=0$, $\Delta\mu_x=0$)**
- **One-third of the ring is used for nonlinear optimization, instead of one super-cell.**



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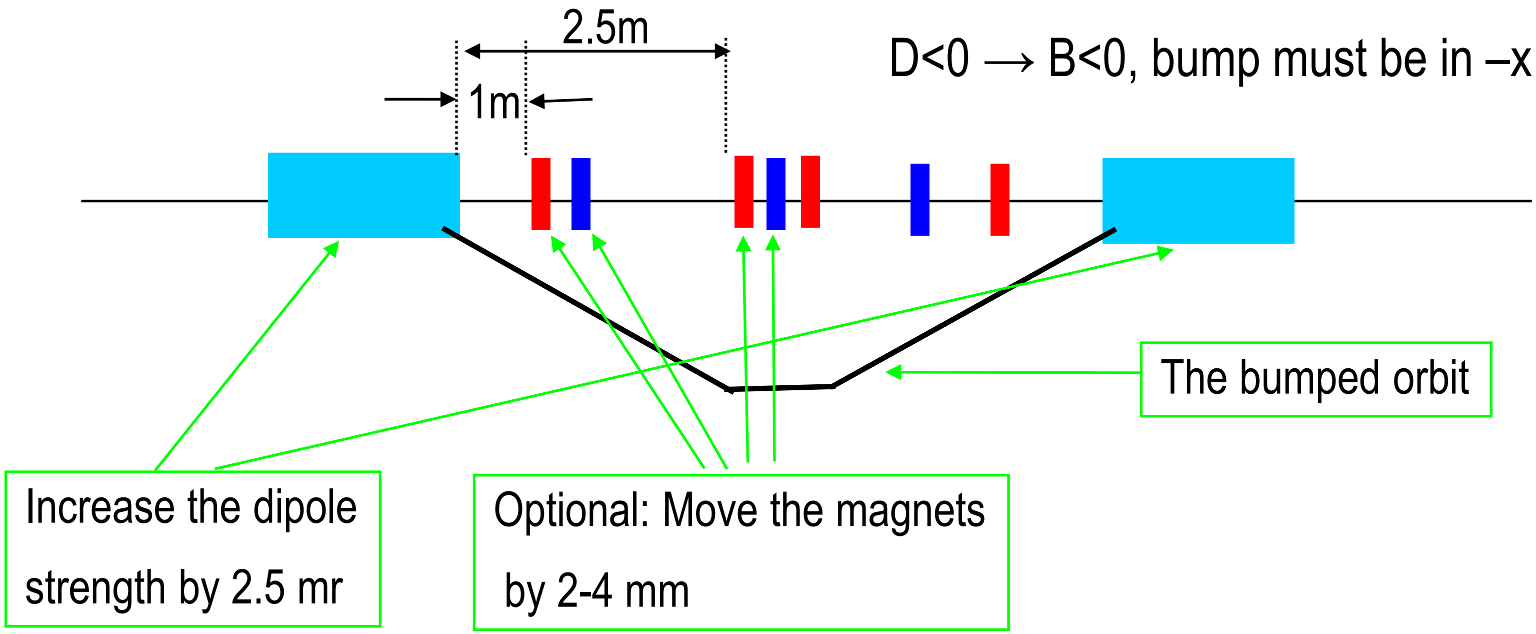
Second approach: Damping Partition

$$D = \oint \frac{\eta_x}{\rho^2}\left(\frac{1}{\rho} + \frac{2}{B}\frac{dB}{dx}\right)ds\left[\oint \frac{ds}{\rho^2}\right]^{-1}$$

D<0 → B<0, bump must be in –x direction



Other changes:

1. Photon Absorbers need to be realigned
2. Circumference, α_c, radiation energy loss, momentum spread

Comparison of Two Approaches

Emittance Reduction by Orbit Bump (θ=2.5mr)

	Emittance (nm)	Momentum spread (%)	J_E	Energy loss (MeV)	Alpha_c (10^{-4})
Bare lattice	2	0.051	2	0.286	3.6
BL + 3DW	1	0.083	2	0.67	3.6
BL + bump	0.76	0.06	1.5	0.302	2.3
BL+DP+ 3DW	0.64	0.09	1.68	0.69	2.3

Table 1: Lattice-Parameter Variation with Damping-Wiggler Length L_{DW}

L_{DW}	ϵ_x	σ_δ	τ_x	τ_E	E_{loss}	ν_s	σ_t
m	nm	10^{-4}	ms	ms	MeV	10^{-3}	ps
0	2	5.1	55.3	27.7	0.0191	8.71	9.0
21	0.87	8.3	23.5	11.8	0.673	8.62	15.0
28	0.73	8.6	19.7	9.9	0.803	8.57	15.6
35	0.63	8.8	17.0	8.5	0.932	8.51	16.1
42	0.55	9.0	14.9	7.5	1.062	8.44	16.6

Summary

- Improvements in lattice design: shorter drifts, asymmetric sextupole
- Emittance reduction through damping wiggler: advantages and implementation
- Creating an orbit bump at the DBA center is an effective way to increase the damping partition parameter; and hence reduce the emittance

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