Workshop on Accelerator R&D for Ultimate Storage Rings (Beijing, October 30, 2012)

Lattice Design for SPrign-8 II

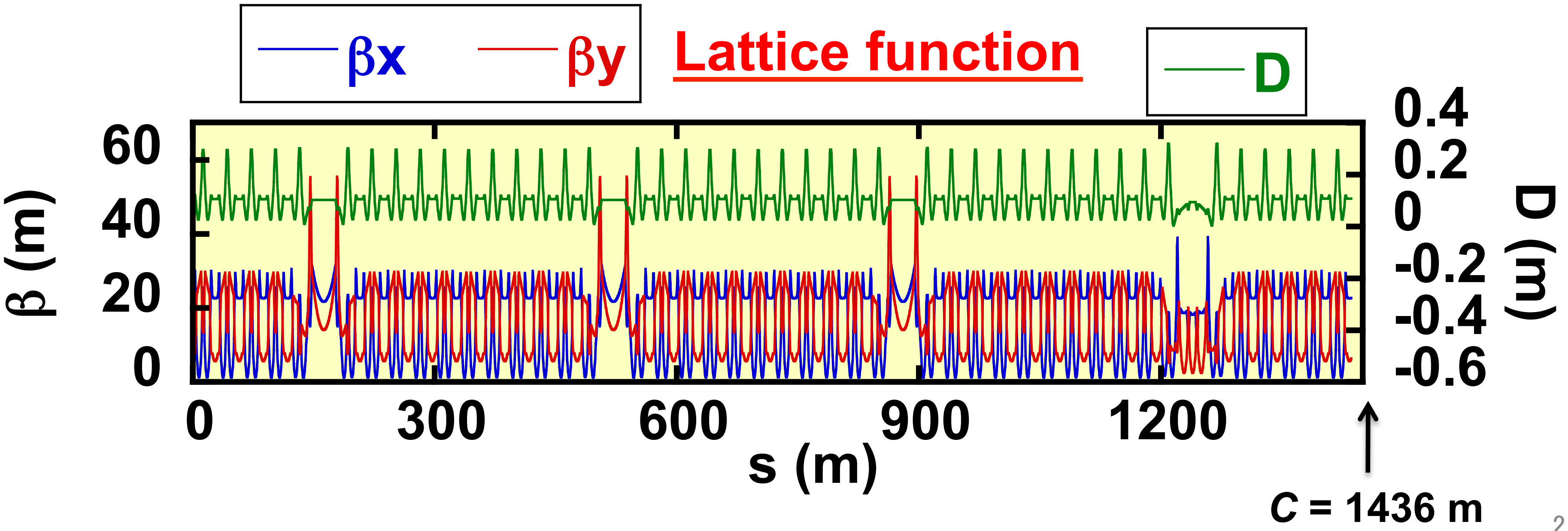
Y. Shimosaki, JASRI / SPring-8

Agenda

1 SPring-8 vs. SPring-8 II
2 Requirements for lattice design of SPring-8 II
3 Strategy of lattice design
4 Latest lattice design
5 Summary

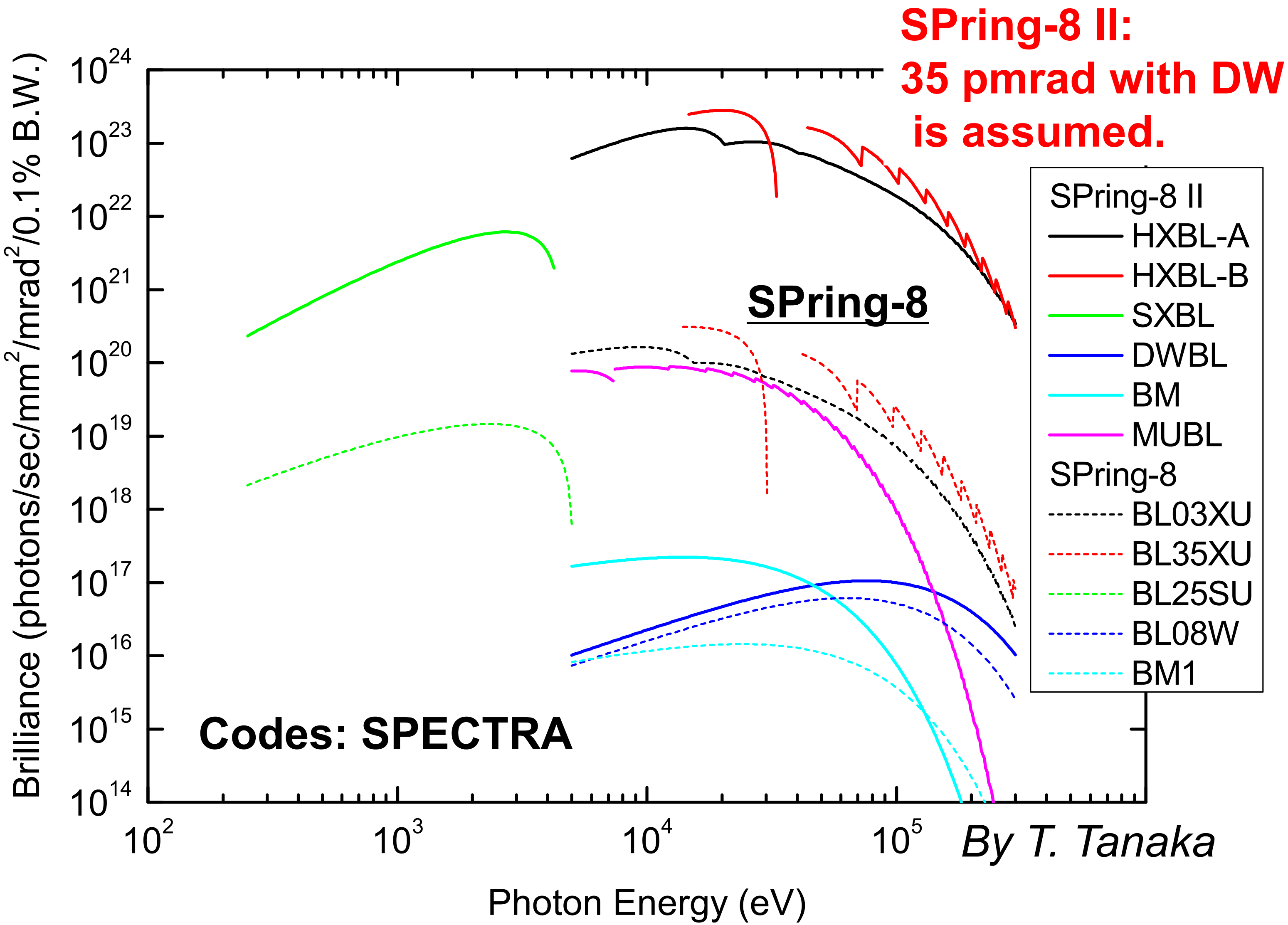
SPring-8

SPring-8: 3rd Generation Synchrotron Radiation Facility (8 GeV, 100 mA, 3.49 nm.rad)



SPring-8 vs. SPring-8 II (1)

Ultimate goal of SPring-8 II: **To provide 10^3 times higher brilliance than that of SPring-8 (0.5 ~ 100 keV).**



SPring-8 vs. SPring-8 II (2)

	SPring-8	SPring-8 II (Latest design)
Electron energy	8 GeV	6 GeV
Stored current	100 mA	300 mA
Lattice	Double Bend (2B)	6 Bend Achromat (6BA)
Natural emittance	3400 pm.rad	67.5 pm.rad (w/o D.W.)
Tune	(40.14, 19.35)	(141.865, 36.65)
Natural chrom.	(-88, -42)	(-477, -191)
Power loss	9 MeV (Bend)	4 MeV (Bend)
Max. B	0.68 T	0.70 T
Max. Q: B'L / Bρ	0.40 m^{-1}	1.49 m^{-1}
Max. Sx: B"L / Bρ	6.44 m^{-2}	110 m^{-2}
Tolerance of Sx aligenement error		$\sigma = \pm 10\ \mu m$ (2σ cut)

Requirements for Lattice Design of SPring-8 II

Requirements:

1. 10^3 times higher brilliance than that of SPring-8 (photon energy of 0.5 ~ 100 keV)
2. Dynamic aperture larger than $|x|$ = 2 mm @ Injection point

etc

Injection Scheme:

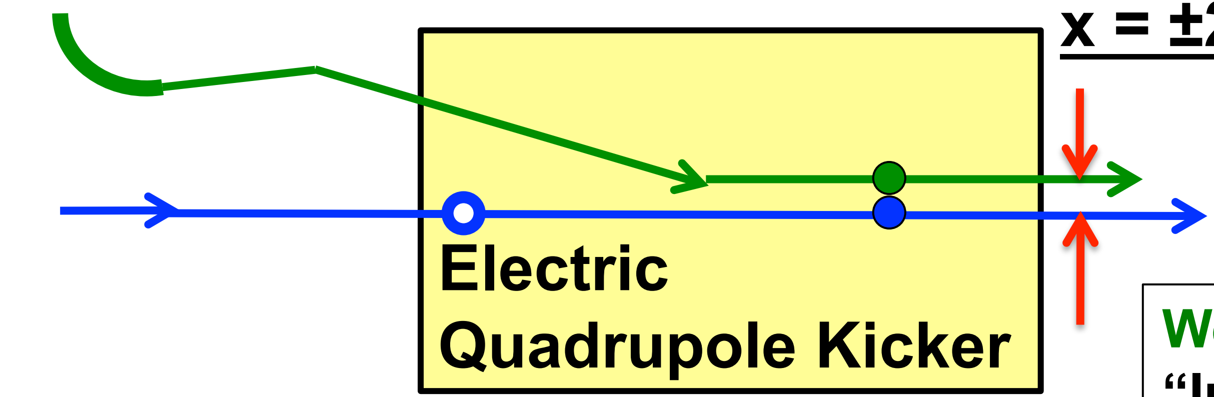
Required dynamic aperture (DA) for off-axis injection:

x = ±2 mm @ Injection point

$(\beta_x, \beta_y, \eta_0) \sim (25, 8, 0)$ (m)

$\alpha_x = \alpha_y = \eta'_0 = 0$

Injector



Wednesday 14:50~ : Soutome, "Injection scheme for the SPring-8 upgrade".

Strategy of Lattice Design for SPring-8 II

Design of Linear Optics

1 as lower natural-chromaticity as Sx becomes lower
2 with low-β for brilliance, and with high-β for injection

↓

Tune Selection

1 for avoidance of strong resonances
2 for (non-)interleaved sextupole

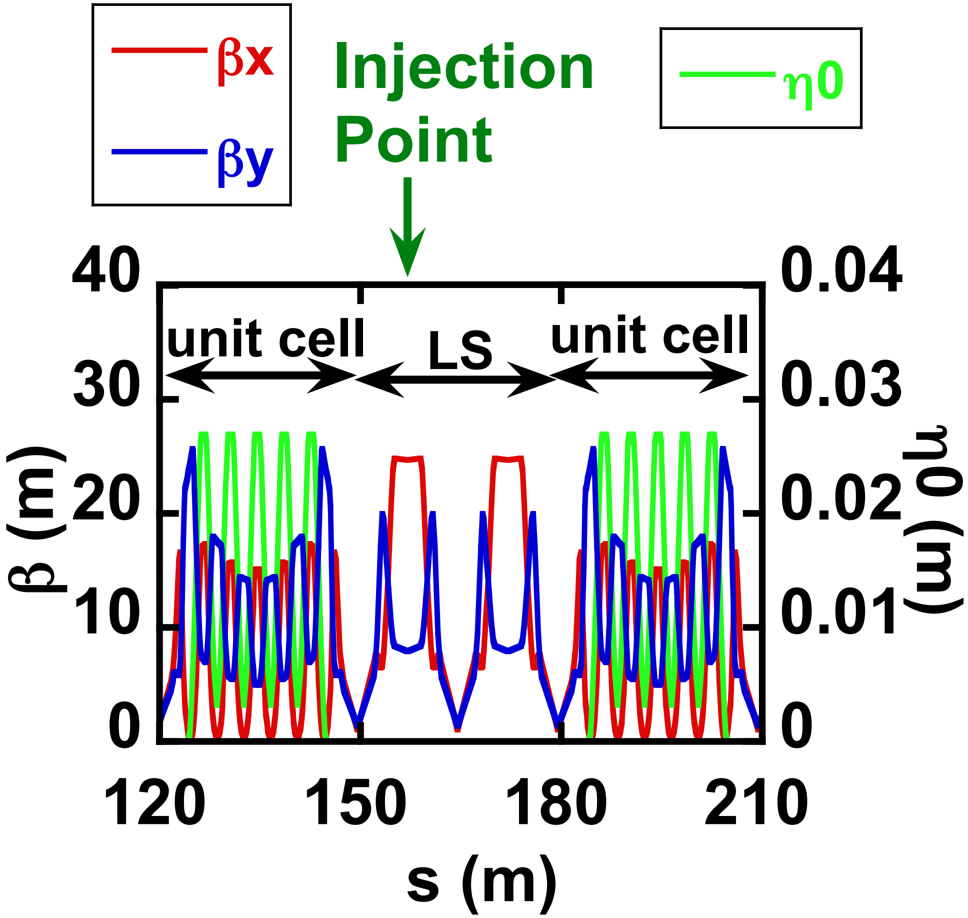
↓

Design of Nonlinear Optics

by harmonic method with (non-)interleaved Sx to collect
1 natural chromaticity,
2 amplitude dependent tunes,
3 nonlinear resonances independent on Δp/p,
4 nonlinear resonances by Q and Sx for off-momentum,
at the same time

Iteration (tune survey, etc)

Design of Linear Optics & Tune Selection



6BA lattice function
(70 pmrad w/o DW)

[1] H. Wiedemann, "Particle Accelerator Physics", Springer.

Lower Natural-Chromaticity
as Sx becomes lower.

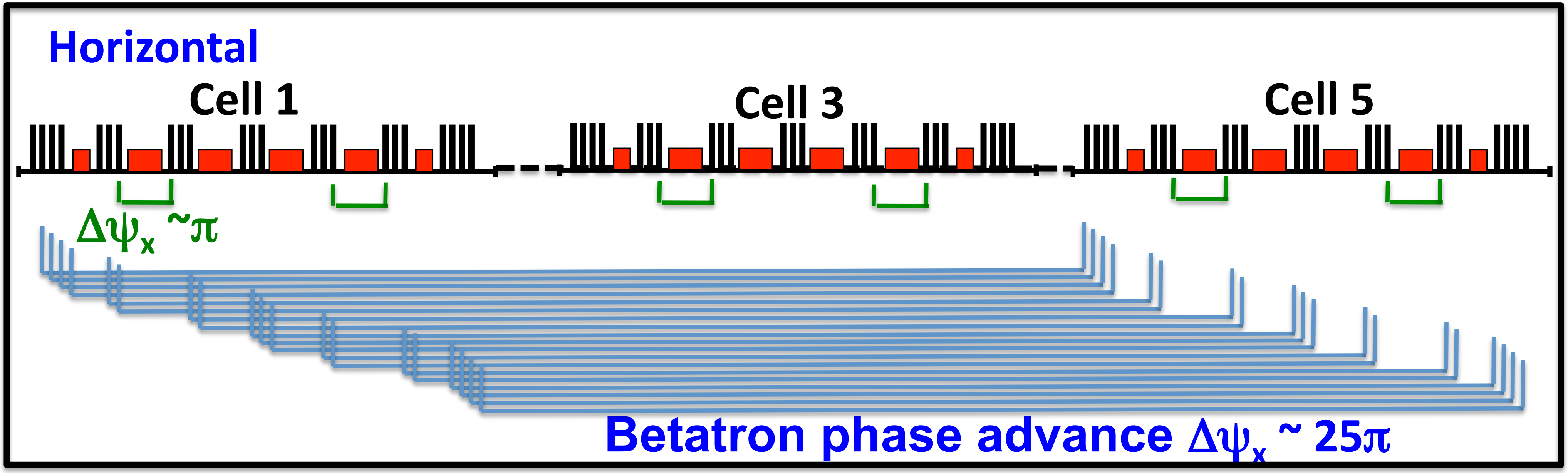
Low-β @ Light Source Point
to increase brilliance [1]
$\beta_x \sim \beta_y \sim L / 2\pi \sim 1$ m.

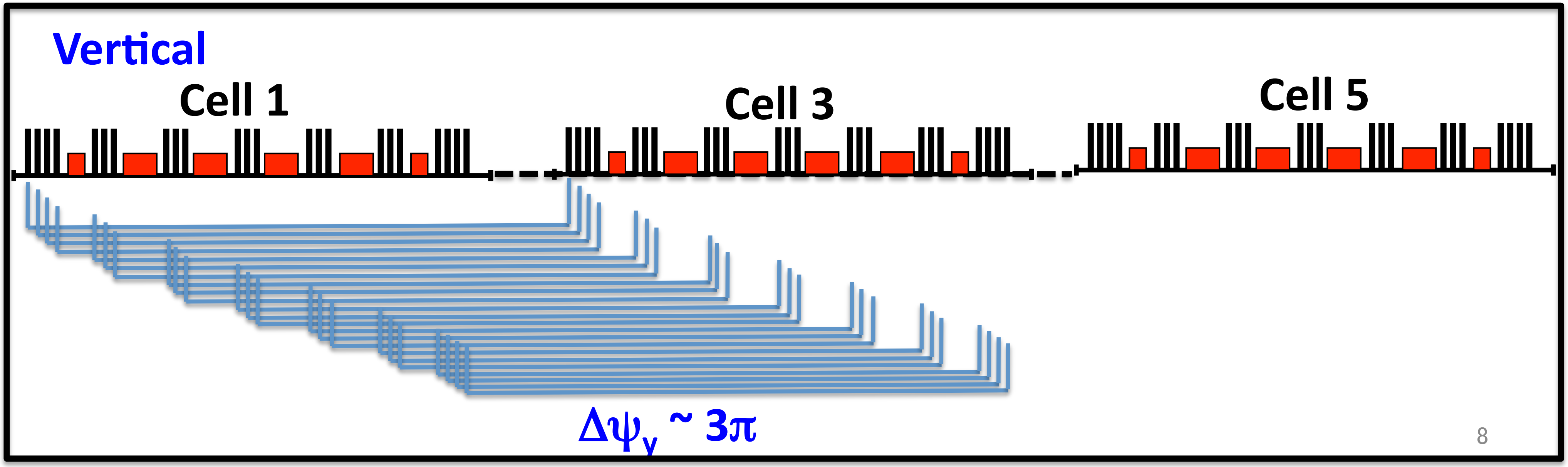
High-β @ Injection Point
to enlarge dynamic aperture
$\beta_x \sim 25$ m at long straight.

Tune Selection
to avoid strong resonances,
to adjust phase advance
for (non-)interleaved Sx.

(Non-)interleaved Sextupole

- I transformation





Strategy of Lattice Design for SPring-8 II

Design of Linear Optics

↓

Tune Selection

↓

Design of Nonlinear Optics

by harmonic method with (non-)interleaved Sx to collect

1. **natural chromaticity,**
2. **amplitude dependent tunes,**
3. **nonlinear resonances independent on $\Delta p/p$,**
4. **nonlinear resonances by Q and Sx for off-momentum,**

at the same time

Iteration (tune survey, etc)

Design of Nonlinear Optics (What & How)

Isolated Resonance Hamiltonian

(Qx, Qy): Tune

What

How

Resonant potential induced by Sx without Δp/p

$$\langle H\rangle \propto \boxed{\left\langle U\left(Q_x \sim \text{int.}\right)\right\rangle_{Sx} + \left\langle U\left(3Q_x \sim \text{int.}\right)\right\rangle_{Sx} + \left\langle U\left(Q_x \pm 2Q_y \sim \text{int.}\right)\right\rangle_{Sx}}$$

Set to ~ 0

(Off-momentum) Resonant potential by Q

$$+\frac{\Delta p}{p}\boxed{\left\{\left\langle U\left(2Q_x \sim \text{int.}\right)\right\rangle_{Q} + \left\langle U\left(2Q_y \sim \text{int.}\right)\right\rangle_{Q}\right\}}$$

Cancel

(Off-momentum) **by Sx**

$$+\frac{\Delta p}{p}\boxed{\left\{\left\langle U\left(2Q_x \sim \text{int.}\right)\right\rangle_{Sx} + \left\langle U\left(2Q_y \sim \text{int.}\right)\right\rangle_{Sx}\right\}}$$

Suppress

+ "(on-momentum) Higher order resonant potentials by Sx"

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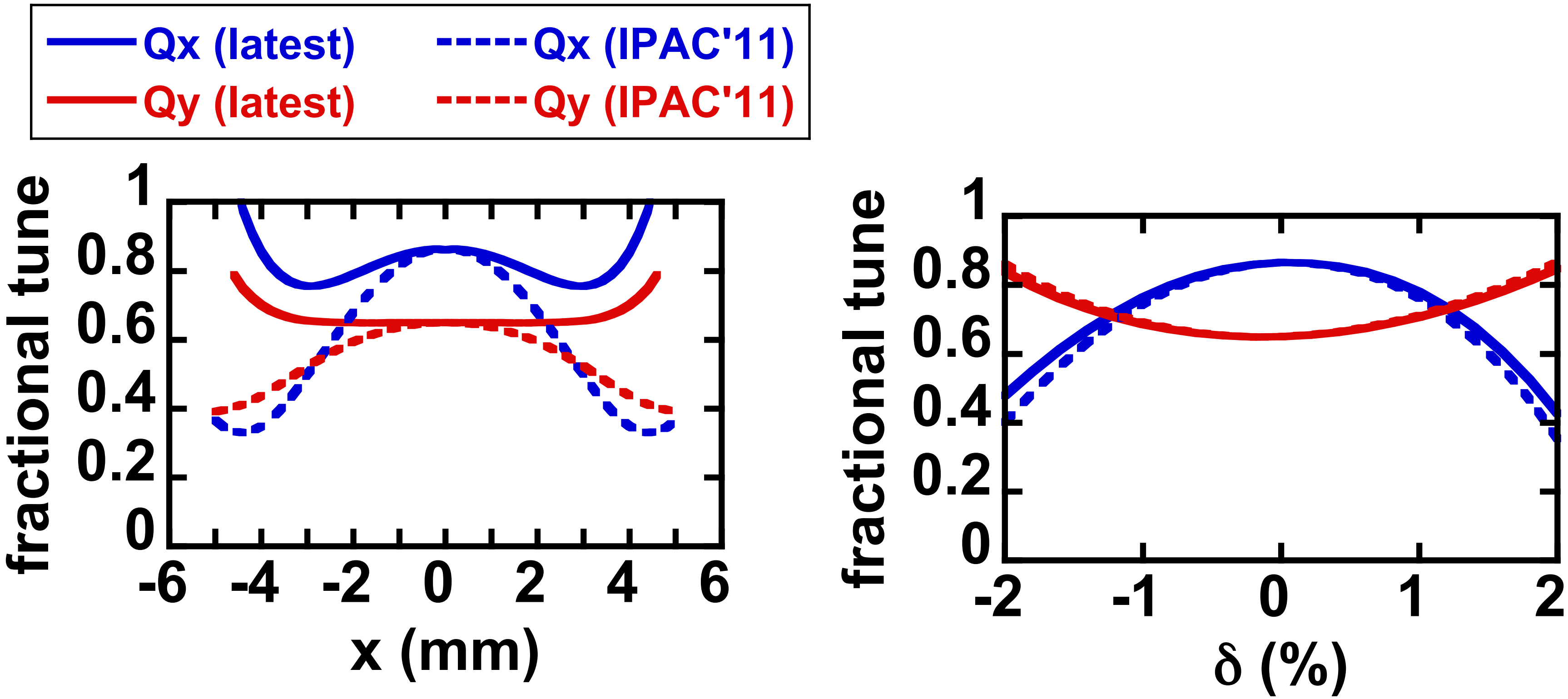
Iteration (tune survey, etc)

Latest Lattice Design

Sextupole Optimization *(latest)*

Amplitude- and momentum-Dependence of Tune
Observed at Injection Point



x dependent tune

momentum dependent tune

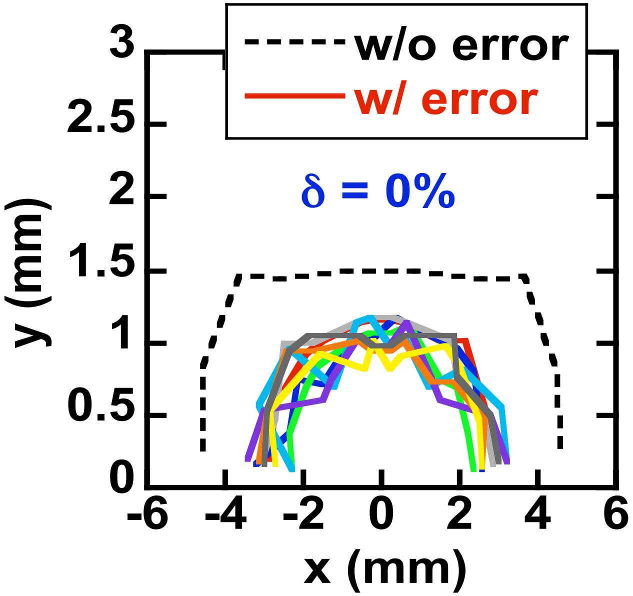
Codes: PATRASH, CETRA, ELEGANT

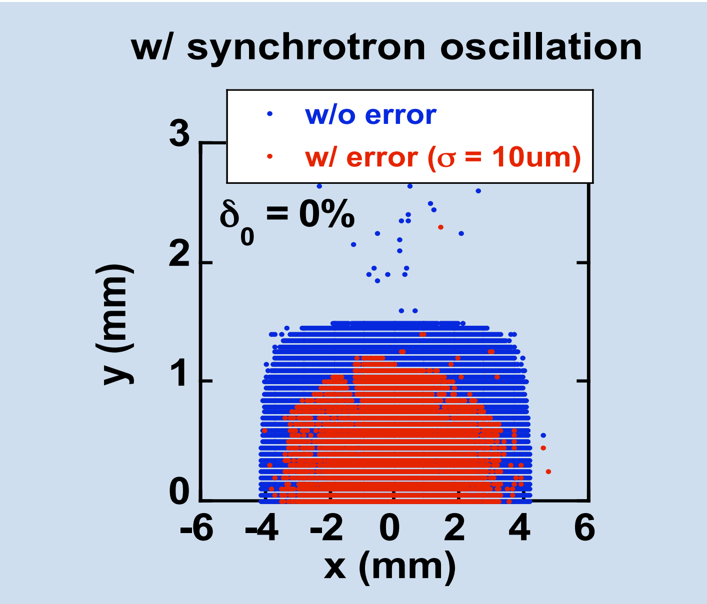
Sextupole Optimization *(latest)*

DA w/ SX Alignment Error (σ = 10μm, cutoff 2σ) at Injection Point

⇧

σ = 5μm @ IPAC'11





Required dynamic aperture (DA) for off-axis injection:

x = ±2 mm @ Injection point

$(\beta_x, \beta_y, \eta_0) \sim (25, 8, 0)$ (m)

$\alpha_x = \alpha_y = \eta'_0 = 0$

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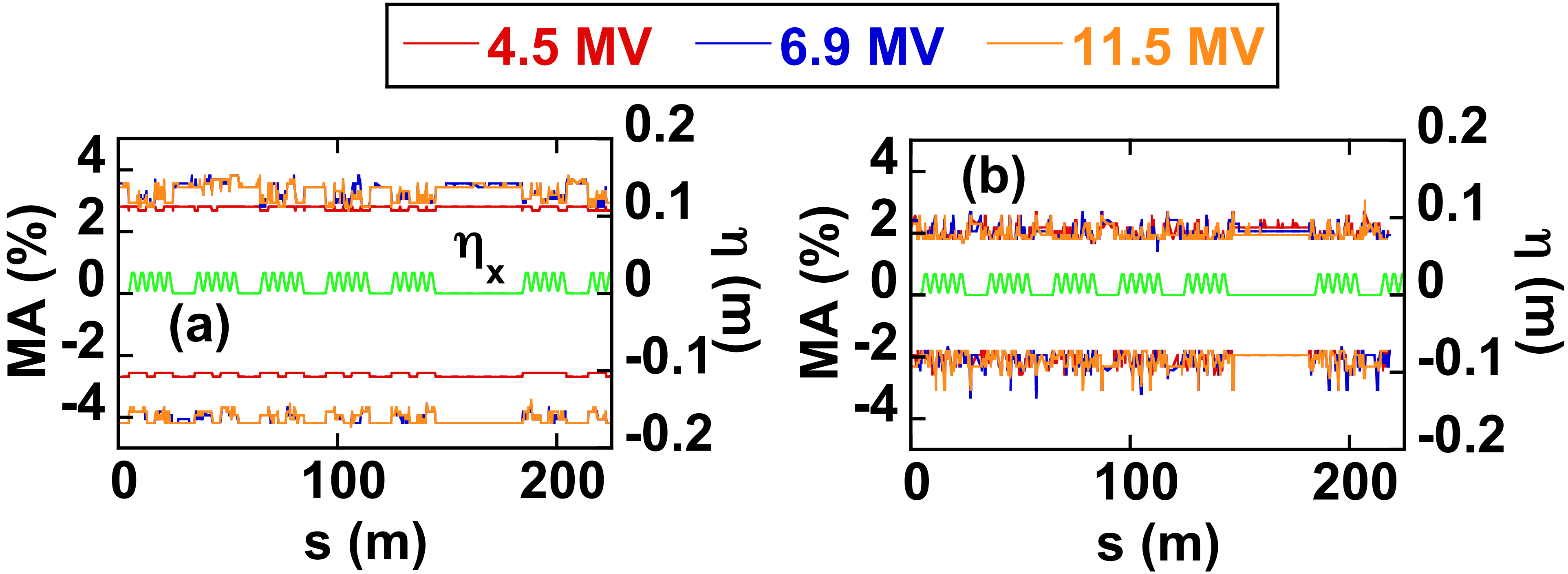
ID's error is not included.

Sextupole Optimization *(latest)*

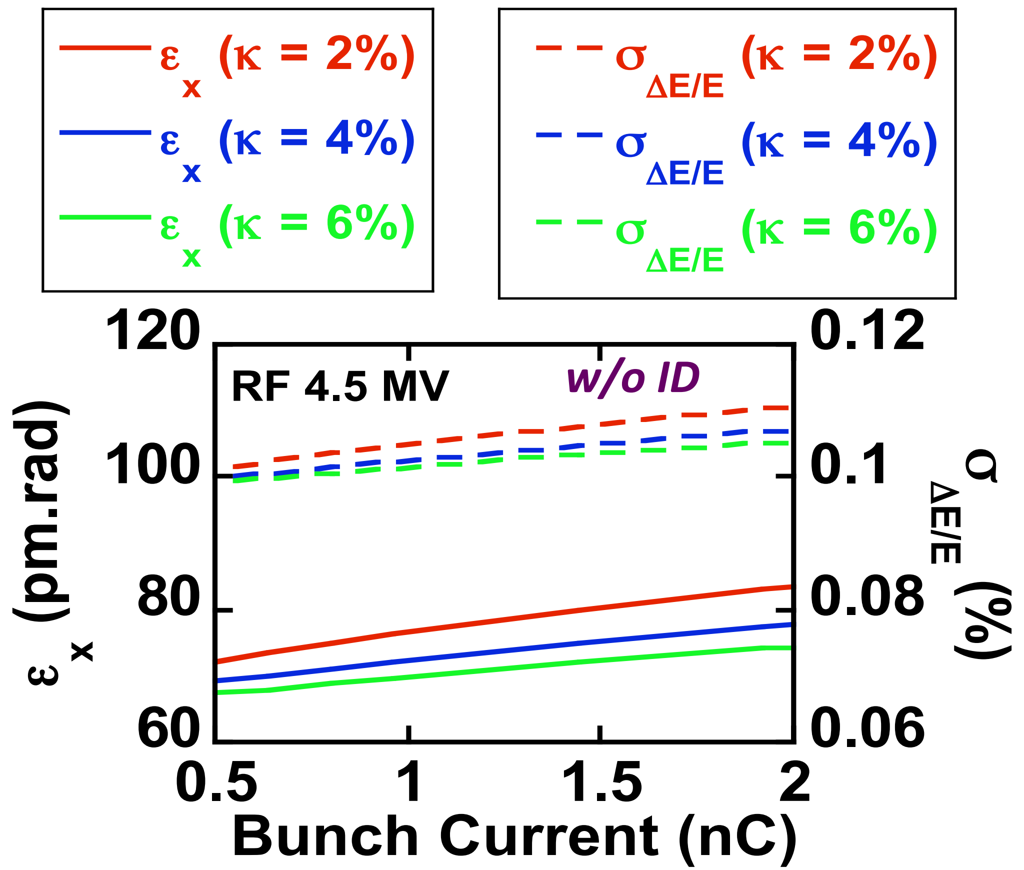
MA w/ SX Alignment Error (σ = 10μm, cutoff 2σ)



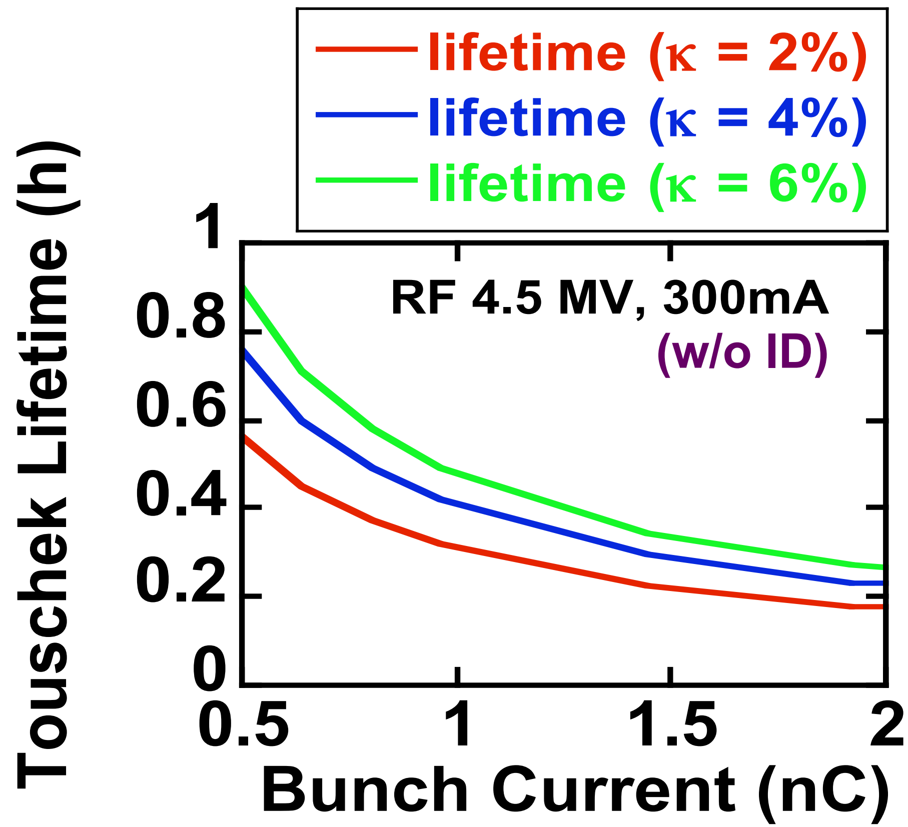
Momentum Acceptance (MA) (a) w/o error and (b) w/ error.

Intrabeam Scattering & Touschek Lifetime

Emittance and Energy Spread



Touschek Lifetime



Bunch Length (rms): 7.7 – 10 ps

cf.) 1nC/bunch ⇔ 0.2mA/bunch

Ref.) K.Bane, PRST-AB 5 (2002) 084403.
K.Kubo, PRST-AB 8 (2005) 081001.

Bunch lengthening by Harmonic cavity seems to be indispensable.
Wednesday 11:10~ : Fujita

Summary

1. **Design study of SPring-8 II is in progress.**
   Ultimate goal: 10^3 times higher brilliance than that of SPring-8 (photon energy of 0.5 ~ 100 keV).

2. **6BA lattice of 70 pmrad is a target.**

3. **Dynamic aperture larger than |x| = 2 mm @ Injection point is required for off-axis injection.**

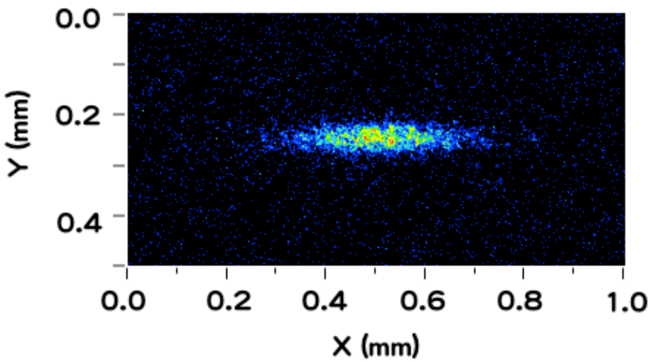
4. **Design of Nonlinear Optics by harmonic method with (non-)interleaved Sx**
   ➡ Dynamic aperture larger than |x| = 2 mm
   w/ SX Alignment Error (σ = 10μm, cutoff 2σ)

5. **Studies are on going ➡**

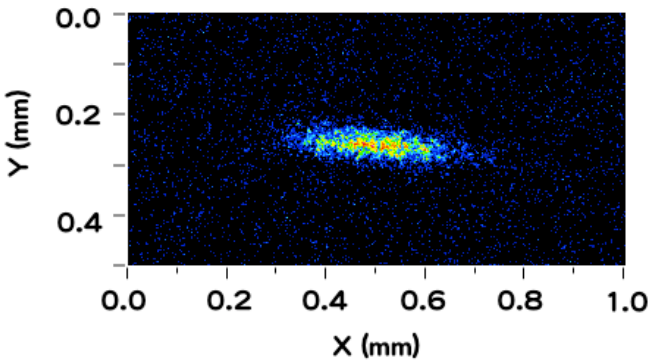
Design study of new optics for SPring-8

Design study of new optics for the SPring-8

1) to provide photon beams with higher brilliance and flux density than those of the present for "current users",
2) to obtain experience for Spring-8 II: justification of design strategy, tuning scenario, genetic algorism, etc.



(Present) 3.4 nm.rad



(New) 2.4 nm.rad

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