Sirius – Accelerator Physics

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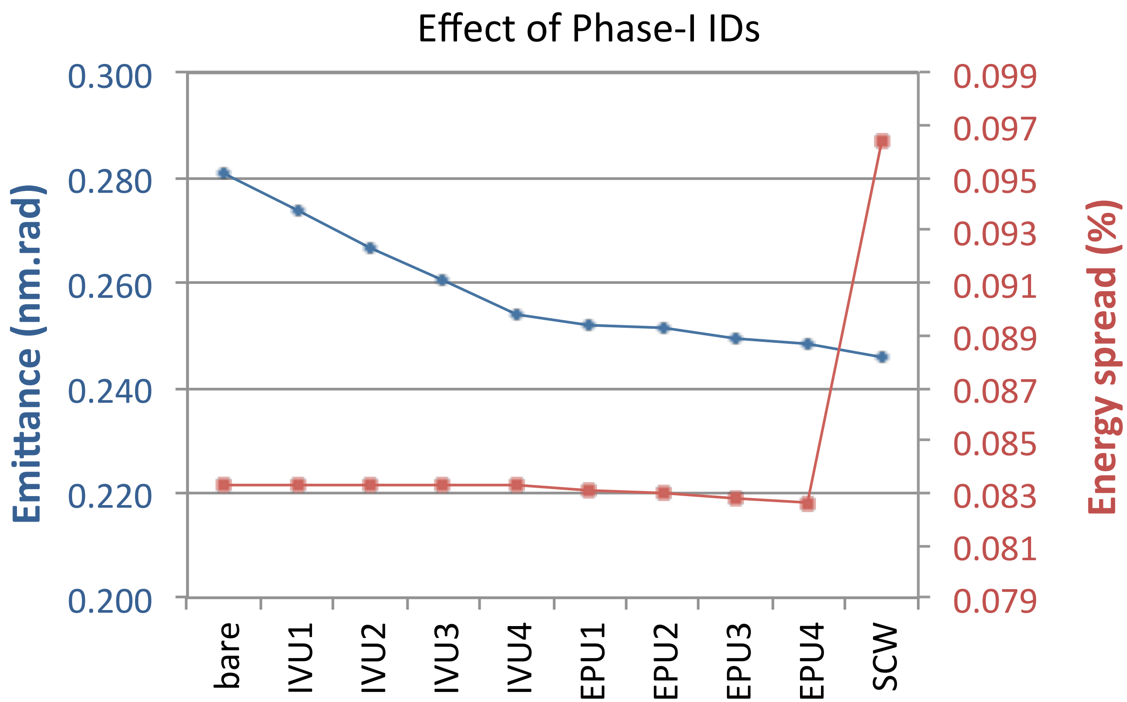
Diffraction Limited Storage Rings workshop – Stanford, Dec. 8th-10th, 2013.

Emittance optimization

- **Other tricks to reduce emittance for given Energy and Number of Dipoles**
  - Dipoles with transverse gradient to increase J_x.
  - Achromatic cells ⇨ IDs help to reduce the emittance.
  - 2 T superbend ⇨ longitudinal field gradient ⇨ strong focusing of the H-function at superbend.
  - Shorter outer dipoles. Outer dipoles are not optimized for emittance reduction because of the zero-dispersion condition. In the optimized condition the dispersion is minimum at the dipole center.
  - Low field dipoles ⇨ reduced energy spread

    ⇨ Longitudinal emittance reduction.

Effect of phase-I IDs



ID	K	λ (mm)	L (m)	B (T)
IVU1	2.07	18	2	1.2
IVU2	2.07	18	2	1.2
IVU3	2.07	8	2	1.2
IVU4	2.07	18	2	1.2
EPU1	3.38	50	3	0.7
EPU2	8	200	3	0.4
EPU3	3.38	50	3	0.7
EPU4	8	200	3	0.4
SCW	22.6	60	3	4.0

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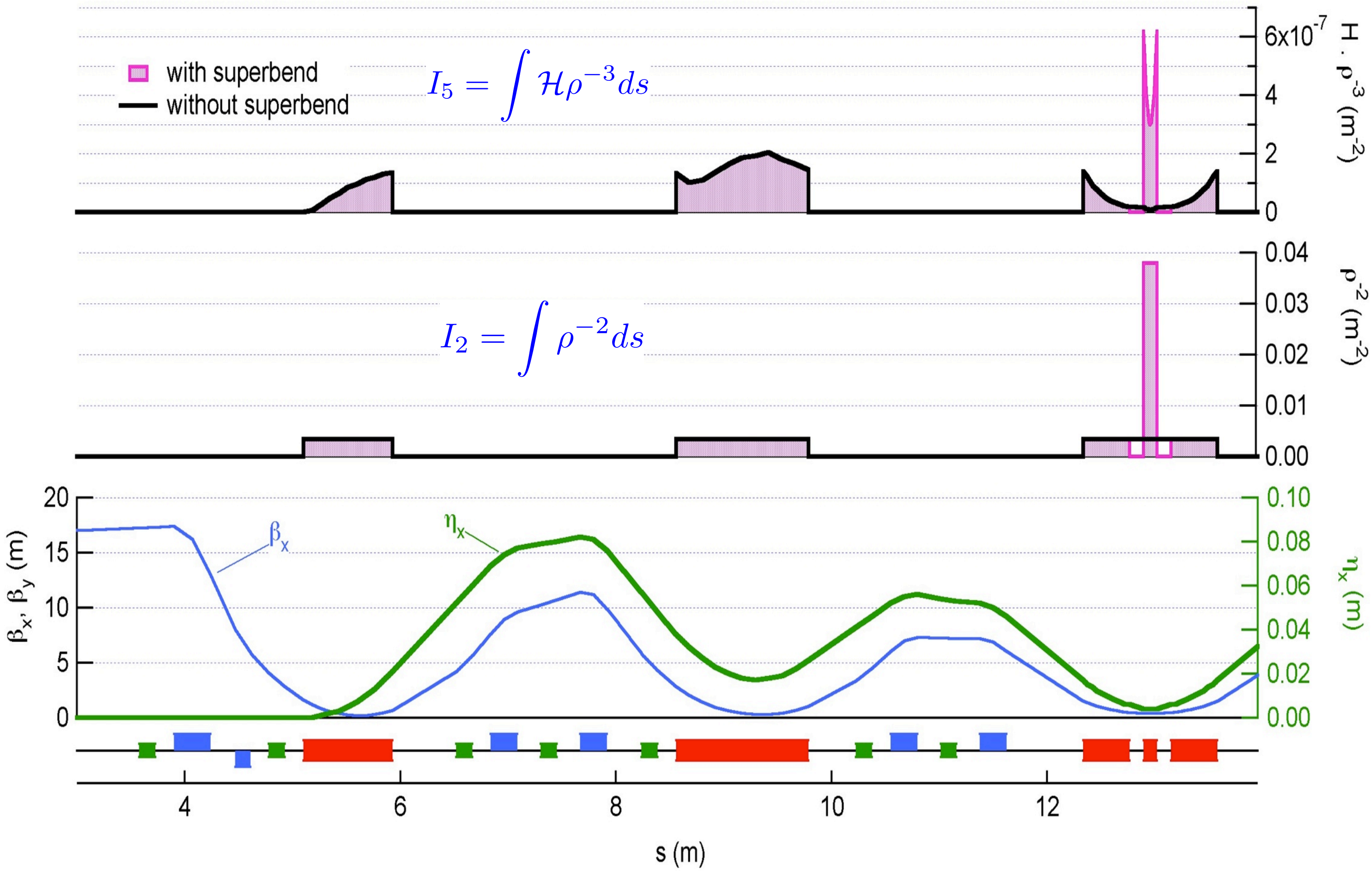
Superbends: longitudinal gradient

$$\mathcal{H} = \gamma_x D^2 + 2\alpha_x D D' + \beta_x D'^2$$

$$\epsilon \propto \frac{I_5}{I_2}$$

$$I_5 = \int \mathcal{H} \rho^{-3} ds$$

$$I_2 = \int \rho^{-2} ds$$



- without superbends: ε = 0.31 nm.rad
- with superbends: ε = 0.28 nm.rad 10% reduction

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Energy spread reduction ?

$$\sigma_\epsilon^2 = C\frac{I_3/I_2}{J_\epsilon}$$

$$\boxed{I_2 = \int \frac{1}{\rho^2} ds}$$

$$\boxed{I_3 = \int \frac{1}{|\rho|^3} ds}$$

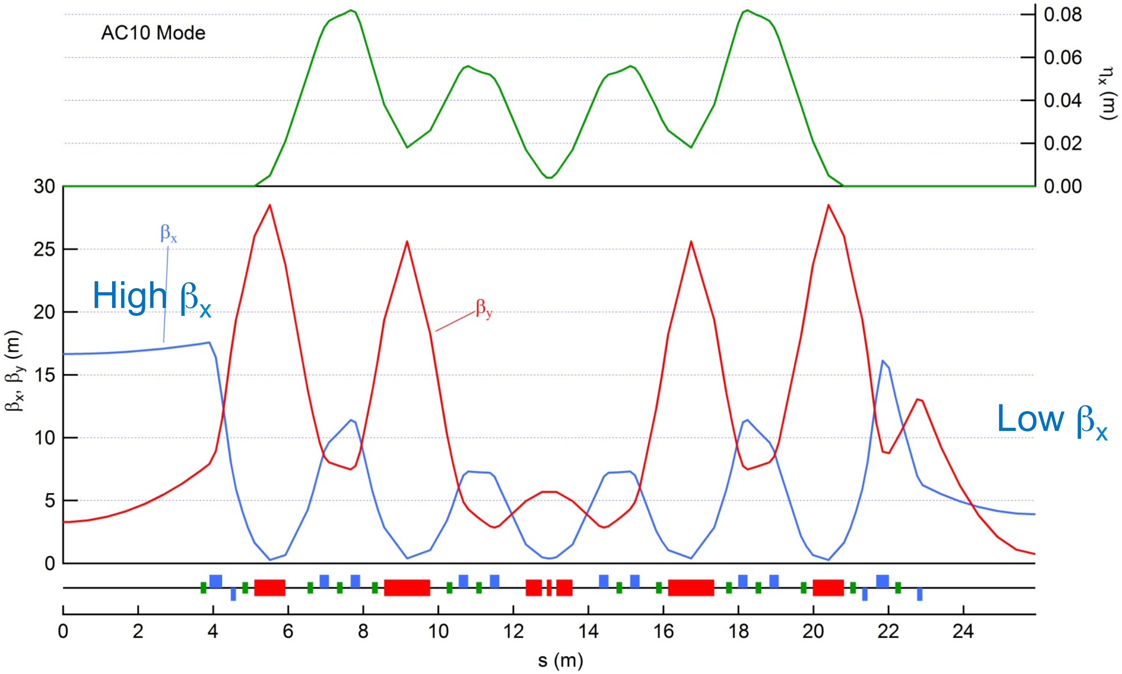
$$\boxed{C = \frac{55}{32\sqrt{5}} \frac{\hbar\gamma^2}{mc}}$$

$$J_\epsilon = 2 + \mathcal{D} \qquad J_x = 1 - \mathcal{D} \qquad \epsilon = C\frac{I_5/I_2}{J_x}$$

$$\sigma_\epsilon = \sqrt{C\frac{I_3/I_2}{2+\mathcal{D}}} \qquad \epsilon = C\frac{I_5/I_2}{1-\mathcal{D}}$$

- Damping is very inefficient: a small reduction in energy spread means a big increase in emittance.
- Using low field dipoles seems to be the best way.

Linear optics – AC10 mode



- Alternating high and low β_x
- 8 chromatic quadrupoles (4 families)
- 2 + 3 matching quadrupoles
- 14 sextupoles (9 families)

Nat. emittance	0.28 nm.rad
Tunes ν_x/ν_y	46.2 / 14.15
Nat. chrom. x/y	-113 / -80
Normal. chrom. x/y	-2.4 / -5.7
Mom. comp.	1.7×10^{-4}
Energy spread	0.08 %
Max. quad grad B'	39 T/m
Max. sex grad B''/2	1870 T/m^2
Dipole grad. B'	-7.8 T/m
τ_h	15.9 ms
τ_v	21 ms
τ_s	12.5 ms
J_x	1.32

Nonlinear optimization

Optimization of driving terms and higher order chromaticities — MAD, OPA, Tracy3

- Variables: Tunes and sextupole configuration
- Phase space tracking, Frequency Map Analysis

Check DA and MA with alignment and multipole errors — Tracy3

until we have a good initial condition for MOGA

Genetic optimization — Elegant / MOGA

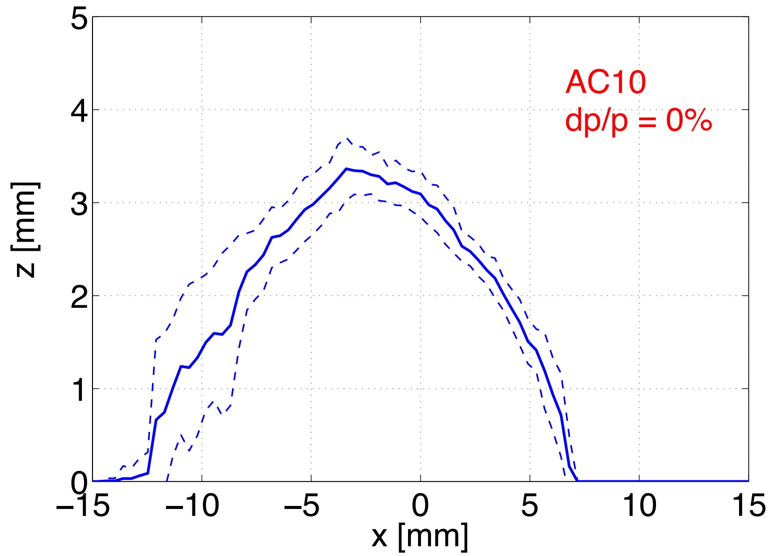
- Lattice model including small alignment and excitation errors to simulate residual orbit after correction. No orbit correction is applied.
- Variables: 9 sextupole families, 9 quadrupole families
- Constraints: lattice symmetry (10 fold + mirror @ cell center)
  tune quadrant, chromaticity, maximum beta functions, zero dispersion in SS
- Objectives: negative side of horizontal DA and Touschek lifetime

Check DA and MA with alignment and multipole errors — Tracy3

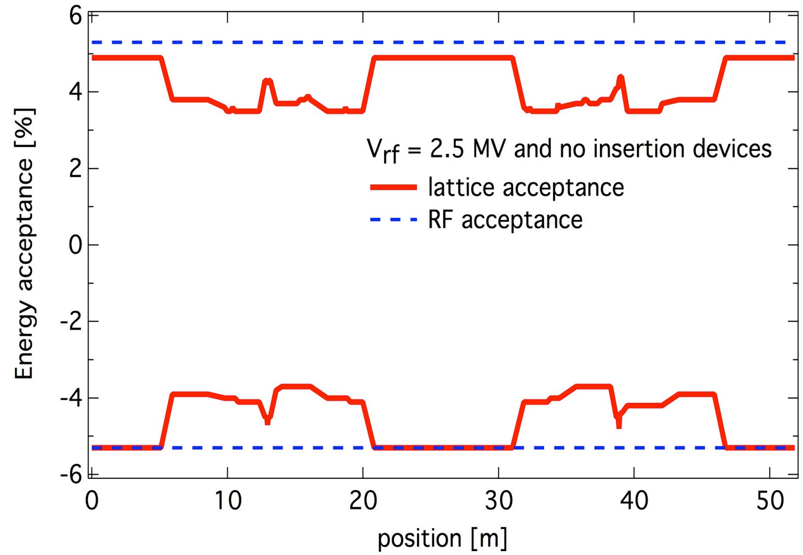
until a satisfactory solution is find

Dynamic aperture and momentum acceptance

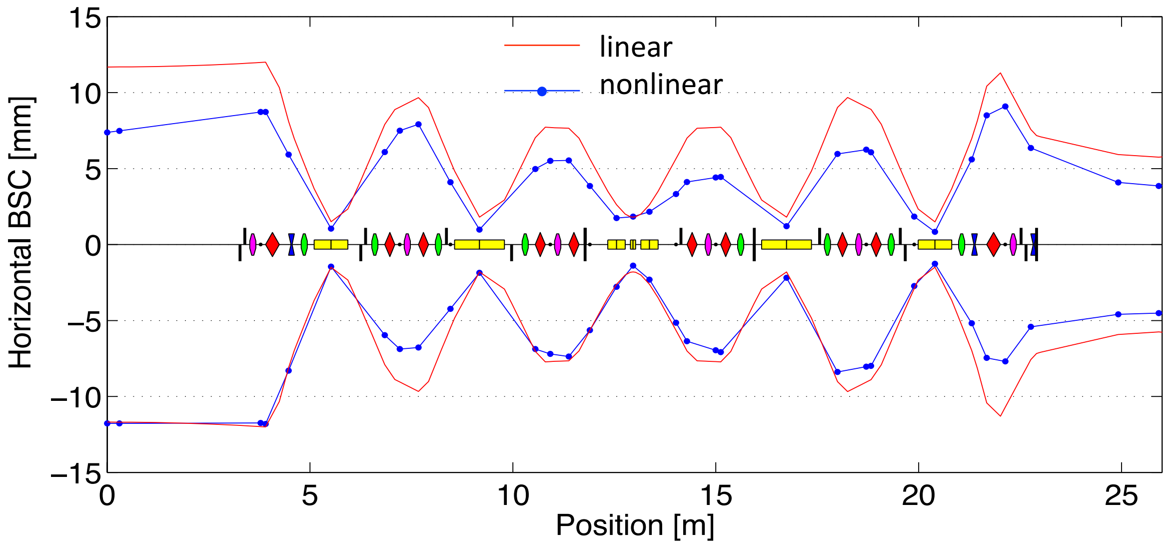
Dynamic aperture



Momentum acceptance



Note asymmetry due to optimization of negative side of DA.
Asymmetric beam-stay-clear allows for installation of small absorbers to shadow BPMs and bellows from radiation in straight sections.

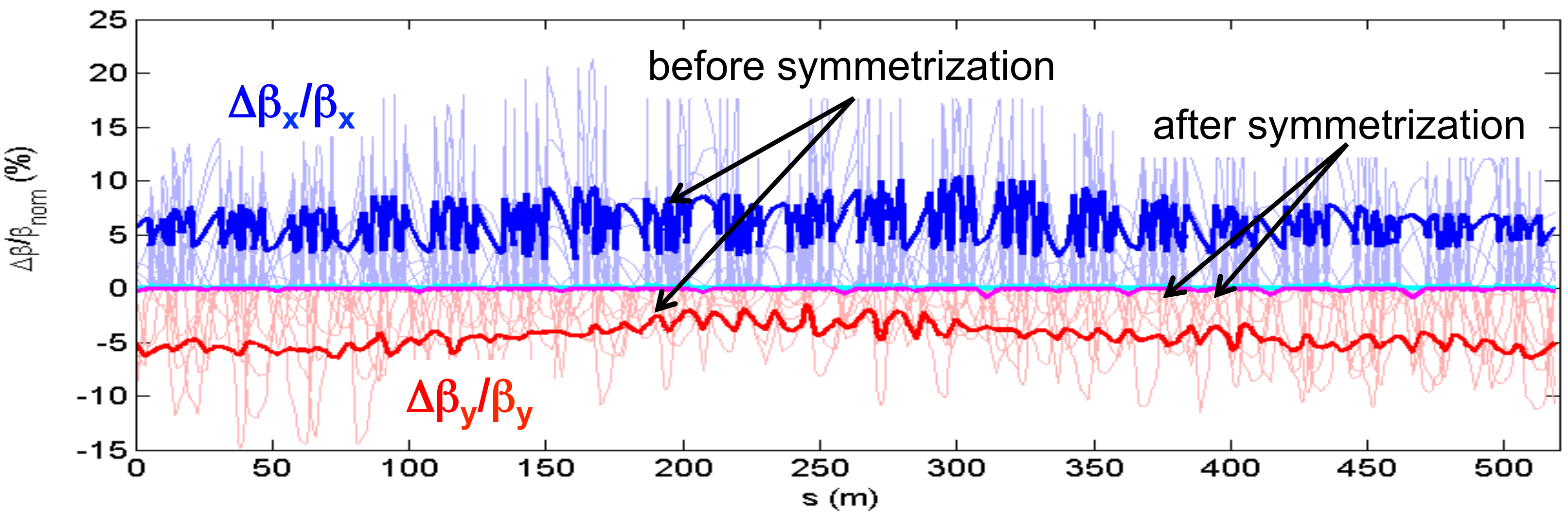


Optics correction – coupling and symmetrization

- Alignment errors dominate DA reduction. Optics is affected by off-centered orbit in sextupoles.

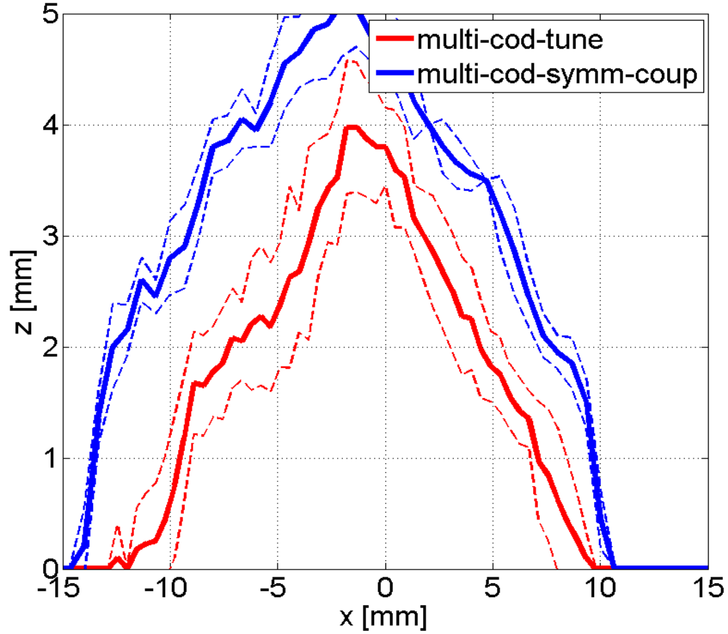
  Magnet alignment tolerances reduced from 60 μm to 30 μm.
- DA improves by restoring design optics. Symmetrization (reduce β-beating) and coupling correction.

  Obs.: β-beating here is caused by non-linearity, not by quad calibration error
- Special care with orbit correction at sextupoles. Place BPMs close to strong sextupoles.

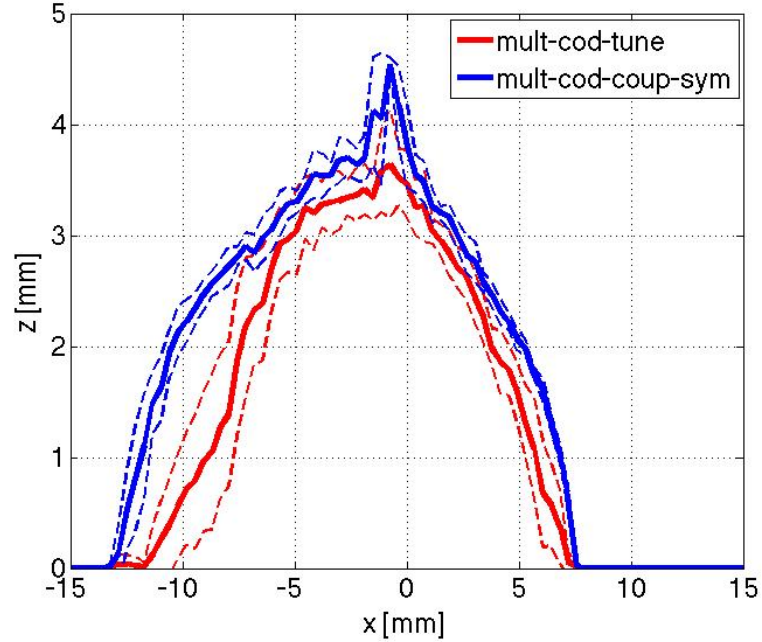


Effect of optics correction on DA

AC 20



AC 10



— without symmetrization

— after symmetrization