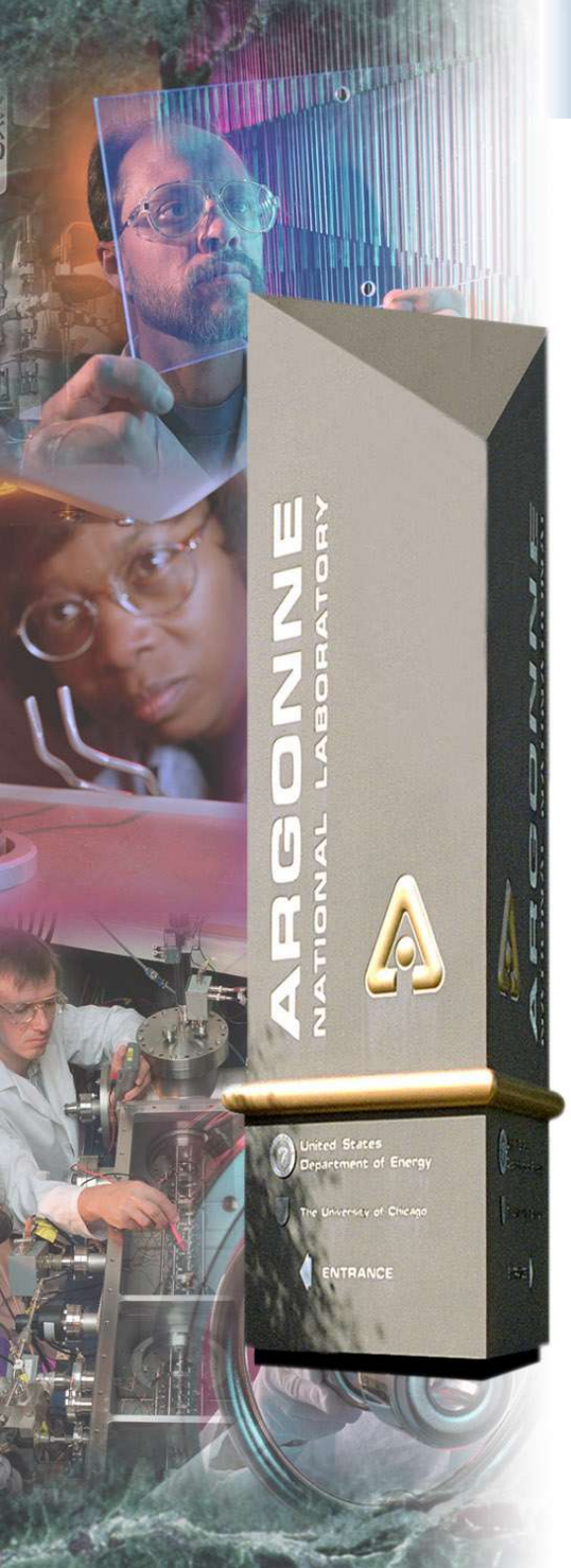

ARGONNE NATIONAL LABORATORY

Progress on Customized Lattice Functions for APS Beamlines

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Outline

- What are “lattice functions” and who cares?
- Examples of useful customizations
- Recent efforts and results.

Review of Lattice Functions

- Electron beam dimensions characterized by areas ($A=\pi\epsilon$) in three phase space planes
  - Horizontal or x plane: position and slope
  - Vertical or y plane: position and slope
  - Longitudinal or z plane: position and energy deviation
- Lattice functions determine partitioning of emittances into beam size and divergence
- At a symmetry location, for vertical plane (ignoring tilts)

$$\sigma_y = \sqrt{\epsilon_y \beta_y} \qquad \sigma_{y'} = \sqrt{\epsilon_y / \beta_y} \qquad \sigma_y \sigma_{y'} = \epsilon_y$$

emittance beta function

Review of Lattice Functions

- Horizontal plane is more complicated because bending magnets disperse beam due to energy spread

$$\sigma_x = \sqrt{\epsilon_x \beta_x + (\sigma_\delta \eta_x)^2}$$

fractional energy spread

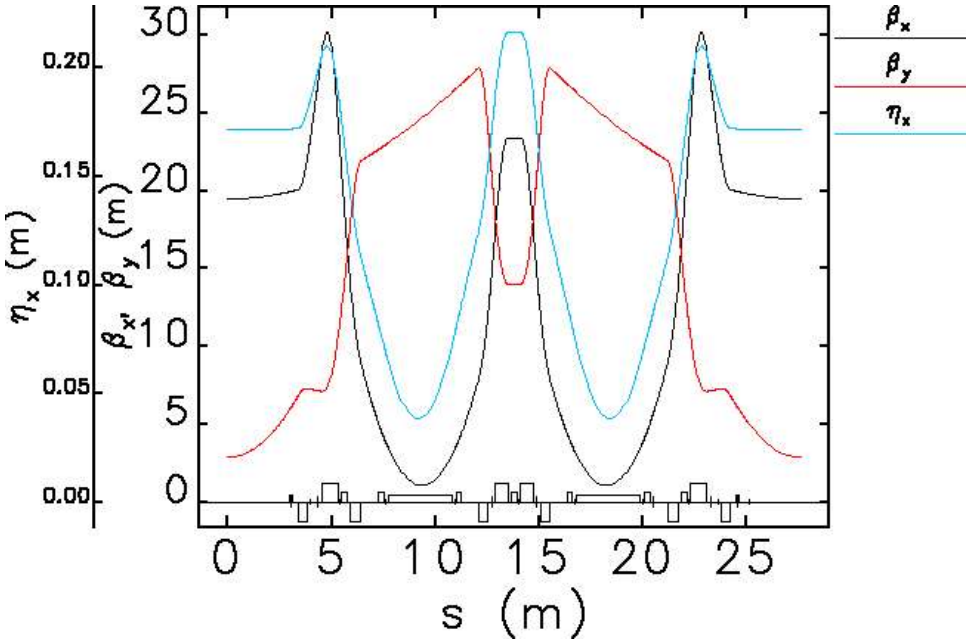
dispersion function

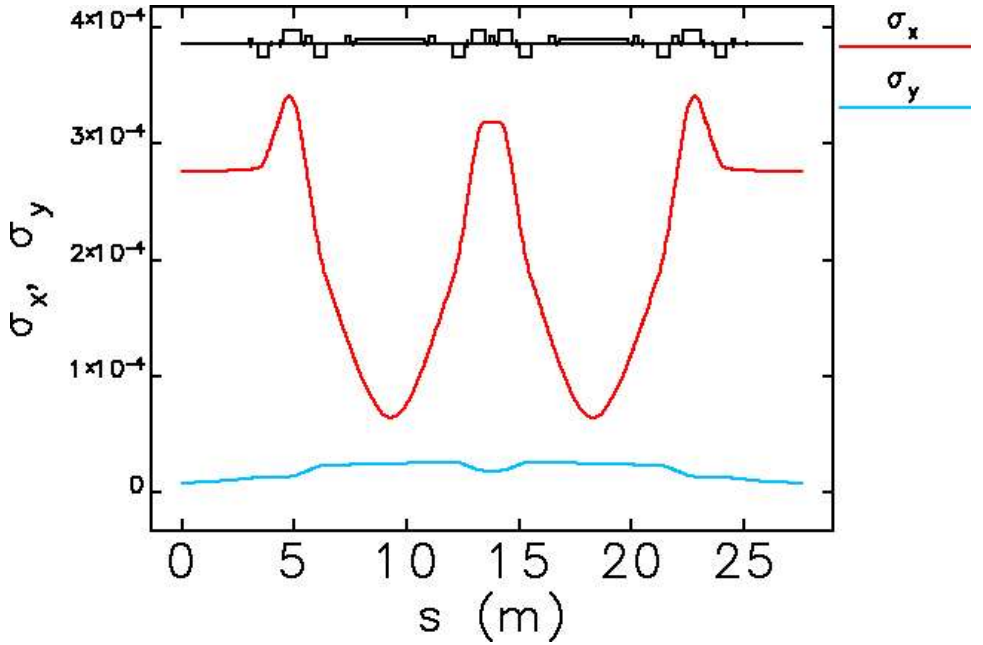
$$\sigma_{x'} = \sqrt{\epsilon_x / \beta_x}$$

$$\sigma_x \sigma_{x'} = \epsilon_{x,\,effective}$$

- The present APS lattice was optimized for low effective emittance at all straight sections
- Presently, all straight sections have nominally identical lattice functions
- The magnets in the APS have individual power supplies
  - In principle, very flexible.

Present Lattice Functions





Progress on Optics Modeling and Control

- APS optics modeling and control is quite advanced
- In the past, implementing a new lattice could be difficult
- Three advances
  - Determination of the lattice functions from experiment now takes about 1 hour[1]
  - We start from a machine model that is well corrected[1]
  - New method for determining how to change power supply currents to get desired field changes[2]
- Presently, a new lattice usually works fairly well the first time.

[1]V. Sajaev and L. Emery, EPAC 2002, 742.
[2]V. Sajaev, ASD/APG/2004-17.

Possible Customizations

- Larger beta function
  - Increase beam size but decrease divergence
- Small beta function
  - Decrease beam size but increase divergence
- Small beta function and dispersion
  - Decrease beam size but increase divergence
  - More effective than beta function alone
- Converging beam
  - Typically beam is at or near a waist
  - With converging lattice functions, x-rays “focus themselves.”

Potential Problems

- Any lattice function change may change the beam emittance
  - We are optimized for low emittance now
  - Essentially any change *increases* the emittance
  - This is easily predicted ahead of time
  - Include as a constraint when modeling changes
- Localized changes break the symmetry of the ring
  - Drives resonances in single-particle dynamics
  - Reduces lifetime
  - Reduces injection efficiency
  - This is harder to predict ahead of time.

Reduced Horizontal Beamsize

- RHB is perhaps the most-requested change
- Also relatively easy
- In X/2004, tried 140 μm with 8 ID
  - Lattice was workable from machine standpoint[1]
  - Effective emittance was 3.2 nm (up from 3.1 nm)
  - Beam line saw no difference due to optics limitations
- Subsequently, found lattice giving 90 μm to one beamline[1]
  - Emittance increases by 10%
  - Lifetime is 6 hours at 100 mA
  - Injection efficiency is ok (60-70%)
  - Will test with 32 ID later this month.

[1]V. Sajaev, P. Ilinski, M. Borland, ASD/APG/2004-01

[2]M. Borland, OAG-TN-2004-056

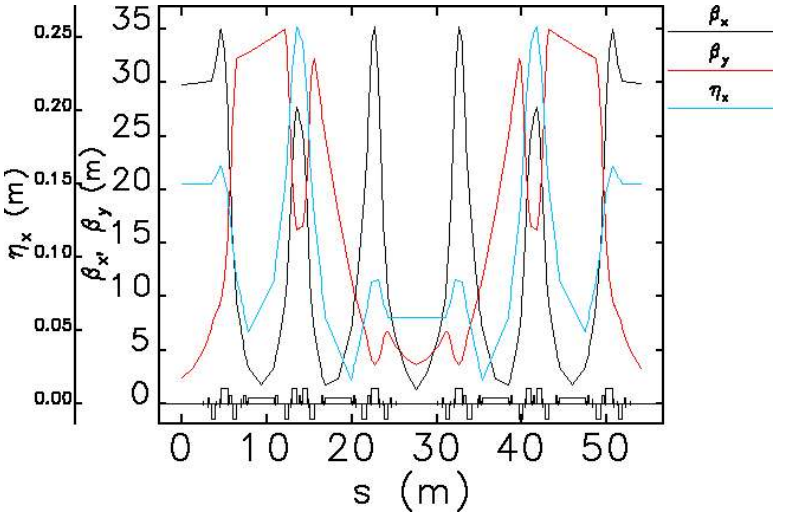
Reduced Horizontal Beamsize

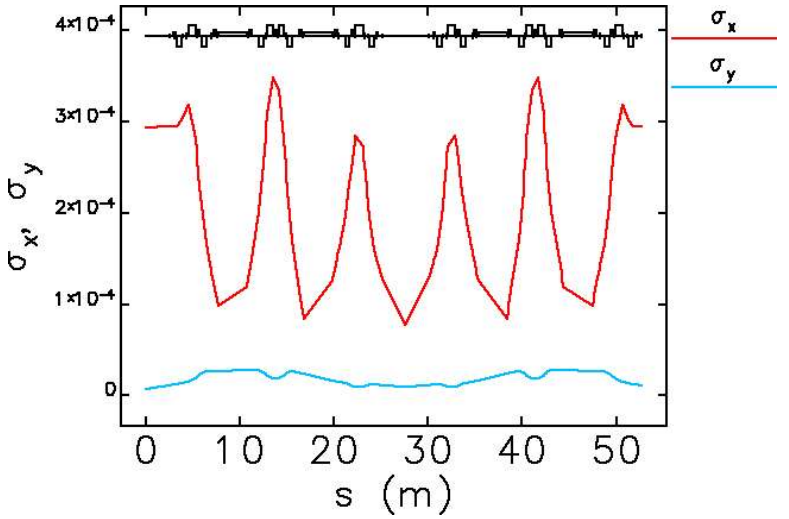
- Working on lattice to provide 120 μm to two beamlines
- Reduction limited by requirement to keep emittance increase under 10%
- Have stored beam and made optics measurements
- Will test with 8 ID and 32 ID in early April
- Important point: as more beamlines want this
  - Emittance goes up and/or
  - Reduction is more limited
- Developed lattice for up to 8 beamlines that addressed this[1]
  - 75-100 μm beamsize
  - Involves increasing integer horizontal tune
  - Difficult in practice so far.

[2]M. Borland, OAG-TN-2004-060

The ESRF Approach

- ESRF alternates between large and small horizontal beamsize
- We developed a similar lattice for APS[1]
- Has smaller effective emittance: 2.5 nm instead of 3.1 nm
- Not very convenient since beamlines are mostly built
- To try this, need upgraded sextupoles ("coming soon")

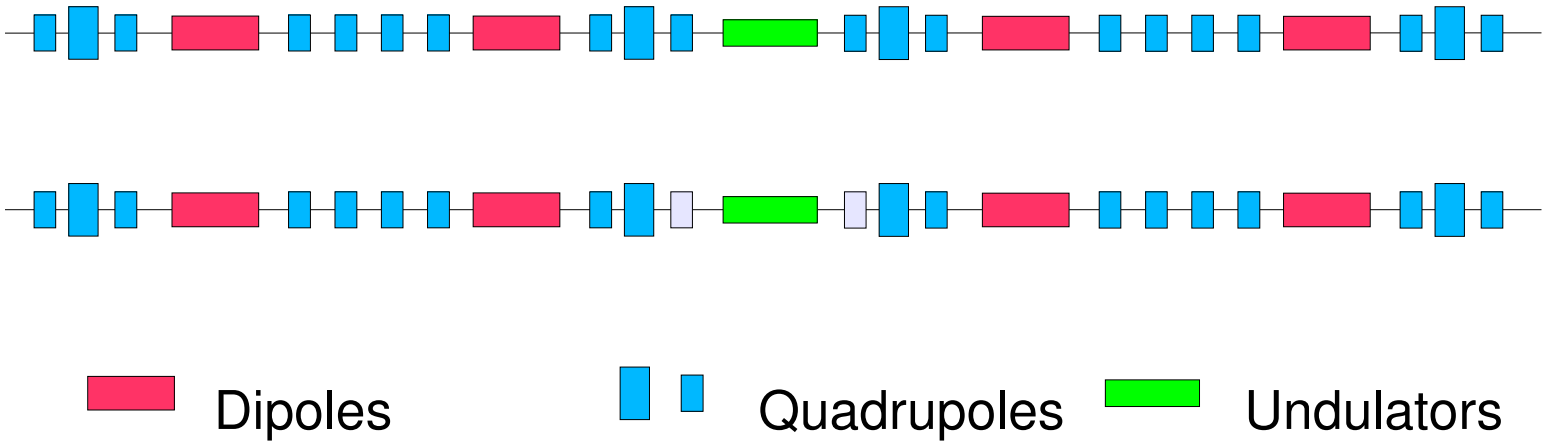




[1]M. Borland, OAG-TN-2004-057.

Long Straight Sections (LSS)

- Another request is for long straight sections
  - We can mock this up by turning off magnets on either side of a straight section
- This was shown experimentally for one straight section in 2001



"Combo Lattices"

- These lattices combine LSS and RHB
- Original lattice[1] targeted existing/anticipated beamlines
  - LSS in 1, 3, 9, 11, 27, and 30
  - RHB (100 μm) in 2, 26, and 32
  - 6 hour lifetime at 100 mA
  - 50~80% injection efficiency
  - 23% increase in emittance
- Trying symmetric combo lattices
  - Expect better lifetime, efficiency
  - RHB (140 μm) in 2, 12, 22, 32
  - LSS in 7, 17, 27, 37
  - Work in progress

[1]M. Borland, OAG-TN-2005-030.

Conclusion

- Significant progress is being made on customized lattice functions
- Trying a new lattice now involves relatively little pain
- Will try some tests with 8 ID and 32 ID in 30 days
- Combo lattice looks promising
- Still hope of up to 8 RHB sections without emittance increase