PAUL SCHERRER INSTITUT

Ultralow emittance ring with energy variation

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Introduction

- General low emittance ring recipe
  - Multi-bend achromat
    - Emittance $\propto \theta^3$ θ: Bending angle
  - Lager ring
    - Emittance $\propto E^2/C^3$ C: Circumference, E: Beam energy
  - Damping wiggler
- Very low emittance ring example
  - PEP-X, C=2.2 km, E=4.5 GeV, ε=11 pm*
  - Tevatron size, C=6.3 km, E=7 GeV, ε=1.8 pm (M. Borland)**
- Alternative design?

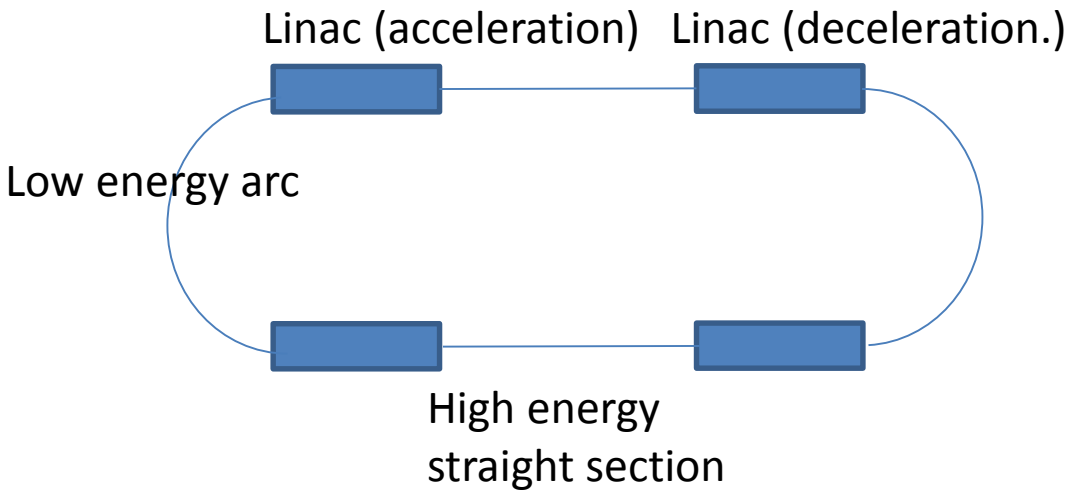
* Y. Cai et al., PRSTAB, 15 054002 (2012)
** M. Borland, IPAC'12, p.1035 (2012)

ERL

- Superconducting cavity R&D
  - Cavities can/will accept 100 mA/or more beam current
  - SC cavity technology is developing continuously
- Difficulties?
  - <10 pm at 5 GeV = normalized emittance of <0.1 μm
  - Injection energy at ~100 MeV
    - 100 mA beam → 10 MW beam power…

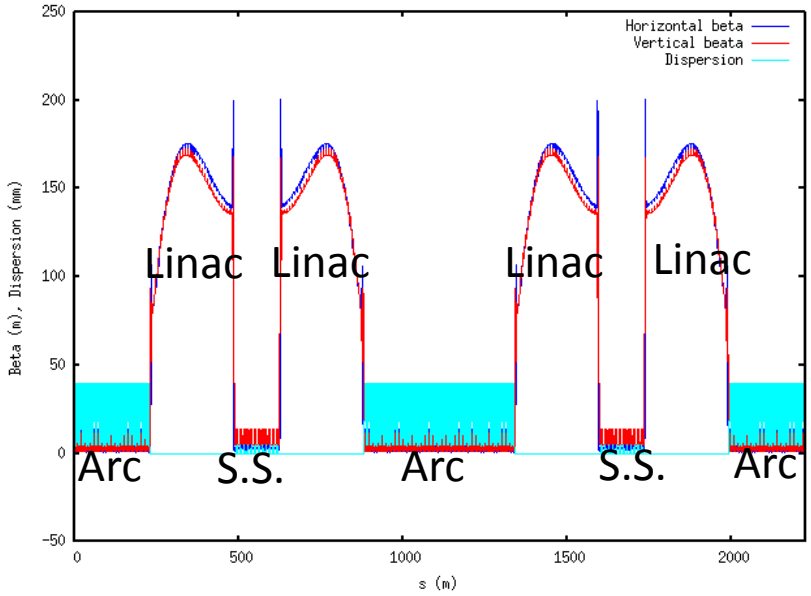
Alternative approach

- Race track
  - "Many-bend" achromat (as in damping ring)
- Energy variation within a ring (acceleration and deceleration)
  - Using superconducting linacs
  - Lower energy at arcs (small emittance), and higher energy at straights (insertion device for light source)
  - Not only small emittance arc but also adiabatic damping to make emittance further small
  - Energy transfer from decelerating cavity to accelerating cavity
    - a la CLIC
    - By beam (second ring)



Reference design (not fully optimized)

Optics parameters

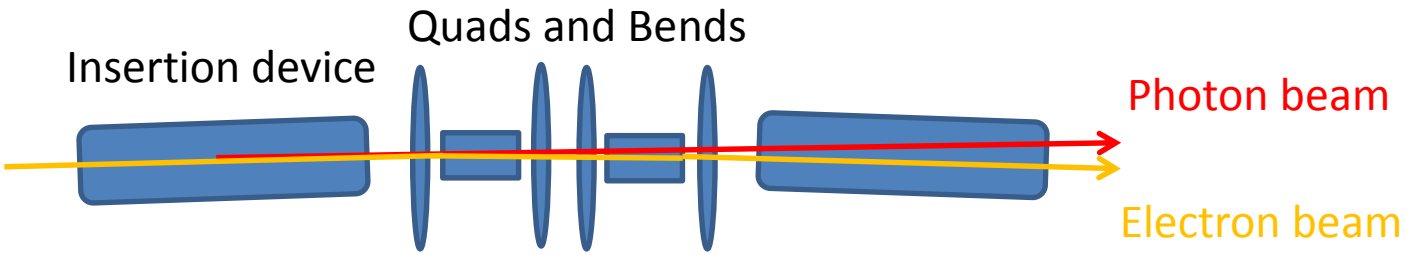


Circumference [km]	~2.2 km
Beam energy (Arc/Straight) [GeV]	2/6
Emittance (Arc/Straight) [pm]	6/2
Energy spread (Arc/Straight) [pm]	0.005/0.0013
Bunch length (ps)	10
Damping wiggler specification	50 m, 25 mm period, 1.5 T
Straight section (can be increased)	14 * 5 m
Momentum compaction factor	1.5×10^{-5}
Damping time (H/V/L, ms)	35.5/35.5/17.8

- A large physical aperture for the arc may be needed for collective effects but it can be done for the low beam energy.
- IBS estimation: ~5 pm in both plane at 200 mA…

“Straight section”

- Straight section is slightly bended to separate electrons and photons



J. Synchrotron Rad. (1998). **5**, 215–221

ID14 ‘Quadriga’, a Beamline for Protein Crystallography at the ESRF

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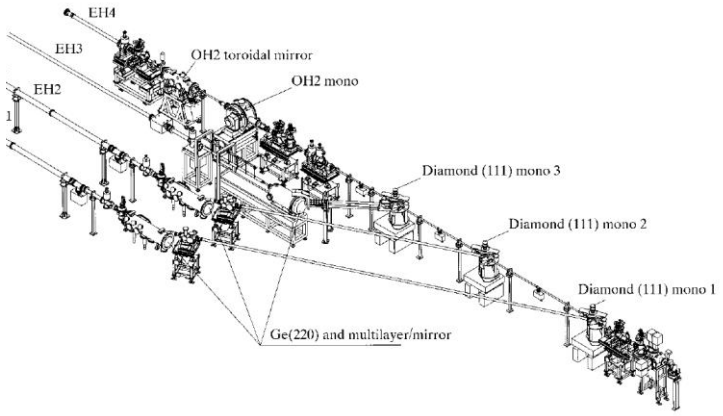

Figure 2
Layout of the optics. Walls of the optics hutches are not shown.

Comparison

	Alternative	PEP-X	Tevatron LS
C (km)	2.2	2.2	6.3
E (GeV)	6	4.5	7
ε (pm)	2	11	1.8
S=E^2/C^3 (GeV^2/km^3)	3.38	1.90	0.20
ε/S (pm.km^3/GeV^2)	0.59	5.78	9.19

Scaling is not valid for very large ring

Scaled emittance can be an order of magnitude better!

Summary

- Ultralow emittance ring with energy variation is investigated
  - Reference design, ~2.2 km, 6 GeV, 2 pm (zero-current)
  - Superconducting RF technology is being developed, and the alternative approach may be attractive in the future?
  - IBS growth dominates the emittance for non-zero-current beam…

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