Compton ring and stacking ring for LC

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NSC KIPT, Ukraine
KEK, Japan; CERN

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- Storage Rings
  - Large current attained with small charge: $I = qc/L$
  - Many interactions of each electron/positron with laser pulses; large recoils caused by Compton scattering
- Lasers
  - Low field strength
  - Temporal and spatial localization of laser pulses

Favorable features of each subsystem may neutralize negative ones

Beam Current + Pulse Energy

Direct: yield y of gammas in Compton sources (number of gammas generated in second) is proportional to product of the beam current I and the energy in the laser pulse p:

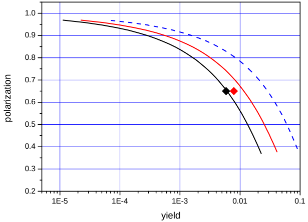
$$y \propto Ip \, ,$$

provided that scattering takes place at each turn.

Optimal Compton Ring (PosiPol'10)

Lattice with laser cooling conditions: $\beta_{\text{hor}}^{\text{cp}} = \beta_{\text{vert}}^{\text{cp}} = 5\,\text{cm}$

param	units	value
E_{beam}	GeV	1.06
U_{rf}	MV	200
E_{las}	eV	1.16
$E_{\text{gamma}}^{\text{max}}$	MeV	20
σ'_x/σ'_z	μm	25/2
σ'_y	mm	0.9
cross angle	deg	8
P_{las}	J	0.5
ϵ_{hor}	10^{-10}m	2.2
ϵ_{vert}	10^{-11}m	2.0
σ_E cp / out	%	5.8 / 1
yield	1/(e turn)	0.12



Performance at 1 A current

- Average positron current 1/0.7 mA (W/Ti targets, simulated)
- Polarisation 0.65

ILC/CLIC average current $50/30\,\mu A$ *(with overhead).*

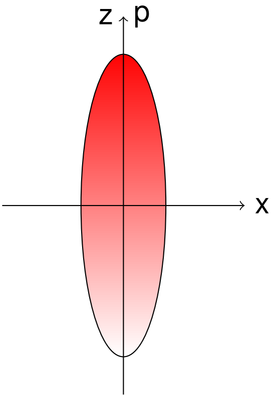
Compton ring sources provide enough positrons and time for cooling

Many interactions + Localization

- Large energy spread in electron bunches
  - requires high RF–voltage
  - limits attainable polarisation

Ability of laser pulses to be localized may help to overcome these drawbacks

Asymmetric Cooling
Steady–state energy spread



- Collision point in dispersive section $\rightarrow$ ‘energy–position’ correlation (J. Urakawa idea)
- Displaced laser pulse $\rightarrow$ laser photons interact with circulated positrons/electrons only when $p > 0$

Steady–state energy spread much smaller:

$$\left\langle p^2 \right\rangle_{\mathrm{as}} \approx 2\pi^2 \left\langle p^2 \right\rangle_*^2 = 2\pi^2 \left(\frac{7}{10} \gamma \gamma_{\mathrm{las}} \right)^2 ,$$

$\left\langle p^2 \right\rangle_*$ is rms ‘symmetric’ spread (e.g. CLIC CR 5.8% sym, 1.5% asym)

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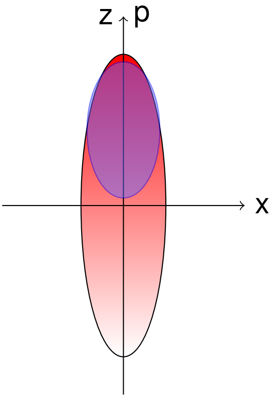

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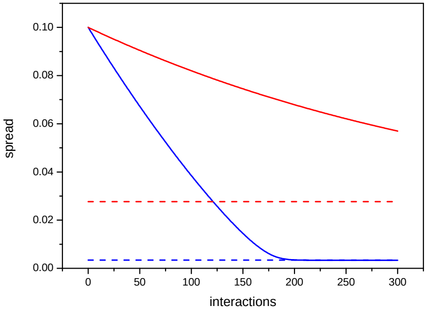
Asymmetric (fast) Cooling
CLIC Damping Ring



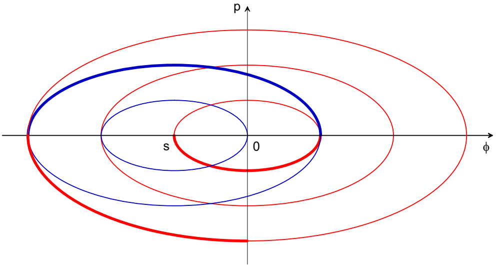
param	units	value
E_{beam}	GeV	2.86
U_{rf}	MV	20
E_{las}	eV	0.116
$E_{\mathrm{gamma}}^{\mathrm{max}}$	MeV	14.6
σ'_x/σ'_z	μm	50/50
σ'_y	mm	1.0
crossing	deg	0
P_{las}	J	0.85
σ_E s / as	%	2.8 / 0.34
yield	1/(e t)	0.19 / 0.1

Time scales per collision

Asymmetric cooling feasible for damping rings (200 coll $\approx$ 3 ms)

Damping of Coherent Oscillations (Compton Injection)

Is it possible to damp coherent oscillations in less than period?



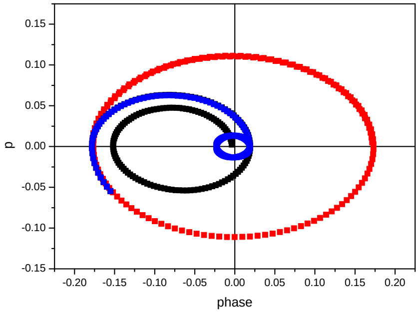
Synchrotron phase plane

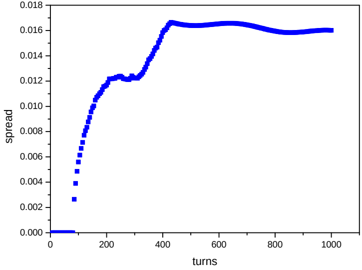
Idea

- Center–of–weight moves along ellipses in the phase plane centered at:
  - origin – no energy loss
  - synchronous phase – to compensate energy loss with rf acceleration
- Switching laser on/off at $p = 0$ redirects bunch from one ellipse to another

Compton Injection – Simulations

DR with small momentum compaction, $\alpha = 2 \times 10^{-6}$





Spread in injected bunch vs. turns

Synchrotron phase plane

Compton injection possible in principle

Summary and Outlook

Conclusion

- 'Storage ring + laser' systems able to generate intense beams of highly polarised positrons
- Application of specific localization of laser radiation may enhance performance of Compton sources and damping rings
- Fast damping of coherent synchrotron oscillations principally possible
- Issues in transversal motion may occur

Studies to do

- Betatron dynamics at fast cooling
- Simulations of fast cooling
- ...