Compton Ring
for Polarized Positron Source

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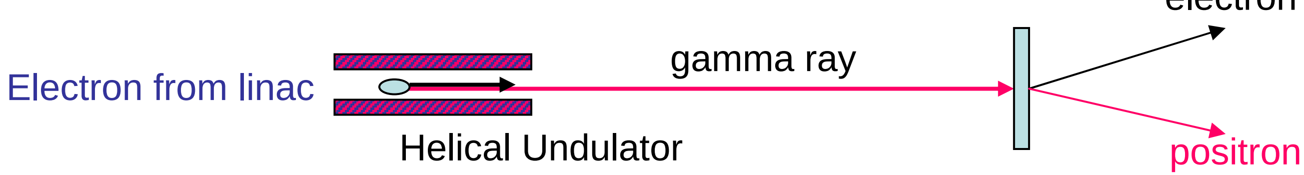
Laser wire mini-workshop
Oxford, England

Polarized Positron Source for ILC (1)

Undulator Method



Basic design of ILC, but we have many technical difficulties …

1) We must pass through the 150GeV electron beam to 150m long helical undulator.
   The physical aperture of the undulator is only a few mm.

2) Operation mode of electron ring can not change freely to change.
   Fast ion instability is strongly depends on the fill pattern of electron damping ring.

For the backup of the undulator method,
we investigate the new design of positron source.

Polarized Positron Source for ILC (2)

Compton Method with Pulsed Laser

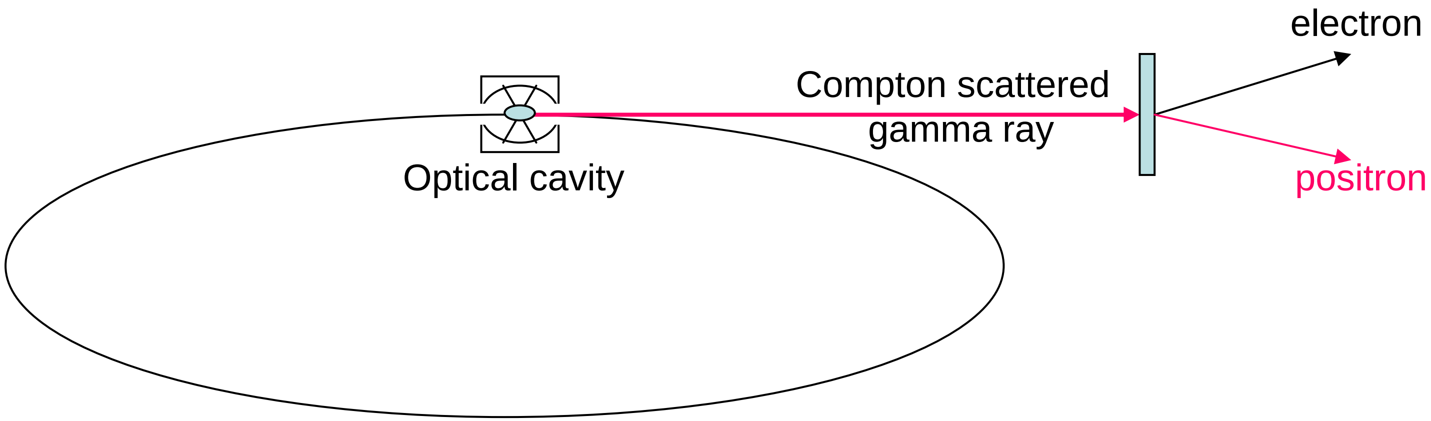
The design of Compton based positron source has been investigated for ILC.

Original design is for the warm LC
with the pulsed CO2 laser and 5GeV electron linac.

But, It is difficult to apply the technology to the cold LC for the bunch structure.

Polarized Positron Source for ILC (3)

Compton Method with Mode-lock Laser and Storage Ring

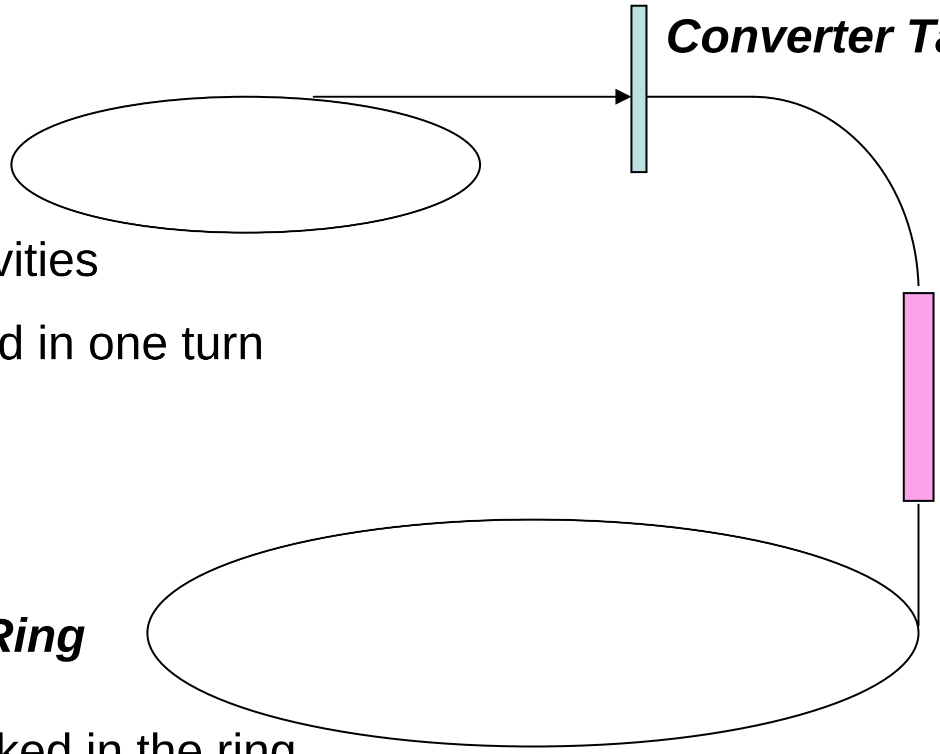


Electron is reused to the collision of the laser by storing to the circular ring, which is called to Compton ring.

Laser light is also reused with optical cavities.
The solid state mode locked laser light is used for the collision.

Conceptual Design of the Polarized Positron Generation with Compton Ring

Converter Target



Compton Ring
with 30 optical cavities

1 gamma generated in one turn

5GeV linac

Main Damping Ring

100 pulse is stacked in the ring

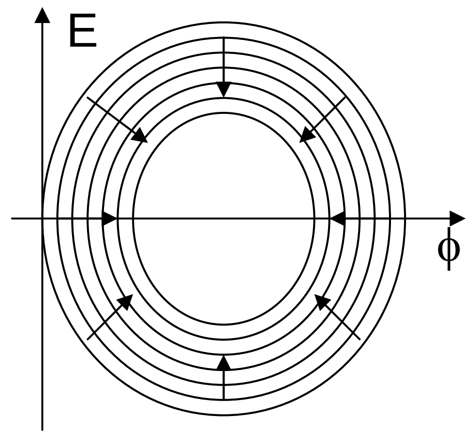
For this technology,
the design of the Compton ring is one of the key issues.

Compton ring

Problem 1 : Energy Shift $\Delta E \cong 2N\gamma^2 E_{laser}$; $N = N_{pos}/N_{ele}/n_{conv}$

i.e.) 1.3GeV $N_{ele} = 5e10$, $N_{pos} = 2e10$ and $n_{conv} = 0.35\%$,

$\Delta E \cong 3.3\text{GeV}$



In order to reduce the energy shift,

⇨ ***To produce the fast synchrotron frequency ring (the order of few hundred kHz)***

Problem 2 : Energy Spread $\sigma_E \cong 2\gamma^2 E_{laser}\sqrt{N}$

i.e.) 1.3GeV $N_{ele} = 5e10$, $N_{pos} = 2e10$ and $n_{conv} = 0.35\%$,

$\sigma_E \cong 316\text{MeV}$

⇨ ***To produce large RF bucket***

Possible Solution of the Compton Ring Parameters

$$\sigma_z^2 \cong \sqrt{\frac{c\alpha C^2}{2\pi f_{RF}} \frac{E_0}{qV_{RF}}} \left(\frac{\sigma_p}{p}\right)^2 \qquad f_s \cong \sqrt{\frac{c\alpha f_{RF}}{2\pi C} \frac{qV_{RF}}{E_0}}$$

$E = 1.3GeV$, $f_{RF} = 100MHz$, $V_{RF} = 500MV$, $C = 300m$,
$\alpha = 0.001m$, $\sigma_{E0} = 0.05\%$, $\sigma_{z0} = 1.6mm$, $f_s = 78\ kHz$ ($f_0 = 1MHz$)

Furthermore, we have still the problems ….

Phase shift -> Phase modulation of optical cavity

Bunch lengthening -> Small conversion efficiency

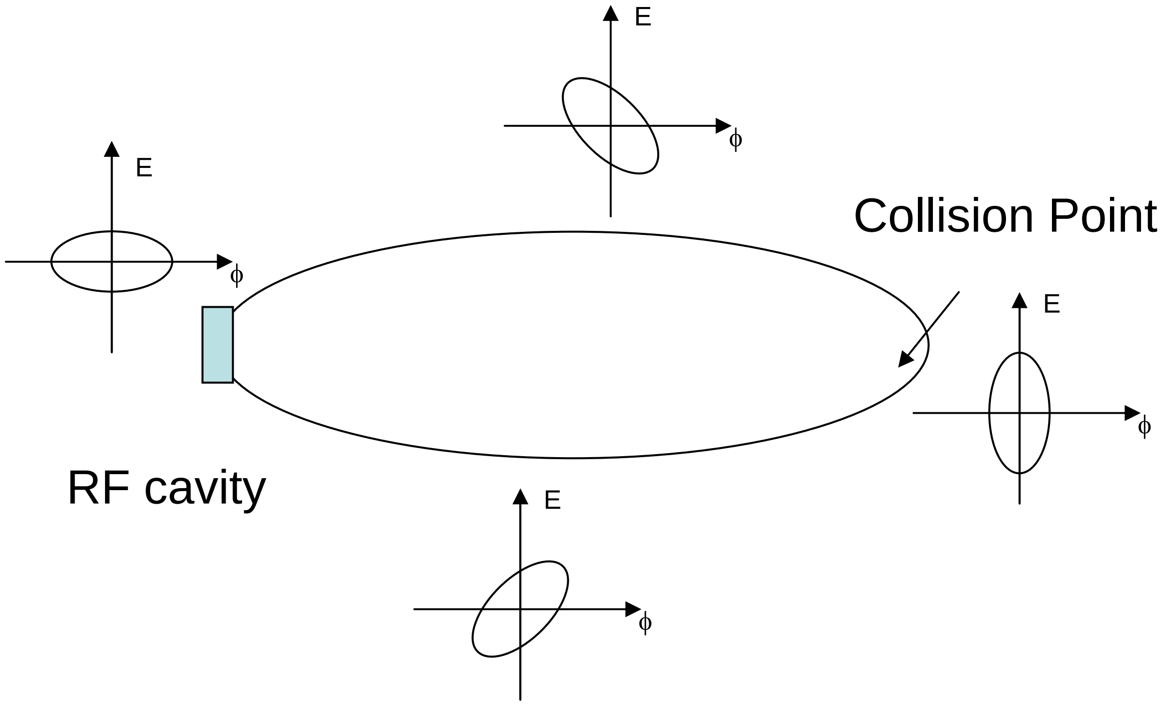
Large beam size at dispersive position
for the small emittance ring with the strong nonlinear field.

Bunch Length Modulation Type of Compton Ring

1) Global bunch length modulation method.

LSF (Longitudinal Strong Focusing Lattice)

Idea is to set the synchrotron frequency to be 2 fs = f0
and to put optical cavities at fs = 90degrees from RF cavity.



Advantages … No phase shift and no bunch lengthening (maybe?)
Small RF voltage to normal ring

.

Disadvantage … We have some optics constraint of $\alpha = \frac{c\pi}{2 f_{RF} C} \frac{E_0}{q V_{RF}}$

For example, $E = 1.3GeV$, $f_{RF} = 100MHz$, $V_{RF} = 1GV$, $C = 300m$

$$\alpha = 0.0204m$$

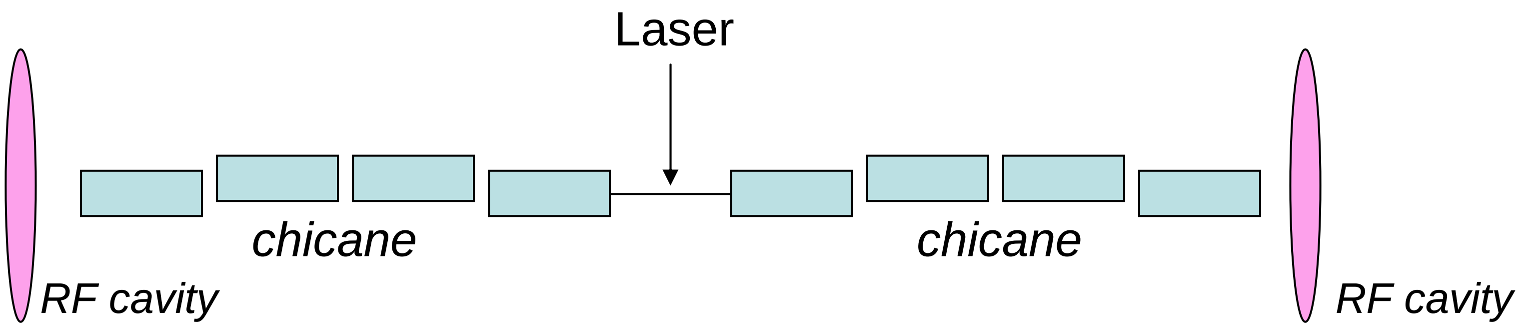
But ….,

we still have a problem of large beam size at dispersive position for the small emittance ring with the strong nonlinear field.

Bunch Length Modulation Type of Compton Ring

2) Local bunch length modulation method.

LLBL (Longitudinal Low Beta Insertion)



Advantages … No phase shift and no bunch lengthening (maybe?)

Not large beam size at dispersive position
by adjusting the momentum cmpaction to be zero at lattice cells

Disadvantage … ***Difficult to make small emittance,***
because the lattice function of chicane section.

Twice RF cavity systems
Phase control in between is important !

Summary of the Compton Ring

	Normal Ring	B.L. Modulation (Global Method)	B.L. Modulation (Local Method)
Phase shift	Yes	No	No
Bunch lengthening	Yes	No	No
Huge dynamic aperture requirement	Yes	Yes	Maybe No
Small emittance lattice	Yes	Maybe Yes	Maybe No
RF system	Large	Large	Huge

Common problem is huge RF system of around few hundred MV
in 300m circumference and 1.3GeV electron ring !

Recommendation of the Compton Ring

My recommendation for Compton ring is adopted to “bunch length modulated ring”.

The global or local modulation methods should be mainly selected
for the following criteria.

What are beam energy and laser wavelength ?
- My recommendation is the set of 1.8GeV electron ring and 1 micron laser, to relax the requirement of the RF bucket height by 40% and to relax the beam size requirement at IP by factor 2.

$$\begin{aligned}(\text{Corrision Rate}) &= \frac{1}{4}\ (2 \times \text{Horizantal and Vertical Beam Size}) \\ &\times 2\ (\text{Conversion Rate of Fundamental to Harmonic Doubler}) \\ &\times 2\ (\text{Photon Density}) \\ &= \ \ 1\end{aligned}$$

How much electron beam current is required ?
- Large current makes number of collision small ! This is strong impact to the requirement of the dynamic aperture.