Laser–Compton Scattering Experiments at the ATF

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1. Polarized e\(^+\) Source based on Compton scattering,
2. CW laser wire results,
3. Pulsed laser wire development,
4. Polarized γ-ray generation,
5. Compact X-ray source,
1. Polarized $e^+$ Source based on Compton scattering
Experiment at KEK-ATF

ATF: Accelerator Test Facility for ILC built at KEK

Collaborating institute: Waseda, TMU, KEK, NIRS, and AIST


1.28 GeV S-band Linac

Accelerator Test Facility

1.28 GeV Damping Ring

Laser-electron collision point

120 m
i) proof-of-principle demonstration
ii) accumulate technical informations: polarimetry, beam diagnosis, …
Compton Chamber

- **e⁻ beam**
- **Power meter window**
- **Combined scanner Screens**
- **Bend**
- **Compton chamber (tri-chamber)**
- **Collision point**
- **Straight section 4 m**
- **Mirror (R)**
- **Al t=2 mm**
- **γ port**
- **Mirror (R)**
- **Laser beam**
- **Mirror (R)**
- **Lens f = 5000 mm**
- **γ-rays**
Positron: production, selection, and polarimetry

Pair creation

γ-ray

10^7/bunch

W- target

N_γ(design) = 1 x 10^7/bunch

2.2 x 10^7/bunch (achieved)

Separation magnet

polarized e^+

Pb

Magnetization

γ-ray

γ-ray

CO₂ Cherenkov counter
5 atm
E_{th} = 7.6 MeV

Bremsstrahlung
Compton
Pair creation

Positron polarimeter

Ne^+(design) = 3 x 10^4/bunch

Pol(expected) = 80%

Asym (expected) = 0.95%
2. CW laser wire results

CW Laser wire beam size monitor in DR

300mW 532nm Solid-state Laser fed into optical cavity

14.7µm laser wire for X scan
5.7µm for Y scan
(whole scan: 15min for X, 6min for Y)
Laser wire block diagram

Optical cavity resonance is kept by piezo actuator

Free spectral range: $532\text{nm}/2=266\text{nm}$
Line width=$0.3\text{nm}$
Beam profile by Laser wire

\[ \sigma_e^2 = \sigma_{\text{meas}}^2 - \sigma_{\text{lw}}^2 \]

\[ \varepsilon \beta = \sigma_e^2 - [\eta(\Delta p/p)]^2 \]

\( \beta: \text{measured by Q-trim excitation} \)
3. Pulsed laser wire development

Experimental results (Pulse Laser Storage)

Laser:

- Mode Lock: Passive
- SESAM
- Frequency: 357 MHz
- Cavity length: 0.42 m
- Pulse width: 7.3 p sec (FWHM)
- Wave Length: 1064 nm
- Power: ~ 6 W

SESAM: SEmi-conductor Saturable Absorber Mirrors
Ext. Cavity:

Cavity: Super Invar

Cavity length: 0.42 m

Mirrors:

- Reflectivity: 99.7%, 99.9%
- Curvature: 250 mm ($\omega_0 = 180 \mu m$)
Storage of laser pulse

Resonance condition:

The relationship with laser and cavity:

\[ L_{\text{cav}} = n \cdot \frac{\lambda}{2}, \]

\[ \Delta l = L_{\text{laser}} - L_{\text{cav}}, \quad \Delta l = 0. \]

The enhancement factor is the function of reflectivity, \( \Delta l \) and laser pulse width.

Perfect resonance: \( L_{\text{laser}} = L_{\text{cavity}} \)

Imperfect Resonance: \( L_{\text{laser}} \sim L_{\text{cavity}} \)

Not resonance: \( L_{\text{laser}} \neq L_{\text{cavity}} \)
• Finesse: $R = 99.9\%$

$$\text{Finesse} = \pi \tau \frac{c}{l}$$

$\tau$: decay time
$c$: light velocity
$l$: cavity length

More than 3000 Times.
実際はOptical MatchingやMode Locking noiseの問題があるので、現状1000倍程度にしてX線生成を優先した。
Pulsed Laser and Electron Beam Collision to measure bunch length

Pulse Laser Wire

(Storage laser pulses in optical cavity):

The systems for New X-ray source & New bunch length monitor at a storage ring

Hear Fukuda’s talk.
EXPERIMENTAL SETUP: Optics
16714MHz Cavity

Electron repetition rate:
357MHz
Electron bunches

Laser Repetition rate:
357MHz
laser pulses

Scattered Gamma beam

Compton Scattering in every 357MHz

As an X-ray source:
An optical cavity stores higher peak power and gets higher flux X-ray with pulse laser than CW laser.

As Beam monitor:
By scanning the laser pulse’s phase in the cavity and measuring the Compton signal count rate; an electron bunch length profile is obtained.
4. Polarized $\gamma$-ray generation using Optical Stacking Cavity
Experimental R/D in ATF
Hiroshima-Waseda-Kyoto-IHEP-KEK

Make a fist prototype 2-mirror cavity
$L_{cav} = 420 \text{ mm}$

Put it in ATF ring

1.28 GeV S-band Linac
Accelerator Test Facility
1.28 GeV Damping Ring
Non planer cavity with 4 mirrors in LAL
4-mirror-cavity

--->

separate functions
& confocal configuration
2-mirror cavity

R1 = R2 = L/2

L

waist

1

waist

l/2 f l f l/2

concentric

4-mirror cavity

R1 = R2 = L

L

L

plane

3

concave

1

waist

d0

d1

d2

plane

mirror

plane

mirror

L

l/2 f d1 d0 d2 f l/2

confocal
\( \gamma \)-ray Generation with Laser Pulse Stacking Cavity (Hiroshima-Waseda-IHEP-KEK)

1. Achieve both high enhancement & small spot size
2. Establish feedback technology
3. Achieve small crossing angle
4. Get experience with e\(^-\) beam

Pulse stacking cavity
\[ L_{\text{cav}} = 420 \text{ mm} \]

1.28 GeV S-band Linac

Accelerator Test Facility

1.28 GeV Damping Ring
5. Compact X-ray source

43MeV end station to separate X-ray and e-beam. 33keV X-ray is deflected by Crystals.

Pulsed laser stacking chamber
Laser Undulator Compact X-ray (LUCX) Project at KEK-ATF

43MeV Multi-bunch beam + Super-Cavity = 33keV X-ray.

Multi-bunch photo-cathode RF Gun

Multi-bunch e-beam 300nC at gun

At present, laser waist size is 90μm in σ. We should reduce both beam size at CP down to 40μm.
33keV X-ray generation based on inverse Compton scattering will start from Oct. 2007 with Super-Cavity.
6. Key components for photon beam source based on laser-Compton scattering

World-Wide-Web of Laser Compton

ERL

4th Generation light source

CLIC e+

Polari-metry

LW monitor
e- source ILC, ERL

ILC e+

Laser Compton

γγ collider

Medical applications

Industrial applications

X-ray source

Optical Cavity

High power laser

4th Generation light source
Electron storage ring
laser pulse stacking cavities
positron stacking in main DR

Compton ring
Electron storage ring

to main linac

Proposed by Posipol Group at Snowmass 2005.
One laser feeds 30 cavities in daisy chain

光共振器中点でサブミクロン、1mJ/pulse・10psecパルスレーザービームを高繰り返し(357MHz)で安定に実現できる小型スーパー光共振器を製作して、その性能を実証する。

高繰り返し(357MHz)、短パルス(10psec, FWHM)、大強度レーザー(1mJ/pulse～100mJ/pulse)のパルスレーザービームをスーパー光共振器で実現する。
New Idea by UK

Use a Misaligned Multipass Cavity

Mirror spacing determines the inter-pulse interval to match to 2.8ns

Slight mirror tilt from perfect auto-collimation or slight shear of one lens gives scanning with equally spaced foci and a controllable spacing

PC gate switches pulse into cavity

Need to keep round-trip losses very low to ensure sufficient passes at sufficient power

Other designs possible
Laser-wire at ATF-EXT

By Grahame Blair (RHUL) et al.

Modify optical lens to realize sub-micron laser waist size.