Pulsed laser wire development for damping rings

KEK, J.Urakawa

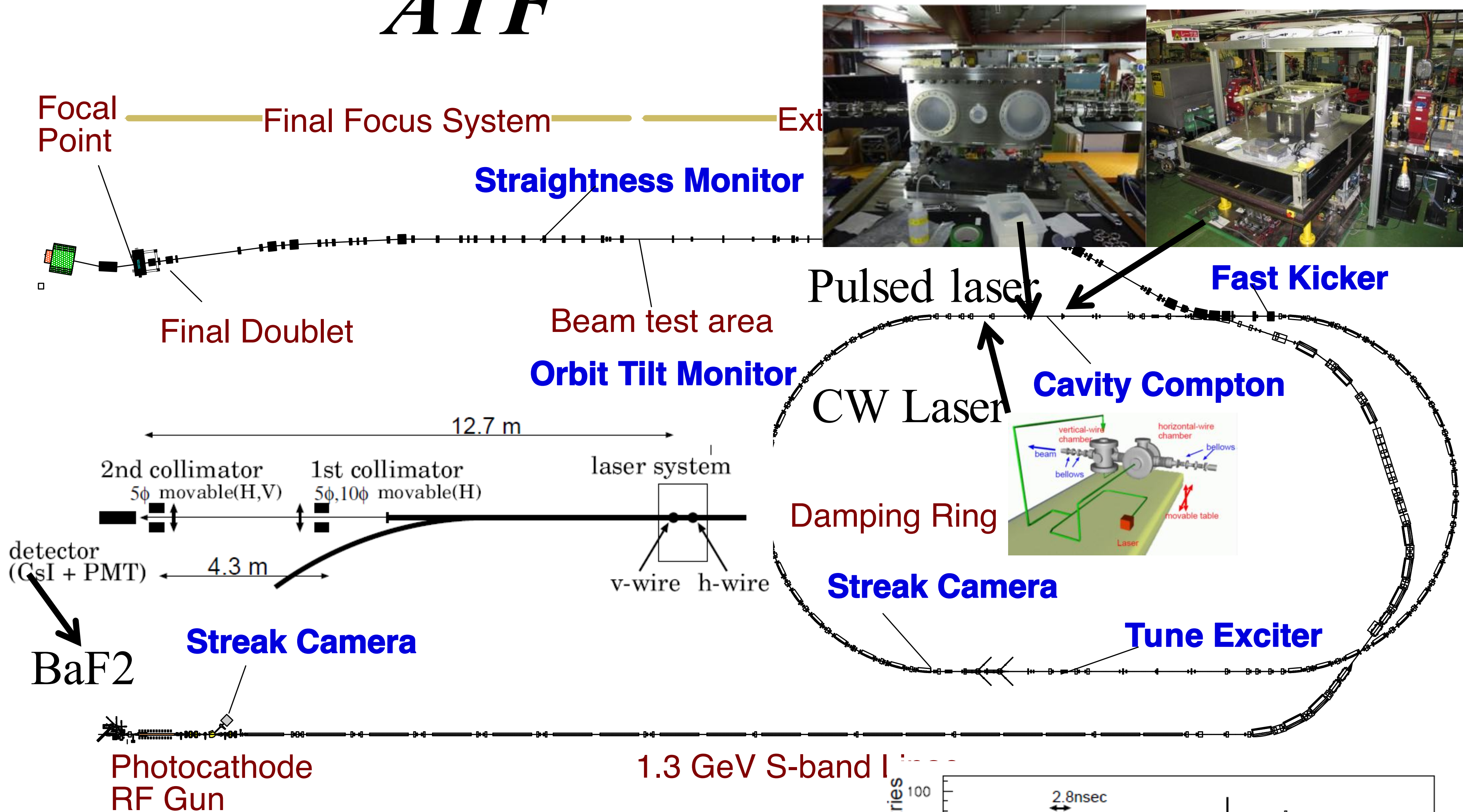
Toward optical cavity pulsed laser wire from CW laser wire keeping micron waist laser size in moderate optical cavity.

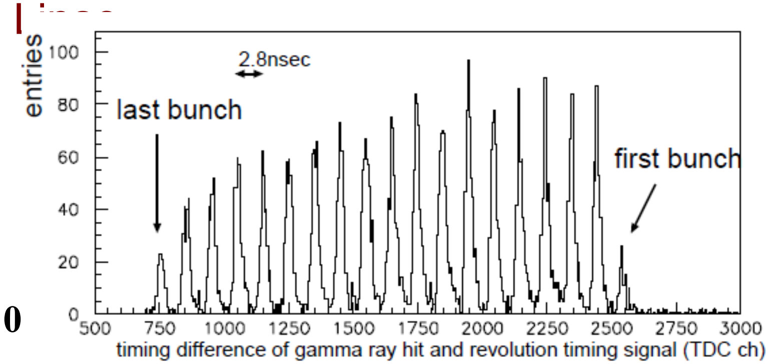
Quick measurements for transverse micron beam profile and pico-second longitudinal beam profile

1. Short review on CW optical cavity laser wire in damping ring
2. Test results of pulsed laser wire to measure bunch length
3. Design for versatile pulsed laser wire in moderate optical cavity
4. Development and experimental plan

ATF

Two 4 mirror Cavity Compton





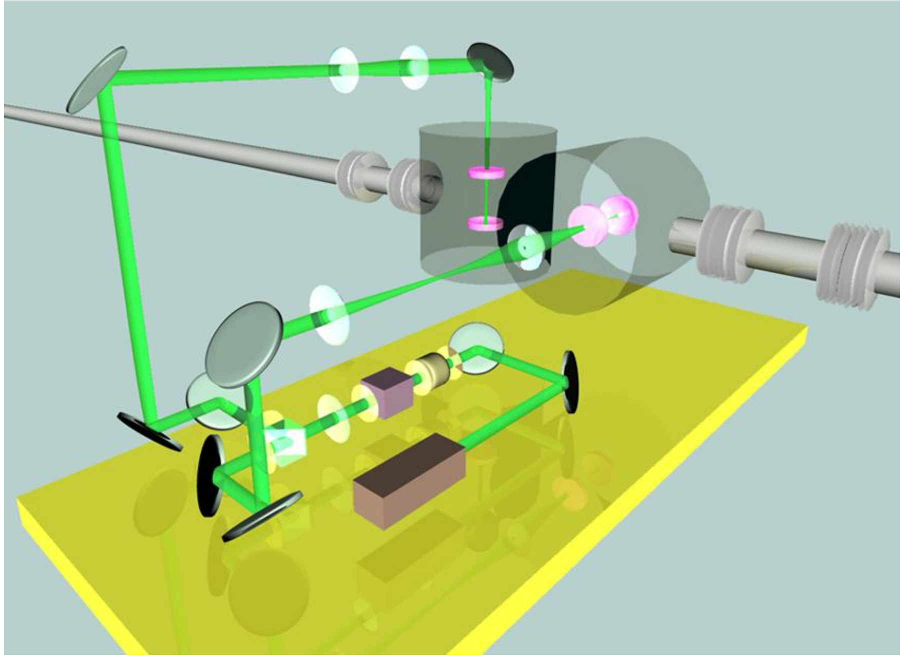
E=1.28GeV, Ne=1x10^{10} e$^-$/bunch

1 ~ 20 bunches, 3trains, 200mA, *Rep=3.125Hz*

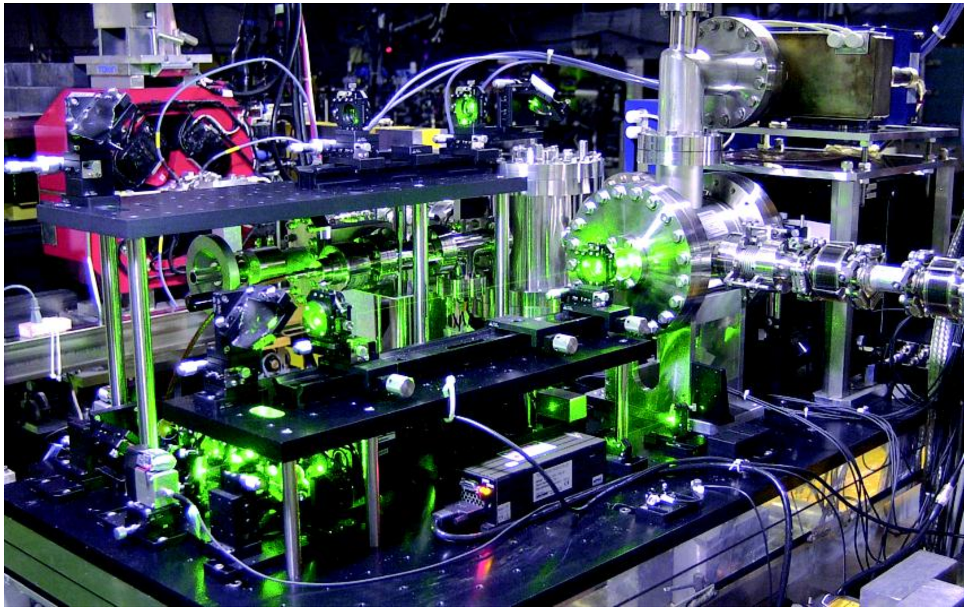
X emit=2.5E-6 **(at 0 intensity),** *Y emit=1.25E-8* **(at 0**

CW laser wire with optical cavity

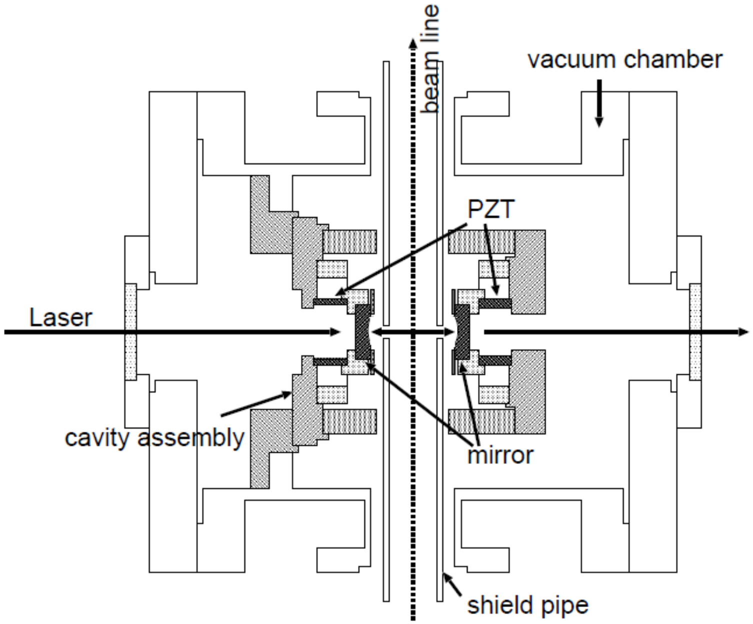
Laser wire beam size monitor in DR



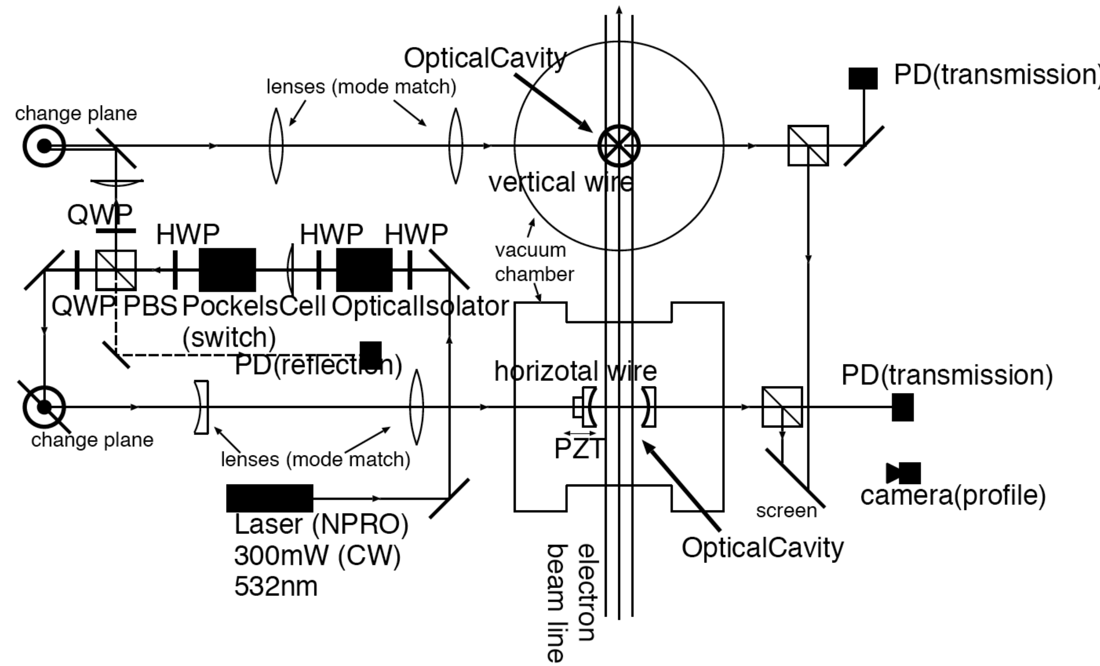
300mW 532nm Solid-state Laser fed into optical cavity

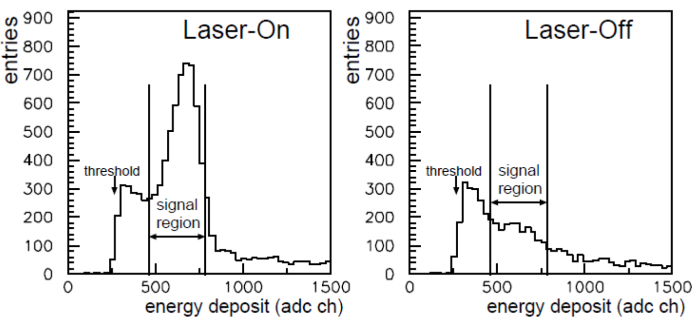


14.7µm laser wire for X scan
5.7µm for Y scan
(whole scan: 15min for X, 6min for Y)

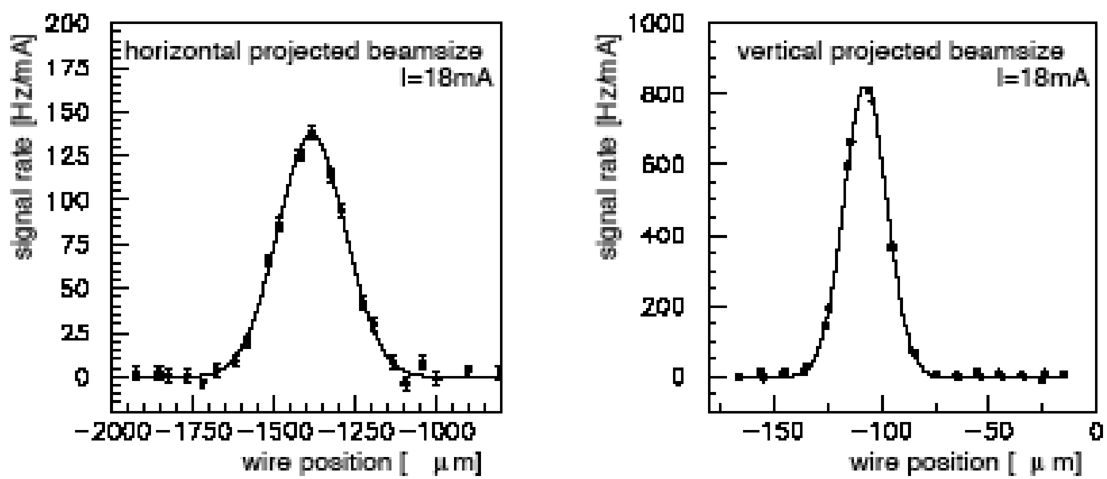


CW Laser wire block diagram





Beam profile by Laser wire

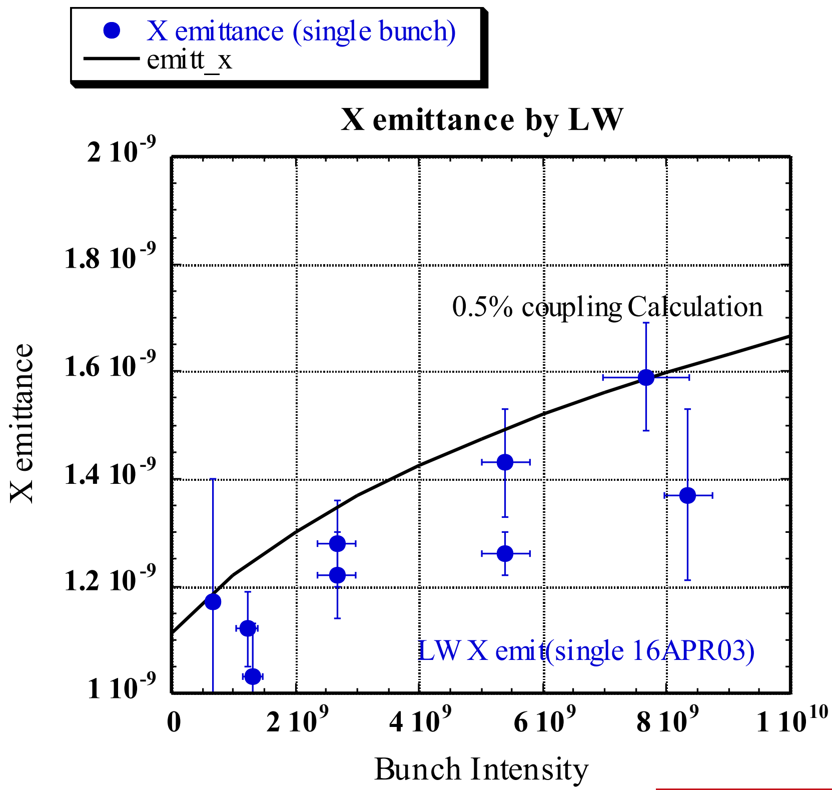


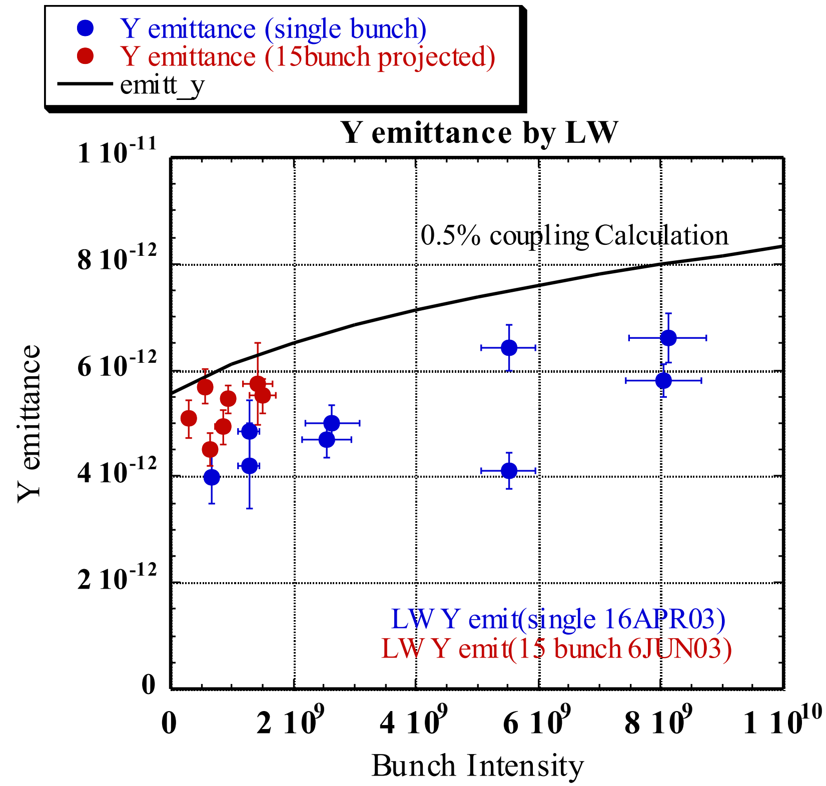
β:*measured by Q-trim excitation*

$$\sigma_e^2 = \sigma_{\mathrm{meas}}^2 - \sigma_{lw}^2$$

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

Emittance by CW Cavity Laser wire





< 0.5% y/x emittance ratio

Y emittance =4pm at small intensity

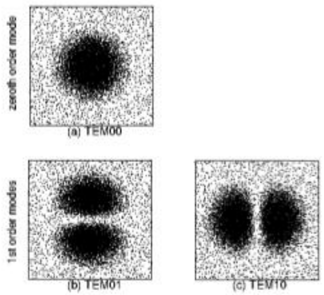
VOLUME 92, NUMBER 5 PHYSICAL REVIEW LETTERS week ending 6 FEBRUARY 2004

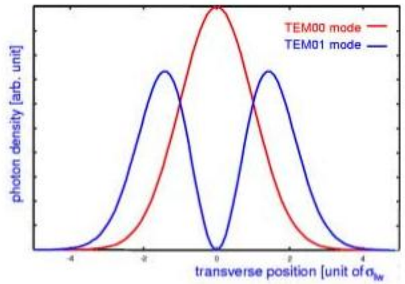
Achievement of Ultralow Emittance Beam in the Accelerator Test Facility Damping Ring

Y. Honda,[1] K. Kubo,[2] S. Anderson,[3] S. Araki,[2] K. Bane,[3] A. Brachmann,[3] J. Frisch,[3] M. Fukuda,[6] K. Hasegawa,[14] H. Hayano,[2] L. Hendrickson,[3] Y. Higashi,[2] T. Higo,[2] K. Hirano,[13] T. Hirose,[15] K. Iida,[12] T. Imai,[9] Y. Inoue,[7] P. Karataev,[6] M. Kuriki,[2] R. Kuroda,[8] S. Kuroda,[2] X. Luo,[11] D. McCormick,[3] M. Matsuda,[10] T. Muto,[2] K. Nakajima,[2] Takashi Naito,[2] J. Nelson,[3] M. Nomura,[13] A. Ohashi,[6] T. Omori,[2] T. Okugi,[2] M. Ross,[3] H. Sakai,[12] I. Sakai,[13] N. Sasao,[1] S. Smith,[3] Toshikazu Suzuki,[2] M. Takano,[13] T. Taniguchi,[2] N. Terunuma,[2] J. Turner,[3] N. Toge,[2] J. Urakawa,[2] V. Vogel,[2] M. Woodley,[3] A. Wolski,[4] I. Yamazaki,[8] Yoshio Yamazaki,[2] G. Yocky,[3] A. Young,[3] and F. Zimmermann[5]

higher mode laserwire

- use TEM01 resonance mode in an optical cavity as a laserwire



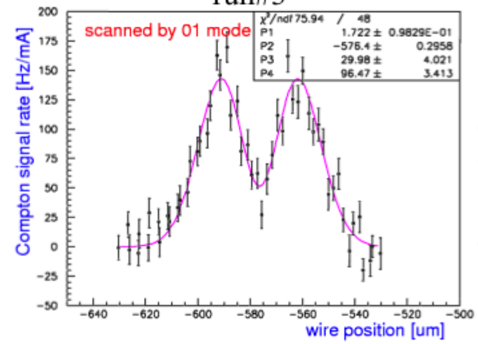


TEM01 mode has two lobe and a node

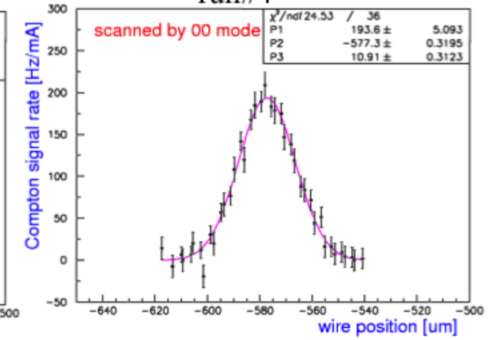
beam experiment

- normal beam

run#3



run#4

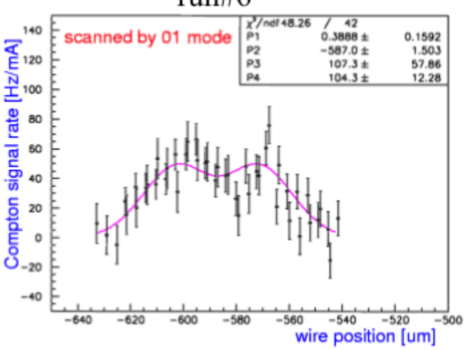


Higher mode CW laser wire to improve the resolution.

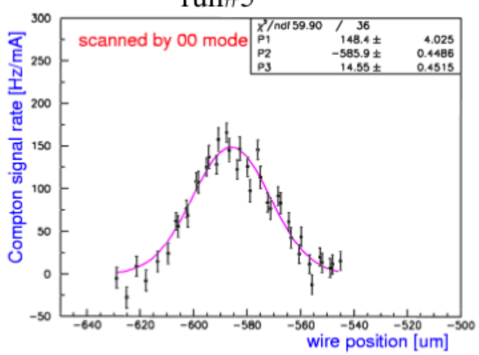
beam experiment

- bigger beam (skew corr. turned off)

run#6



run#5

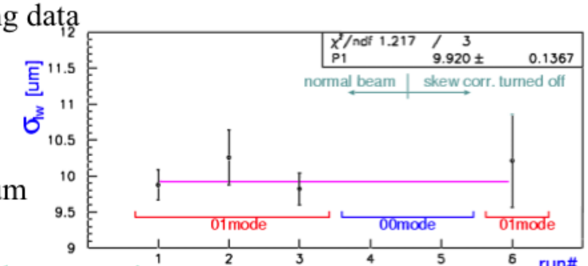


fitted result

- estimation of the laserwire size

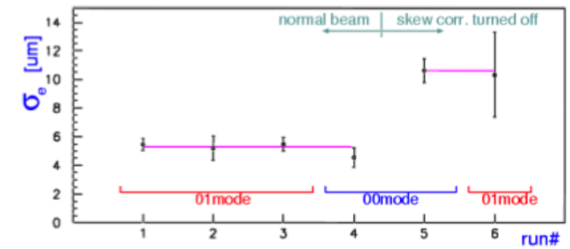
from 01mode scanning data

combined result for the laser size : 9.92 ±0.14um

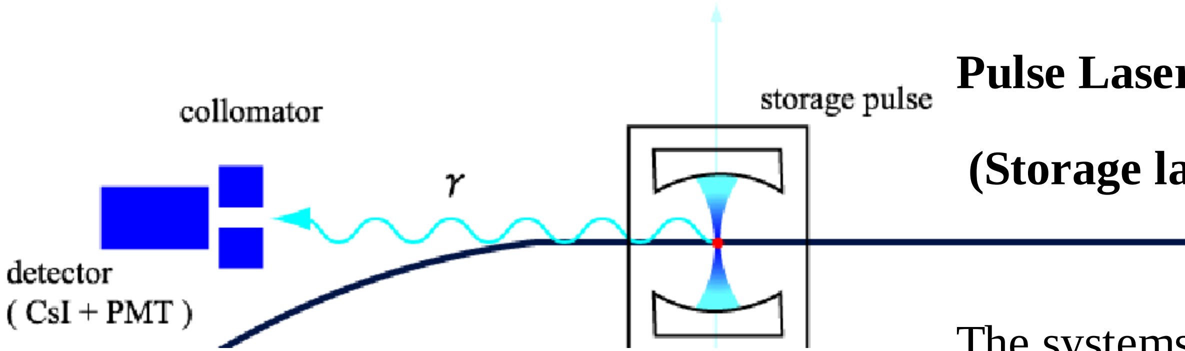


- estimation of the beam size

the result above was used to subtract laser size from 00mode results



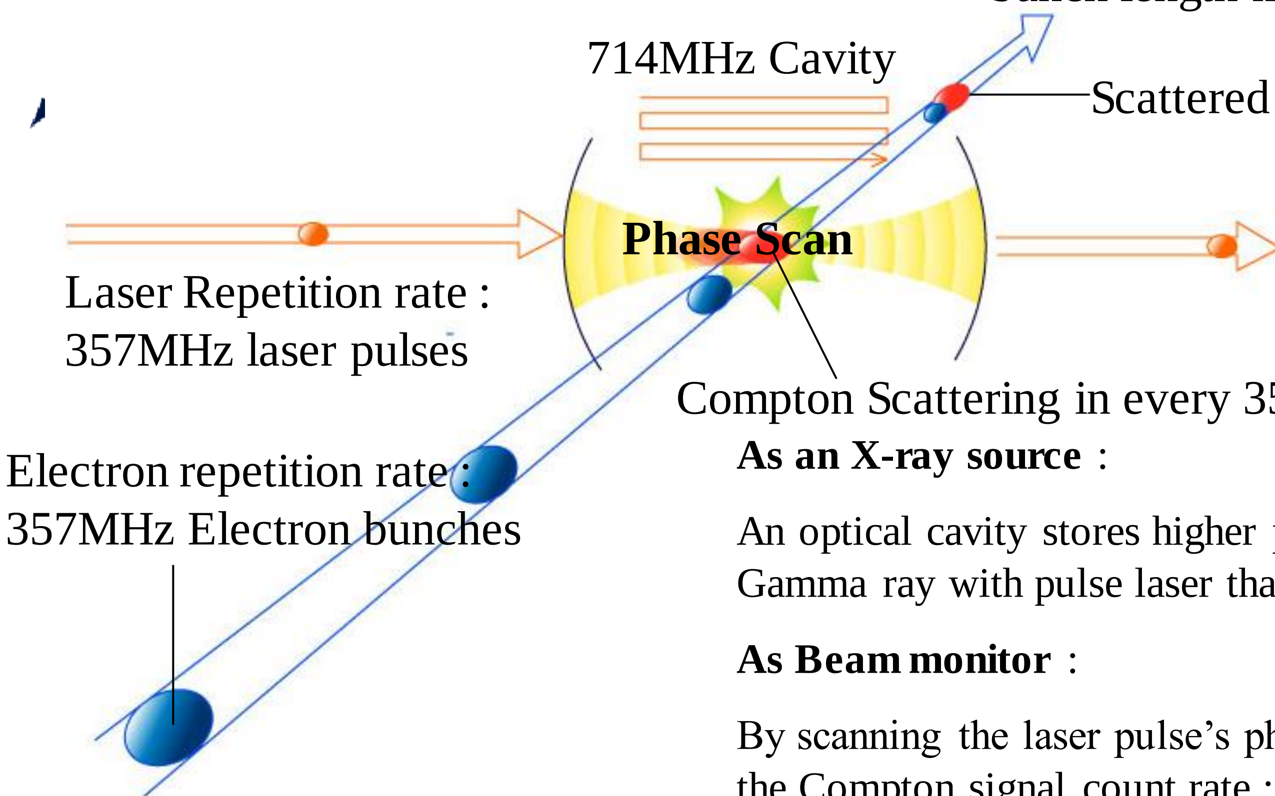
Pulsed Laser Cavity to measure bunch length



Pulse Laser Wire

(Storage laser pulses in optical cavity):

The systems for Gamma ray source & New bunch length monitor at a storage ring.



As an X-ray source :

An optical cavity stores higher peak power and gets higher flux Gamma 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.

Experimental results（Pulse Laser Storage）

Laser:

Mode Lock: Passive SESAM

Frequency: 357MHz

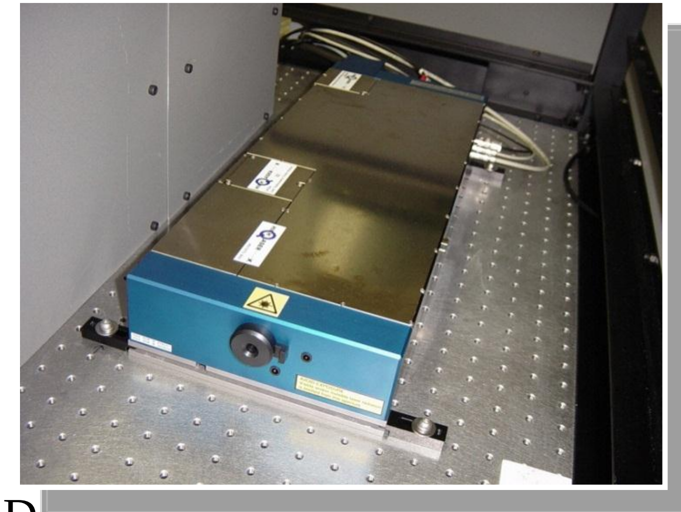
Cavity length:0.42 m

Pulse width: 7.3 p sec(FWHM)

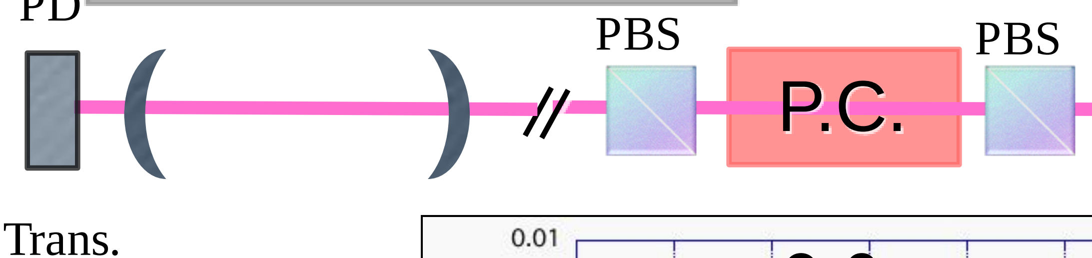
Wave Length:1064 nm

Power:~ 7W

SESAM: SEmi-conductor Saturable Absorber Mirrors



- Finesse measurement
R = 99.96%
More than 3000 times enhancement.



Ext. Cavity:

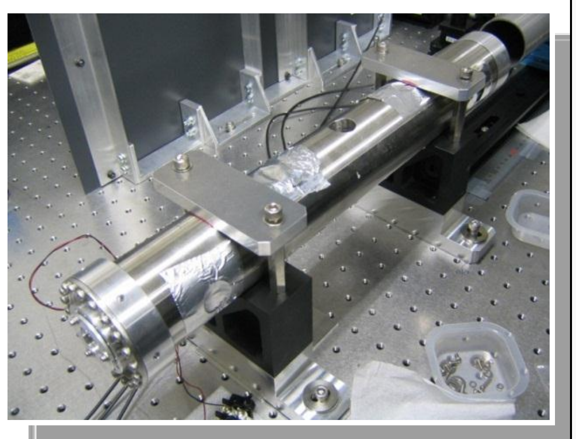
Cavity: Super Invar

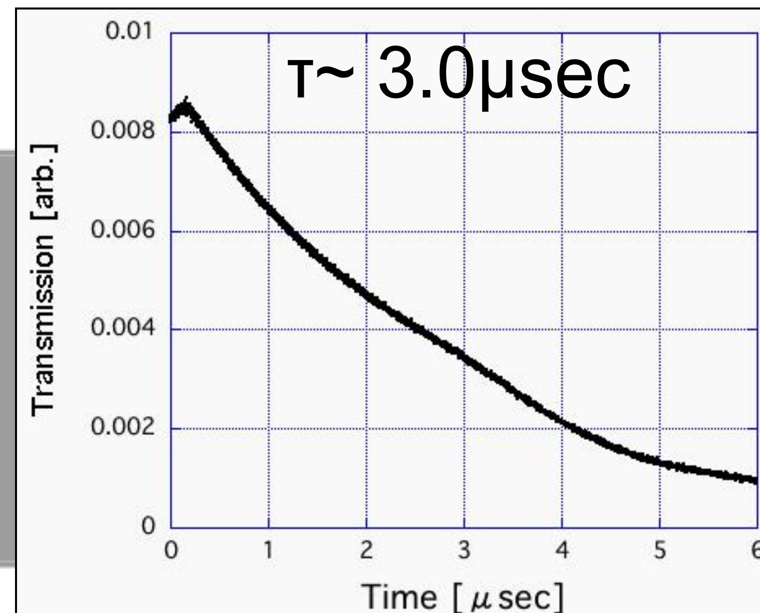
Cavity length: 0.42 m

Mirror Reflectivity: 99.9%

Curvature: 250 mm

(ω_0 = 180μm)





Storage of laser pulse

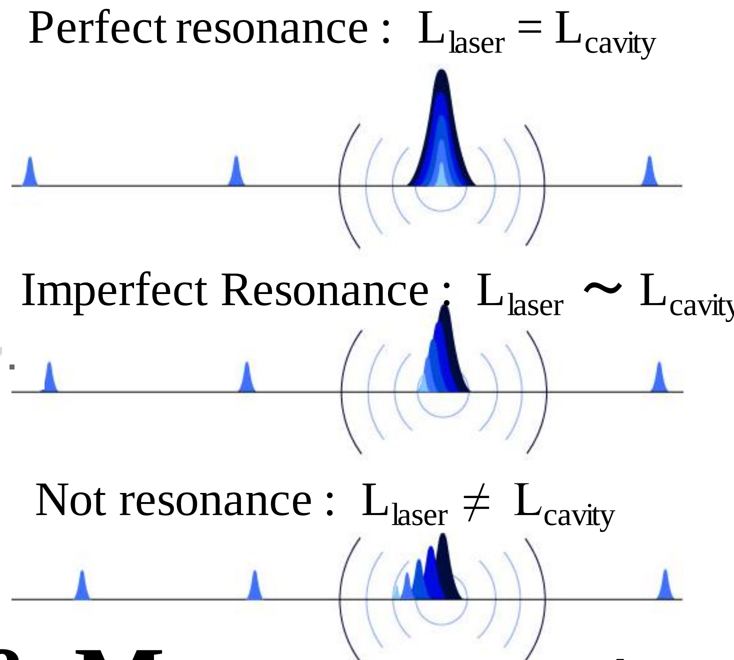
$$\sigma^2 = \sigma^2_{\text{Laser beam waist}} + \sigma^2_{\text{e v-beam waist}}$$

Resonance condition :
The relationship with laser and cavity :

$$L_{cav} = n \cdot \frac{\lambda}{2},$$

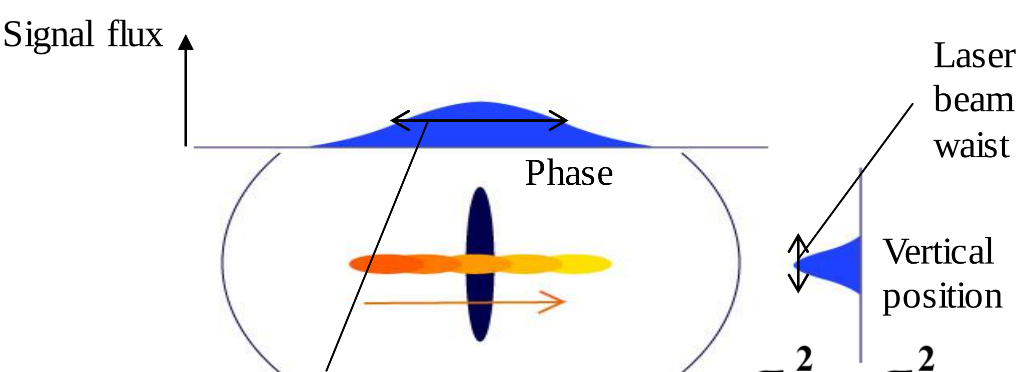
$$\Delta l = L_{laser} - L_{cav}, \qquad \Delta l = 0.$$

The enhancement factor is the function of reflectivity, **Δ l** and **laser pulse width.**



Suppose both electron bunch and laser pulses have a Gaussian intensity distribution, the measured profile is also a Gaussian shape.

Count rate & Measurement



The electron bunch length is 20 ～ 40 psec (10mm).

Laser pulse width (FWHM = 7 psec ; 1 mm) .

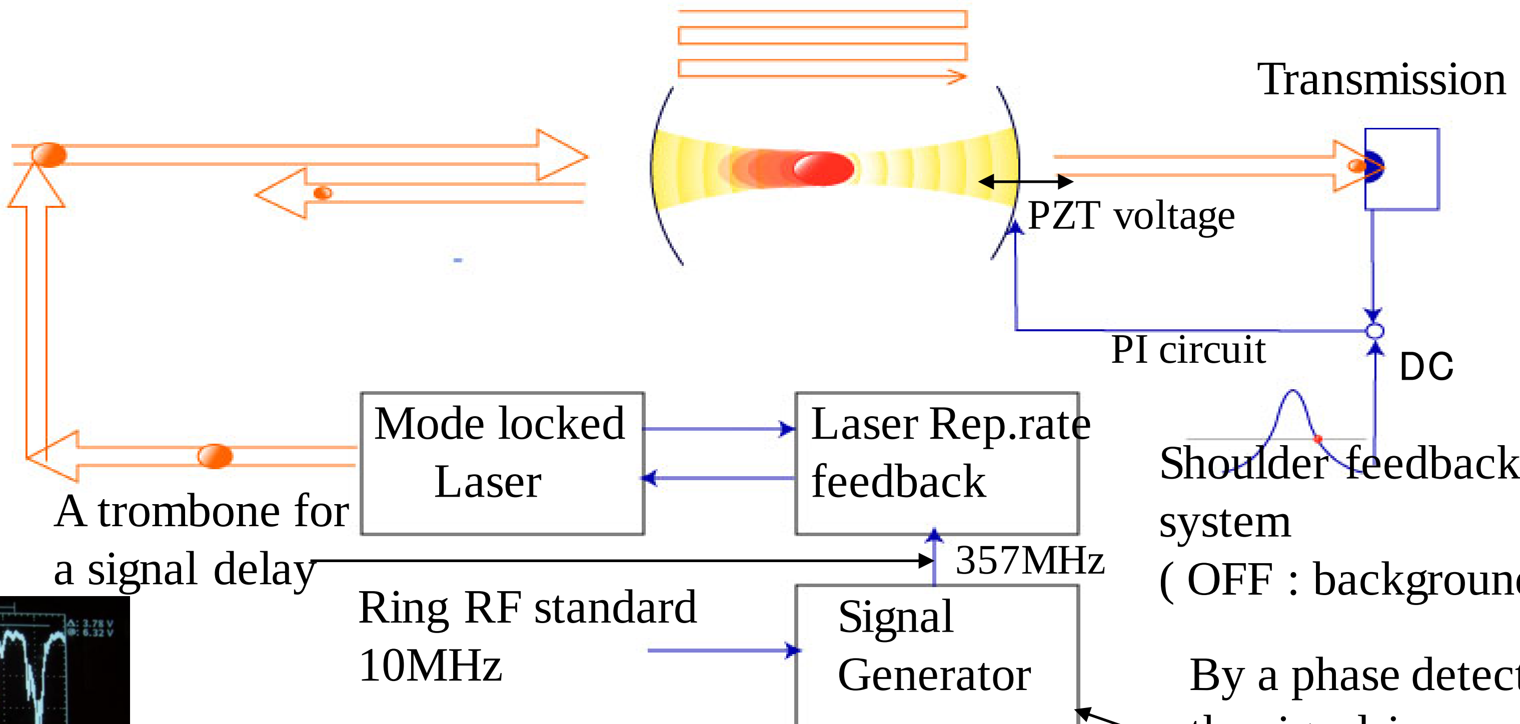
Laserwire beamwaist(120um), electron’s horizontal beamsize (100um).

$$\sigma^2 = \sigma^2_{\text{Laser pulse width}} + \sigma^2_{\text{e bunch length}} + \sigma^2_{\text{Laser beam waist}} + \sigma^2_{\text{e h-beam size}}$$

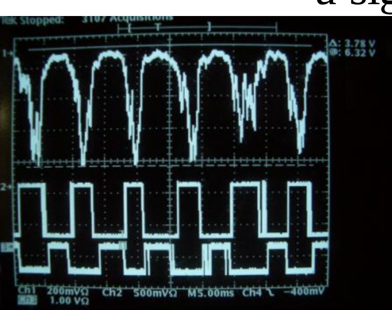
$$\sim \sigma^2_{\text{e bunch length}}$$

OPTICAL CAVITY and Feedback Circuit

- **Cavity length : 714 MHz +/- 2 kHz (from PZT dynamic range)**
  Cavity length is 210mm. It is easy to adjust cavity length with short cavity.
  For cavity's dynamic range , long PZT is used (10um).
- **Mirrors ; The radius of curvature : 250 mm , The reflectivity : 0.997 +/- 0.001**
- **Beam waist > 200 um** Finesse is ～ 1000 . But effective finesse is ～500 , when the length of cavity is 21cm. 4 times reflections occur during each laser pulse injection.

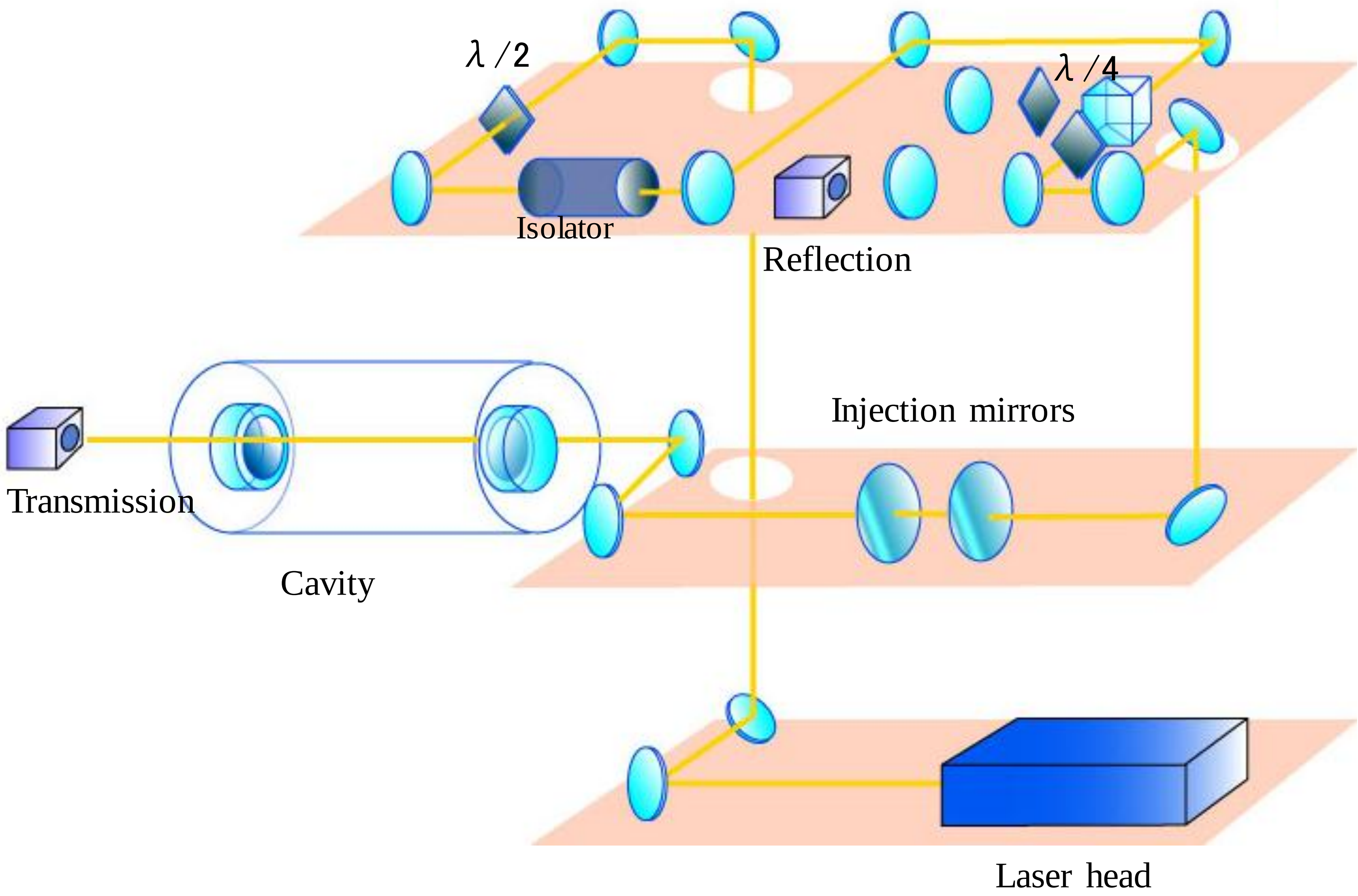


By a phase detector, the signal is synchronized with Ring RF.

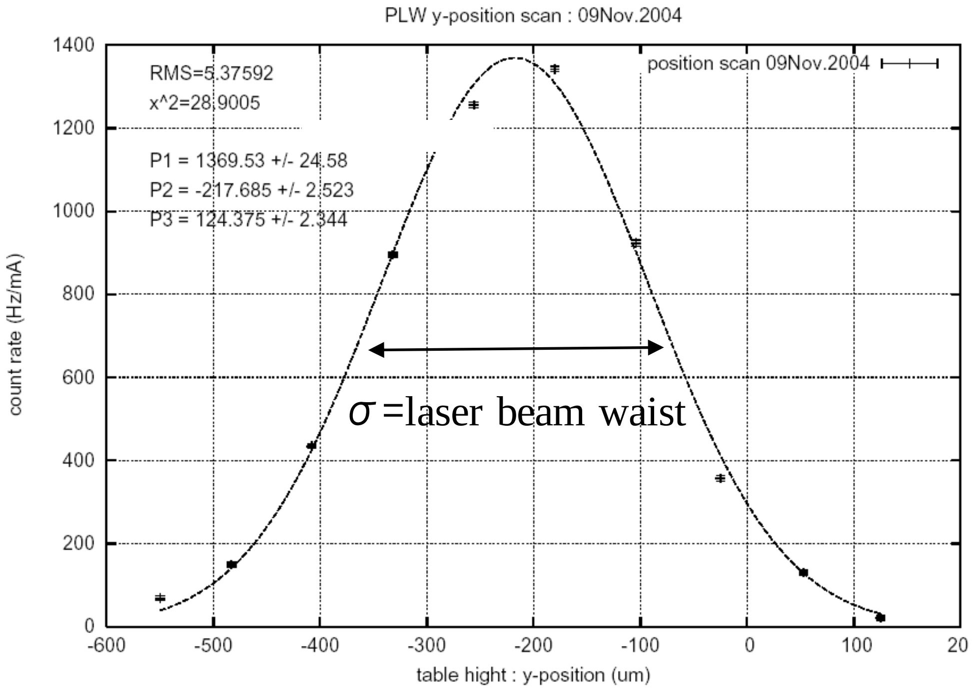


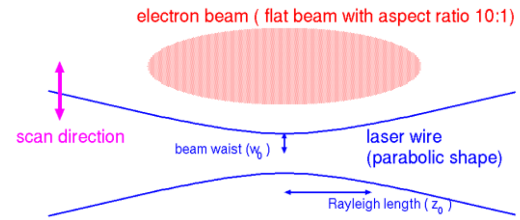
Feedback ON/OFF

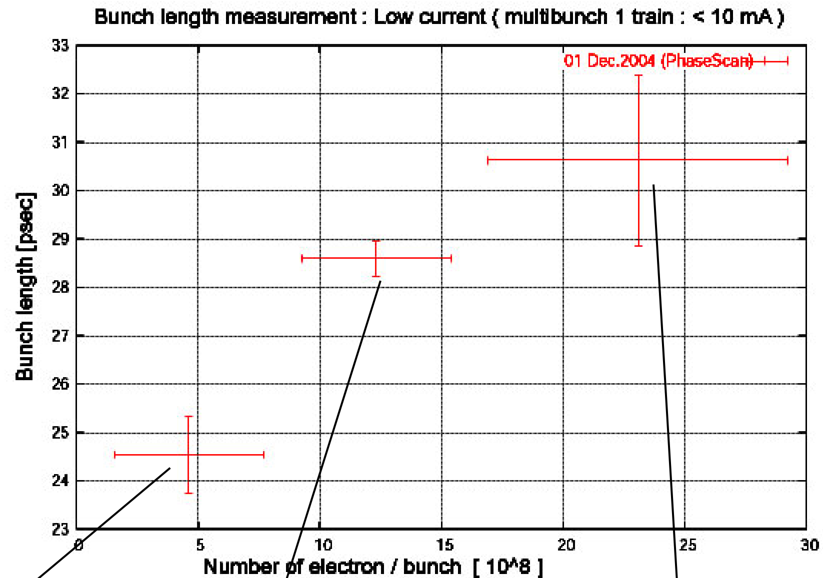
EXPERIMENTAL SETUP : Optics



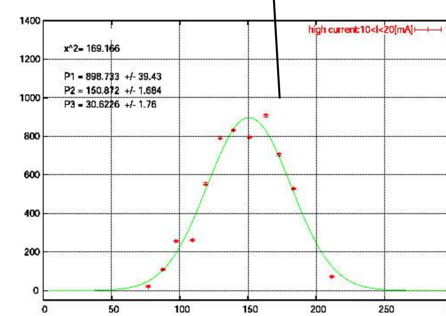
Count rate

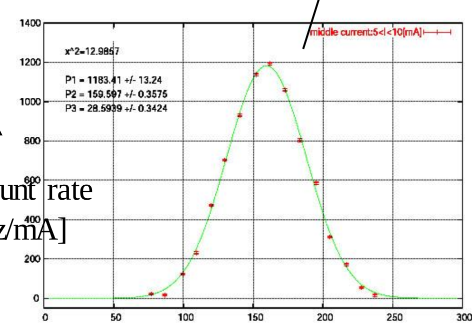




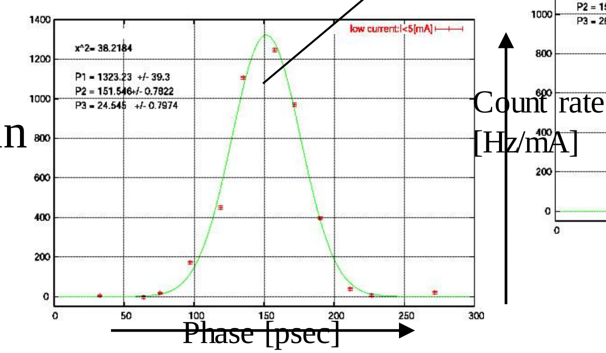


Calculated maximum count rate is～ 2500 [Hz/mA]
Actual count rate is ～ 1500 because of imperfectly adjustment cavity length with shoulder feedback system.





When bunch current is increased , the Gaussian shape of photons count rate changes.



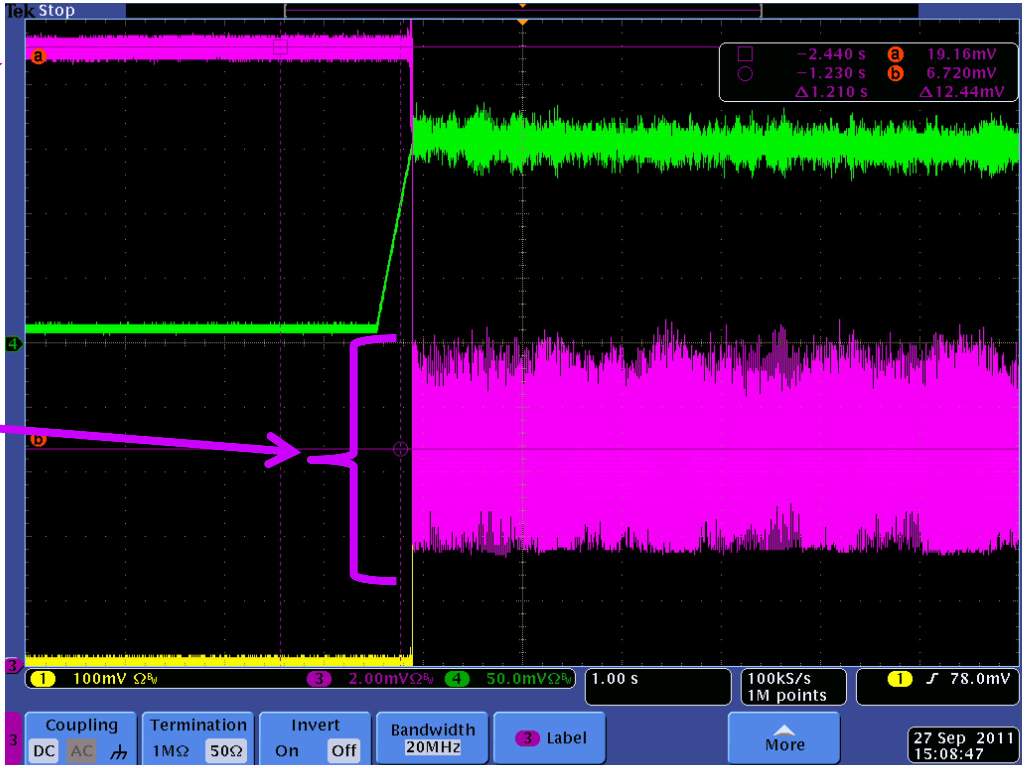
High finesse feedback on a 2-mirror cavity at Orsay

Recently Orsay obtained

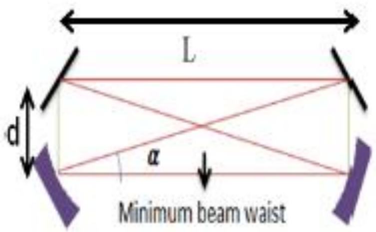
- ❑30000 finesse
- ❑$\Delta\nu/\nu=710^{-12}$ (linewidth=2.5kHz)
- ❑65% coupling stable

DC signal = power reflected by the cavity

Still some optimisation to reduce the oscillations

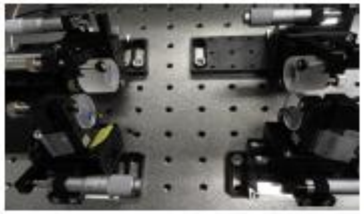


Design for versatile pulsed laser wire in moderate optical cavity

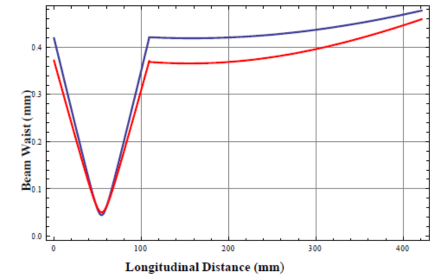


Laser-Compton scattering.

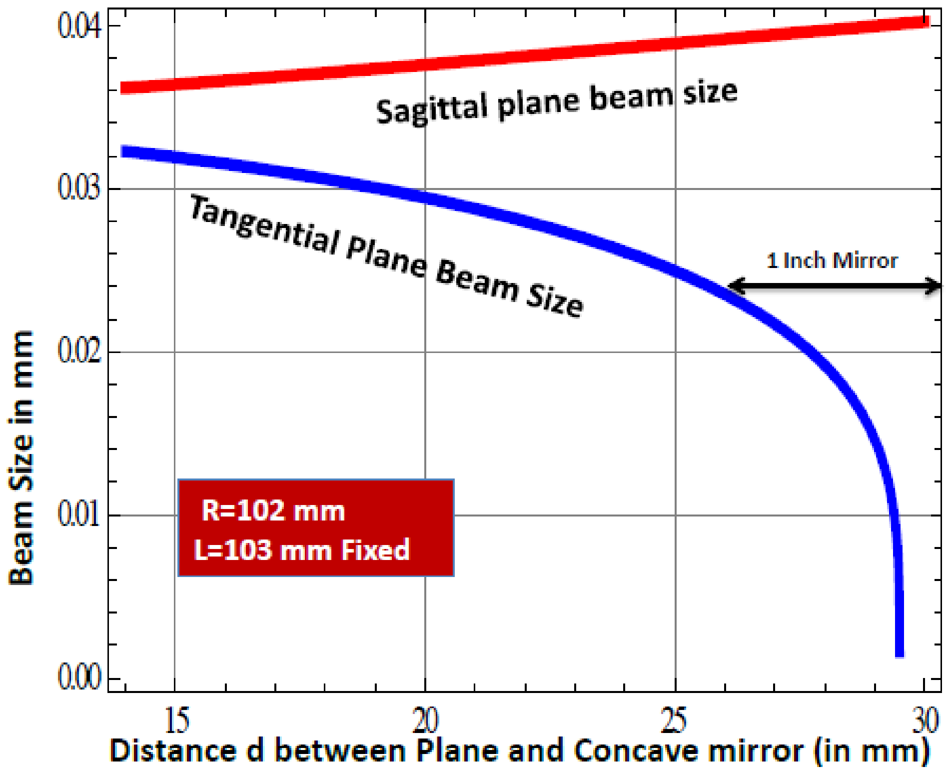
Compact 109 mm Resonator

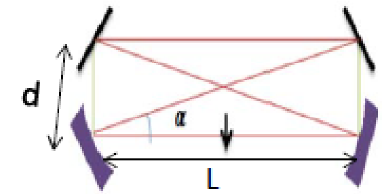


- $\alpha/2$= 0.1464 rad.
- Distance between Plane and Concave Mirror= 32mm



Beam-waist variation with "d"



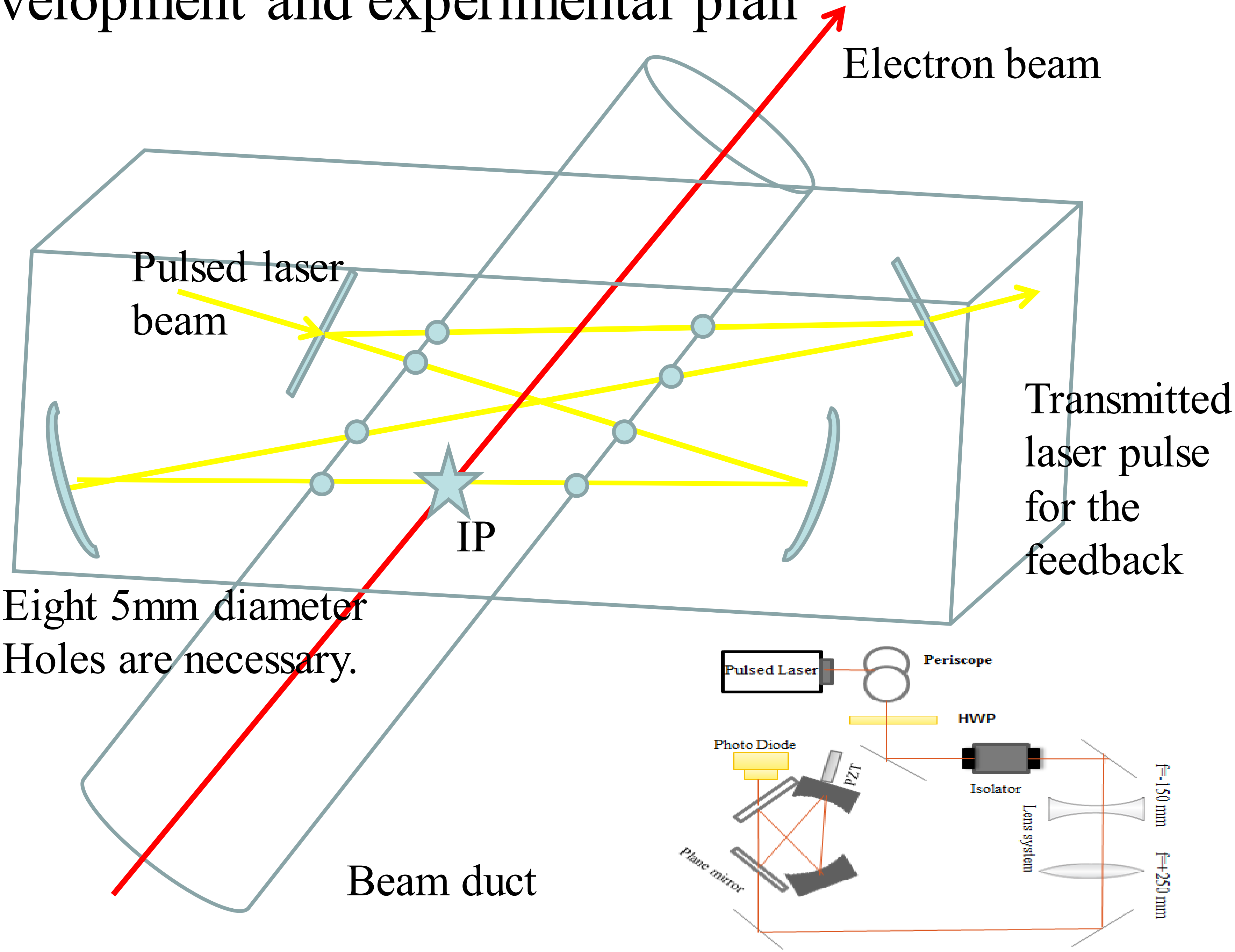


L	103 mm
d	29.2 mm
α	0.1381 rad
Beam size (IR) $\omega_{T,}\ \omega_s$ (2σ)	(12.85, 40) um
Beam Size (Green Laser) ω_T, ω_s (2σ)	(7.5,28.2) um

IR Mode Locked laser Rep. rate = 714.084 M Hz, (420.1 mm Path length)

Total path length of Compact resonator = 420.1 mm

Development and experimental plan



1. Confirmation of laser waist size is under prototype experiment now.
2. We will order the vacuum chamber which has 4 mirrors and laser windows in this year.
3. Measurement experiment will be done in next year at ATF-DR.

My final purpose is;

According to the report of research Committee on partitioning and transmutation cycle, we can say that about 20MeV γ-rays are very effective and necessary for the transmutation on ^{14}C, ^{79}Se and ^{126}Sn which are impossible to transmute using neutron beam.

Also, ^{90}Sr and ^{137}Cs have a giant resonance on γ-N reaction.