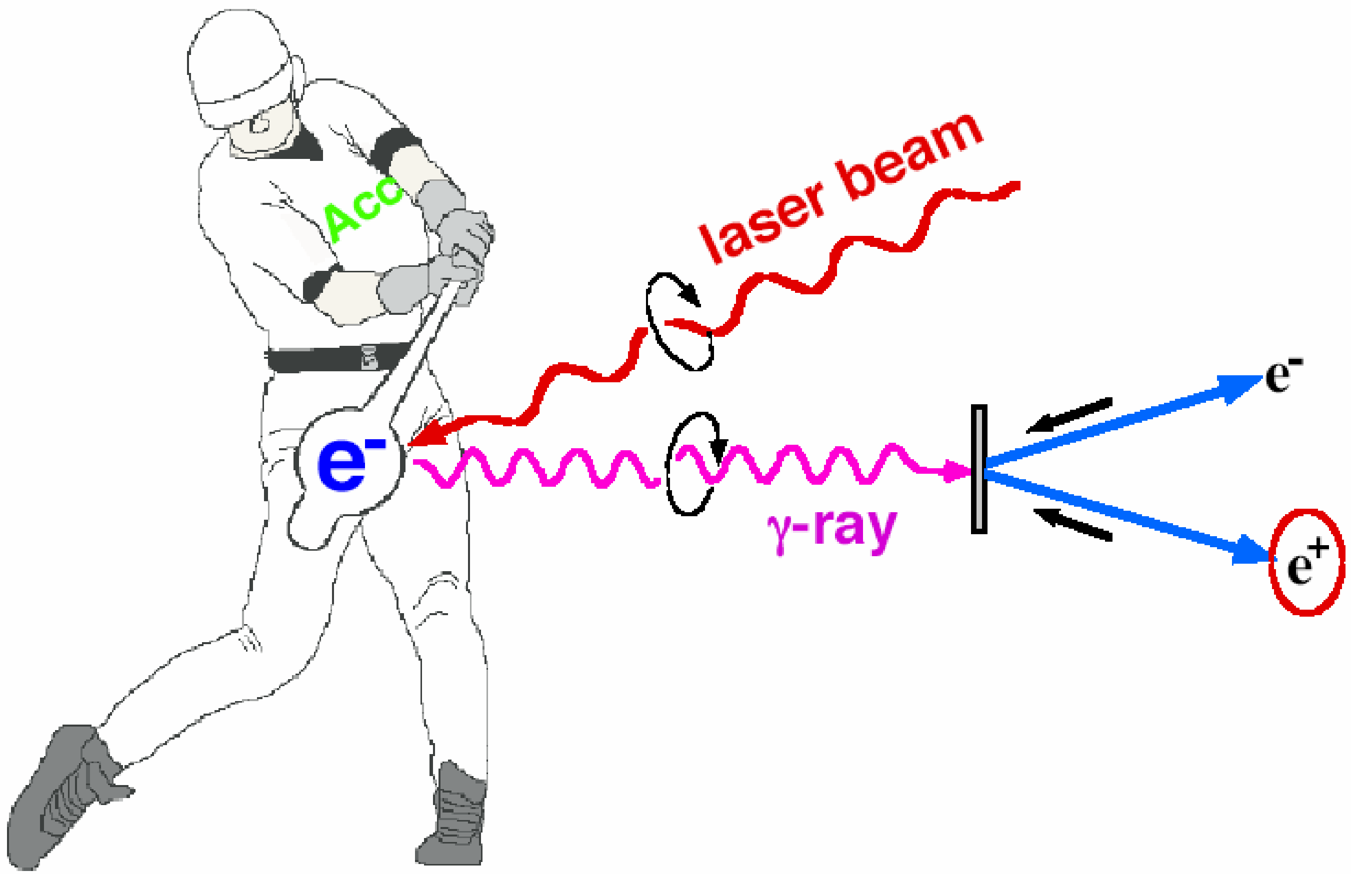
Laser-Compton Scattering Experiments at the ATF

J.Urakawa, KEK

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,**
6. **Key components for photon beam source based on laser-Compton scattering.**

1. Polarized e^+ Source based on Compton scattering

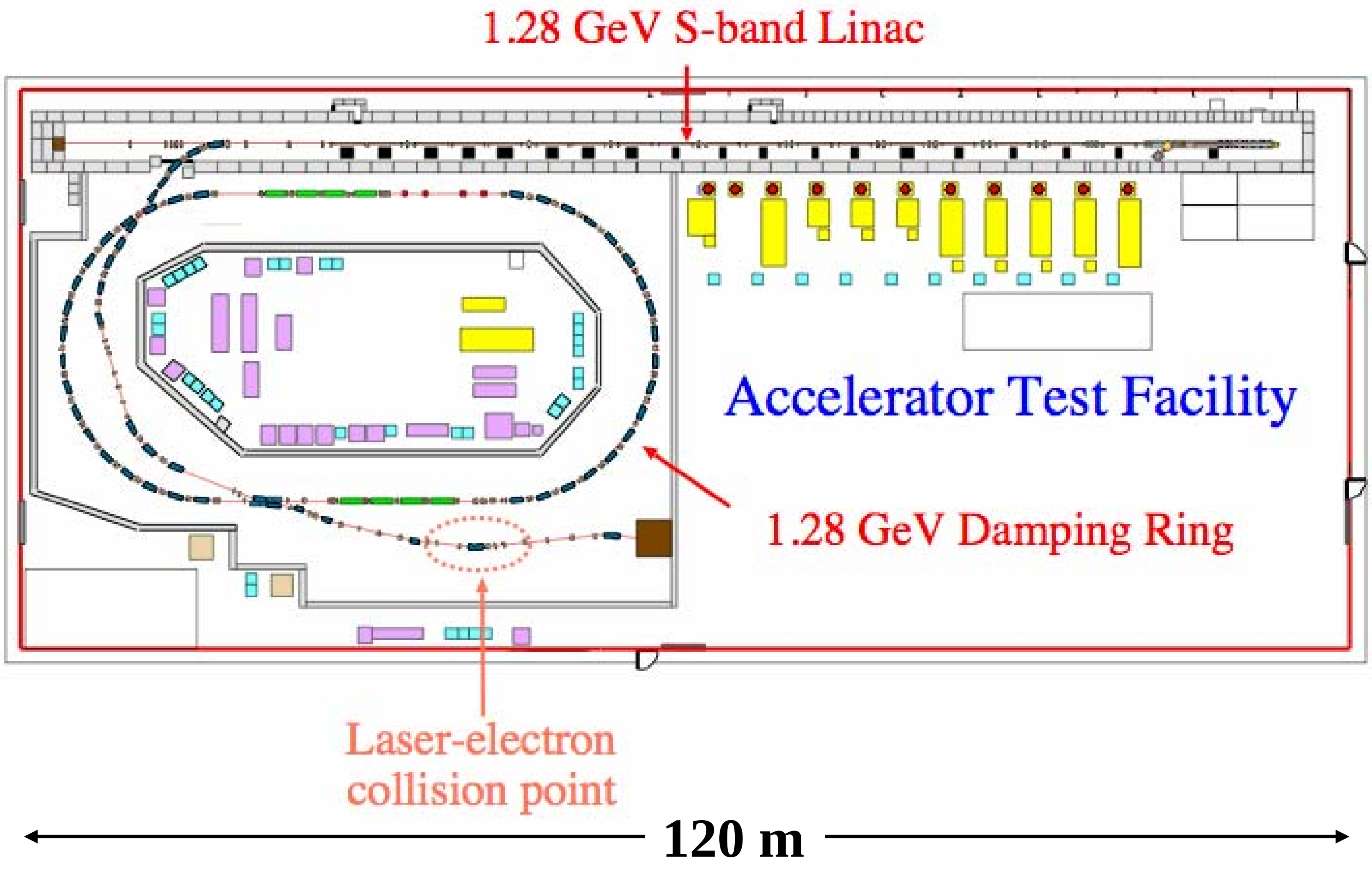


Experiment at KEK-ATF

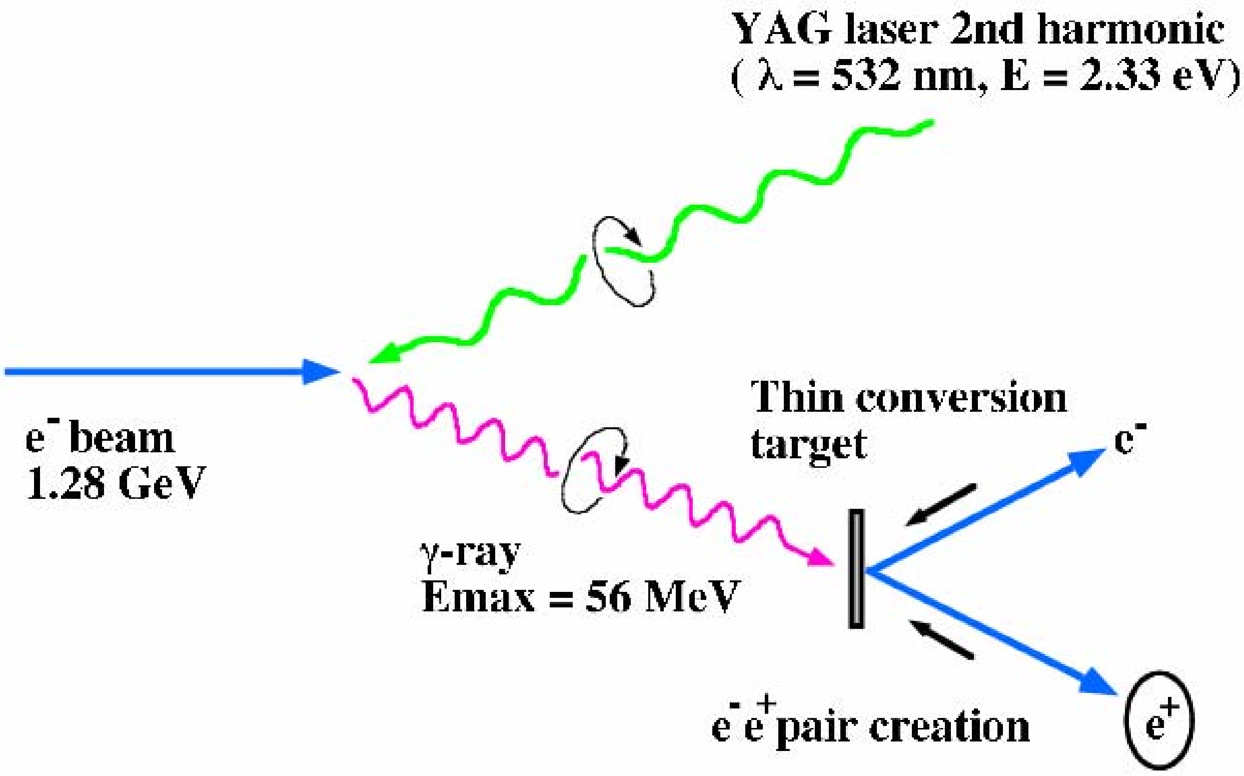
ATF: Accelerator Test Facility for ILC built at KEK

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

T. Omori, M. Fukuda, T. Hirose, Y. Kurihara, R. Kuroda, M. Nomura, A. Ohashi, T. Okugi, K. Sakaue, T. Saito, J. Urakawa, M. Washio, and I . Yamazaki



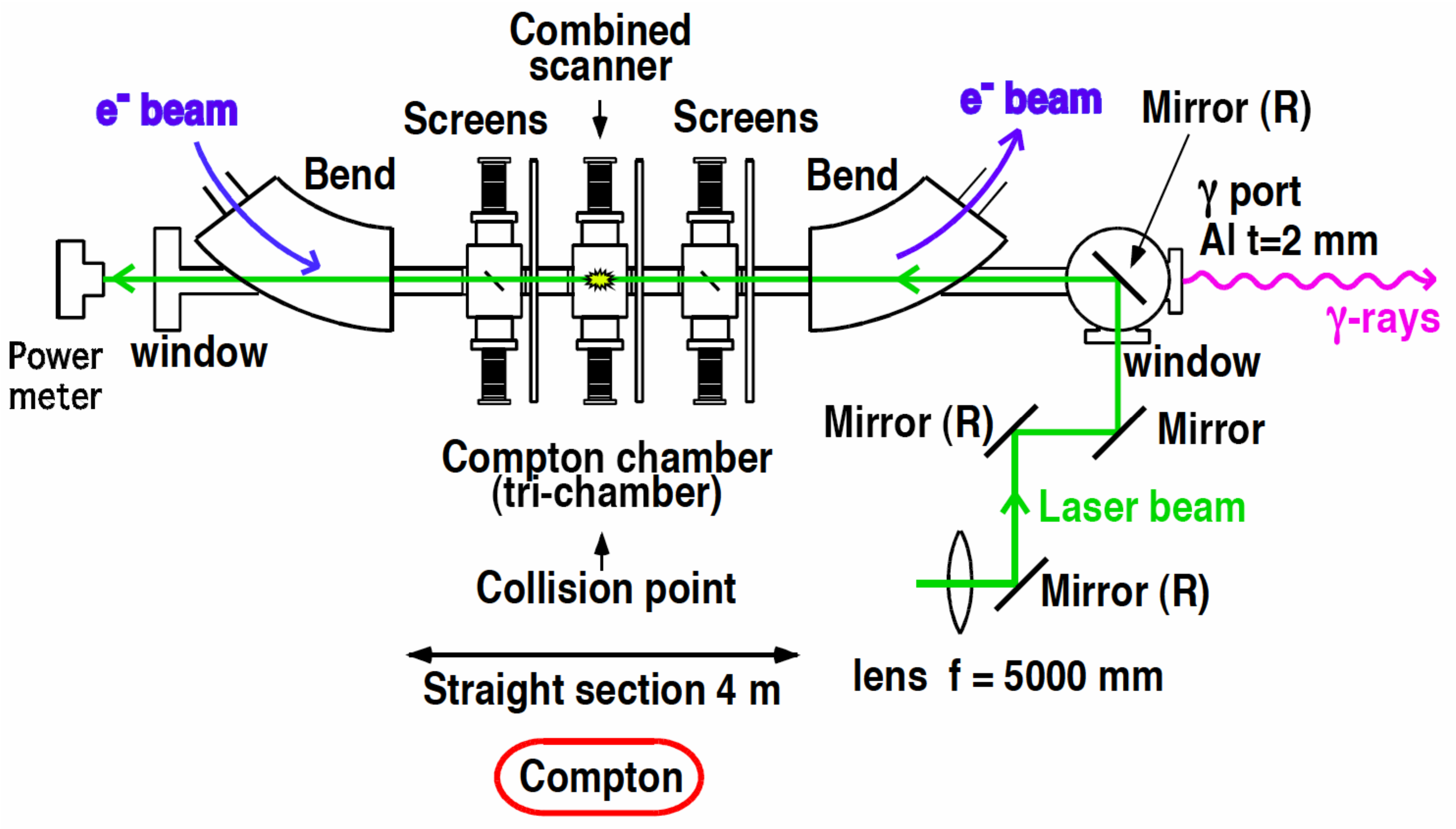
Experiment@KEK



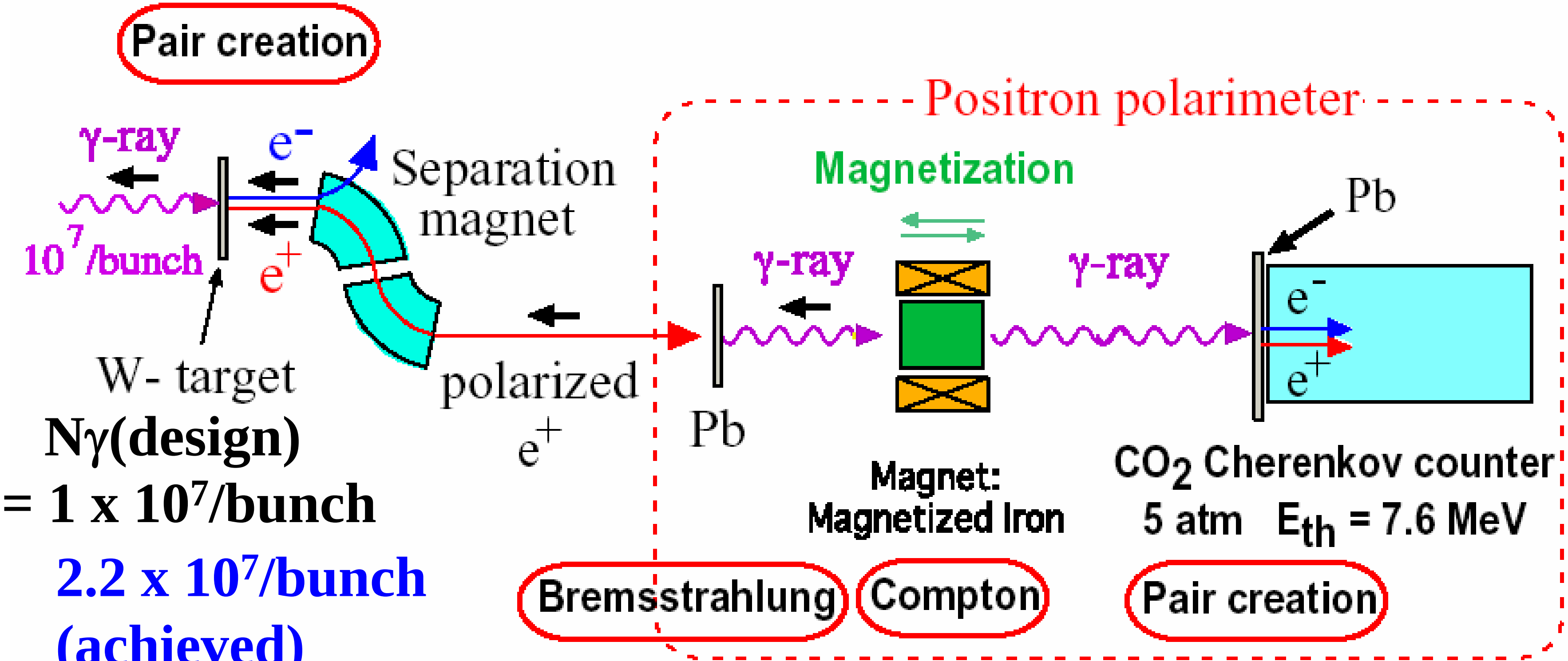
i) proof-of-principle demonstration

ii) accumulate technical informations:
polarimetry, beam diagnosis, …

Compton Chamber



Positron: production, selection, and polarimetry



Nγ(design) = 1 x 10^7/bunch

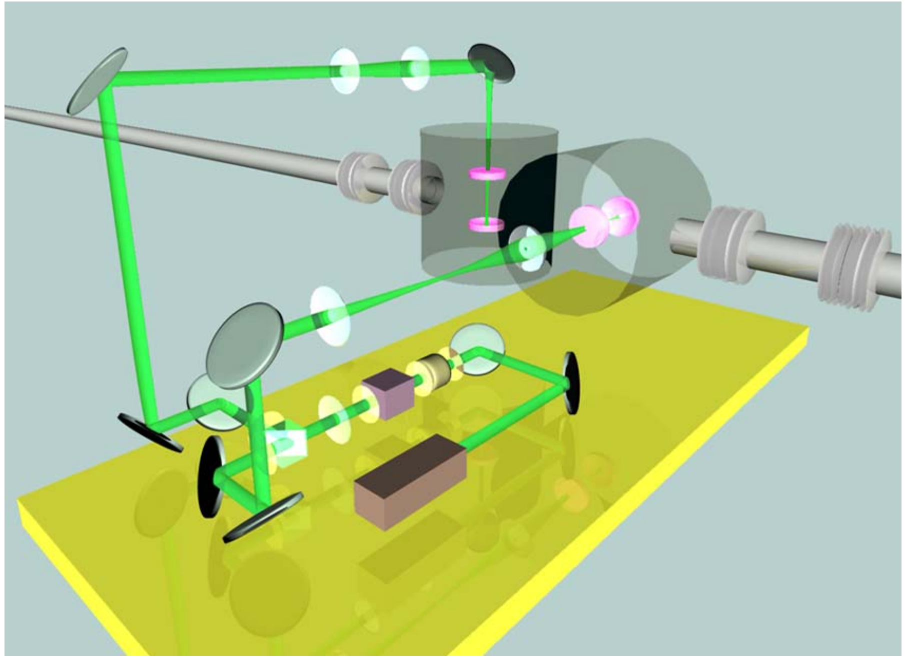
2.2 x 10^7/bunch (achieved)

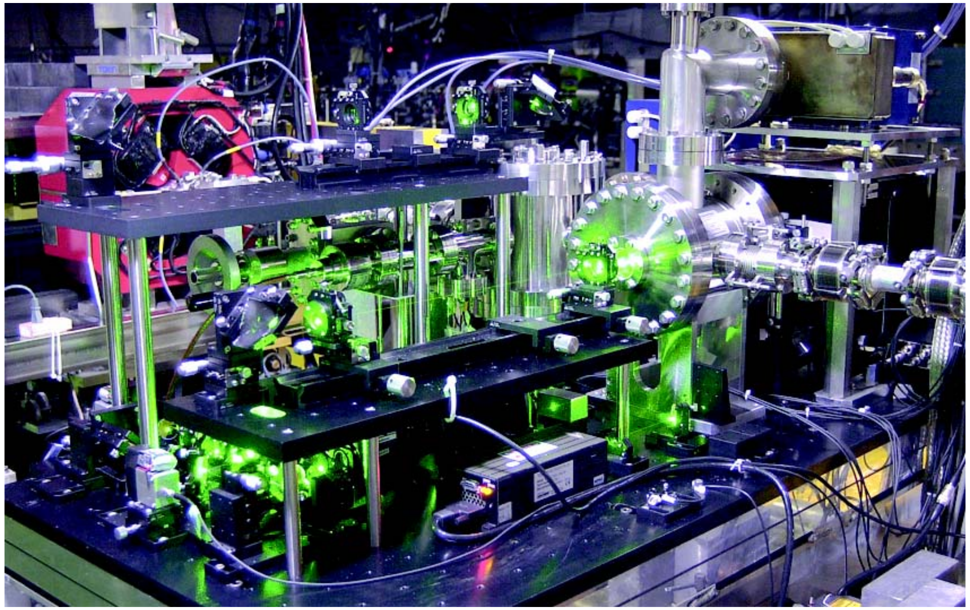
Ne+(design) = 3 x 10^4/bunch

Pol(expected) = 80% **Asym (expected) = 0.95%**

2. CW laser wire results

CW Laser wire beam size monitor in DR

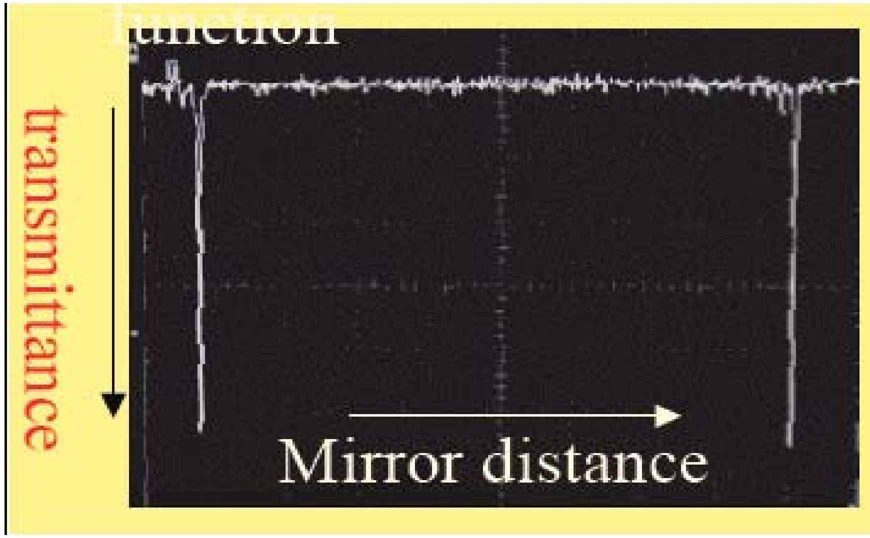


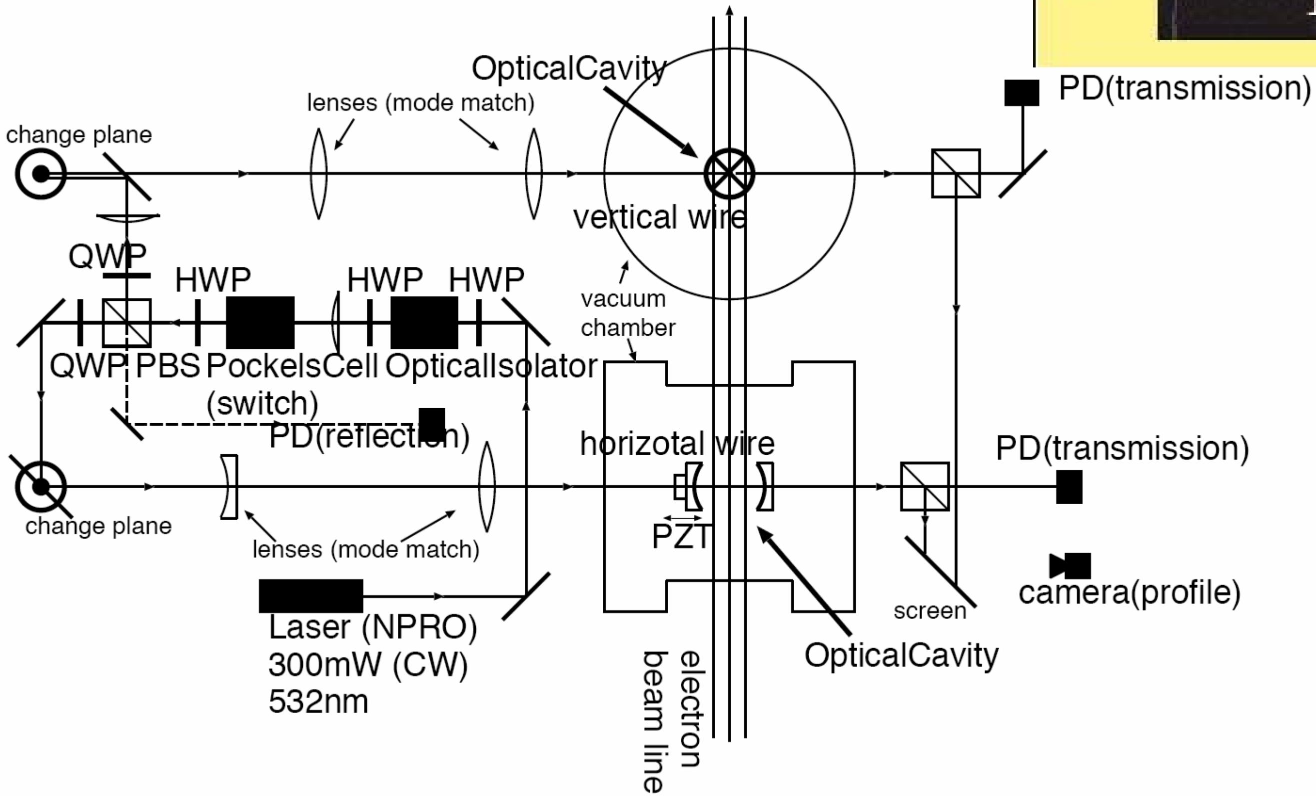


300mW 532nm Solid-state Laser fed into optical cavity

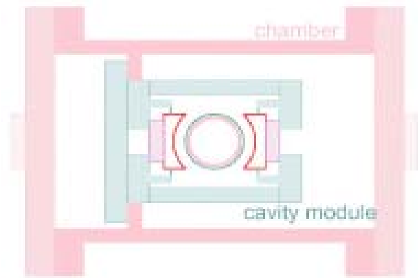
14.7µm laser wire for X scan
5.7µm for Y scan
(whole scan: 15min for X, 6min for Y)

Laser wire block diagram



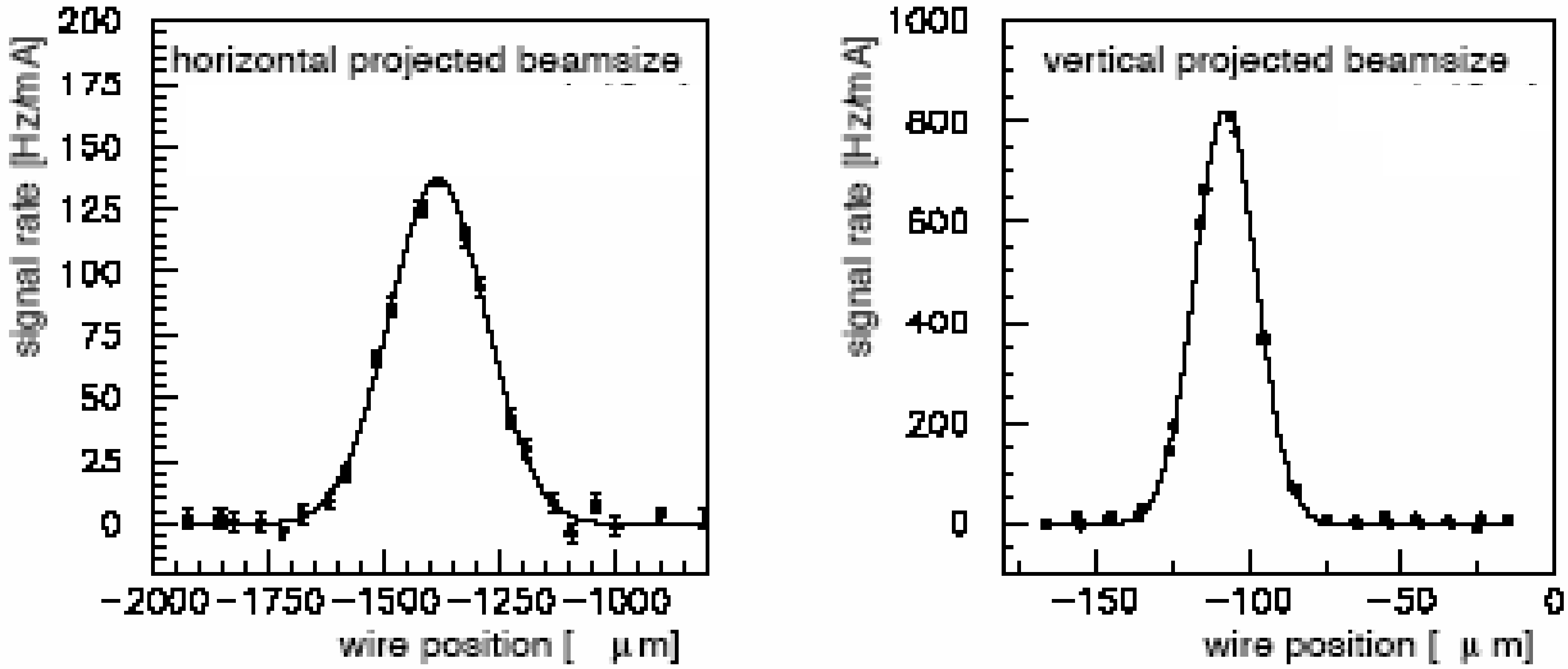


Free spectral range
:532nm/2=266nm
Line width=0.3nm



optical cavity resonance is kept by piezo actuator

Beam profile by Laser wire



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

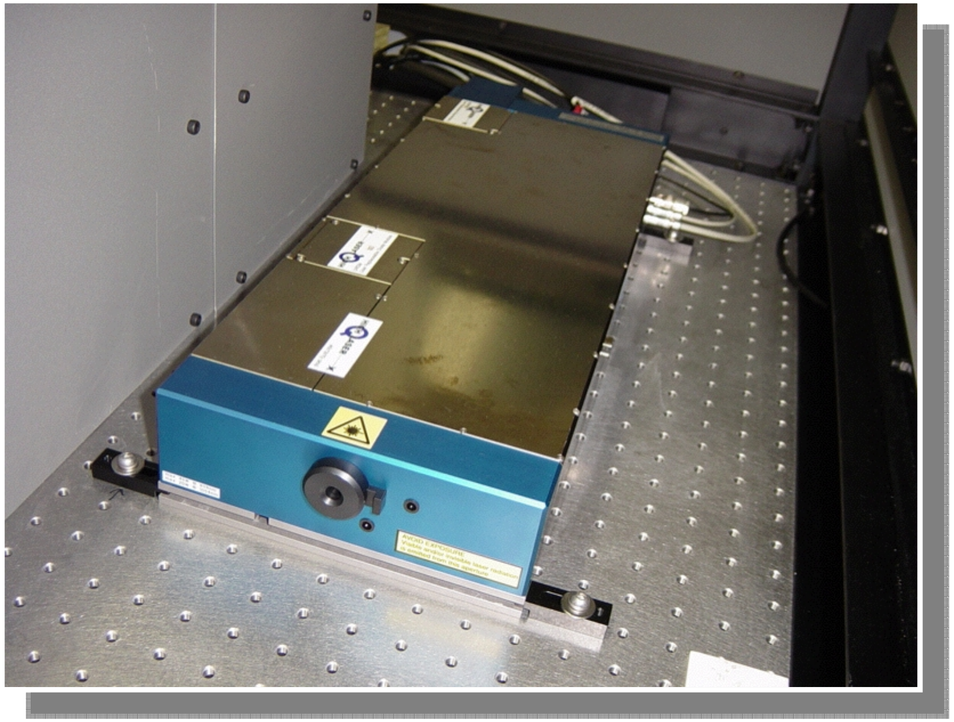
$\varepsilon\beta = \sigma_{\mathrm{e}}^2 - [\eta(\Delta p/p)]^2$ β:*measured by Q-trim excitation*

3. Pulsed laser wire development

Experimental results（Pulse Laser Storage）

Laser:

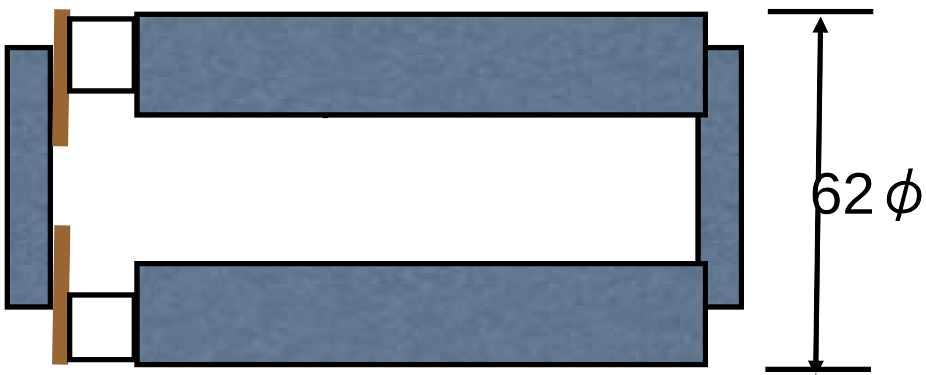
Mode Lock: Passive
SESAM
Frequency: 357MHz
Cavity length: 0.42 m
Pulse width: 7.3 p sec
(FWHM)
Wave Length: 1064 nm
Power: ~ 6W

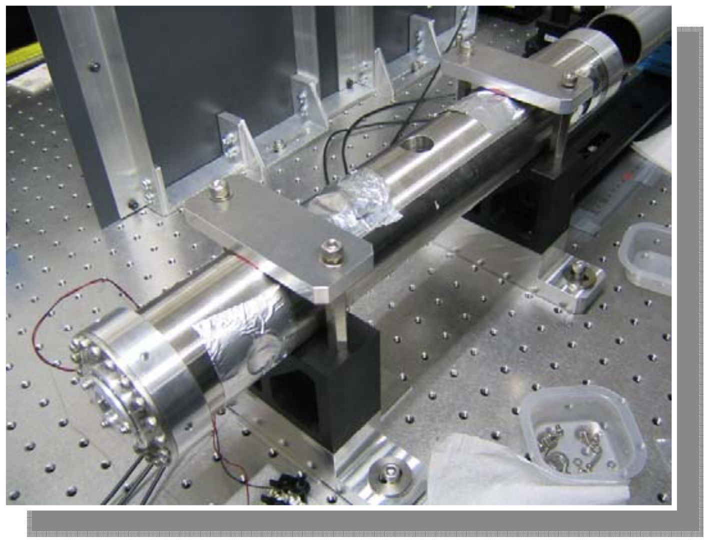


SESAM: SEmi-conductor Saturable Absorber Mirrors

Ext. Cavity:

Cavity:	Super Invar
Cavity length:	0.42 m
Mirrors:	
Reflectivity:	99.7%, 99.9%
Curvature:	250 mm (ω_0 = 180 μm)





Storage of laser pulse

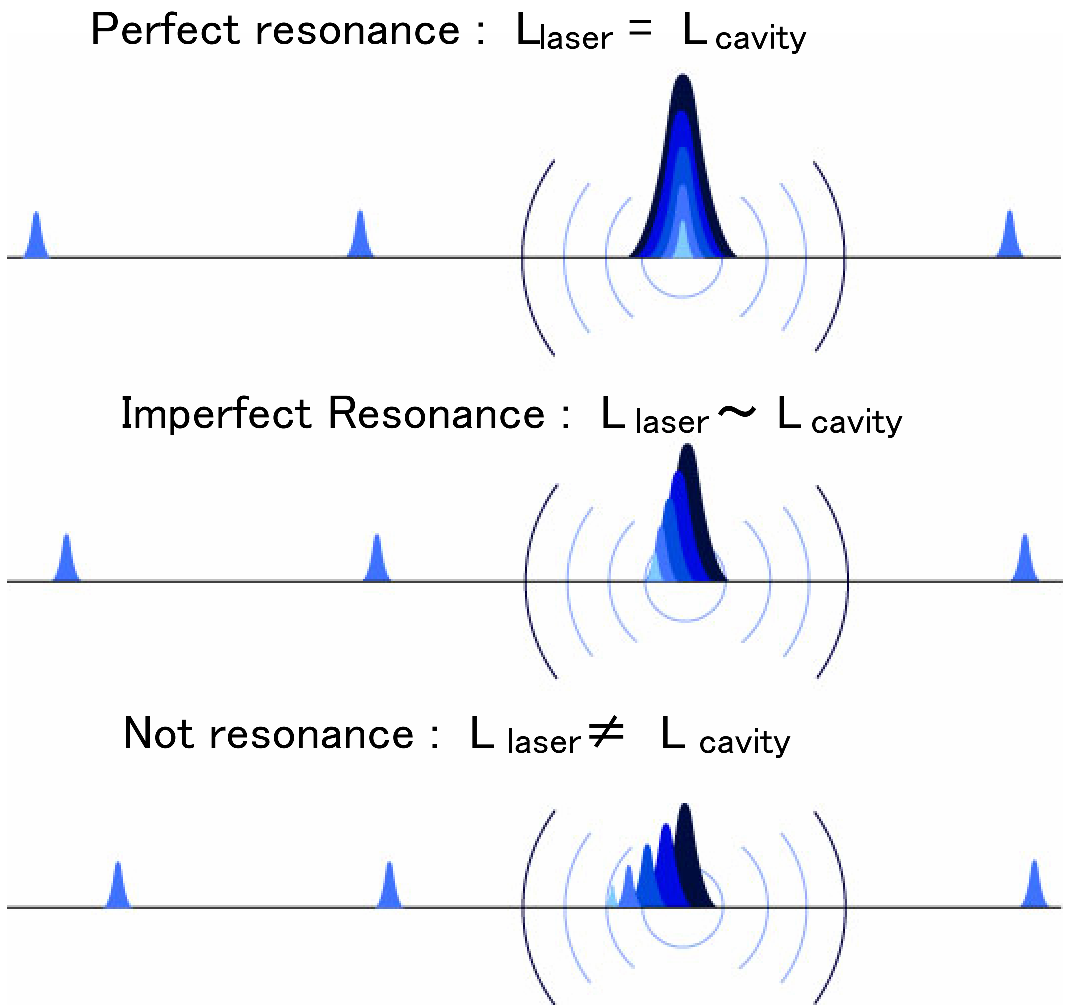
Resonance condition :

The relationship with laser and cavity :

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

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

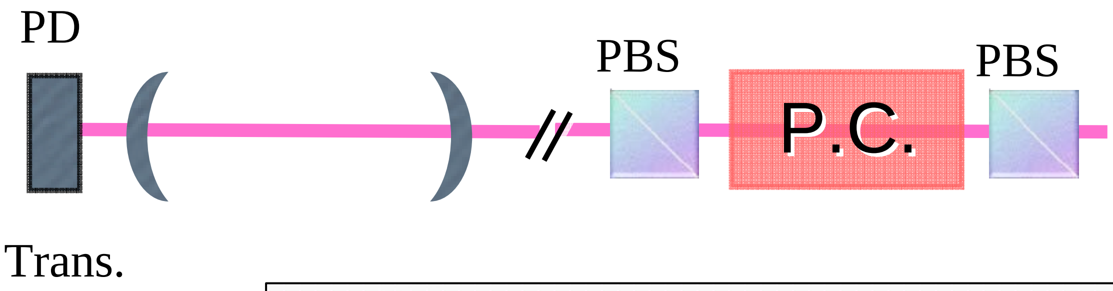
The enhancement factor is the function of reflectivity, **Δl and laser pulse width.**

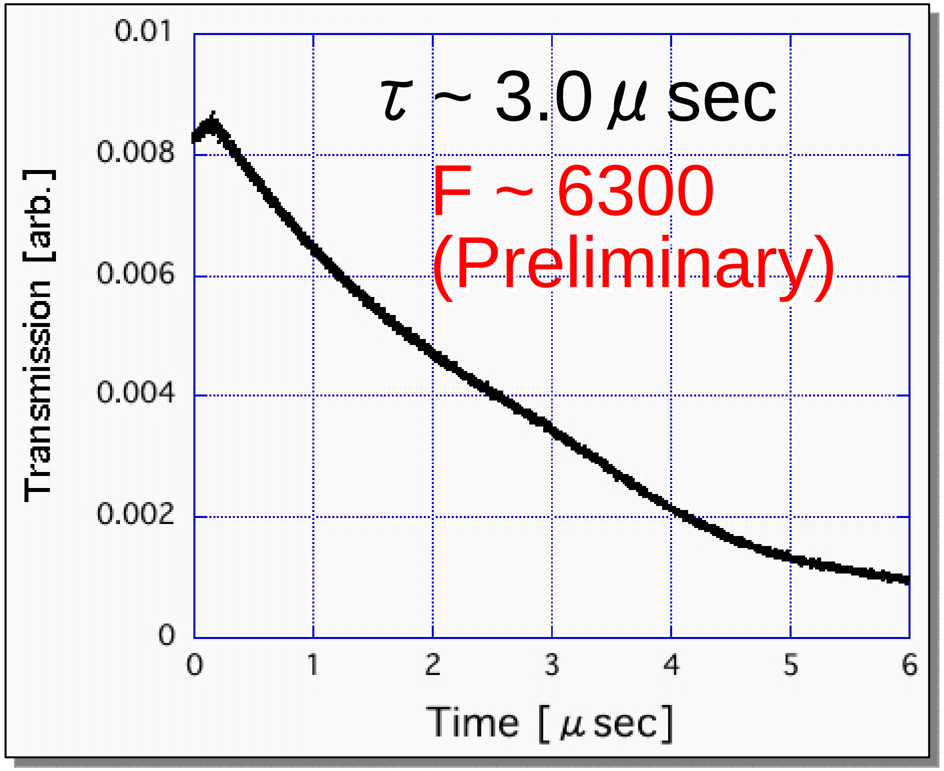


・Finesse: R = 99.9%

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

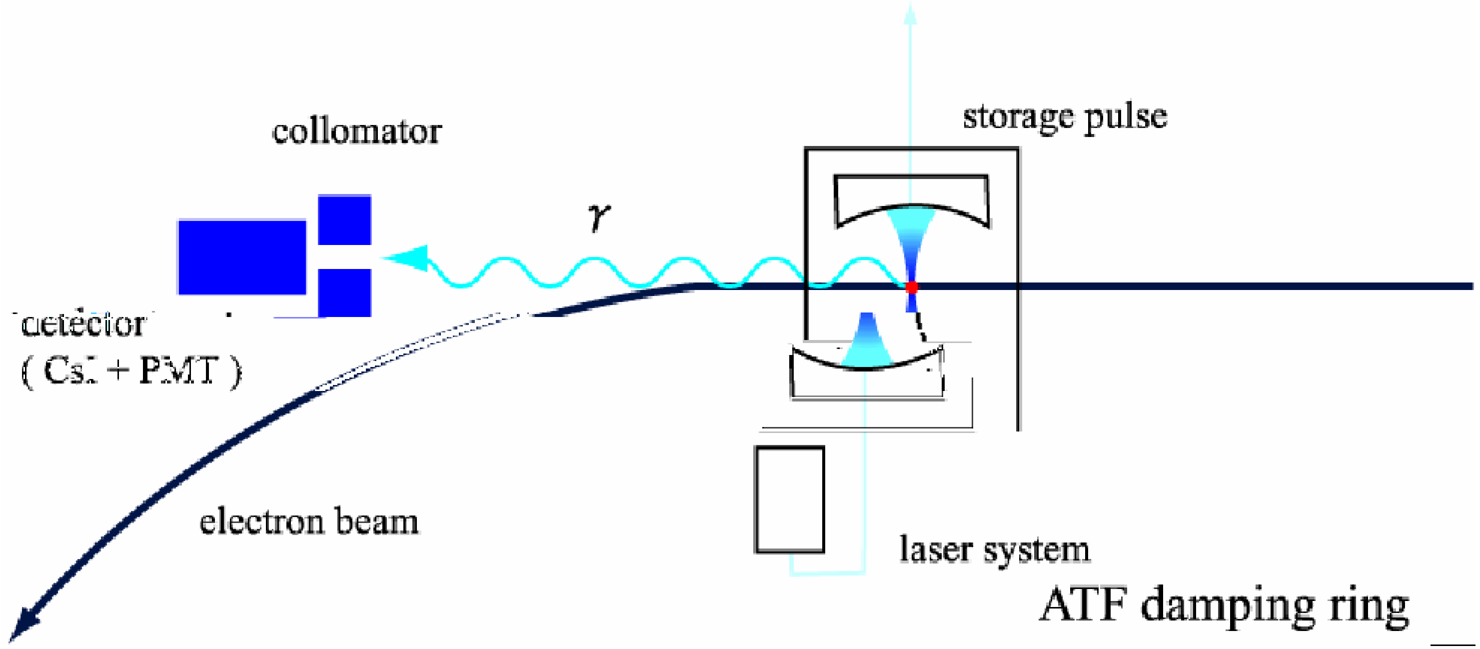
τ :decay time
c: light verocity
l: cavity length





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

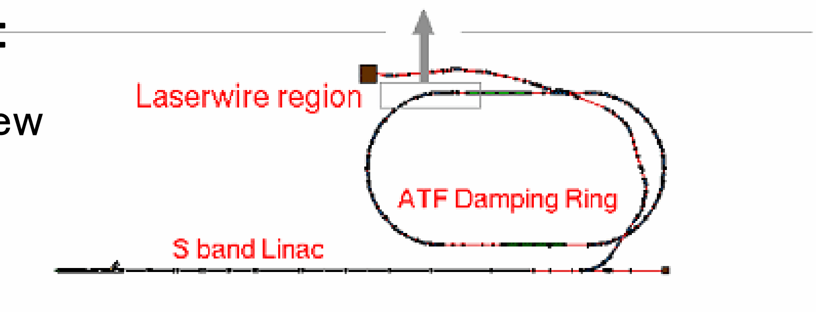


Pulse Laser Wire

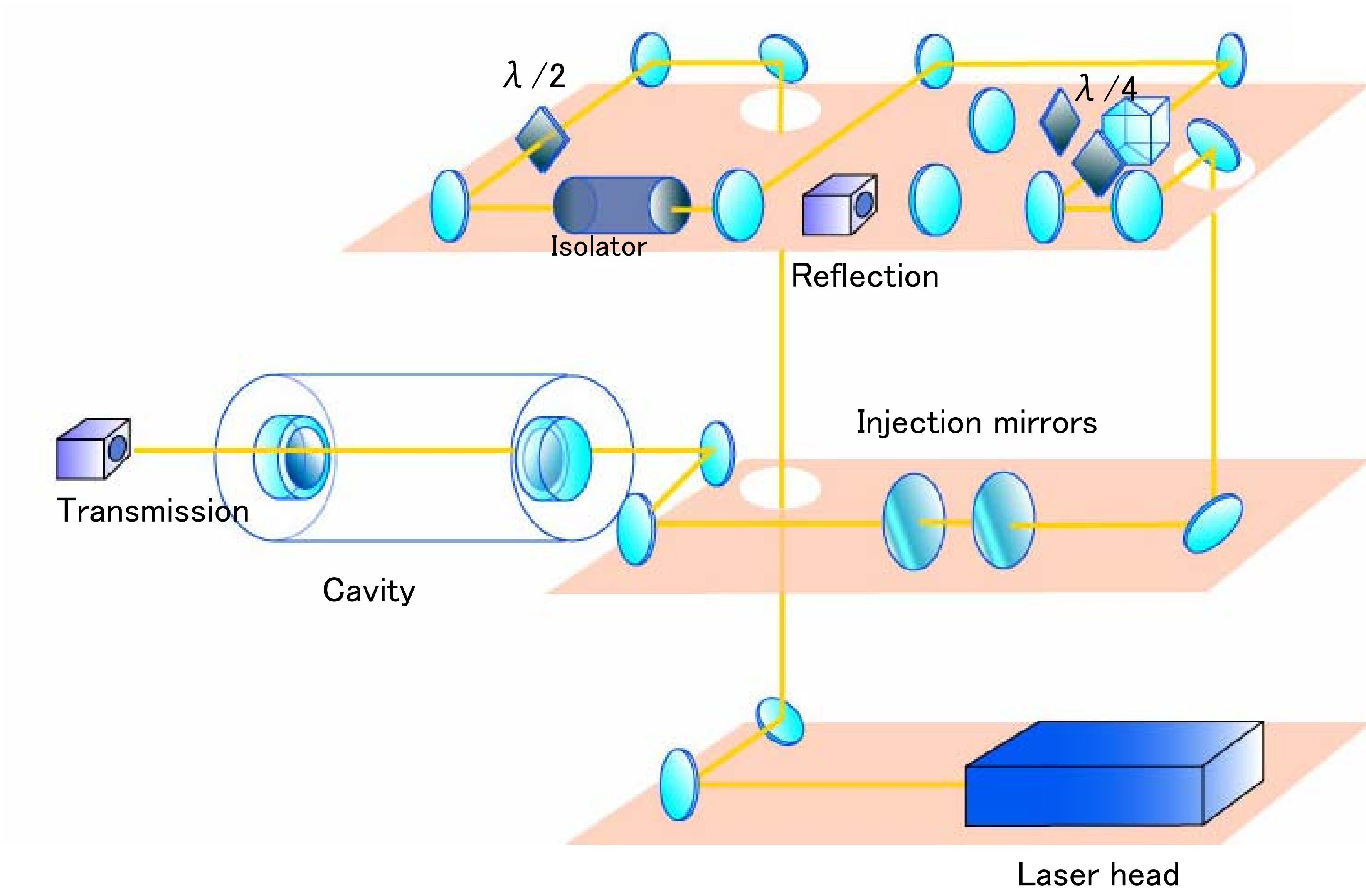
(Storage laser pulses in optical cavity):

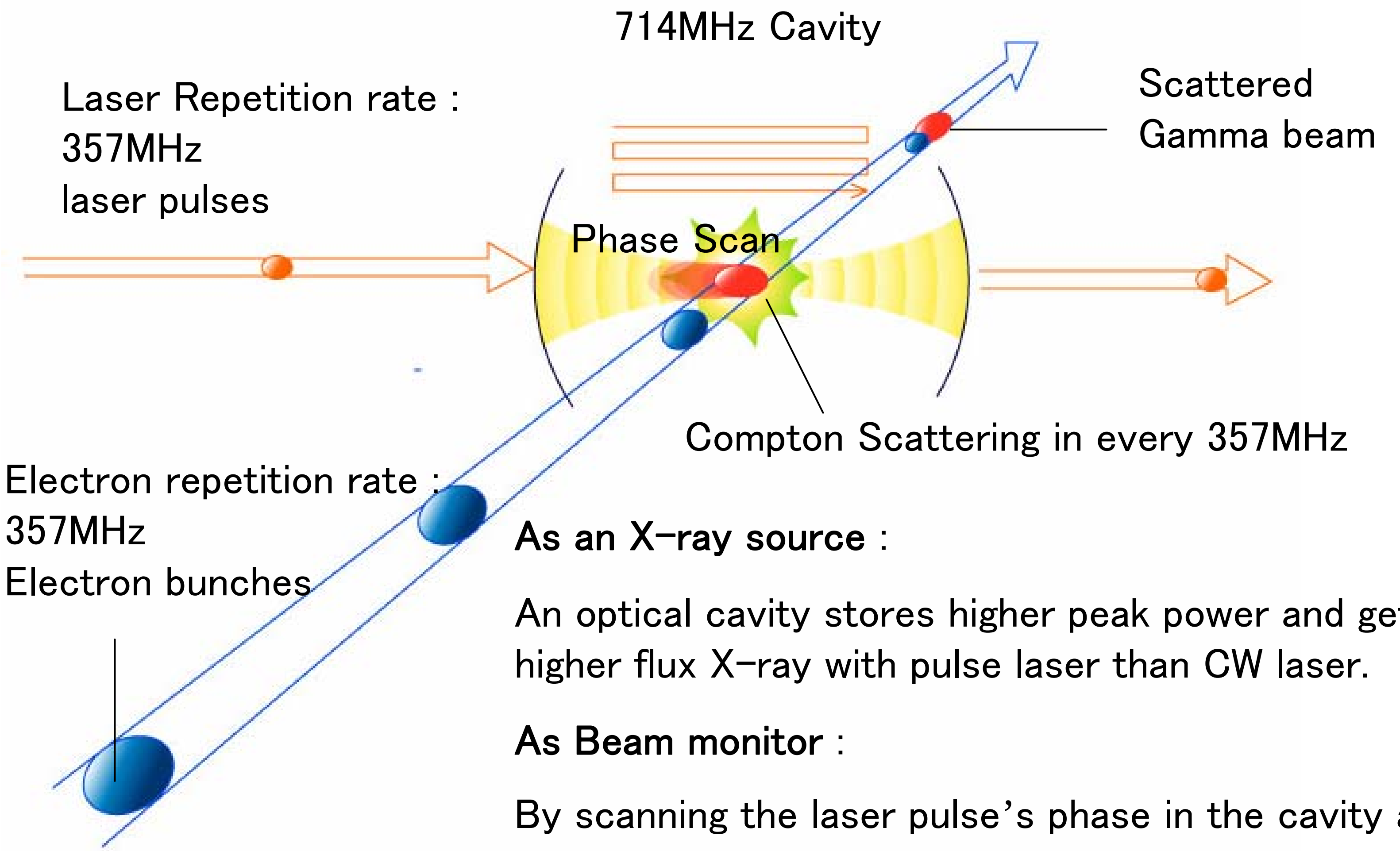
The systems for New X-ray source & New bunch length monitor at a storage ring

Hear Fukuda's talk.



EXPERIMENTAL SETUP : Optics





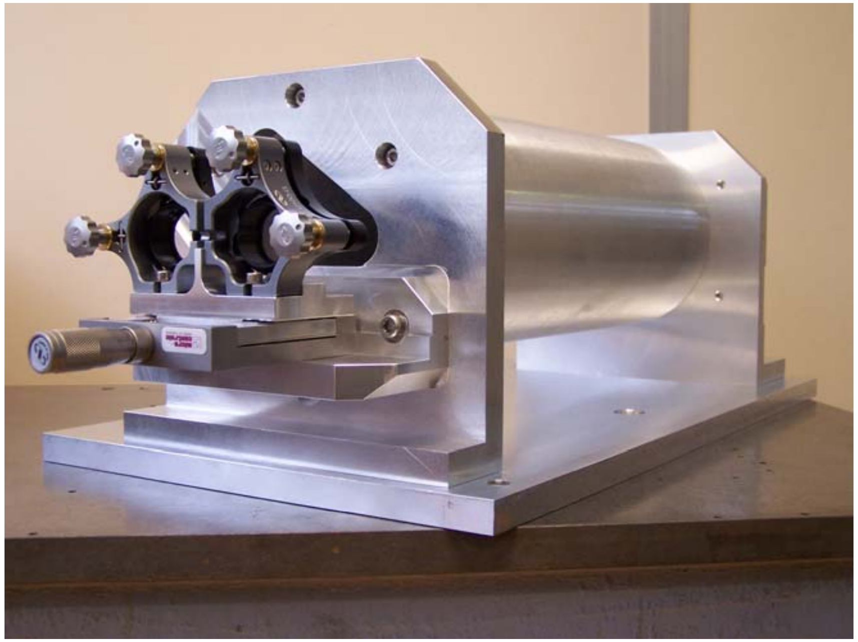
As an X-ray source :

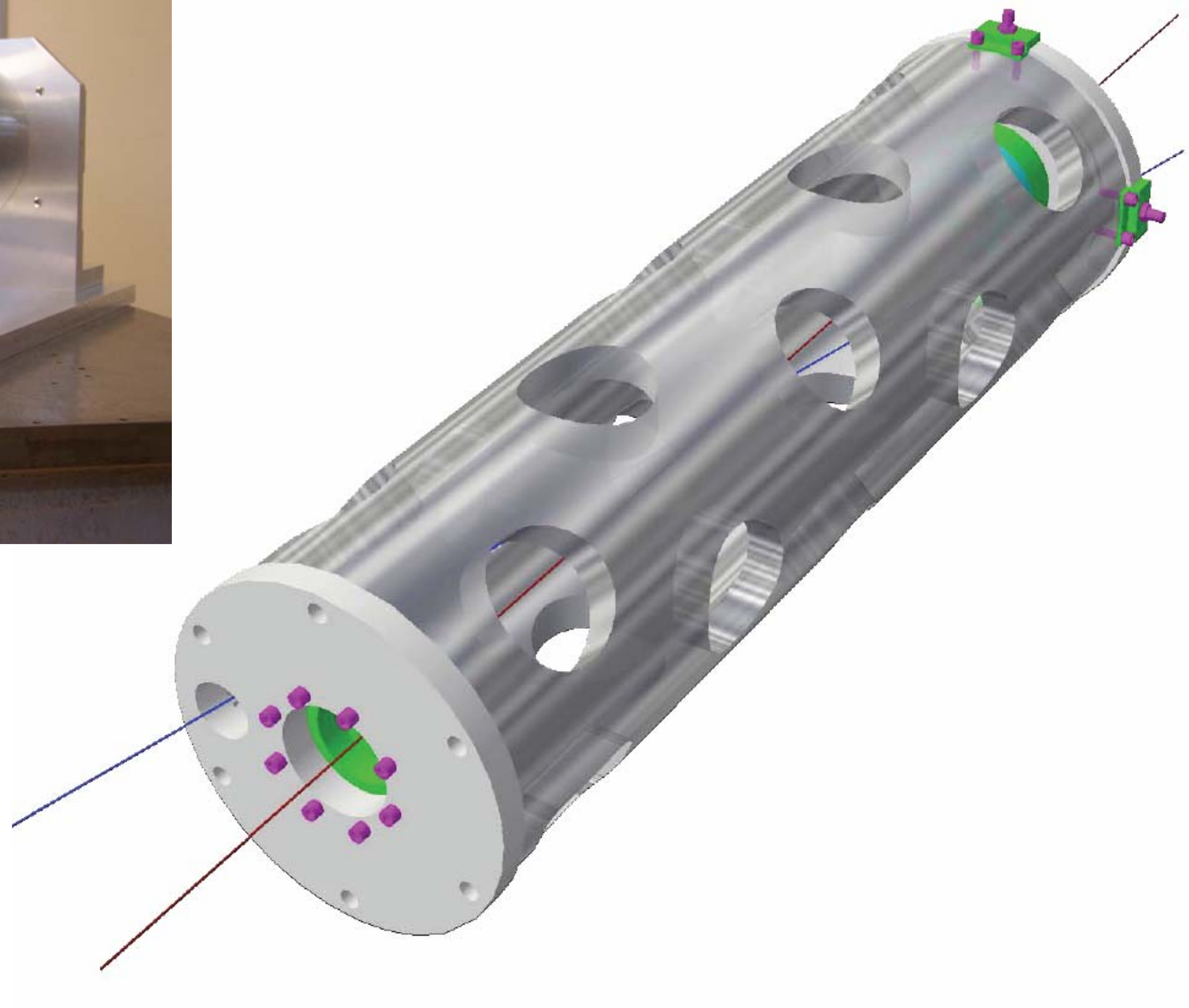
An optical cavity stores higher peak power and gets higher flux X-ray with pulse laser than CW laser.

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.

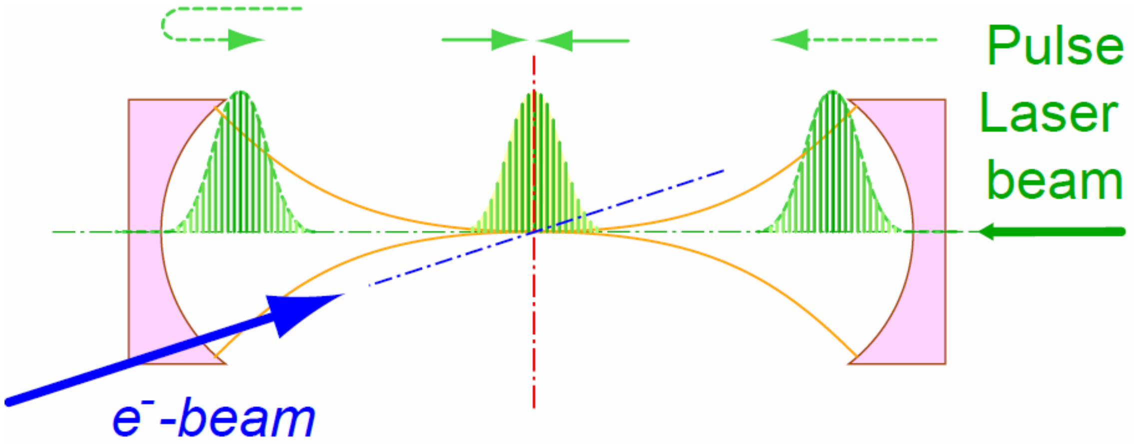
4. Polarized γ-ray generation using Optical Stacking Cavity





Experimental R/D in ATF

Hiroshima-Waseda-Kyoto-IHEP-KEK

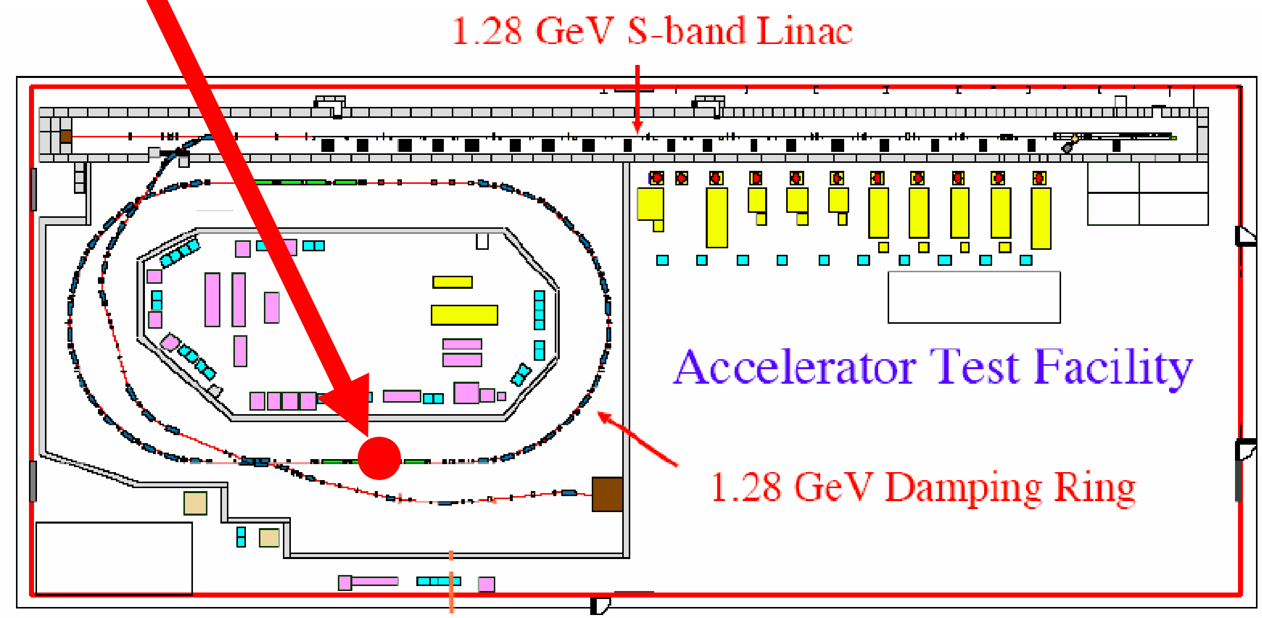


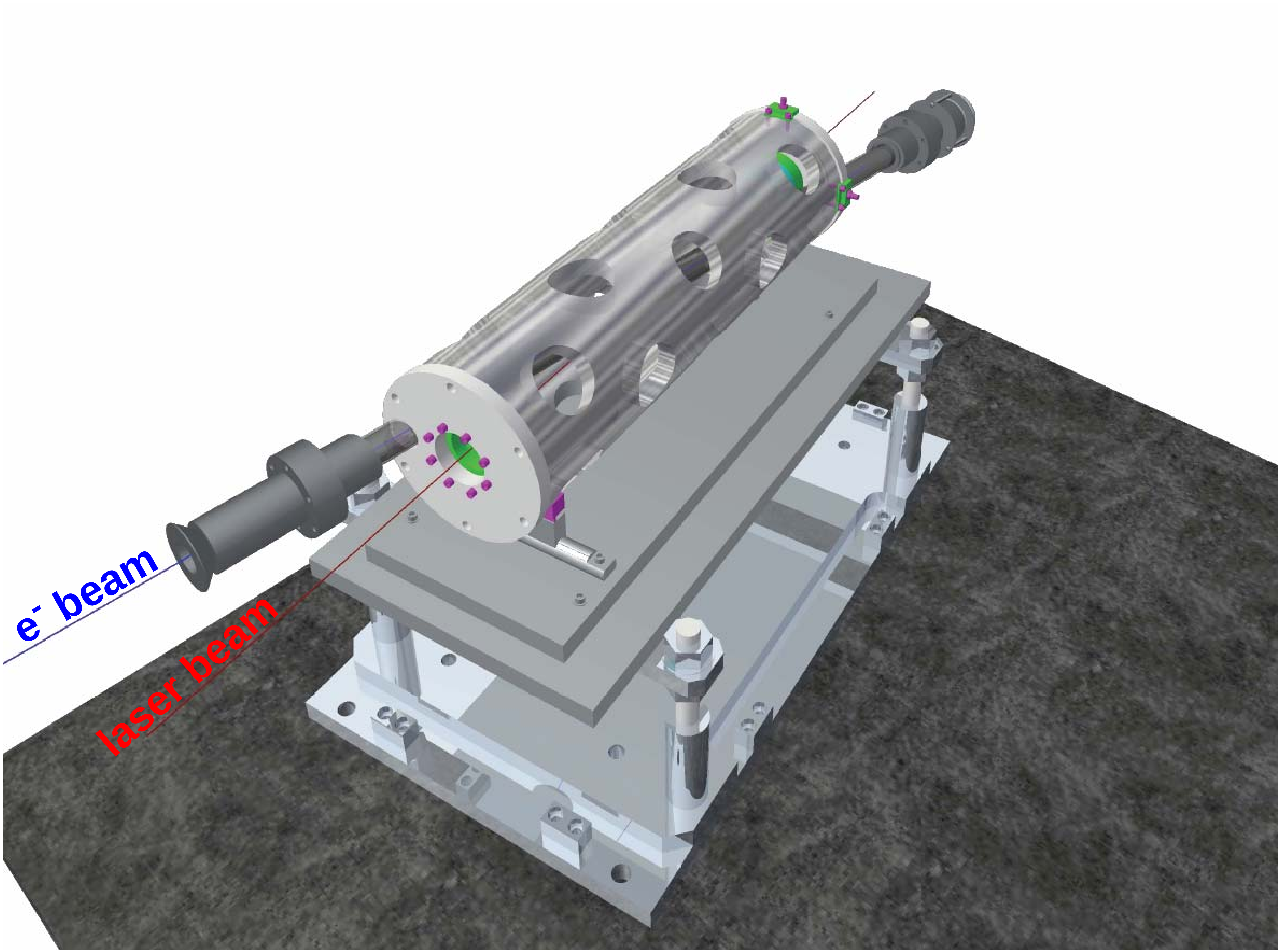
Make a fist prototype

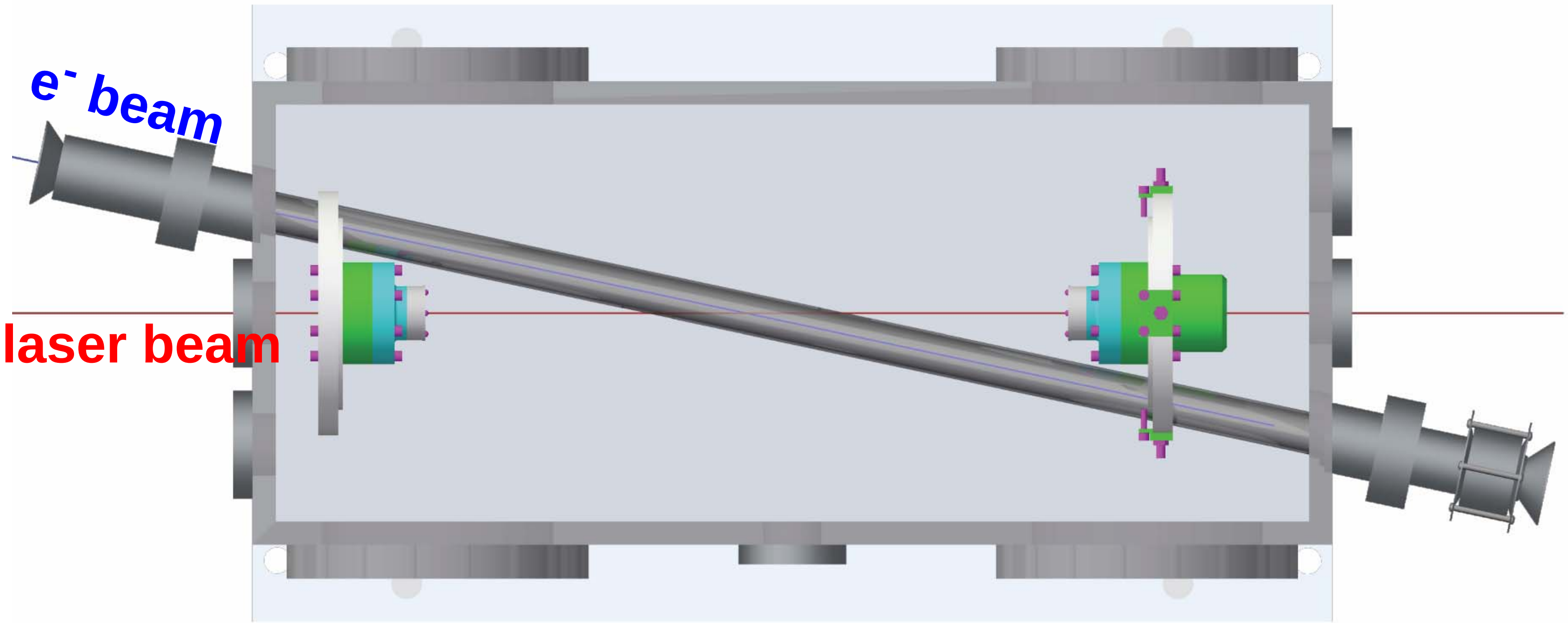
2-mirror cavity

L_{cav} = 420 mm

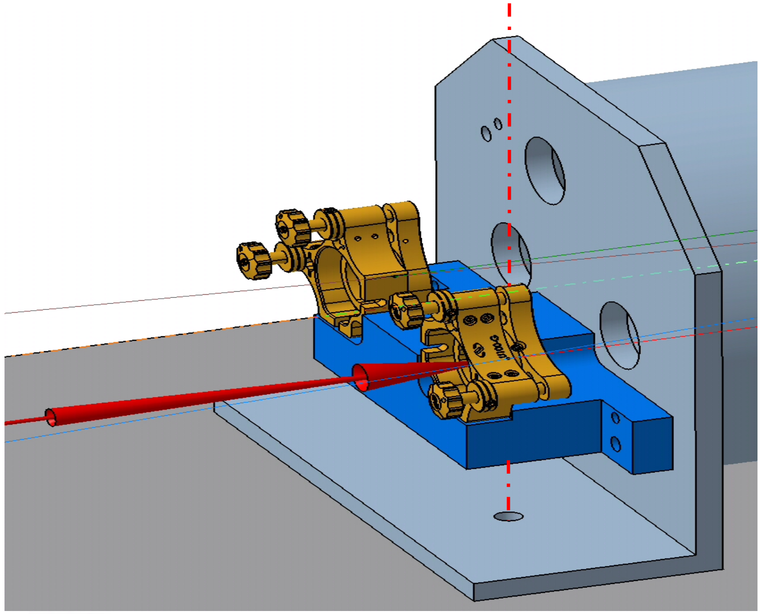
Put it in ATF ring

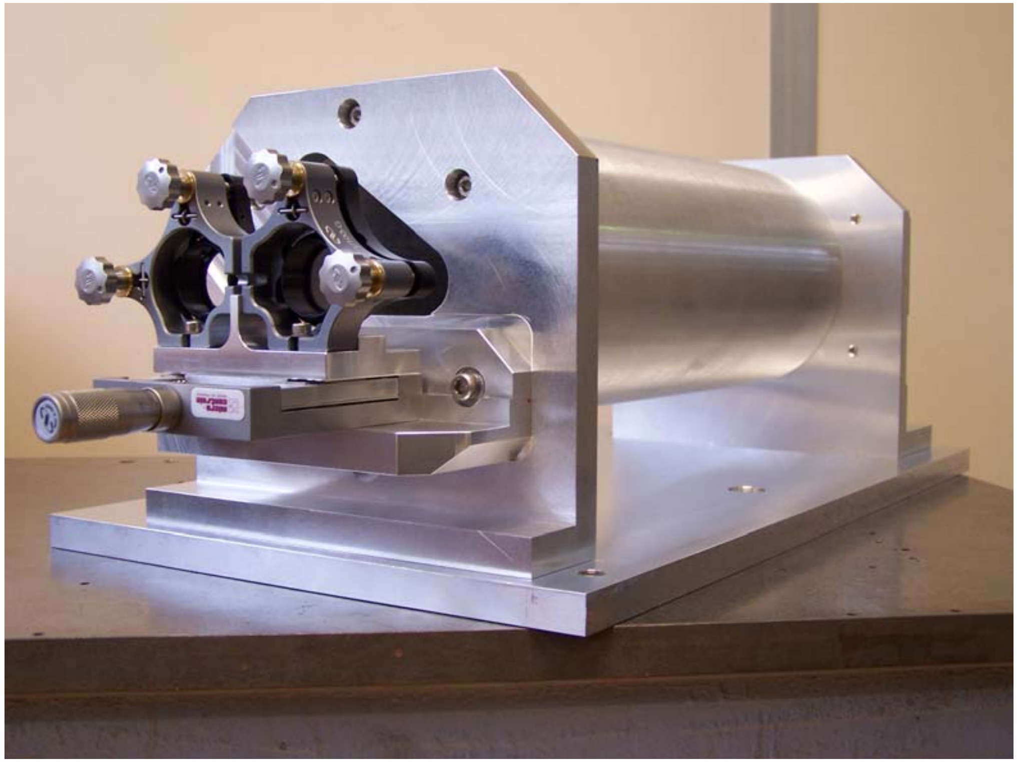


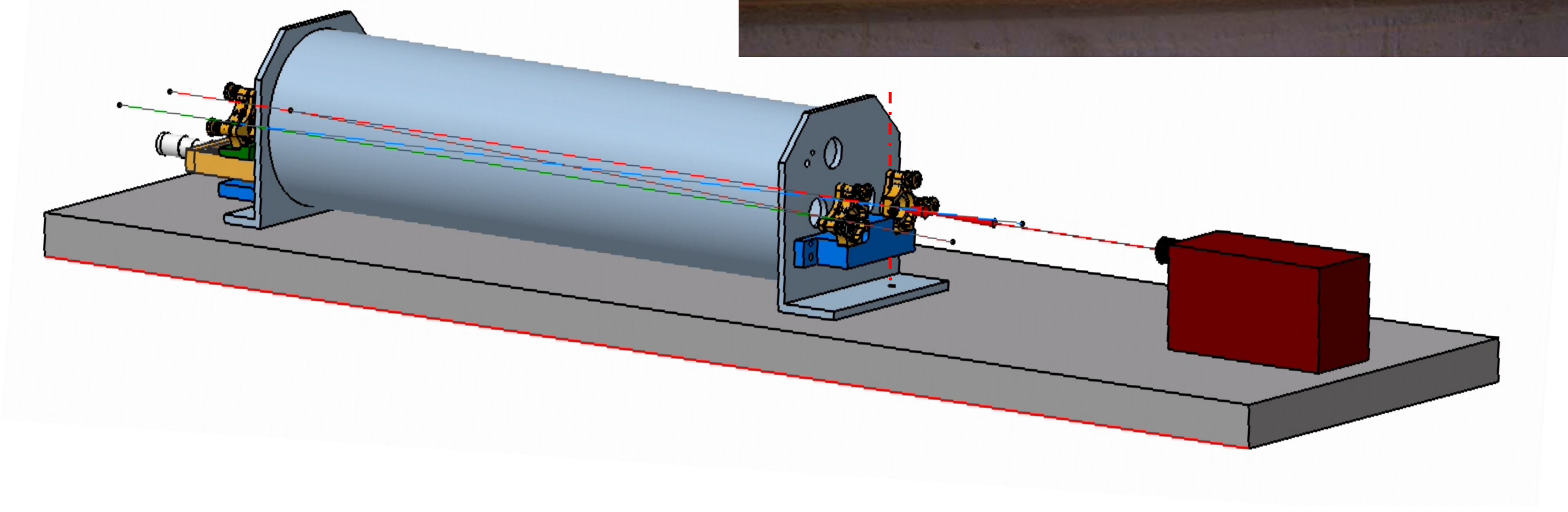

e⁻ beam
laser beam

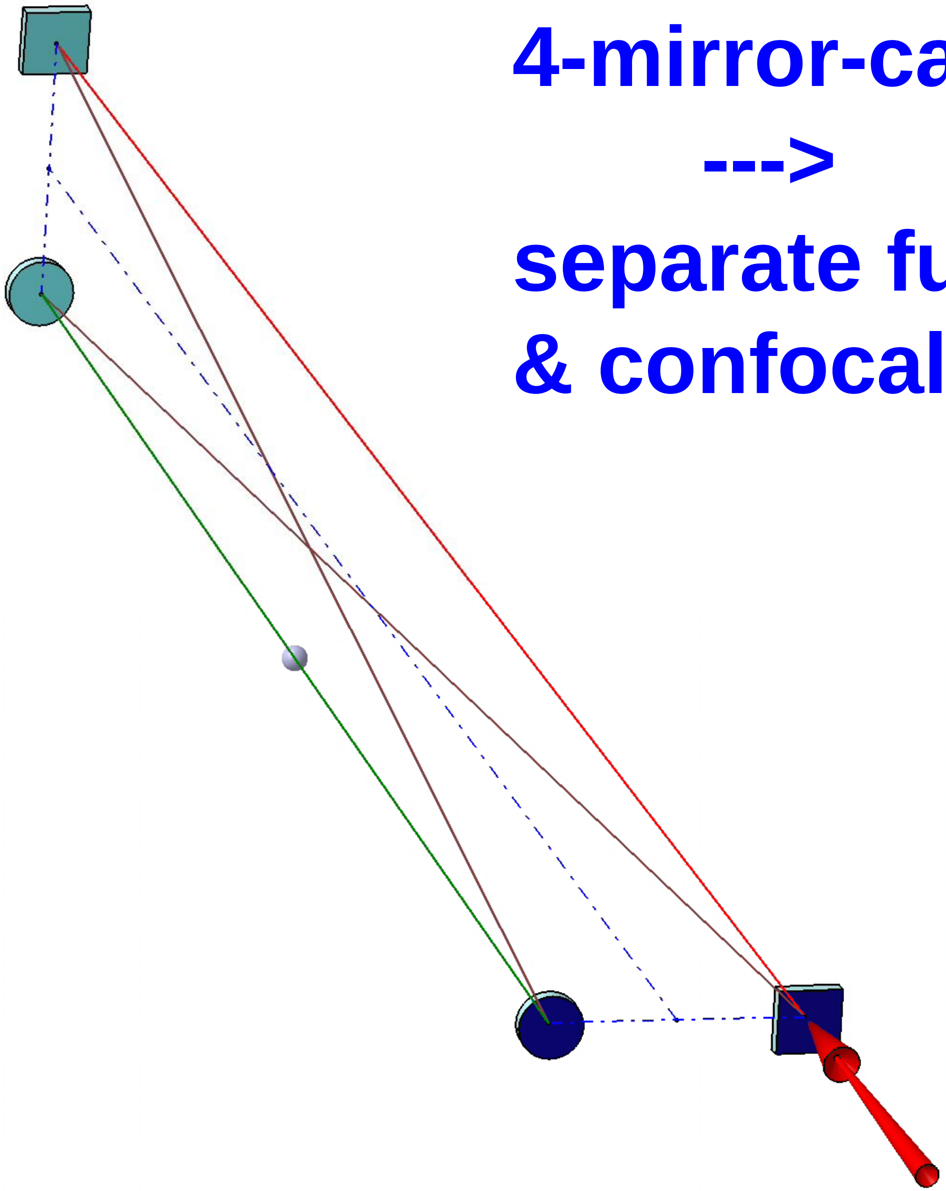

e- beam
laser beam

Non planer cavity with 4 mirrors in LAL





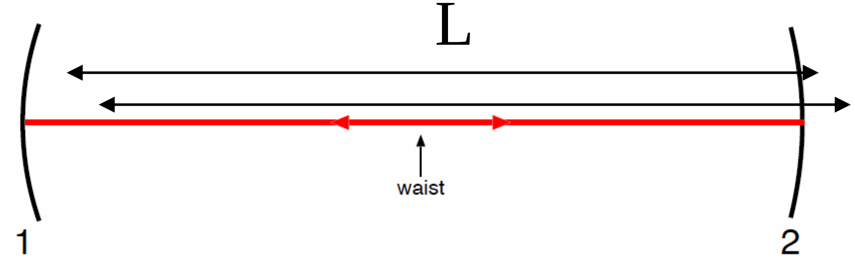


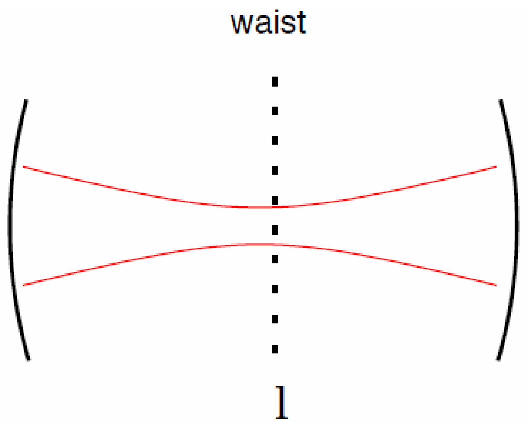


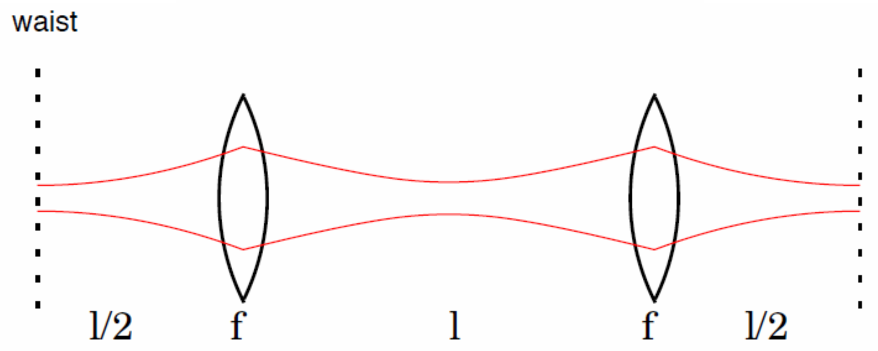
4-mirror-cavity
--->
separate functions
& confocal configuration

2-mirror cavity

R1=R2=L/2



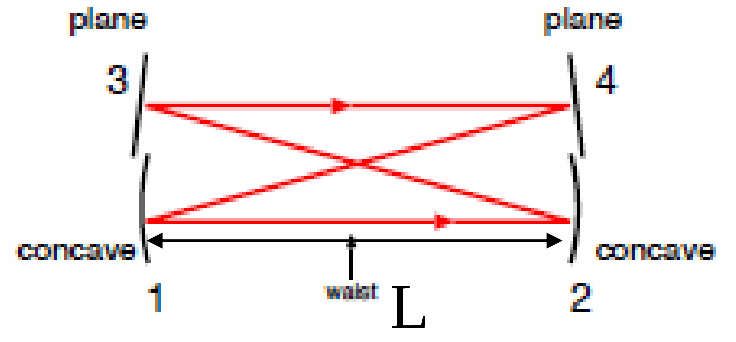


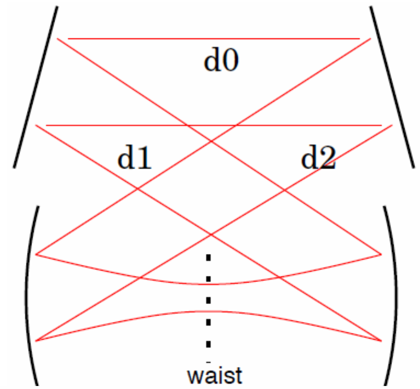


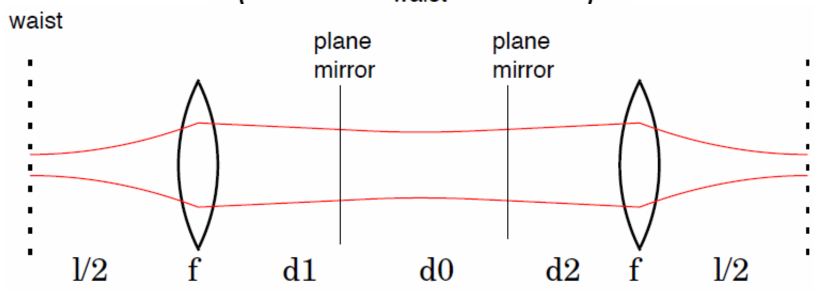
concentric

4-mirror cavity

R1=R2=L

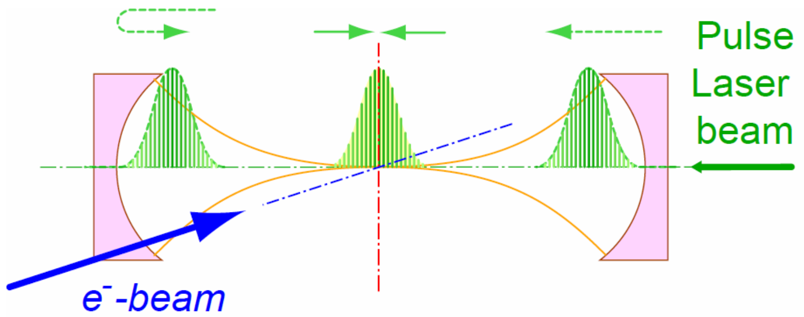






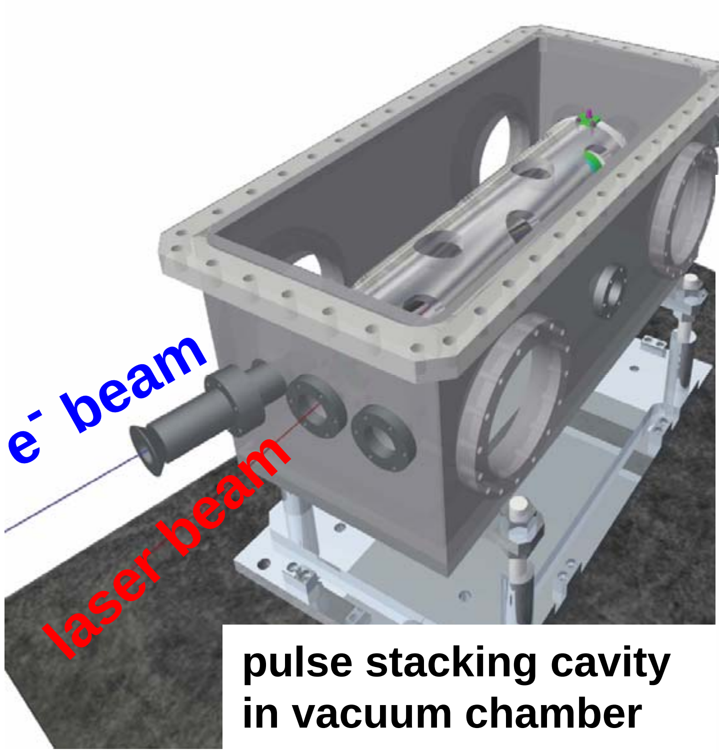
confocal

γ-ray Generation with Laser Pulse Stacking Cavity (Hiroshima-Waseda-IHEP-KEK)

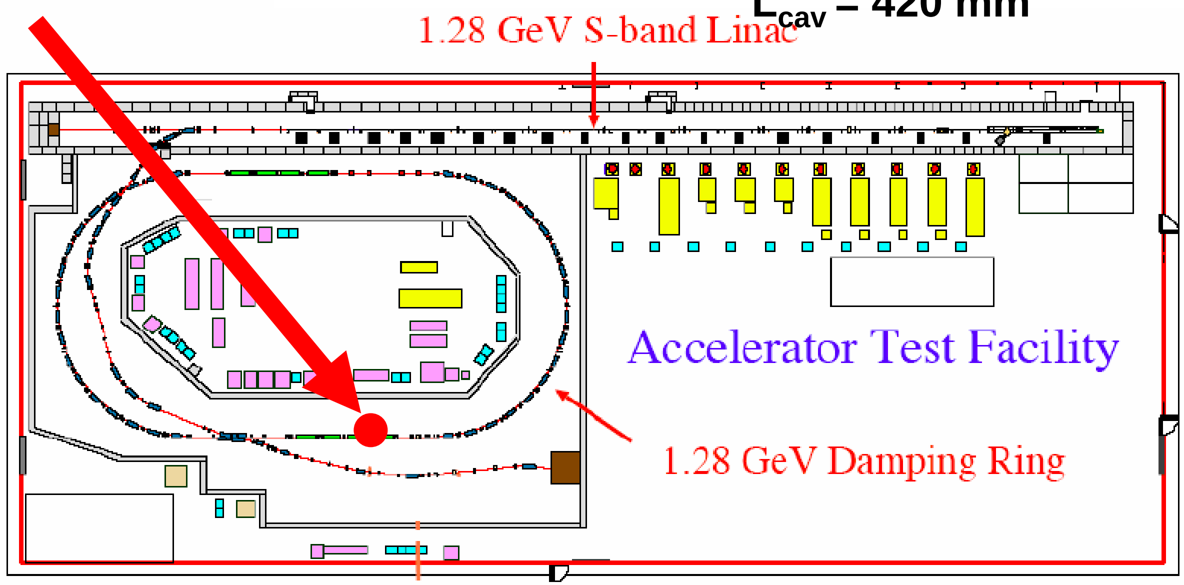


1. **Achieve both high enhancement & small spot size**
2. **Establish feed back technology**
3. **Achieve small crossing angle**
4. **Get experience with e⁻ beam**

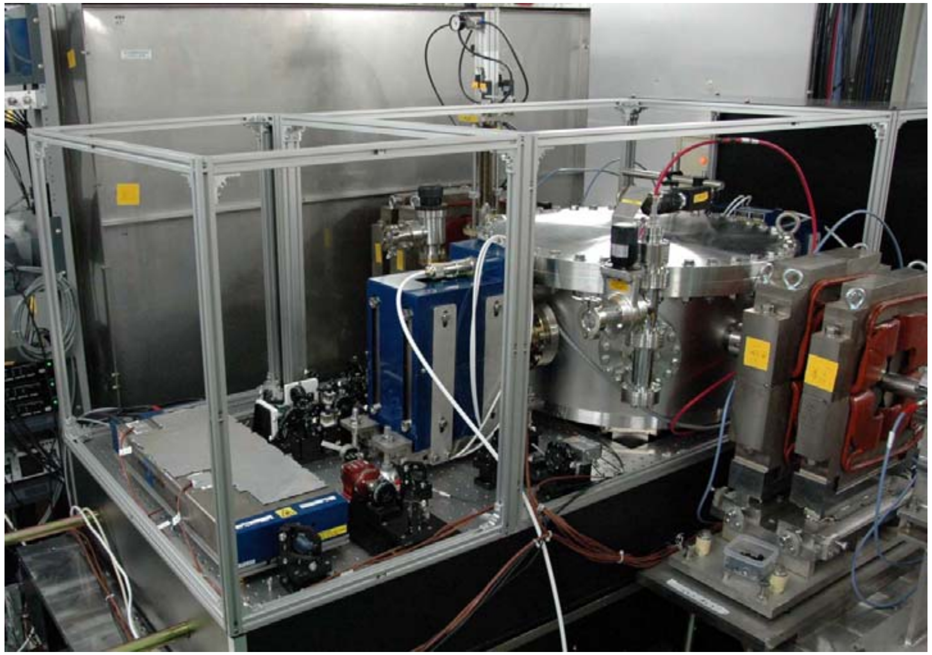
Pulse stacking cavity
L_{cav} = 420 mm



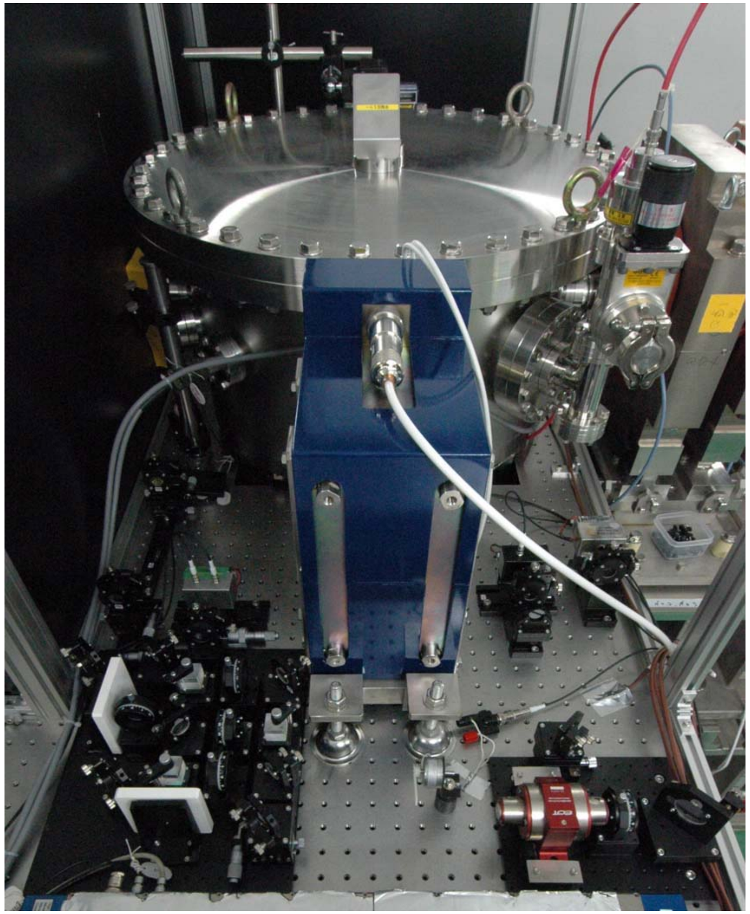
pulse stacking cavity in vacuum chamber



5. Compact X-ray source



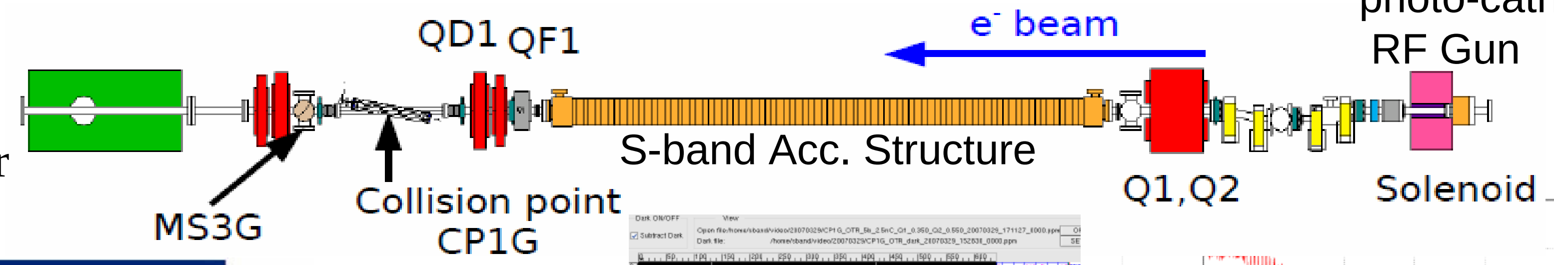
43MeV end station to separate X-ray and e-beam. 33keV X-ray is deflected by Crystals.

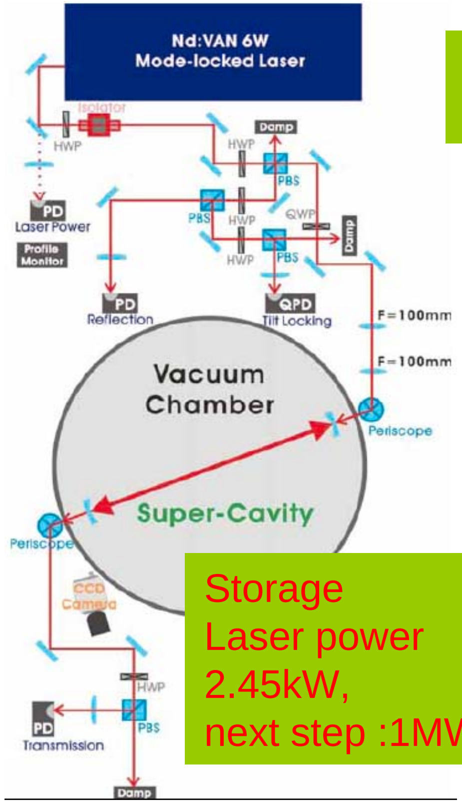


Pulsed laser stacking chamber

Laser Undulator Compact X-ray (LUCX) Project at KEK-ATF

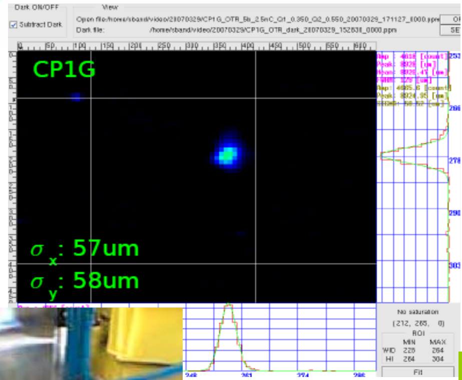
43MeV Multi-bunch beam+ Super-Cavity = 33keV X-ray.

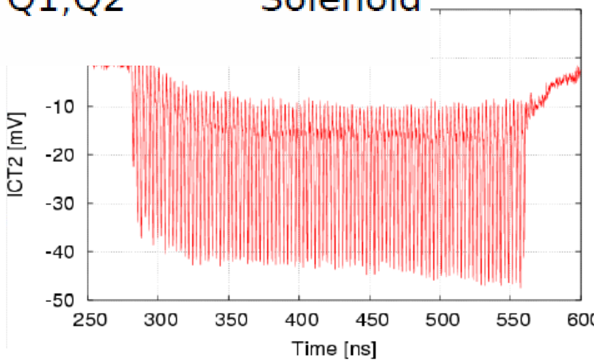




Storage Laser power 2.45kW, next step :1MW

Beam size at CP 60μm in σ



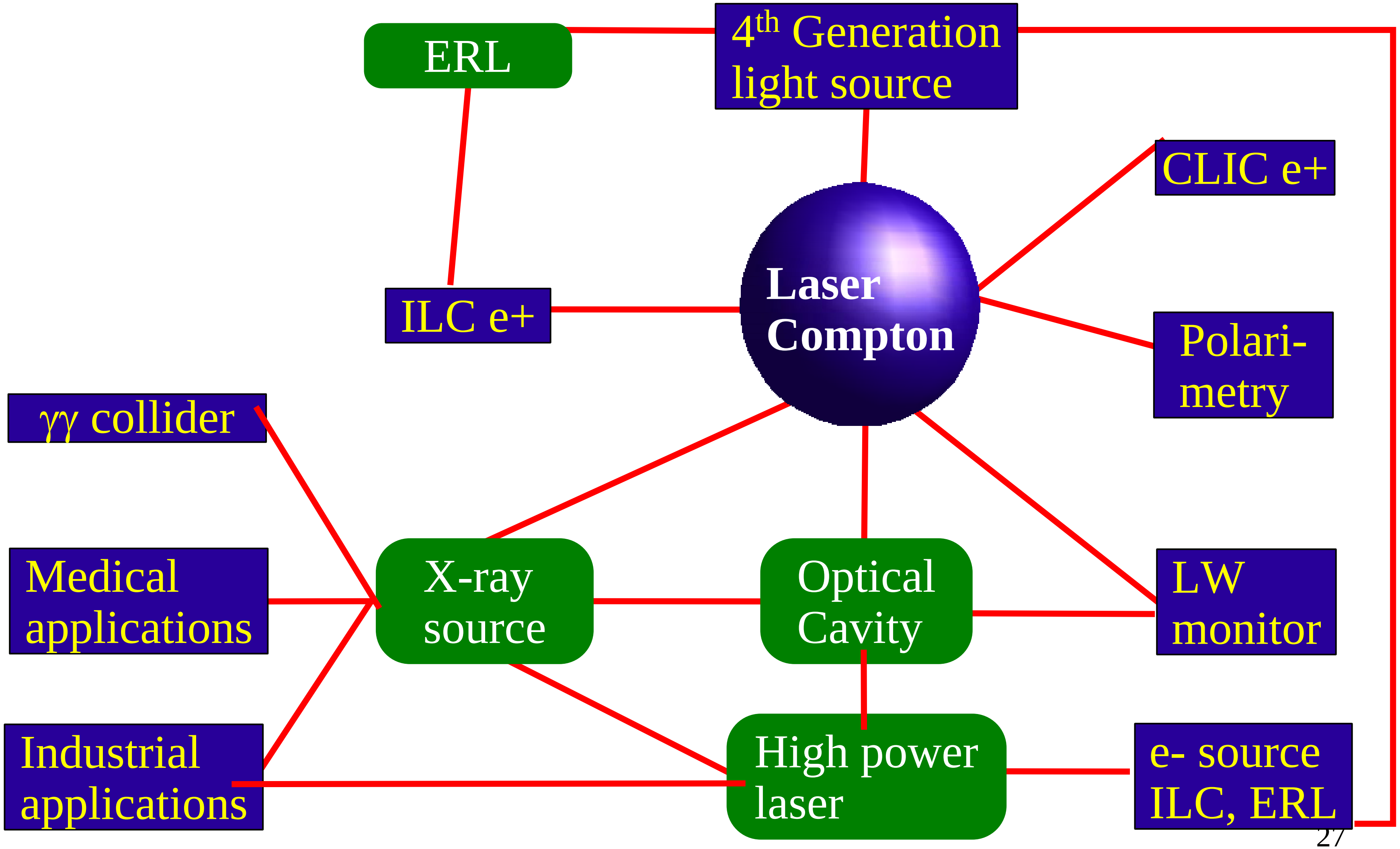


Multi-bunch e- beam 300nC at gun

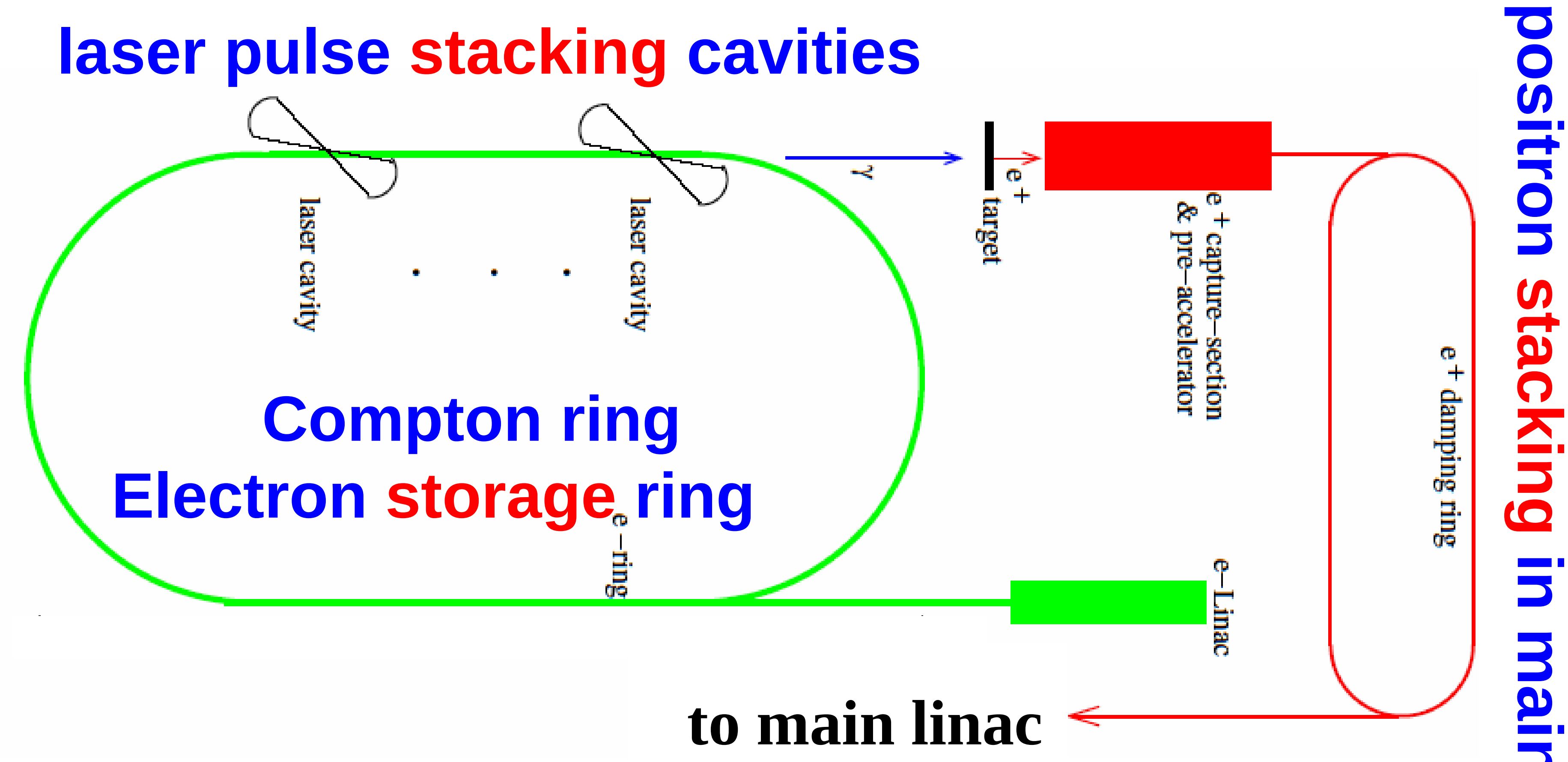
At present, laser waist size is 90μm in σ. We should reduce both beam size at CP down to 40μm.
33keV X-ray generation based on inverse Compton scattering will start from Oct. 2007 with Super-Cavity.

6. Key components for photon beam source based on laser-Compton scattering

World-Wide-Web of Laser Compton

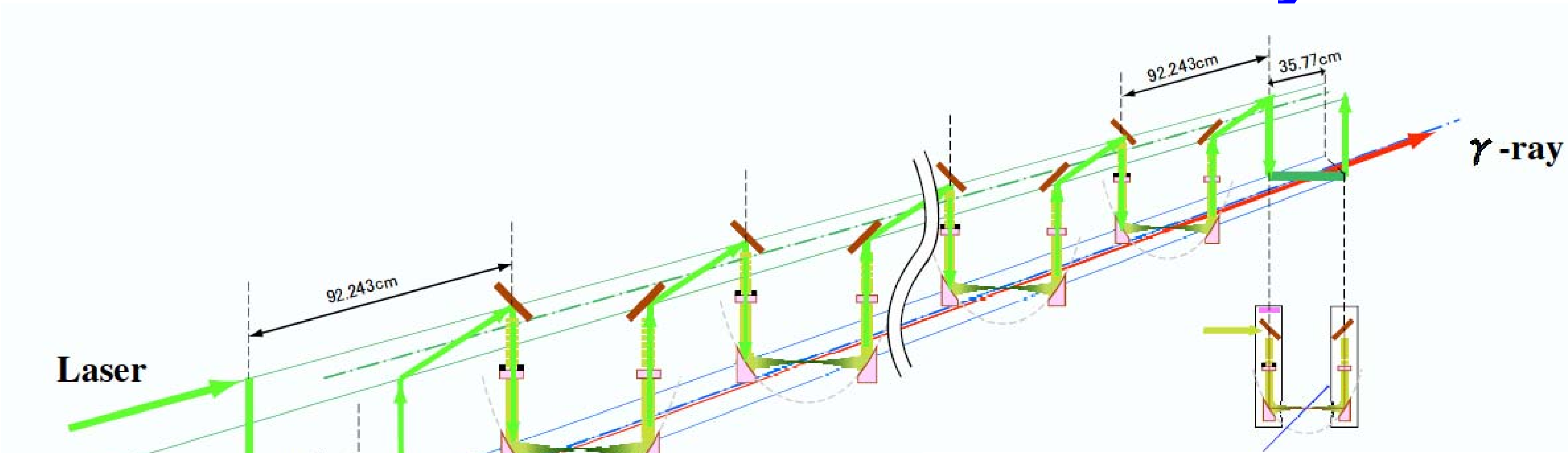


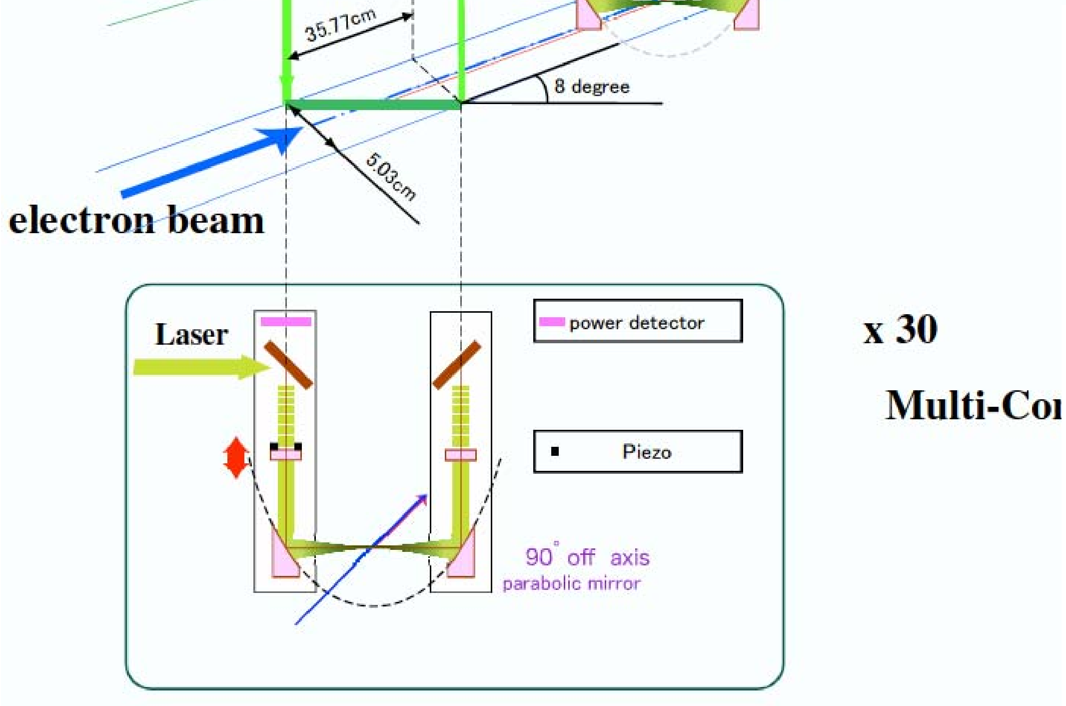
Re-use Concept



Proposed by Posipol Group at Snowmass 2005.

One laser feeds 30 cavities in daisy chain



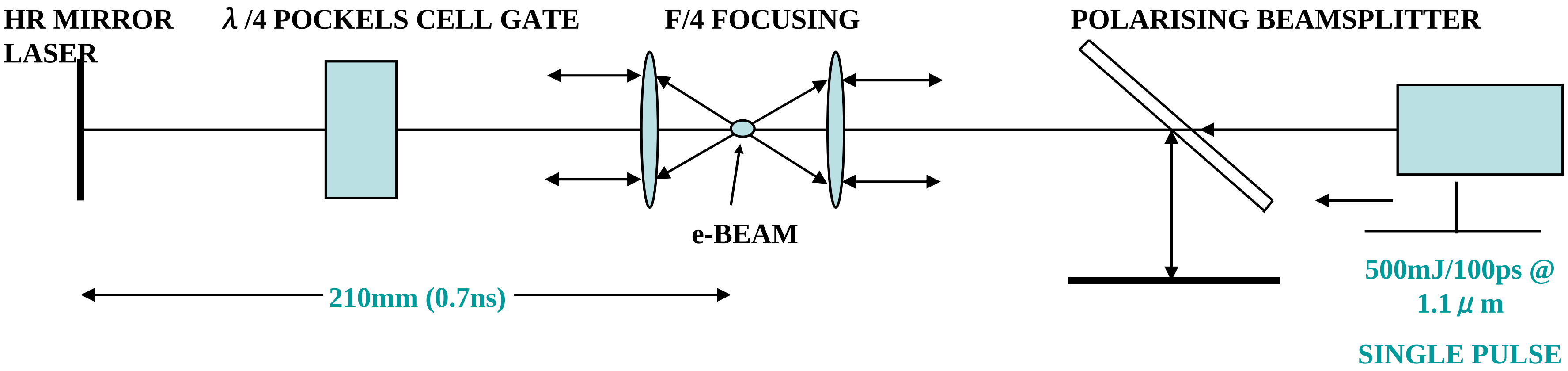


光共振器中点でサブミクロン、1mJ/pulse・10psecパルスレーザービームを高繰り返し(357MHz)で安定に実現できる小型スーパー光共振器を製作して、その性能を実証する。

高繰り返し(357MHz)、短パルス(10psec, FWHM)、大強度レーザー(1mJ/pulase〜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

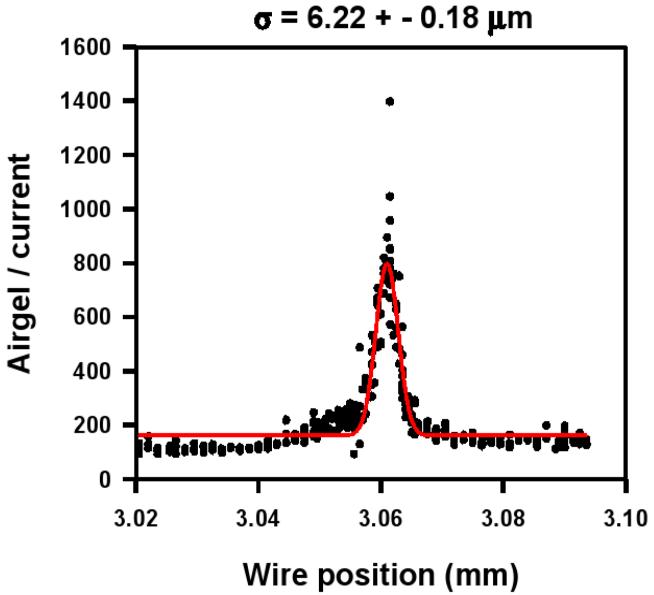
Need to keep round-trip losses very low to ensure sufficient passes at sufficient power

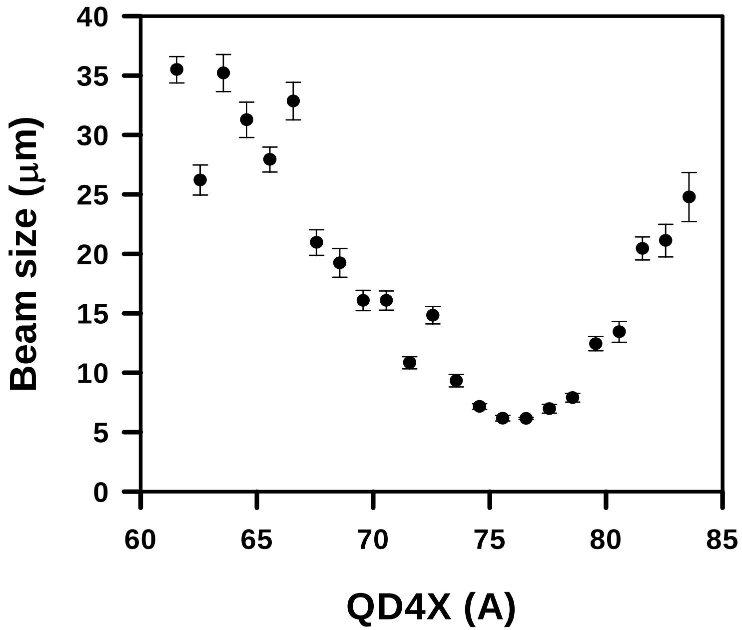
Other designs possible

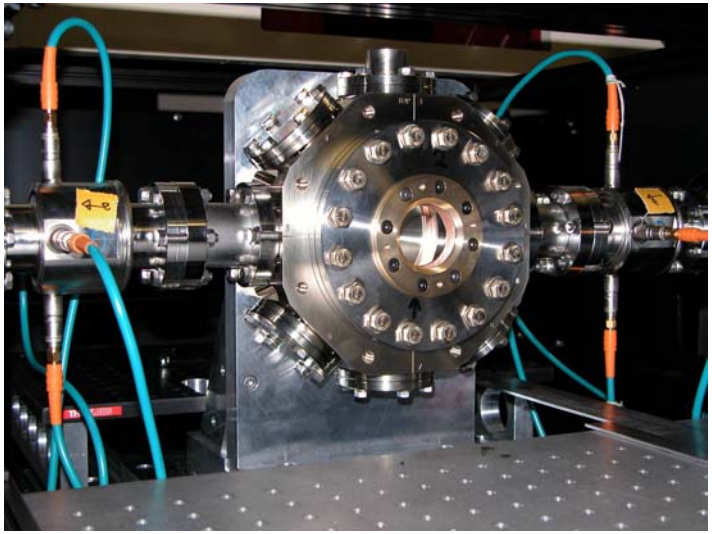
Laser-wire at ATF-EXT

By Grahame Blair (RHUL) et al.

6min 43s







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