Status of g ray generation at KEK-ATF

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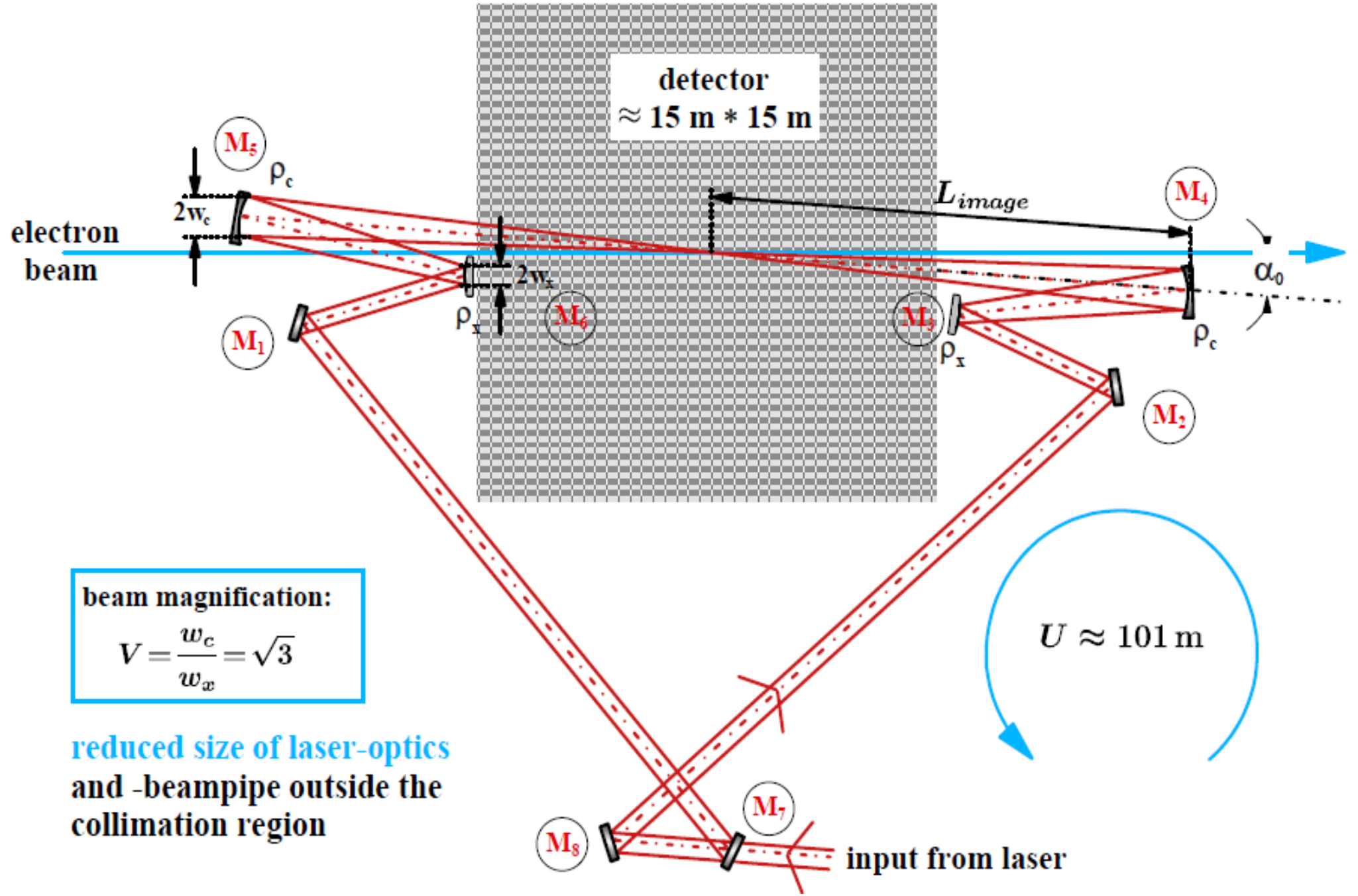
for

French Labs. : LAL (Orsay) in Collaboration with
CELIA (Laser lab., Bordeaux) and
LMA (mirror coatings Lab., Lyon)
Japanese Labs. : KEK, ATF group,
Hiroshima University

- Introduction
- Status of the cavity R&D
- Out Look

24 October 2012
LCWS2012

Proposed telescopic, passive, resonant external cavity



beam magnification:

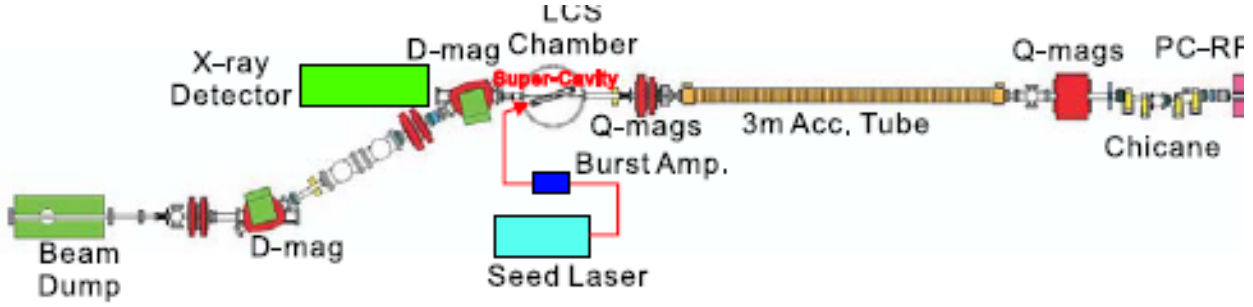
$$V = \frac{w_c}{w_x} = \sqrt{3}$$

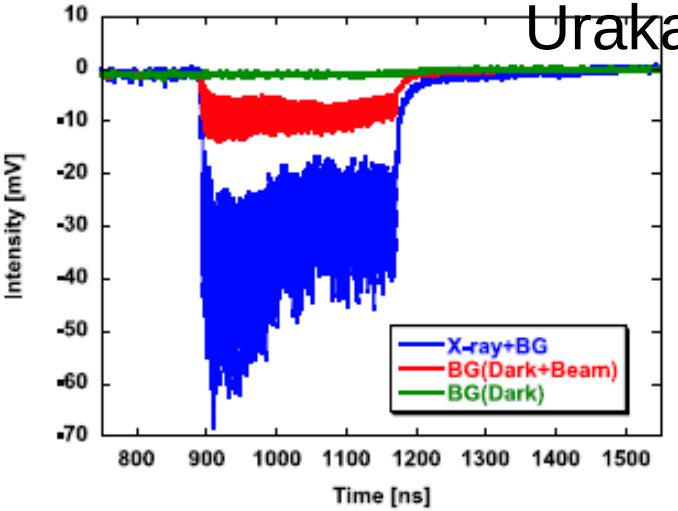
reduced size of laser-optics
and -beampipe outside the
collimation region

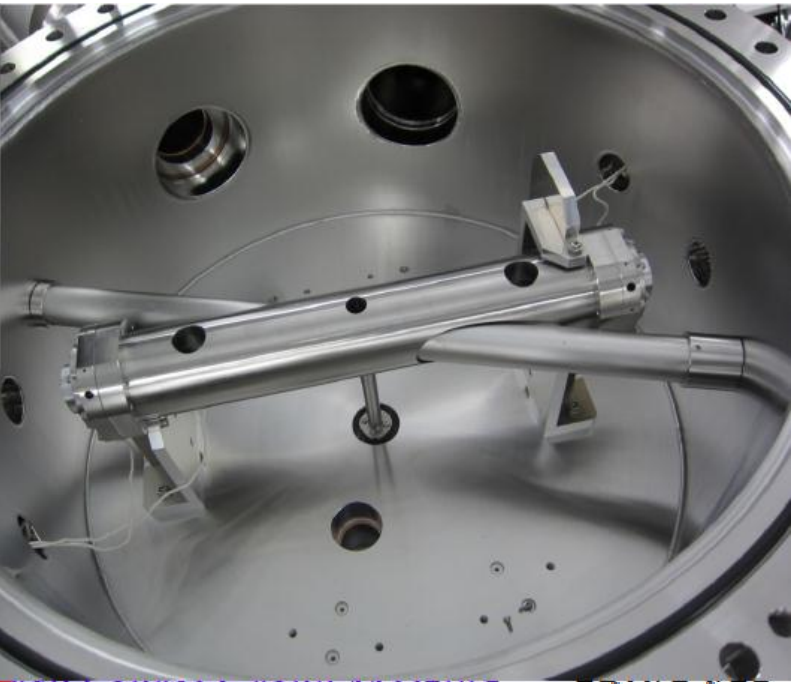
Four optical cavity projects at KEK

- 3D four mirror cavity for gamma ray at ATF
- 2D four mirror optical cavity X-ray. LUCX
- 2D four mirror cavity for X-ray with two cylindrical lenses
- Compact 2D four mirror optical cavity for fast laser wire scanner

Urakawa

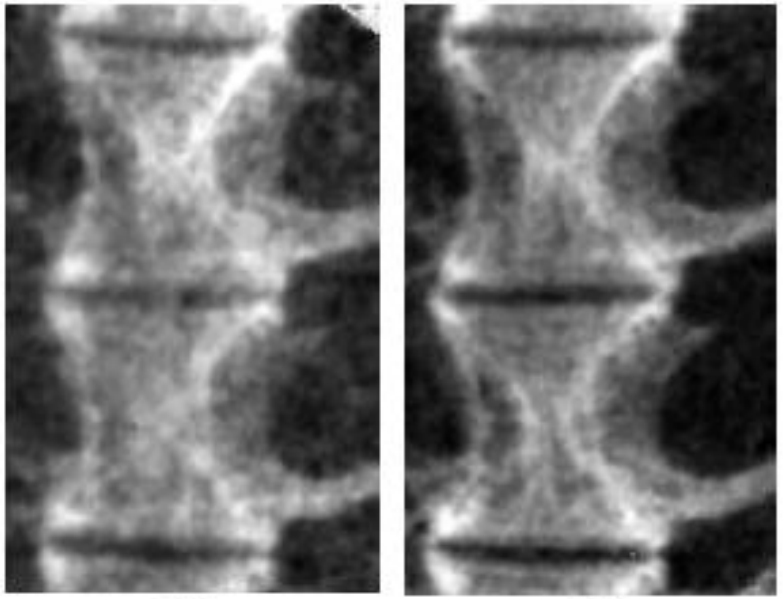






The mirror of two mirror cavity had the surface damage around 2 to 6mJ/pulse.

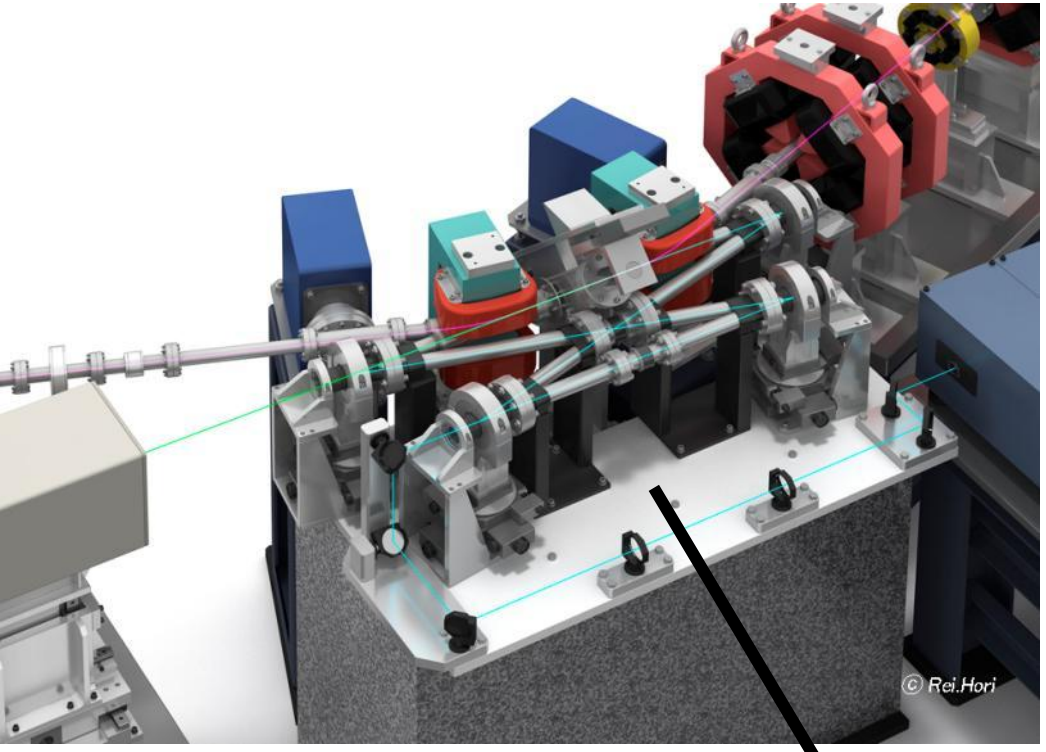
Electron beam		Laser pulse	
Quantity	Value	Quantity	Value
Energy	30 MeV	Wavelength	1064 nm
Charge	0.4 nC/bunch	Pulse energy	400 μJ
Number of bunches	100/train	Cavity finesse	2650
Bunch spacing	2.8 ns	Pulse spacing	2.8 ns
Beam size (rms)	200/53 μm (H/V)	Spot size (rms)	30.3 μm
Bunch length	10 ps (FWHM)	Pulse duration	7 ps (FWHM)
Repetition rate	1.56-12.5 Hz	Colliding angle	20 deg

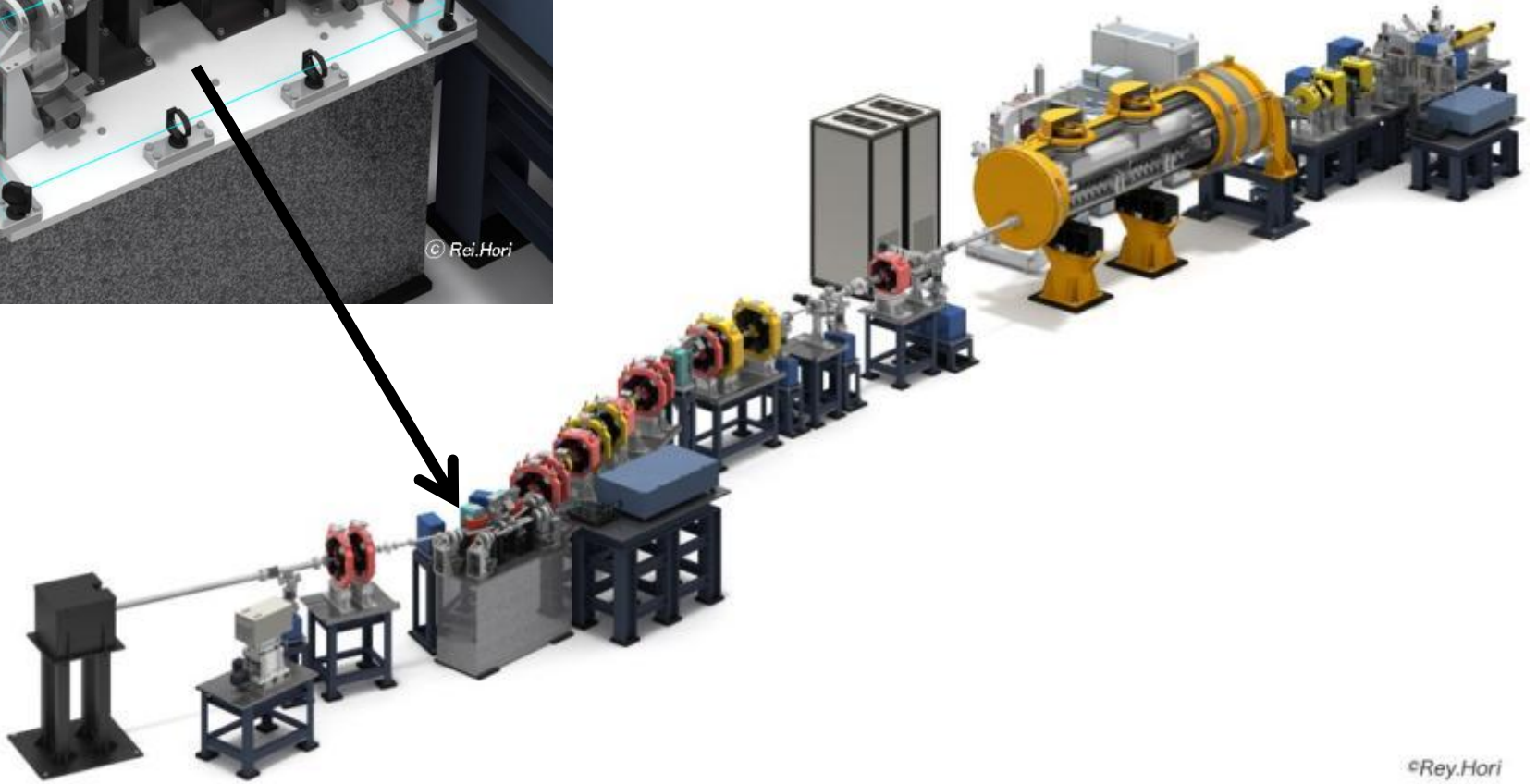


(A) (B)

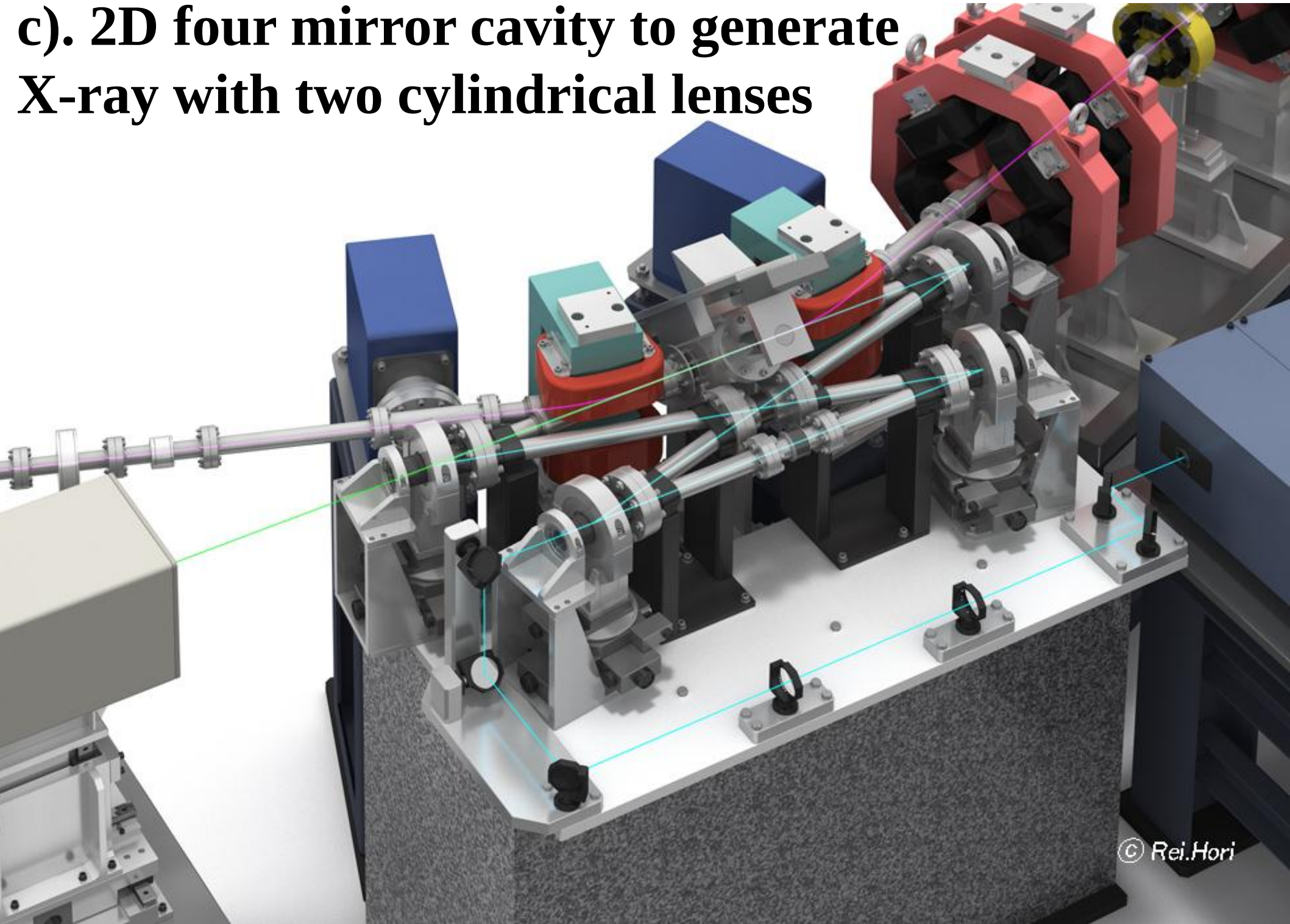
Quantum Beam Technology Program (QBTP)

Development for Next Generation Compact High Brightness X-ray Source using Super Conducting RF Acceleration Technique



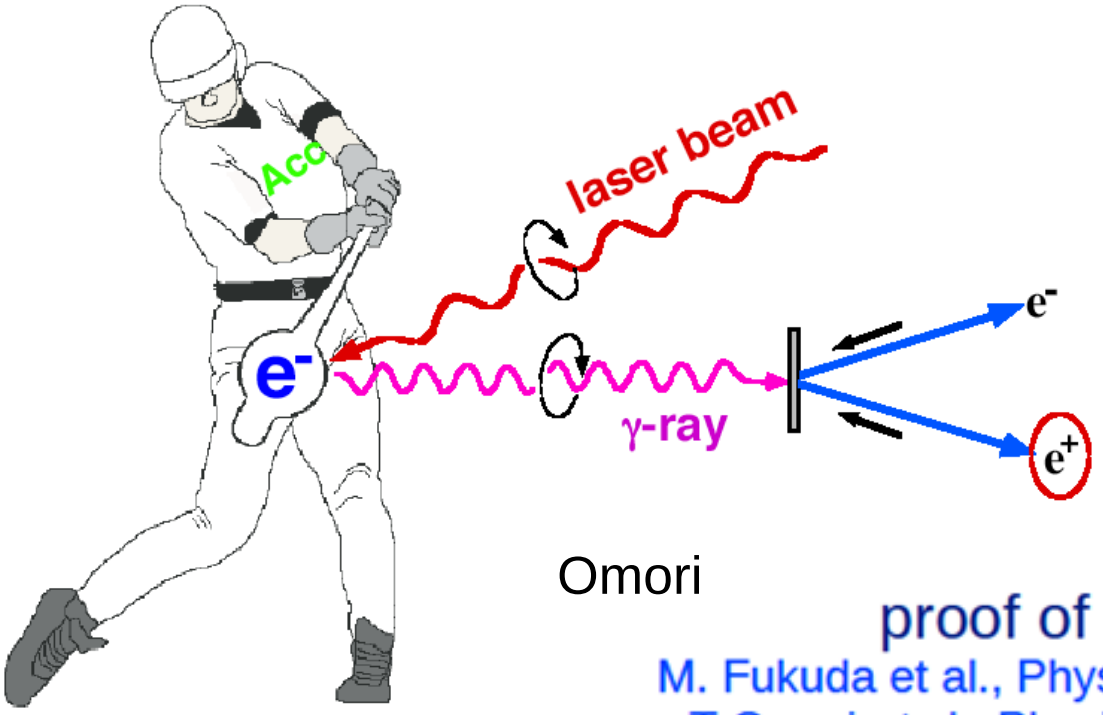


c). 2D four mirror cavity to generate X-ray with two cylindrical lenses



Compton at KEK ATF

- Polarized e+ by laser Compton Scheme



Omori

Ee~1GeV for 10MeV gammas

easy to control polarization

proof of principle experiment

M. Fukuda et al., Physical Review Letters 91, 164801 (2003)

T.Omori *et* al., Physical Review Letters 96, 114801(2006)

Toward the positron sources

-> increase intensity of gamma rays

Staking Laser Pulses in Optical Cavity

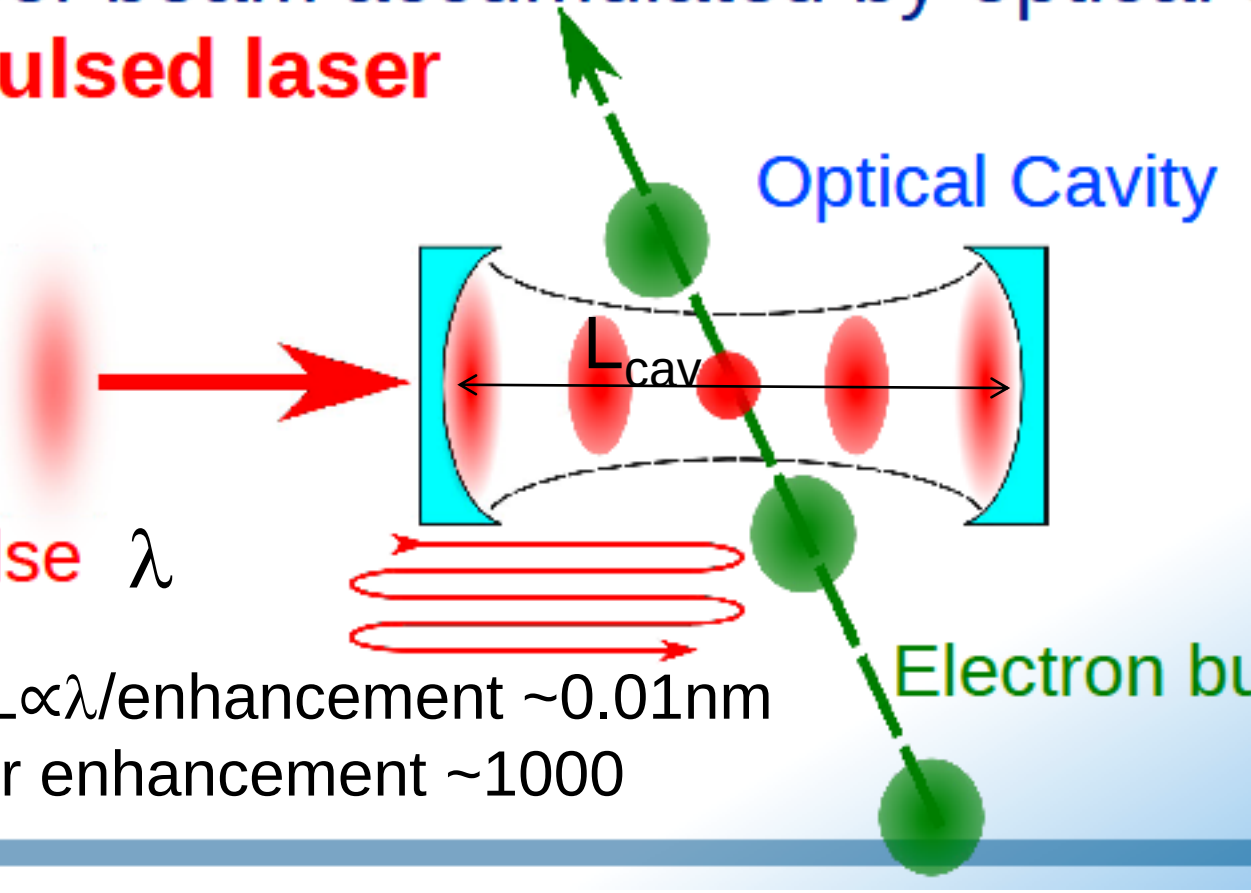
Miyoshi PosiPol2010

Increase power of laser beam at interaction point for increasing gamma yield.

➡ **enhancement with optical cavity**

Laser beam accumulated by optical cavity

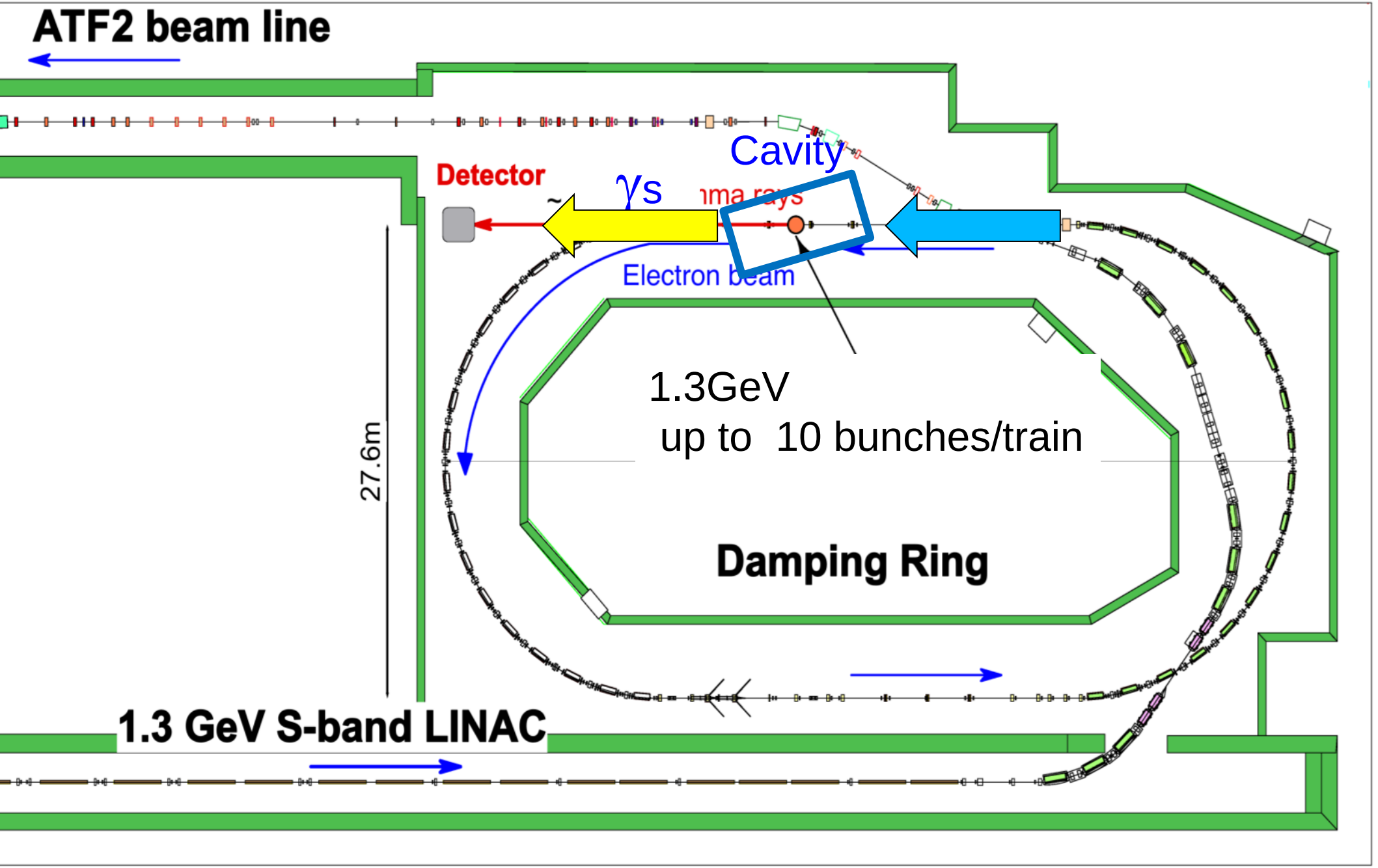
➡ **use pulsed laser**



$$L_{cav} = m\frac{\lambda}{2}$$

dL∝λ/enhancement ~0.01nm
for enhancement ~1000

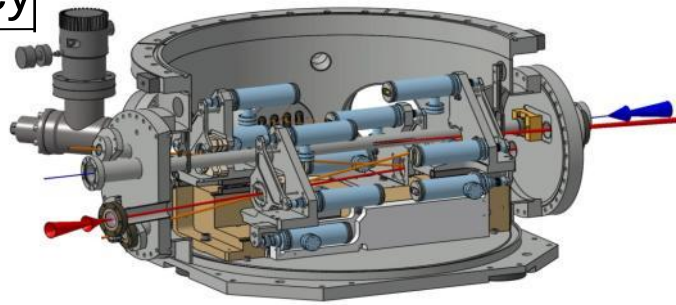
Experiments at the KEK ATF



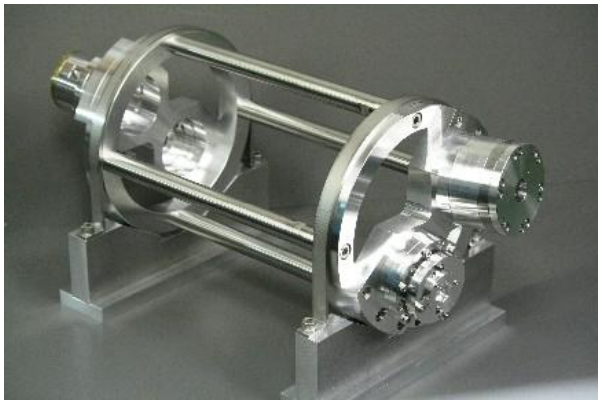
Brief History

- 2007　2 Mirror cavities installed
  - 2.5kW　γ rays generate
- 2010 French 4 Mirror cavity installed

Reported FJPPL2010 Annecy

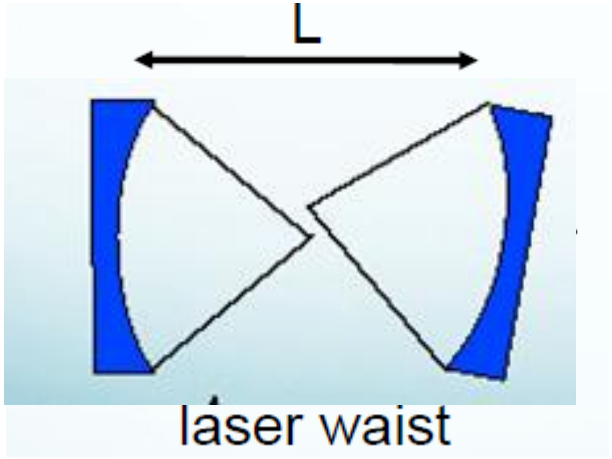


  - γ rays confirmed
- 2011 earthquake
  - No major damage to our equipment.
  - beam back in June 2011

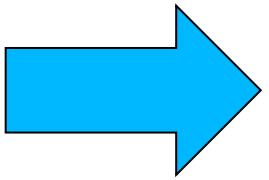


- 2011　KEK-Hiroshima 4 mirror cavity installed
  - γ rays confirmed

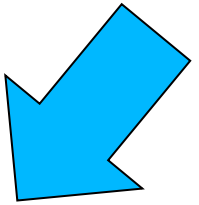
We should go to 3D 4 mirror ring cavity to get small sport size

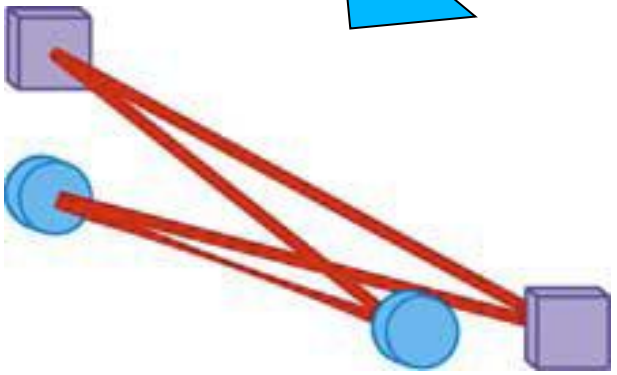


2 mirrors is not stable for small spot size



2d 4M has astigmatism

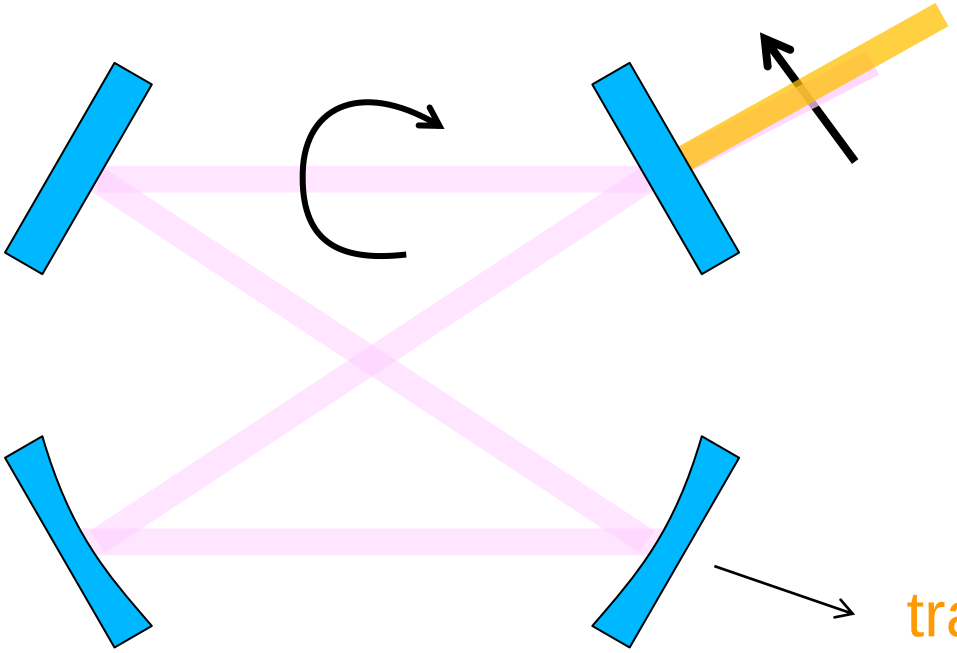


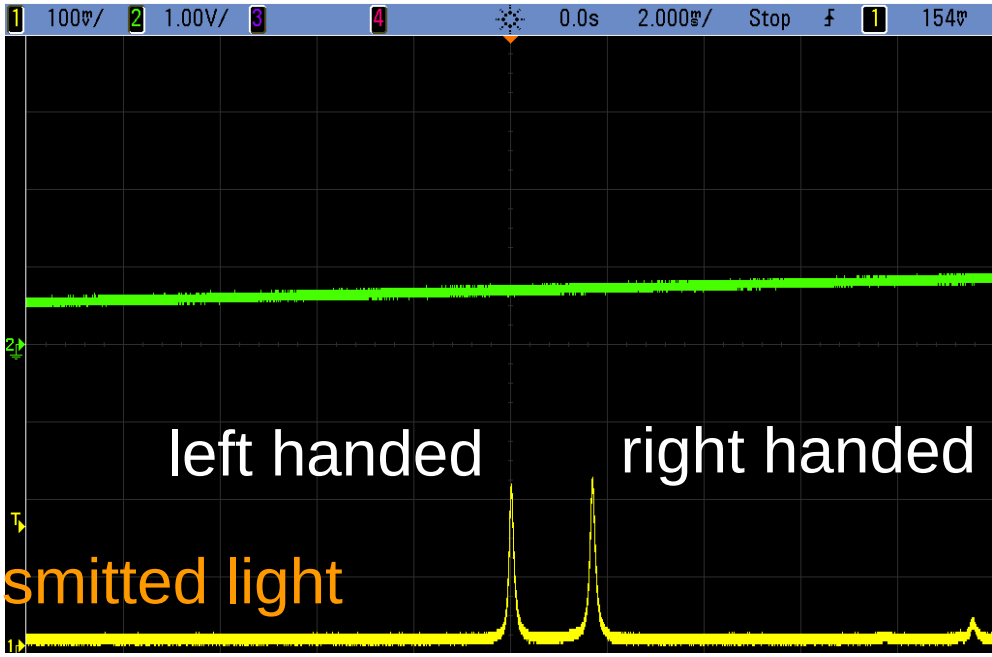


3D (or twisted) 4M ring cavity

3 Dimensional 4 Mirror Cavity

- Resonates only for circular polarization
  - geometric phase due to twisted pass
  - cavity only resonates with circular polarization
  - usable for pol. switching

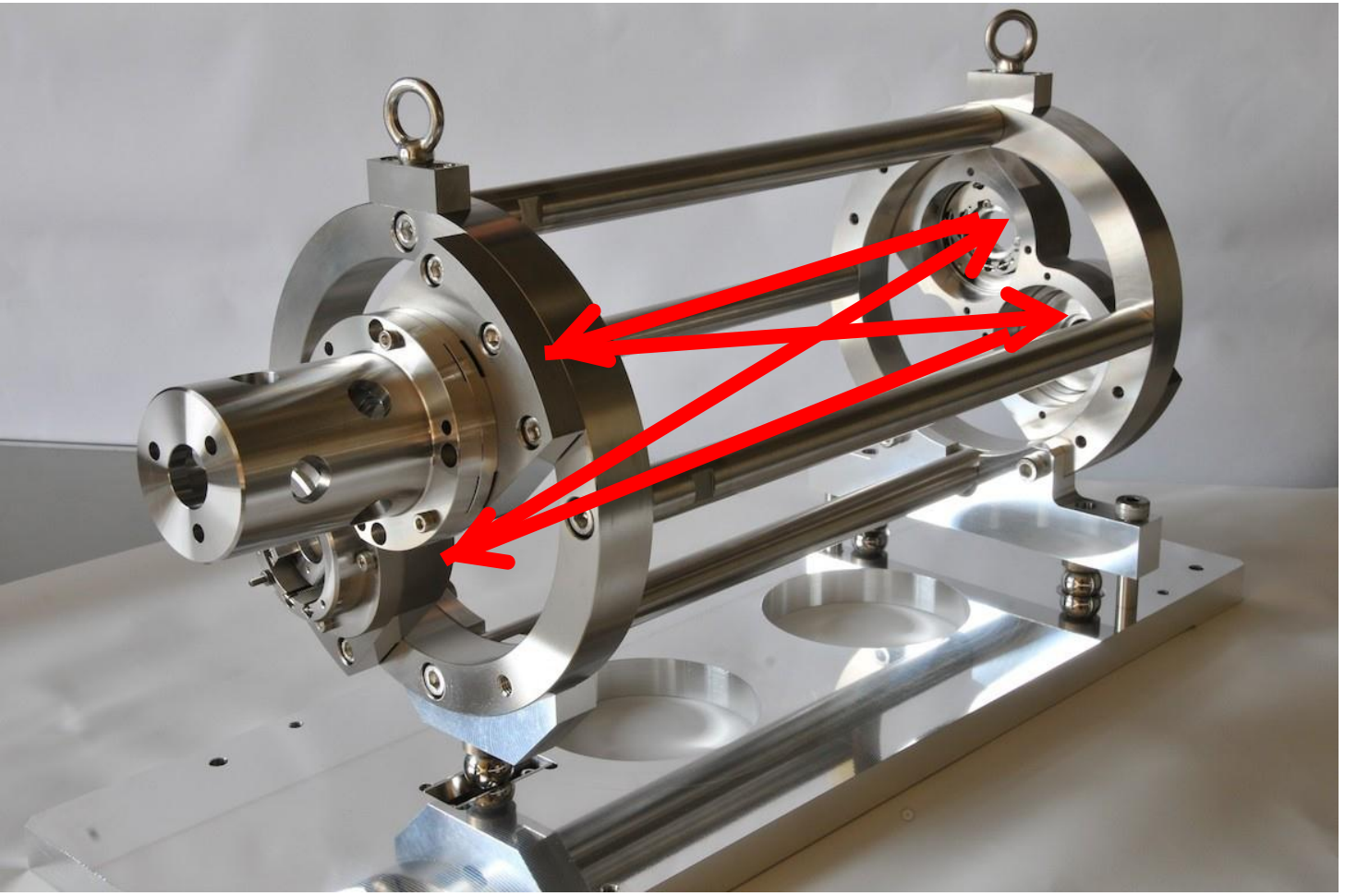


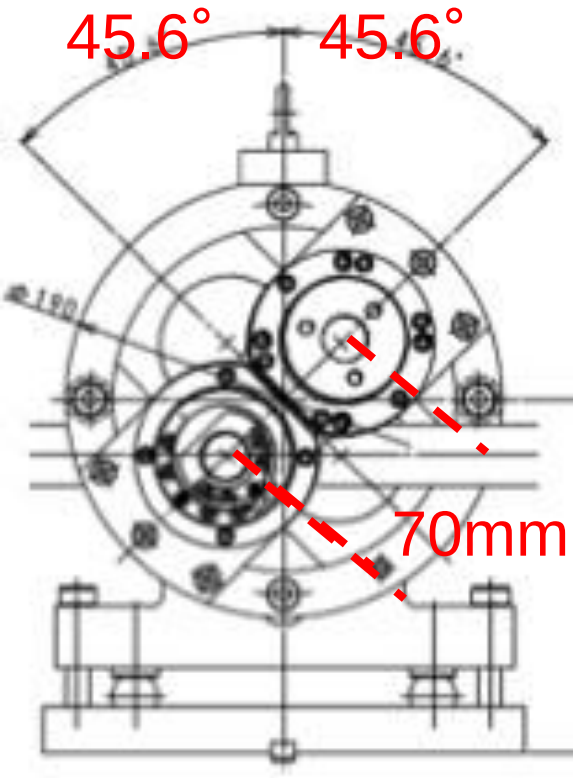


transmitted light

circumference of the cavity

New cavity
to be installed into the ATF





Two 4 mirror cavities are at the ATF

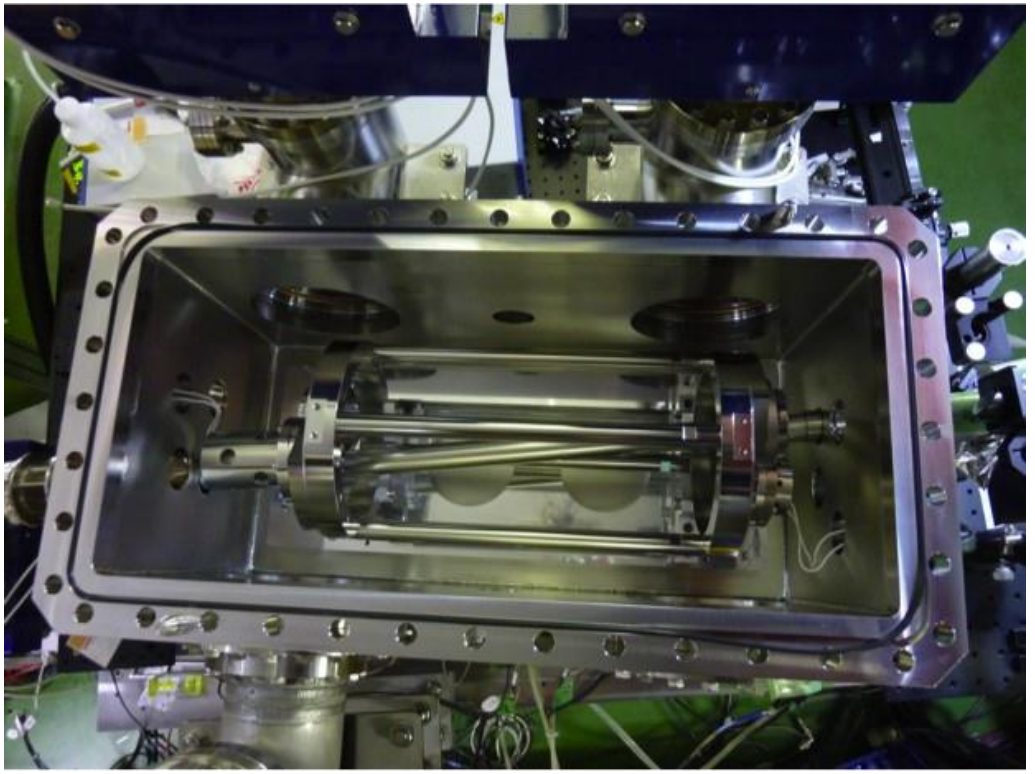
KEK-Hiroshima
installed 2011

relatively simple control system
employs new feed back scheme

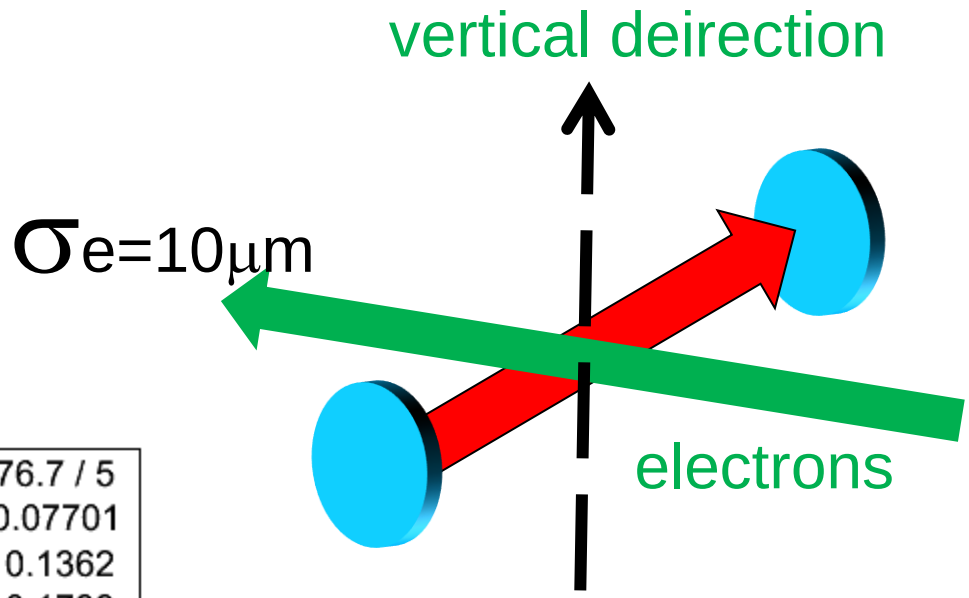
LAL-Orsay
installed summer 2010

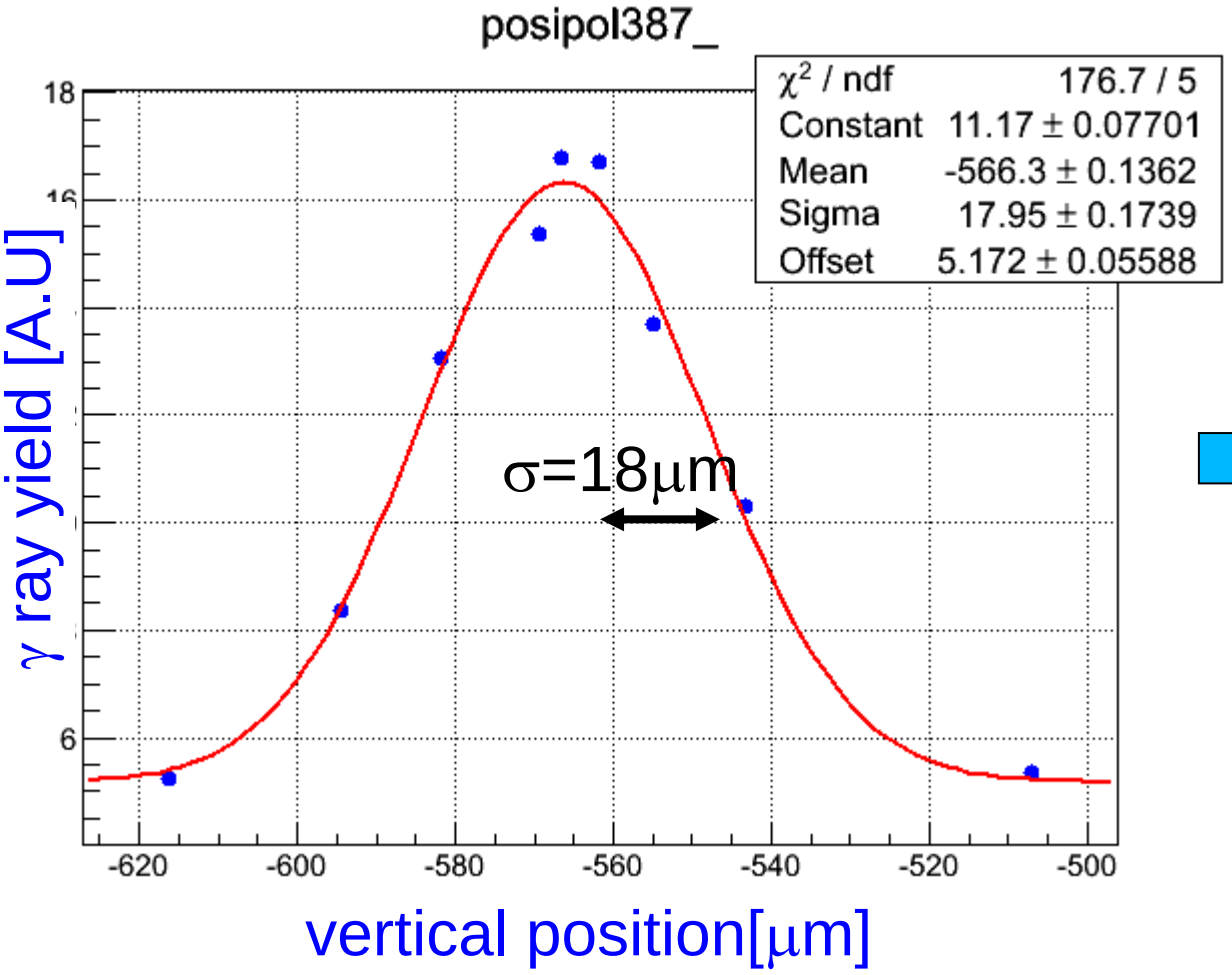
sophisticated control
digital PDH feedback

Installation of KEK Hiroshima cavity



Laser spot size
15μm achieved





σL=15μm

it was 30μm w/ 2 M cavity

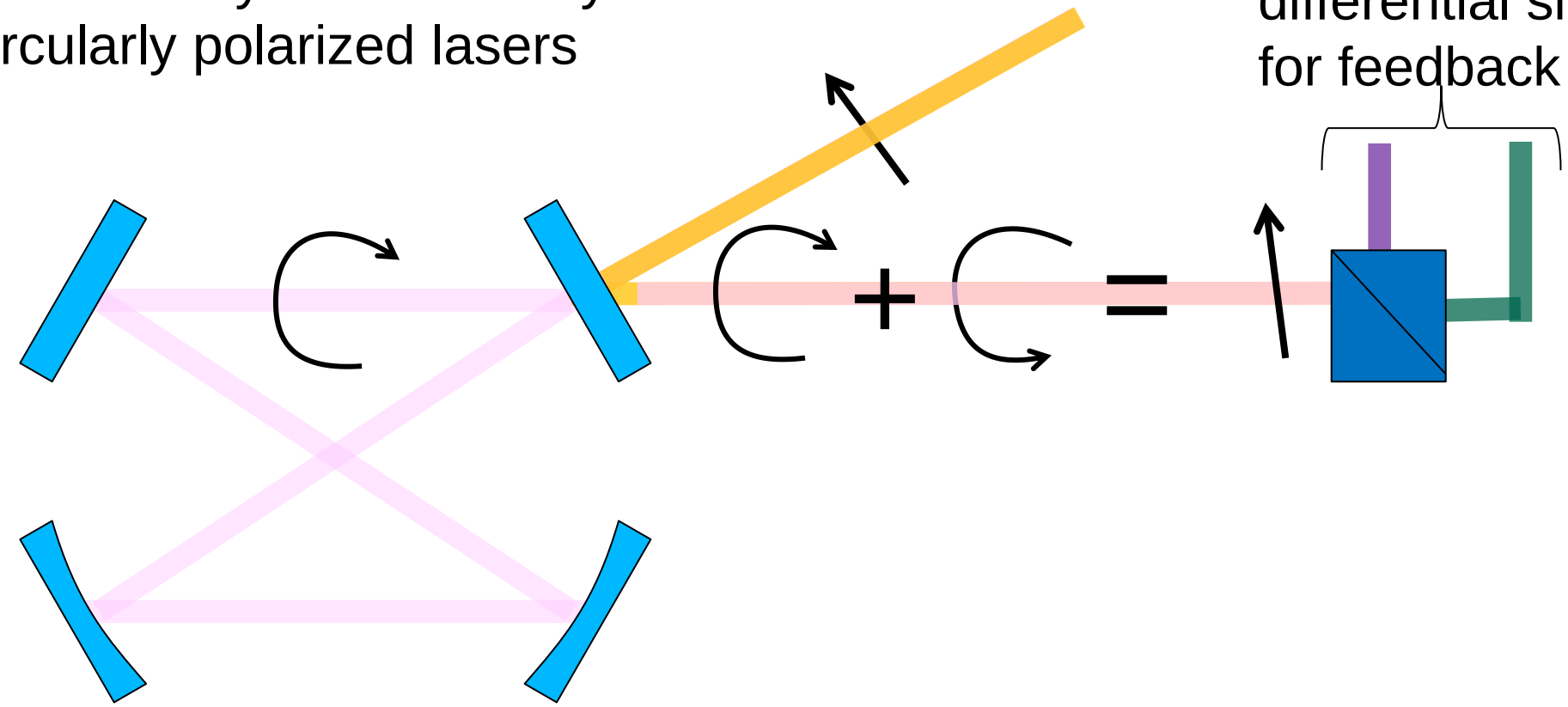
Cavity length feedback with 3D feature

cavity length must be $L = n\lambda/2$ with very high precision

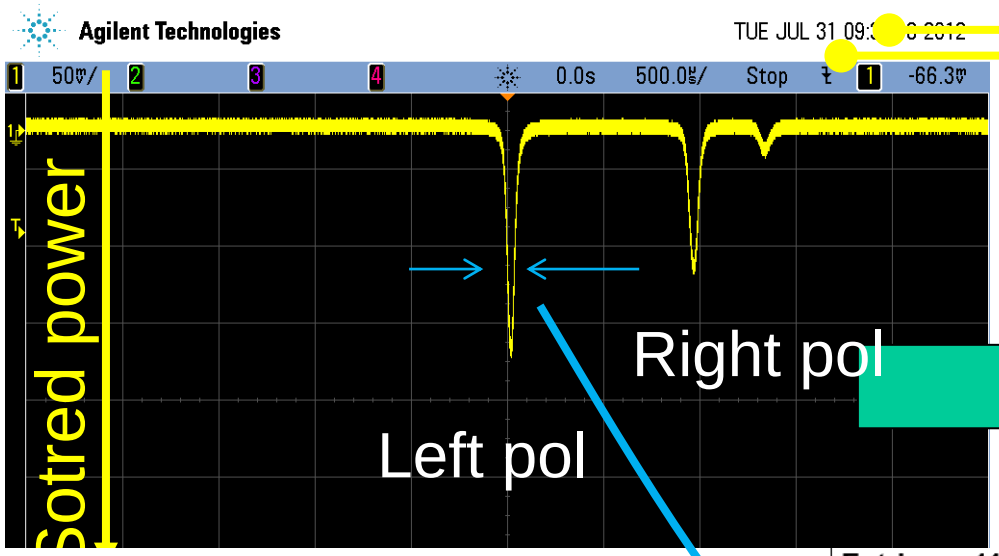
(for enhancement of 1900 $dL << 87pm$ while $L = 1.64m$)

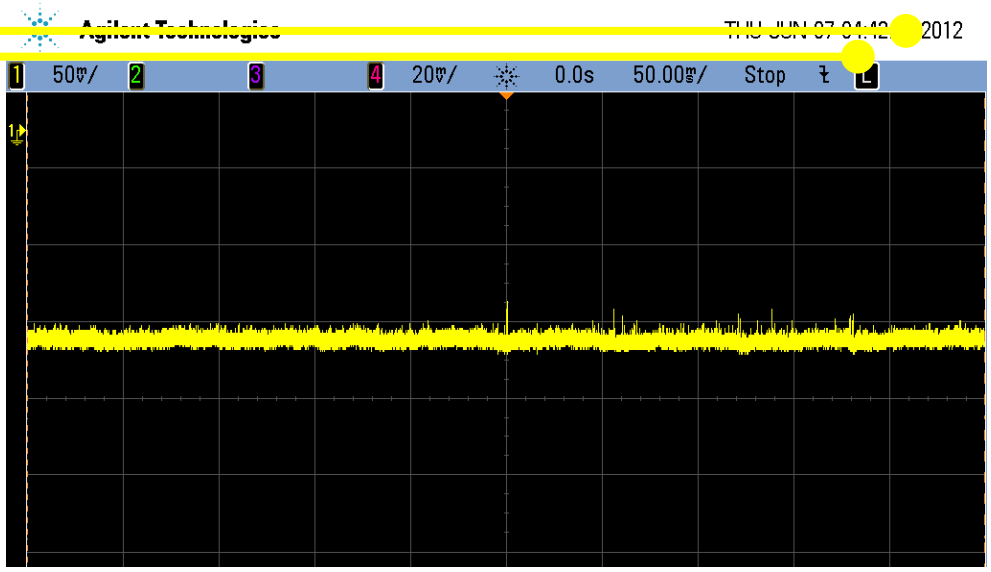
3D4M cavity resonate only with circularly polarized lasers

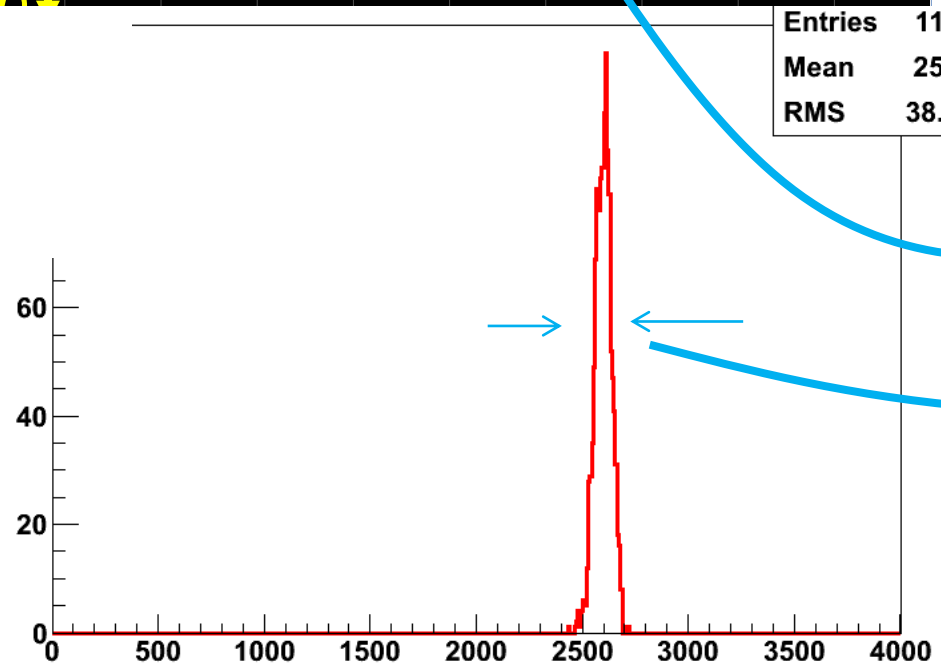
differential signal for feedback



Stored Laser Power in the cavity







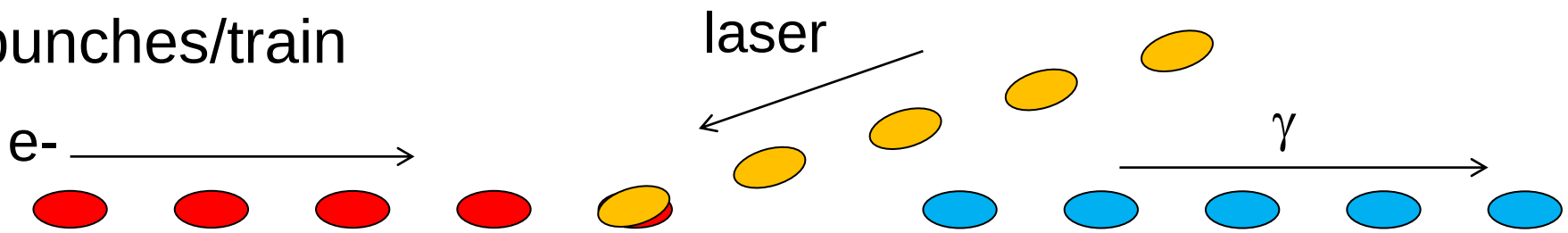
FWHM: 110pm

4pm

Laser Power 2.6kW
(1850 enhancement)
Time Jitter＝8.0ps

g ray Generation / electron

5bunches/train



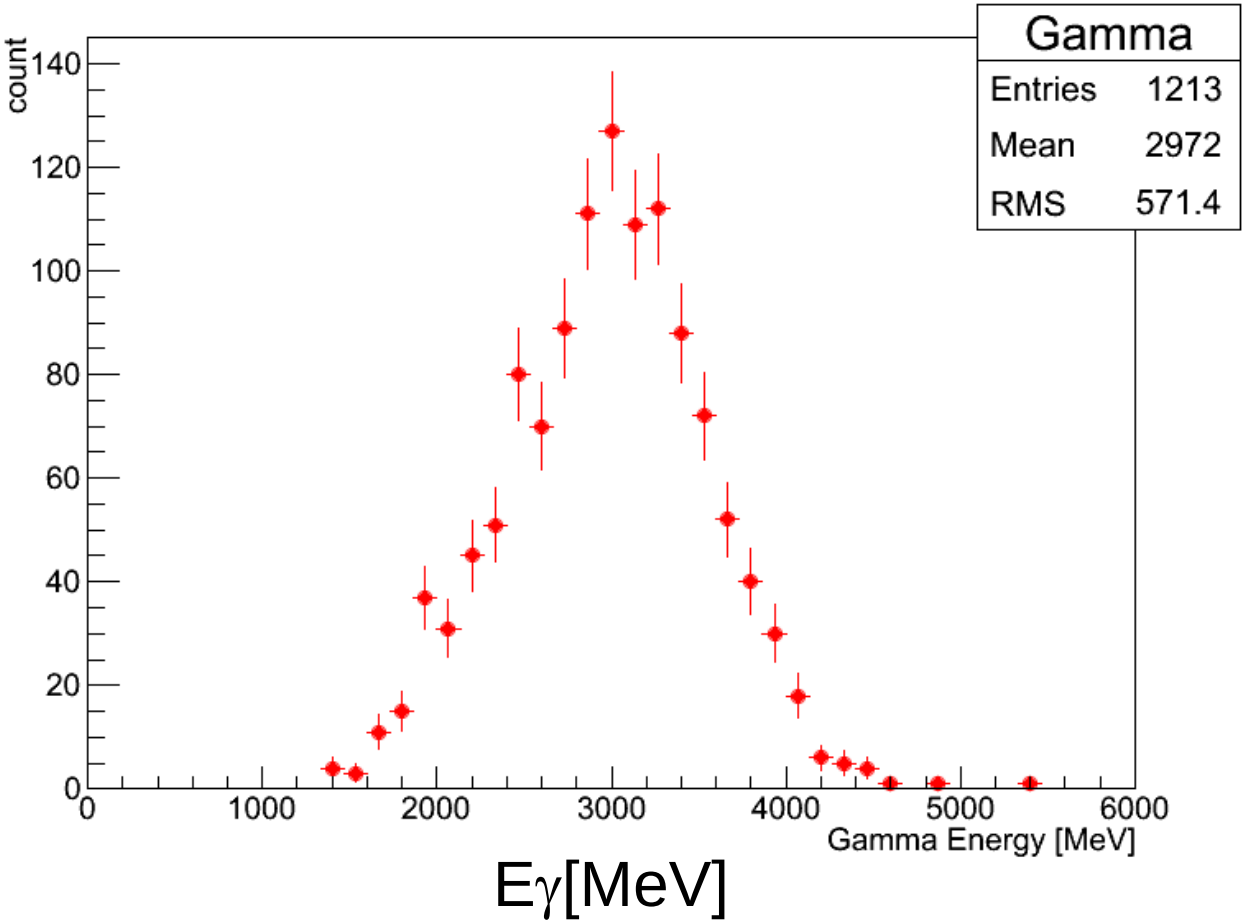
5.6ns

2970±20 MeV

⇒ ~120γs/train

ATF 2.16MHz

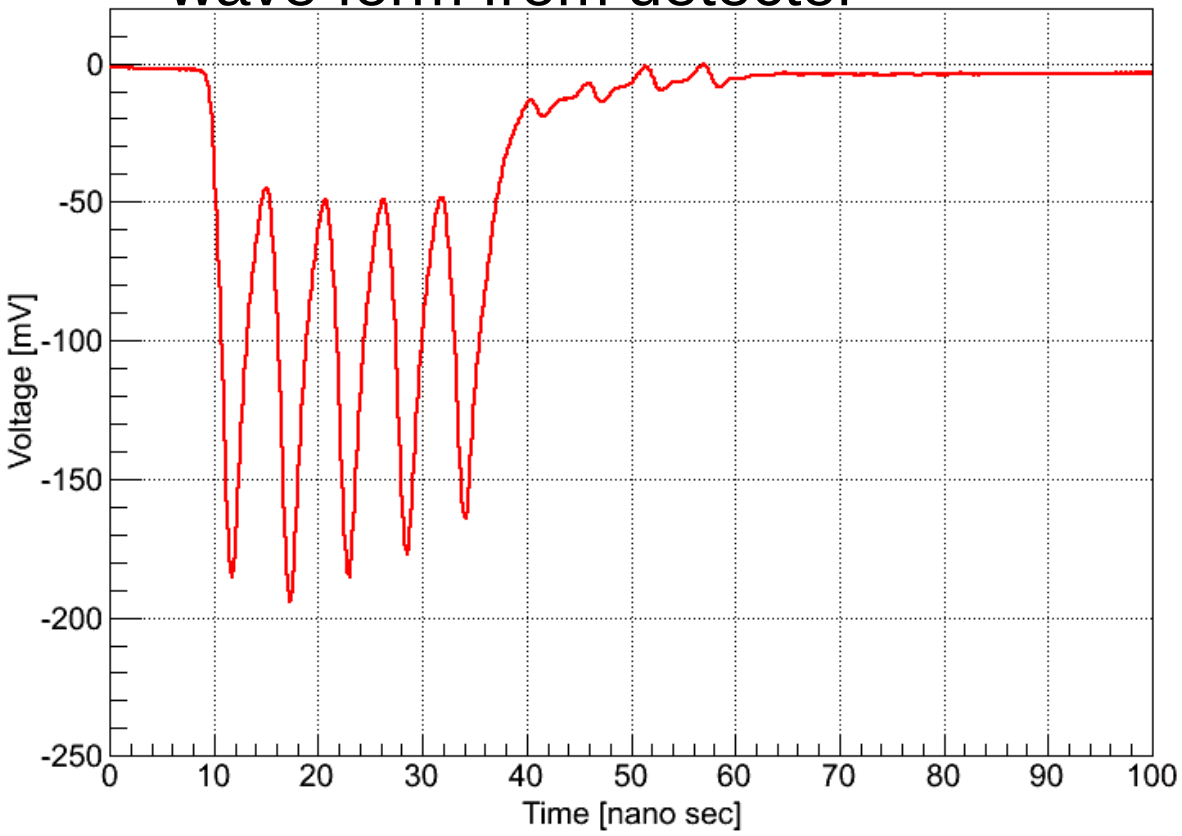
~2.6×10^8/sec



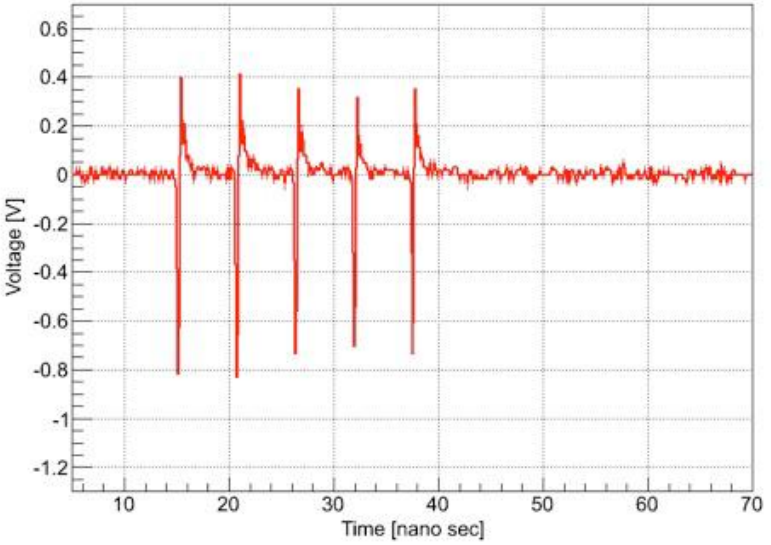
Eγ[MeV]

bunch/bunch measurement

wave form from detector

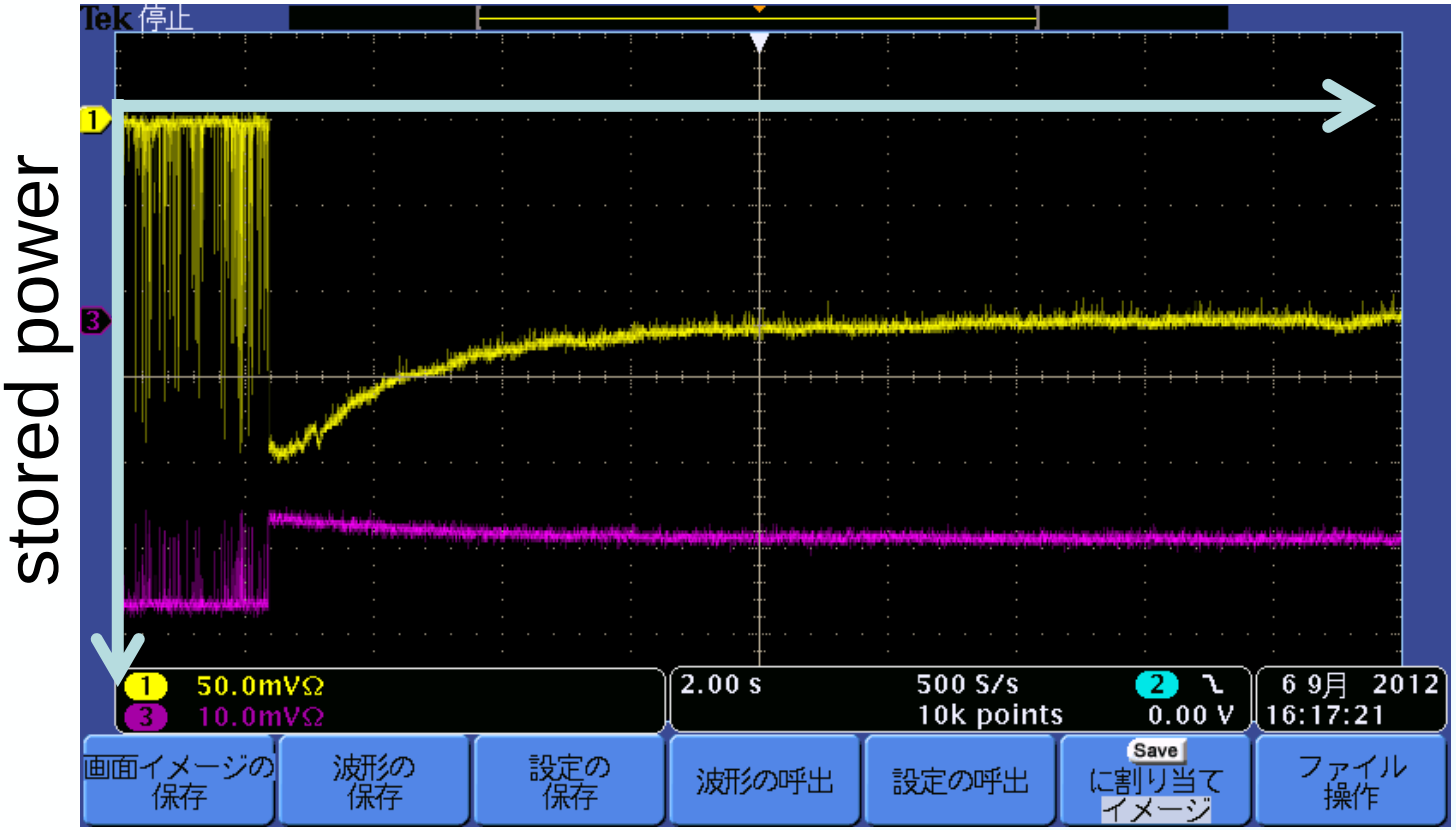


e- bunch monitor



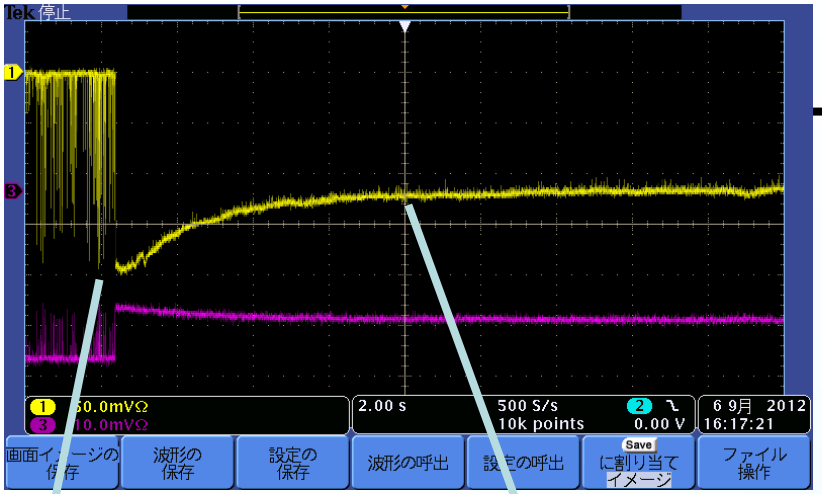
- ～117/train ⇒ consistent w/ calorimeter measurement
- no bunch dependence (yield is proportional to e- current)

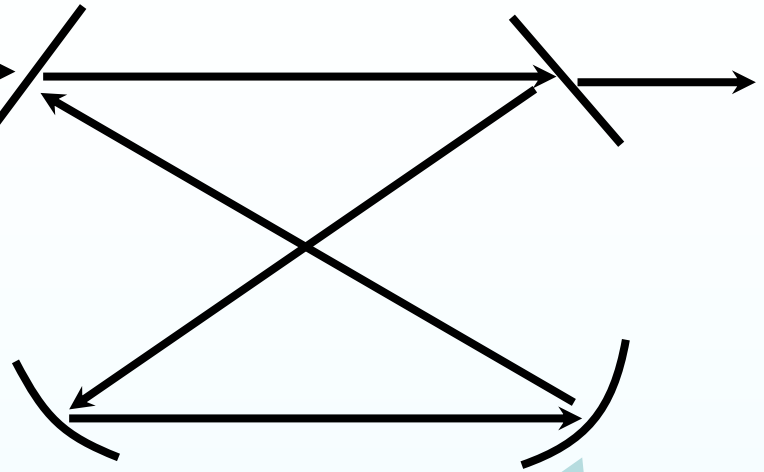
We start to see thermal effect

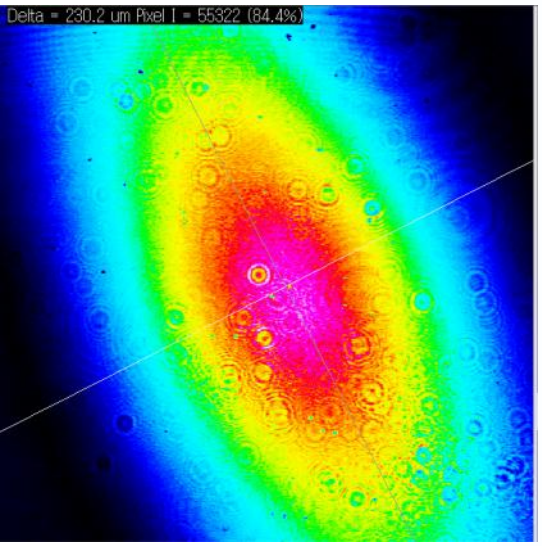


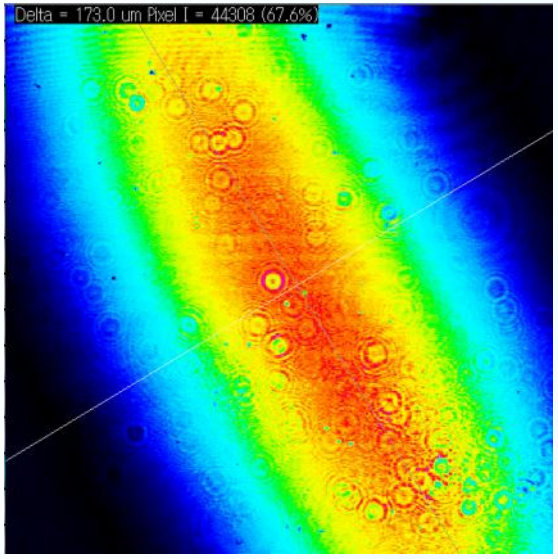
- Stored power decreases after a few seconds
- could not compensate from outside
  - -> not just thermal expansion

We start to see thermal effect









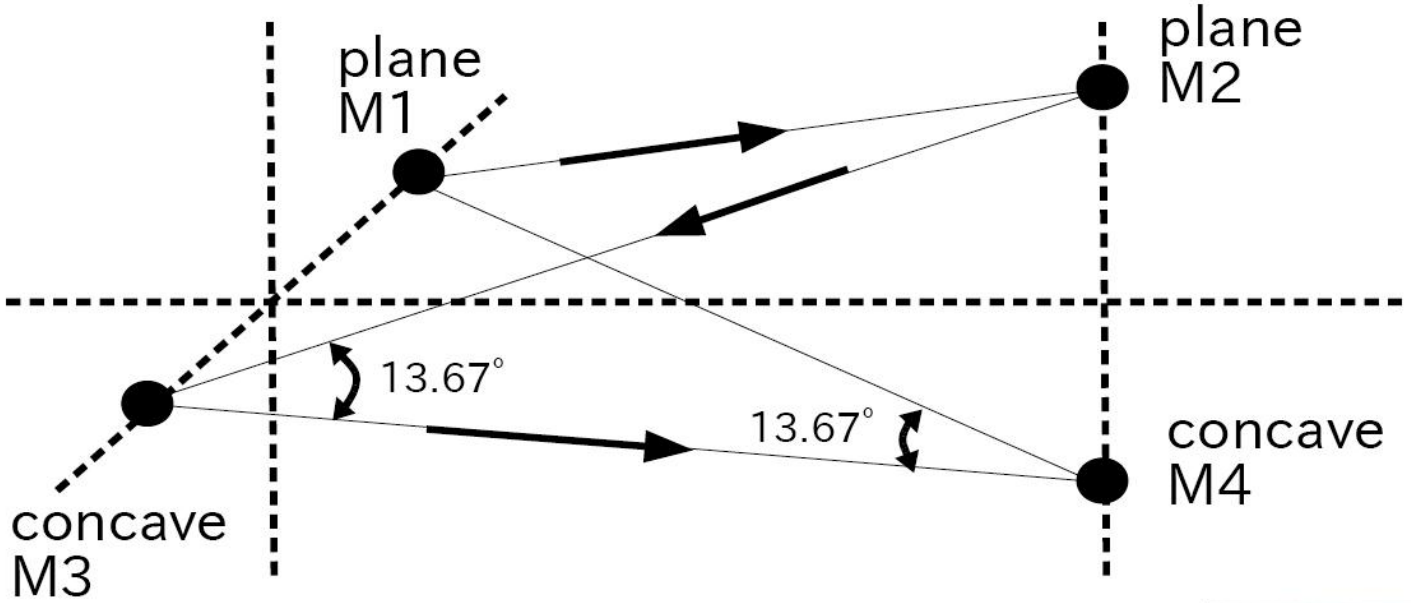
Presumably, change of curvature of mirrors

Power loss on the mirror ~200ppm

Status and plan of KEK-Hiroshima cavity

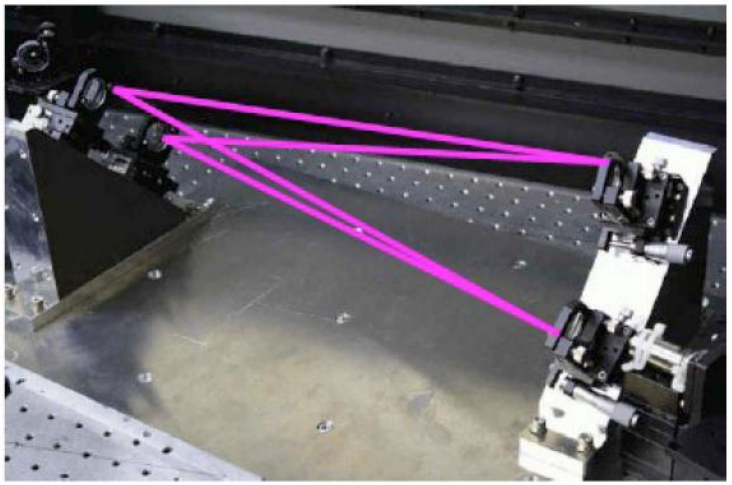
- 2.6KW stored as of 25 May 2012 (1850 enhnsement)
  - 30 γs / bunch -> 150 γs /train
  - correspond to 3.3 × 10^8 γ/s
- observation of bunch/bunch generation
  - Planed to be replaced w/ a Lead glass counter
- Plan
  - digital feedback (on going)
  - 16600 enhancement (finesse 48,000)
  - compensate thermal effect
    - cylindrical lenses
      - low loss mirror ~1ppm
      - adaptive optics

Configration of test bed

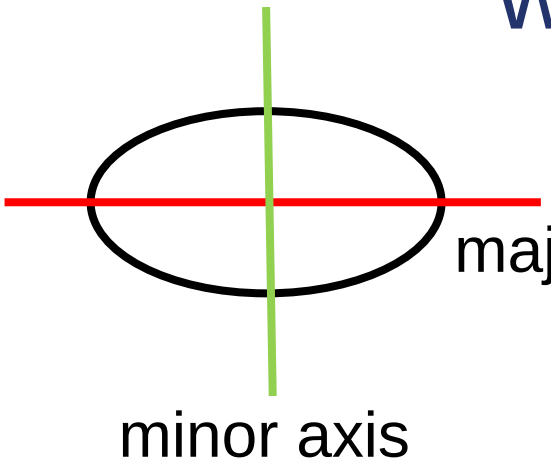


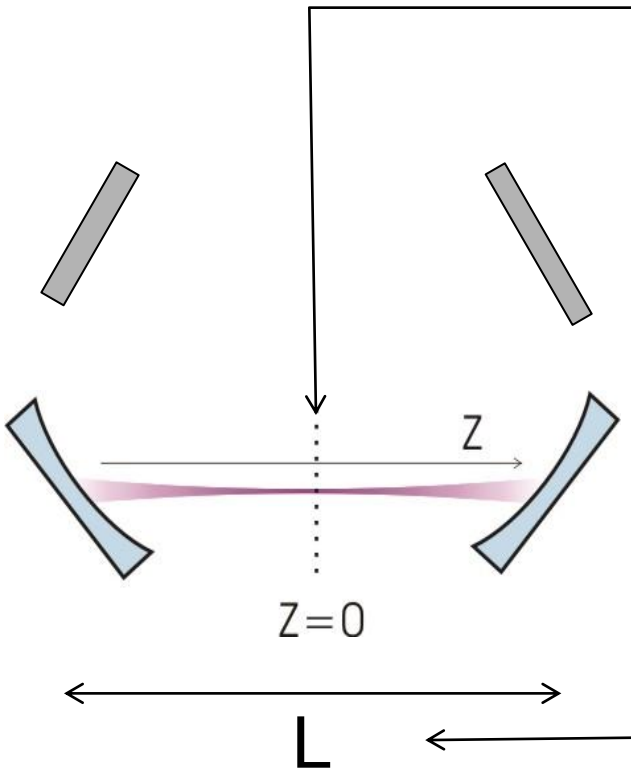
L1=M1-M2=420mm
L2=M2-M3=420mm
L3=M3-M4=420mm
L4=M4-M1=420mm

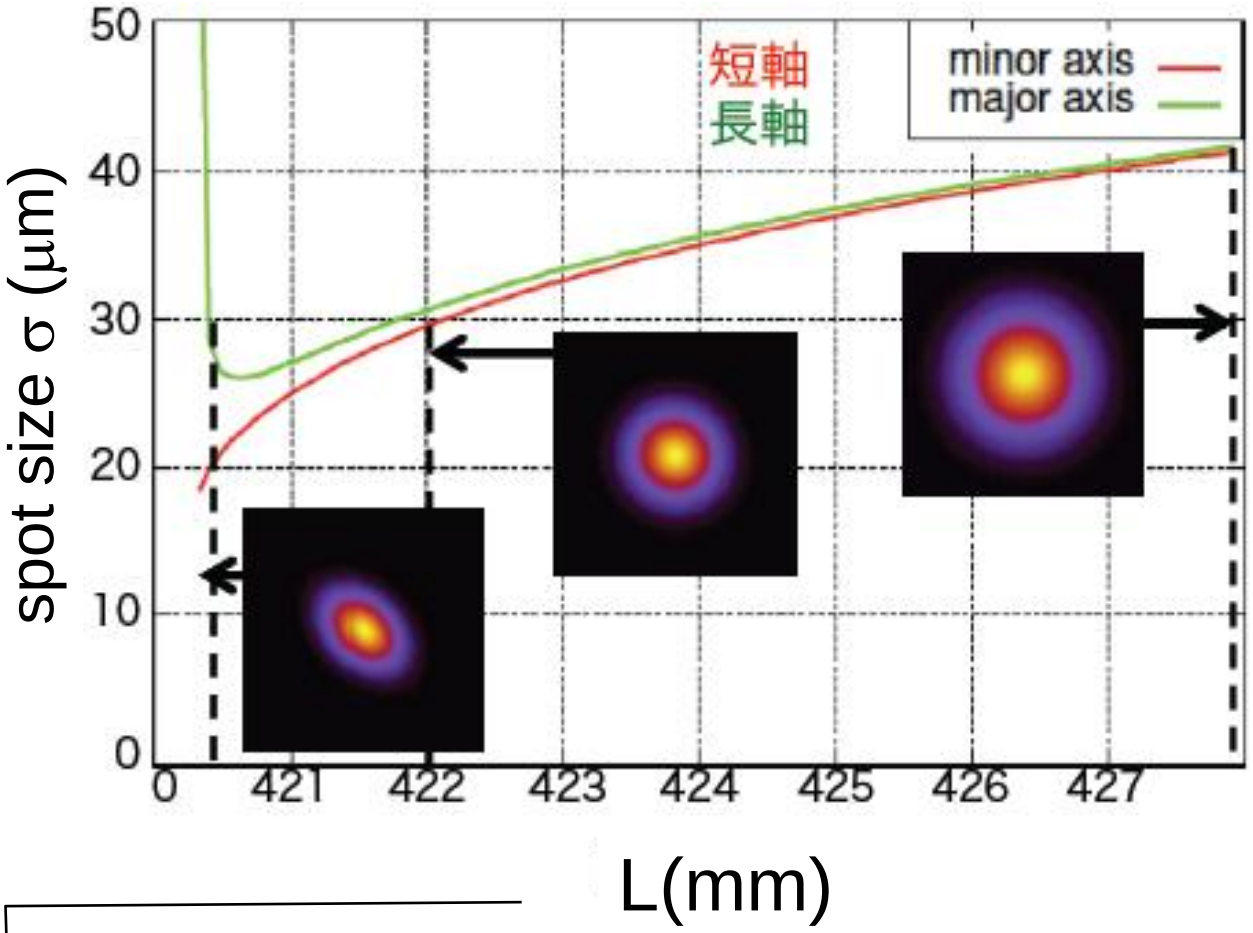
M2-M4=100mm
M1-M3=100mm



calculation of spot size w/ test bench geometry

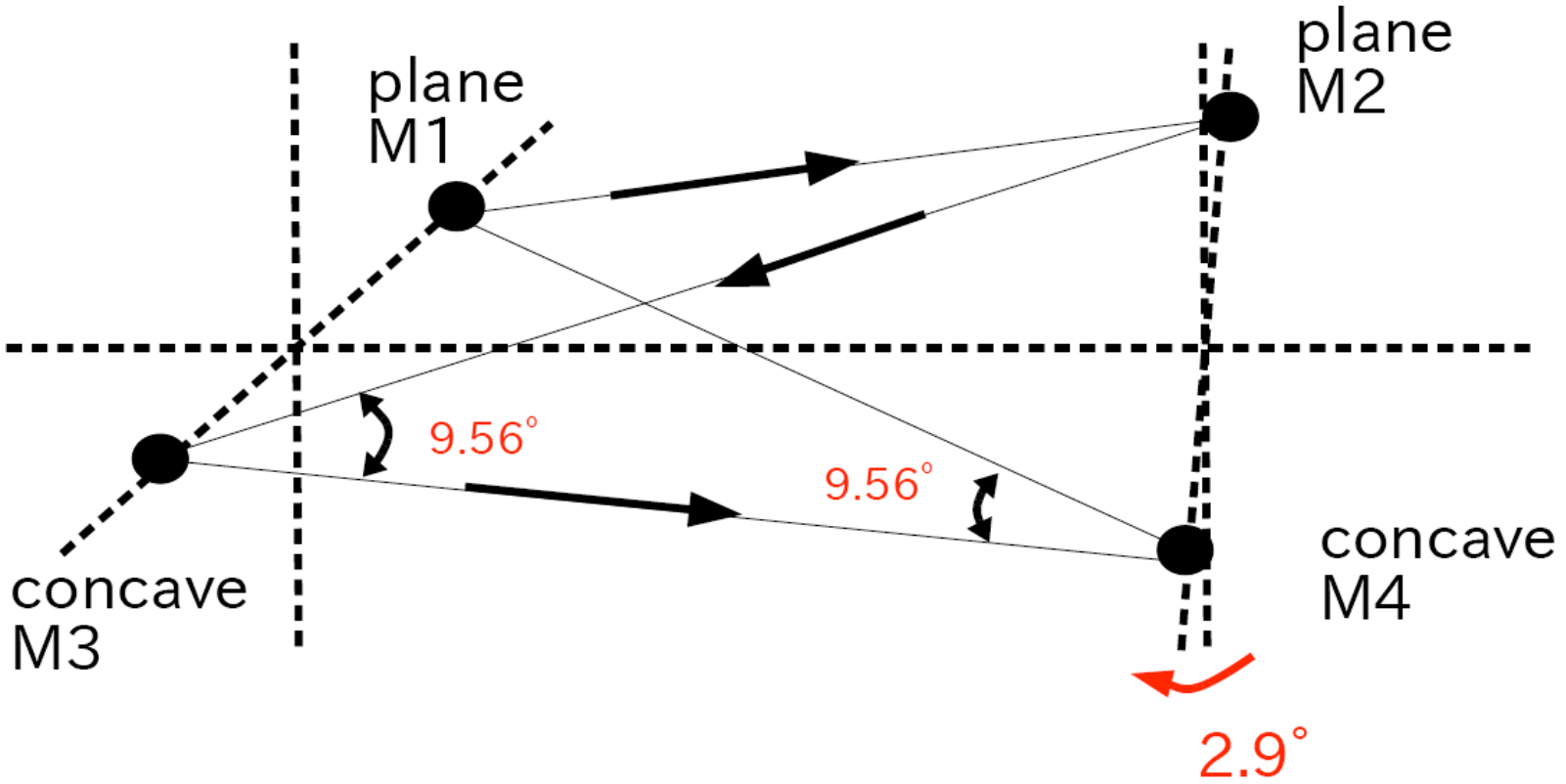






spot size is not sufficiently small with test bench geometry

new geometry

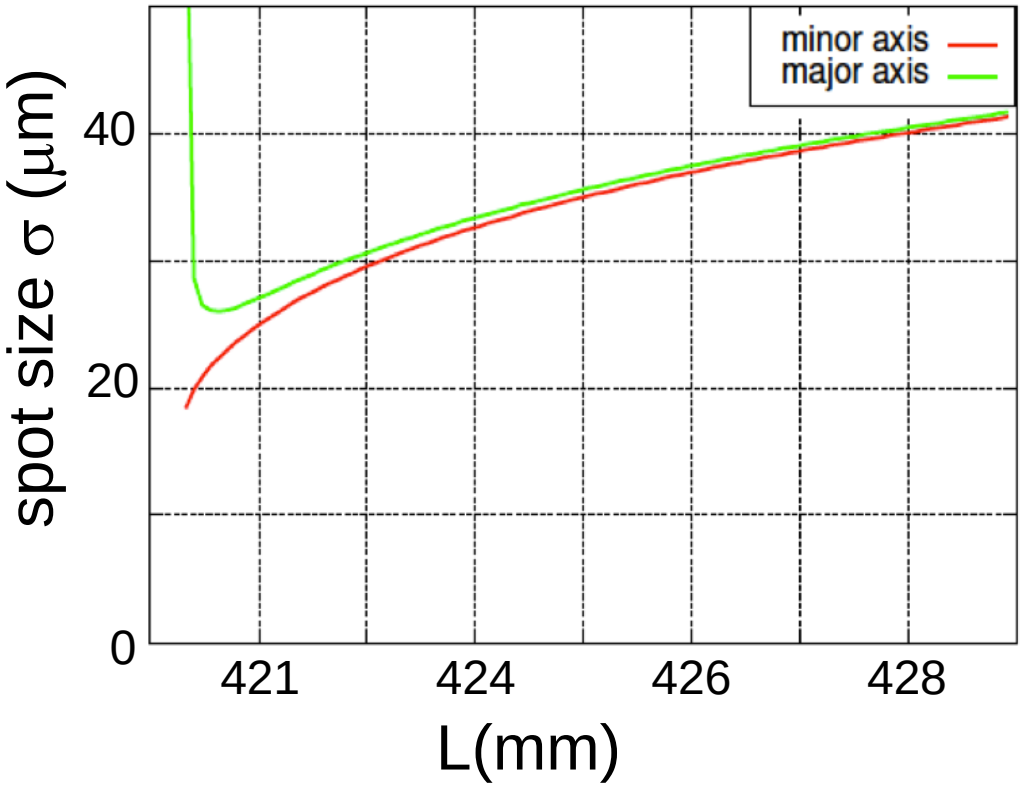


L1=M1-M2=420mm
L2=M2-M3=420mm
L3=M3-M4=420mm
L4=M4-M1=420mm

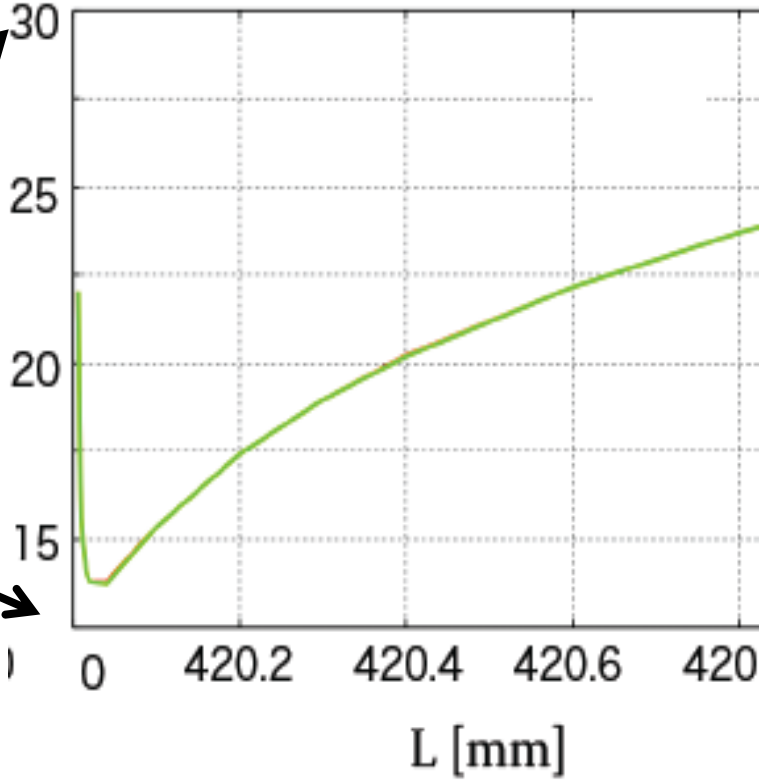
M2-M4=70mm
M1-M3=70mm

expected spot size w/ new geometry

Before optimization



After optimization



laser spot size of 15 μm is expected with new geometry