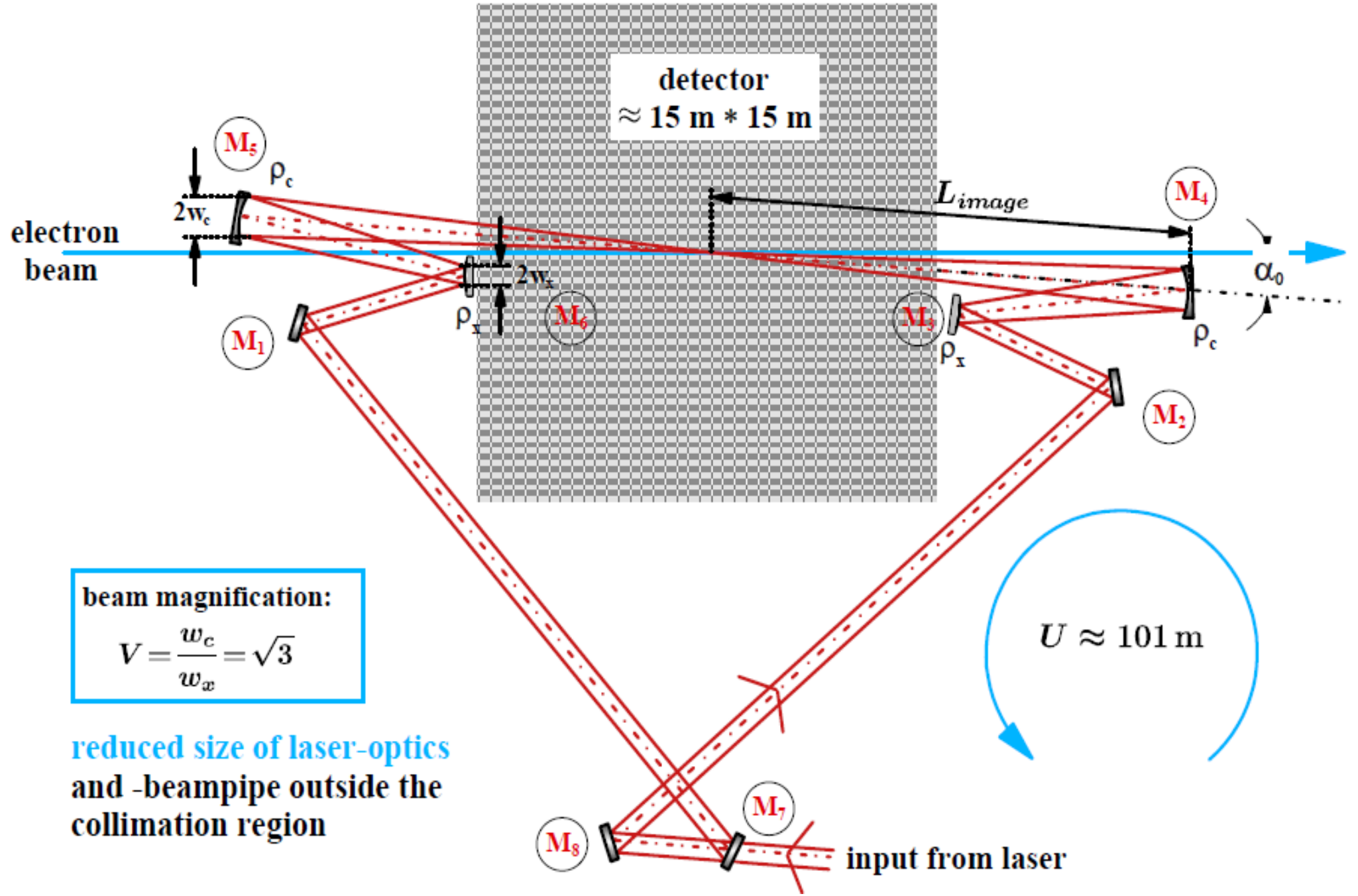
Status of the optical cavity R&D at ATF

T.Takahashi
Hiroshima University
for collaborators

IWLC2010
Geneva
20-October-2010

Proposed telescopic, passive, resonant external cavity

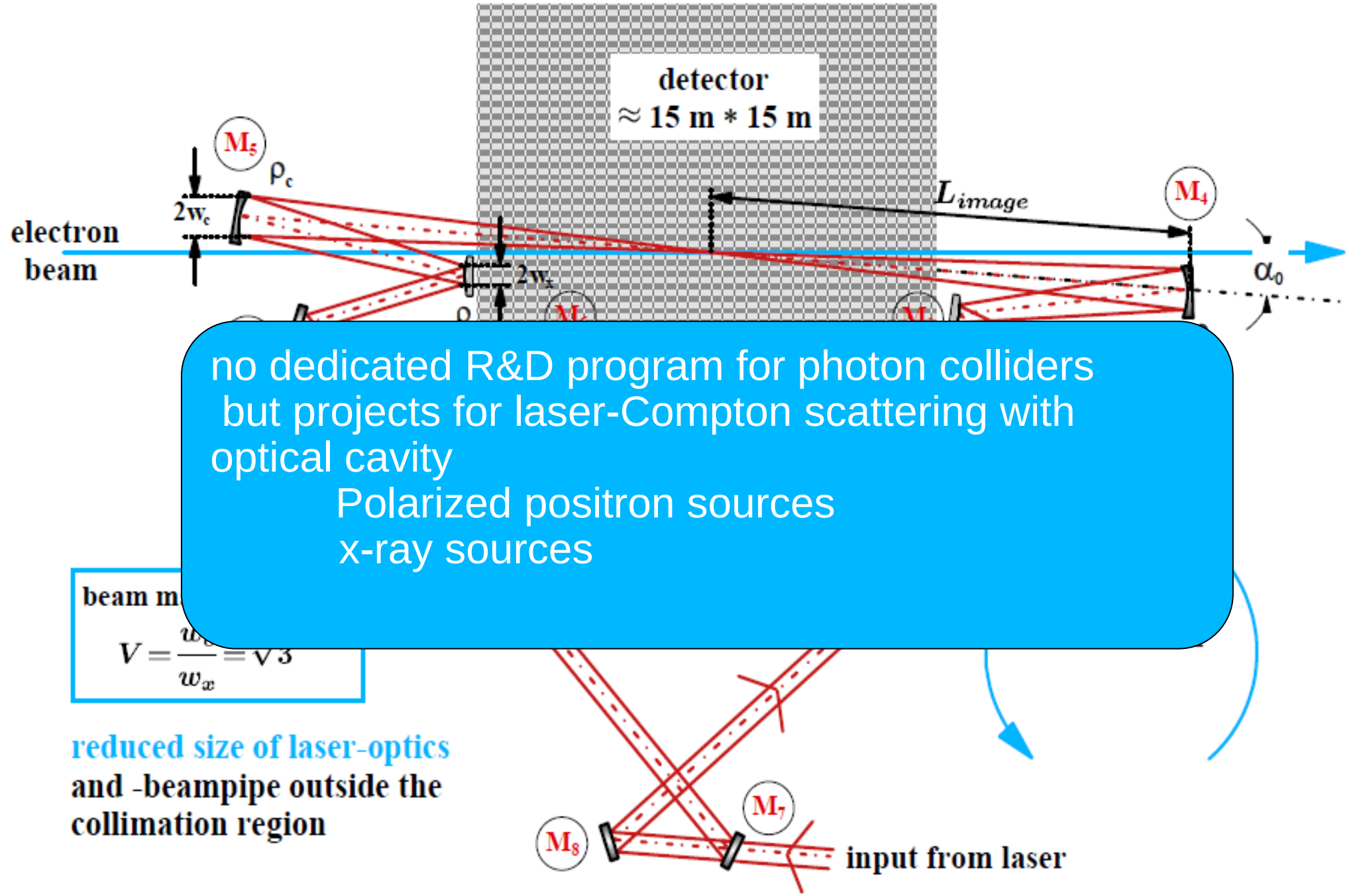


beam magnification:

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

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

Proposed telescopic, passive, resonant external cavity



no dedicated R&D program for photon colliders
but projects for laser-Compton scattering with optical cavity

Polarized positron sources

x-ray sources

beam m

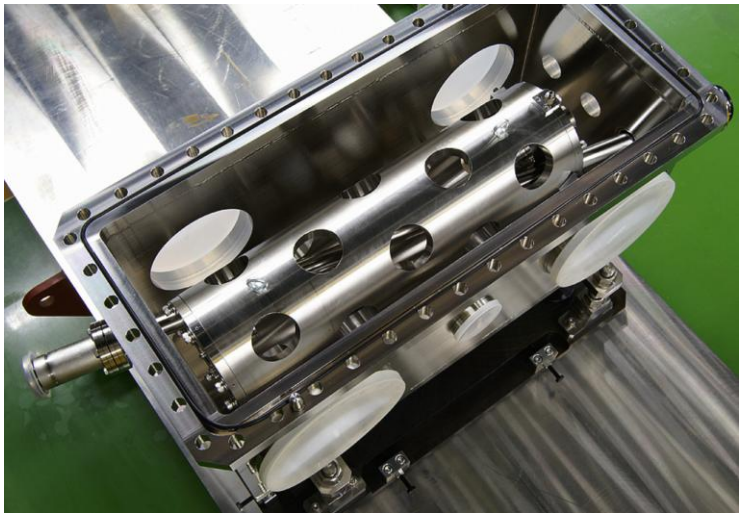
$$V = \frac{w_z}{w_x} = \sqrt{3}$$

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

Prototype Cavities

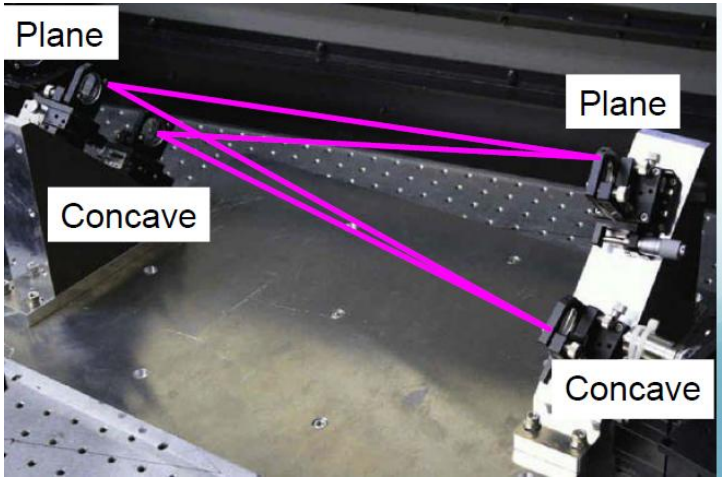
2-mirror cavity at KEK ATF

moderate enhancement
moderate spot size
simple control

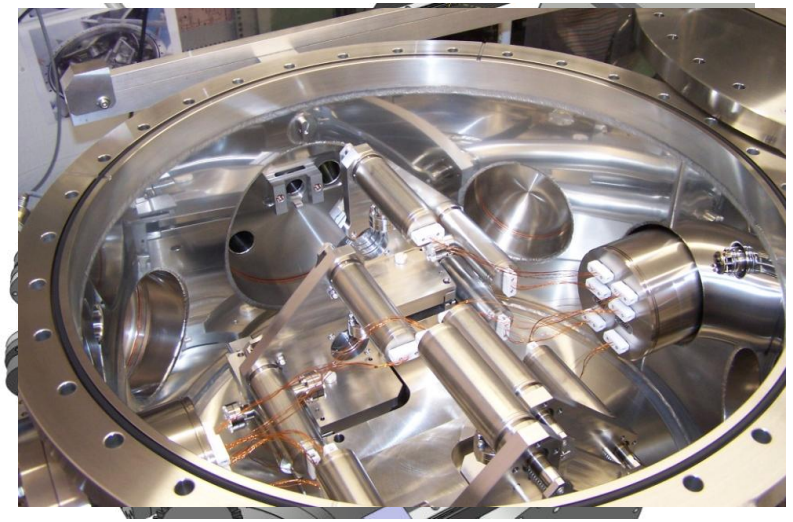


experiences with accelerator

4-mirror test bed at KEK



4-mirror cavity at LAL

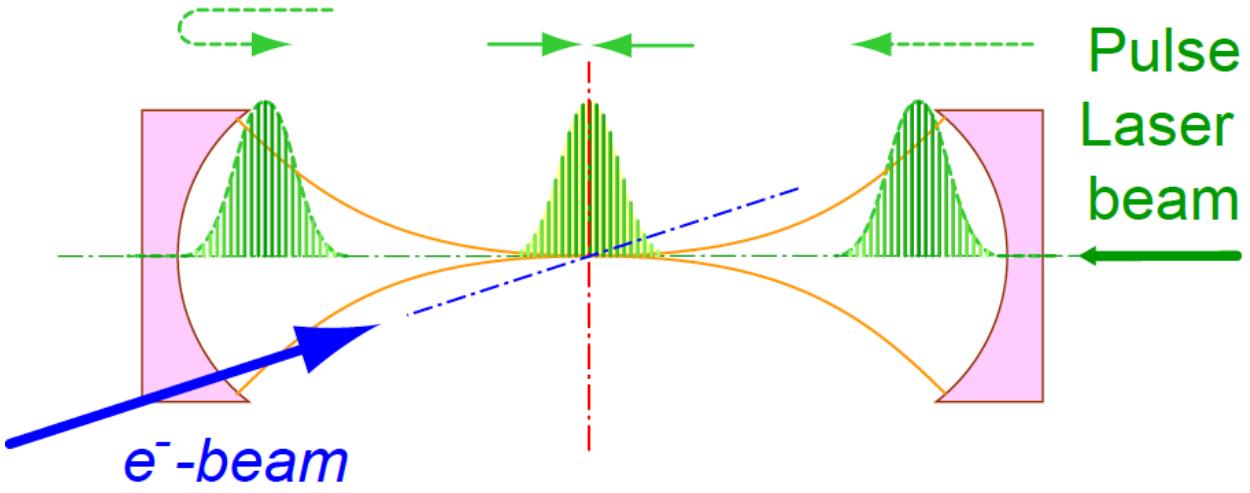


high enhancement, small spot size

STATUS OF THE 2 MIRROR CAVITY

Experimental R/D in ATF

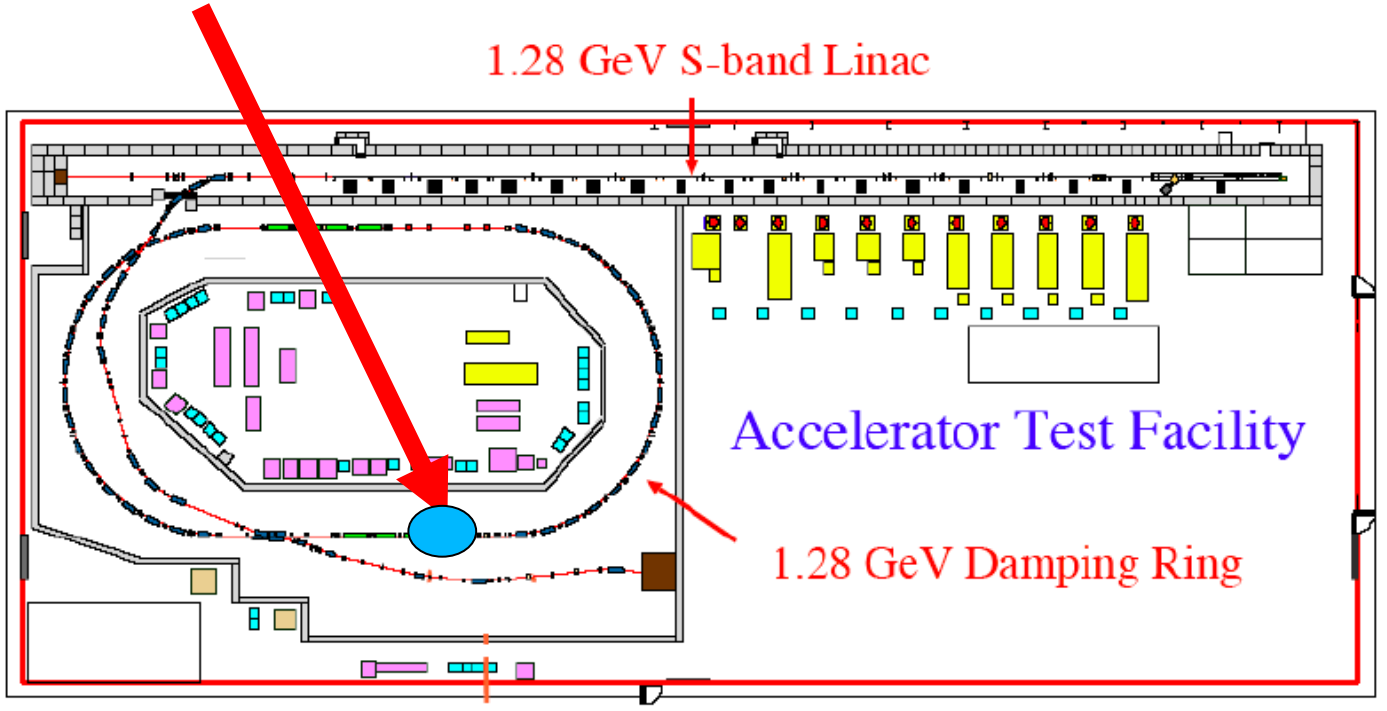
Hiroshima-Waseda-Kyoto-IHEP-KEK



prototype
2-mirror cavity

L_{cav} = 420 mm

Put it in ATF ring



AFTER TILC09

slide at ALCPG09

- One of the Mirror was replaced with the higher reflectivity one
  - 99.6% -> 99.9%
  - power enhancement
    - 250 -> ~750
  - more precise controll required (~0.1nm)

- Status of the cavity w/ new mirror
  - Finess ~2000 with feedback on before vacuum on
  - now in preparation for beam
  - hope to get 3 times more photons by the end of the year

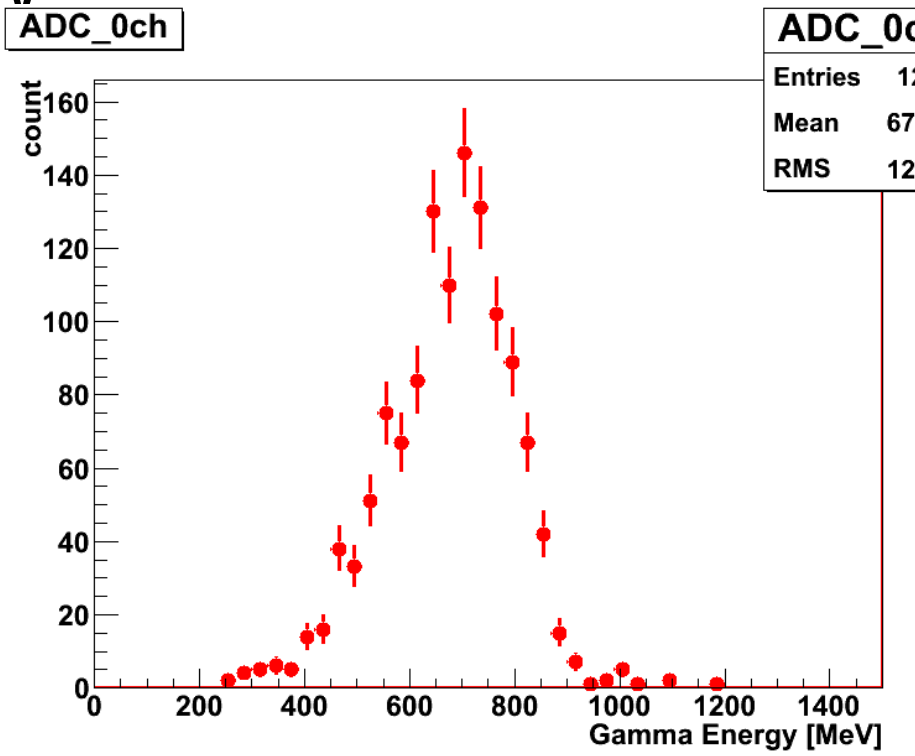
W/ Larger enhancement cavity in 2009

After, extensive studies;

Power enhancement of the cavity ~ factor 3

Laser power 500W to 1.48kW

- 10.8γ/train at 1 bunch (2.2mA)
- 26.8γ/train10cunches(6.7mA)



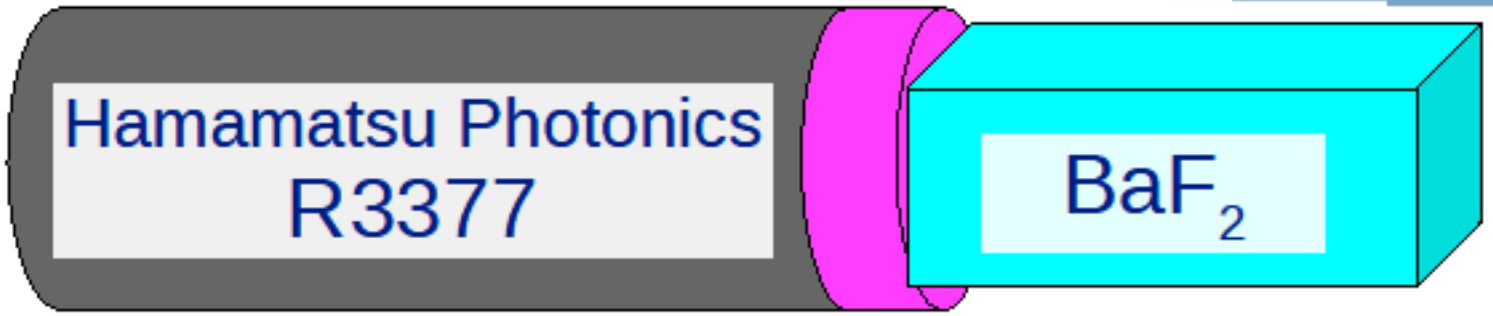
The electron beam was not tuned enough in 2009

demonstration of 3 times more g by beam tuning

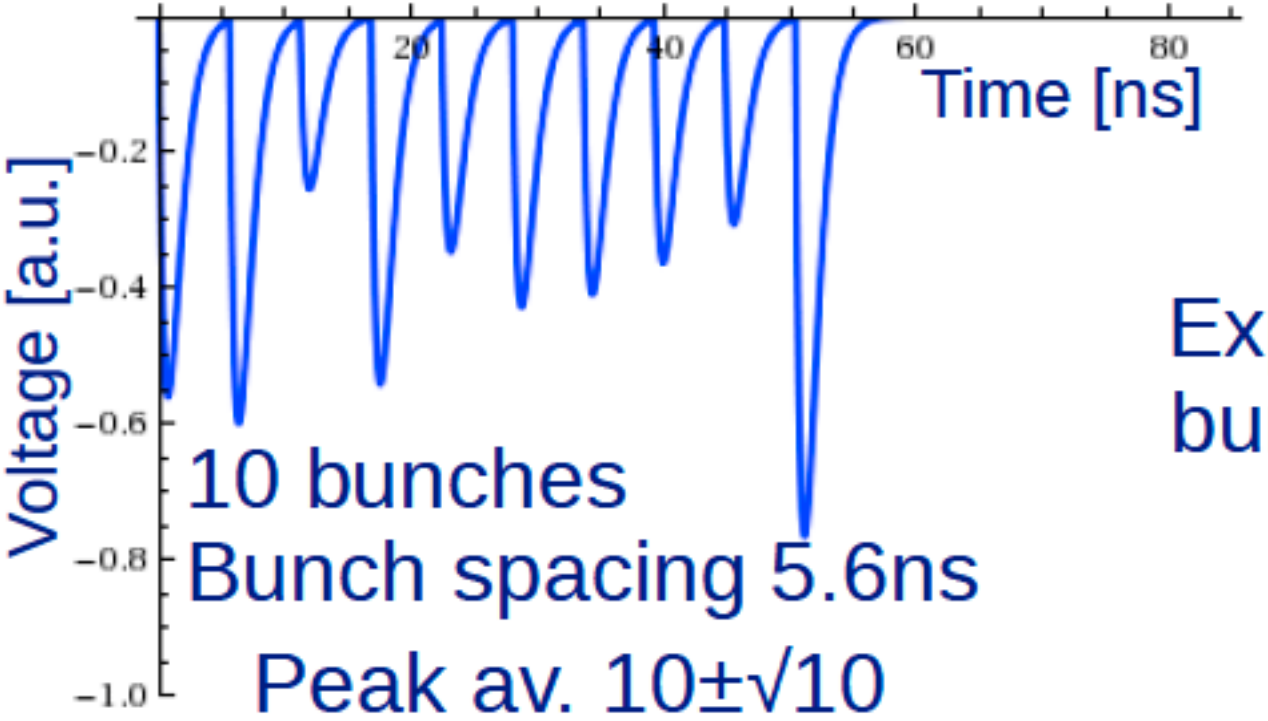
bunch by bunch observation soon

New Gamma-ray Detector

Miyoshi PosiPol2010



Result of simulation



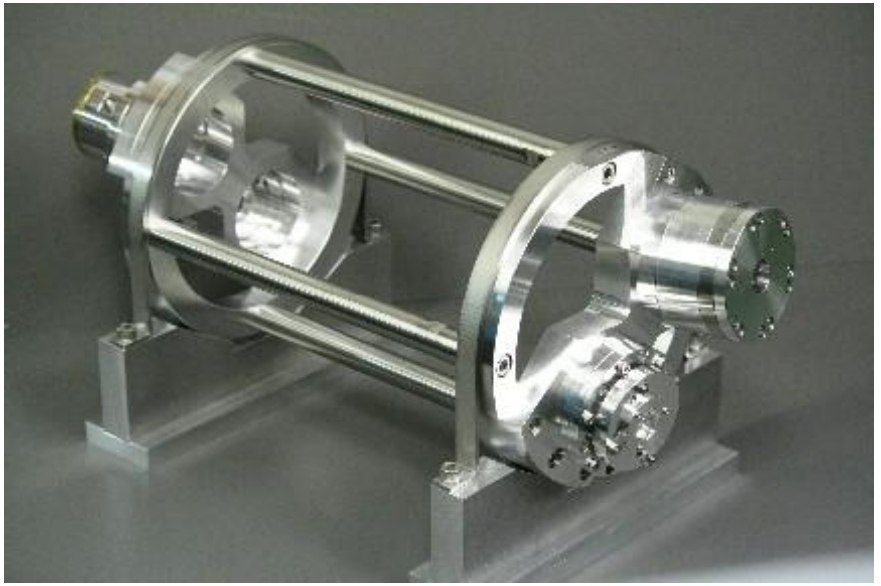
10 bunches

Bunch spacing 5.6ns

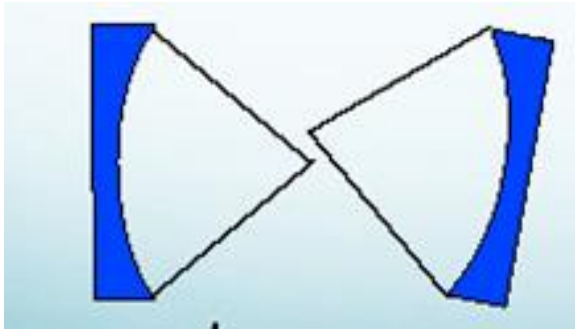
Peak av. 10±√10

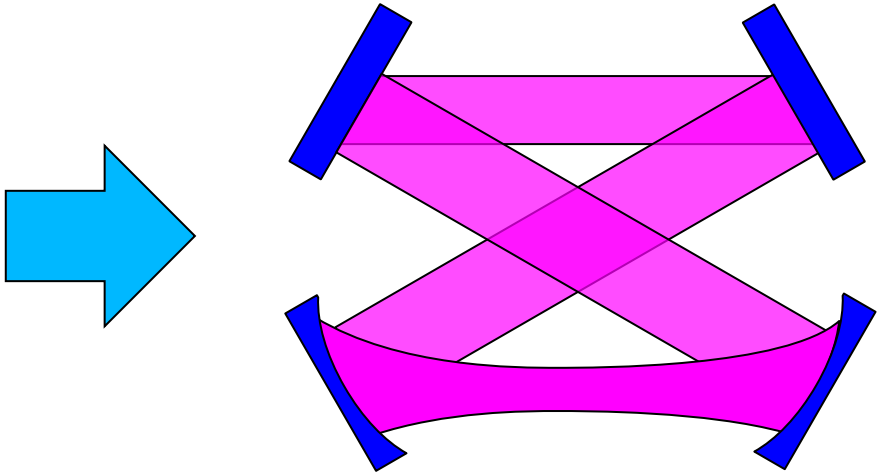
Expected to obtain bunch information.

4 MIRROR CAVITY

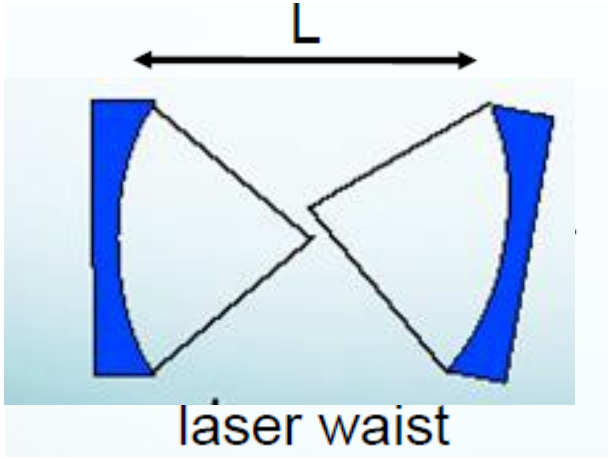


to get higher enhancement and smaller beam waist





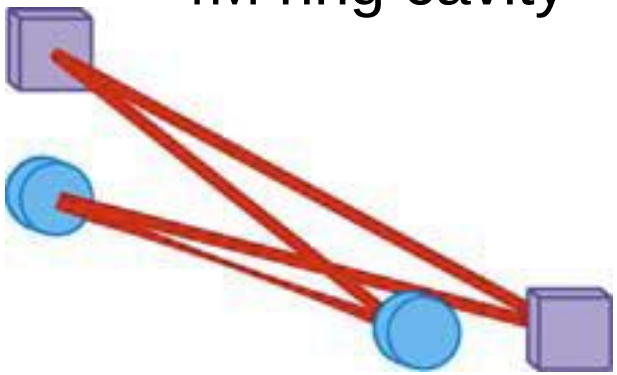
We should go to 3D 4 mirror ring cavity to get small sport size

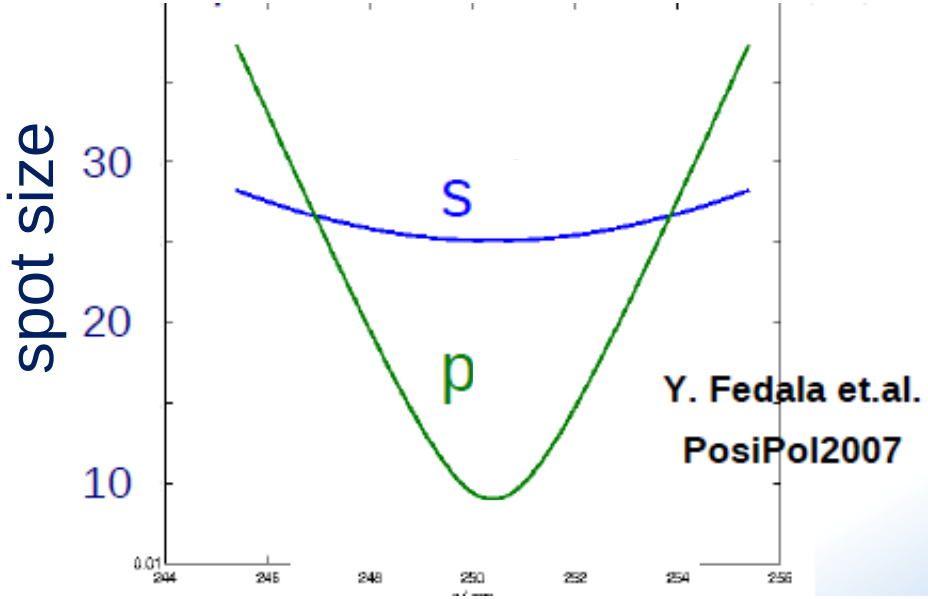


2 mirros is not stable
for small spot size

2d 4M has astigmatism

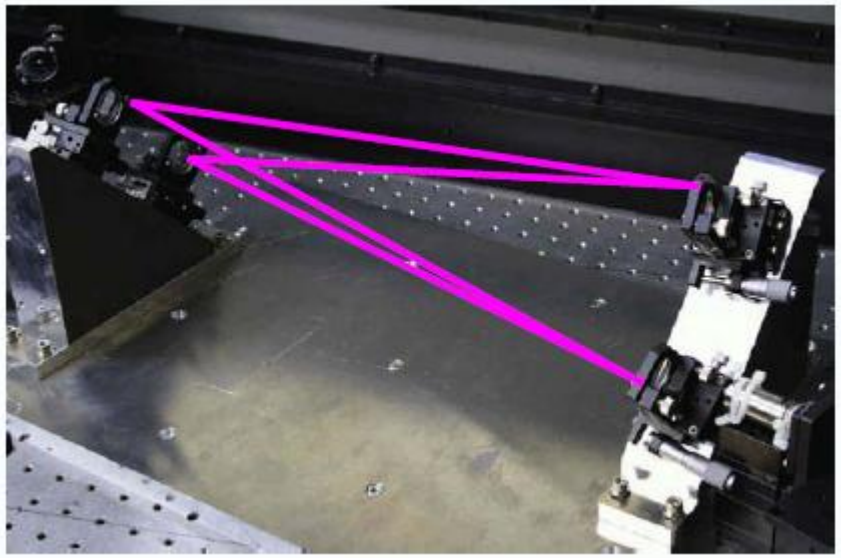
3D (or twisted)
4M ring cavity

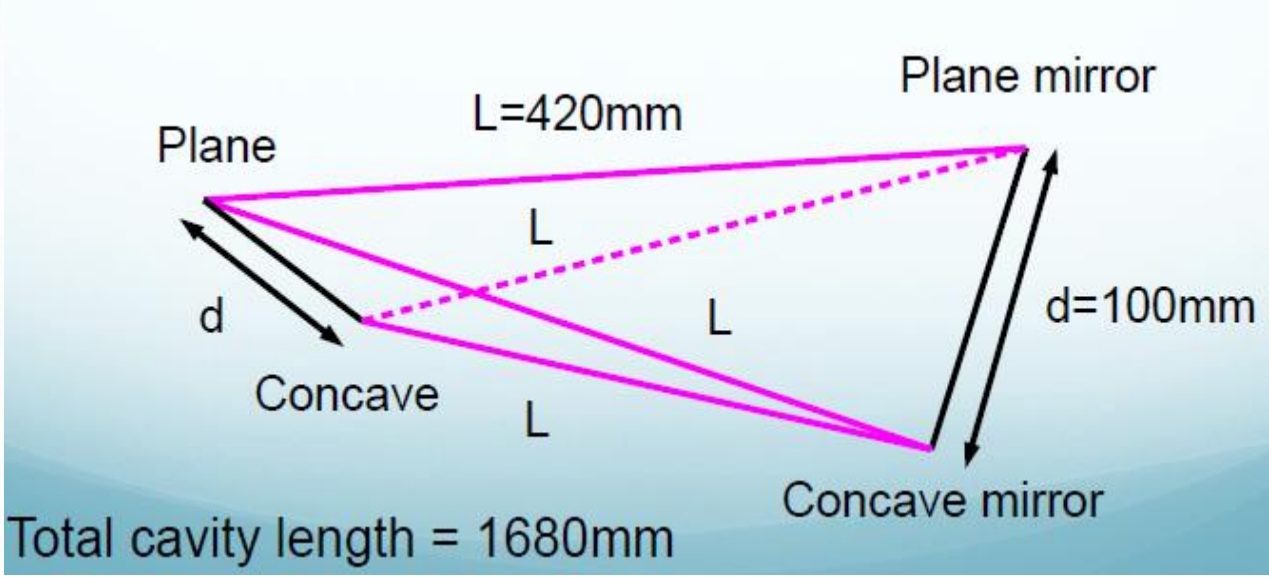




4M cavity test bed at KEK

- in 4M ring cavity, photons travel twisted path.
  - got geometric phase
    - the cavity only resonate w L or R handed state
  - and more,,,





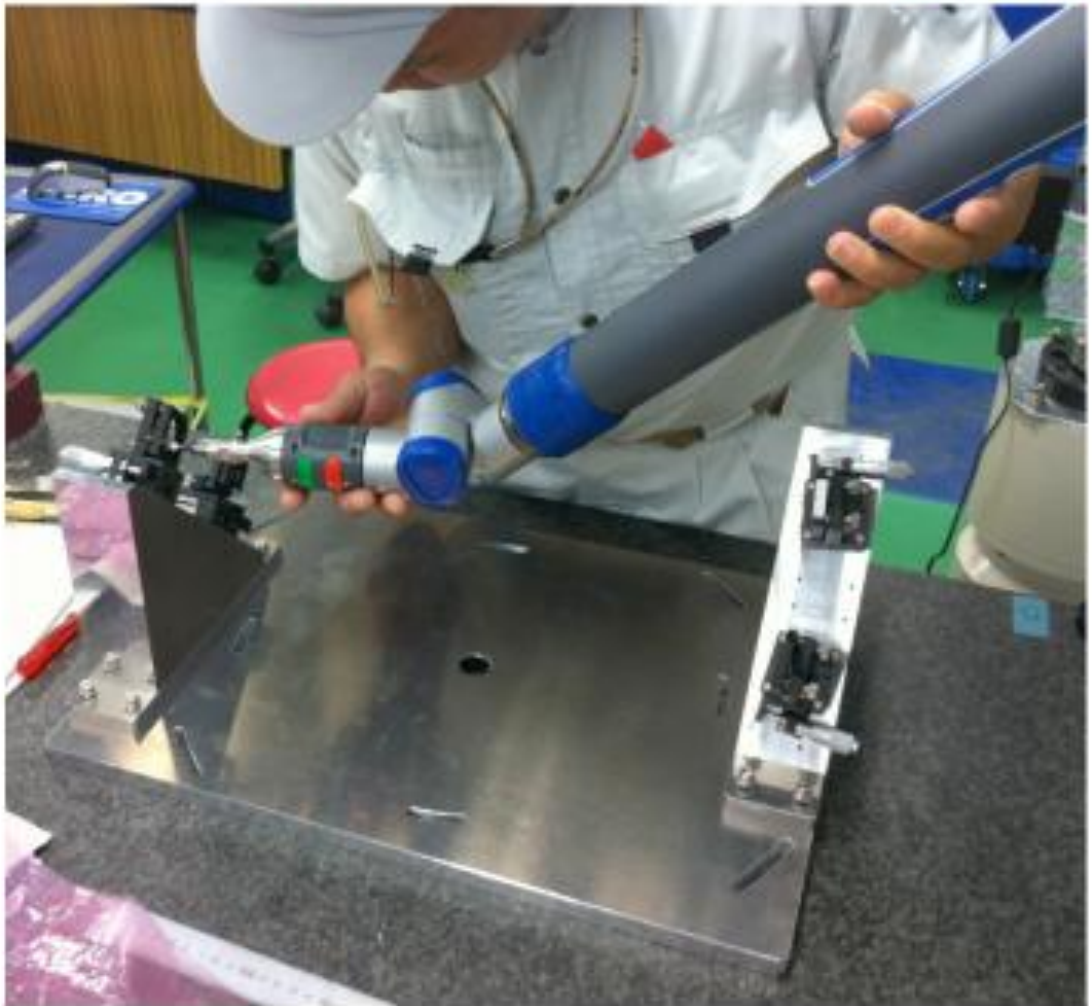
optical feature of the 3D4M cavity
is being studied on test bed

3D Measuring Machine

FaroArm

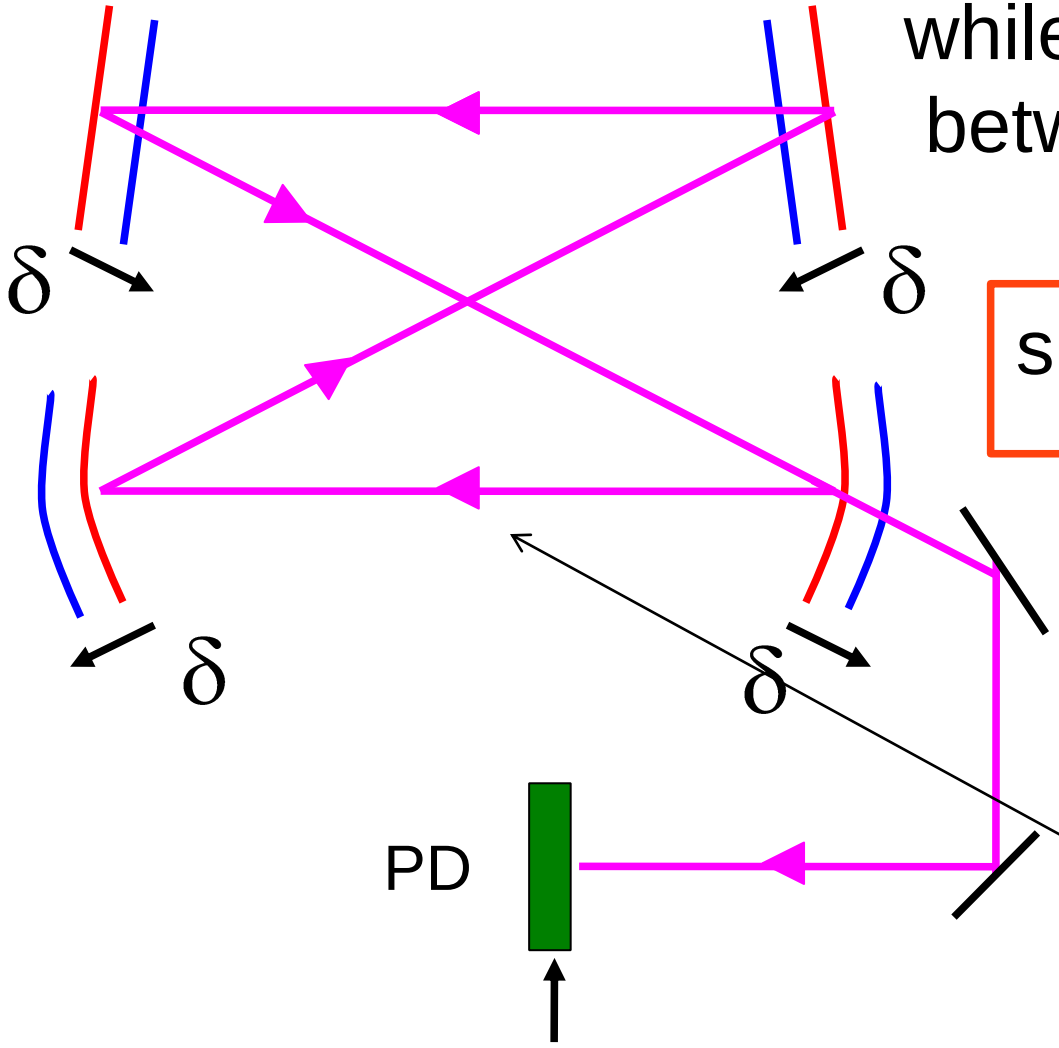
Measure 3D position in 100 micron accuracy.

In order to make comparison with the theoretical model calculations, to reduce ambiguity in geometry is important.



a parameter of the 4M cavity

δ: keeping circumference constant
while changing distance
between mirrors

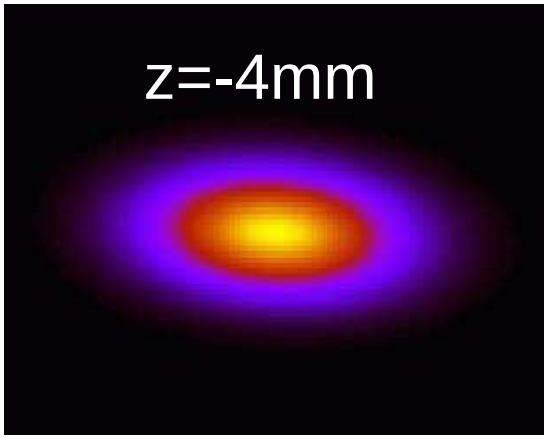


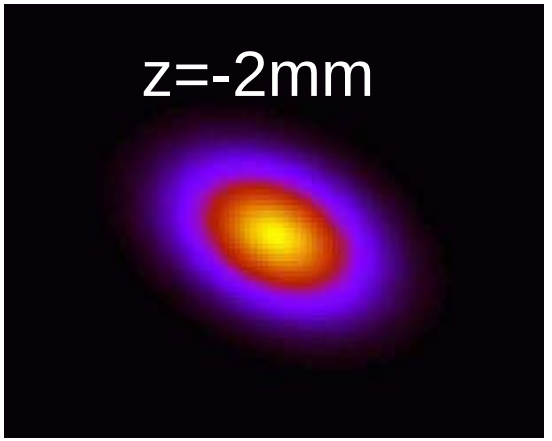
smaller δ : smaller beam waist

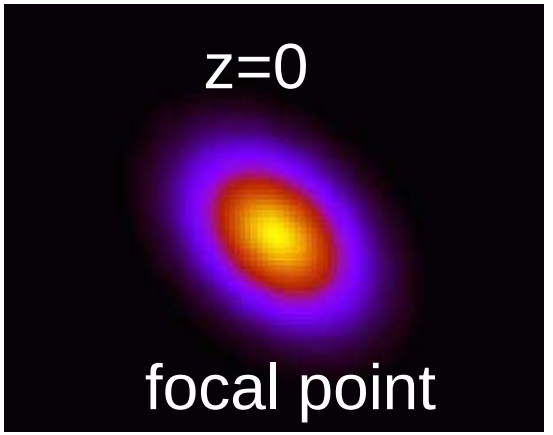
measure beam profile here-->estimate beam size in the cavity

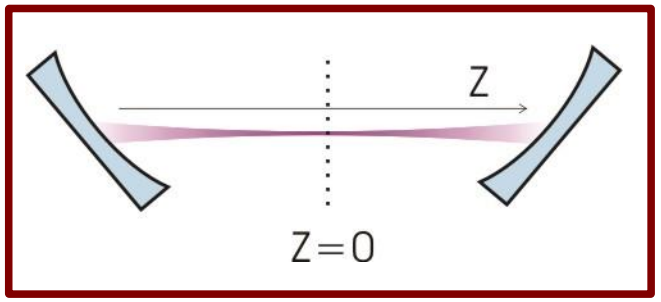
calculated profile around focal point

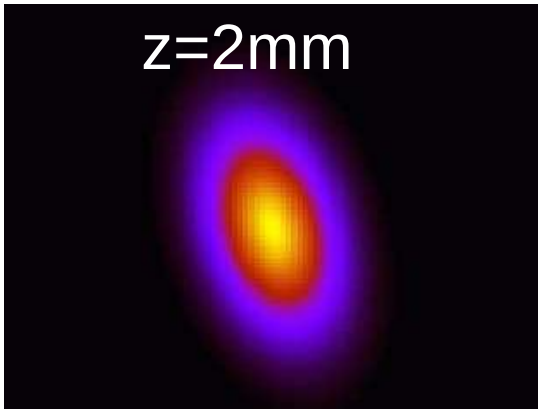
δ=0.2mm,

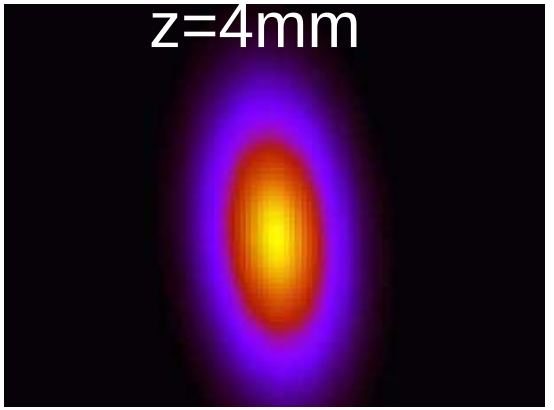








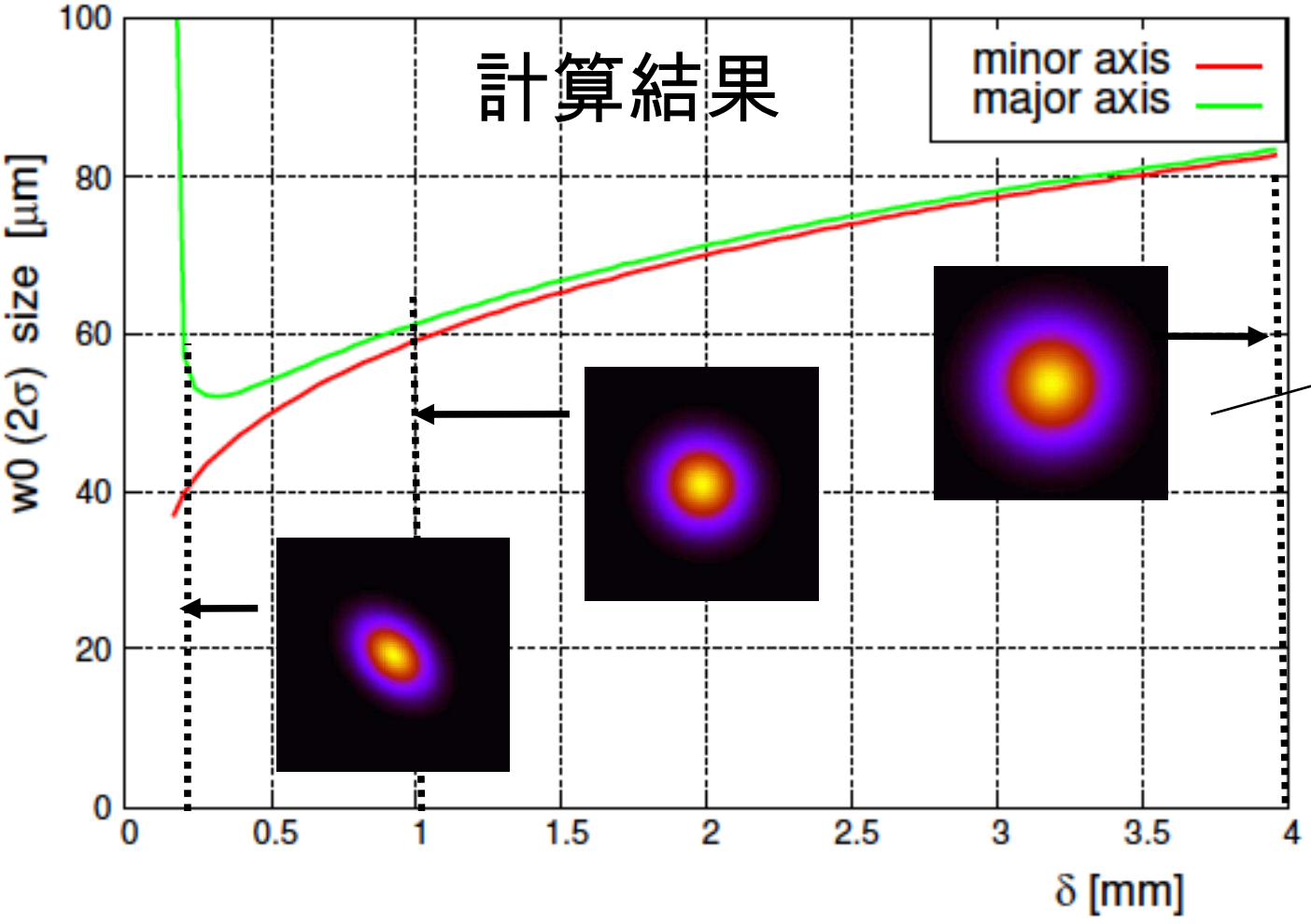


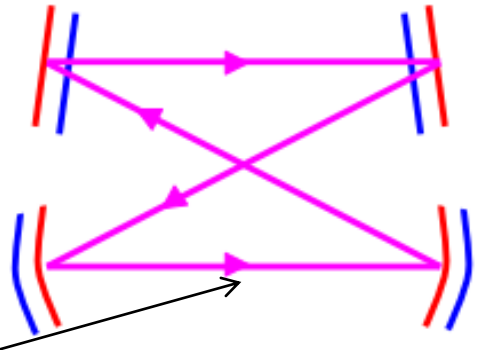


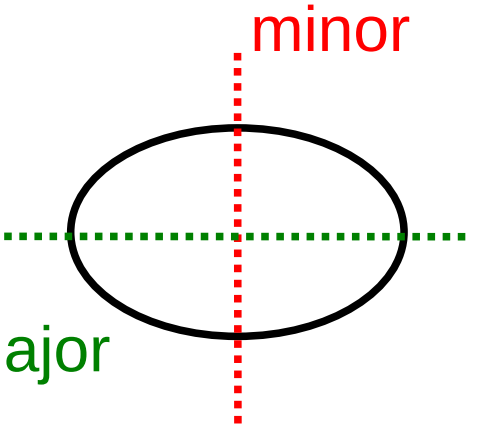
profile is rotating during its propagation!

angular momentum of light

spot size at the center of two focusing mirrors

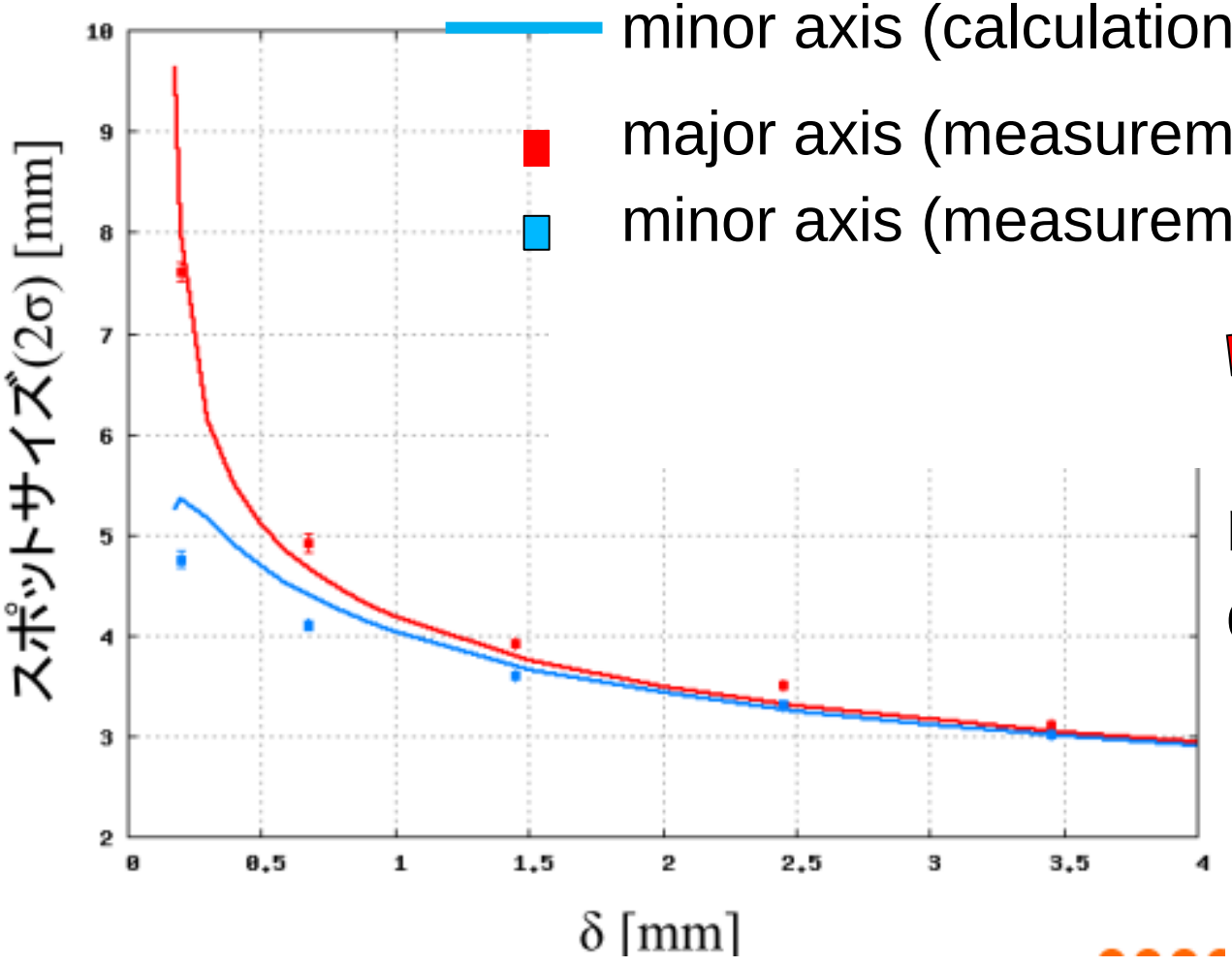


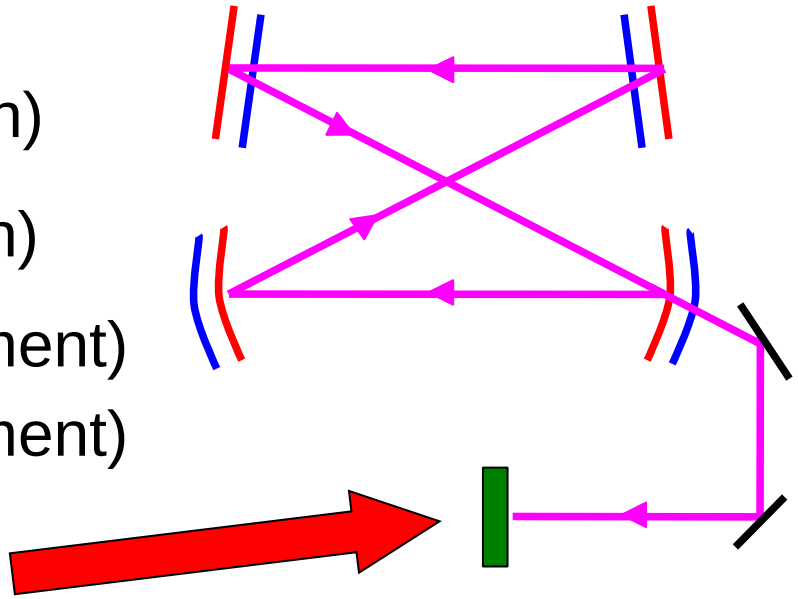




smallest with this prototype
2σ=(52μm、43μm)

Profile of transmitted light



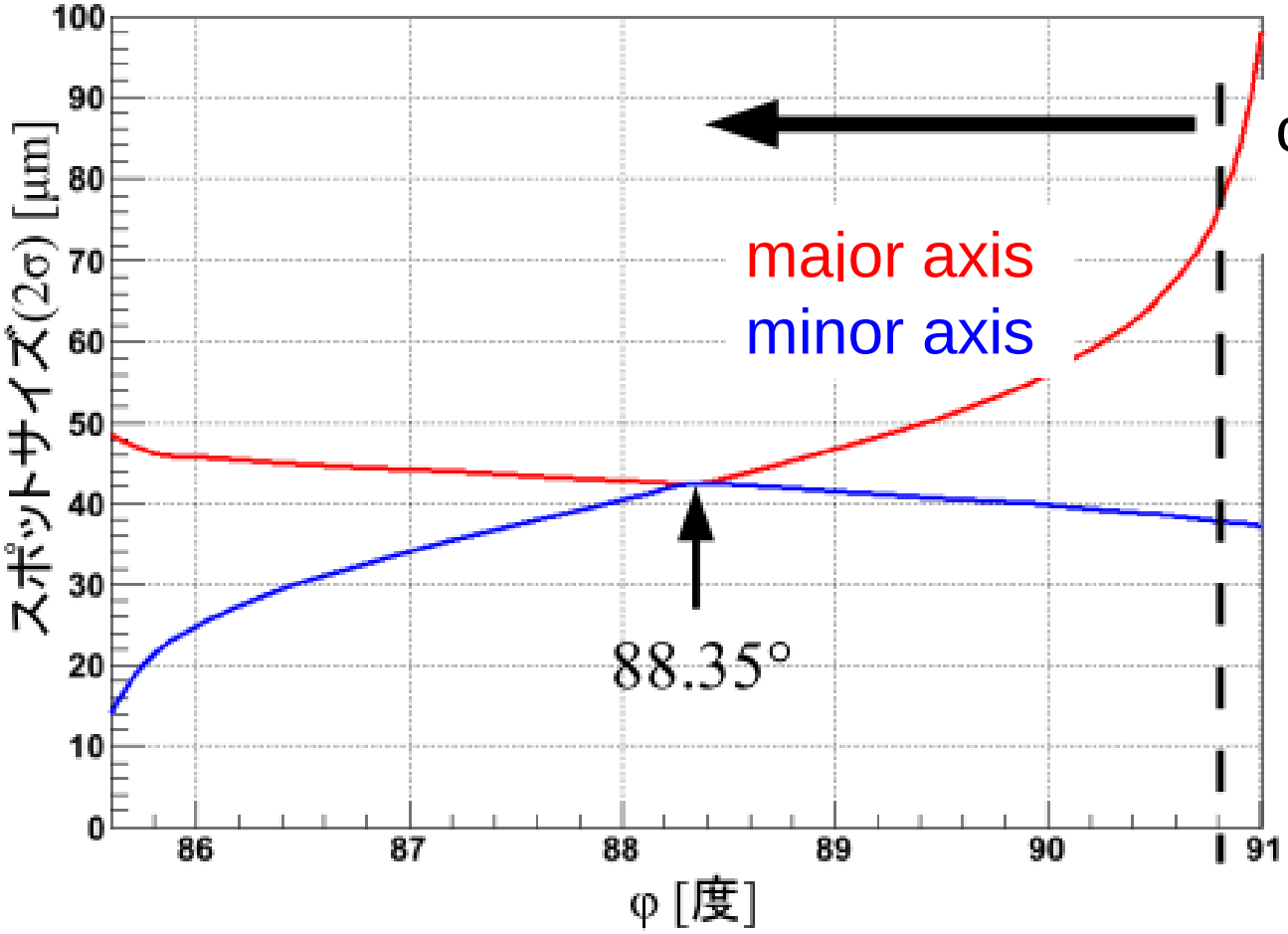


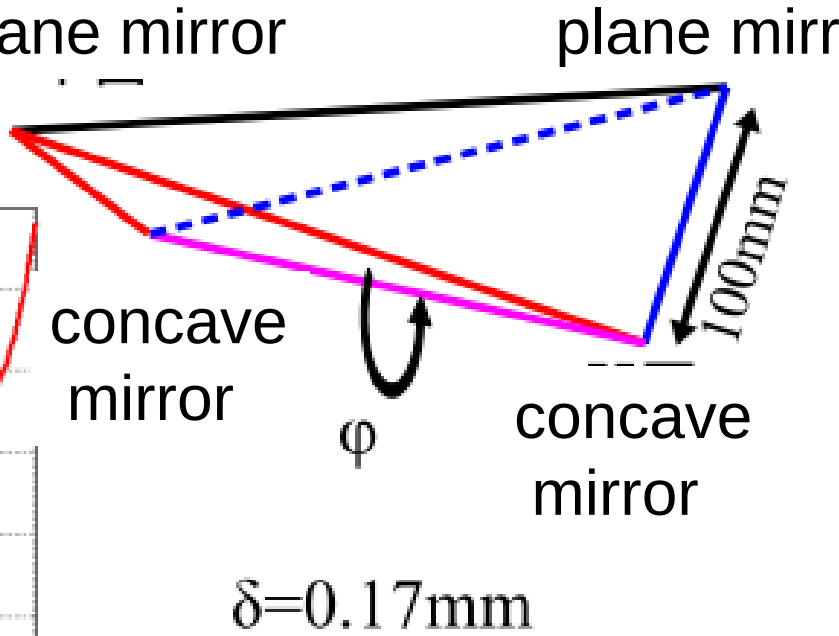
measurements are
consistent with calculatio

find better solution

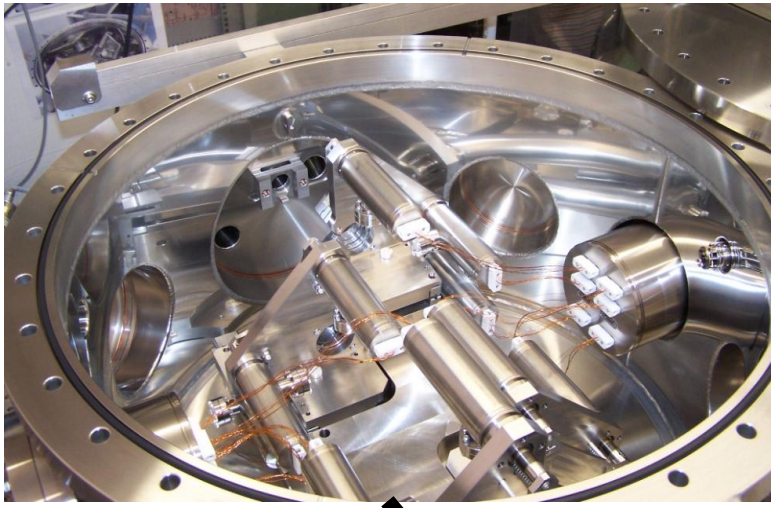
for smaller spot size

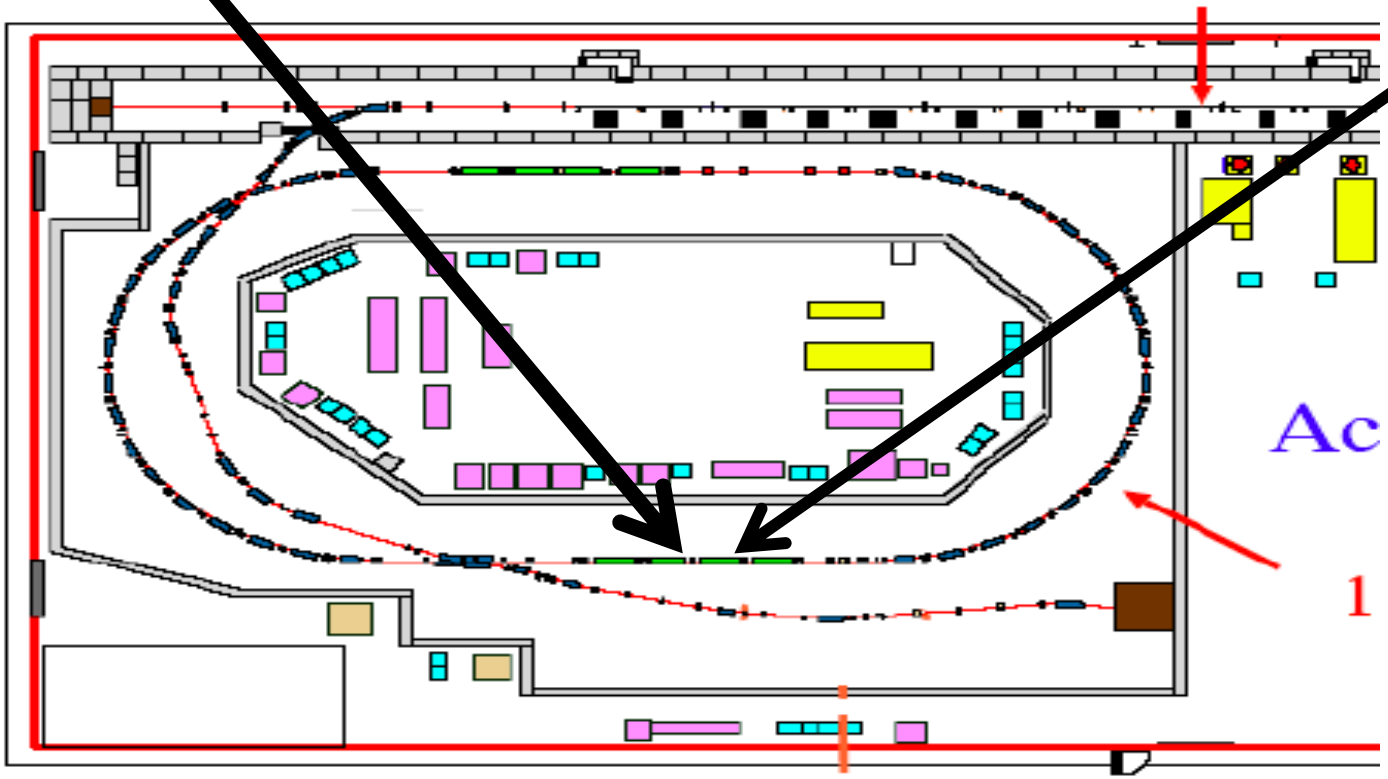
spot size at focal point





LAL cavity has been installed to KEK/ATF



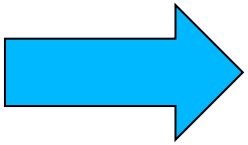


Summary

- good experience and γ ray demonstration at the ATF with 2 mirror cavity

setp by step and steady improvement

- progress understanding of 4 mirror ring cavity through prototype construction and calculation



more complicated but interesting feature of 3D cavity

- In near future

•bunch by bunch information with 2 M cavity

•4M cavity in the ATF ring

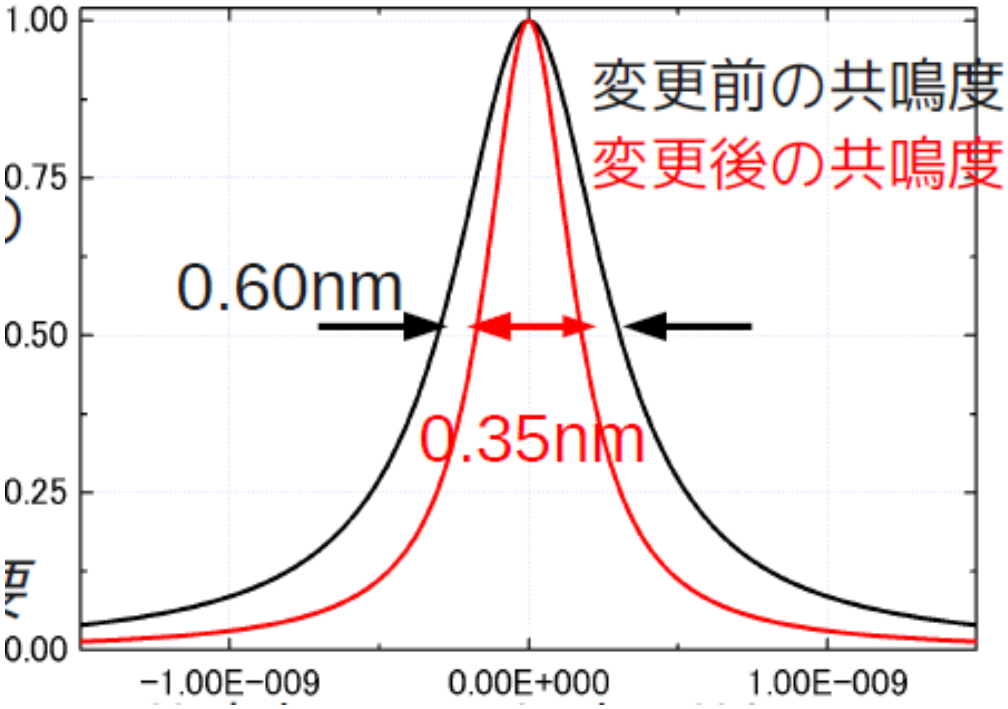
- •LAL cavity installed -> prepared for collisions
- •KEK-Hiroshima type being designed

More enhancement
More precise control

- (99.64%, 99.64%) to (99.64%, 99.94%)
- enhancement: 250 to 760

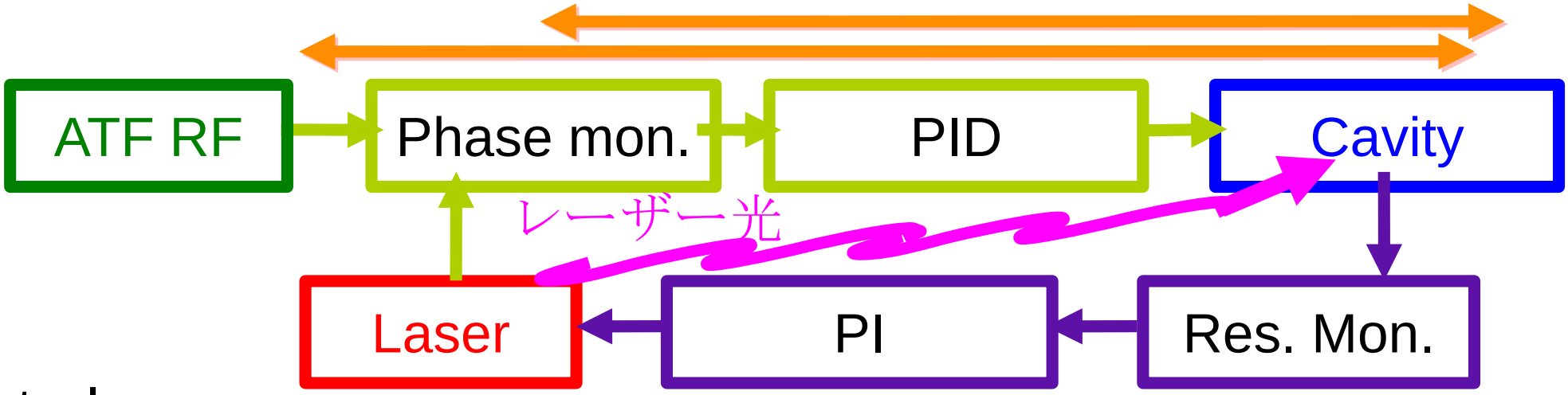
Witdh of resonant peak got down to 0.35nm from 0.60nm

More precise(~faster) control of cavity



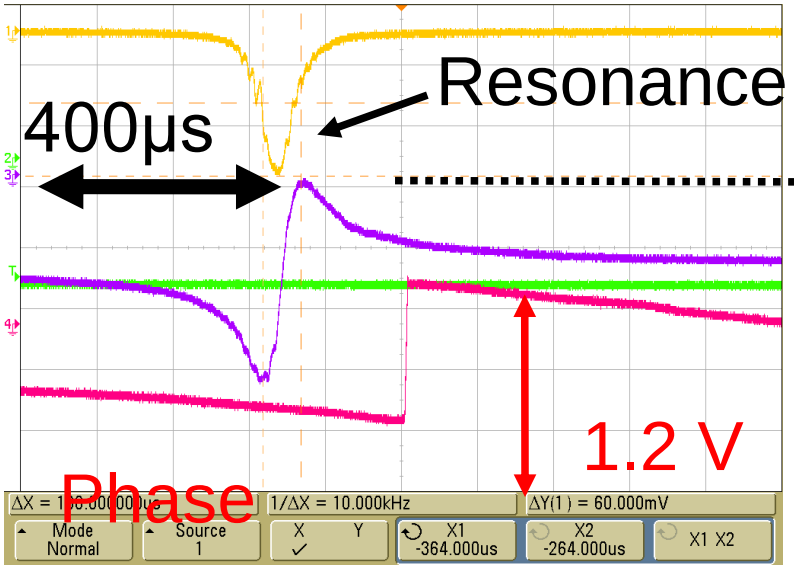
cavity length [nm]

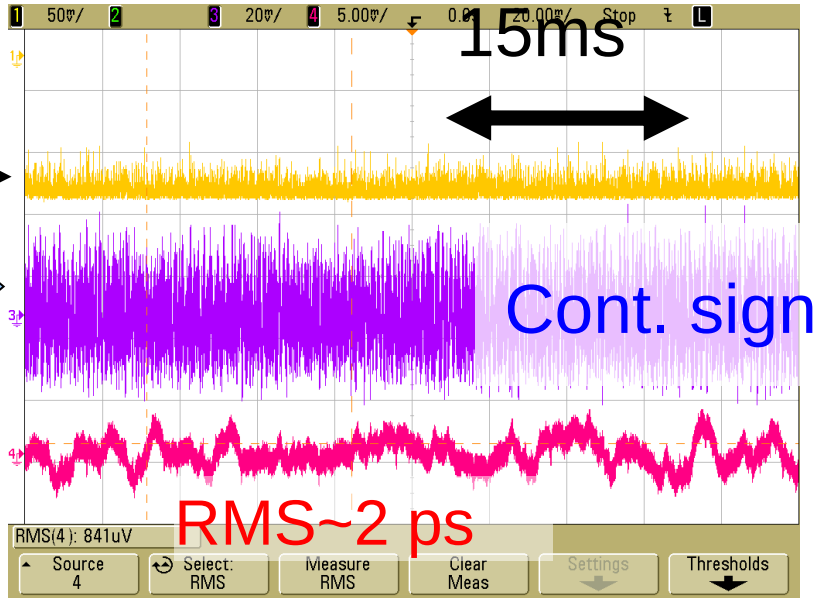
Feed back system in 2008



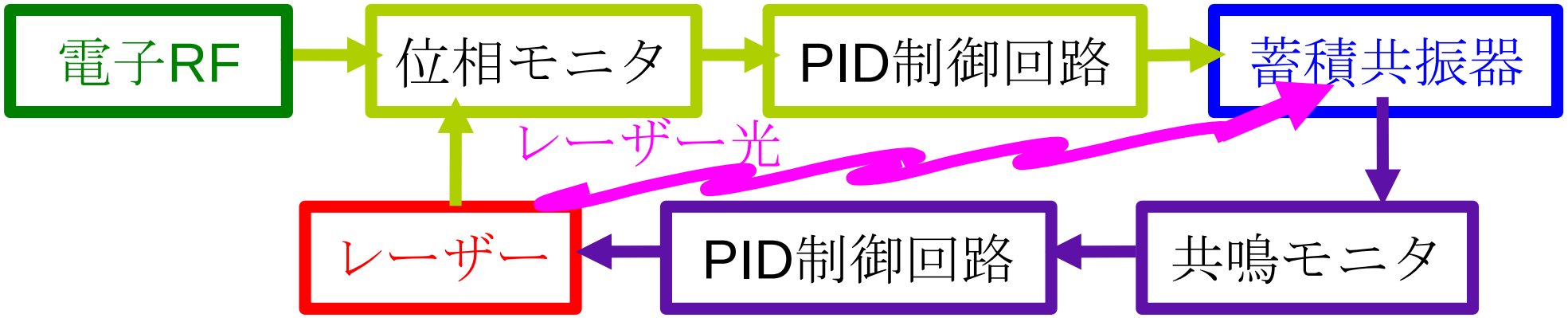
Control:
Laser to keep resonance
Cavity for timing synchronization

Keeping resonance at
250 enhacement
with timing jitter ~2ps





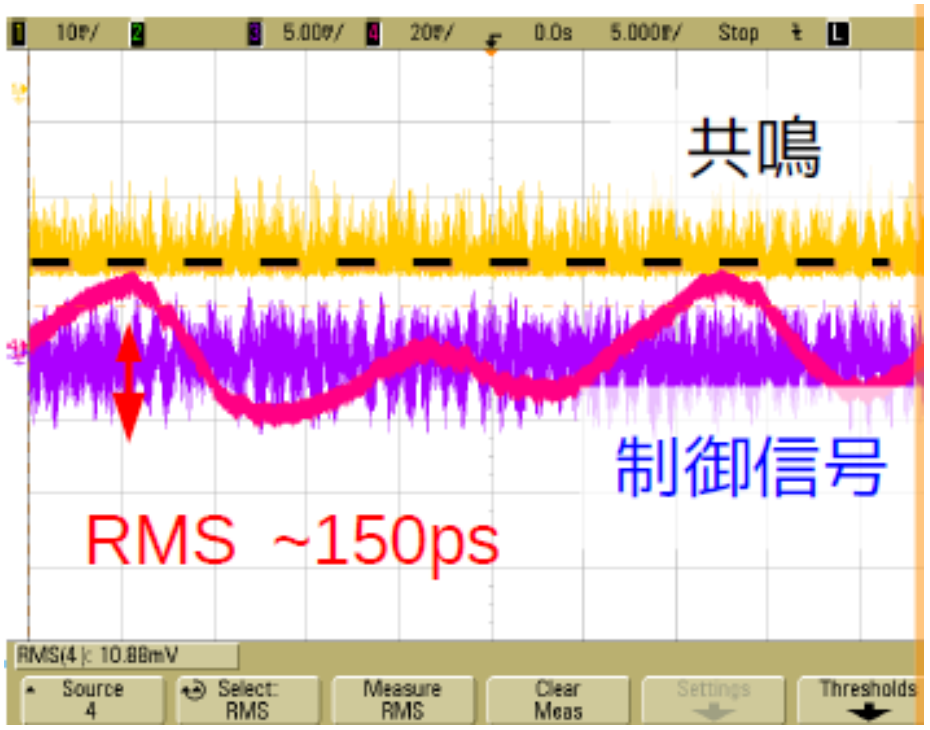
Initial performance with 760 enhancement



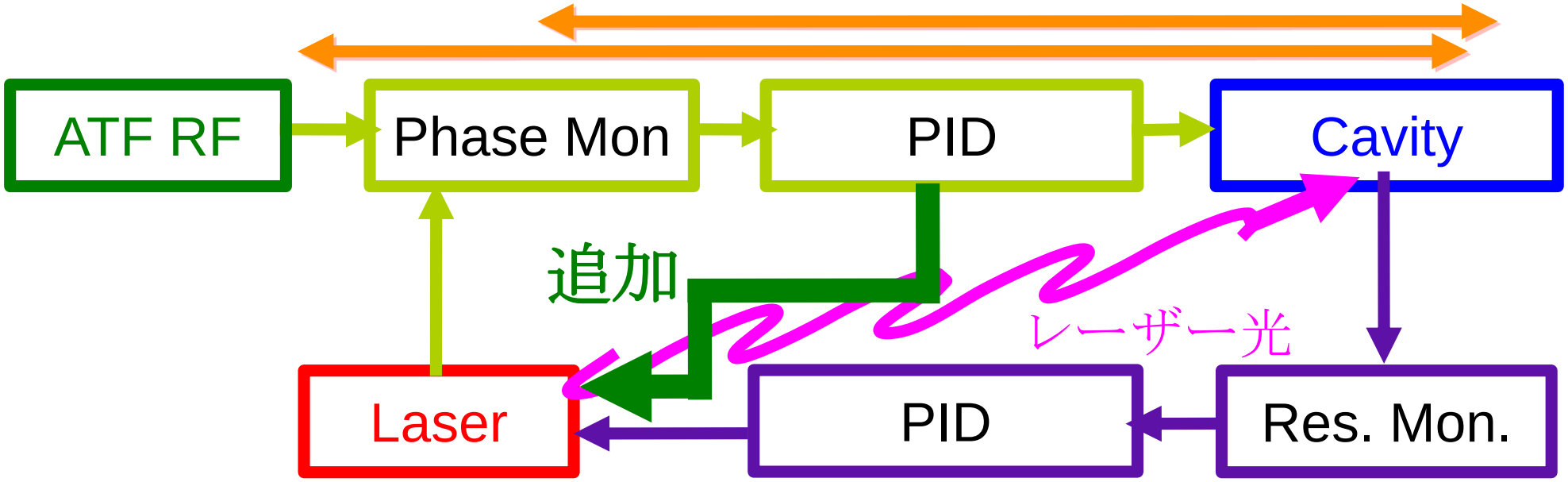
Faster feed back to laser to keep resonance

Larger fluctuation of laser timing

timing control could not follow

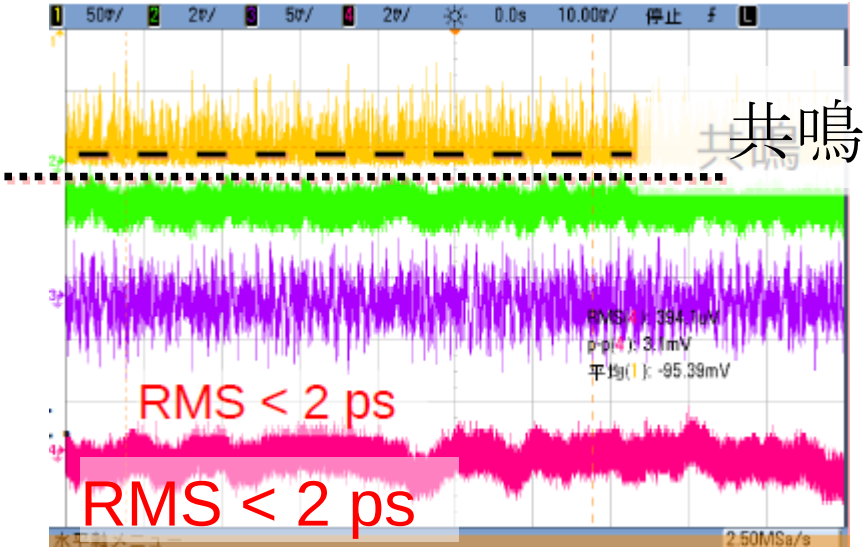


New feedback system

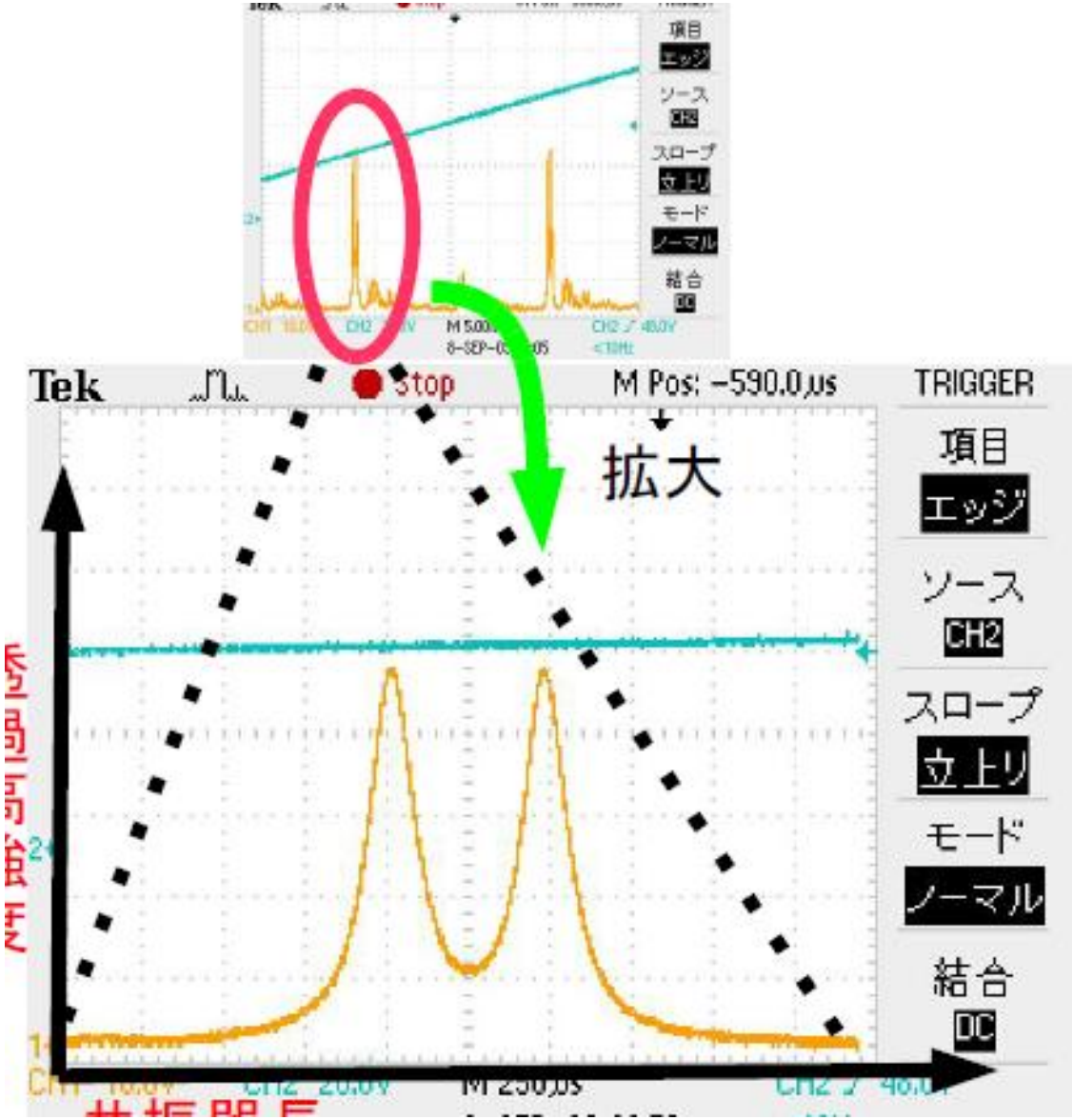


New feedback control
+ improve emviromnet

Timing jitter is now < 2ps



at ALCPG09

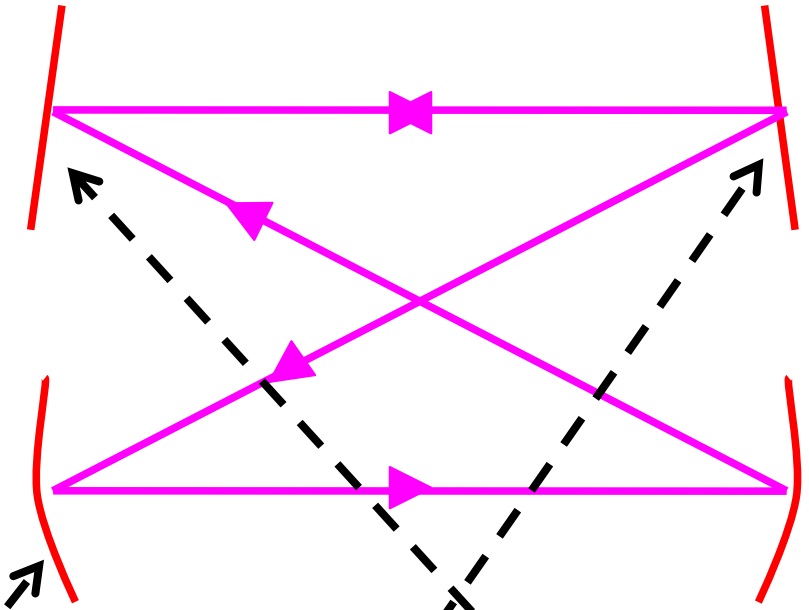


3D 4M cavity resonates with left and right circular polarizaton separately

This is due to geometric phase since light travels twisted path

but situation was more complicated

Image rotation during light propagation



M(z)=D(L/2).R(θ).F(f2,f1).D(L).R(θ).D(L).R(θ).D(L).R(θ).F(f1,f2).D(L/2)

$$R[\theta] = \begin{pmatrix} \cos\theta & \sin\theta & 0 & 0 \\ -\sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & \cos\theta & \sin\theta \\ 0 & 0 & -\sin\theta & \cos\theta \end{pmatrix}$$