Status and Plan of Compton γ-ray Generation at KEK-ATF

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for

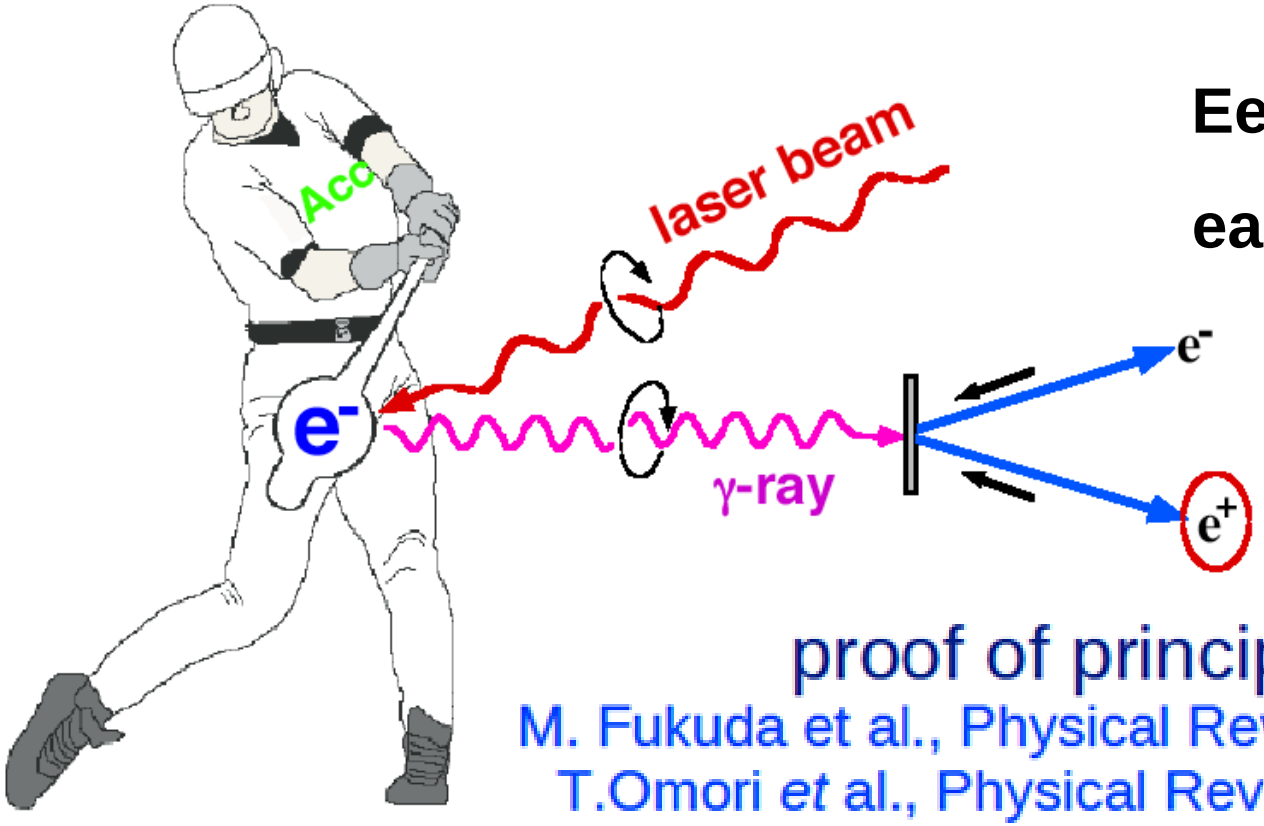
Japanese Labs. : KEK, ATF group,
Hiroshima University

13 February 2014
ATF Project Meeting at KEK

Laser-Compton Scheme and Laser Pulse Stacking

Introduction

- Polarized e+ by laser Compton Scheme



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

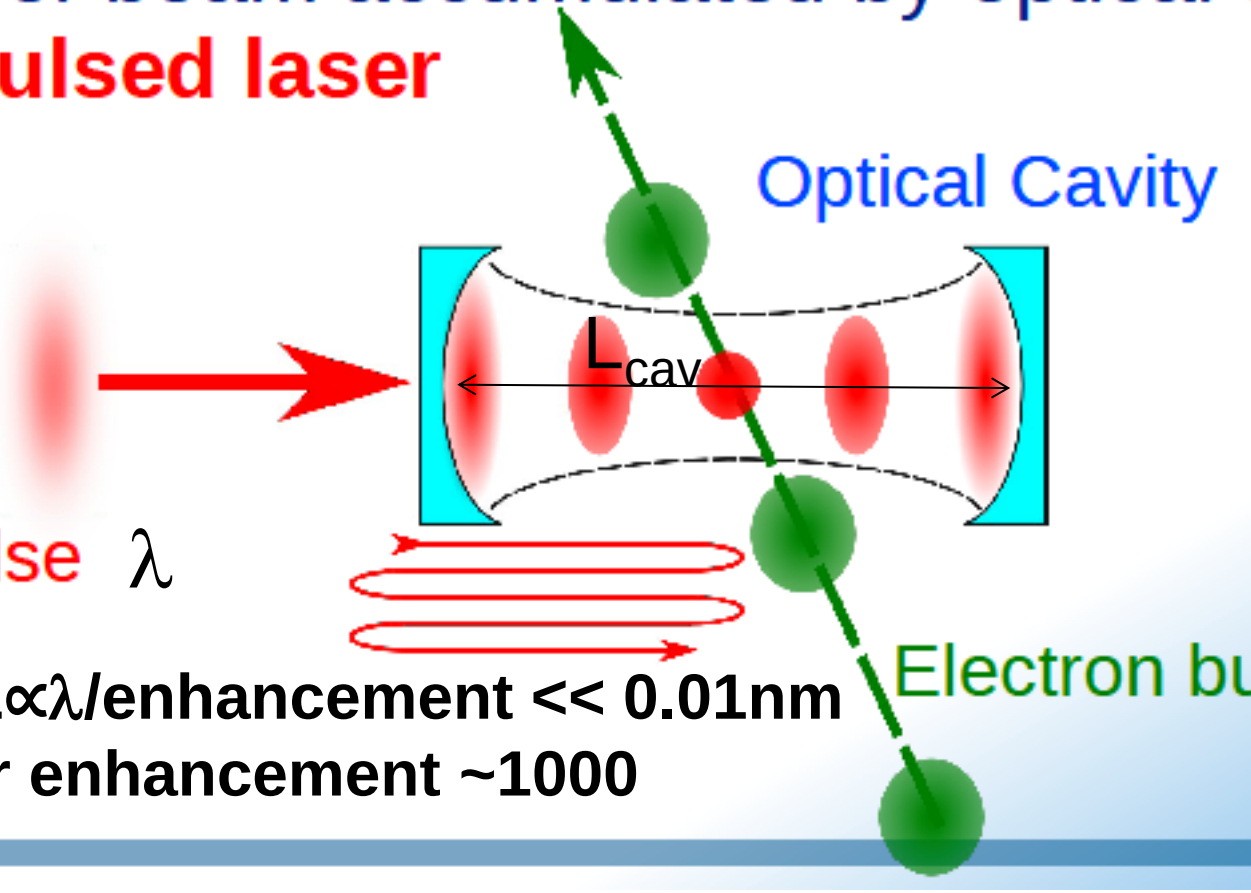
Miyoshi PosiPol2010

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

➡ **enhancement with optical cavity**

Laser beam accumulated by optical cavity

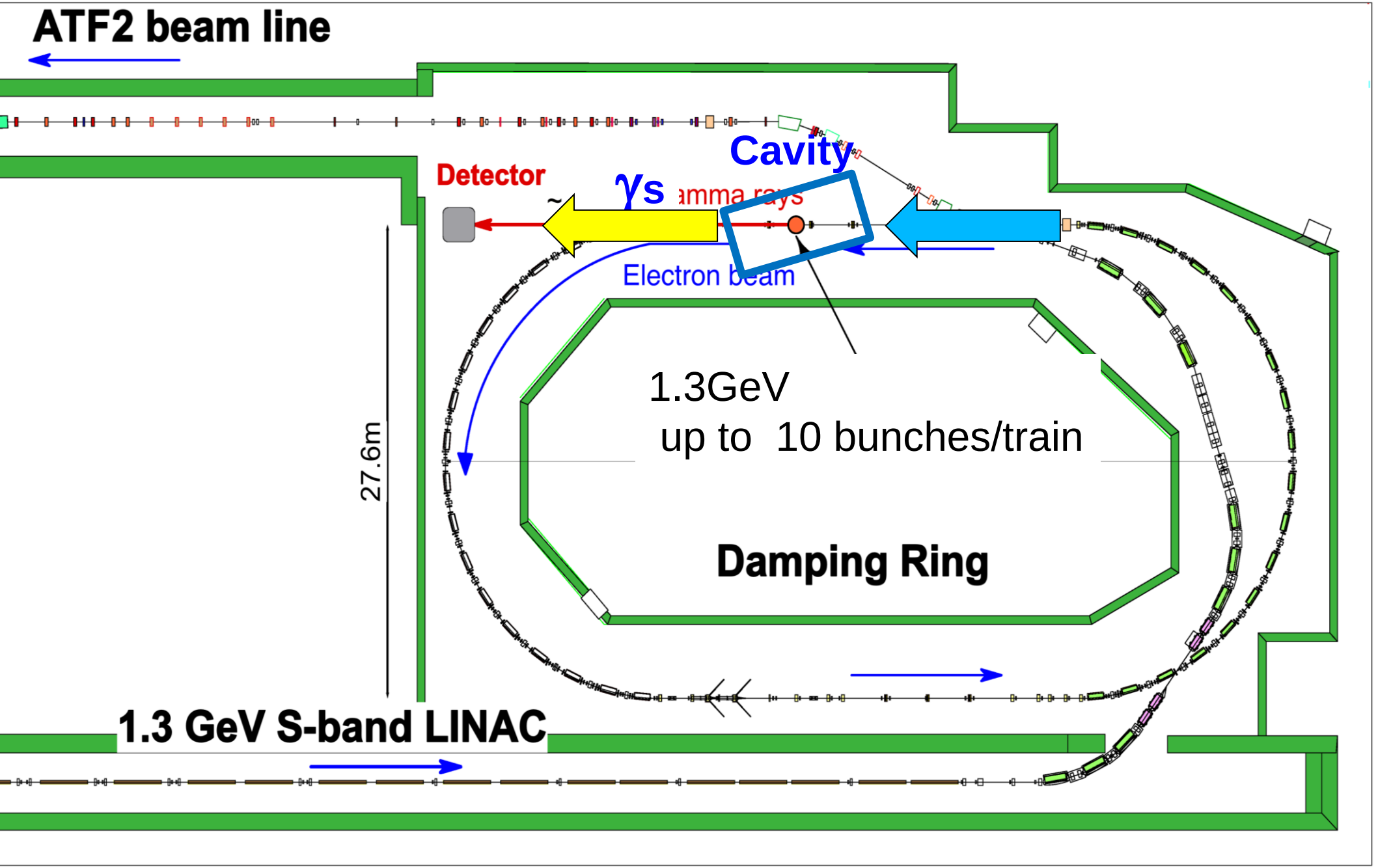
➡ **use pulsed laser**



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

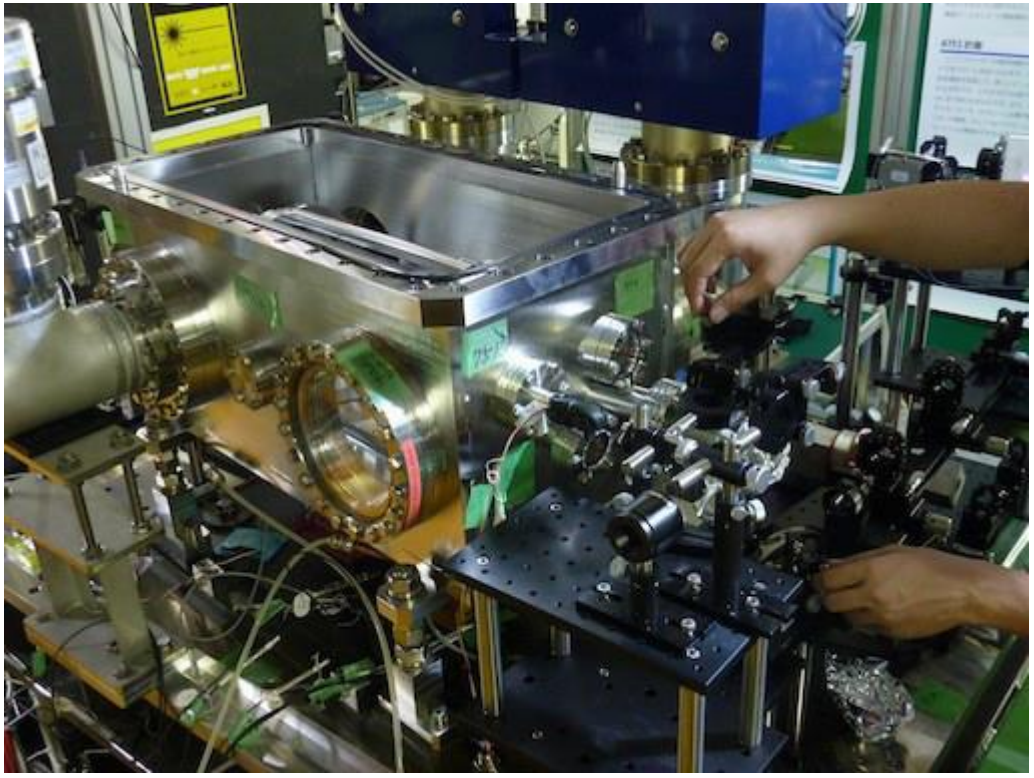
dL∝λ/enhancement << 0.01nm
for enhancement ~1000

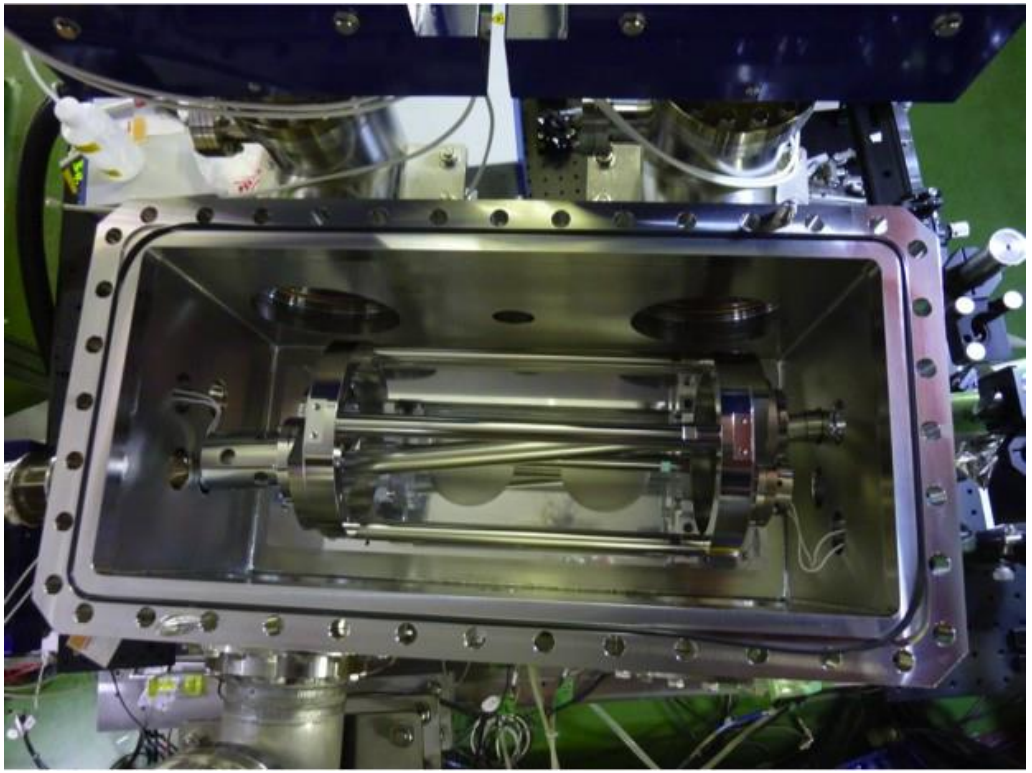
Experiments at the KEK ATF



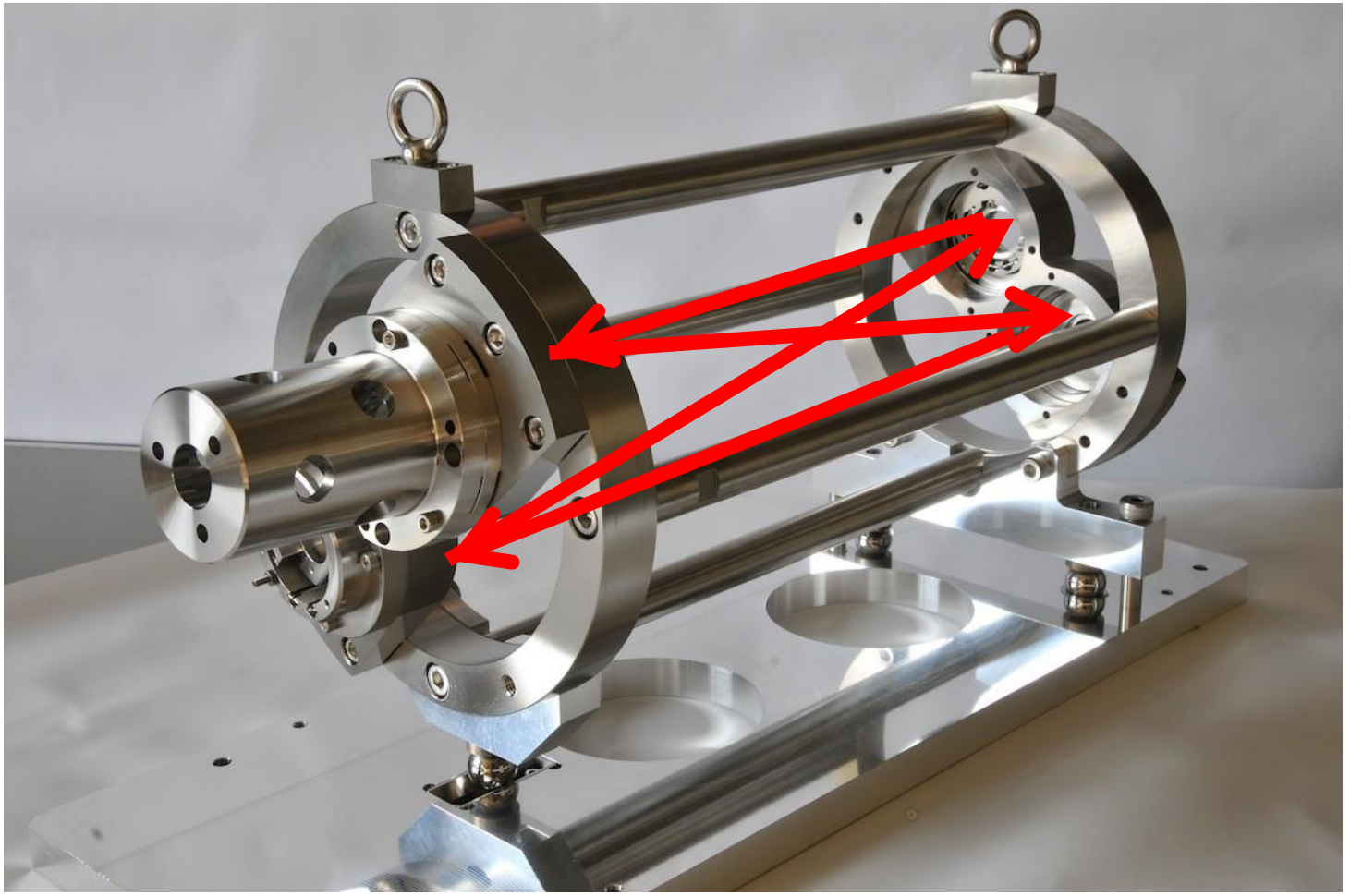
KEK-Hiroshima 4-mirror Cavity

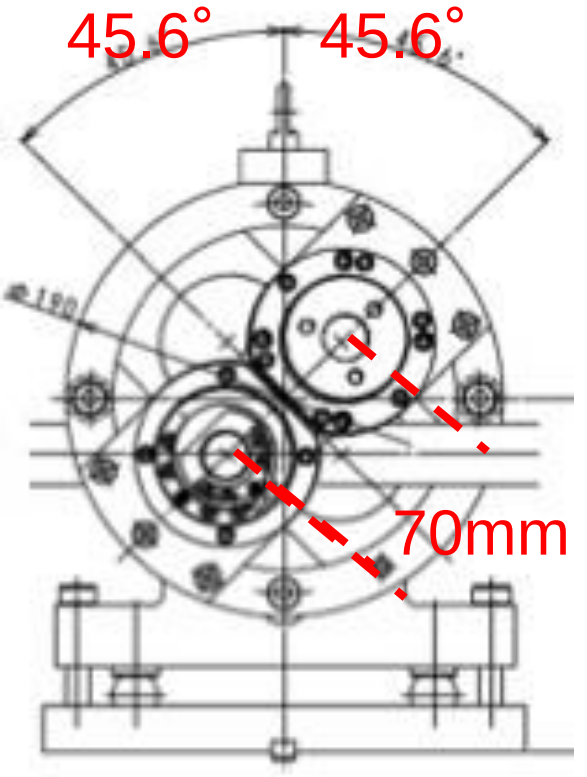
2011 Autumn: New KEK-Hiroshima Cavity was Installed





New KEK-Hiroshima Cavity (4-Mirror Cavity)

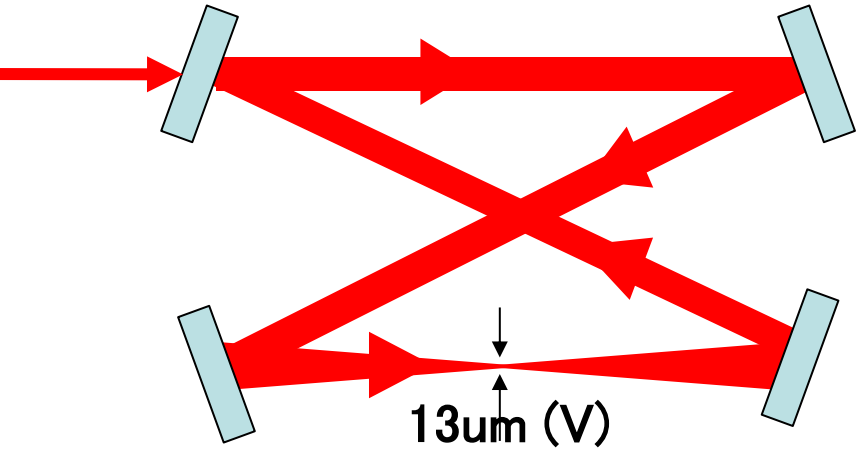


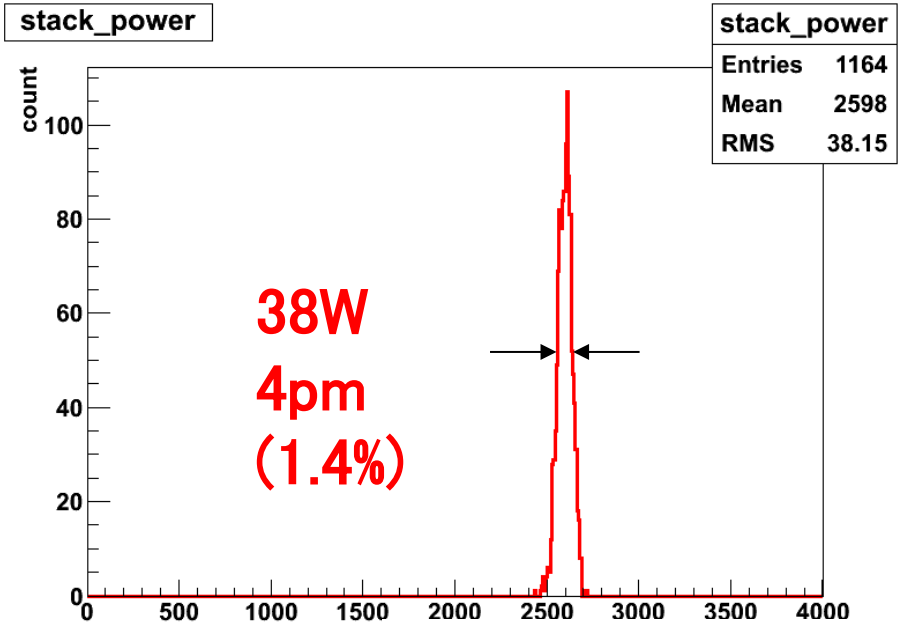


3D configuration (twisted) for round profile

Stable resonance with small spot size

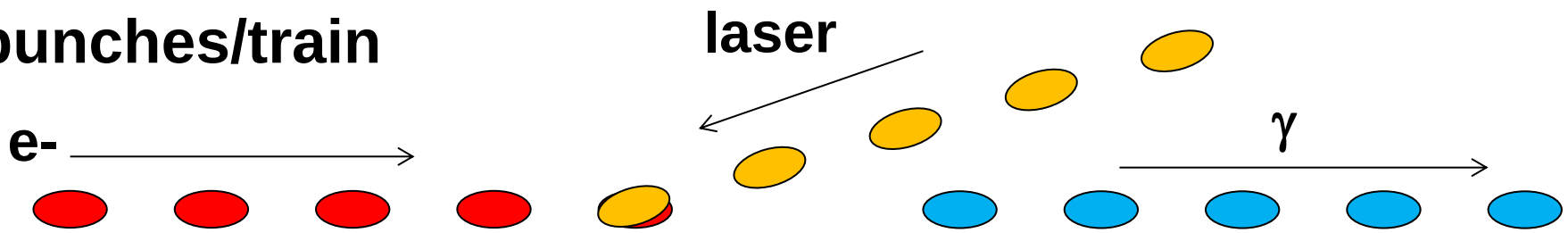
- Stable resonance by new feedback sys. (analog)
- 2.6kW average power w/ 1.4% fluctuation
- laser waist size at IP(σ)=13um (vertical scan)
- Finesse 4040+−110 (Enhance = 1200)





γ-ray Generation / electron

5bunches/train



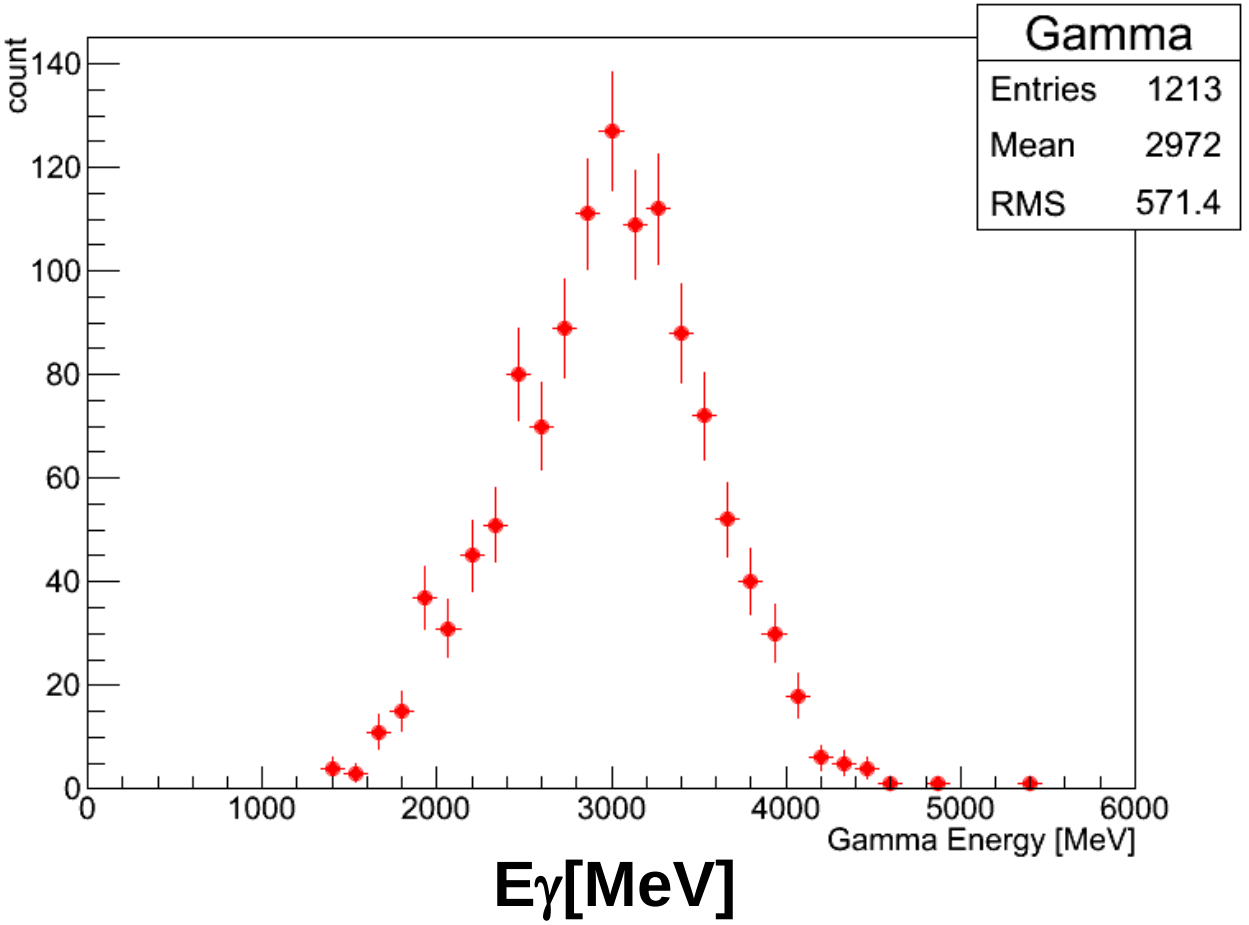
5.6ns

2970±20 MeV

⇒ ~128γs/train

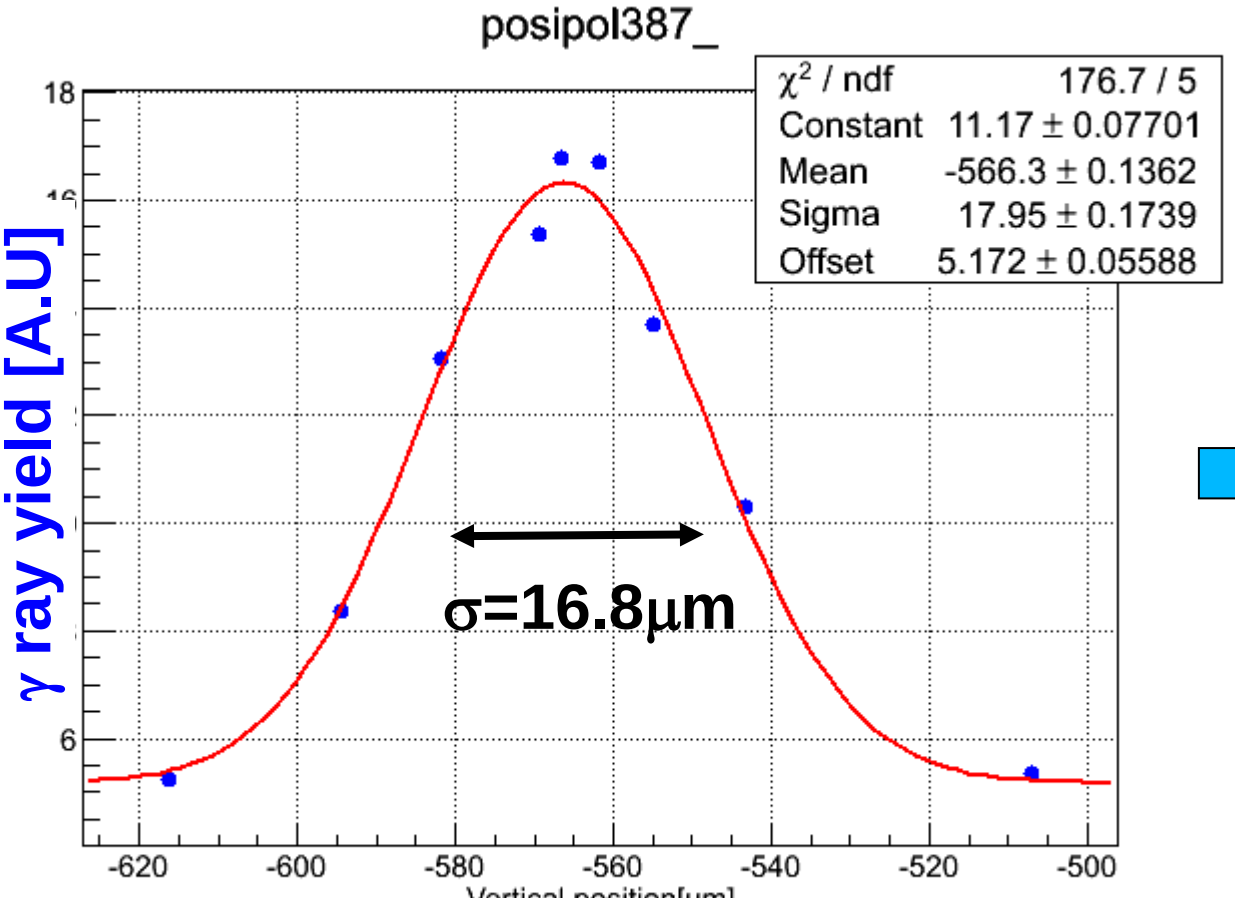
ATF 2.16MHz

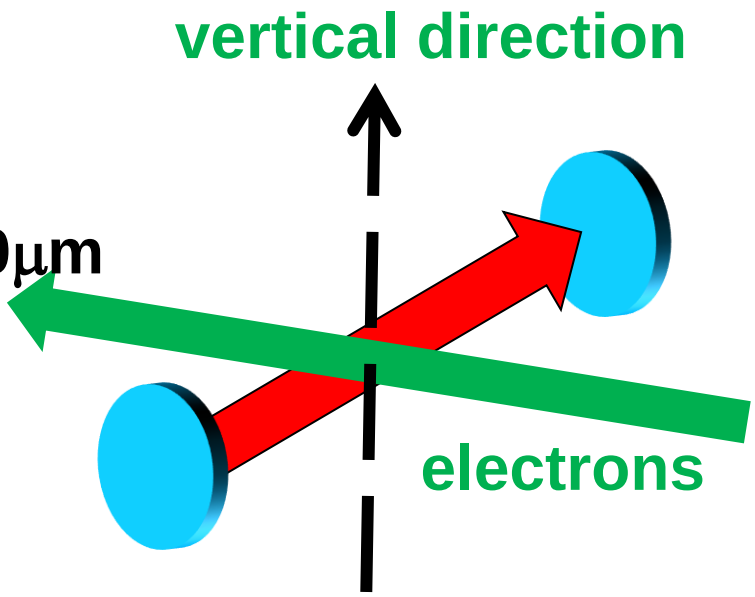
~2.6×10^8/sec



Eγ[MeV]

Laser vertical spot size 13μm achieved



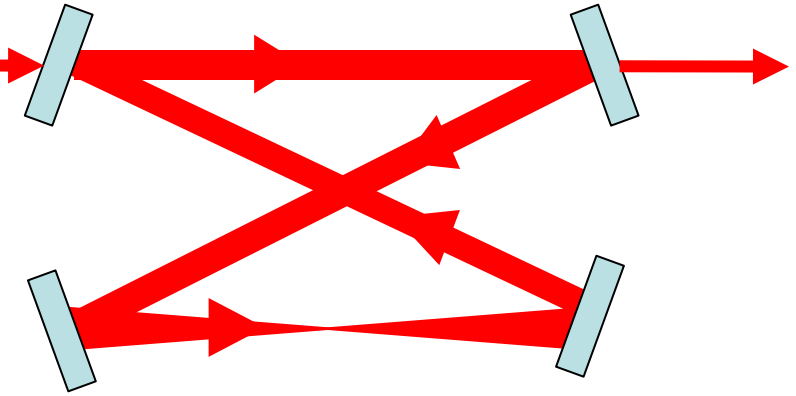


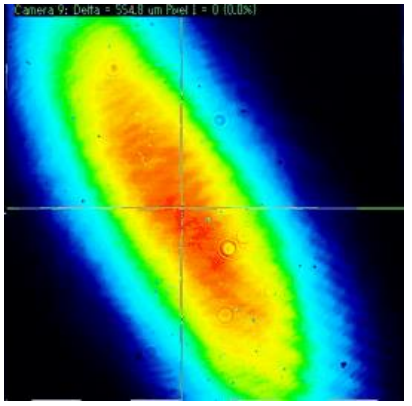
σL(V) =13μm

it was 30μm w/ 2 M cavity

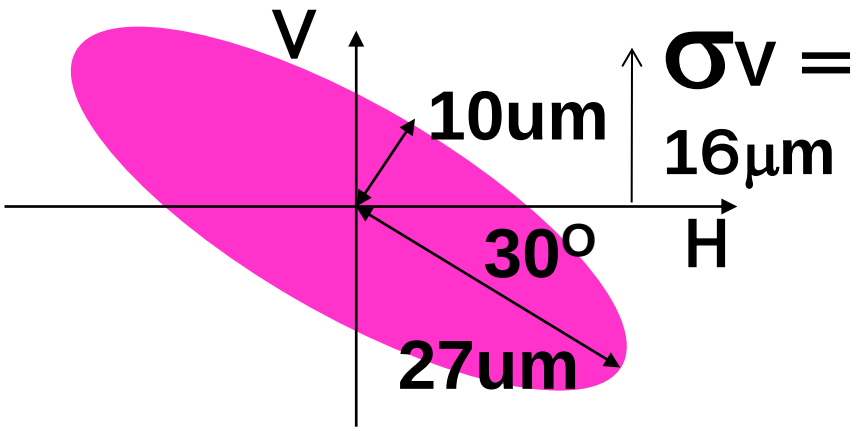
Laser profile at IP

Proflie measurement
of transmission light



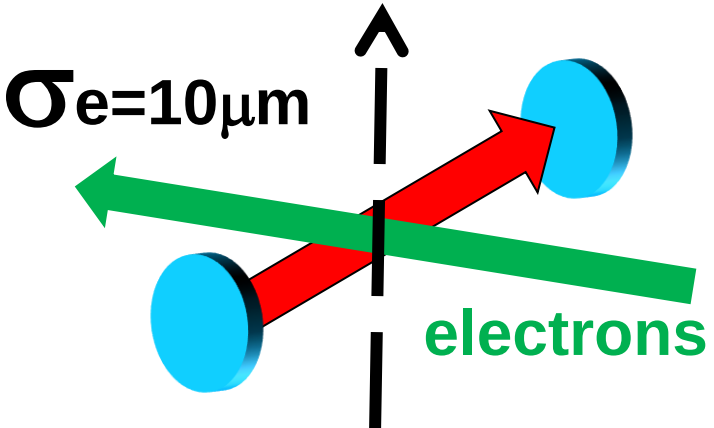


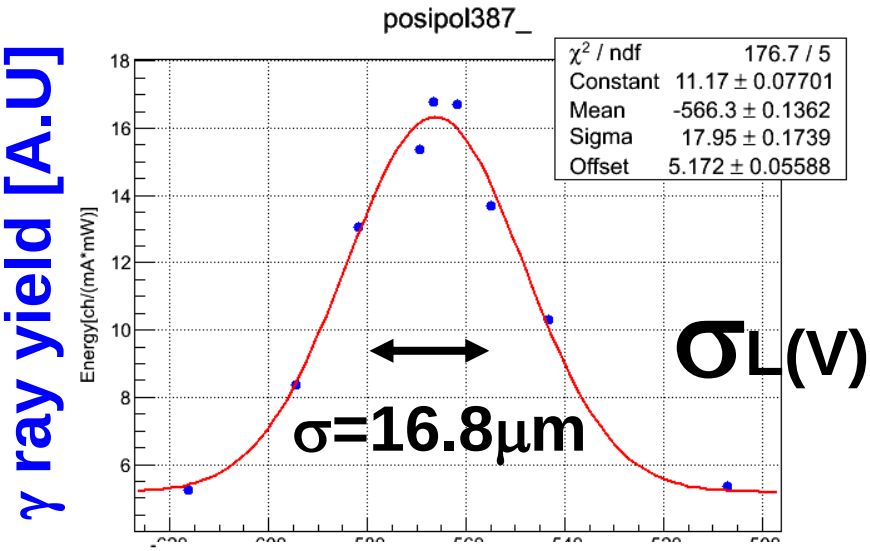
Proflie Estimation
at IP vis T_matrix



Vertical Position Scan

vertical direction

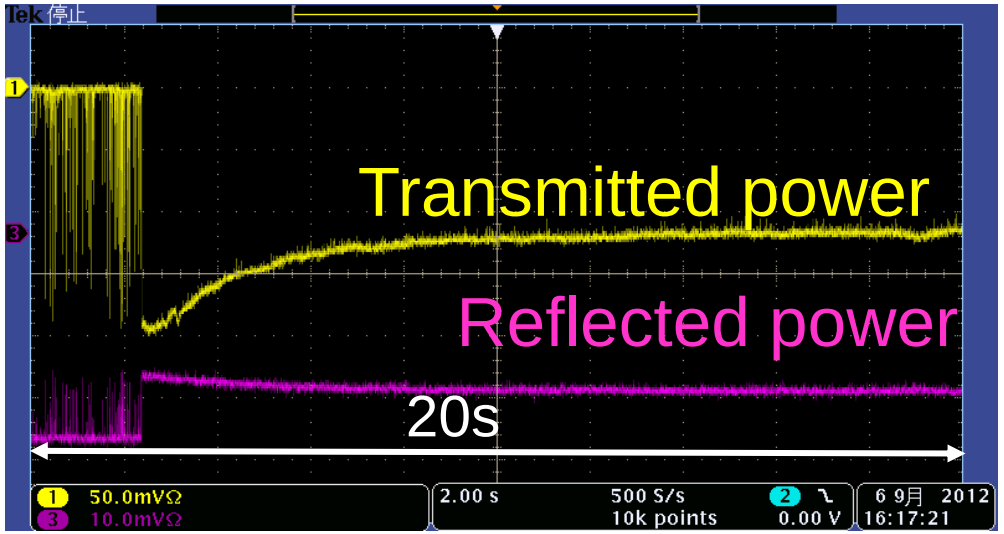




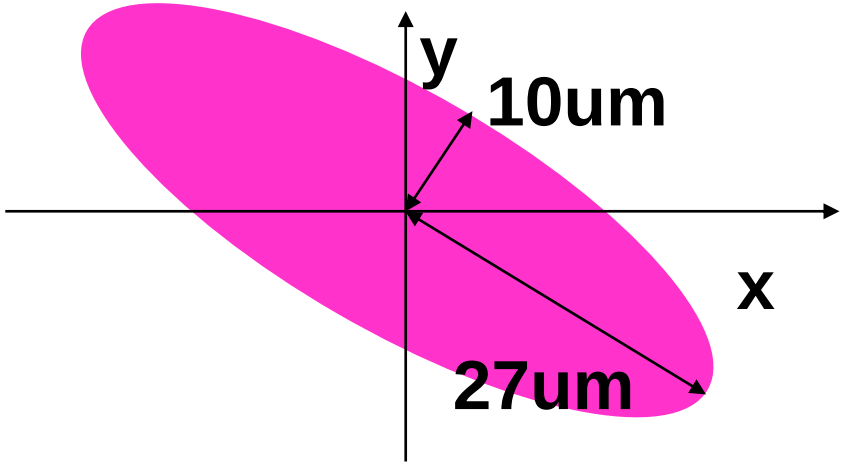
Issues

Issues

Issue (1)



Issue (2)



- **Possibly a thermal effect**

  Stored power decrease as time goes

  due to (unexpected) power loss on mirrors

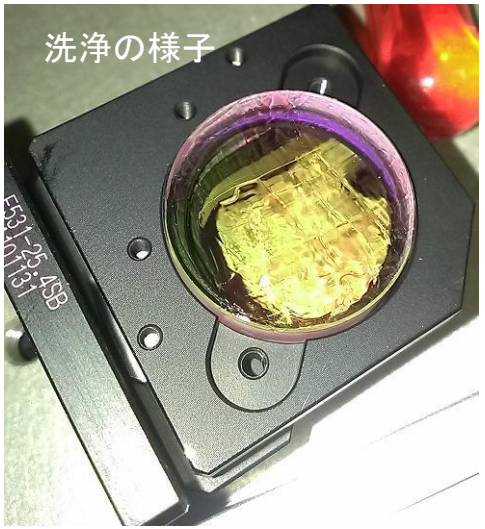
- **Profile at the IP**

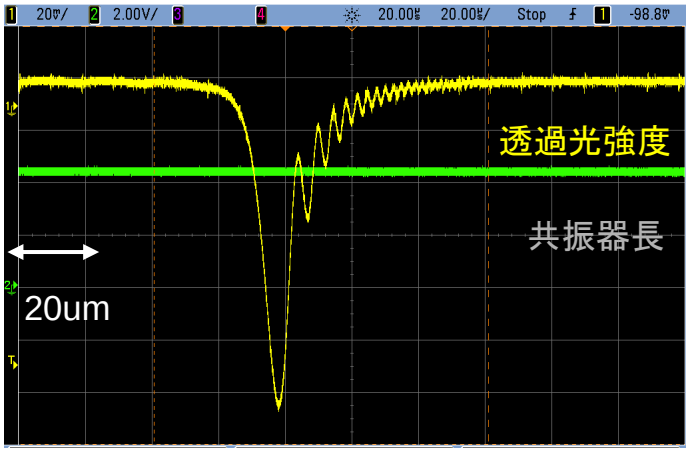
  Not round

  must revisit optical property in the cavity

Issue (1) Cure:

Cleaning the mirrors w/ First Contact





Before

R = 0.999846 + - 0.000003 (Loss：50ppm)

After

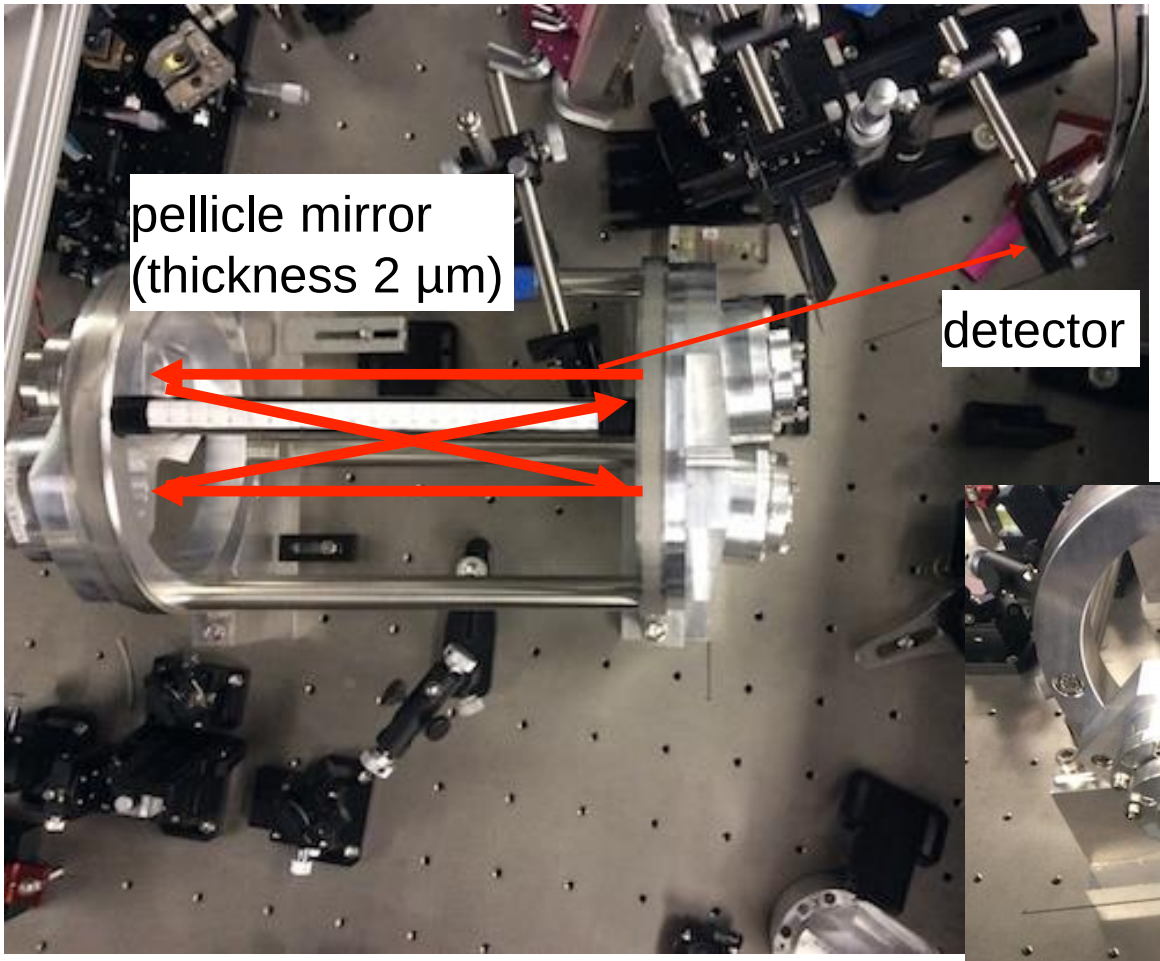
R = 0.999864 + - 0.000003 (Loss：30ppm)

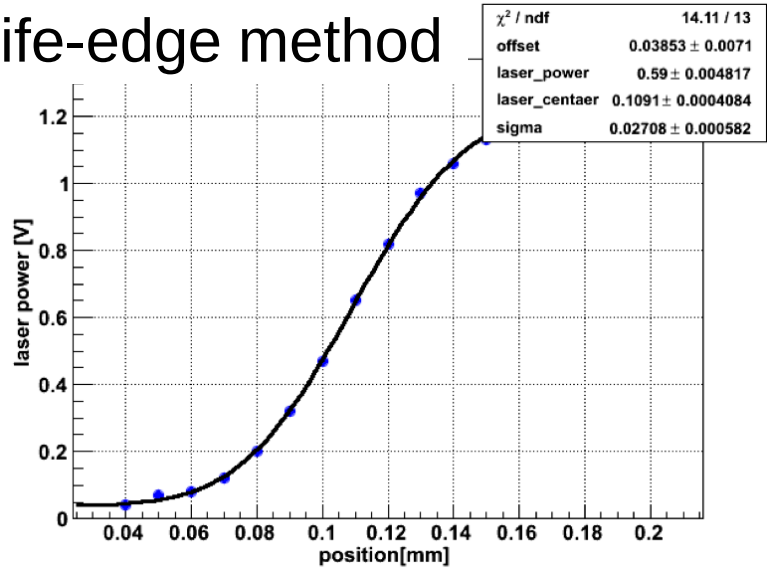
Issue (1) Cure:

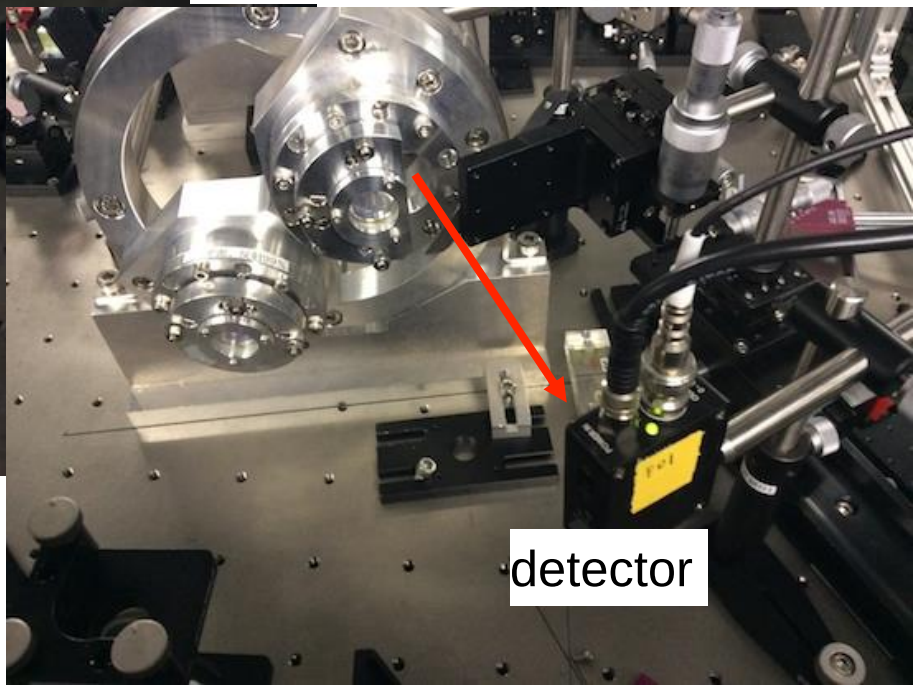
We must be

Issue (2) Study:
Quasi-direct Profile measurement at / near IP

knife-edge method

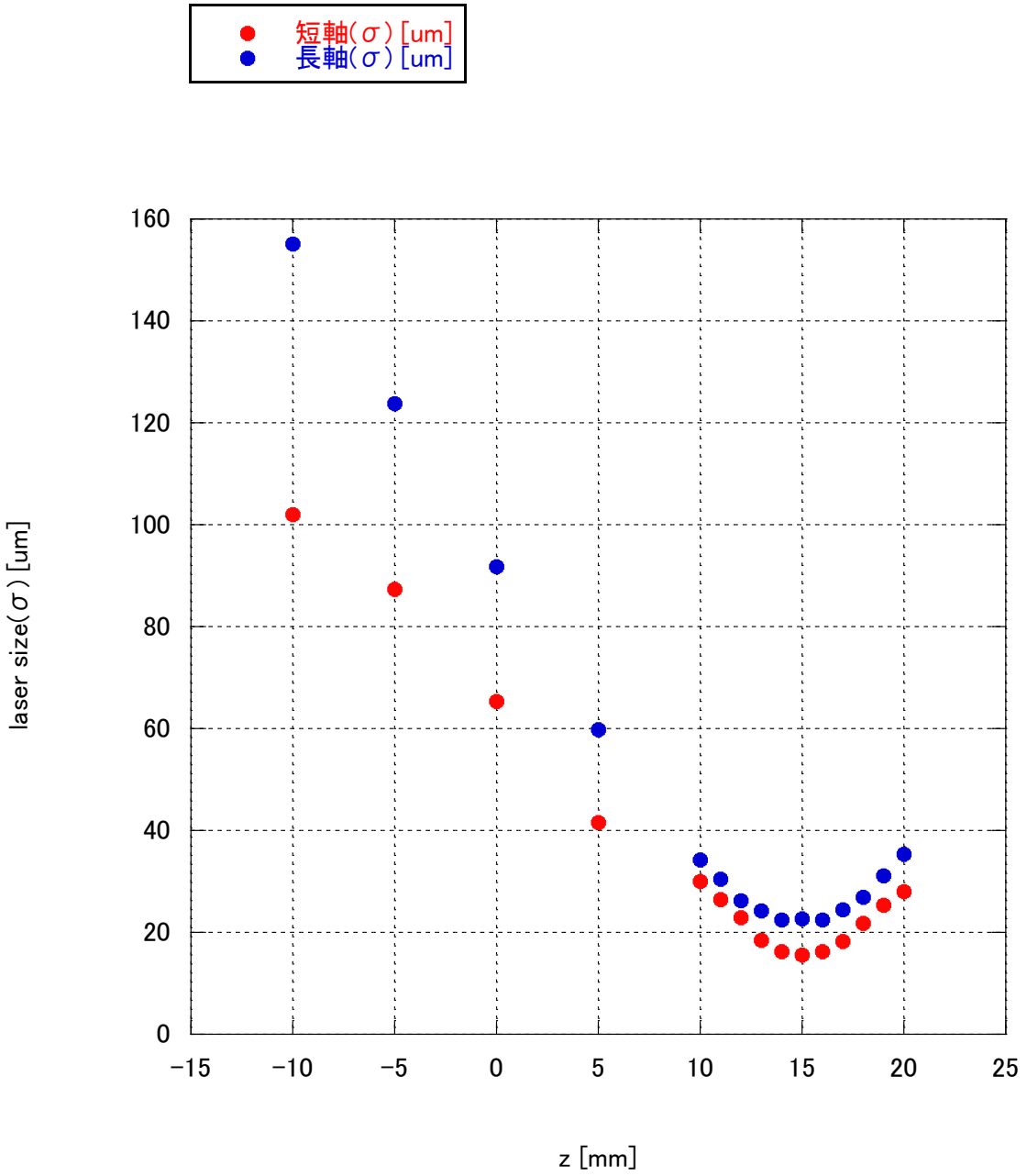






Issue (2) Study:

Quasi-direct Profile measurement at / near IP



Summary

Summary

- Current 3D4M cavity works well.
  - we have basic technologies in our hand.

- but,
  - optical properties yet to be understood (profile is NOT round).
  - mirrors should be studied for high power storage.

- How to deal with Issues? It is clear.
  - step back once to basic study(PHYSICS) to go forward.

Backups

next ?

- Gloal: More than 100 times more power in the cavity
  - power enhancement
  - injection laser power
- Mirrors with
  - higher reflectivity
  - low loss (LMA, REO, ATFilms)
- Understand EM wave behavior in the cavities

Two 4-mirror cavities are at the ATF

KEK-Hiroshima
installed autumn 2011

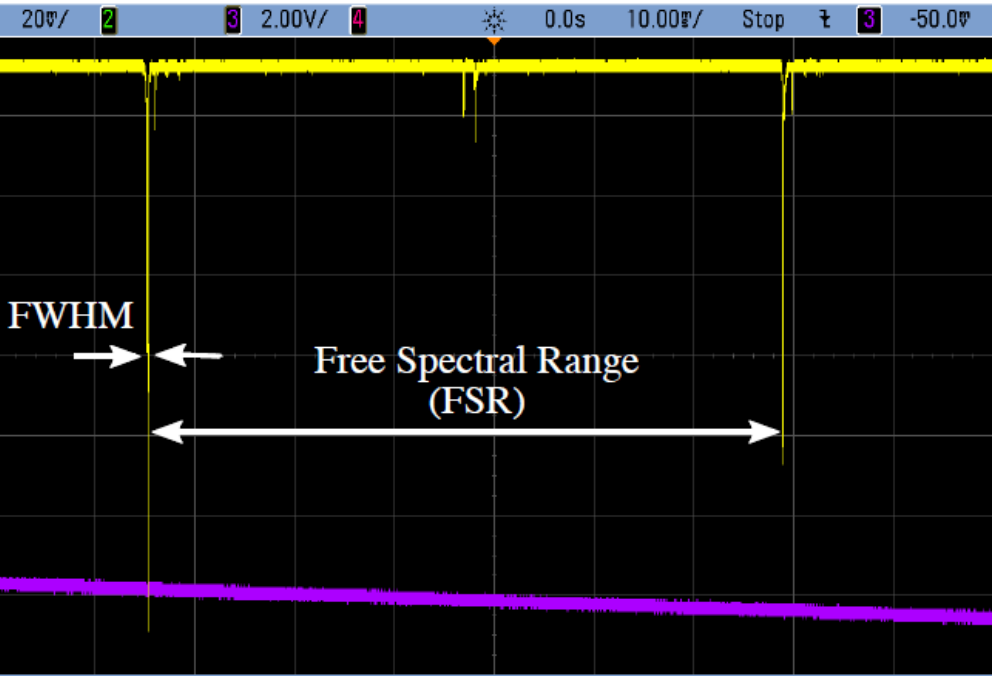
relatively simple control system
employs new feed back scheme

LAL-Orsay
installed summer 2010

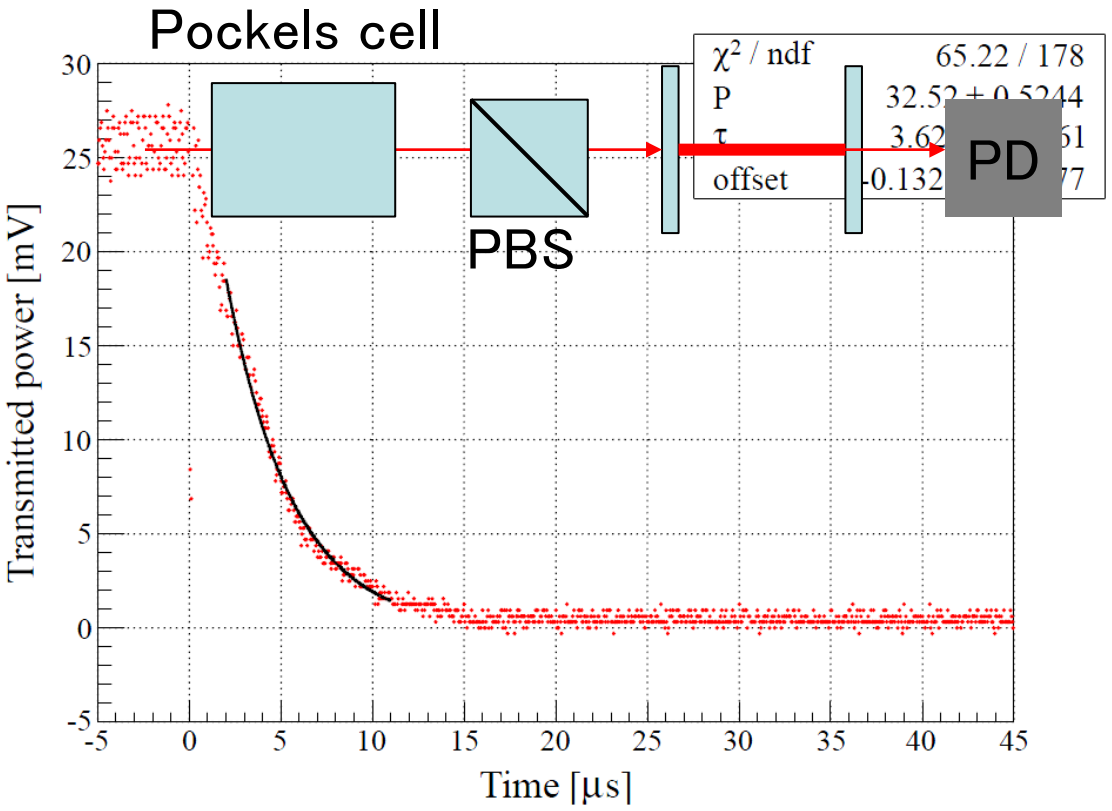
sophisticated control
digital PDH feedback

Finesse measurement

Airy Function



Decay time measurement



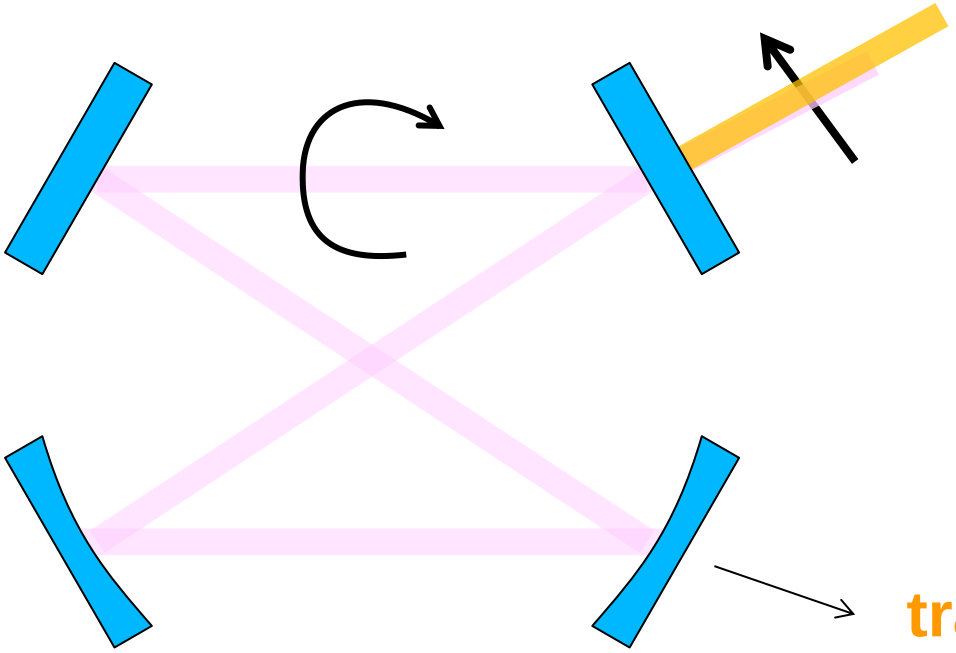
Finesse: 4040±420

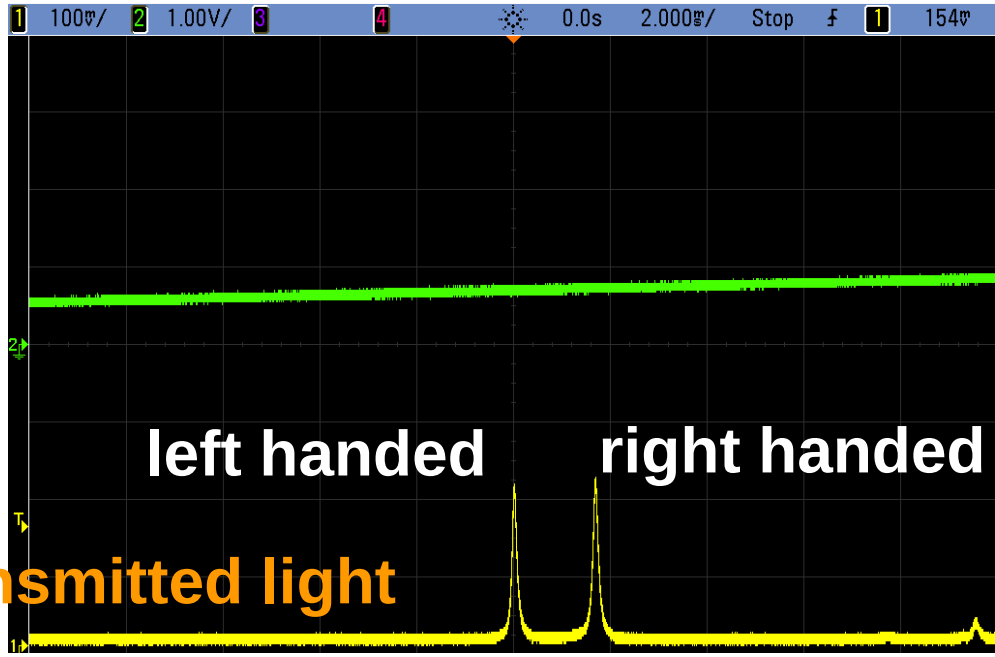
4040±110

Both Consistent but smaller than expected, 4830, from mirror reflectivity

3-Dimensional 4 Mirror Cavity

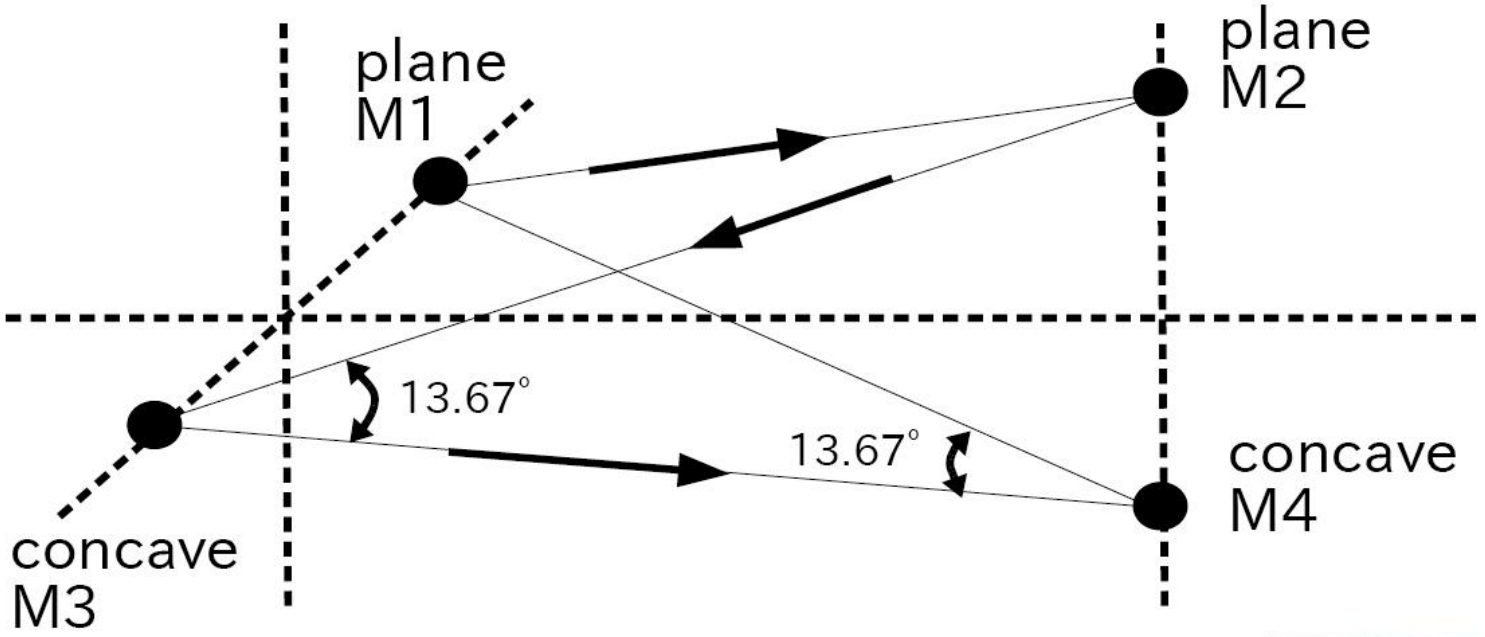
- Resonates only for circular polarization
  - geometric phase due to twisted pass
  - cavity only resonates with circular polarization
  - usable for pol. switching





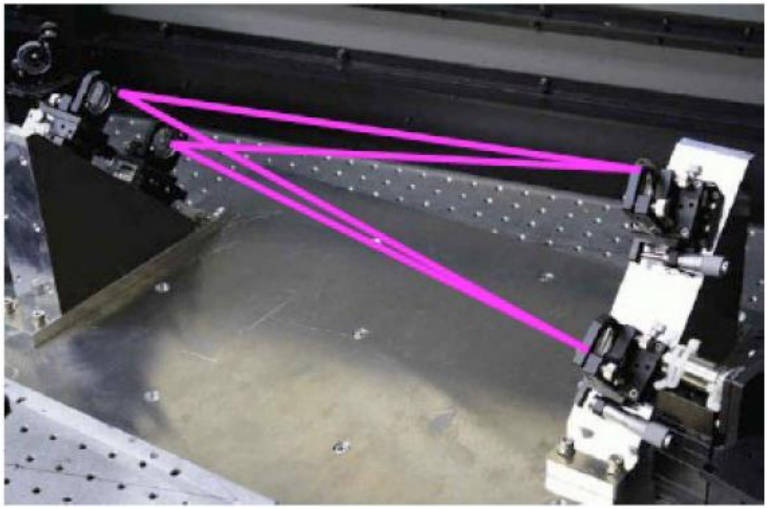
circumference of the cavity

Configuration of Test Bench

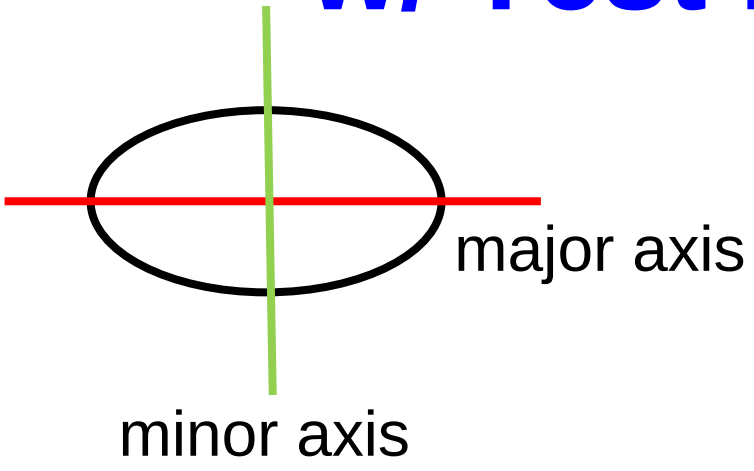


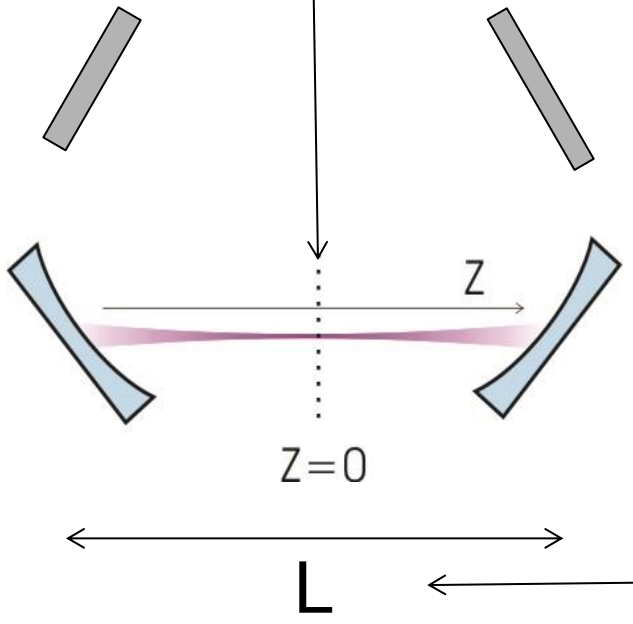
L1=M1-M2=420mm
L2=M2-M3=420mm
L3=M3-M4=420mm
L4=M4-M1=420mm

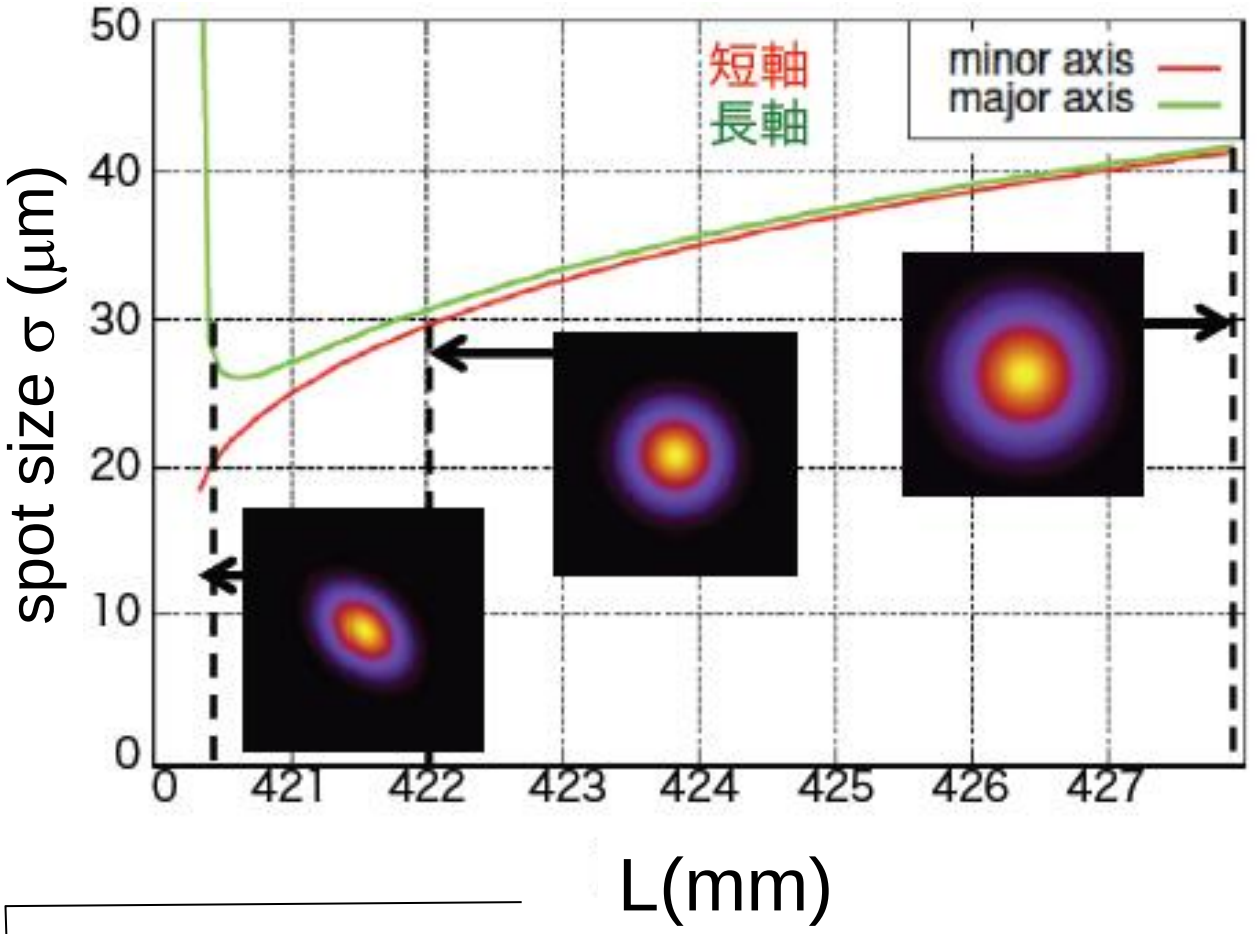
M2-M4=100mm
M1-M3=100mm



Calculation of Spot Size w/ Test Bench Geometry

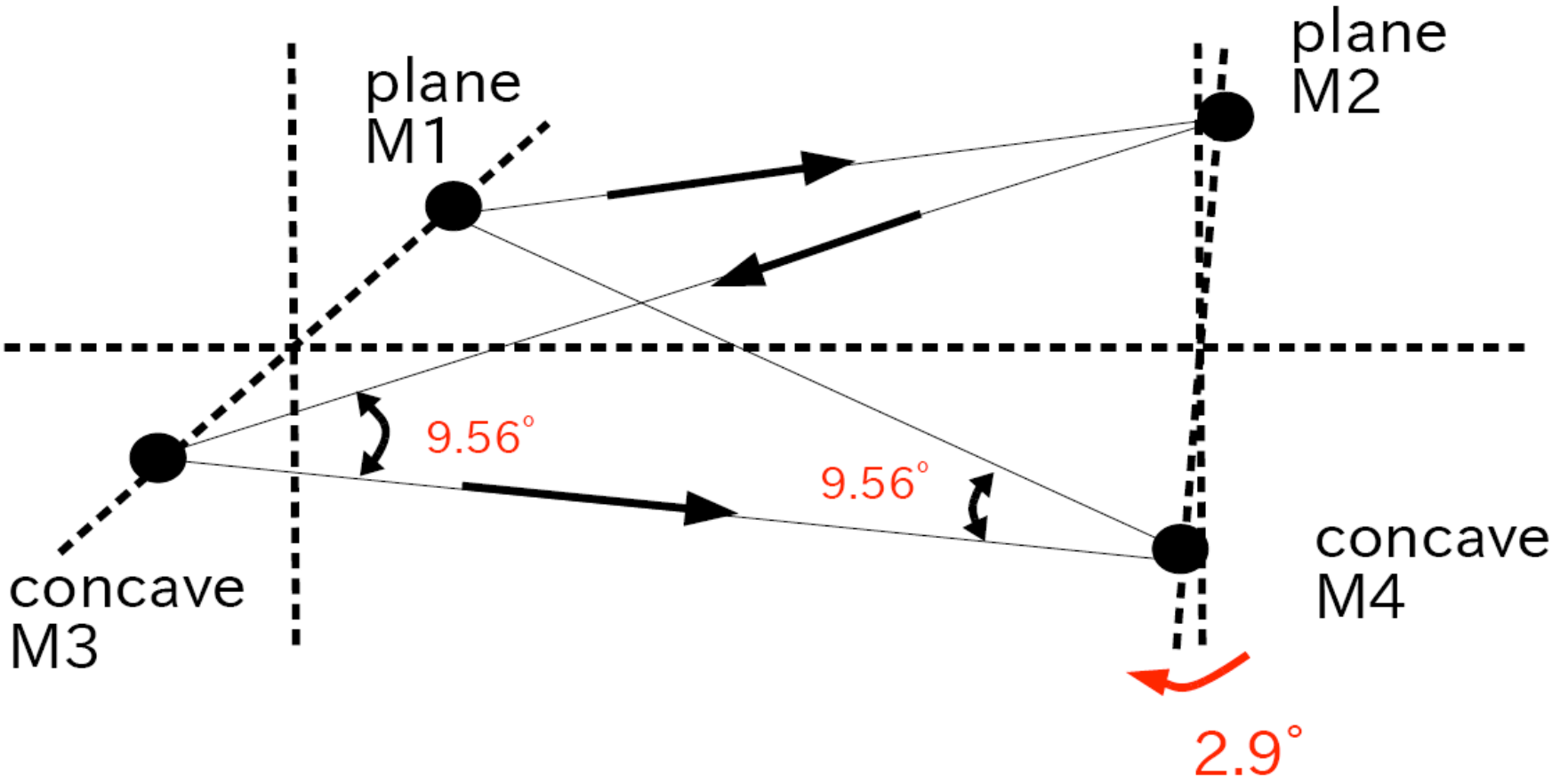






spot size is not sufficiently small with test bench geometry

New Geometry

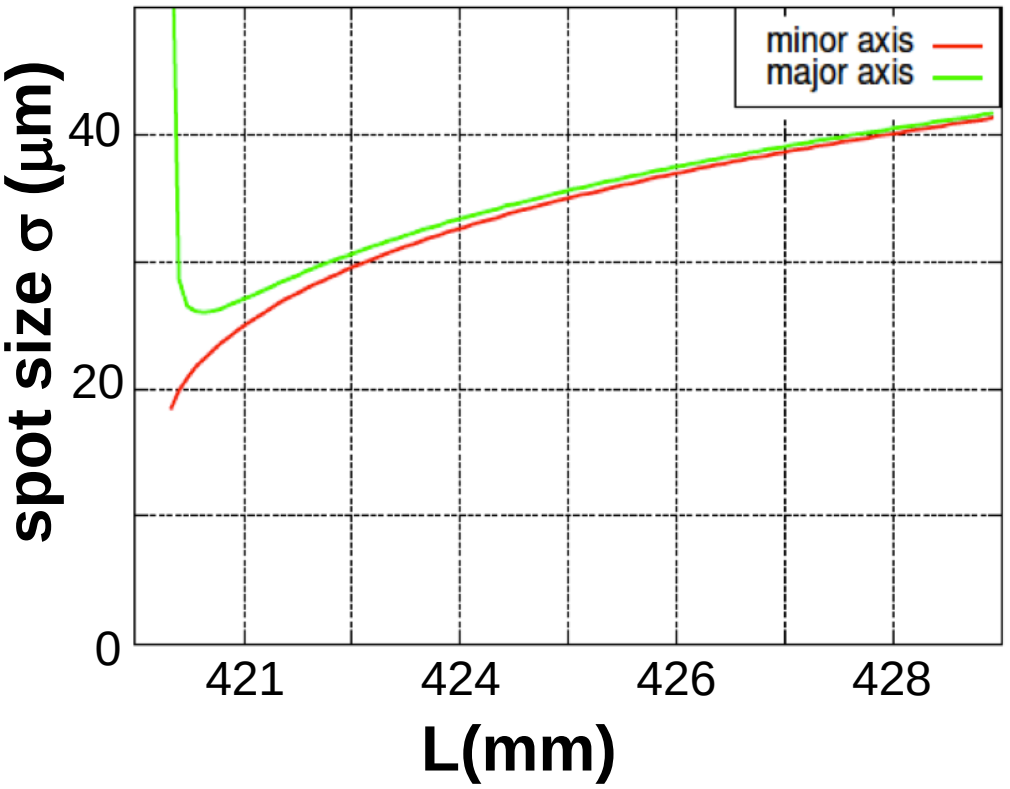


L1=M1-M2=420mm
L2=M2-M3=420mm
L3=M3-M4=420mm
L4=M4-M1=420mm

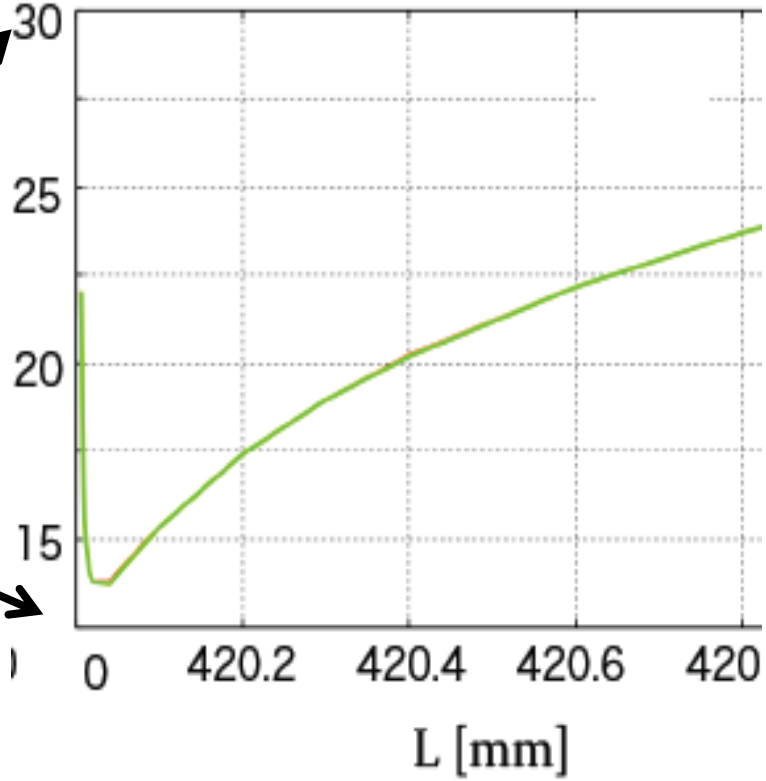
M2-M4=70mm
M1-M3=70mm

Expected Spot Size w/ New Geometry

Before optimization

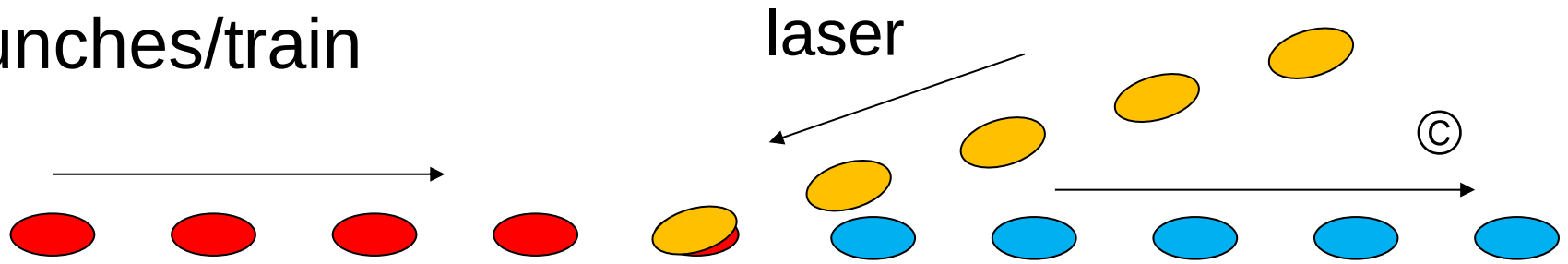


After optimization

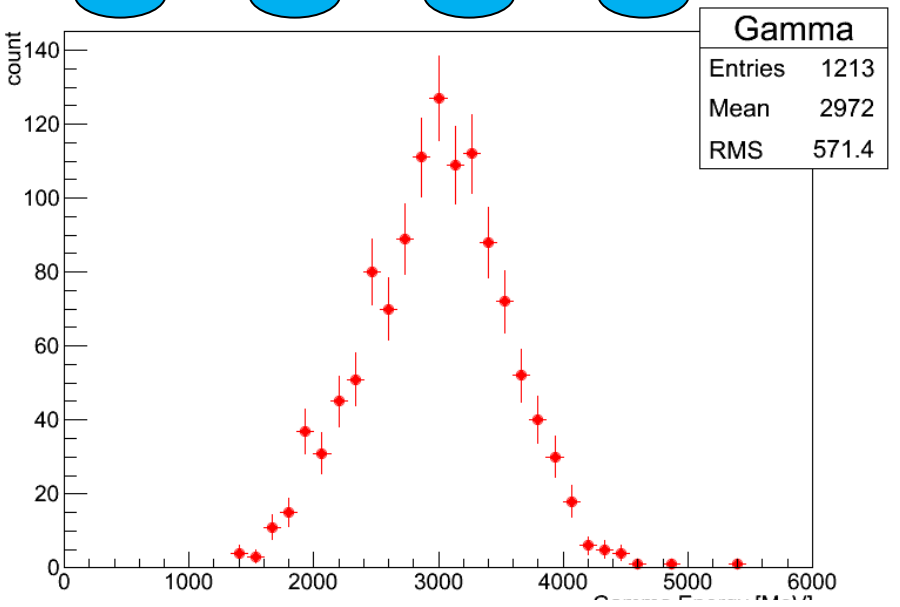


laser spot size of 15 μm is expected with new geometry

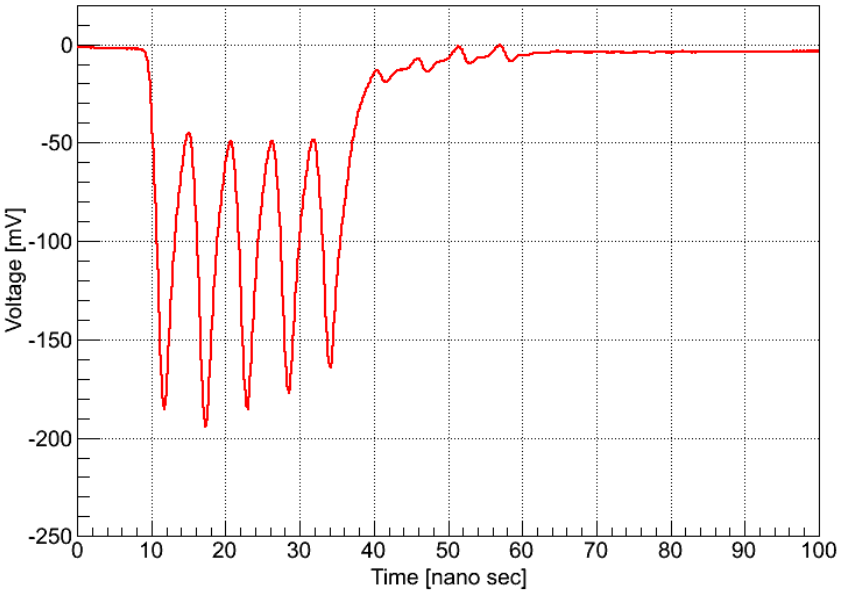
5bunches/train



- # of ©s =123.8/train



- confirmed stable photons from each bunch

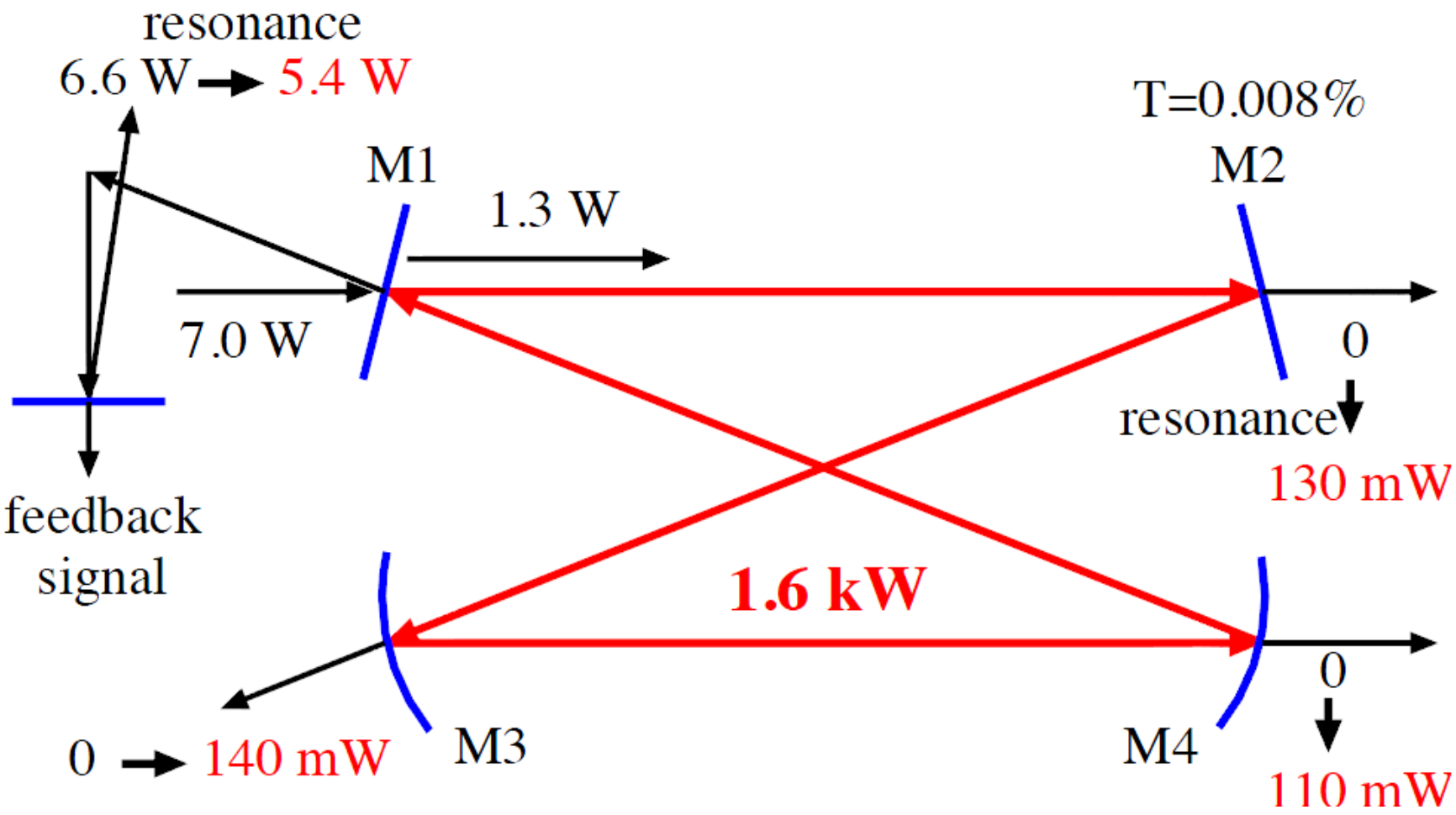


Status as the last meeting

- **What achieved**
  - **2.6 kW stored w/ 1.4 % stability**
  - **128 photons/train**
  - **laser waist size 13 ⌈m in vertical direction**

- **What to be confirmed**
  - **finesse**
  - **power balance**
  - **laser profile at IP**

Power Balance



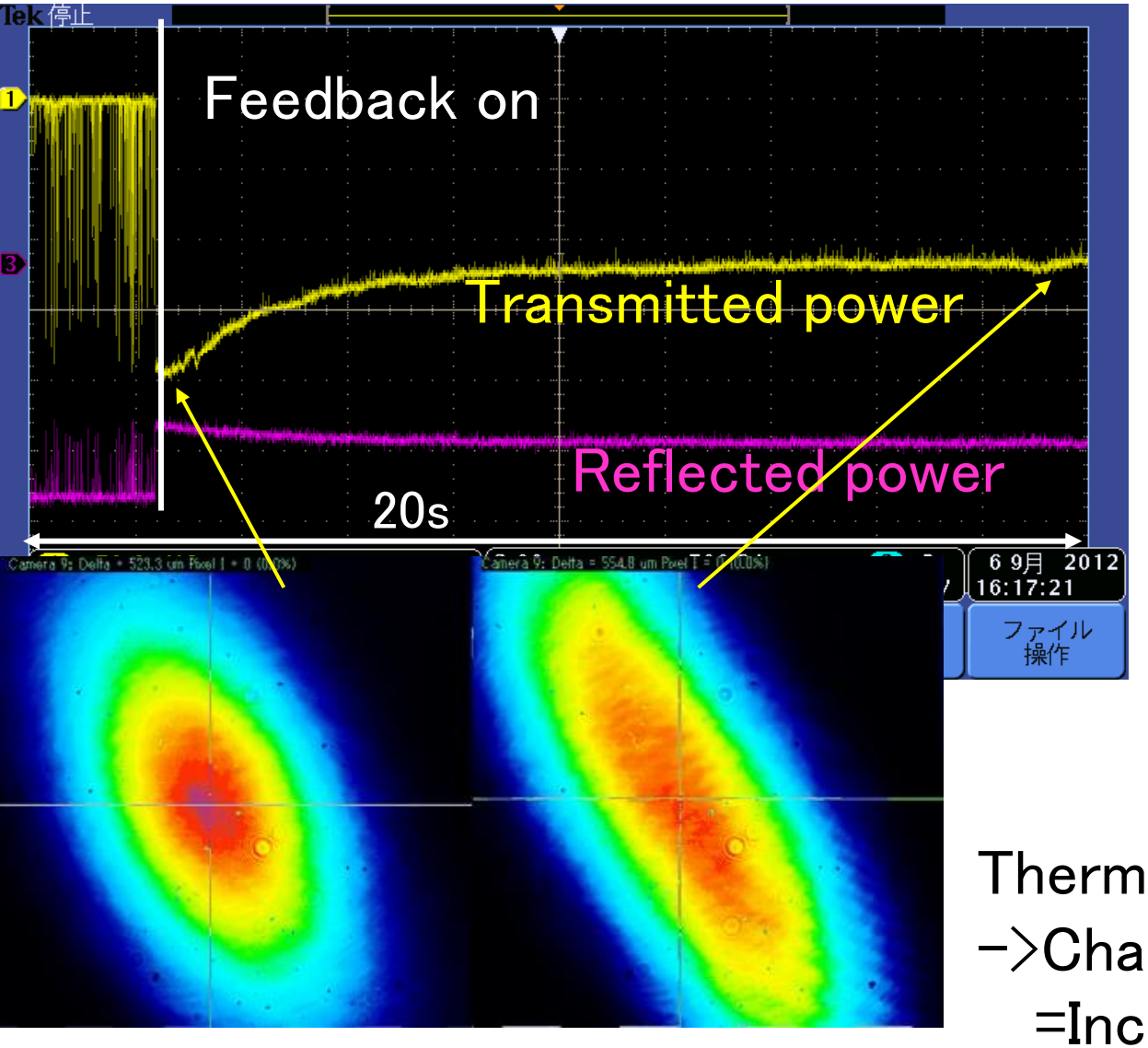
Stacked power

Injected Power x Enhancement =1.6kW

Tansmitted Power / Transmission =1.6kW

⇒Two Estimations are Consistent

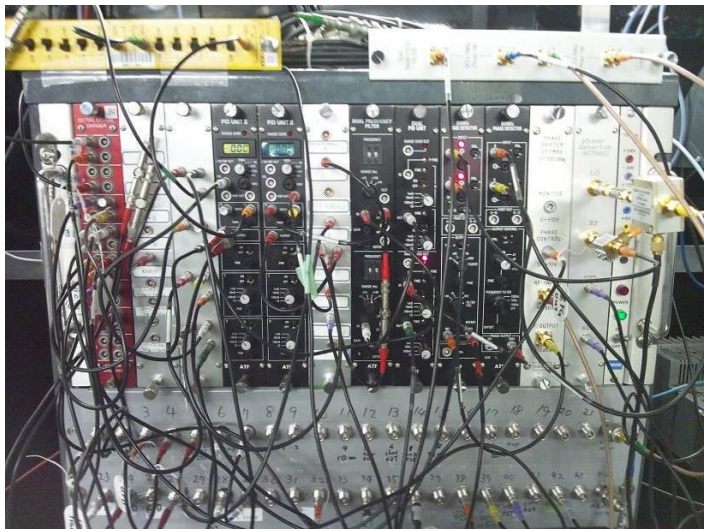
Decrease in stack power

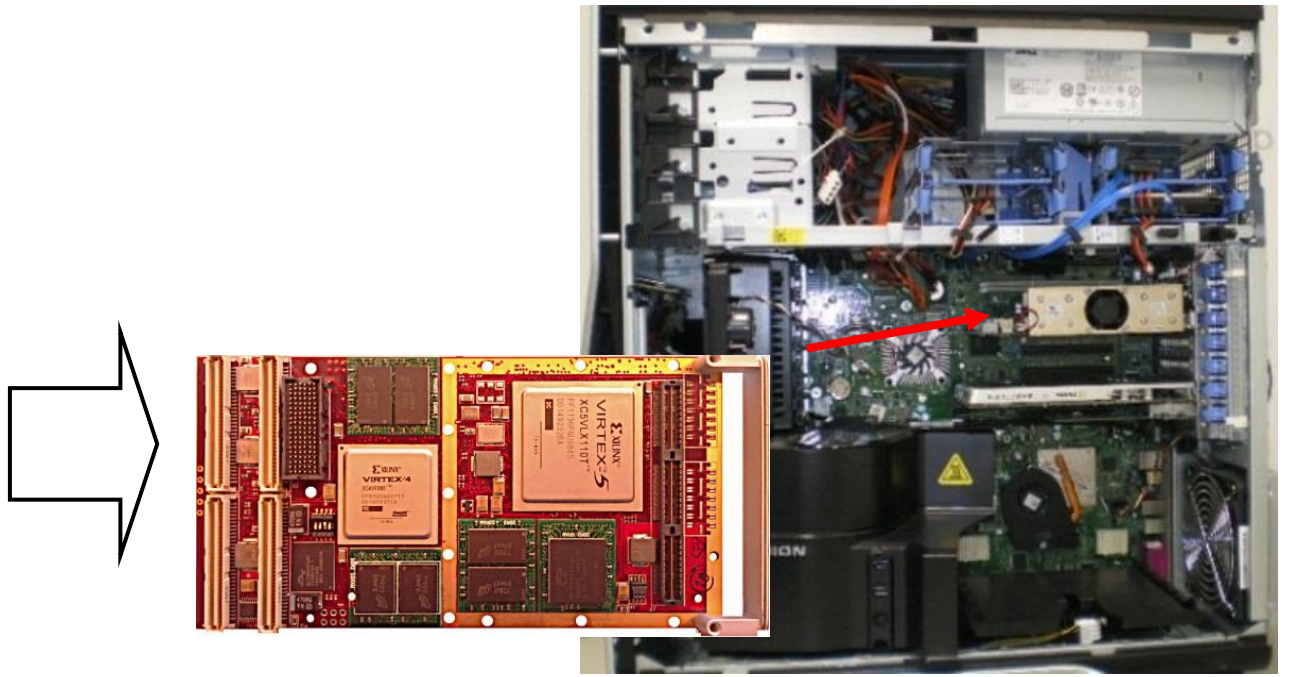


Thermal deformation of the mirror
->Change of transmitted pofile
=Incident efficency is reduced.

Ongoing: Installation Digital Feedback

Feedback circuit : analog -> digital





Expected Advantages

- large fexibility
- Auto control

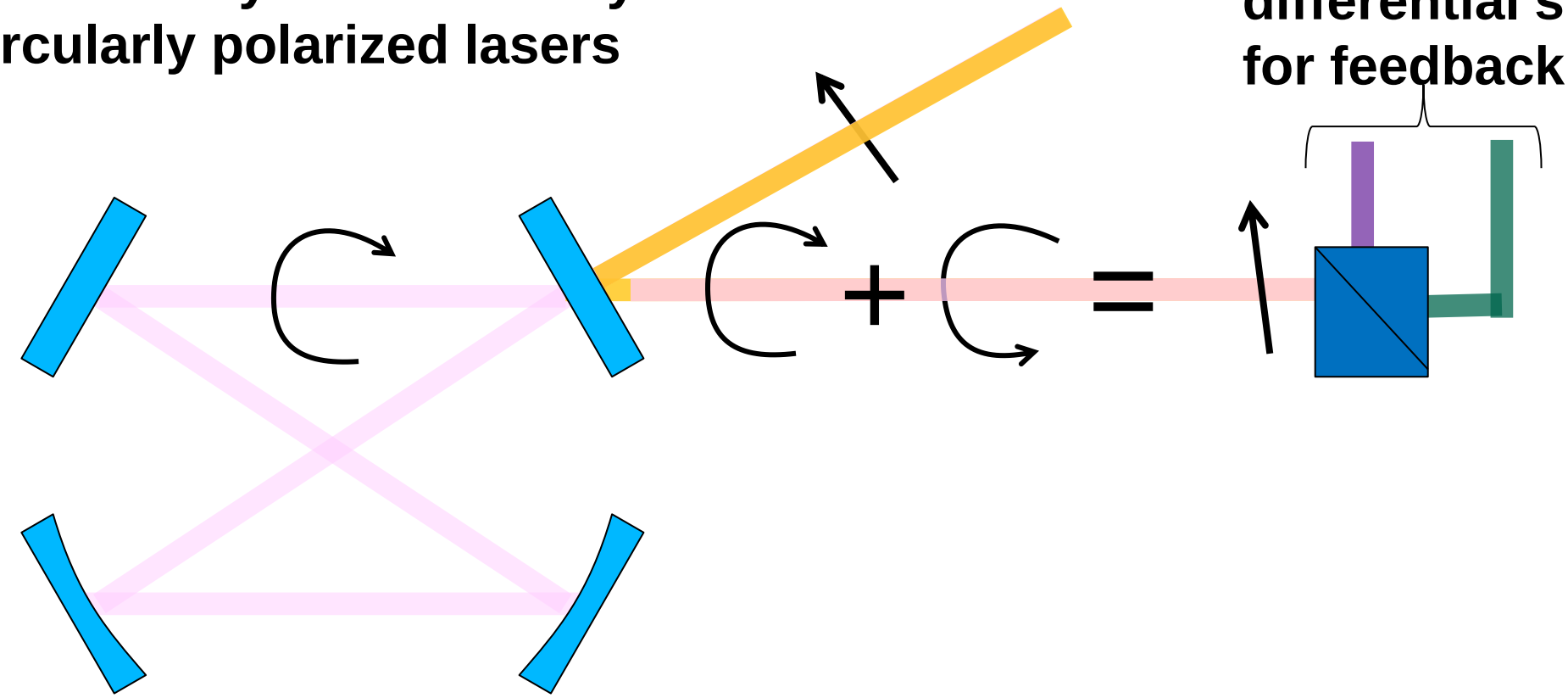
Cavity Length Feedback with 3D Feature

cavity length must be L = nλ/2 with very high precision

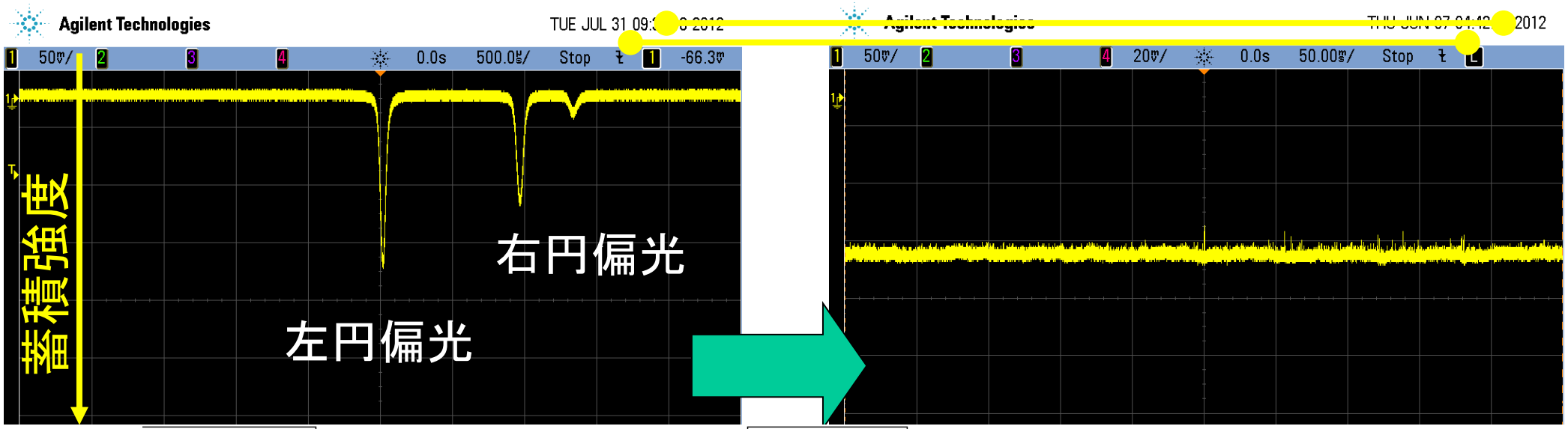
(for enhancement of 1900 dL<< 87pm while L = 1.64m)

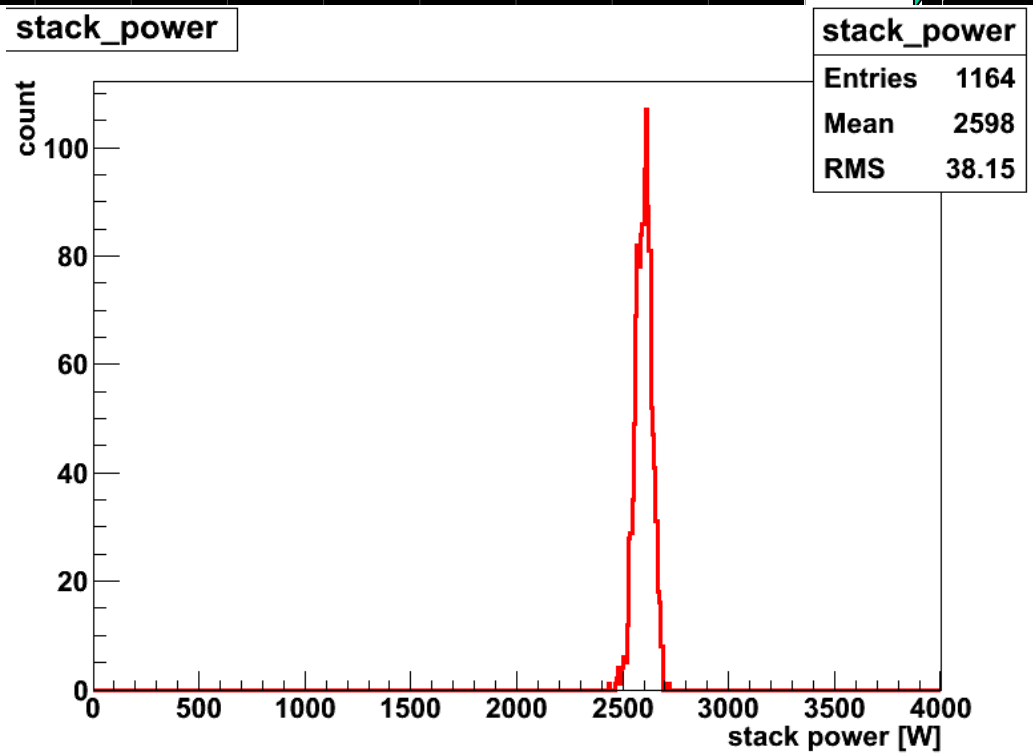
3D4M cavity resonate only with circularly polarized lasers

differential signal for feedback



Stored Laser Power in the Cavity



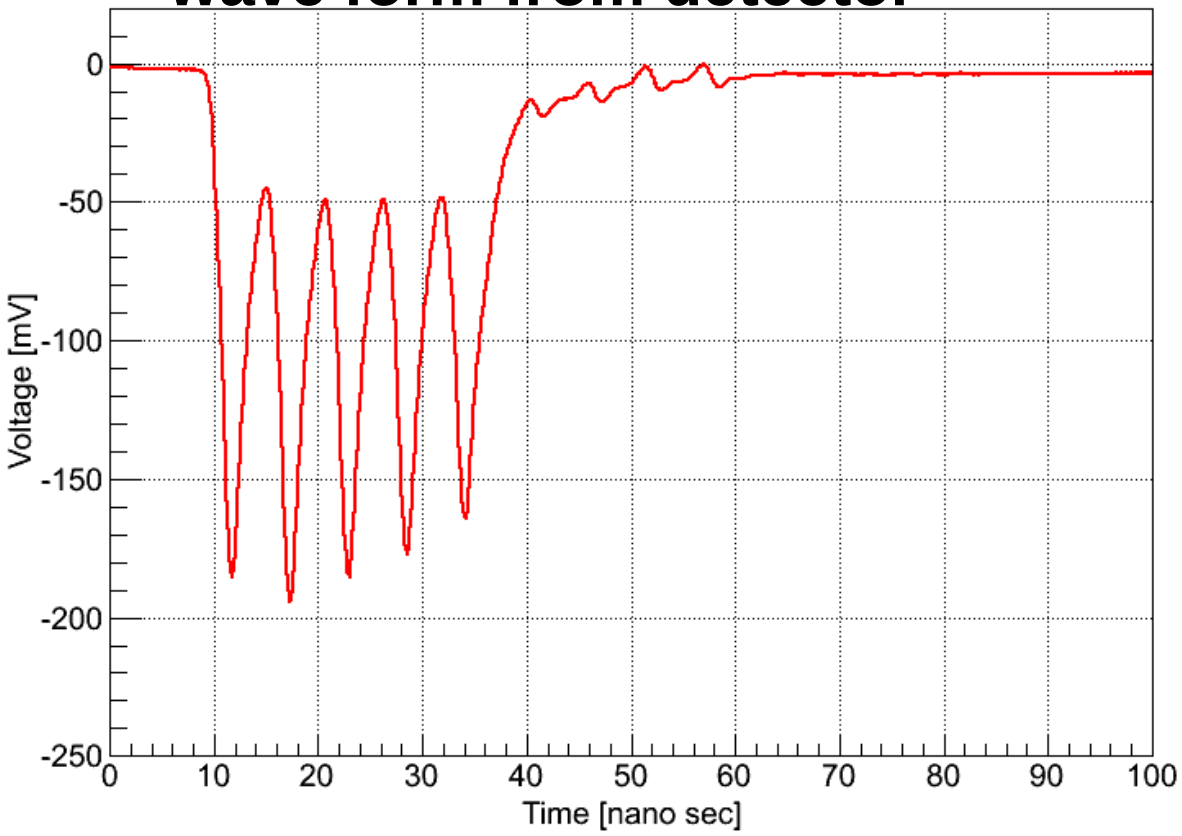


stack_power	
Entries	1164
Mean	2598
RMS	38.15

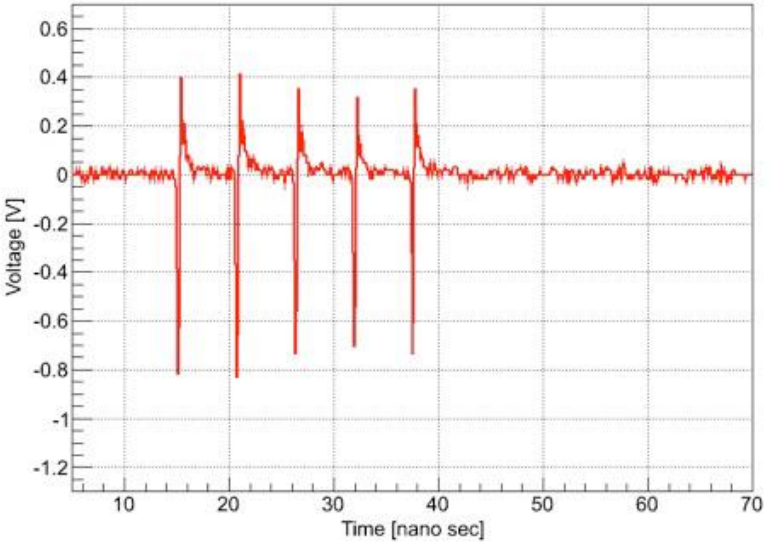
Laser Power 2.6kW
Time Jitter＝8.0ps

Bunch-by-Bunch Measurement

wave form from detector



e- bunch monitor



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