ATF laser-Compton status

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LCWS 2014 @ Belgrade
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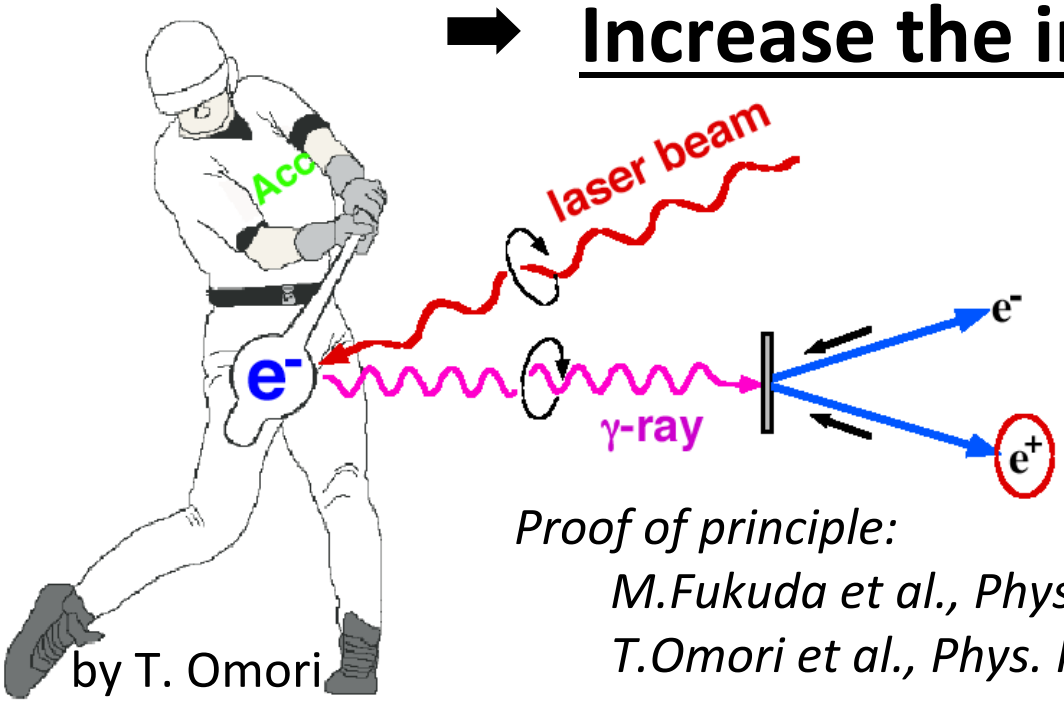
Contents

- ATF Compton status
- Low loss mirrors
- High enhancement cavity

Polarized e+ by the Compton scheme

- ~1 GeV electrons for ~10 MeV gammas
- Polarized positrons
- Fast polarization switching

➡ **<u>Increase the intensity of gammas</u>**



by T. Omori

Proof of principle:

M.Fukuda et al., Phys. Rev. Letts. 91, 16480(2003)

T.Omori et al., Phys. Rev. Letts. 96, 114801(2006)

Staking Laser Pulses in Optical Cavity

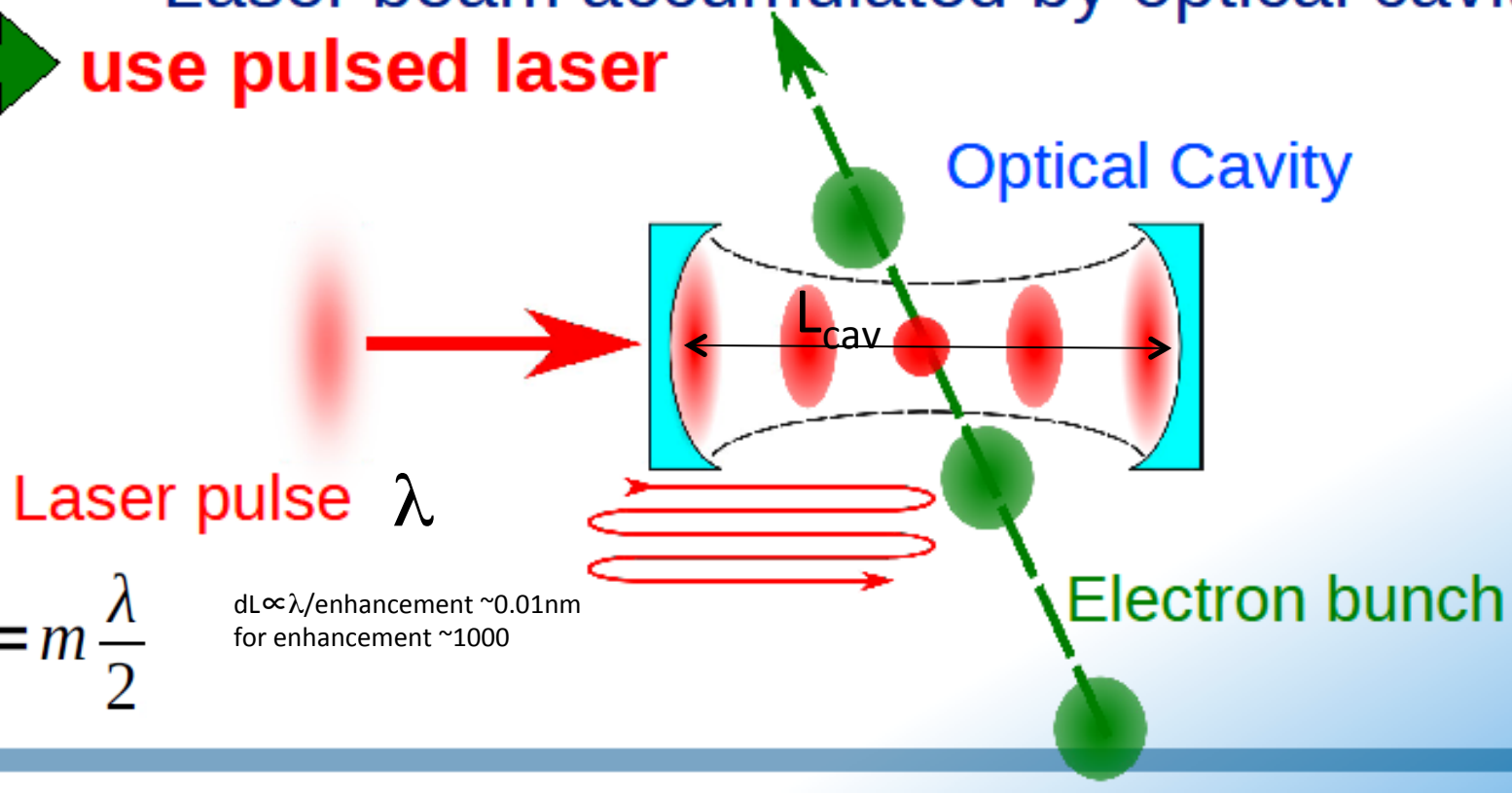
Miyoshi PosiPol2010

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**



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

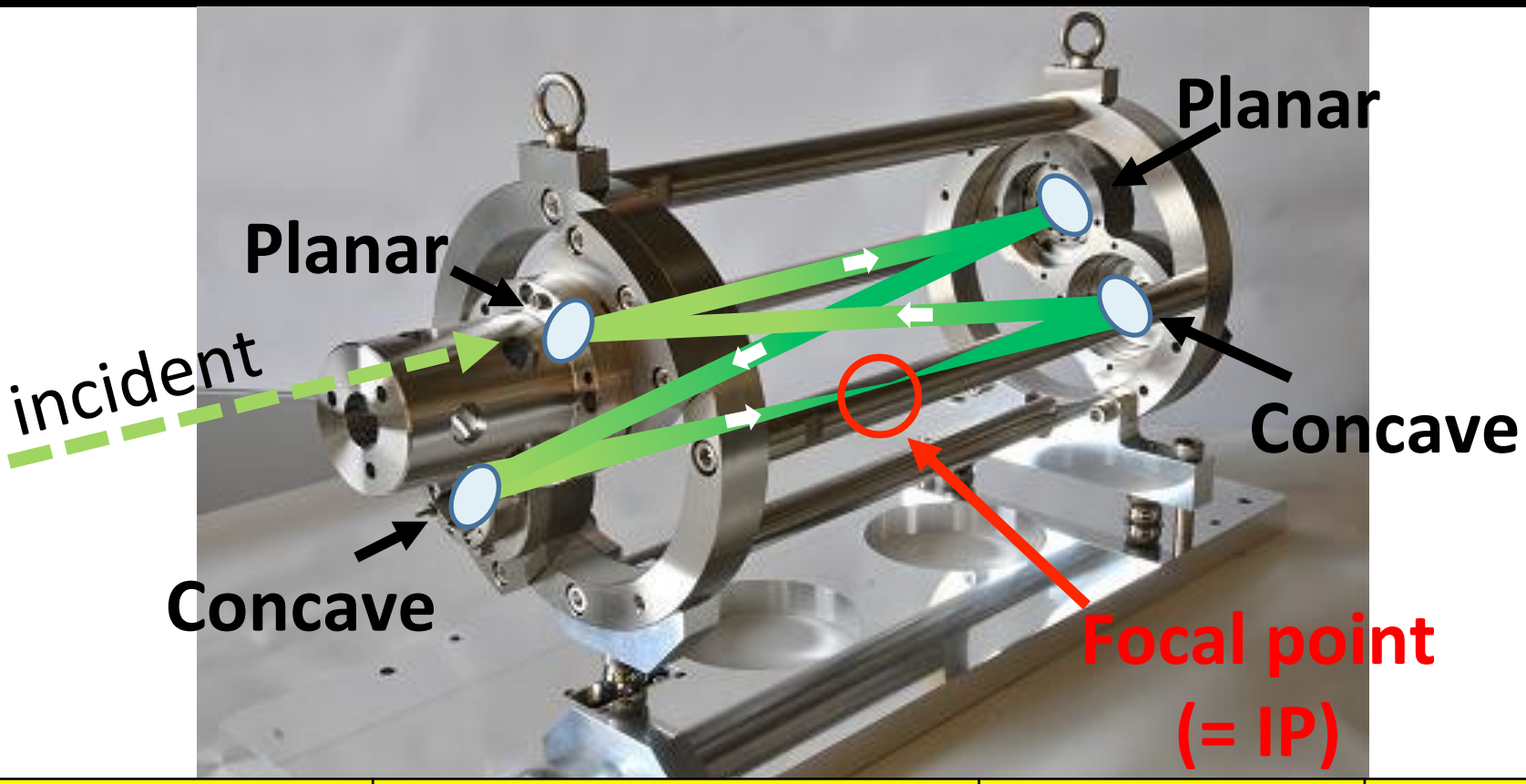
dL∝λ/enhancement ~0.01nm
for enhancement ~1000

Two 4 mirror cavities are at the ATF

KEK-Hiroshima
installed 2011

LAL-Orsay
installed summer 2010

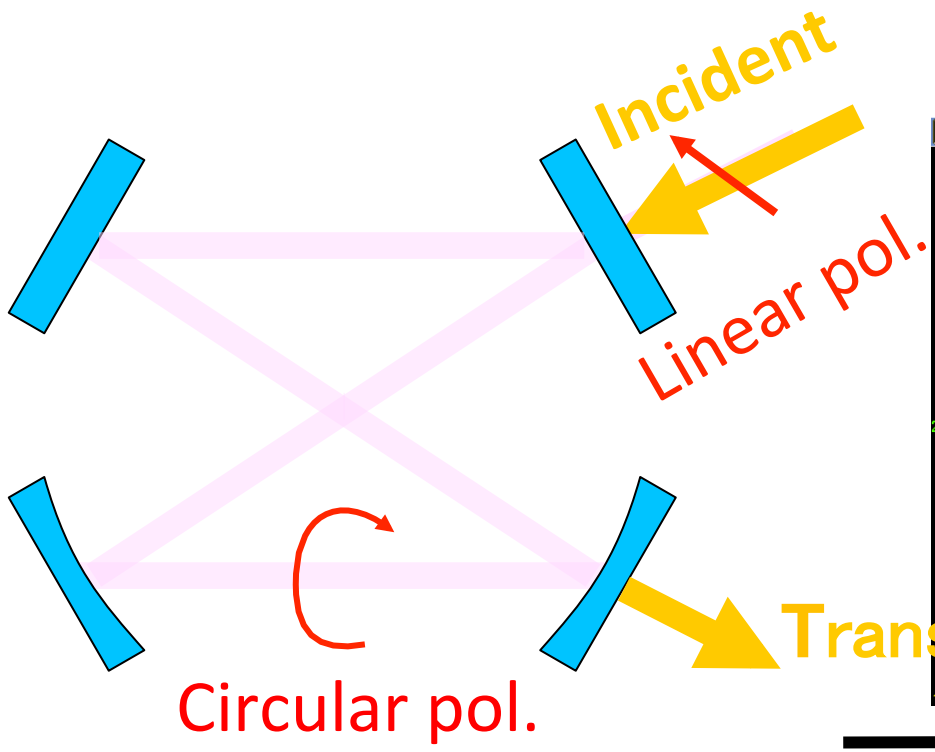
Cavity in ATF ~2014

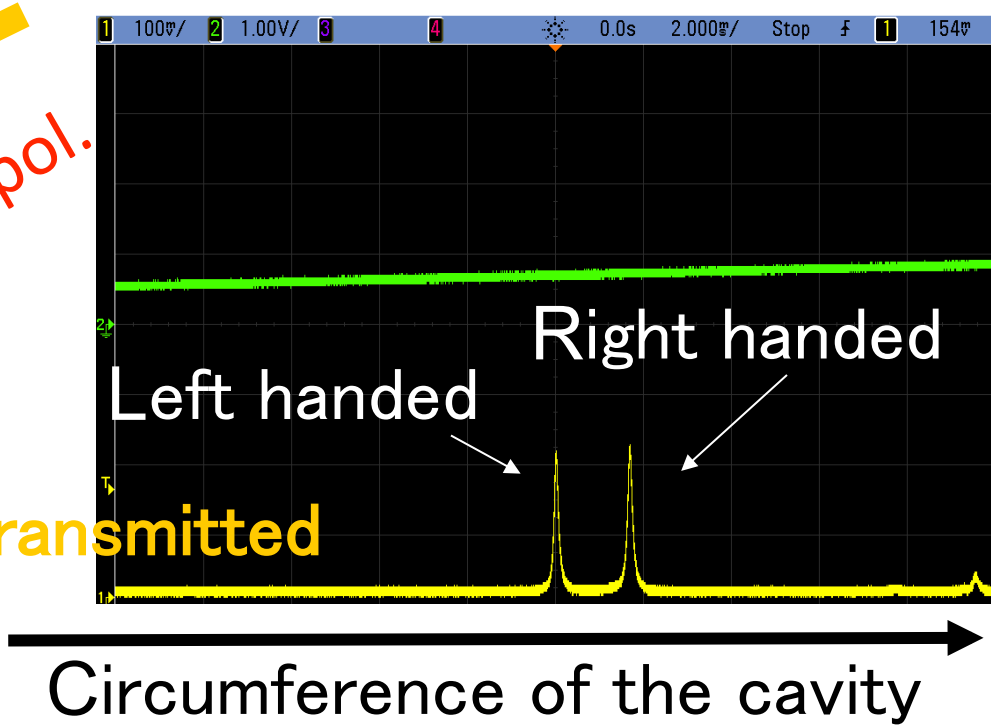


Circumference	Enhancement factor (measured)	Finesse (measured)	Laser size @IP
1.68 m	1,230	4,040	13 μm

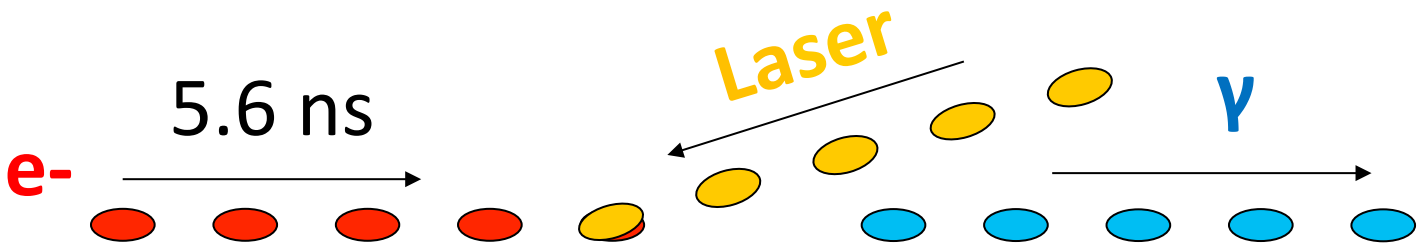
3 Dimensional 4 Mirror Cavity

- Resonates only for circular polarization
  - geometric phase due to twisted pass
- Polarization switching by controlling cavity length



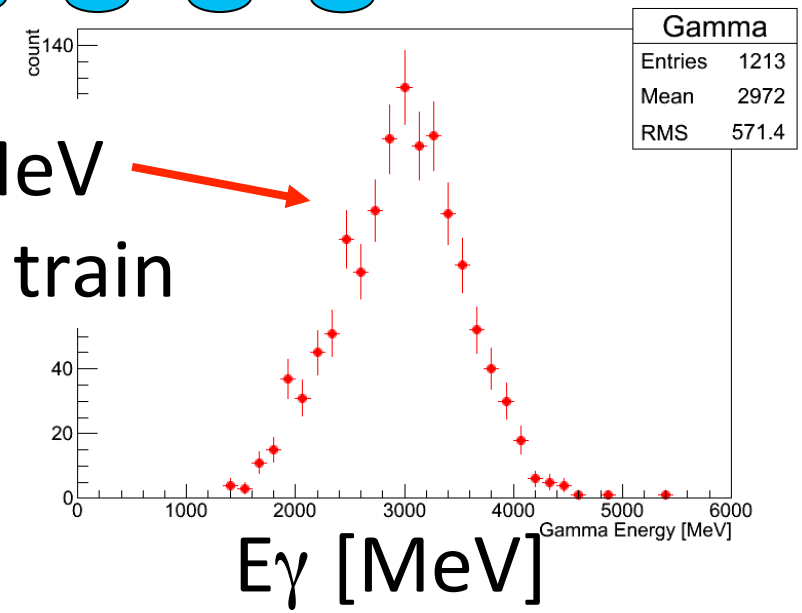


Gamma-ray generation of 2012-2013



5 bunches / train
with 2.16 MHz

2970±20 MeV
= ~120 γs / train



Gamma-ray generation:

~2.6 × 10^8 γs / sec

Stored laser power:

2.6 kW avg. with input power*: **2.2 W**

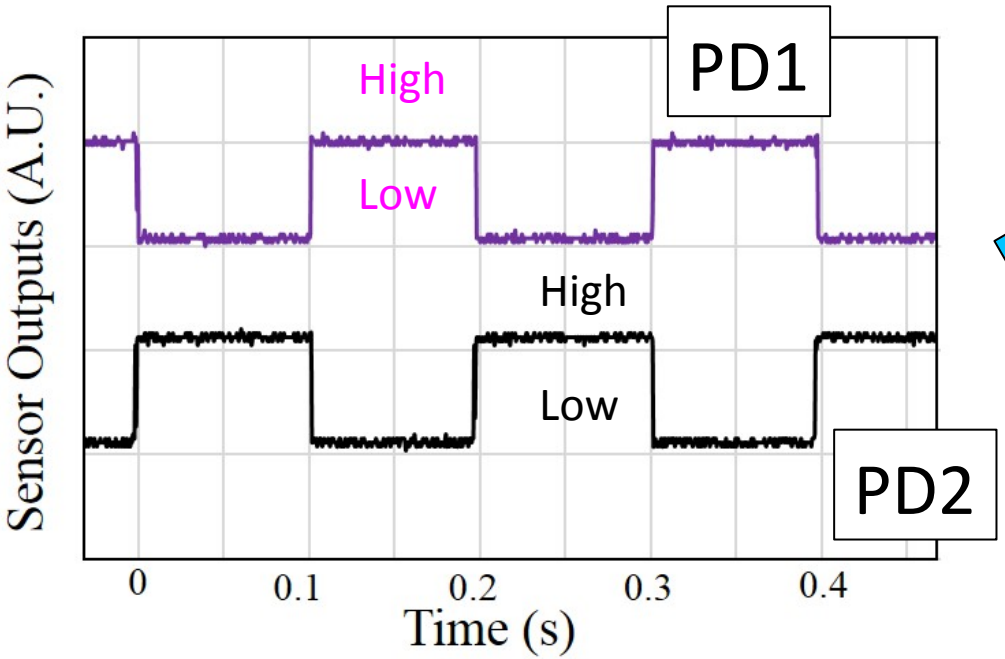
⇒ enhancement factor: **1,230**

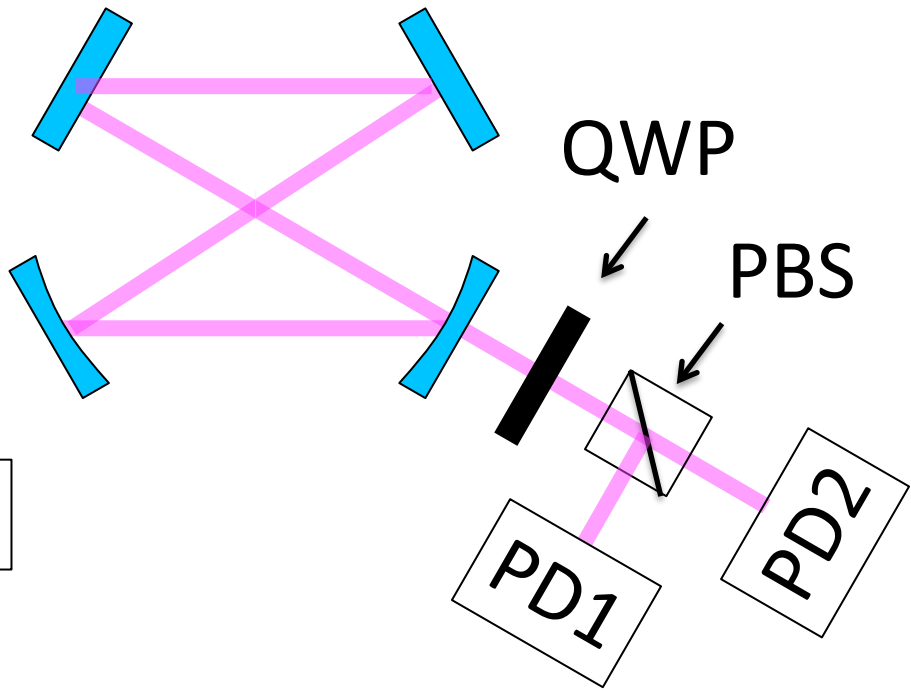
T. Akagi et al., NIM A 724 (2013) 63–71.

*Increasing the coupling efficiency

Polarization switching

Continuous switching with 10 Hz





The switching freq. is limited O(kHz)
by the band width of the feedback system.

R&D for the high power storage

Toward high power storage

Go to the high enhancement cavity

➡ 1,230 × O(10)

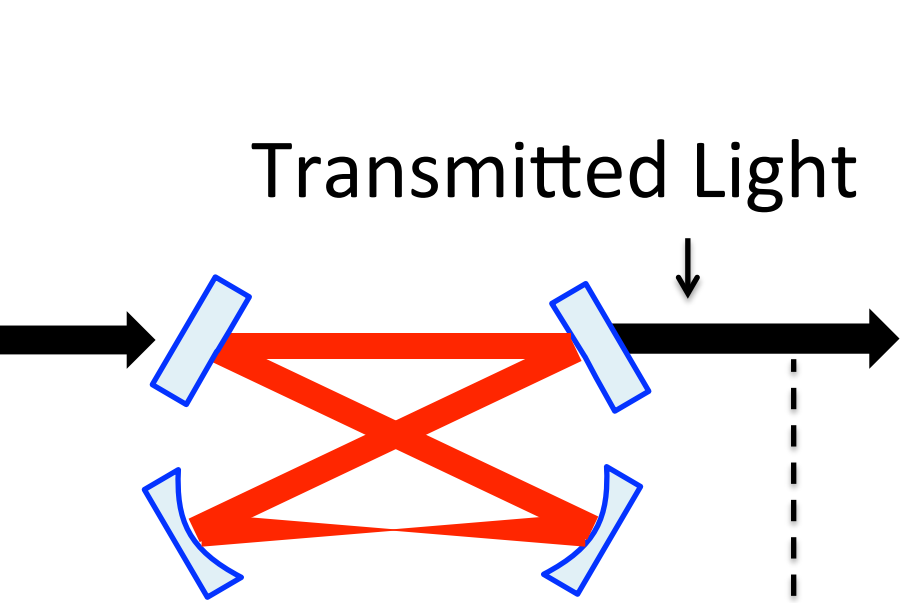
- High finesse optical cavity
- Improvement of the feedback system

Overcome two major issues

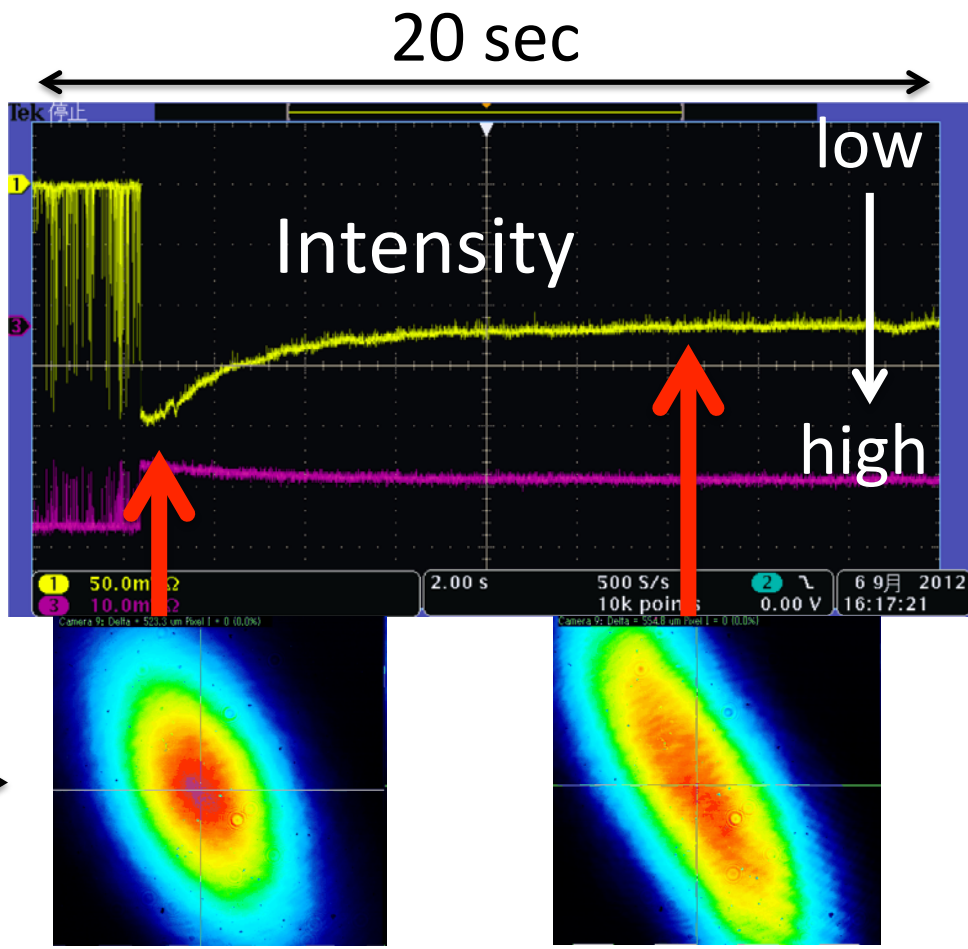
- Elliptical profile
- Thermal deformation of mirrors

Two issues for high power storage

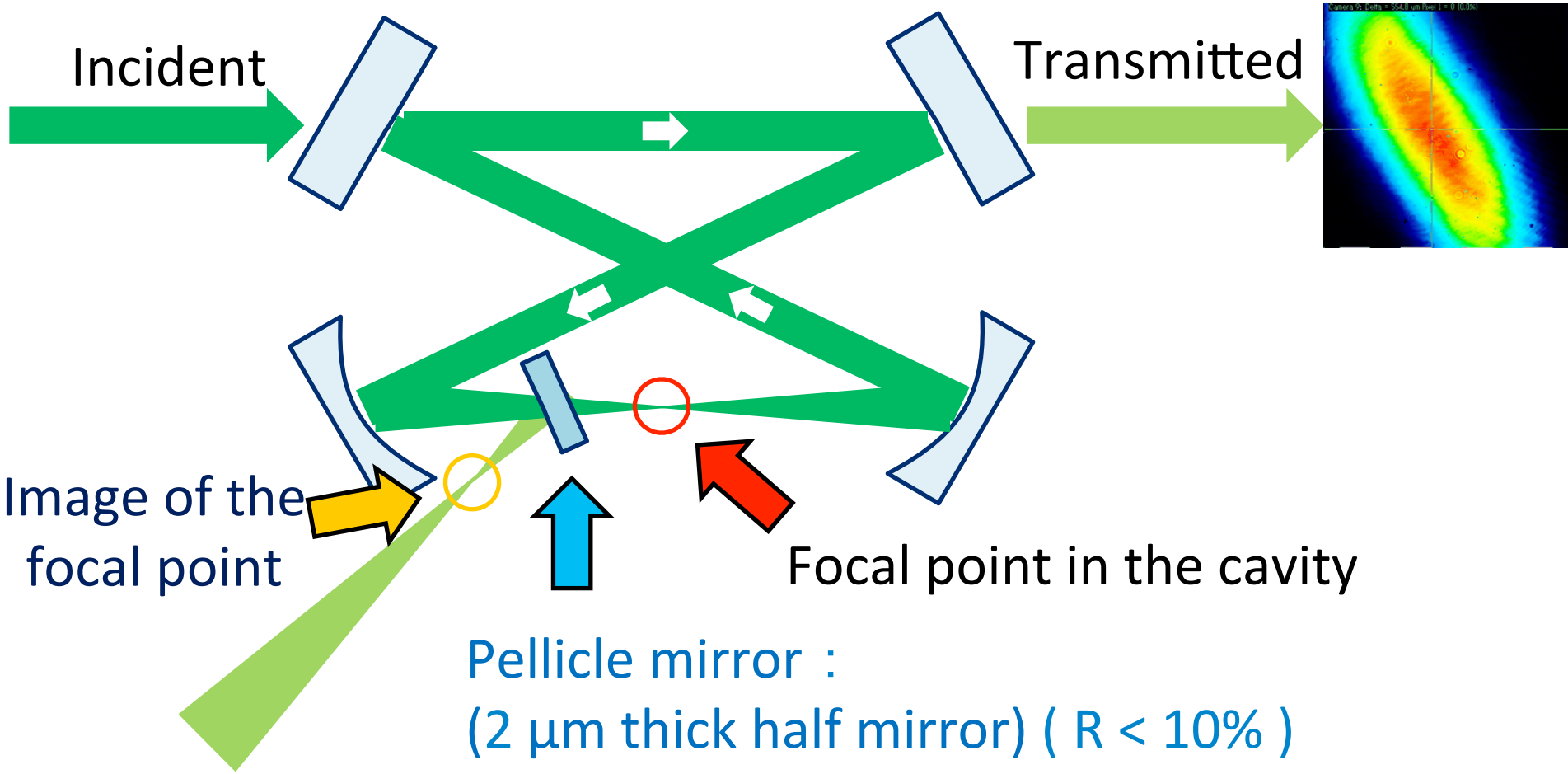
- **Thermal deformation of mirrors**
- **Elliptical profile**



Stored power:
2.6 kW

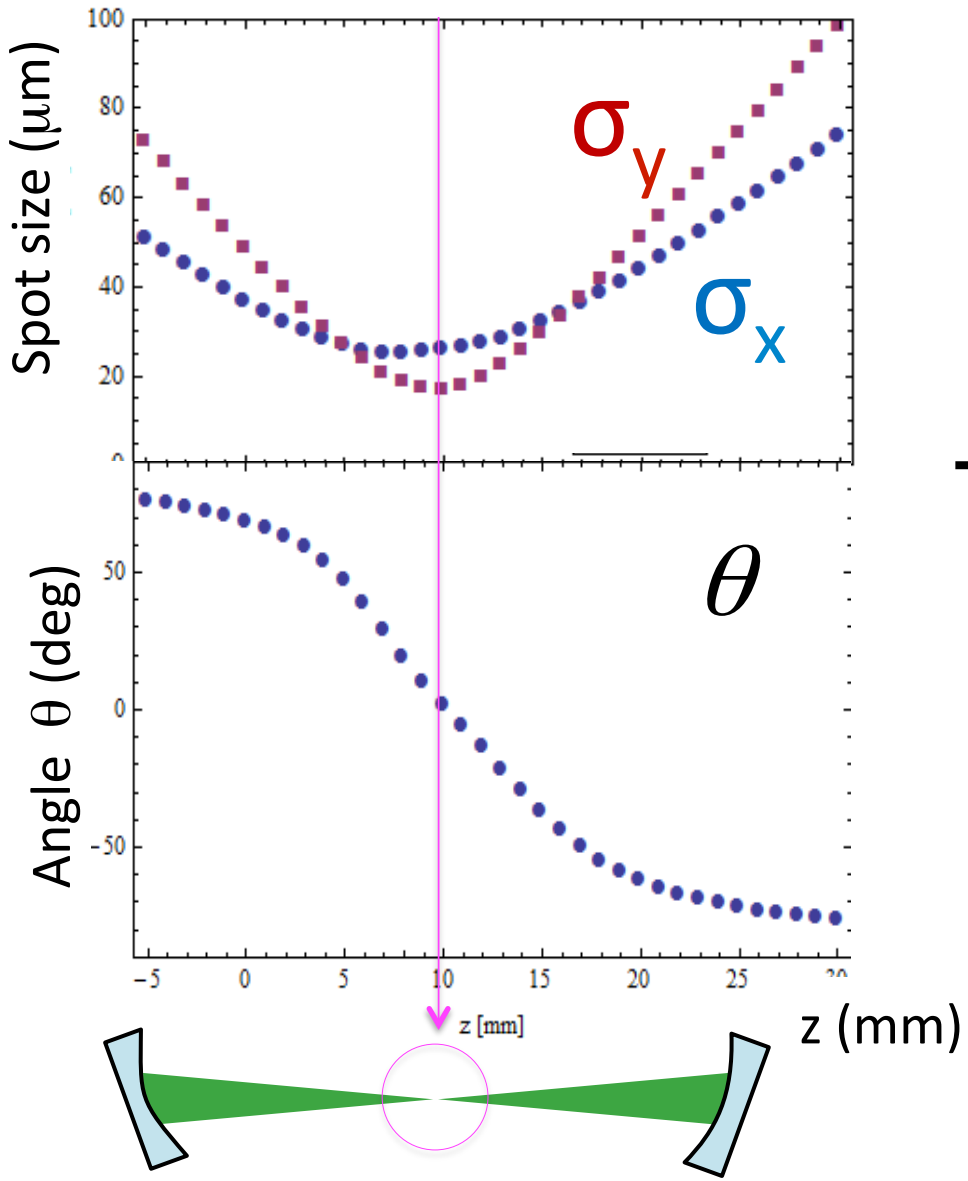


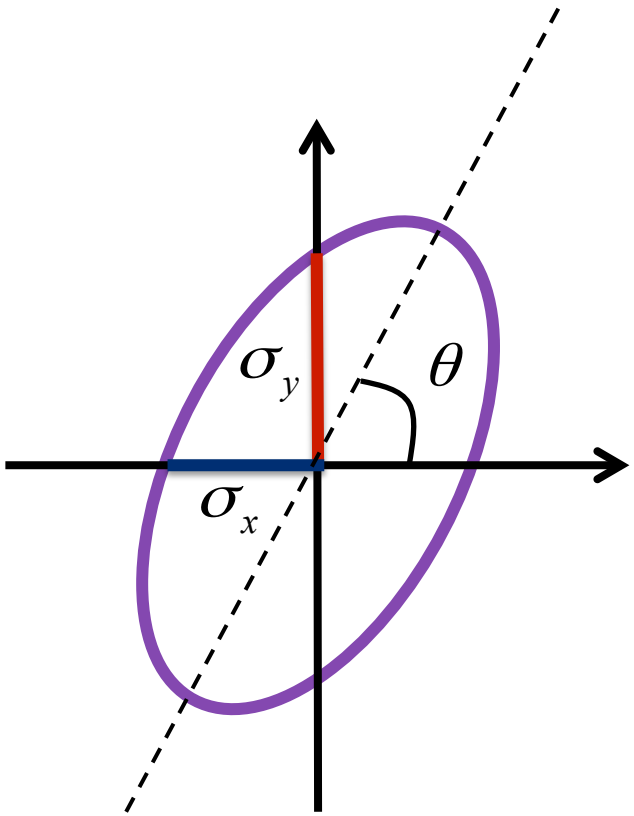
Systematic investigation of the profiles



- Profiles at the focal point can be observed outside

Laser profiles near the focal point





Laser profile is rotating around the focal point

T. Takahashi POSIPOL2014

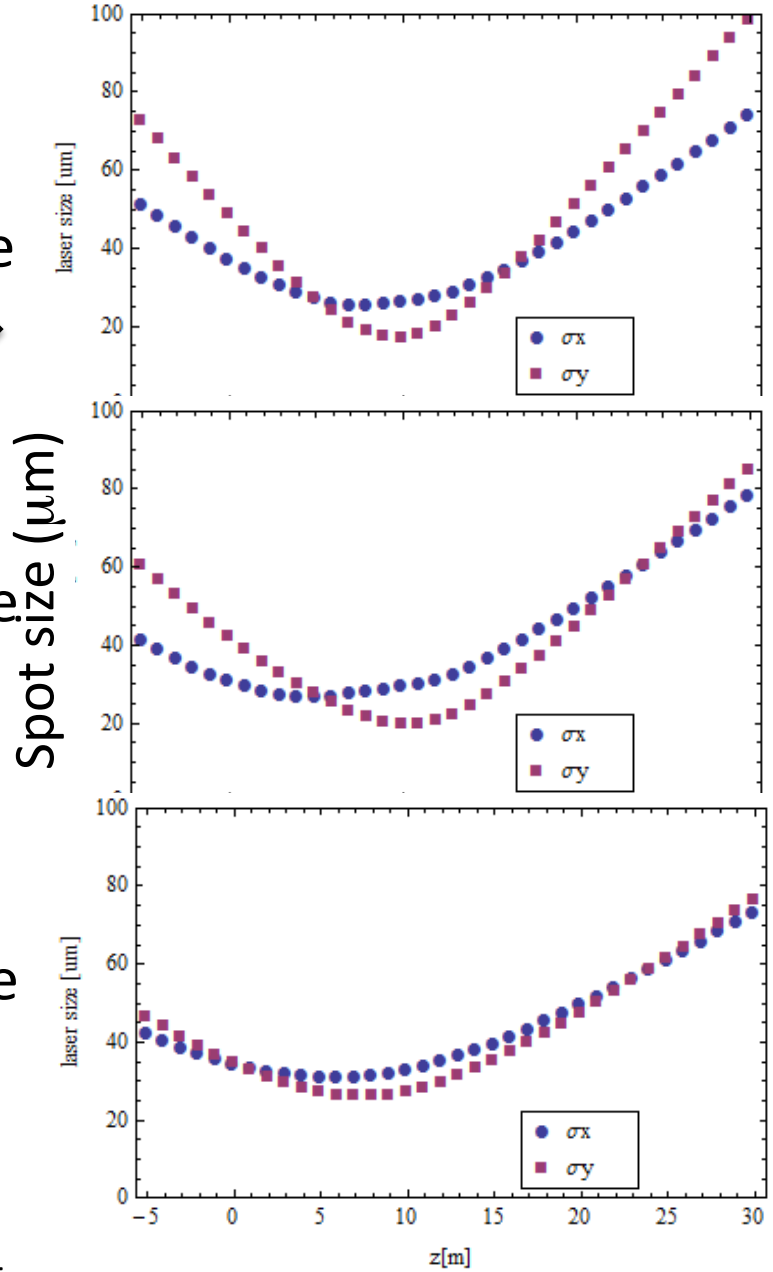
Laser profiles near the focal point

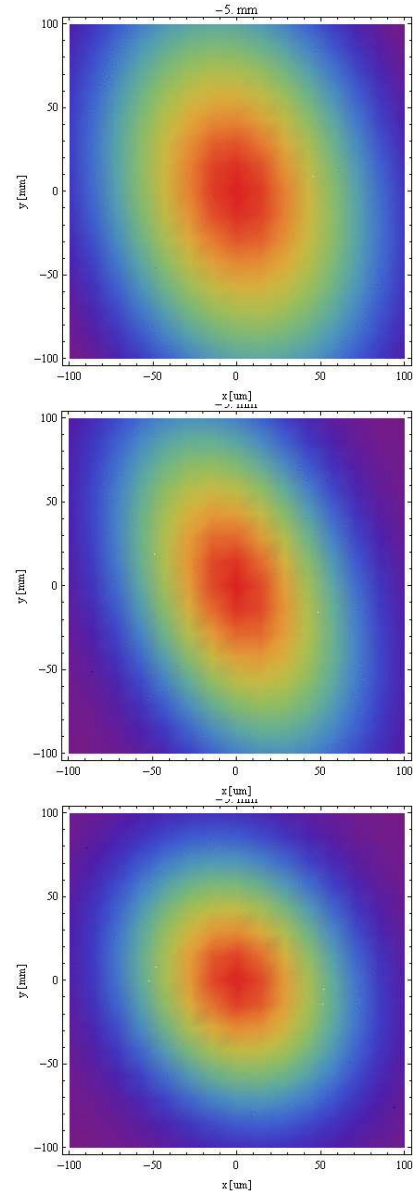
3 configurations:

minimum focal size ~15 µm

minimum focal size ~20 µm

minimum focal size ~25 µm

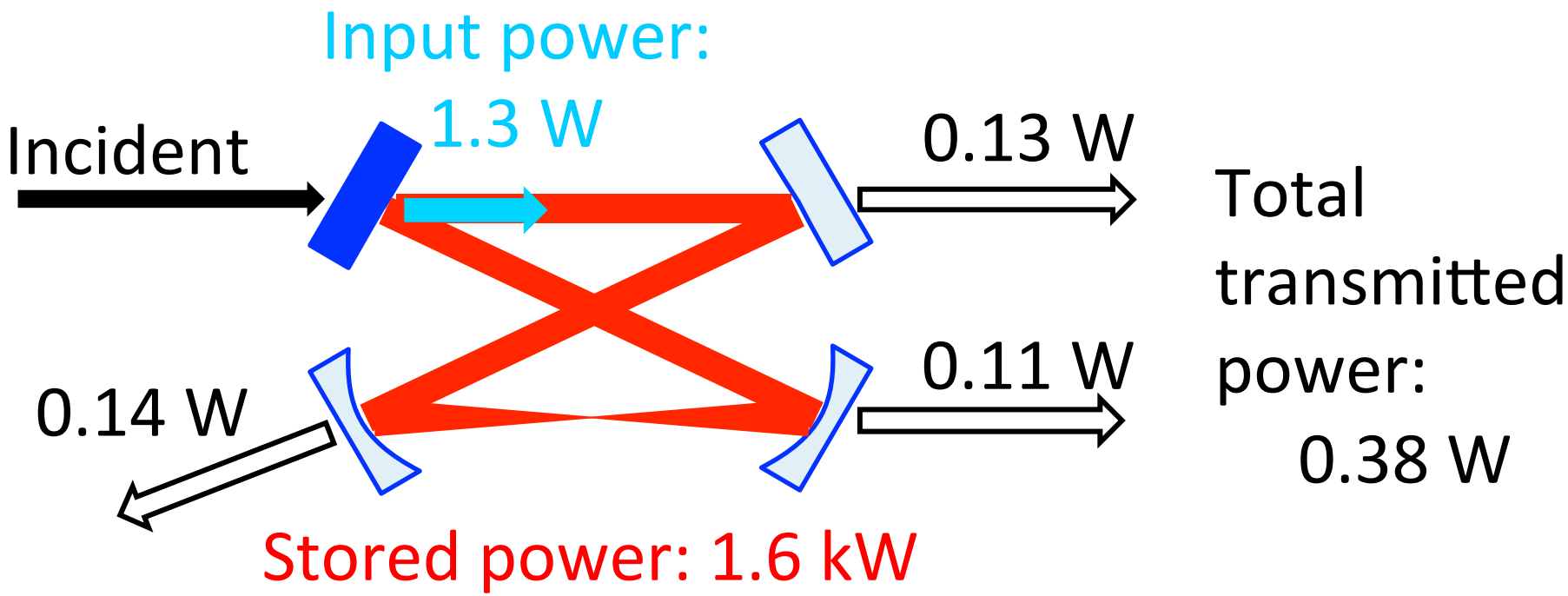




T. Takahashi POSIPOL2014

the thermal issue and the low loss mirror

Measurement of the power balance



Average power loss of each mirror:

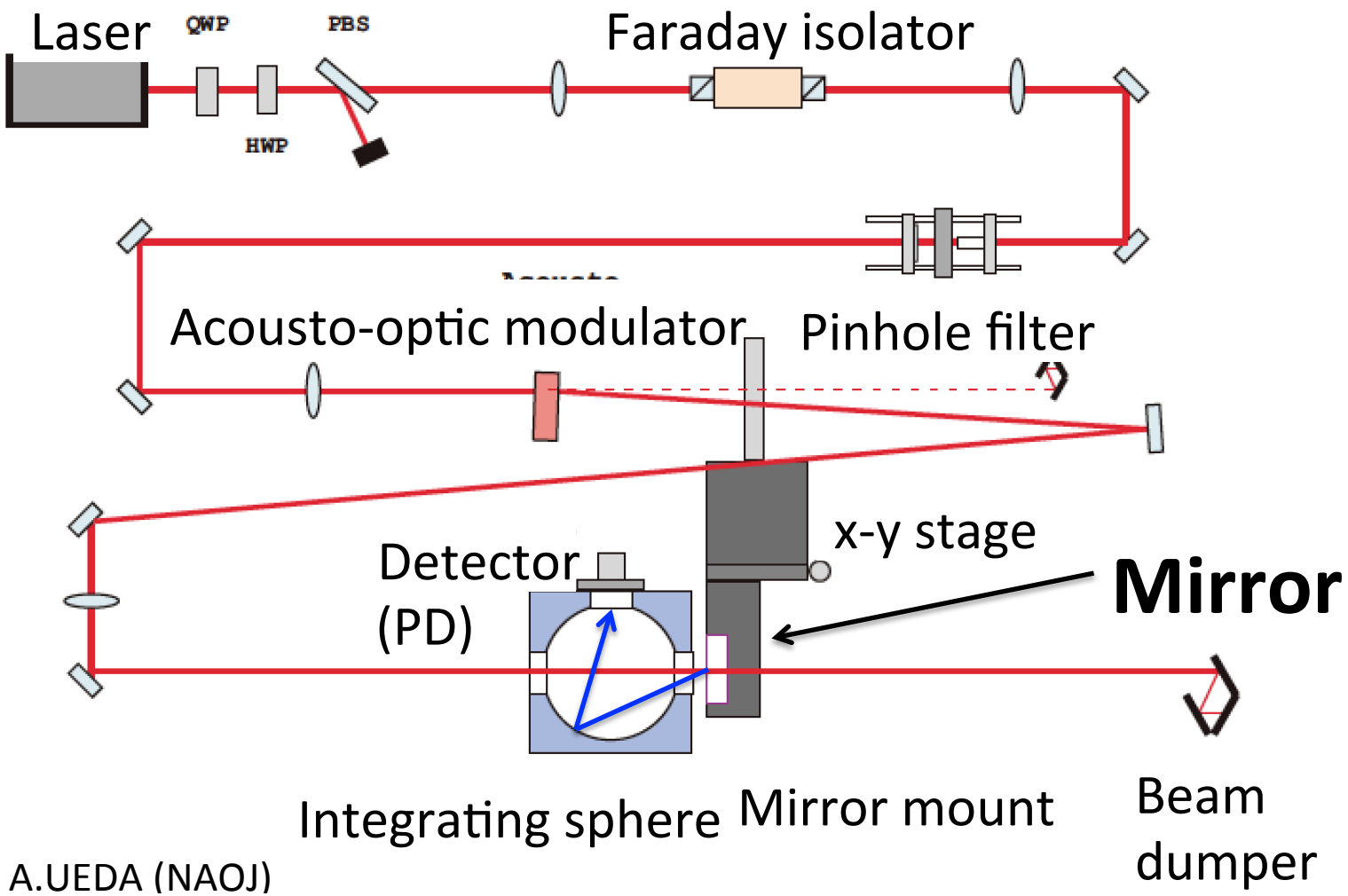
➡ 140 ppm

Specification:

➡ a few 10 ppm

Mirrors were contaminated (?)

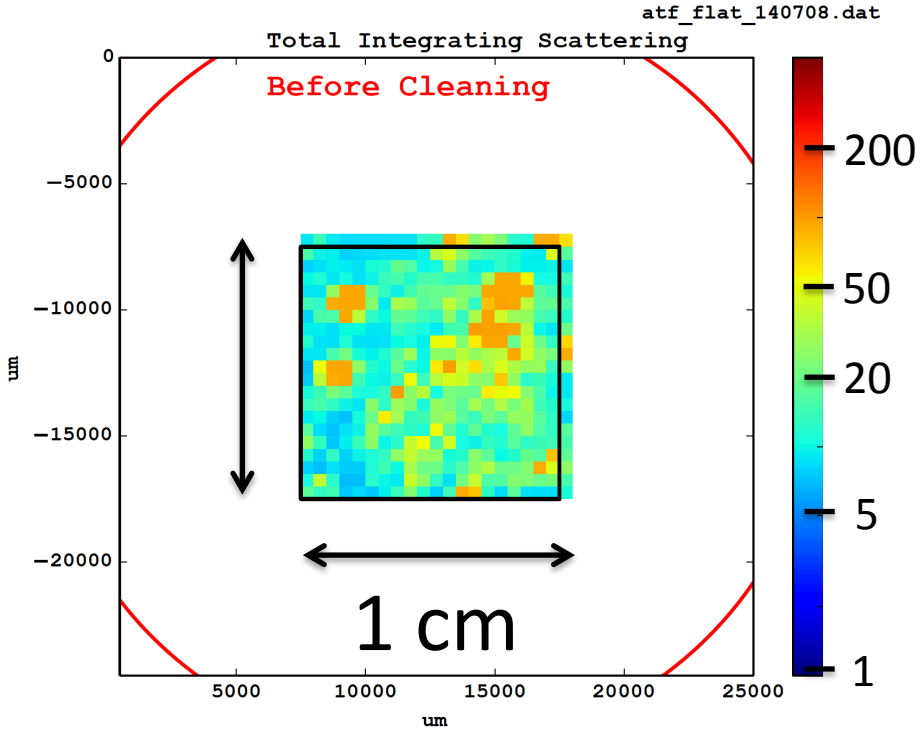
Scattering loss measurement

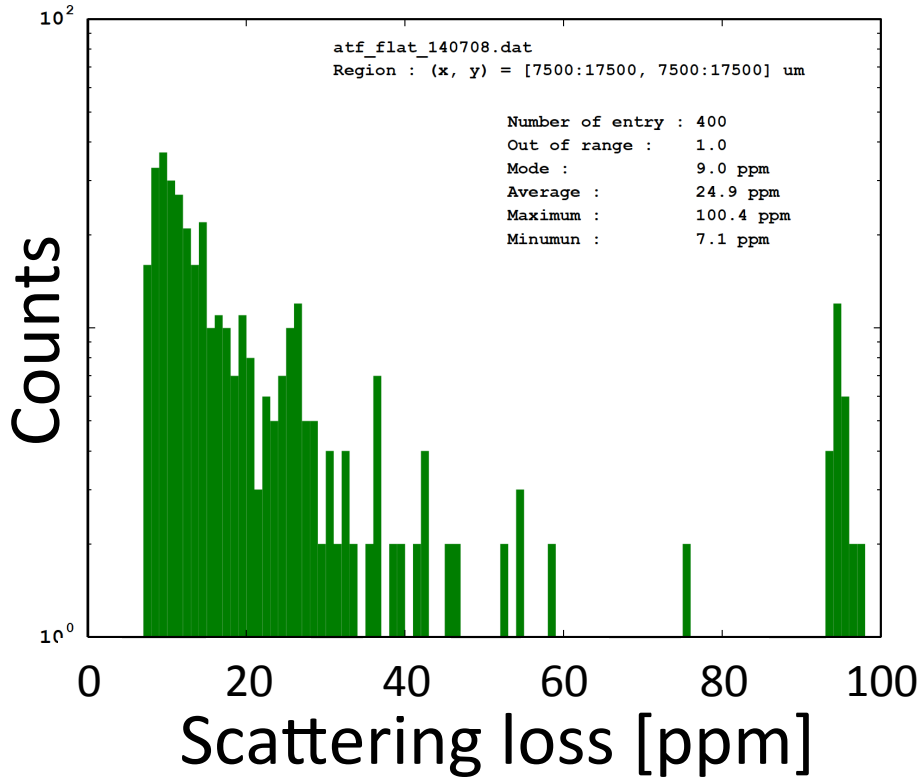


D.TATSUMI, A.UEDA (NAOJ)

Setup @ NAOJ: National Astronomical Observatory of Japan

Example of results





Average 24.9 ppm

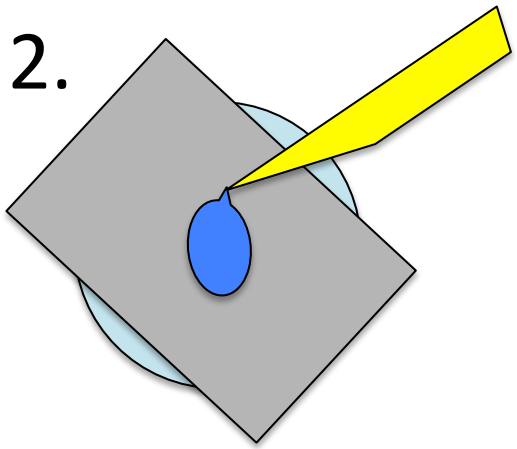
(Specification < 10 ppm)

- We tried to clean this mirror.

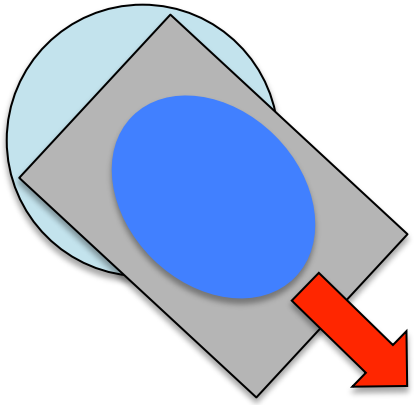
Cleaning method

We cleaned the mirror by using the **"drag wiping method"**.

1. 2.



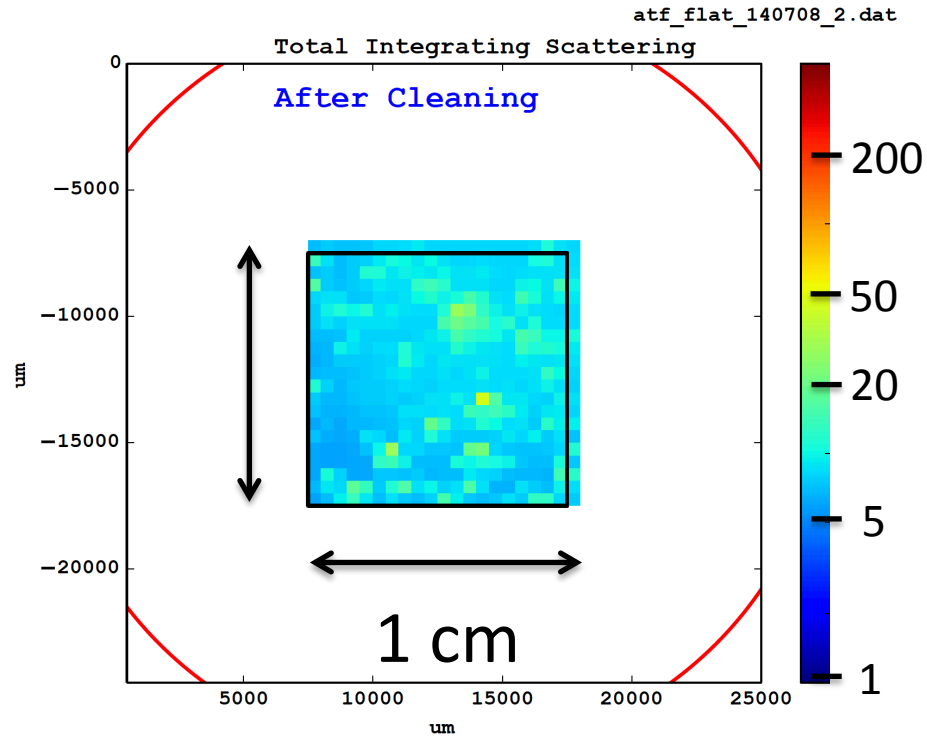
3.

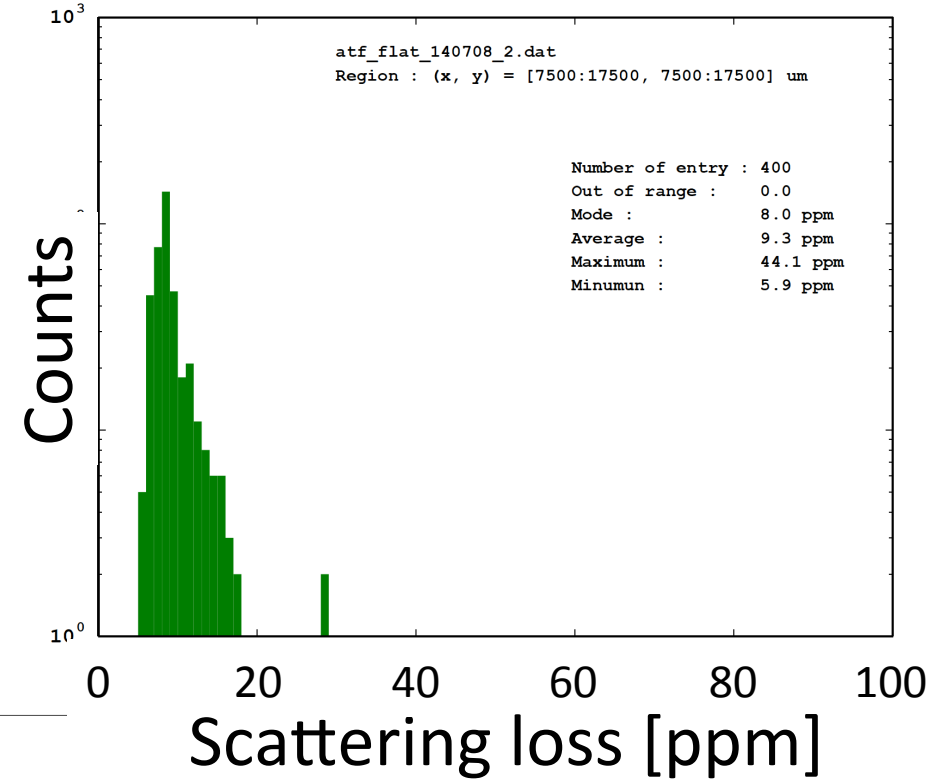


1. Put a paper on the mirror
2. Drip a few drops of 2-Plopanol
3. Slide the paper outward
4. Repeat about 100 times

D. Tatsumi, "How to clean mirrors?", NAOJ. Optics & photonics news, June (1990) 29.

The result after cleaning



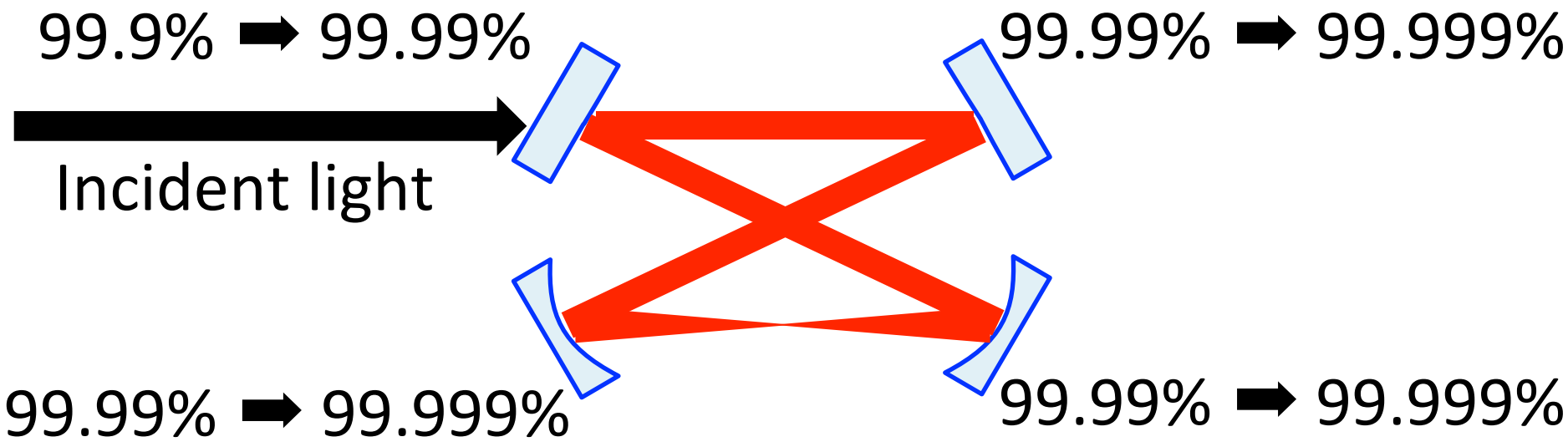


Before 24.9 ppm ➡ After 9.3 ppm

(Specification < 10 ppm)

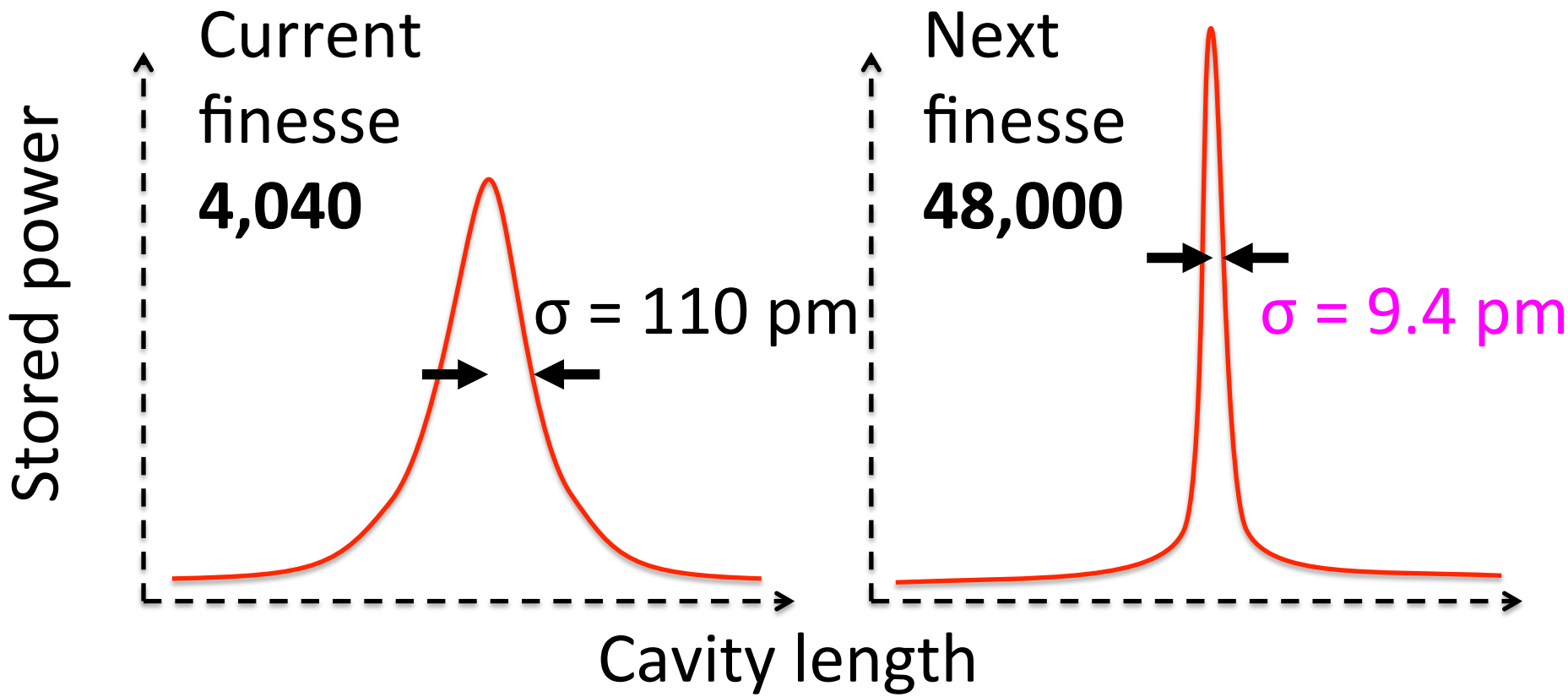
toward the high enhancement cavity

High finesse cavity



	Enhancement Factor	Finesse
~2014	1,230	4,040
Upgrade plan	16,600	48,000

Requirement for the feedback system

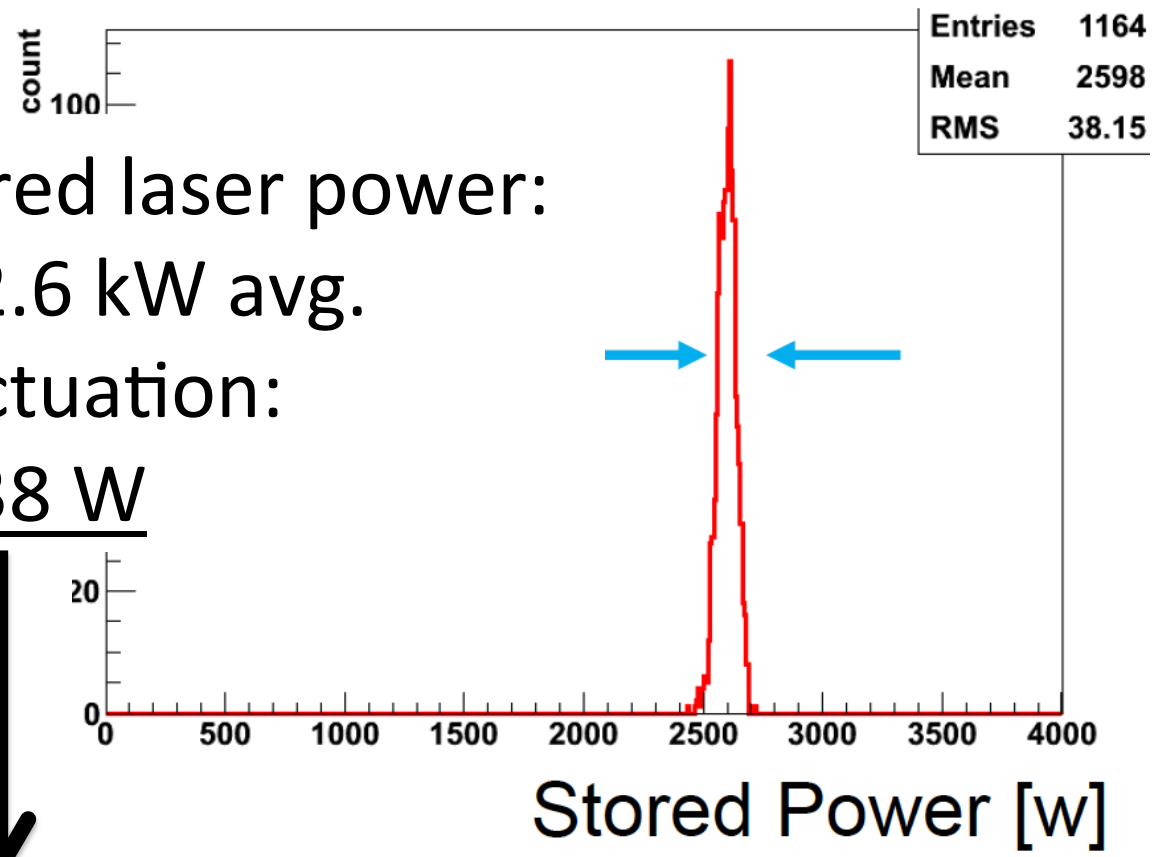


Requirement for the cavity length:

< 9.4 pm (1σ)

Requirement for the feedback system

Result @ 2012-2013



Stored laser power:

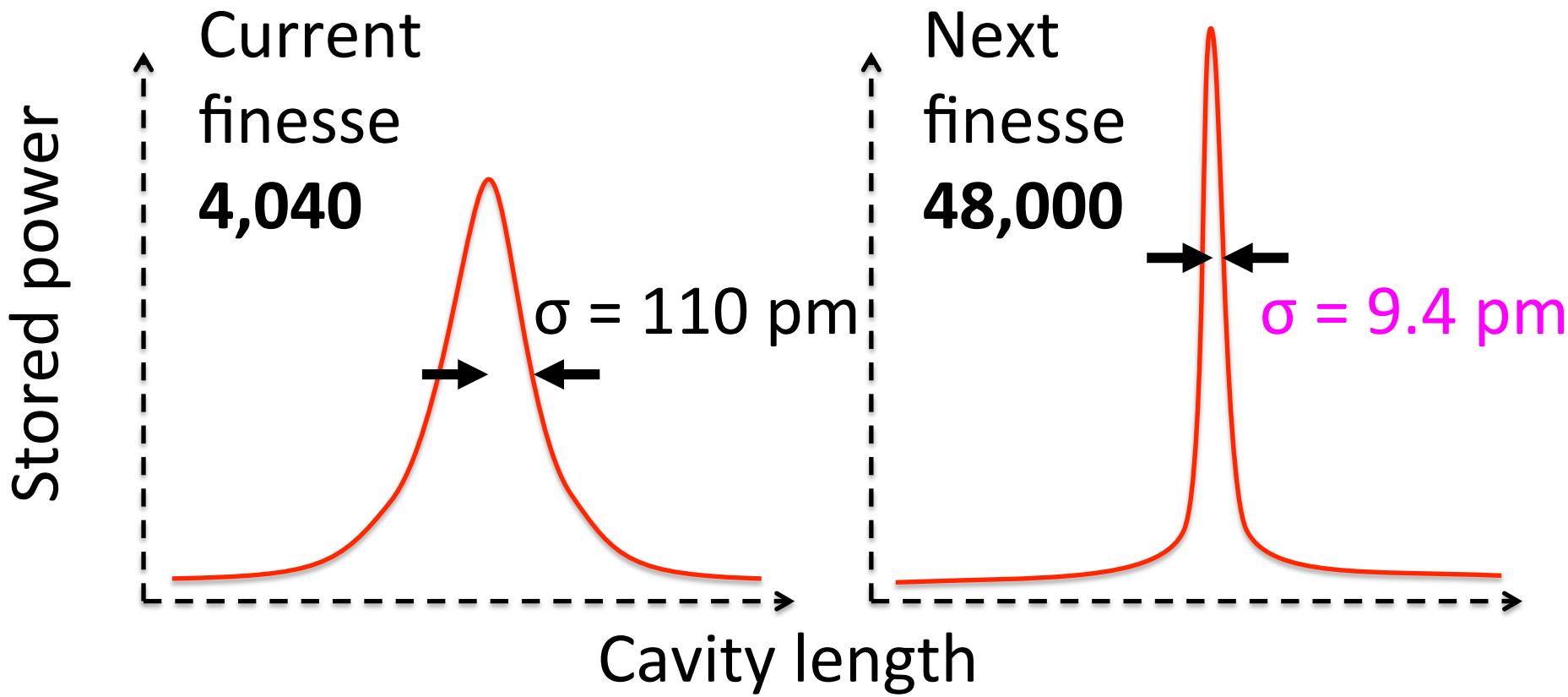
2.6 kW avg.

Fluctuation:

38 W

Precision of cavity length: 14 pm (1σ)

Requirement for the feedback system



Requirement for the cavity length:

< 9.4 pm (1σ)

Current achievement ➡ 14 pm (1σ)

Feedback system improvement

Understand the controlled system

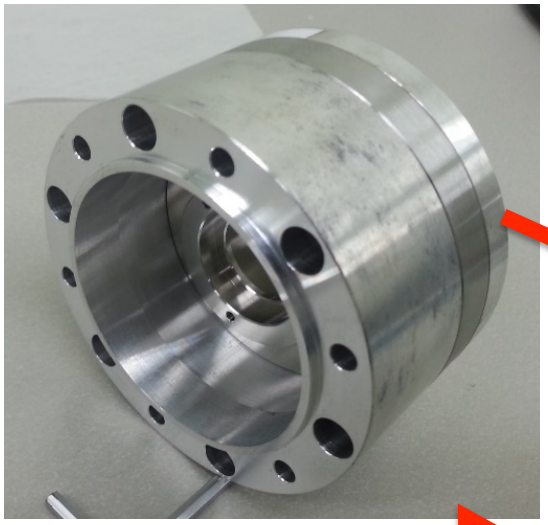
- Response characteristics of actuators
- Mechanical vibration characteristics
- Noises

Improve feedback controller

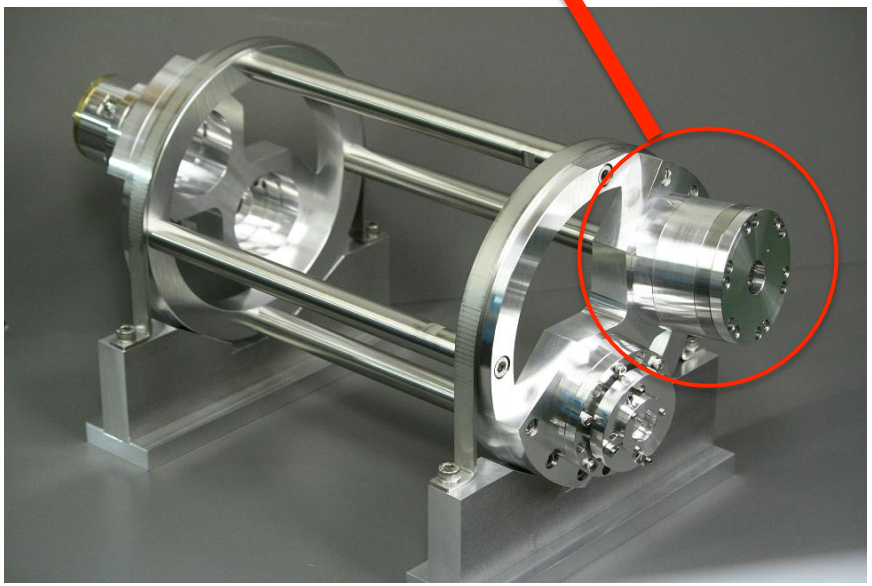
- Digital feedback
- Multichannel controller
- Add some functions

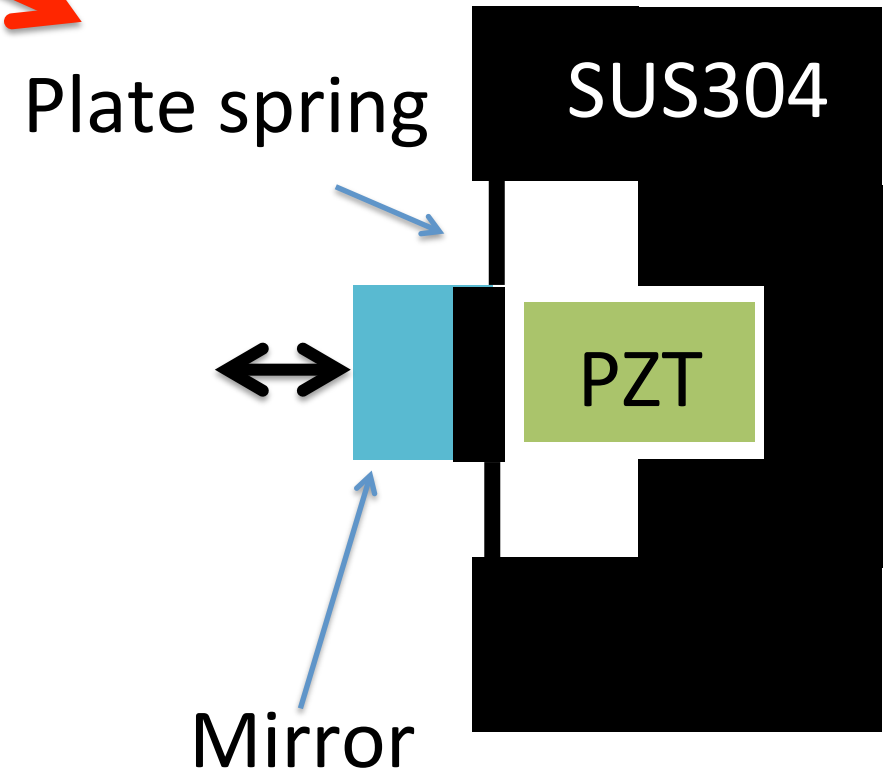
etc.

PZT actuator & mirror holder

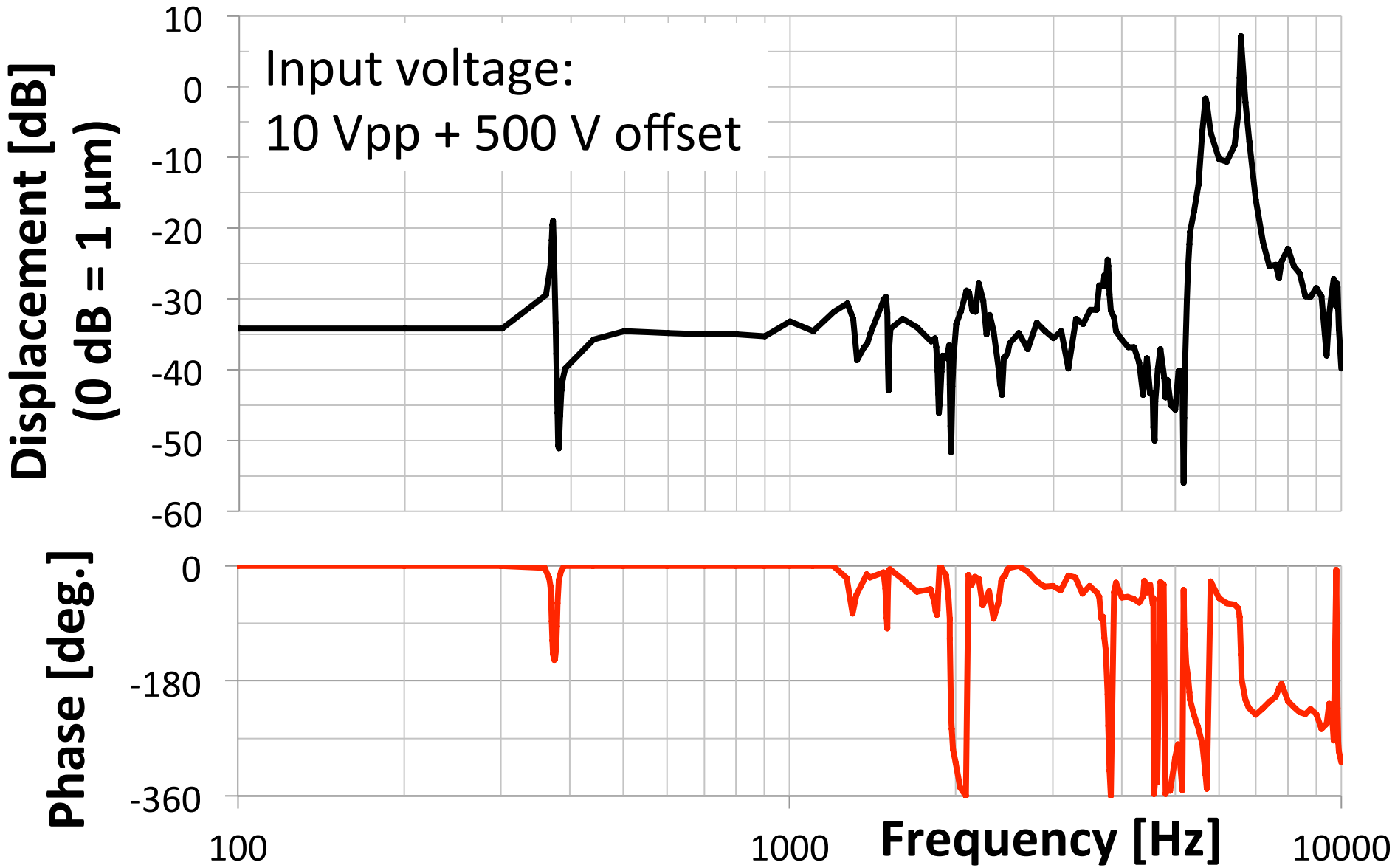


- controlling the cavity length

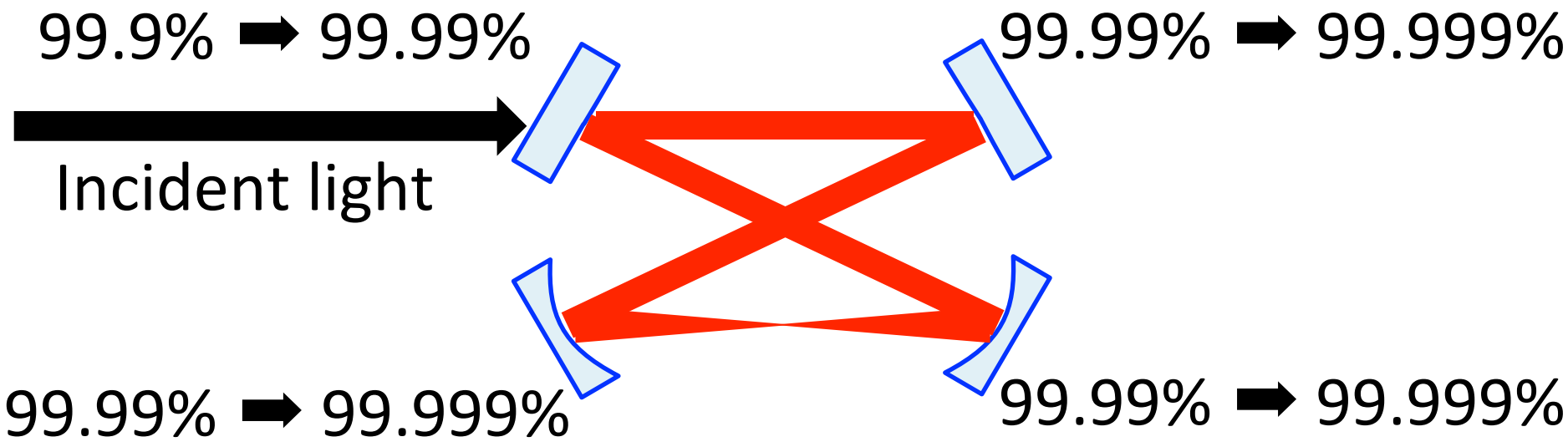




Response of the mirror displacement



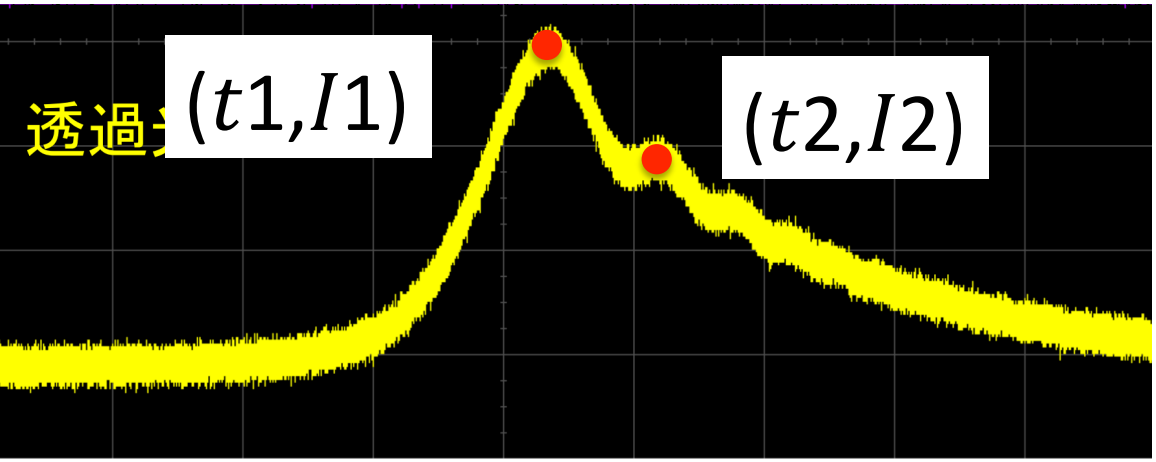
Expected finesse of 48000



	Enhancement Factor	Finesse
~2014	1,230	4,040
Upgrade plan	16,600	48,000

Finesse in the new configuration

Intensity of the transmitted light
with fast PZT scan



Life time of photons:

$$\tau = \frac{t_2 - t_1}{\ln(I_1) - \ln(I_2)}$$

$$= 40 \pm 1\,[\mu s]$$

Measured finesse: 45,000 ± 100

Summary

Achieved:

- 2.6 kW storage with enhancement factor of 1,230
- 10 Hz polarization switching

Toward higher power storage:

- Elliptical profile ➡ direct profile measurement
- Thermal issue ➡ mirror cleaning
- Feedback system ➡ measurement of actuators
- Cavity upgrade ➡ finesse of 45,000

Near future:

<u>O(10) kW storage with the high finesse cavity</u>

backups

Summary

Achieved:

- 2.6 kW storage with enhancement factor of 1,230
- 10 Hz polarization switching

Toward higher power storage:

- Elliptical profile ➡ direct profile measurement
- Thermal issue ➡ mirror cleaning
- Feedback system ➡ measurement of actuators
- Next cavity ➡ finesse of 45,000

Near future:

<u>O(10) kW storage with improved feedback system</u>

What performance we want

- X-ray source
  3 mJ / pulse × 357 MHz ～ 1 MW

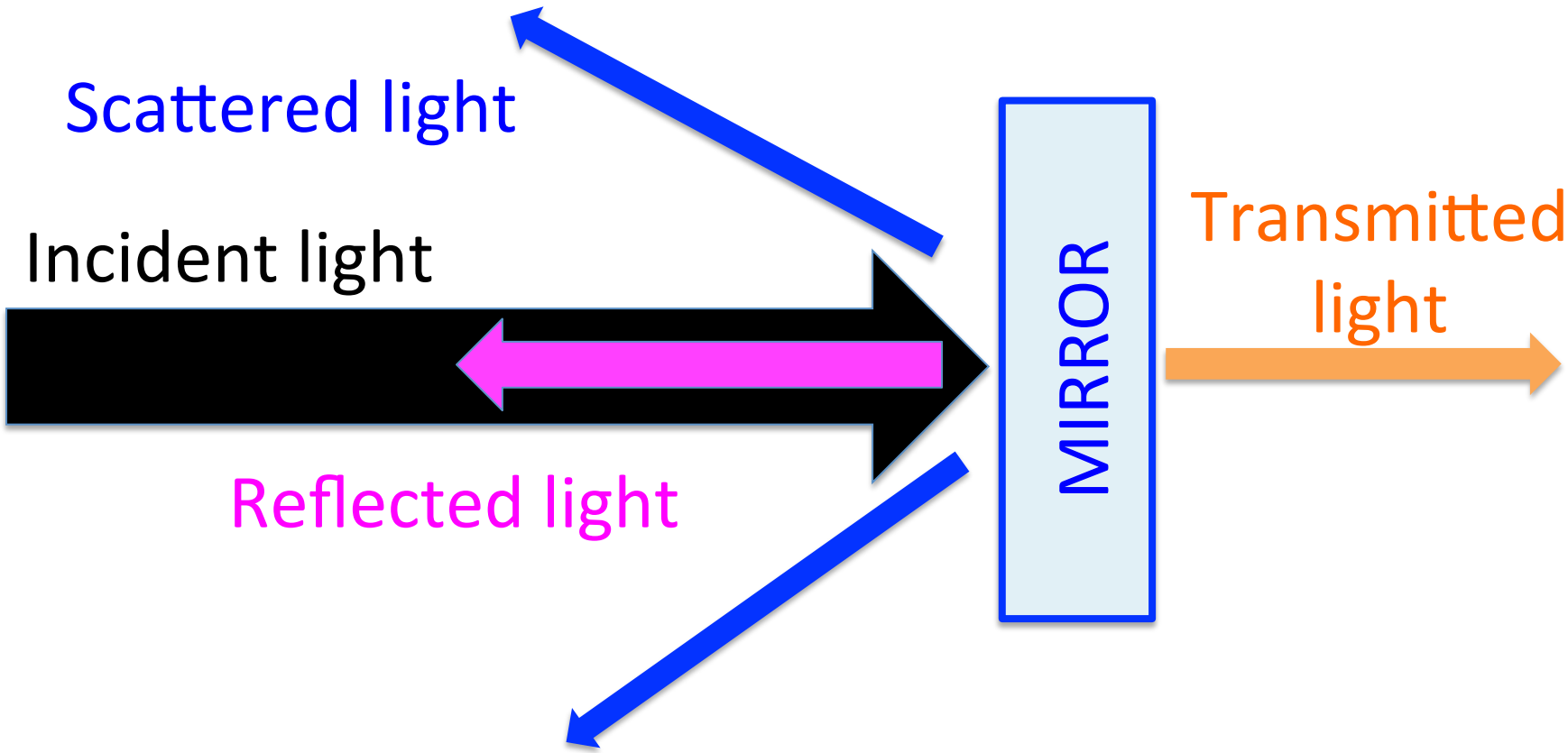
- ILC polarized e+ source
  600 mJ / pluse × 2640 × 5 × 100 ～ 800 kW

- gamma-gamma collider
  10 / pulse × 2640 × 5 ～ 100 kW

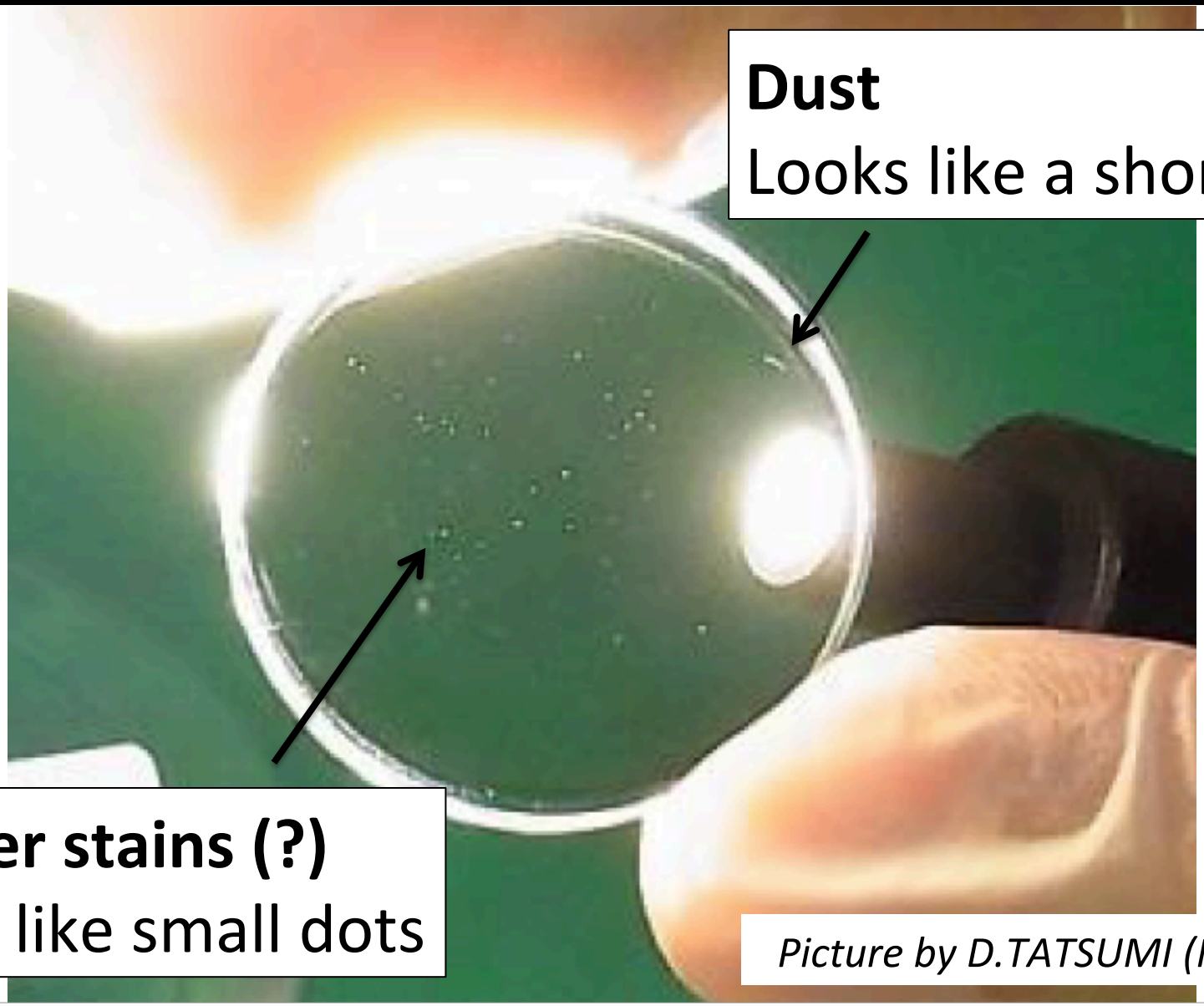
⇨ **Target stored power: about 1 MW (avg.)**

Measurement of the scattering loss

To get to know how much a mirrors was contaminated, we tried to measure the **<u>scattering loss</u>** of the mirror.



Picture of a dirty mirror

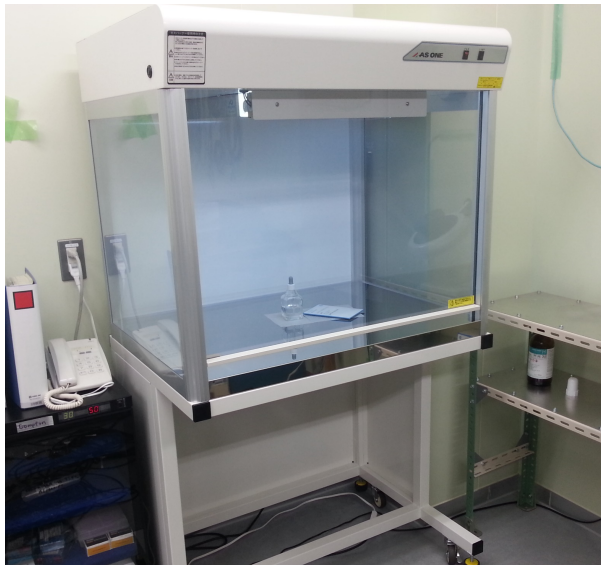


Dust
Looks like a short lint

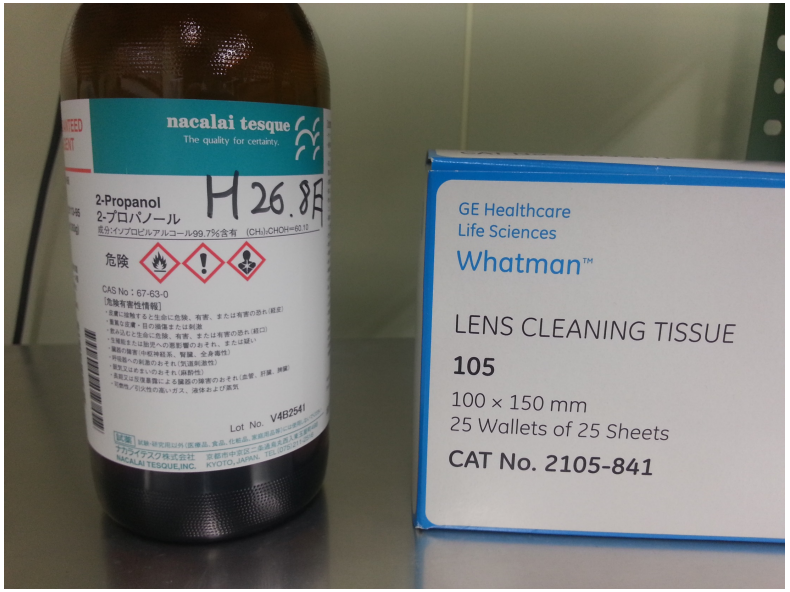
Water stains (?)
Look like small dots

Picture by D.TATSUMI (NAOJ)

Cleaning items



- Clean bench
- 2-Propanol 99.7 %
- Lens cleaning paper
- Lamp to use for checking the mirror surface

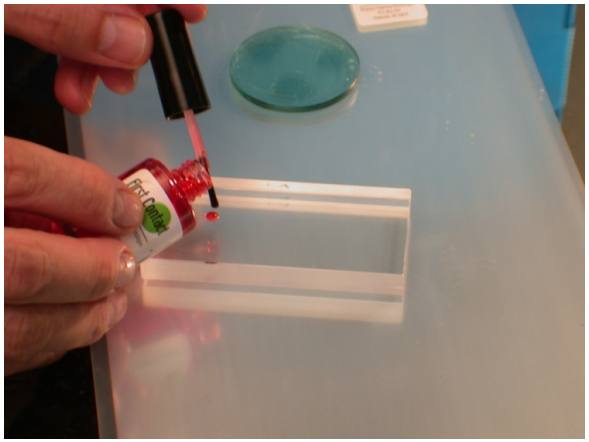


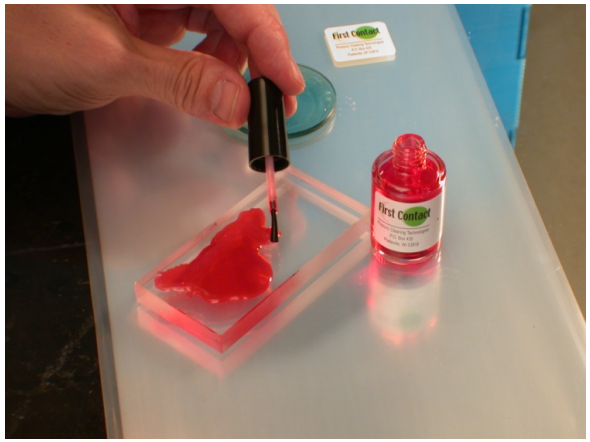
Another cleaning method

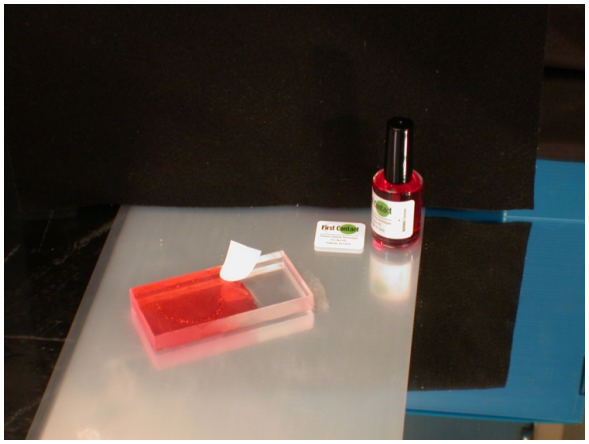
First Contact®

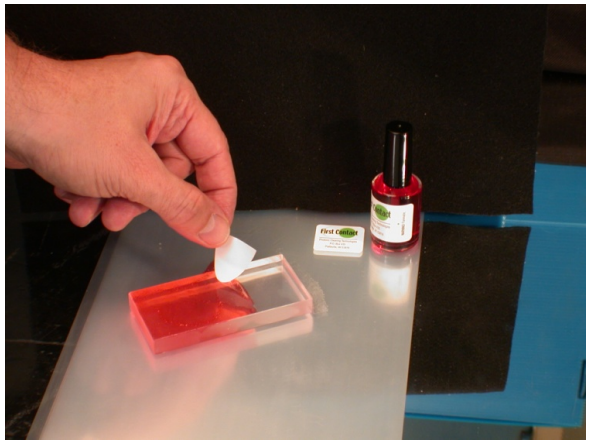
Popular cleaning method
in the gravity-wave measurements

http://www.photoniccleaning.com/

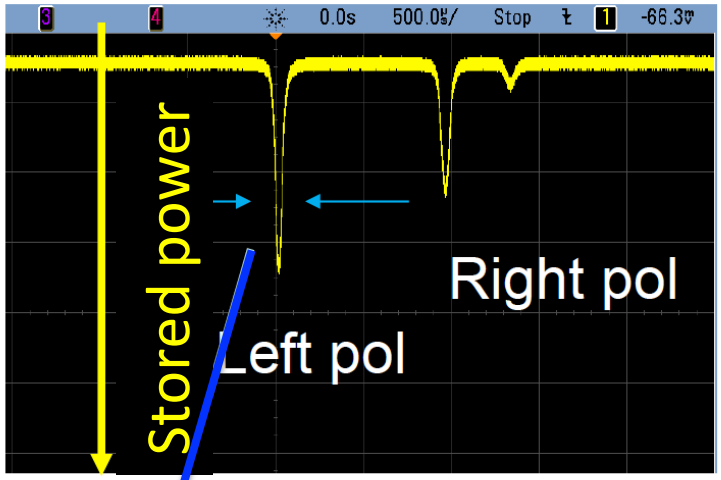




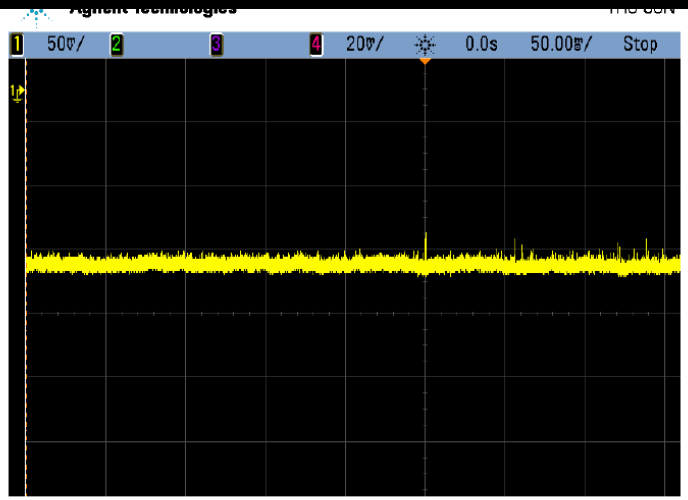




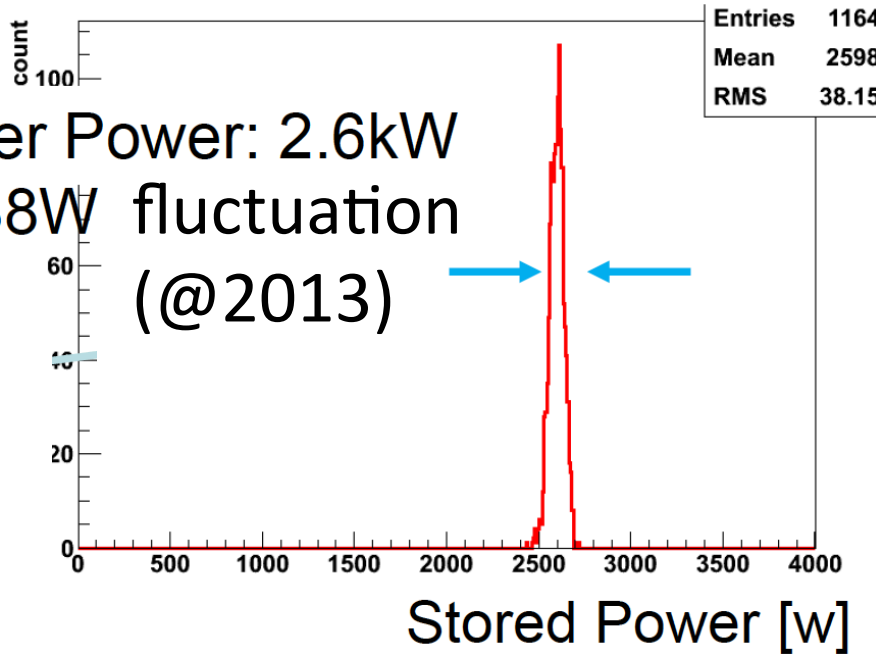
Controlled cavity length ~2014



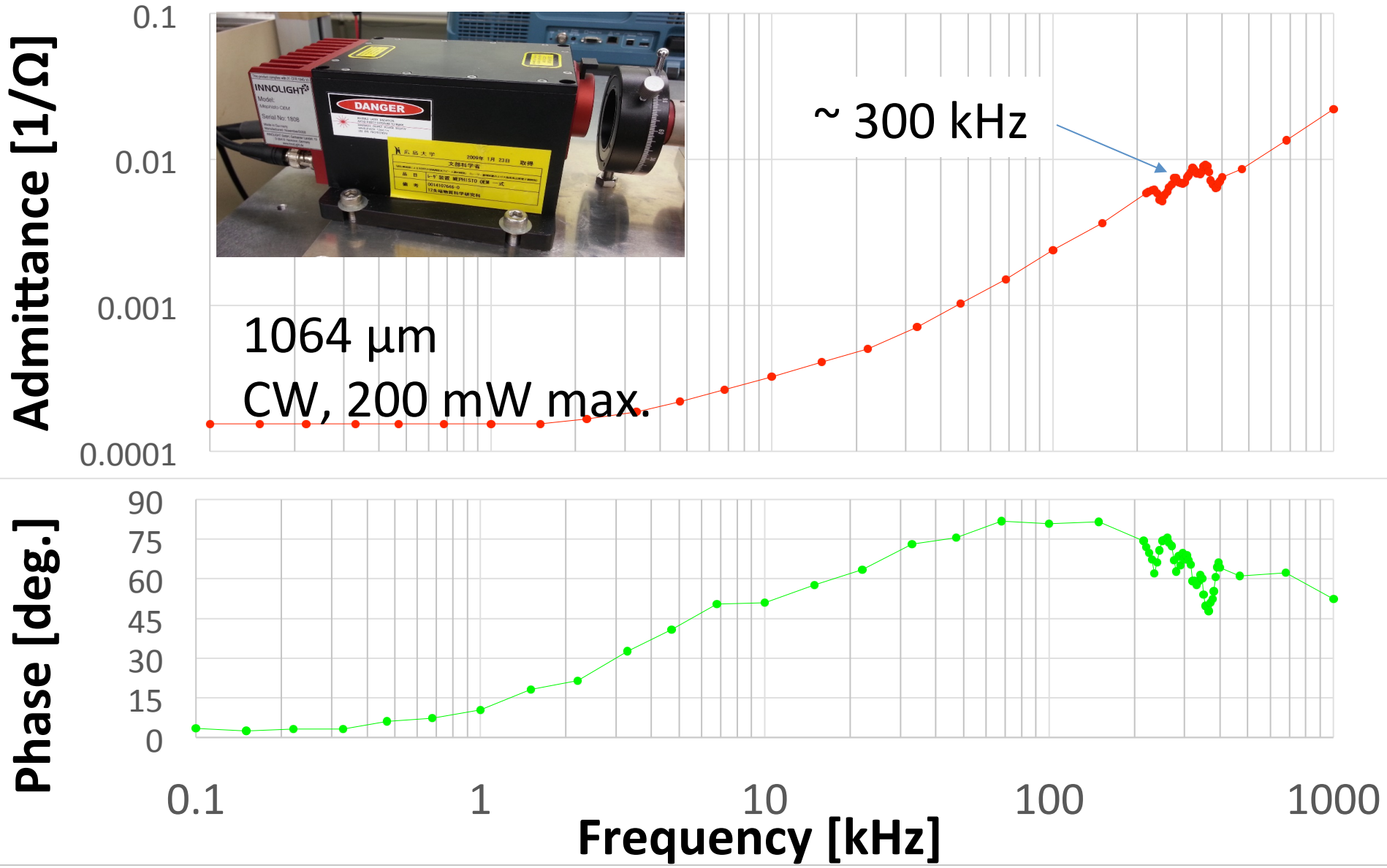
Feedback ON



Achieved **14 pm (1σ)**

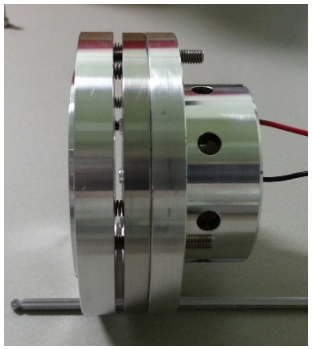


Response of laser-PZT (freq. controller)



Response of cavity-PZT (length controller)

No-load



Mounted in a mirror holder unit

Improve feedback controller

DSP: Digital signal processer

s-BOX (TMS320C6713 DSK)

- I/O : 6 inputs, 8 outputs
- Response band width: ~20 kHz

New cavity mirrors

Type	Supplier	Reflectance (spec.)	**Transmittance (measured)**
Planar, incident	REO	99.99 %	70 ± 7 ppm
Planar	LMA	99.999 %	10 ± 3 ppm
Concave	LMA	99.999 %	10 ± 3 ppm
Concave	LMA	99.999 %	10 ± 3 ppm

* 0.001 % = 10 ppm

Estimated performances

Average transmittance: 25 ppm

Effective reflectance of each mirror: 99.9965 %

➡ **Average power loss of each mirror:**
10 ppm

and also,

➡ **Enhancement factor of the cavity:**
~15,000

* 0.001 % = 10 ppm