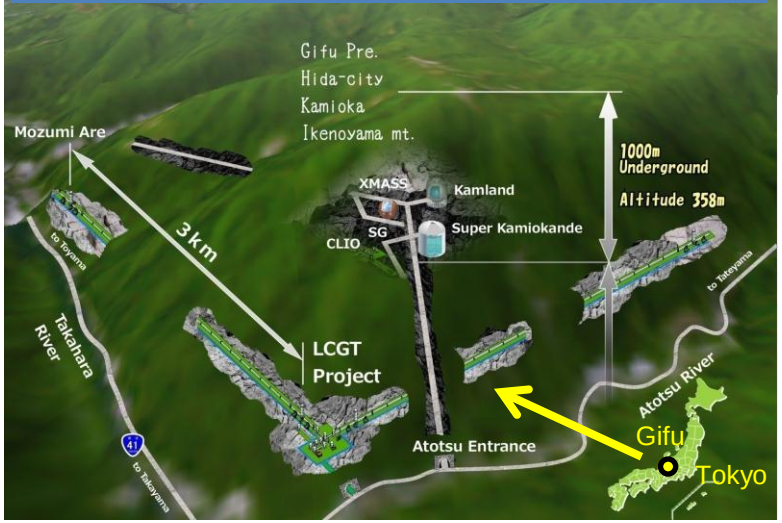
Sapphire for the LCGT project

Eiichi Hirose
ICRR, University of Tokyo

Kyohei Watanabe, Norikatsu Mio
PSC, University of Tokyo

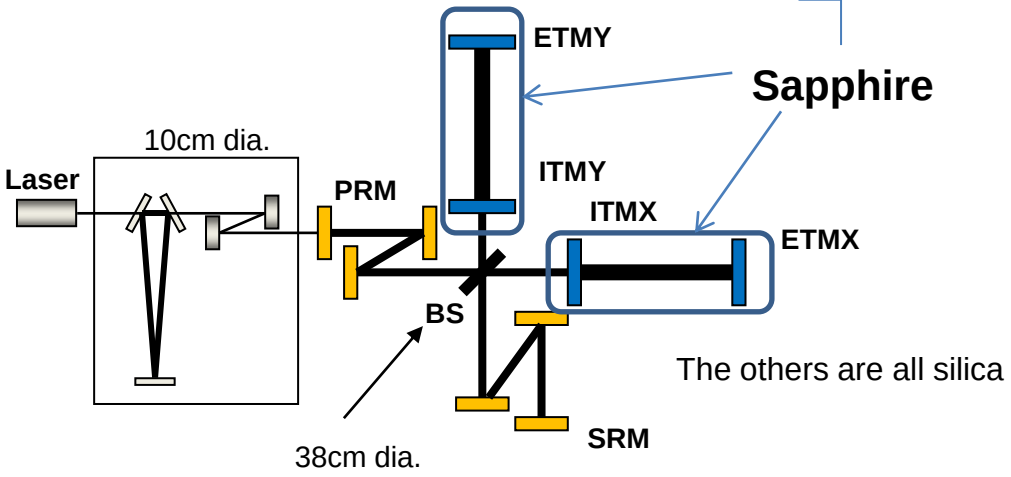
LCGT project

- **Underground**
  Low seismic noise
- **Cryogenic mirrors and suspensions**
  Reduction of thermal noise



Project got started last September and now under construction

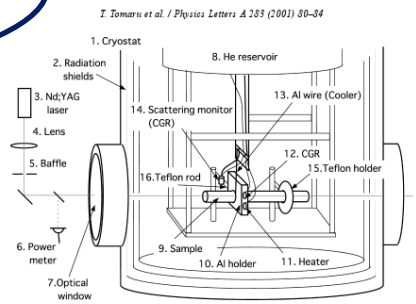
@ low temperature, sapphire has
- high mechanical Q (low loss)
- large heat conductivity



Requirements to sapphire
- 25cm dia. x 15 thickness (30 kg)
- absorption < 20ppm/cm
- orientation < 0.04 deg

A few methods to measure optical absorption

Basic idea is that small optical absorption changes temperature



- **Laser calorimeter**
- **Changes index of refraction**

  Changes optical length

  => interferometer

  Changes direction of laser beam

  => Photo-thermal deflection method
- **Causes thermal expansion**

  Causes a sound wave

  => Photo-acoustic detection

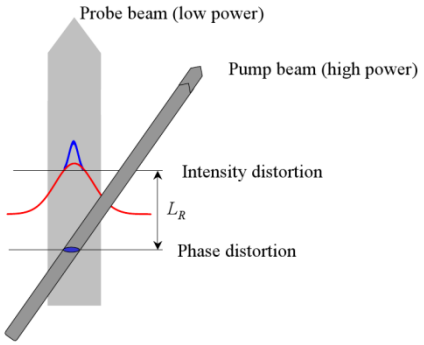
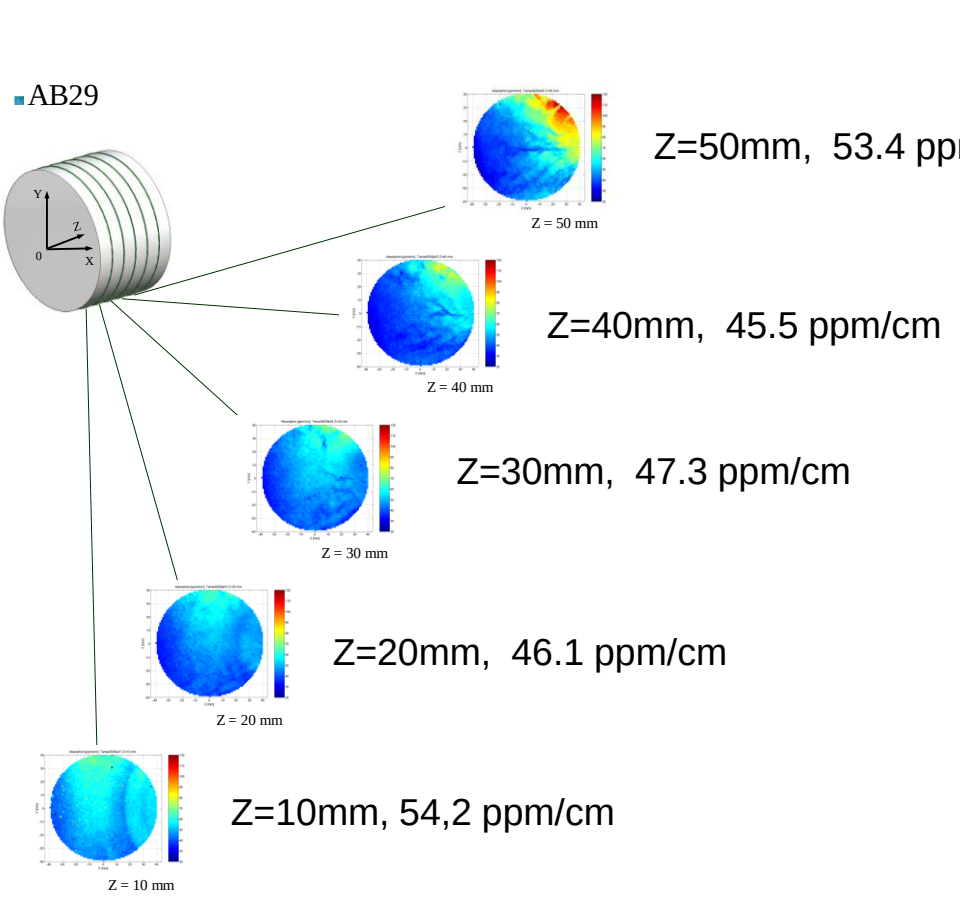


Photo-thermal deflection method

C-axis 100 mm dia. x 60 mm thickness



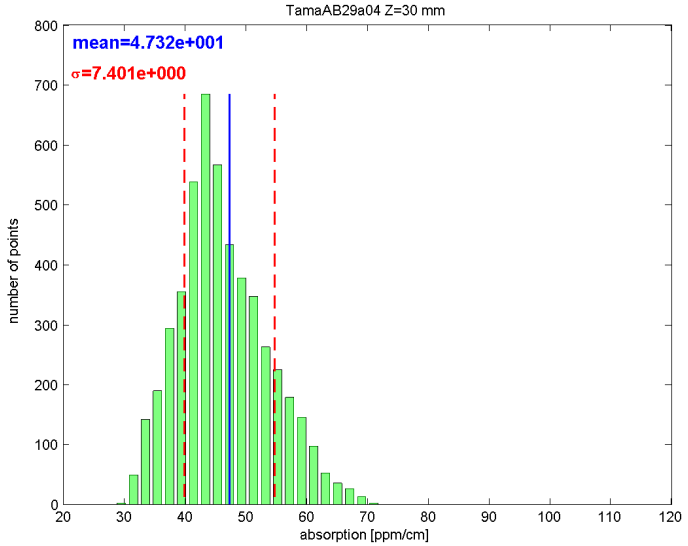
Z=50mm, 53.4 ppm/cm

Z=40mm, 45.5 ppm/cm

Z=30mm, 47.3 ppm/cm

Z=20mm, 46.1 ppm/cm

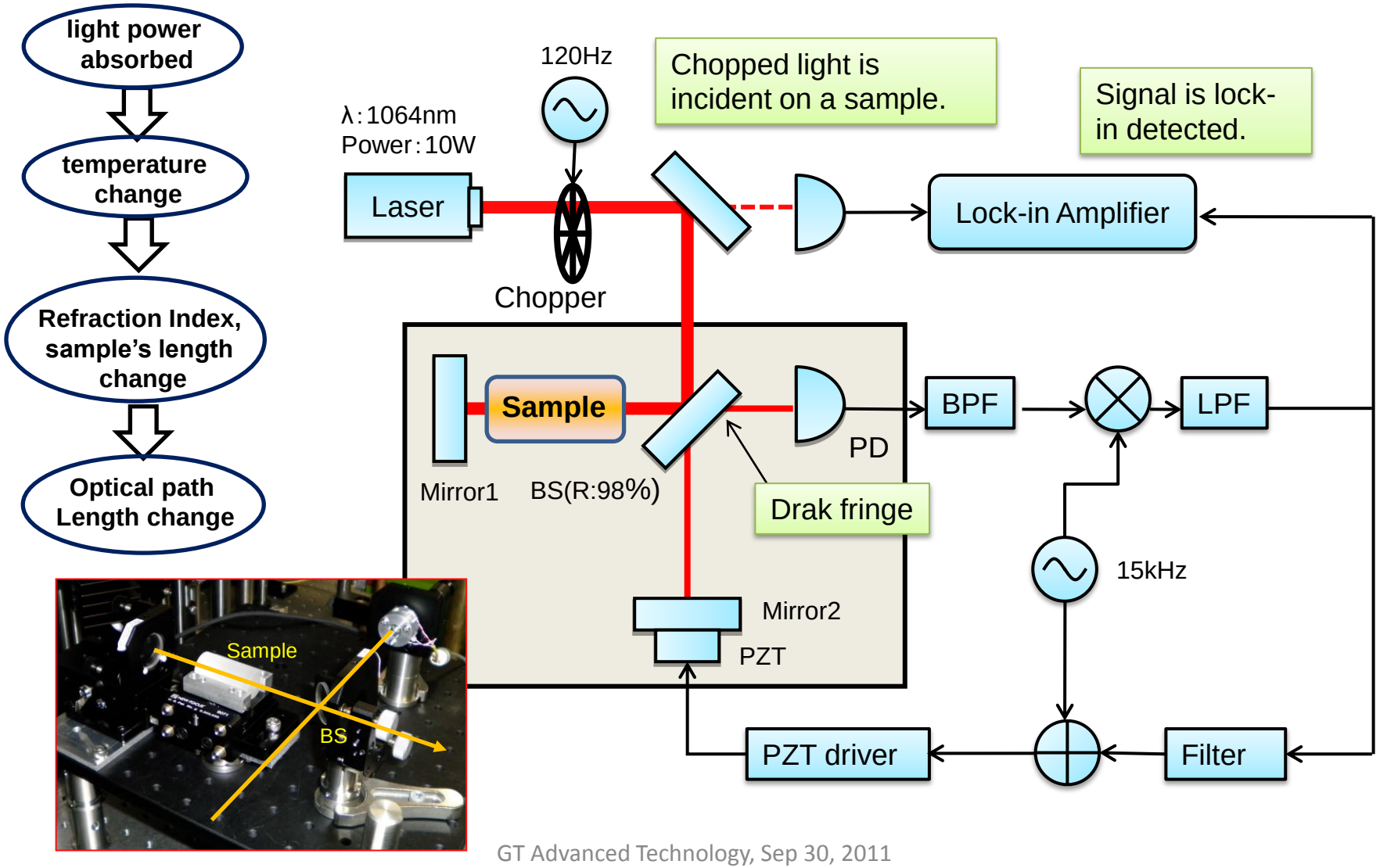
Z=10mm, 54,2 ppm/cm



Z=30mm (2005)

5

Interferometric method



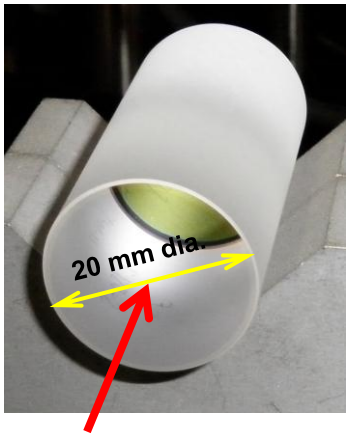
Result for BK7

Heat Equation

$$c\rho\frac{\partial T}{\partial t} = \beta P + \kappa\nabla^2 T$$

energy source from laser light

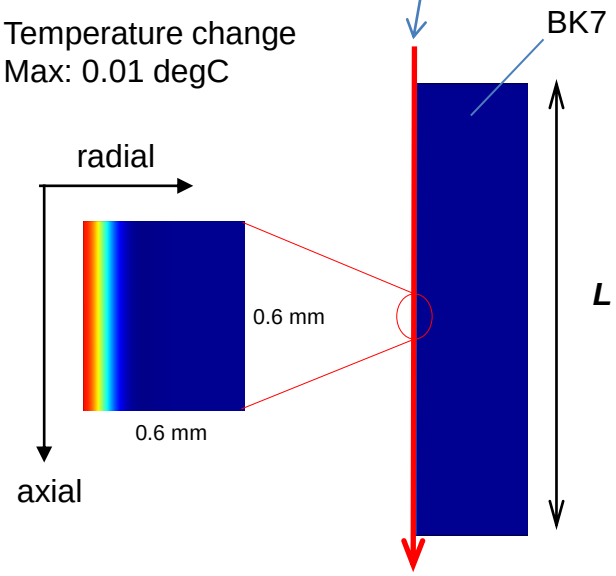
Standard glass ,
optical absorption (10^{-3}-10^{-4} /cm)

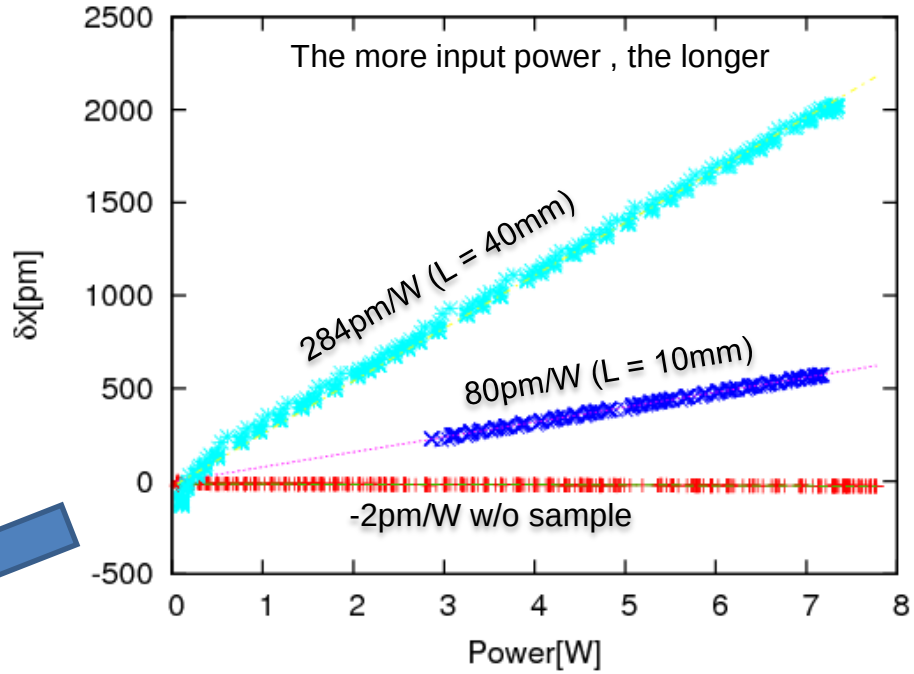


Laser dia. = 0.1 mm

FEA (Finite Element Analysis)
Is used to calculate absorption

Temperature change
Max: 0.01 degC





Optical absorption
10mm: 2230 ppm/cm
40mm: 2300 ppm/cm

Calibration

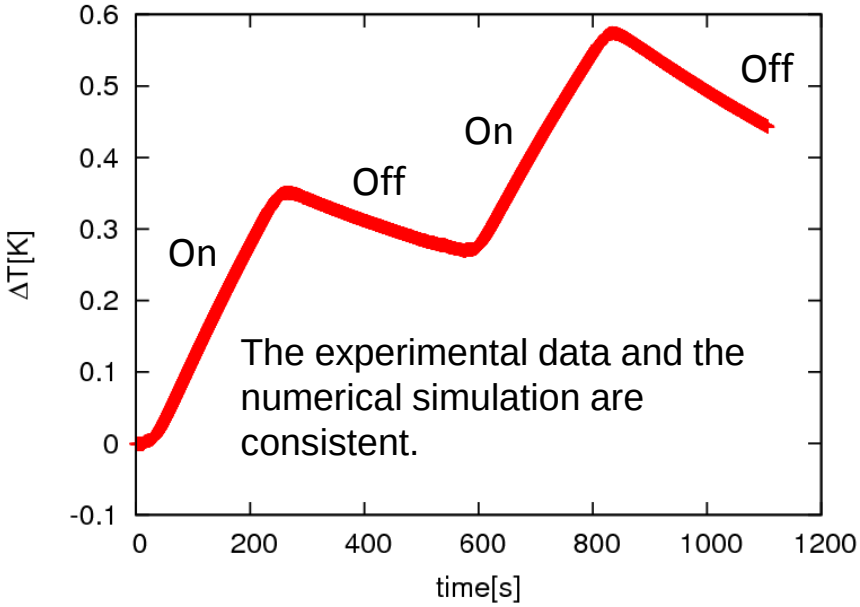
Comparison with another method

- A thermistor is attached on a lateral surface of the BK7 sample in order to measure the temperature change of the sample.
- The difference between the gradient of the temperature change is almost independent of the boundary condition.

$$\rho c \left.\frac{\partial T}{\partial t}\right|_{\text{on}} = \beta I L - hS\Delta T$$

$$\rho c \left.\frac{\partial T}{\partial t}\right|_{\text{off}} = -hS\Delta T$$

$$\left.\frac{\partial T}{\partial t}\right|_{\text{on}} - \left.\frac{\partial T}{\partial t}\right|_{\text{off}} = \frac{\beta I L}{\rho c}$$

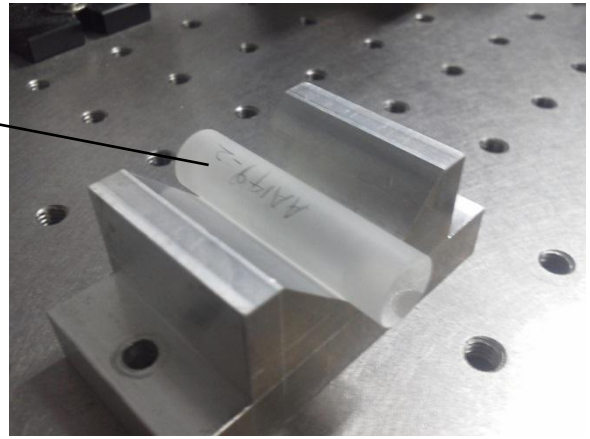


Optical absorption 1600 ppm/cm

Big difference from the other method

Sapphire sample

C-axis rod (10mm dia., 40mm length)



CRYSTAL SYSTEMS
27 CONGRESS STREET
SALEM, MA 01970
978.745.0088 FX 978.744.5059
www.crystalsystems.com

PRICE QUOTATION

TO: University of Tokyo
ATTN: Norikatsu Mio

DATE: 11/25/09
QUOTE #: 11-10-107-1
RFQ #: LCGT
NO. PAGES: 1

QUANTITY	DESCRIPTION	UNIT PRICE
	HEM CSI White Premium Optical Grade Sapphire Test Rods (0001)±1° 10.00 mm ± .1mm Ø x 40.00 mm ± .1mm Long 10-50 polish ends, fine grind OD Ends flat to λ/4 within an 80% C.A. Ends parallel to < 1 arc minute	US Dollars

Preliminary result

10 Samples

absorption [ppm/cm]

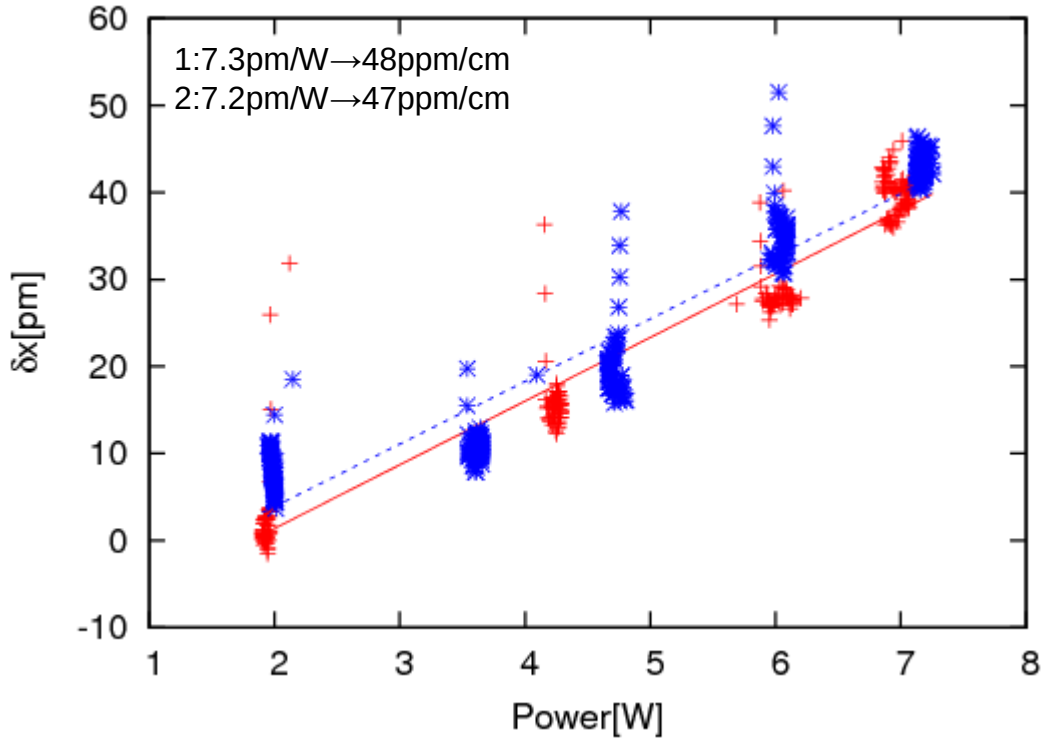
AA149	48	47		
AC150	229	138	682	687
P401	34	32	65	67

- AC150 shows quite high absorption. why ?
- P401 contains lower pair and high absorption pair. What is the difference?

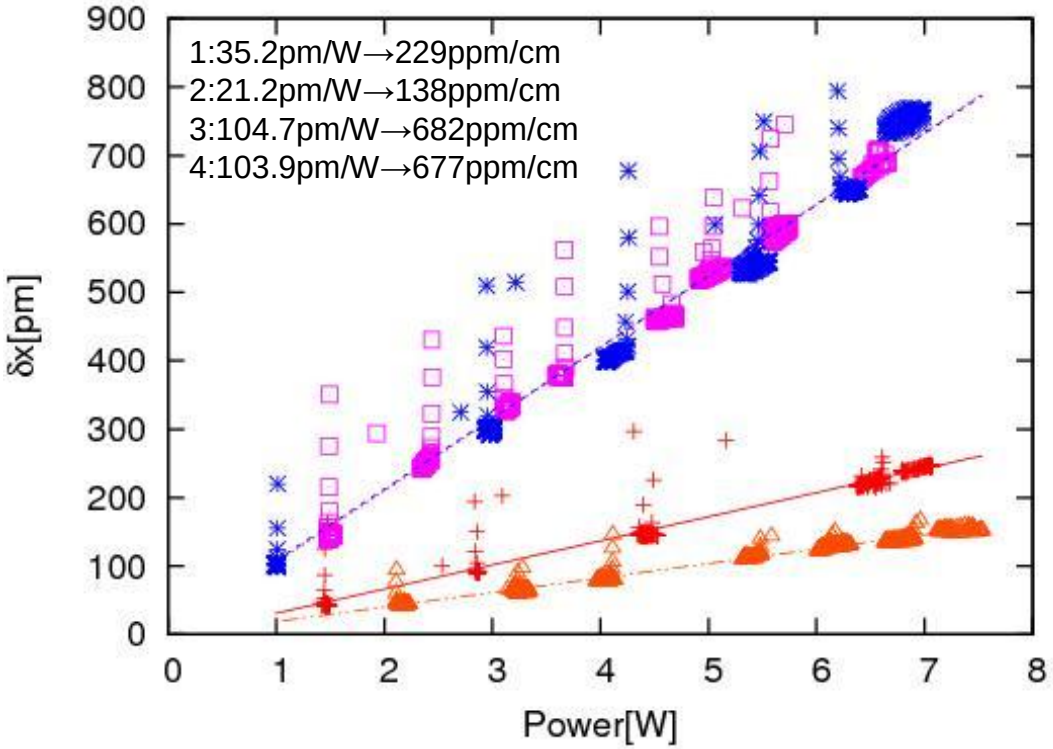
Conclusion

- LCGT project started last year and the detector is under construction
- We need sapphire that meets the requirement
- Measured absorption and the result shows some variation from sample to sample

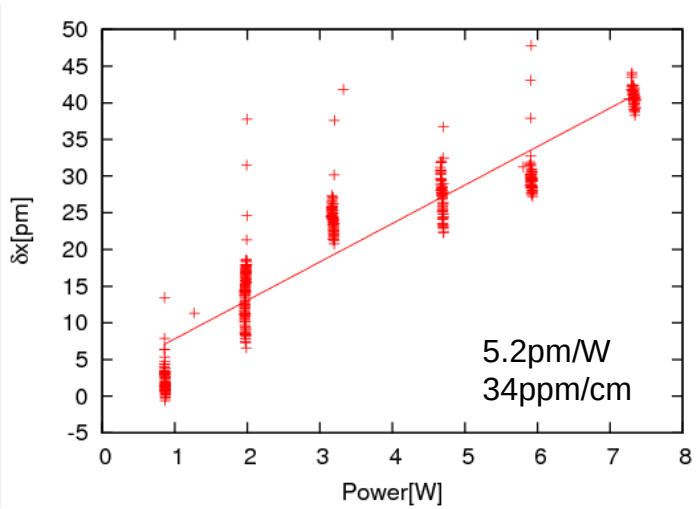
AA149

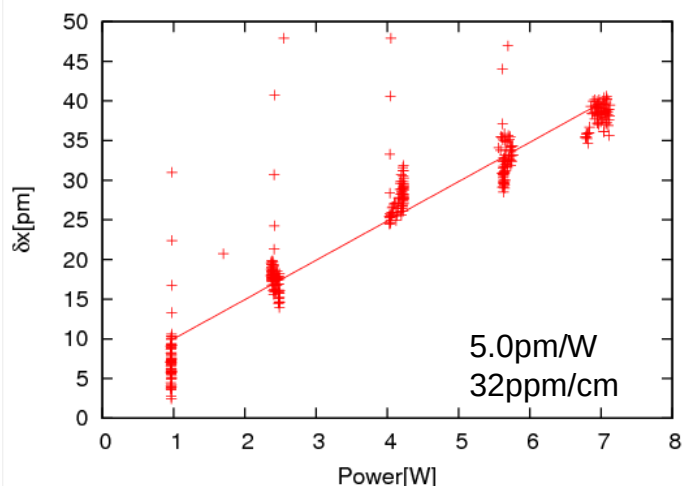

1:7.3pm/W→48ppm/cm
2:7.2pm/W→47ppm/cm
δx[pm]
Power[W]
60
50
40
30
20
10
0
-10
1
2
3
4
5
6
7
8

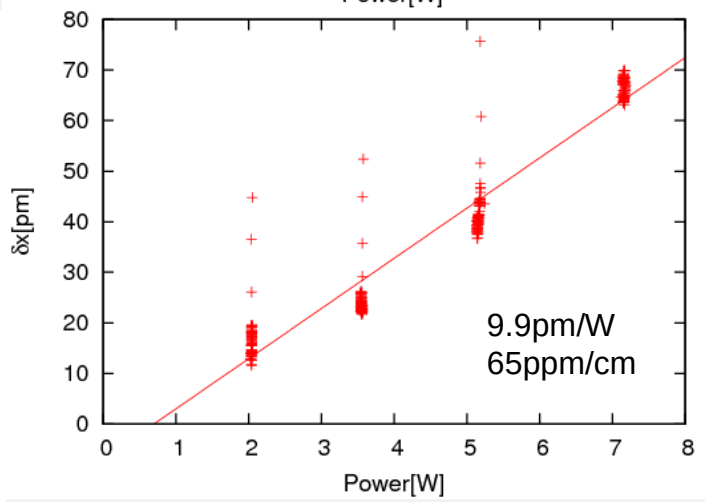
AC150

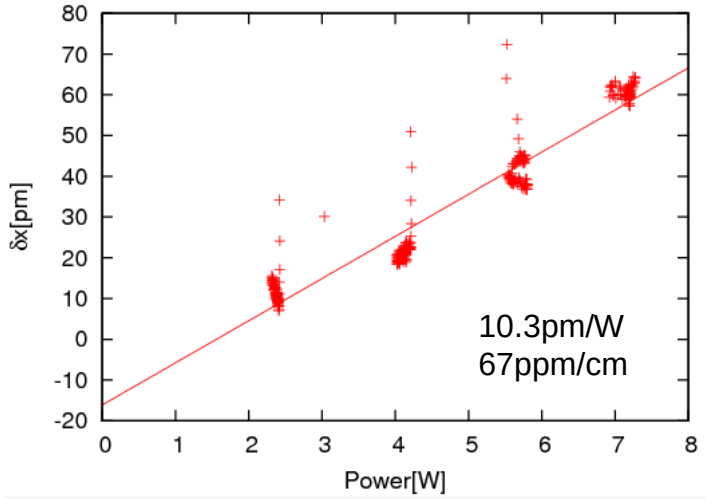

1:35.2pm/W→229ppm/cm
2:21.2pm/W→138ppm/cm
3:104.7pm/W→682ppm/cm
4:103.9pm/W→677ppm/cm
δx[pm]
Power[W]
0
100
200
300
400
500
600
700
800
900
0
1
2
3
4
5
6
7
8

P401


δx[pm]
Power[W]
5.2pm/W
34ppm/cm


δx[pm]
Power[W]
5.0pm/W
32ppm/cm


δx[pm]
Power[W]
9.9pm/W
65ppm/cm


δx[pm]
Power[W]
10.3pm/W
67ppm/cm