Development of an absorption bench and some results about crystalline coatings

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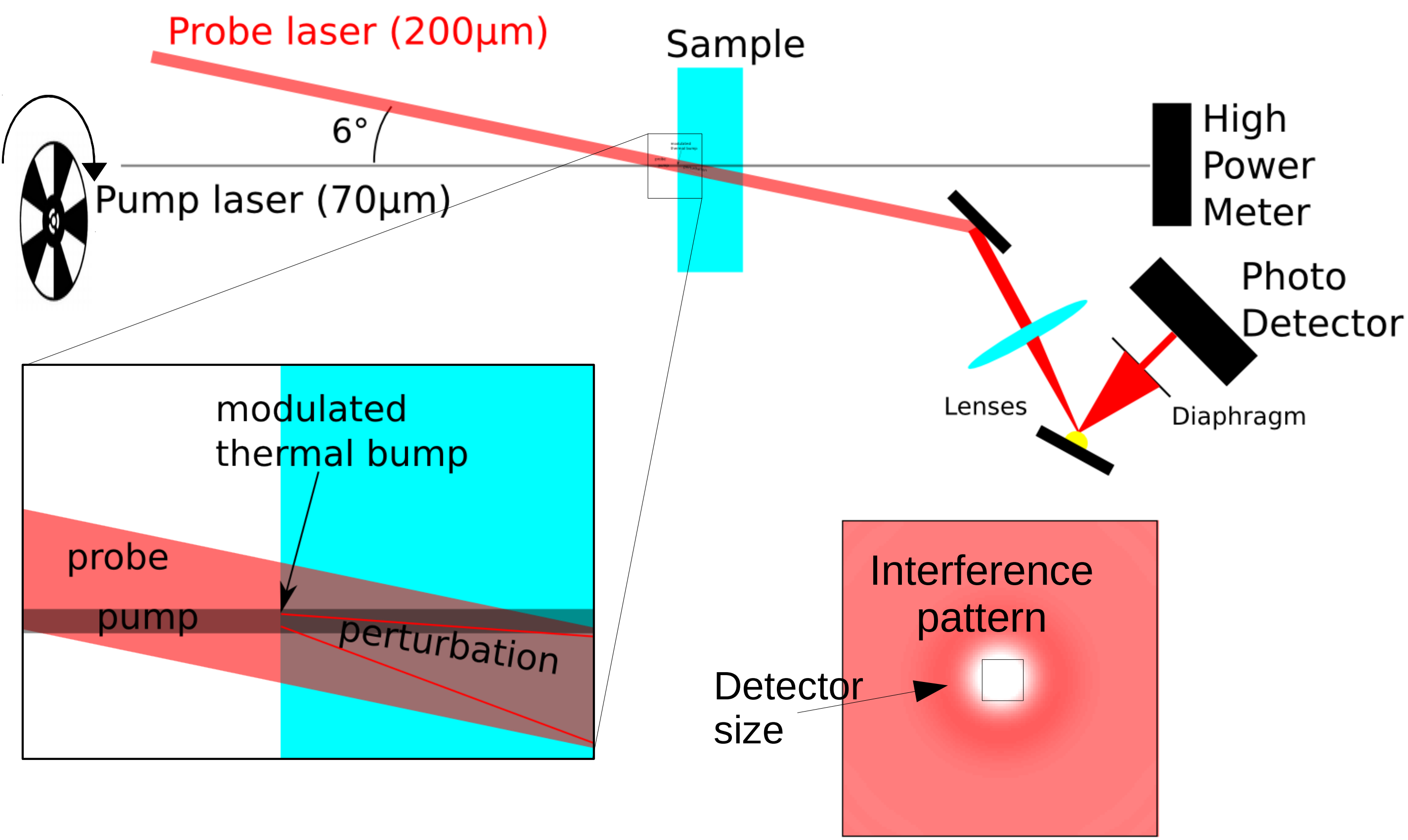
Motivation

- Study the absorption of Sapphire, scans and maps
- Characterize the KAGRA mirrors, bulk and surface absorption
- R&D – Investigate on Crystalline coating to reduce mechanical losses.

Absorption measurement method at NAOJ

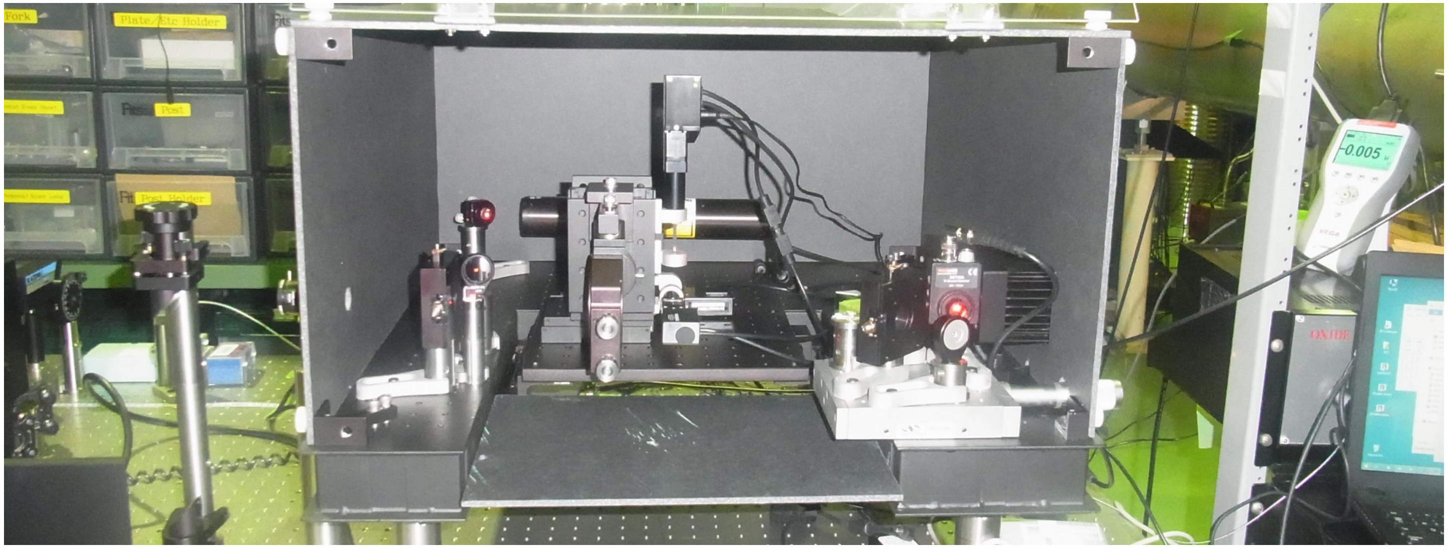


- The 1064nm pump periodically changes the temperature of the sample
- The thermal lens effect changes the probe wavefront
- After some propagation, the perturbation makes interference with the main mode
- The detector sense the intensity variation of the central part of the spot.
- This variation is proportional to the pump **absorption rate**

Photo-thermal
Common-path
Interferometer

from the company
Stanford Photo-Thermal Solution

Experimental setup



- Scan along the sample depth
- 2D maps of the surface and inside the substrate
- High power pump laser (25W)
- Best sensitivity:
  - Silica: <1 ppm/cm (bulk) <0.1 ppm (surface)
  - Sapphire: <5 ppm/cm (bulk) <0.5 ppm (surface)

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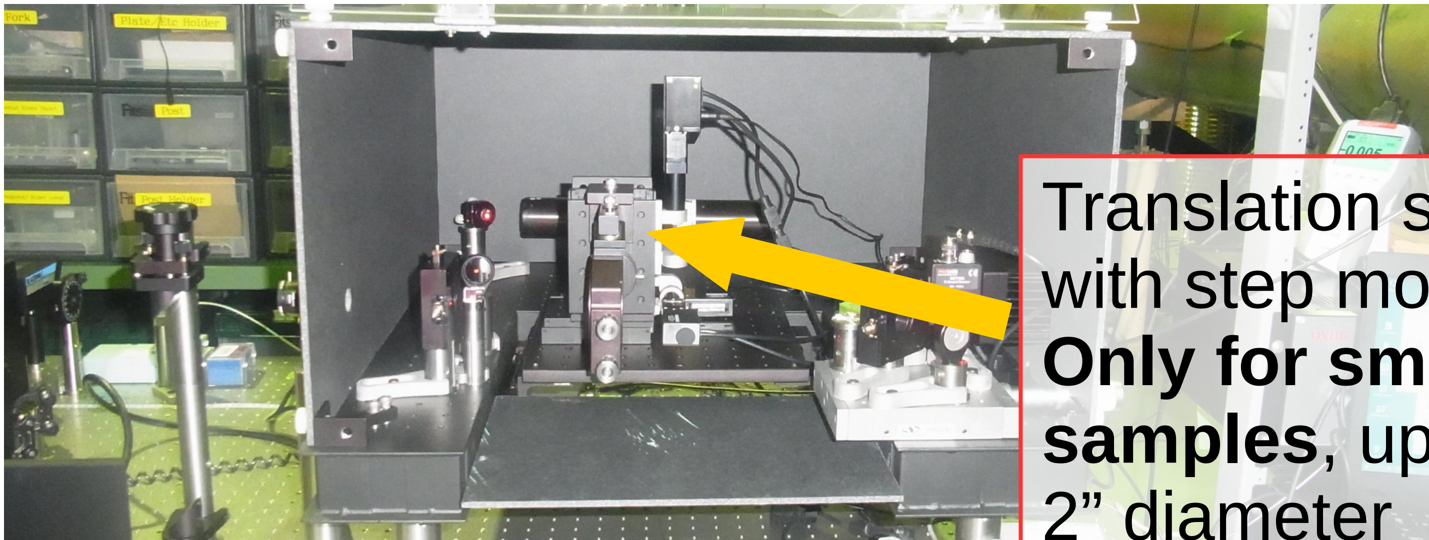

Translation stage with step motors
Only for small samples, up to 2” diameter

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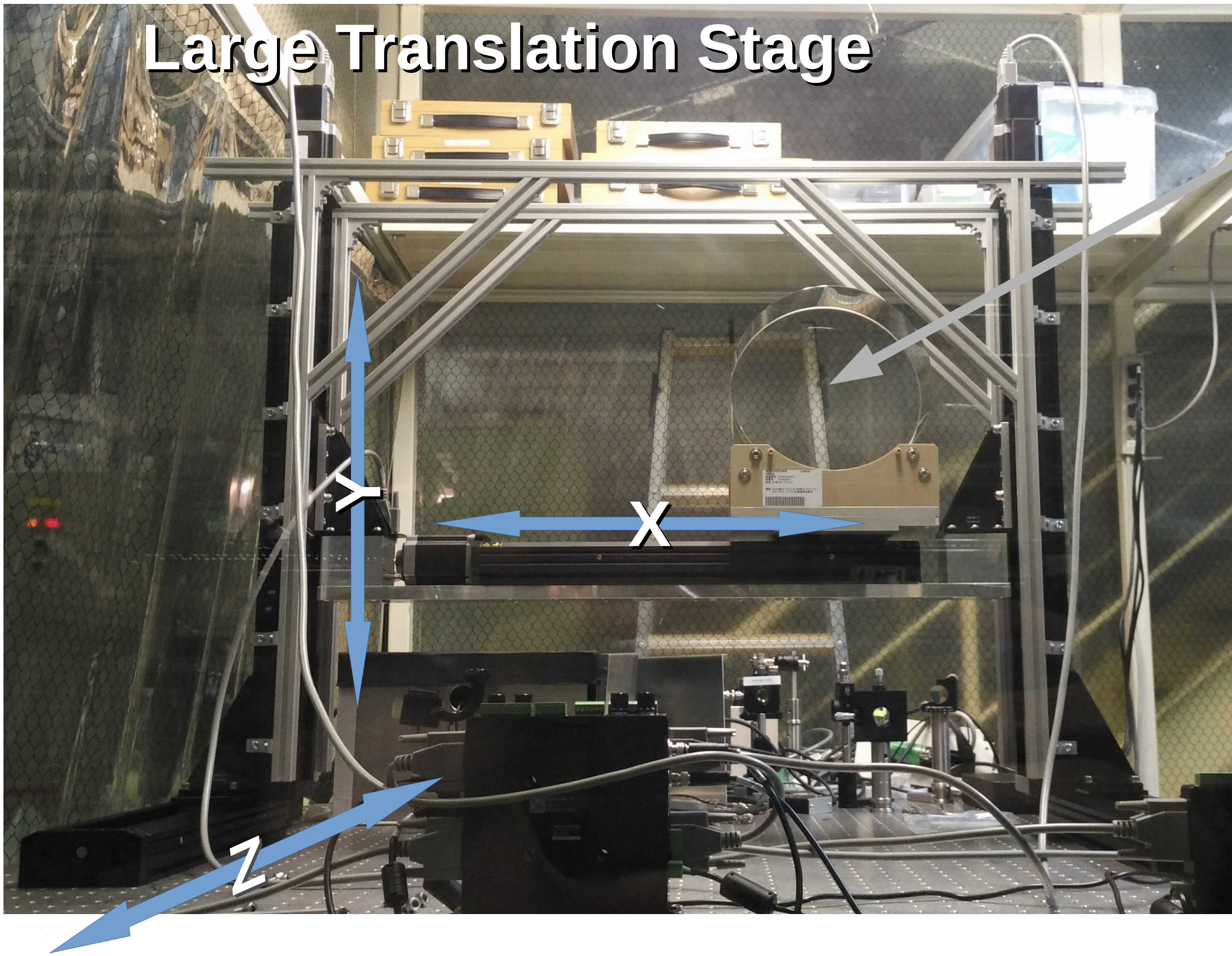
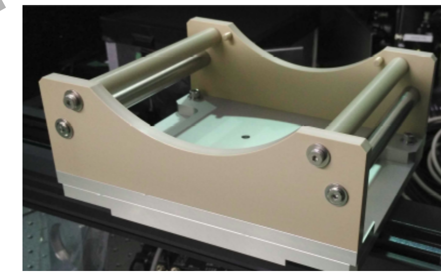
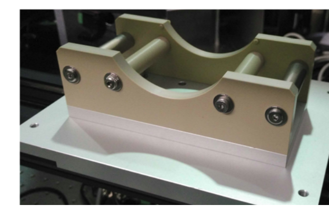


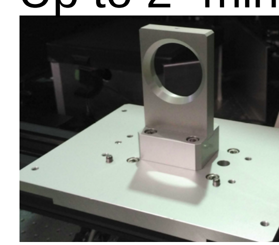
KAGRA mirror size



TAMA mirror size



Up to 2” mirror size

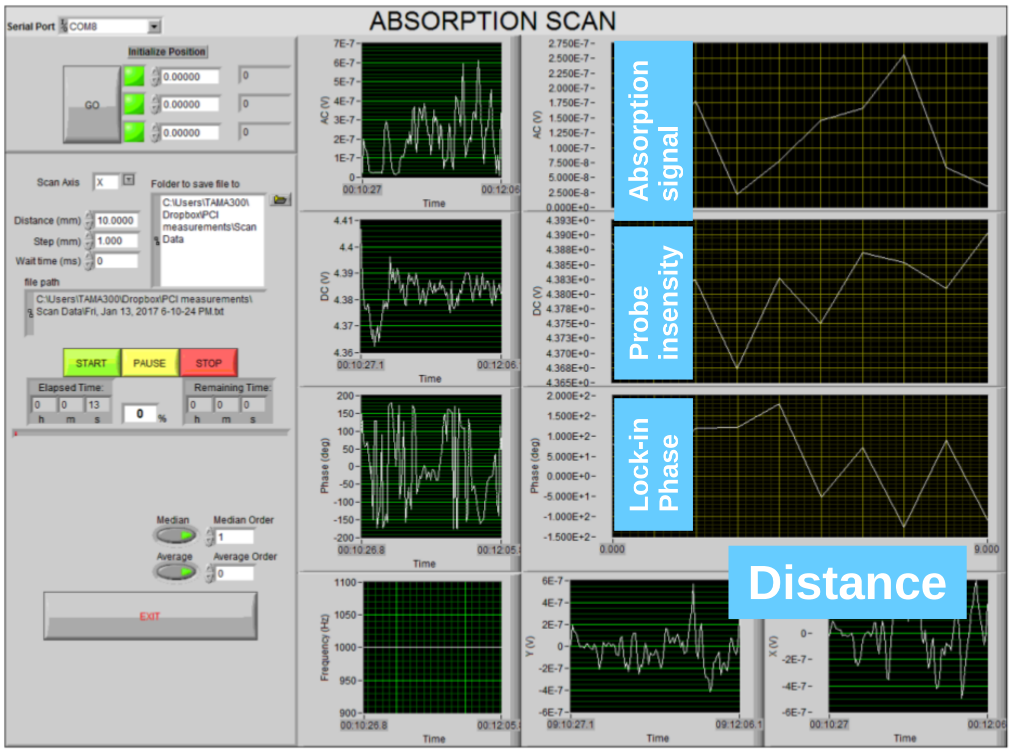


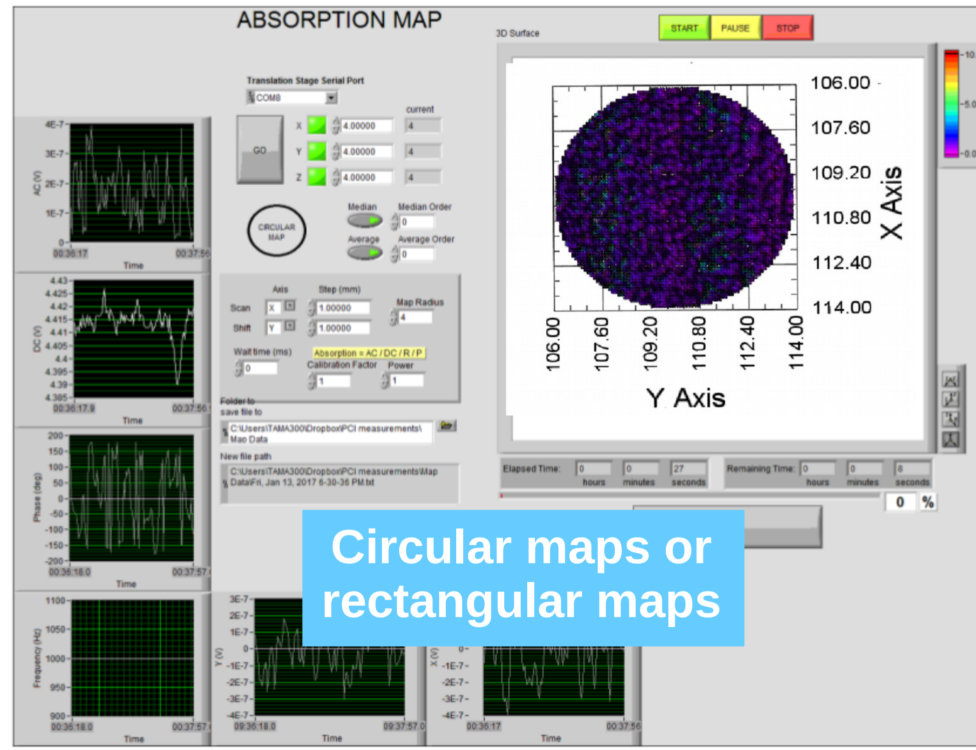
Experimental setup

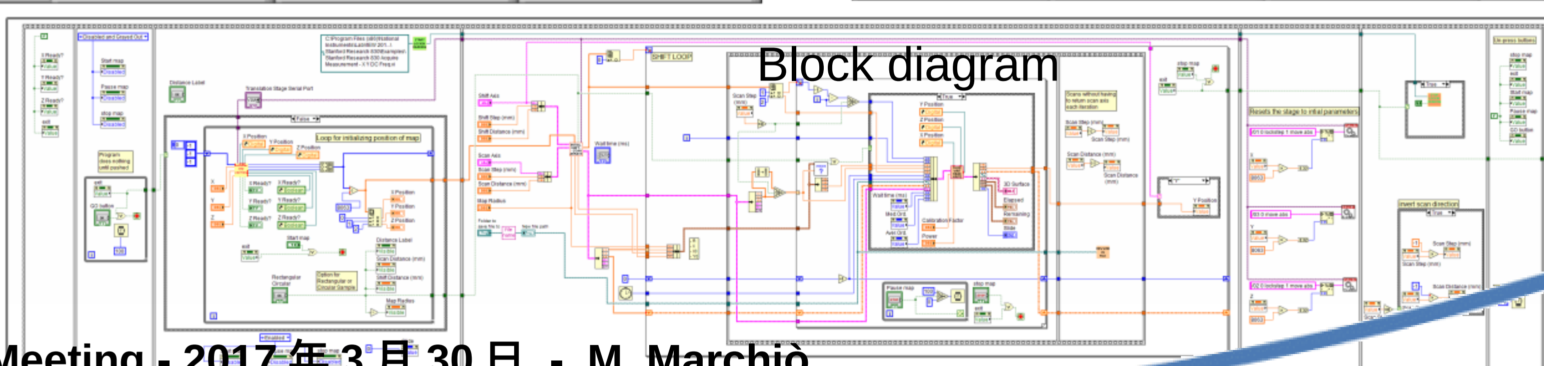
LABVIEW SOFTWARE

Commercial software couldn't control the large translation stage

→ We made it from scratch







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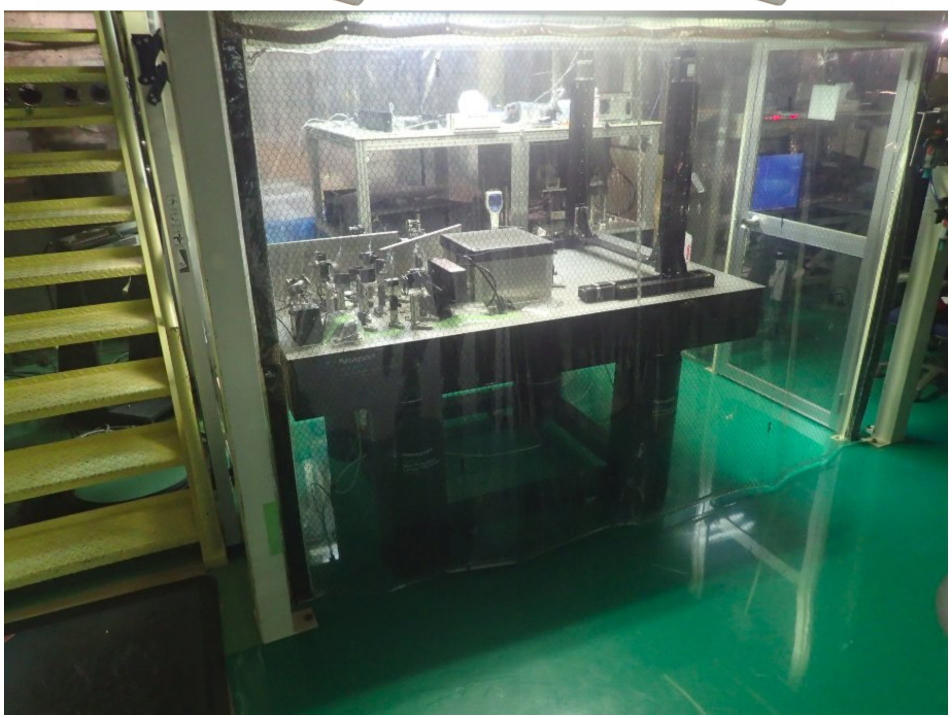


- Clean booth in TAMA300 central room
- HEPA SS-MAC-103 (2 units)
- Currently: ~7 particles/L (0.3μm)

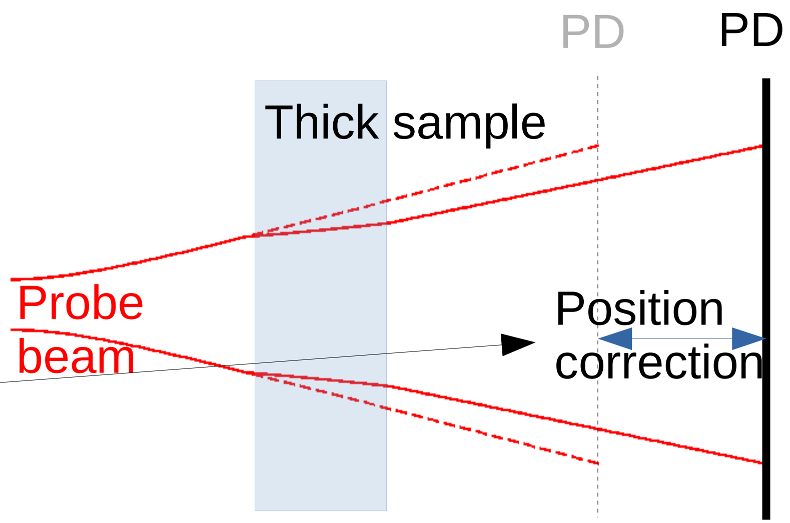
Want it cleaner!

- Will replace the filter with new one
- Will remove all unnecessary objects and clean up often.
- Will use clean suits and prepare a clean entrance.

Calibration

- Reference sample used now:
  Schott glass NG12
  3.6mm thick
  abs=22%/cm (spectrophotometer)

- For thicker samples
  → Photo-detector position correction
  Thickness * (n-1) / n

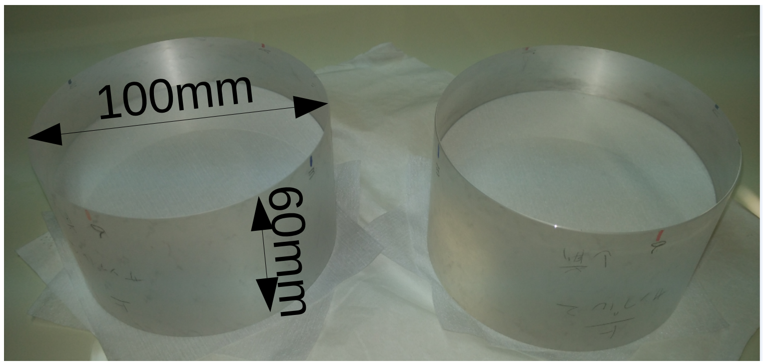


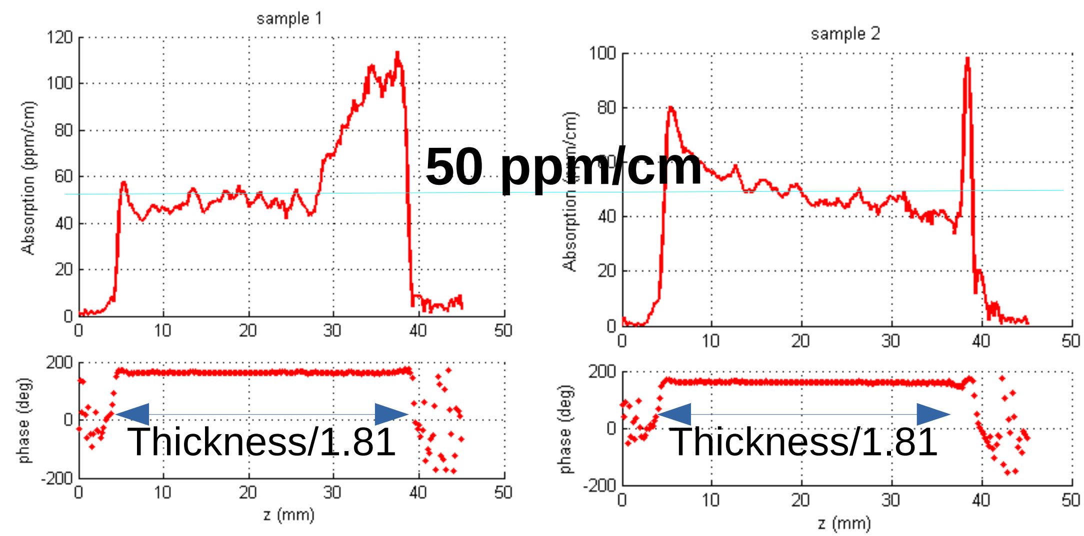
from presentation JPS autumn 2016
JGW-G1605695-v1 for more details

- Different materials have different thermal response
  → calibration correction factor is needed
  NG12 → silica **0.73**
  NG12 → sapphire **3.34**
  provided by the company Stanford Photo-Thermal Solution

Calibration

We measured TAMA300 size sapphire samples

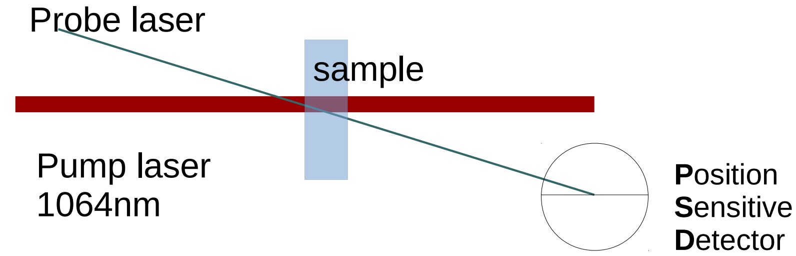




Brought it to LMA in Lyon (France)
use Photodeflection technique
Measured value = **25 ppm/cm**

We have to improve the calibration accuracy

PHOTOTHERMAL DEFLECTION METHOD



Calibration

- To avoid material correction factors
  →will use a Titanium doped sapphire to calibrate

Low doping rate (0.01%)→ same thermal proprieties

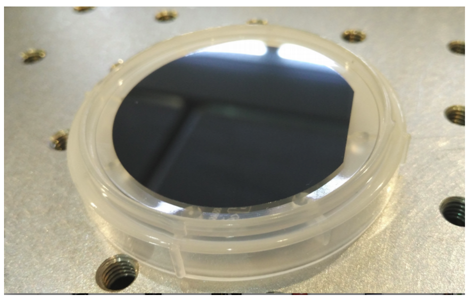
Absorption @1064 ~2 %/cm

We can measure it with spectrophotometer

Ti:Sapphire
Abs: ~2%/cm

- In addition, collaboration with Mio-san
  use **Michelson absorption method** at Mio laboratory
  for calibration check

R&D on Crystalline coatings



CMS CRYSTALLINE MIRROR SOLUTIONS

- Grown with Molecular Beam Epitaxy (MBE) on a **GaAs** substrate
- Then transferred onto **silica** or **sapphire** substrate

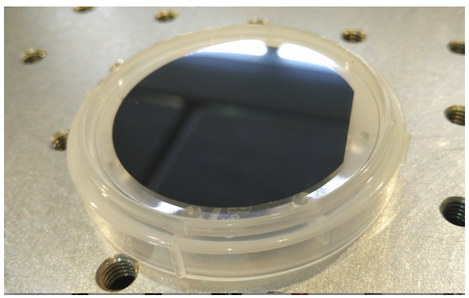
Optical performances

Measurements at LMA (France)	**Coating on silica substrate**	**Coating on sapphire substrate**
Trasmission @1064nm	6ppm	6ppm
Roughness	1nm RMS	0.1nm RMS
Scattering @1064nm	9.5ppm	6ppm
Absorption @1064nm (1W)	0.4 ± 0.4 ppm/cm	<below noise>

Presentation JGW-G1605695-v1 for more details

LMA LABORATOIRE MATÉRIAUX AVANCÉS

R&D on Crystalline coatings



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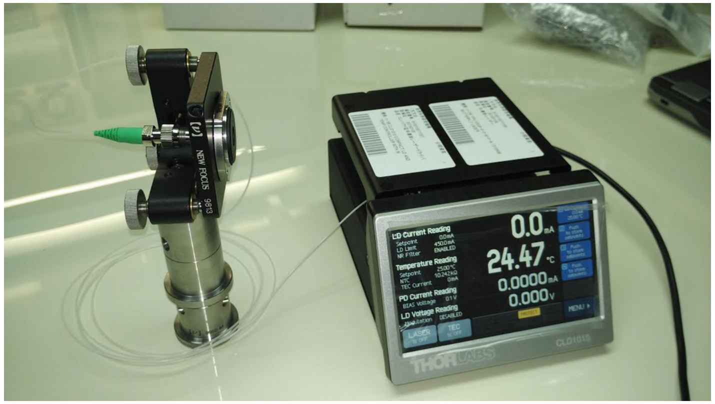
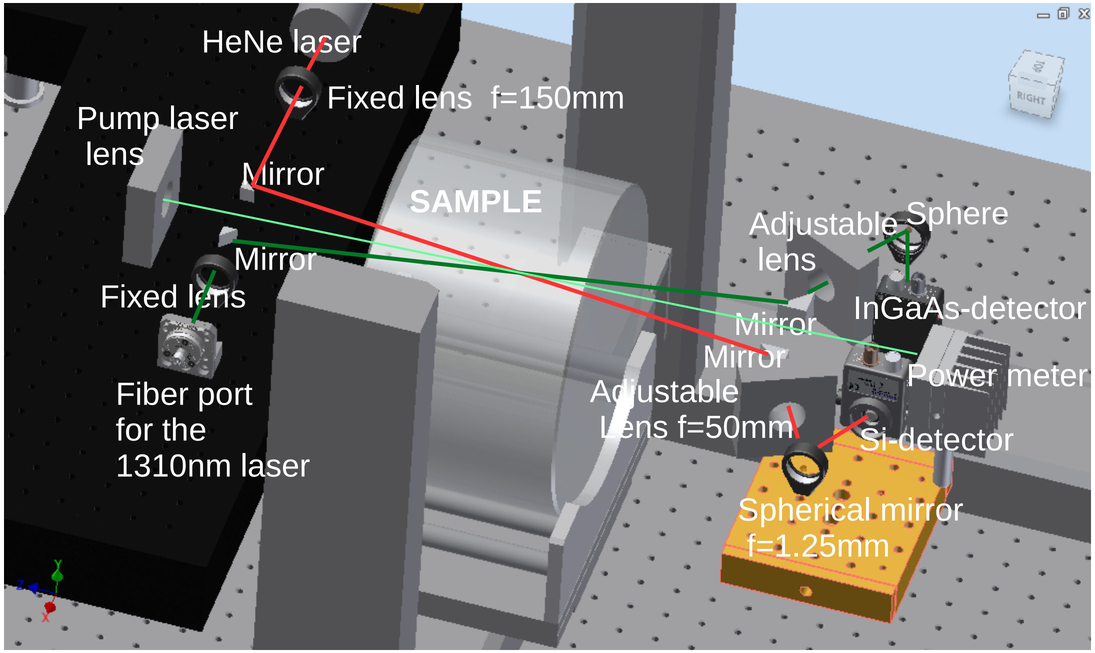
R&D on Crystalline coatings

- Currently installing a 1310nm probe laser



- We will be able to measure GaAs samples, which are not transparent to 633nm
- We have a **25W power pump** laser (1064nm), more precision
- We have a translation stage to make maps of the surface absorption



Design of two probe lasers (633nm and 1310nm)

Summary

- Assembly of large translation stage ✓
- Able to measure thick sample ✓
- LabView software for automatic scan and maps ✓
- R&D: good results on crystalline coatings ✓

- Soon make the environment perfect clean
- Soon improve the calibration accuracy
- Soon be able to measure KAGRA sapphire test masses
- Soon be able to measure GaAs samples

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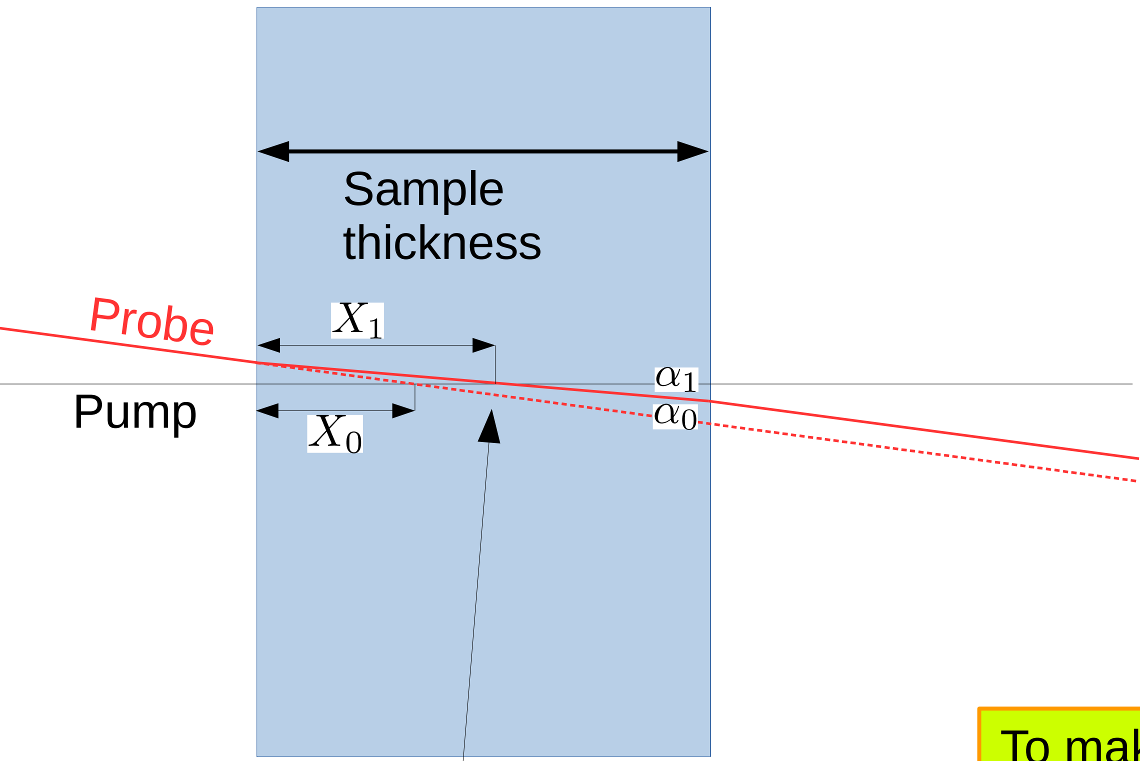
Thank you for your attention

The probe angle in the material (Snell's law)



Real position of the pump-probe cross point

$$\sin(\alpha_0)n_0 = \sin(\alpha_1)n_1$$

$$X_1 = X_0\frac{\tan(\alpha_0)}{\tan(\alpha_1)} = \frac{n_1}{n_0}\frac{\cos(\alpha_1)}{\cos(\alpha_0)}$$

$$n_0 = 1$$

$$n_1 = 1.76$$ Sapphire

$$\alpha_0 = 6^\circ$$

$$X_1 = X_0 \cdot 1.81$$

To make a scan surface-to-surface of a KAGRA substrate we have to translate the sample by 150mm/1.81 = 83 mm (instead of 150mm)

This is important in the design the new setup