Mirror absorption bench setup and commissioning

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Introduction

Motivation:

- Minimize mirror optical absorption to make cryogenic operation as easy as possible.

Objectives:

- Measure absorption of KAGRA substrates and coatings
- Investigate new mirror materials for future upgrades

Steps:

- Setup optical absorption measurement system
- Validate the calibrations
- Make absorption measurements

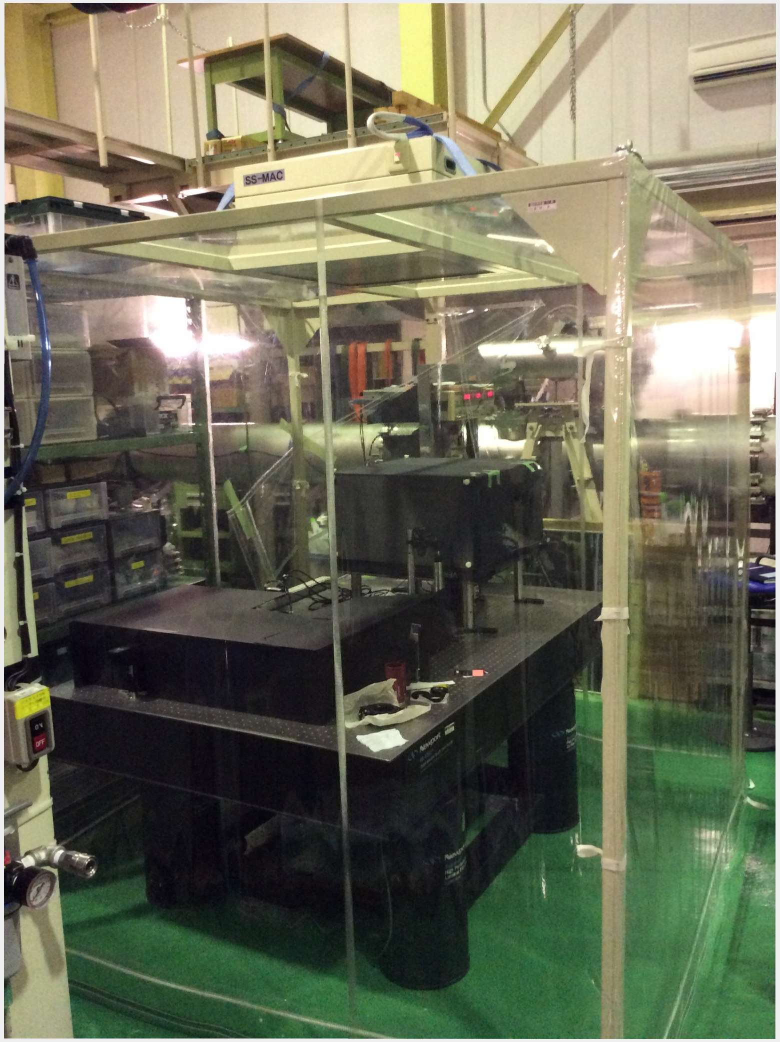
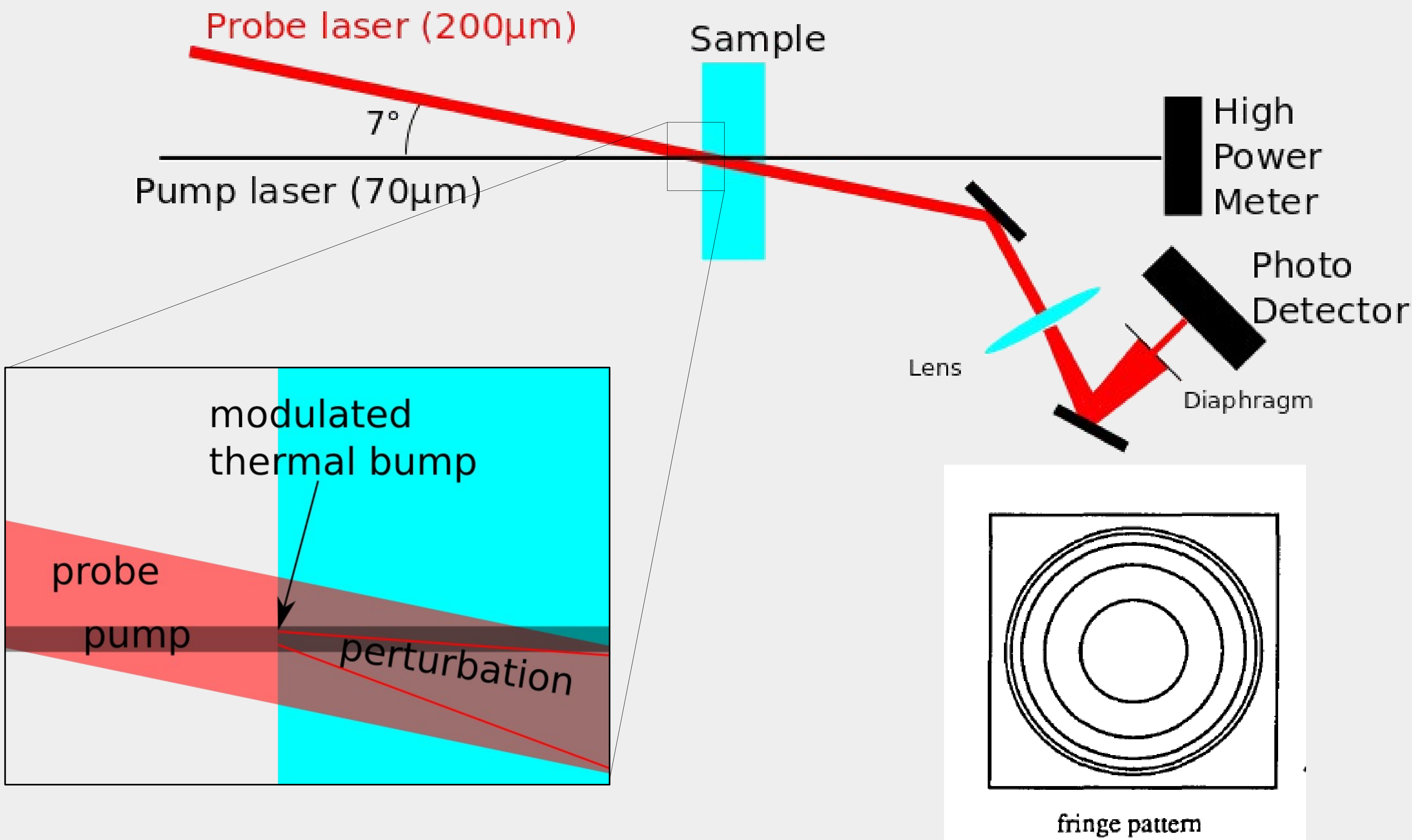


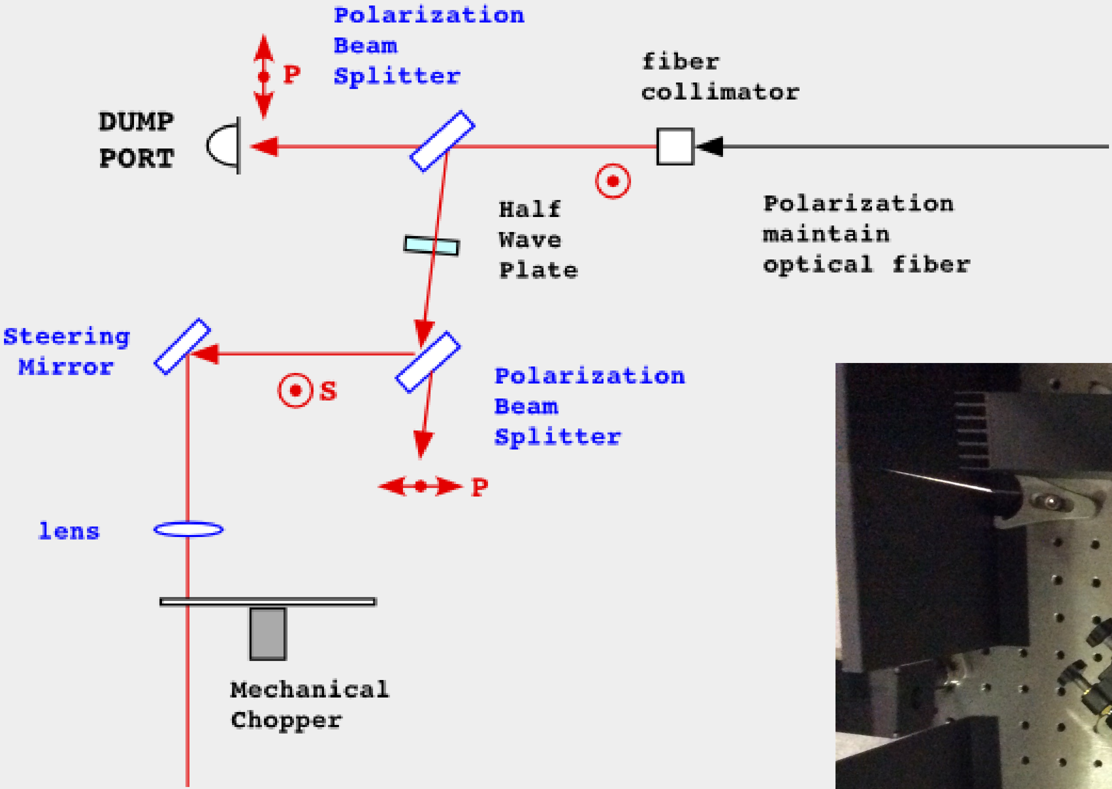
Photo-thermal
Common-path
Interferometer

How it works

$$e^{ikz}e^{i\Delta\phi(t)} \simeq e^{ikz} + i\Delta\phi(t)e^{ikz}$$

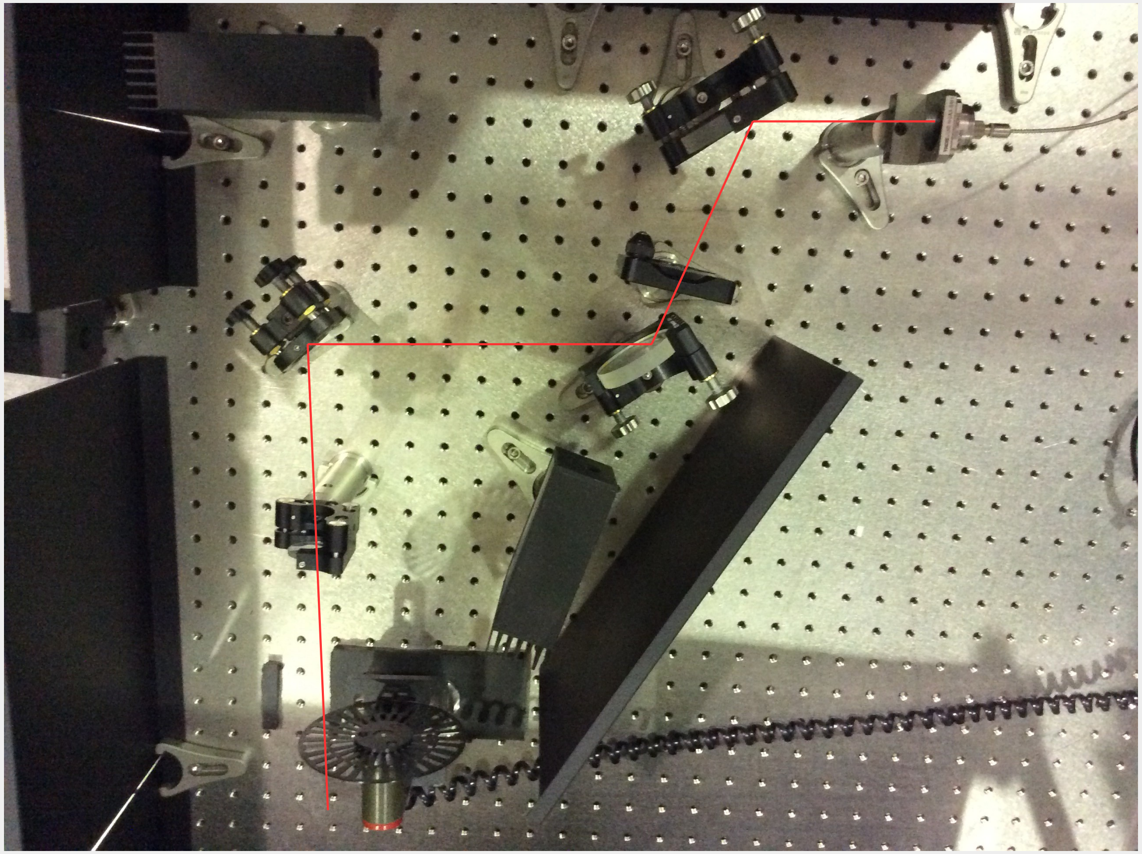


Experimental setup: pump beam

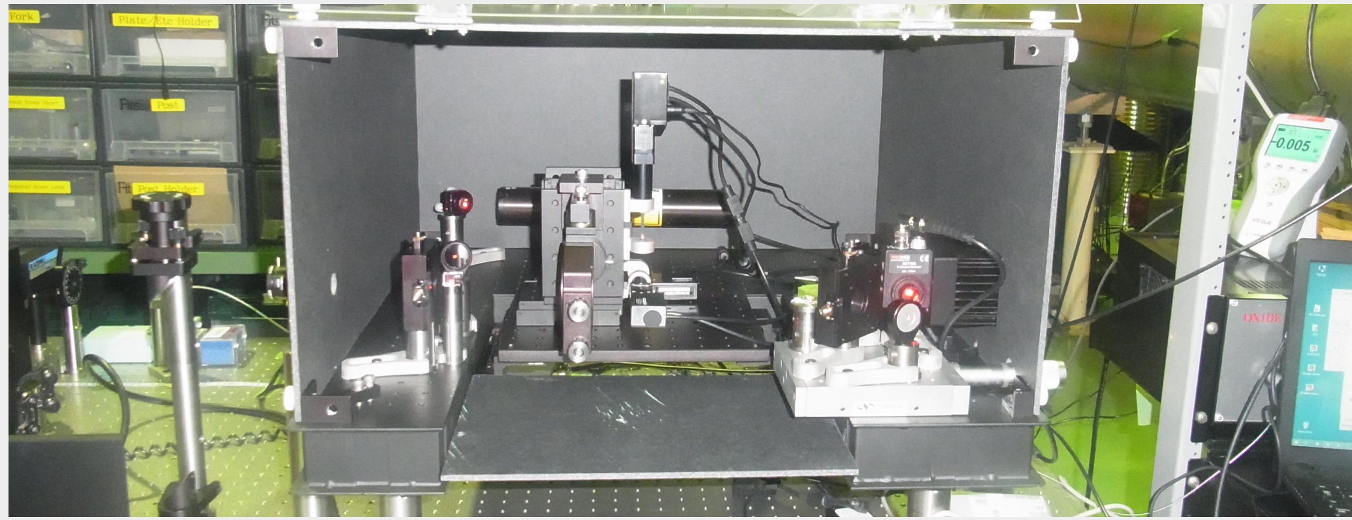


From high power laser diode 1064nm. Up to 25W

To the absorption measurement system. Up to ~10W

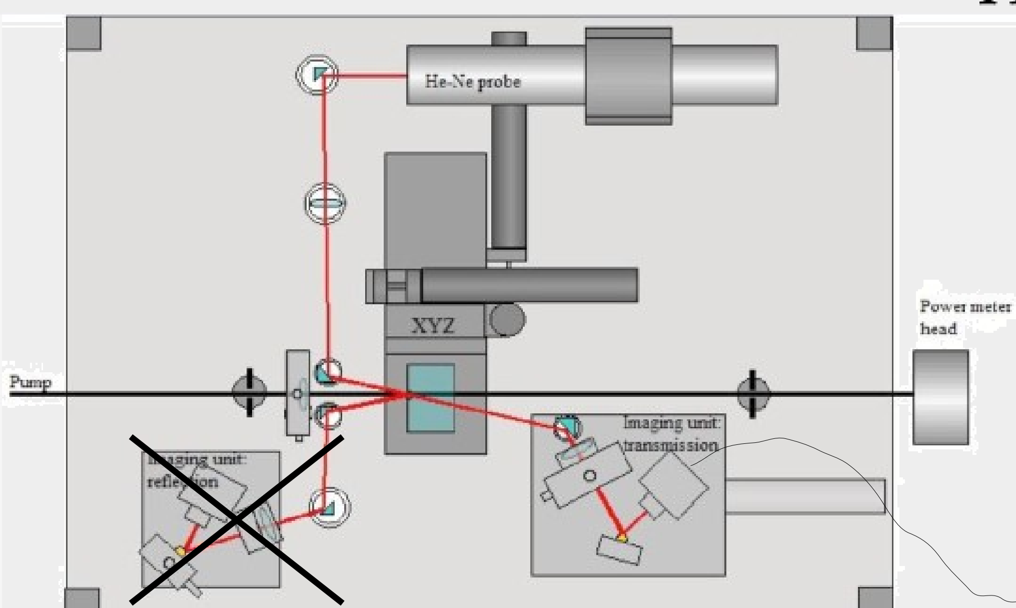


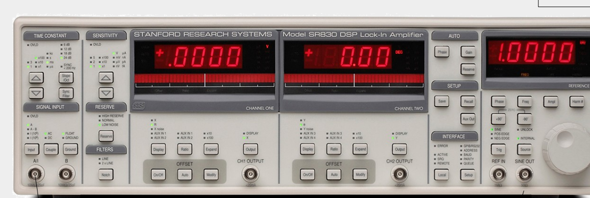
Experimental setup: absorption measurement system



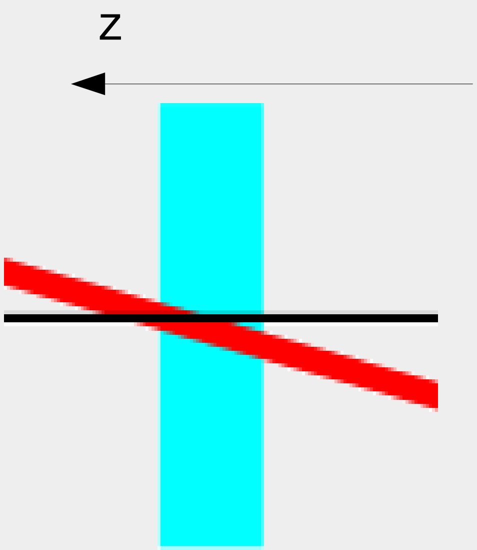
$$\mathrm{Abs} = \frac{AC[V]}{DC[V] \cdot P[W] \cdot R[W^{-1}]}$$

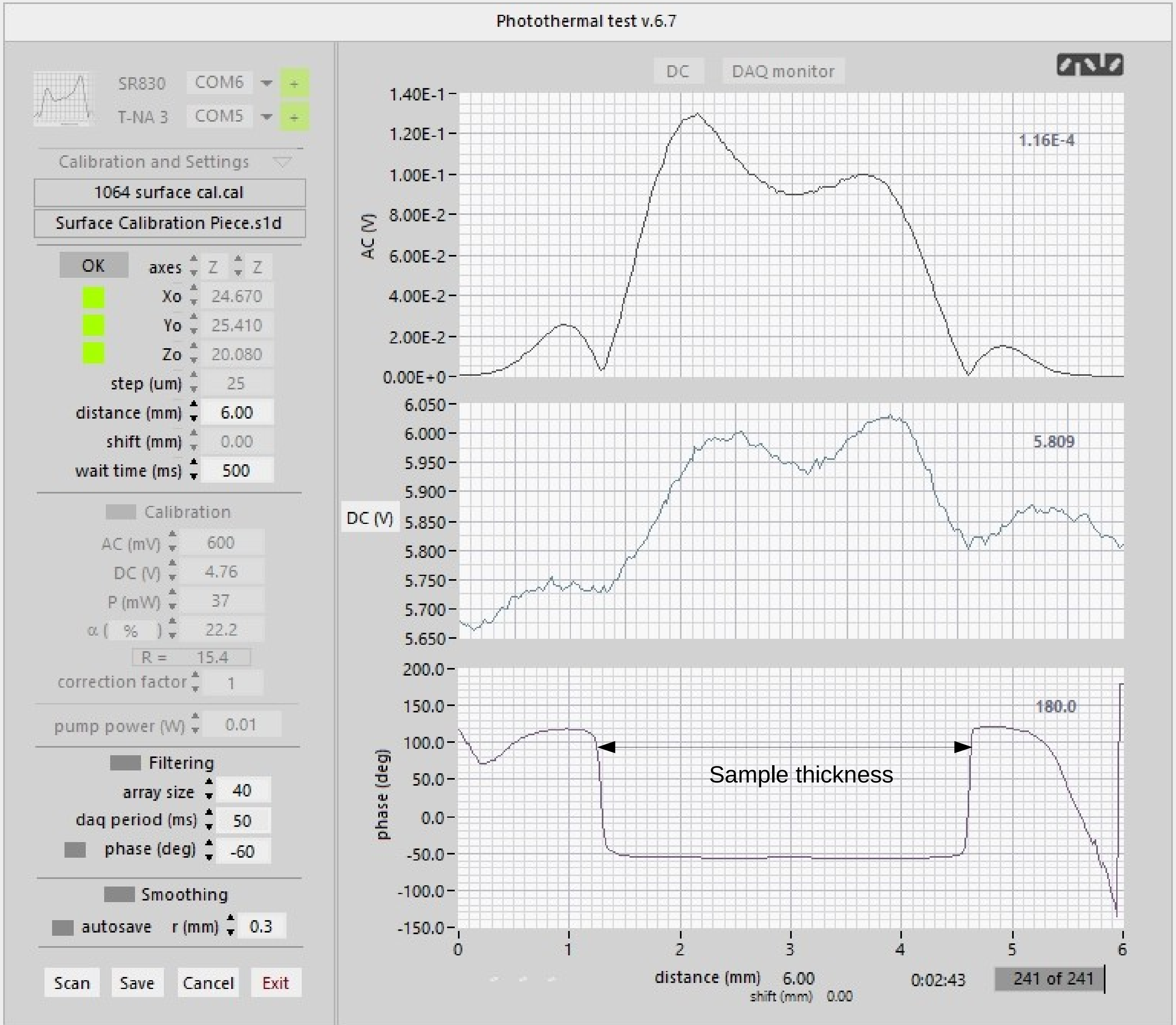
Calbration factor





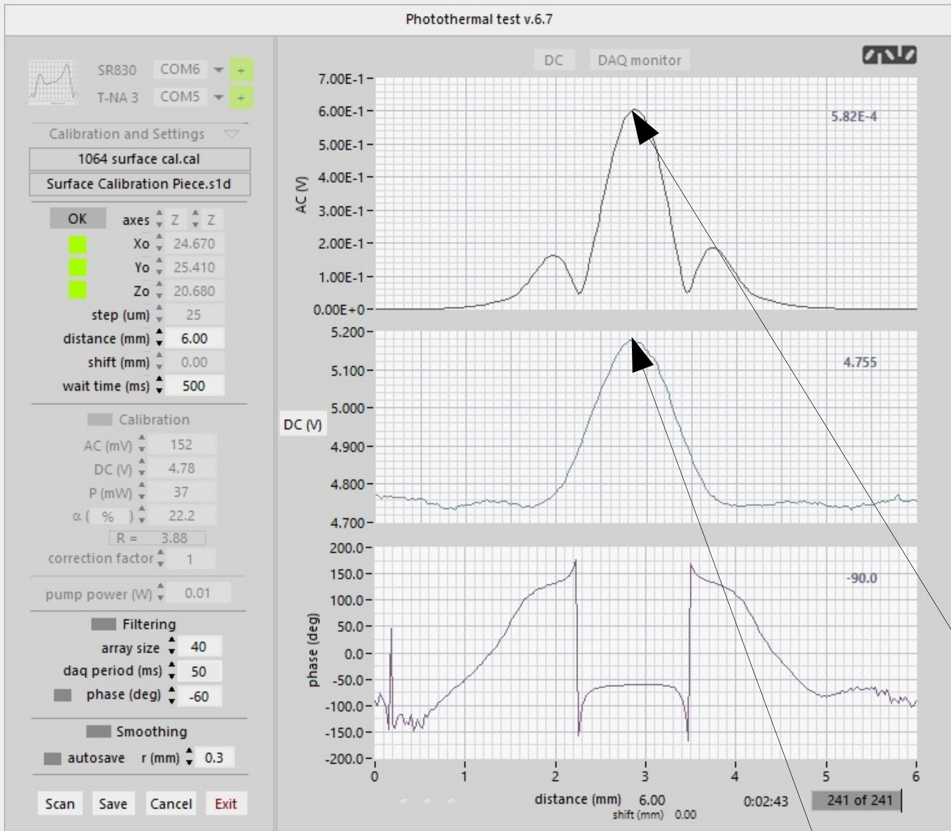
Scanning along Z axis



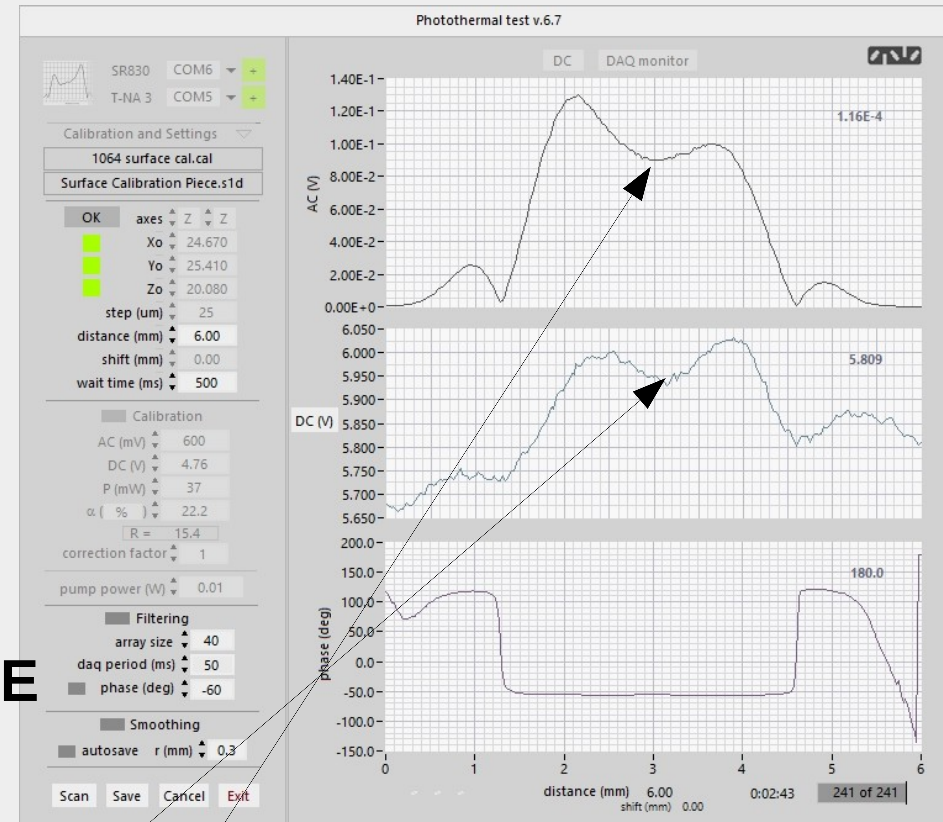


Measurements:

SURFACE ABSORPTION



BULK ABSORPTION



AC

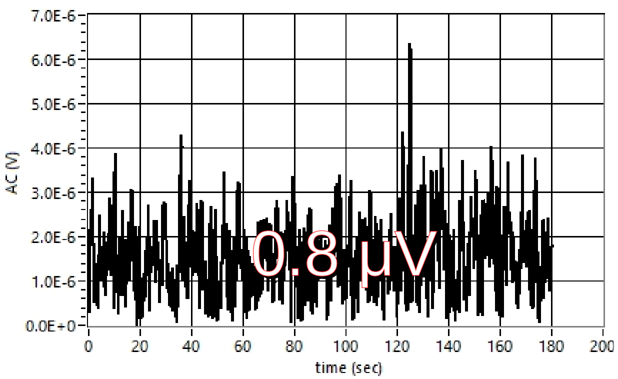
DC

PHASE

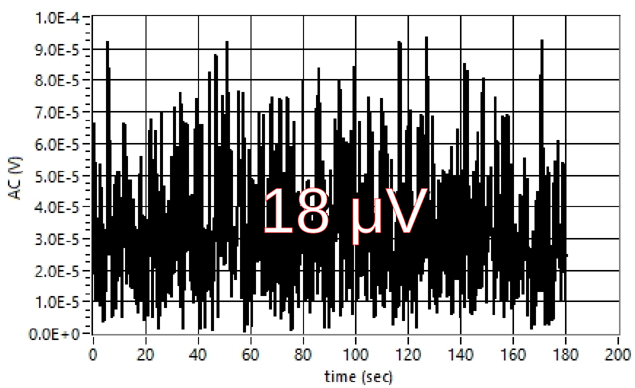
$$\mathrm{Abs} = \frac{AC[V]}{DC[V] \cdot P[W] \cdot R[W^{-1}]}$$

Noise level

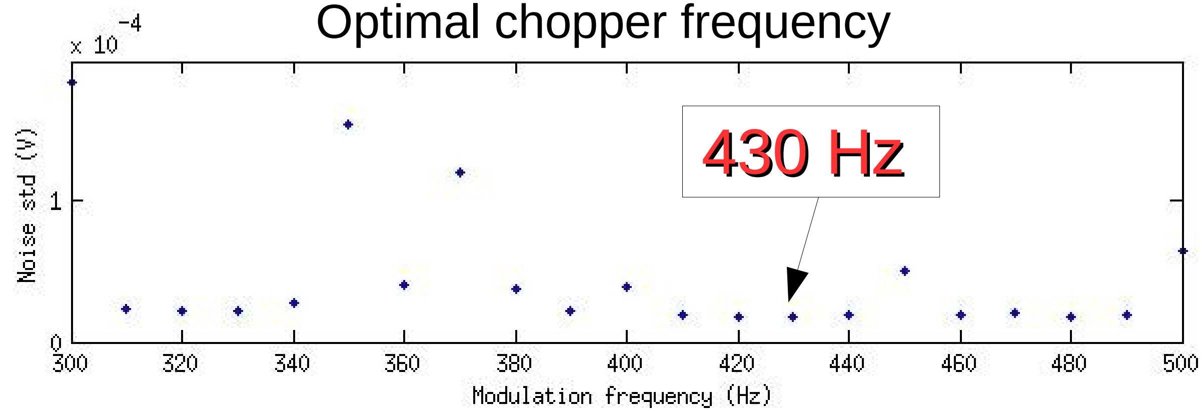
Probe OFF



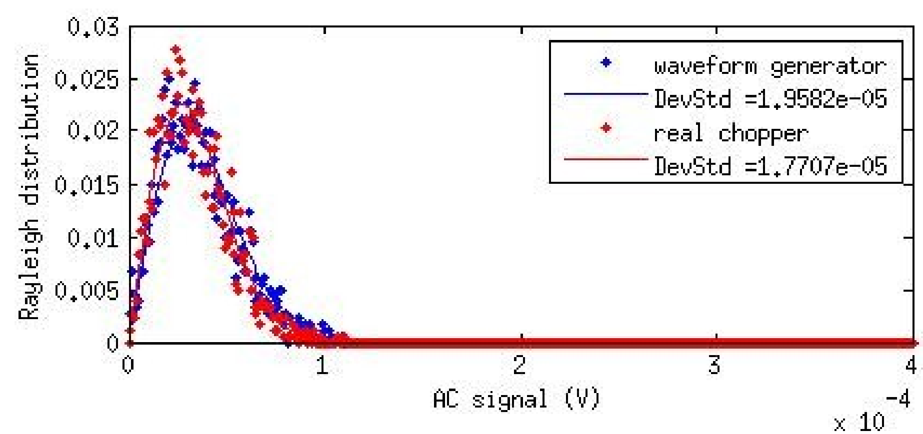
Probe ON



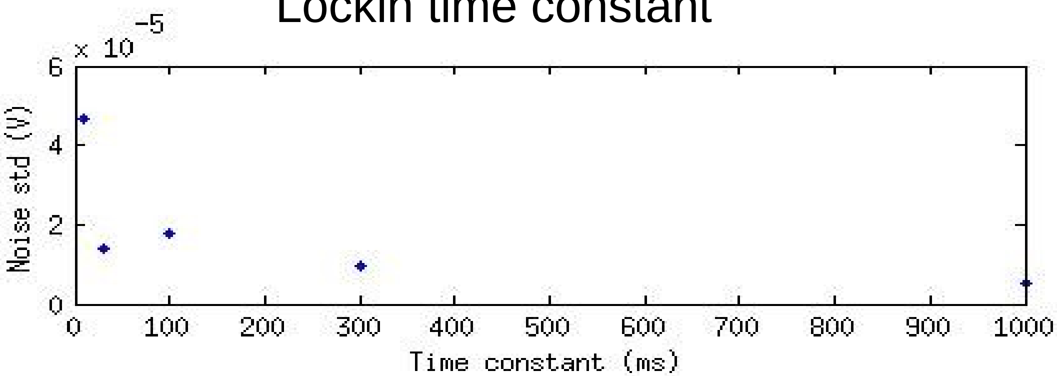
Optimal chopper frequency



With and without chopper



Lockin time constant



Noise comes from the probe laser:

- Spot position
- Power fluctuation

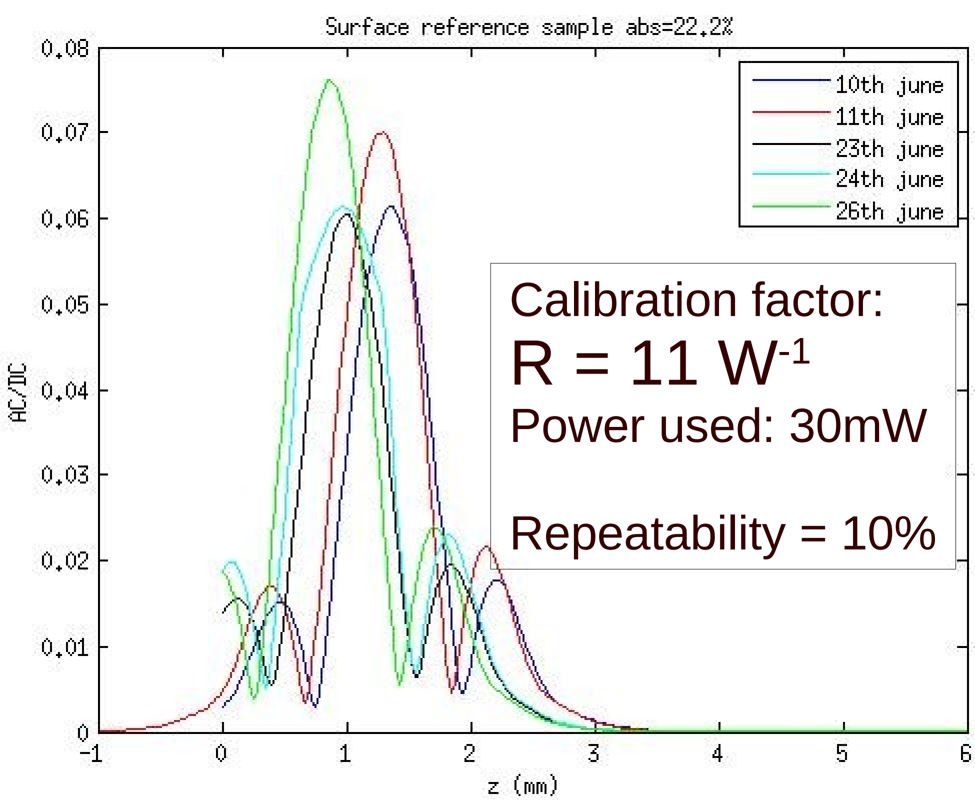
Calibrations

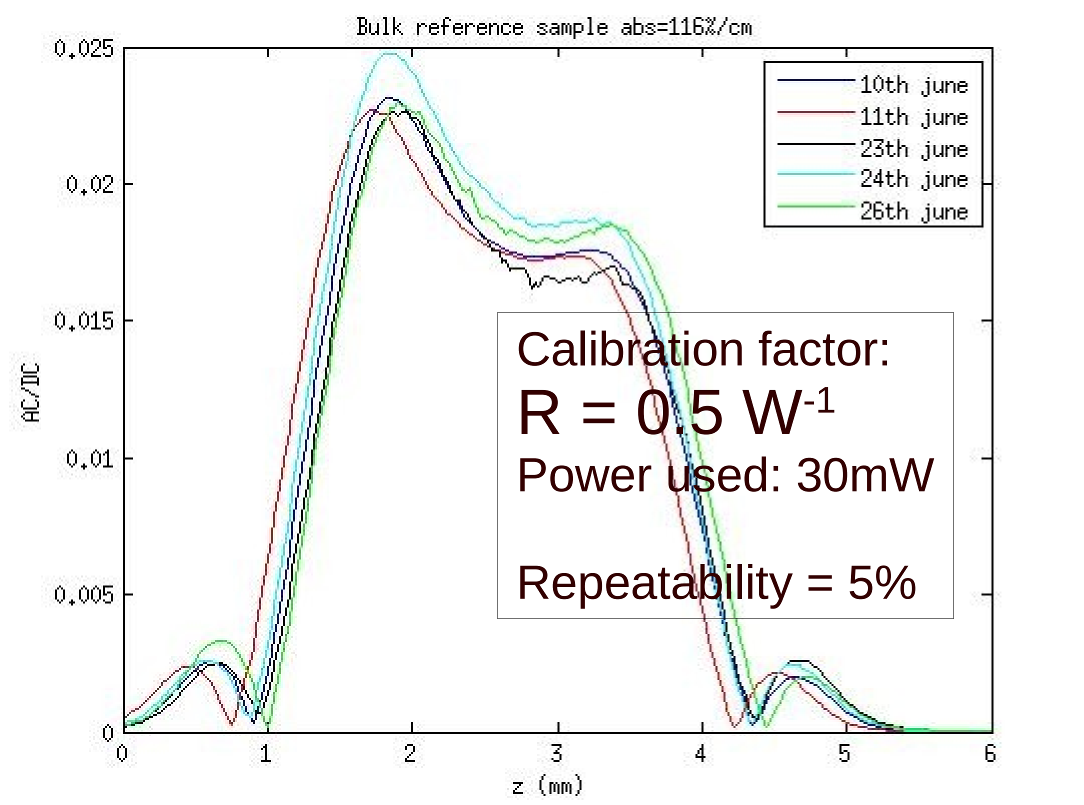
SURFACE Reference sample:

Newport FRQ-ND02
Nominal absorption: **22.2%** at 1064 nm
Spectrophotometer measurement: **22.0%**
Thickness 3mm

BULK Reference sample:

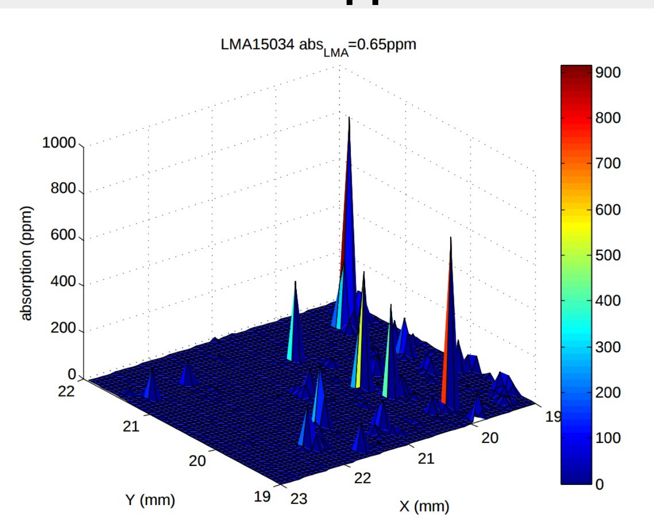
Schott glass NG-12
Nominal absorption: **116%/cm** at 1064 nm
Spectrophotometer measurement: **104%/cm**
Thickness 3.6mm

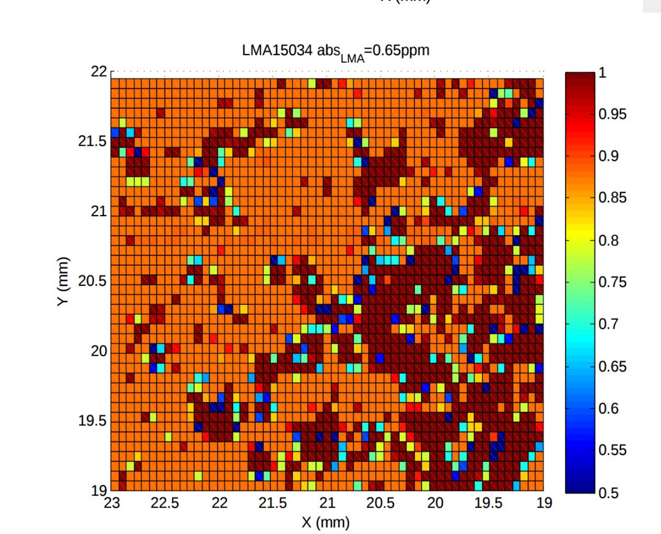




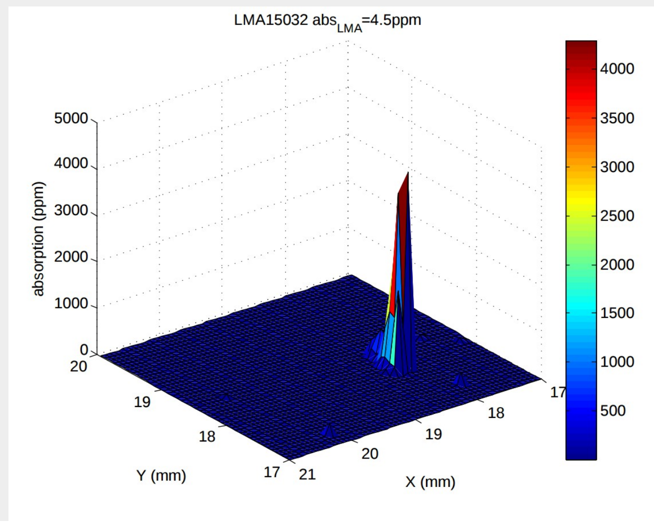
LMA Surface sample: Maps

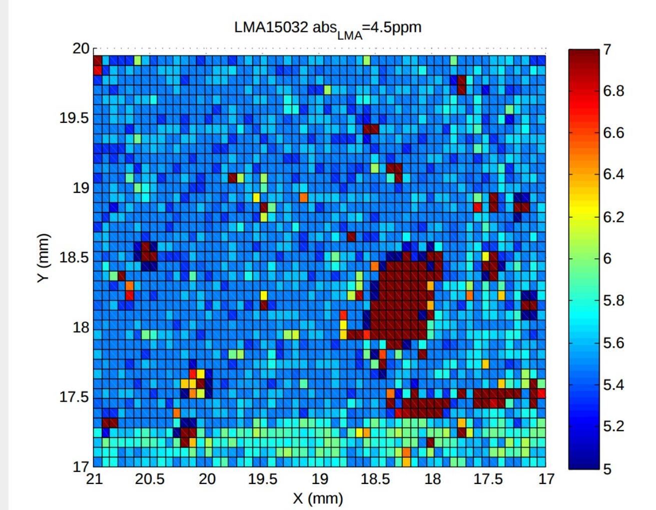
Surface sample 15034
nominal = **0.65ppm**
pump power = 6.3W
Resolution 70μm x 70μm
measured = **0.85ppm**



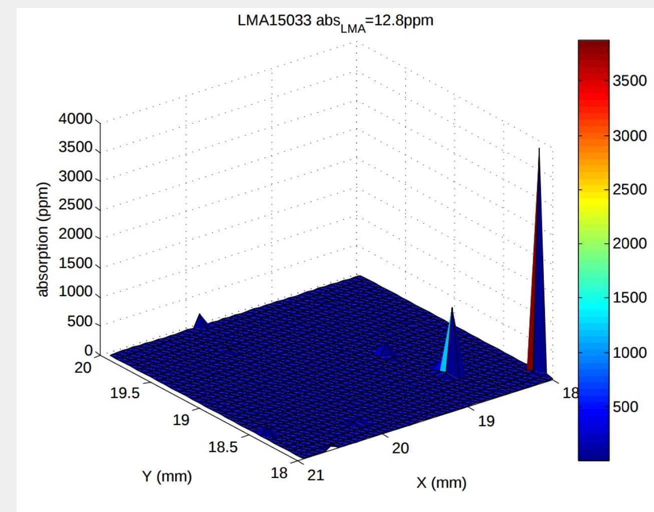


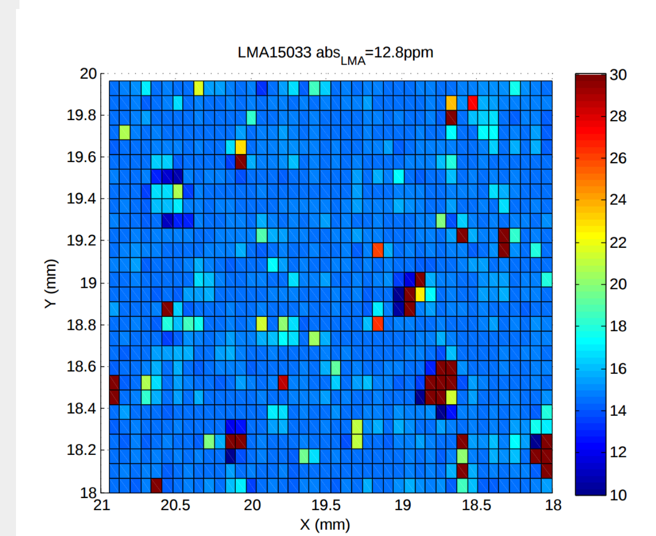
Surface sample 15032
nominal = **4.5ppm**
pump power = 3.36W
Resolution = 70μm x 70μm
measured = **5.4ppm**



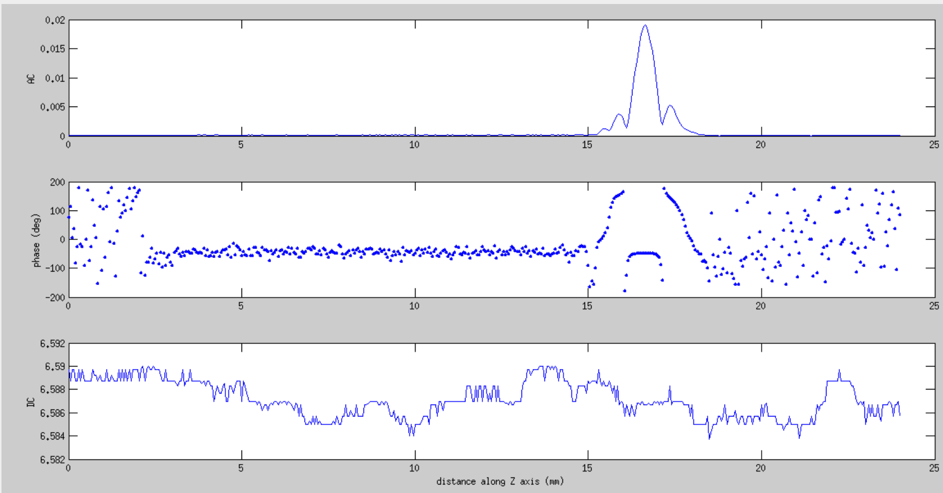


Surface sample 15033
nominal = **12.8ppm**
pump power = 1.18W
Resolution = 70μm x 70μm
measured = **14ppm**





LMA Bulk sample

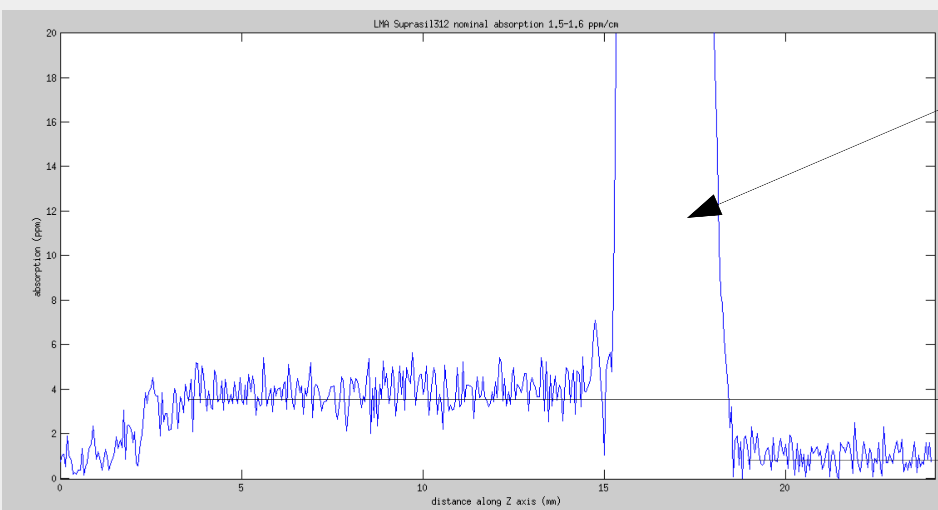


Suprasil 312

Nominal = **1.5 ppm/cm**

pump power = 9.5W

Measured = **3 ppm/cm**



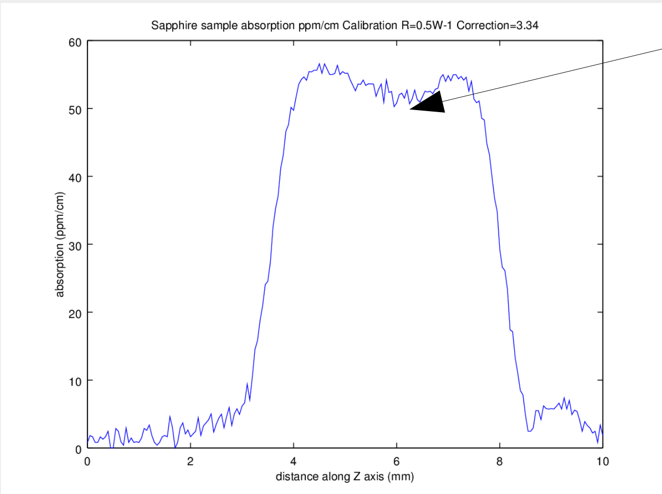
High absorption on back surface
To be understood...

4 ppm

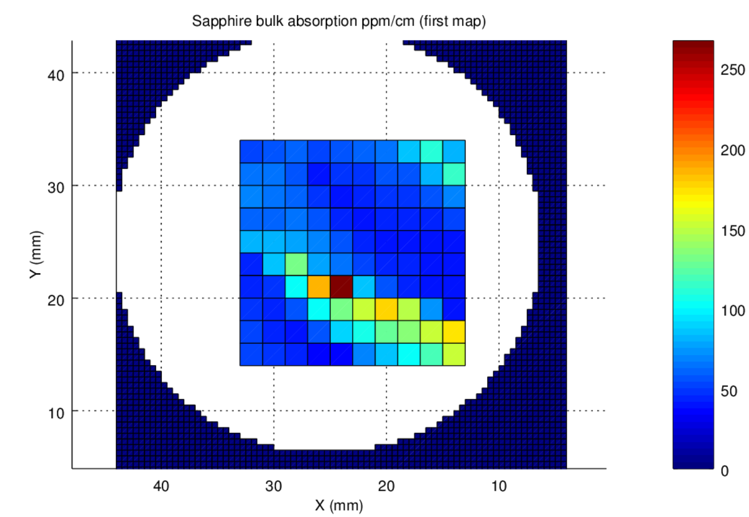
1 ppm

Sample thickness 20mm

Sapphire sample from Shinkousha



50 ppm

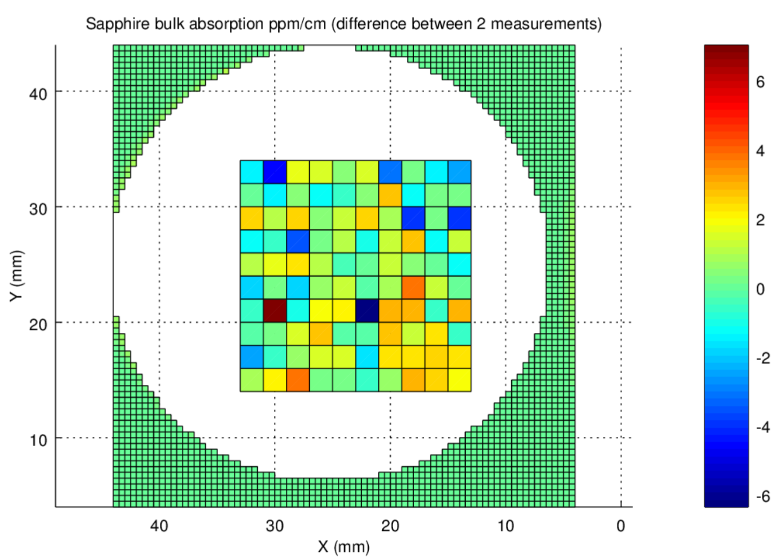


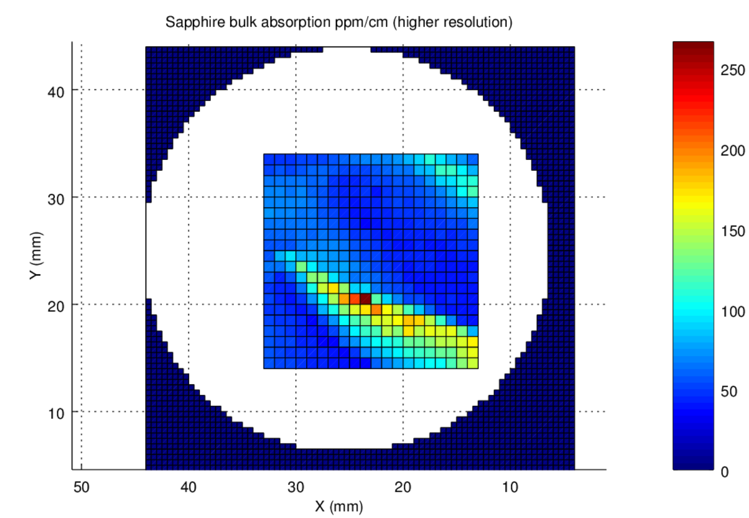
Min= **37 ppm/cm**

Max= **310 pm/cm**

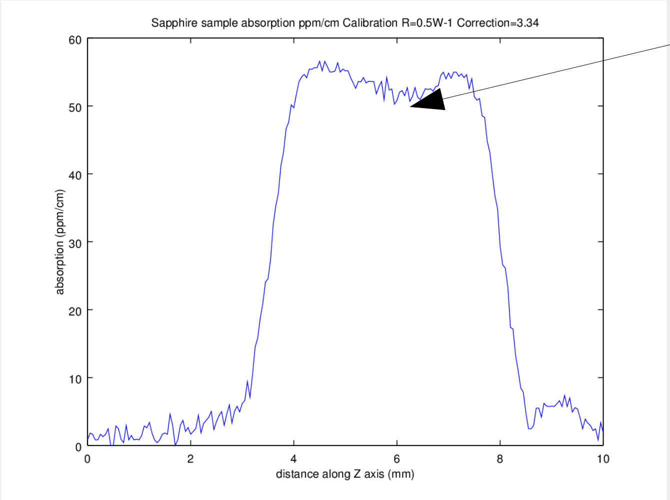
pump power =9.5W

Calibration factor:
$R=0.5W^{-1}$
Correction factor
provided by stanford
PTS = 3.34

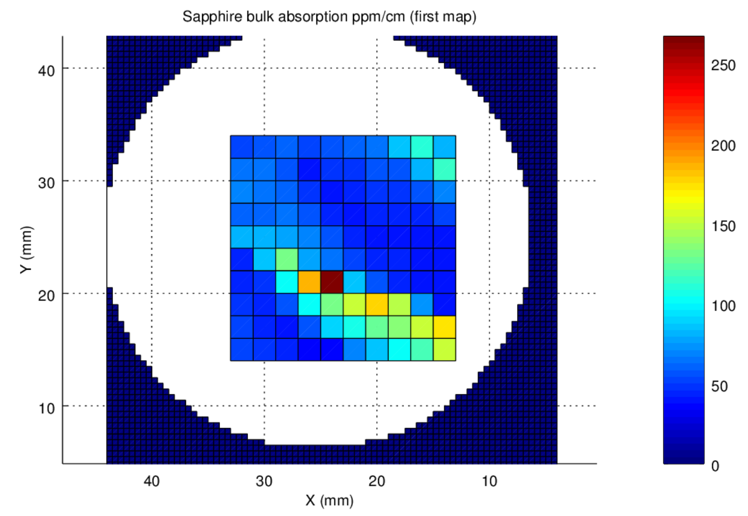




Sapphire sample from Shinkousha



50 ppm



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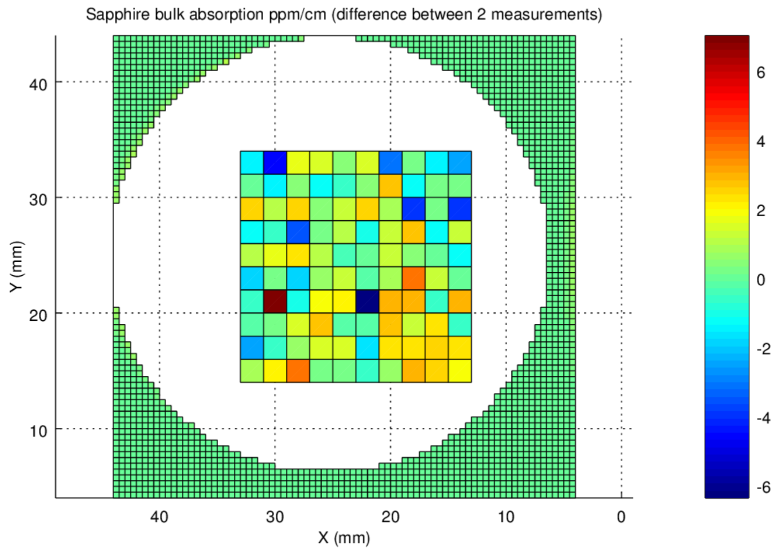
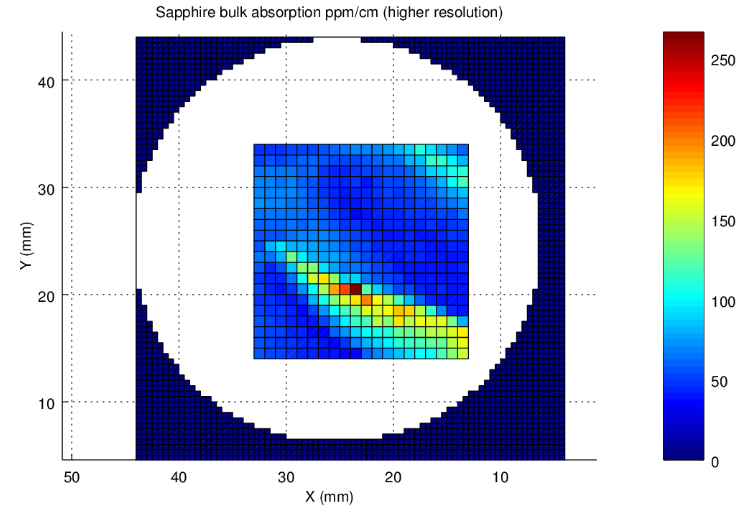
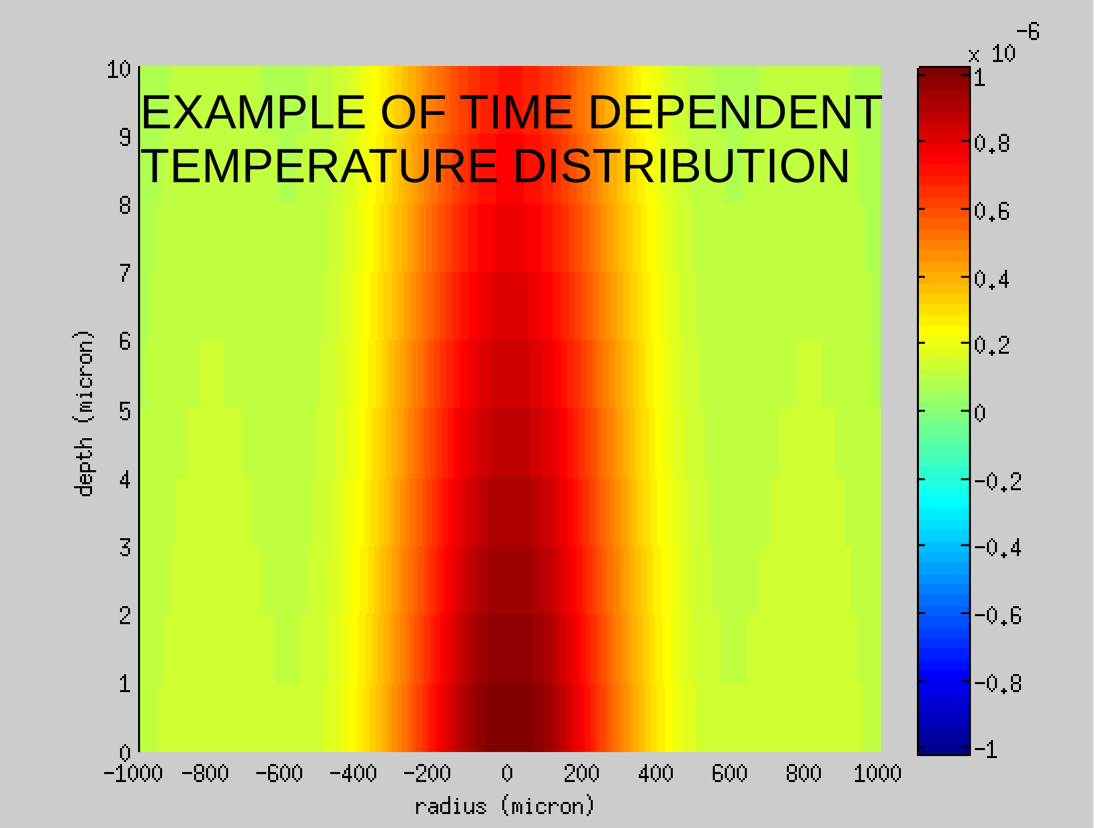




NOT HOMOGENEOUS

Next steps: correction factor for different materials

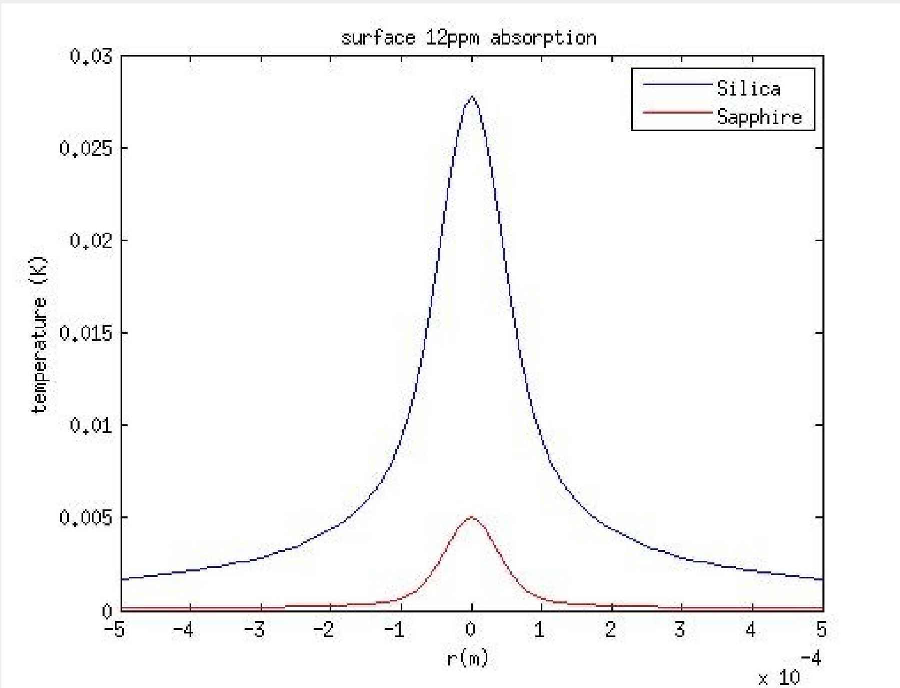
- Calculate temperature distribution for different thermal parameter
- Use refraction index distribution in an optical simulator (OSCAR)
- Calculate the expected signals for several thermal parameters
- Calculate how the calibration factor changes

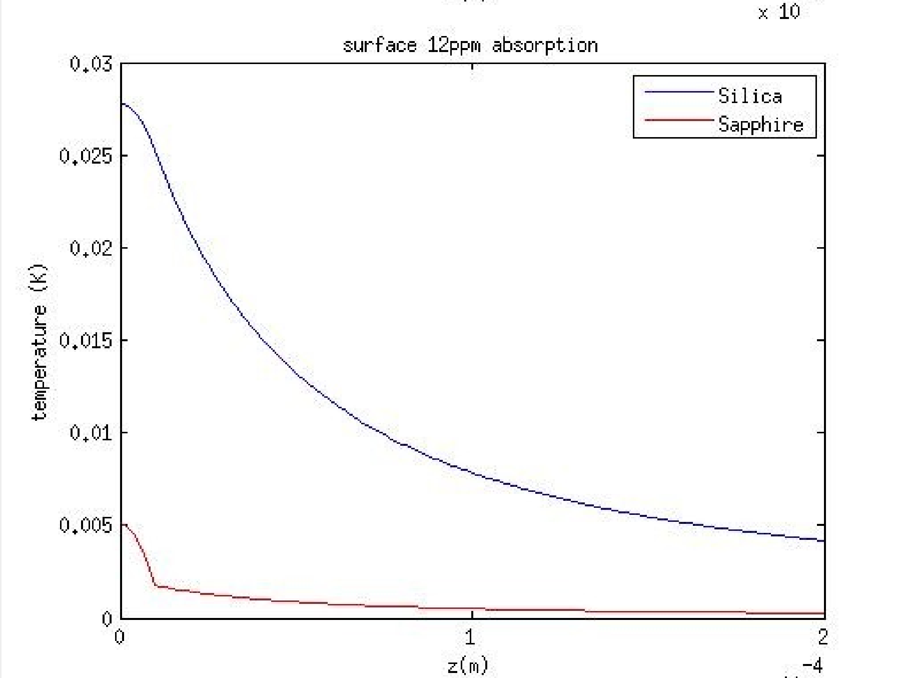


Photothermal deflection spectroscopy and detection
W. B. Jackson, N. M Amer, A. C. Boccara, D. Fournier (1981) Applied Optics, vol.20(8) p. 1333-1344

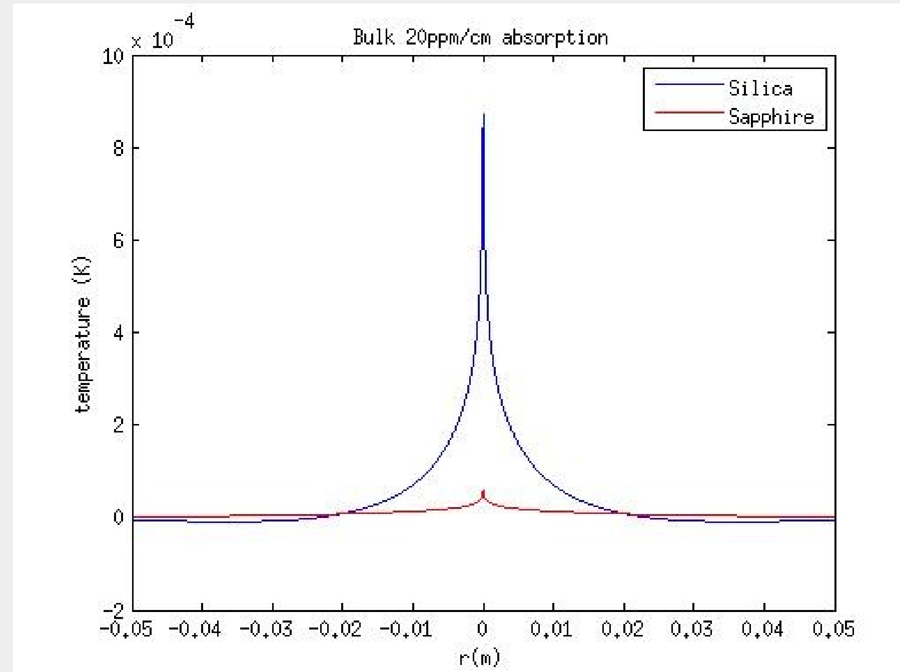
Temperature distribution for Silica and Sapphire

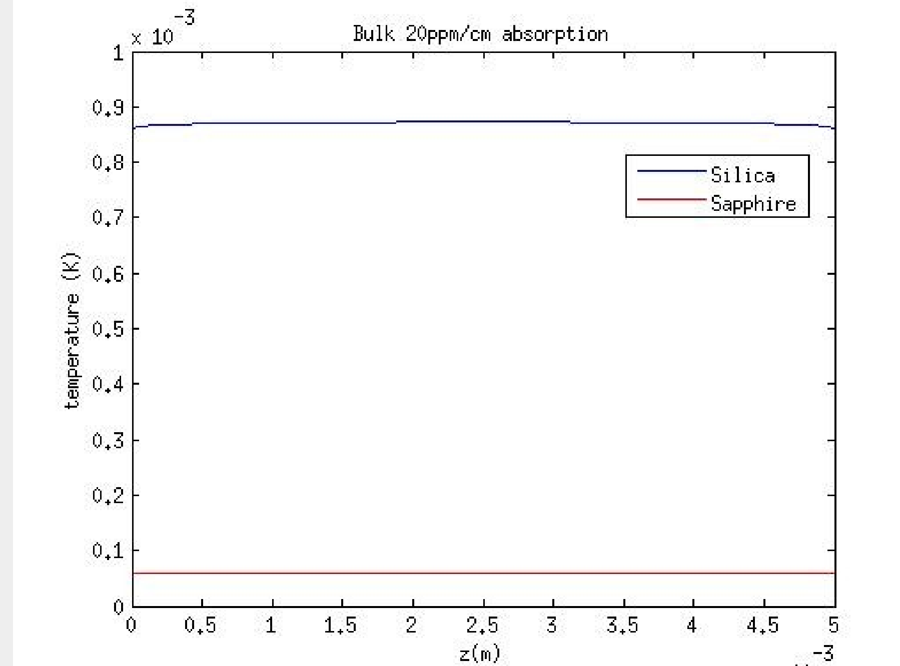
SURFACE ABSORPTION





BULK ABSORPTION





Summary and Perspectives

STATUS

- Absorption bench operating

- **NEXT STEPS**
- Set the translation stage for large mirrors
- Installing everything in the clean room
- Measure KAGRA substrates (scan and maps)
- Measure KAGRA coatings
- Investigate new materials for future mirrors

Aknowledgment to:

- Danièle Forest, Laurent Pinard and Gerome Degallaix of Laboratoire des Matériaux Avancés (LMA), Lyon, France for providing the samples and a lot of useful advices

Thank you for the attention!