Development and test of an absorption bench to characterize the KAGRA mirrors R&D status report

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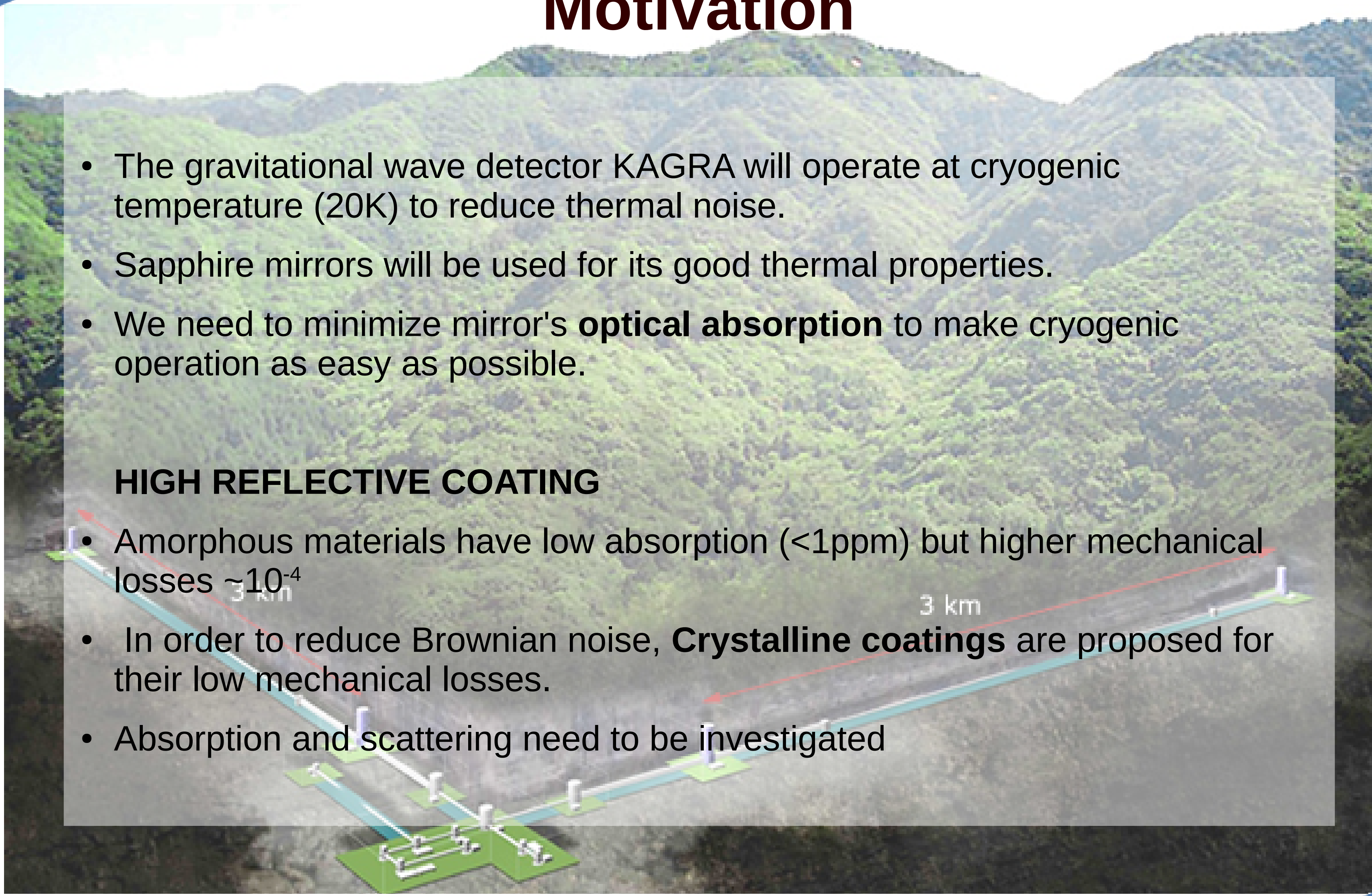
Motivation

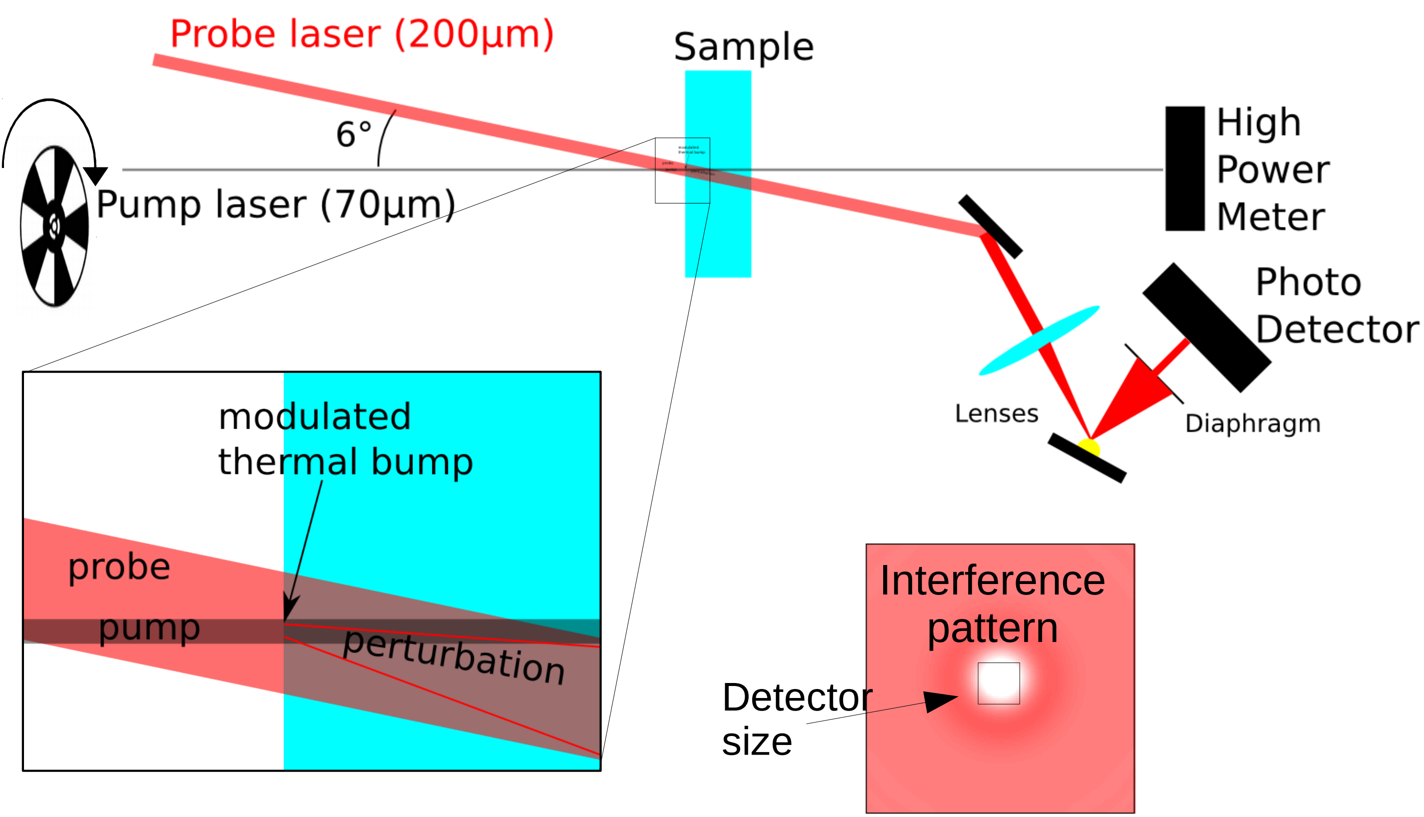


- The gravitational wave detector KAGRA will operate at cryogenic temperature (20K) to reduce thermal noise.
- Sapphire mirrors will be used for its good thermal properties.
- We need to minimize mirror's **optical absorption** to make cryogenic operation as easy as possible.

HIGH REFLECTIVE COATING

- Amorphous materials have low absorption (<1ppm) but higher mechanical losses ~10^{-4}
- In order to reduce Brownian noise, **Crystalline coatings** are proposed for their low mechanical losses.
- Absorption and scattering need to be investigated

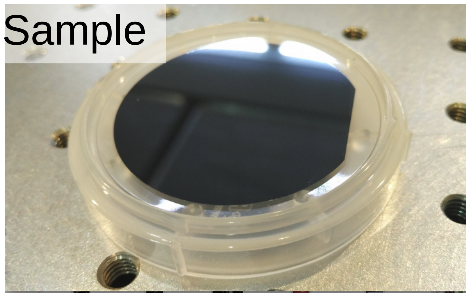
Absorption measurement method at NAOJ



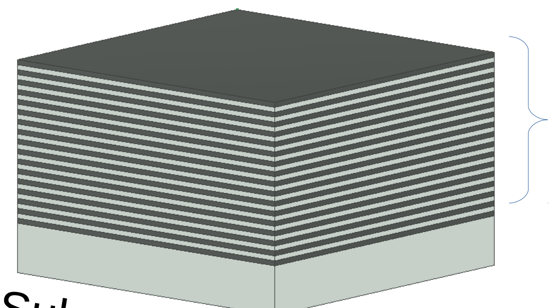
- The pump periodically changes the temperature of the sample
- The thermal lens effect changes the probe wavefront
- After some propagation, the perturbation makes interference with the main mode
- The detector sense the intesity variation of the central part of the spot.
- This variation is proportional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

Photo-thermal
Common-path
Interferometer

High reflective crystalline coatings

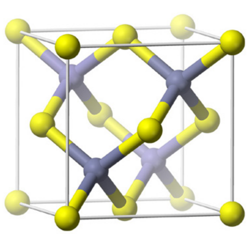


2 inches diameter



Substrate

35.5 doublets of GaAs / $Al_{0.92}Ga_{0.08}As$



zinc blende structure

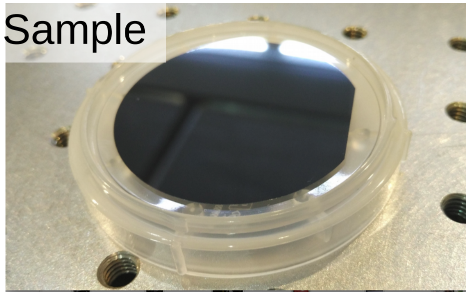
- As a KAGRA R&D activity we are doing investigation on AlGaAs crystalline coatings
- We have two samples from the company:

CMS CRYSTALLINE MIRROR SOLUTIONS

- High reflective Bragg mirror at 1064nm
- Grown with Molecular Beam Epitaxy (MBE) on a **GaAs** substrate
- Then transferred onto **silica** or **sapphire** substrate

Transmission measurements

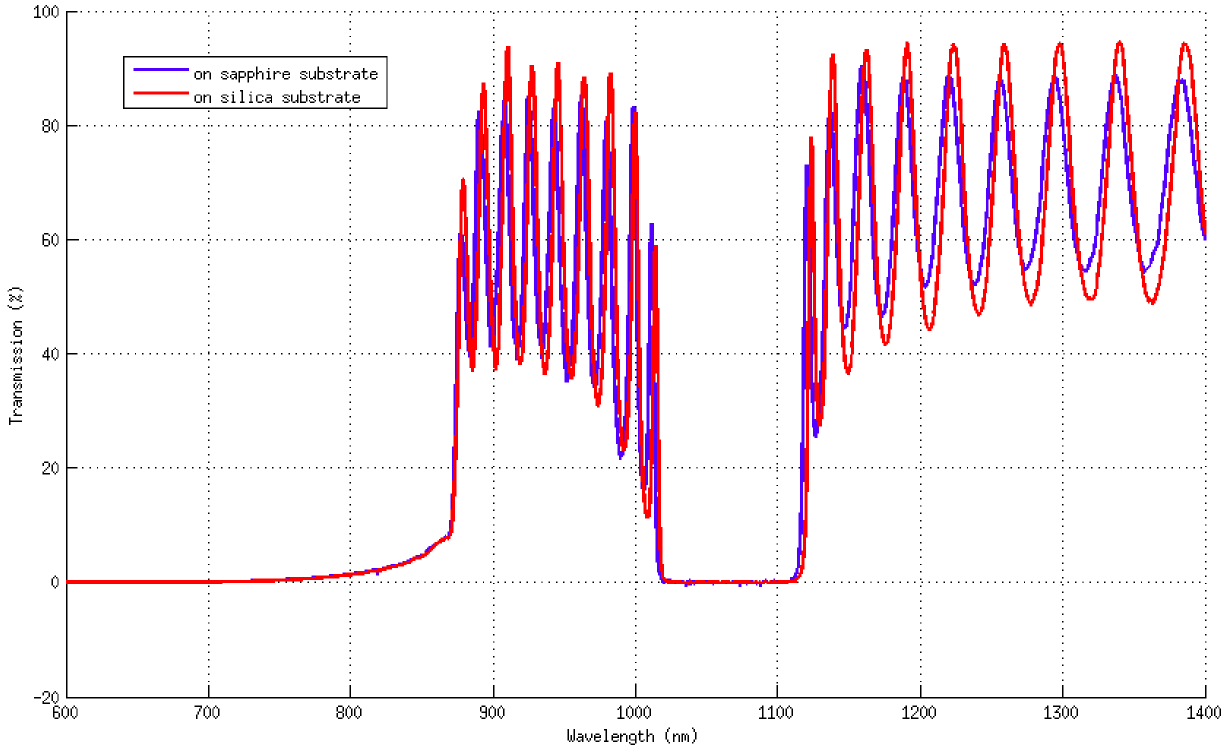
We have two samples



2 inches diameter

GaAs / $Al_{0.92}Ga_{0.08}As$ transferred on **silica** substrate	GaAs / $Al_{0.92}Ga_{0.08}As$ transferred on **sapphire** substrate

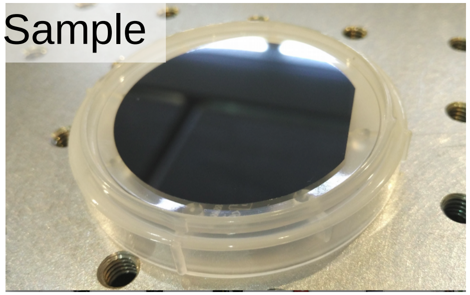
6ppm @1064nm **6ppm @1064nm**



Scattering measurements

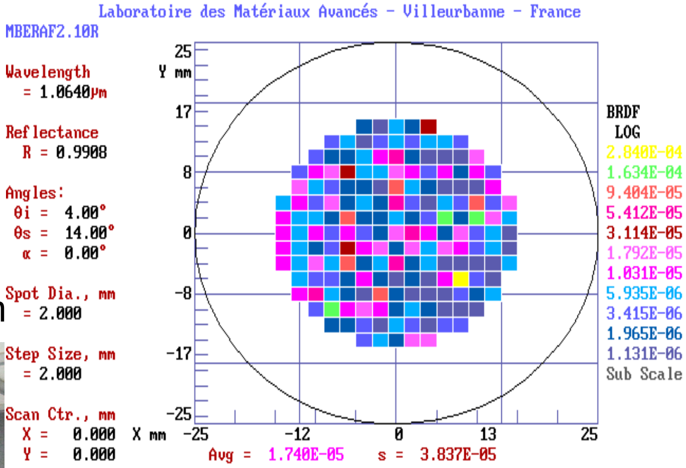
We have two samples

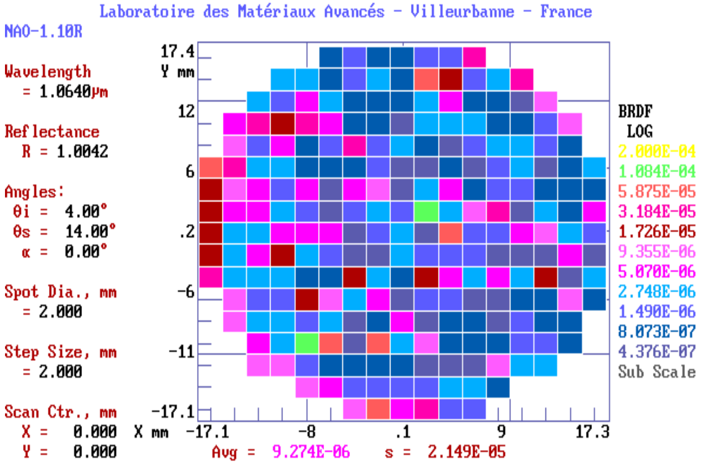
Sample



2 inches diameter

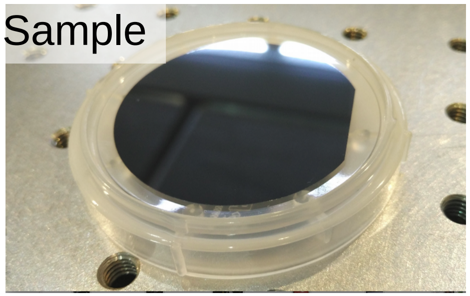
GaAs / $Al_{0.92}Ga_{0.08}As$ transferred on **silica** substrate	GaAs / $Al_{0.92}Ga_{0.08}As$ transferred on **sapphire** substrate
9.5 ppm	**6ppm**





Scattering measurement system

Roughness measurements

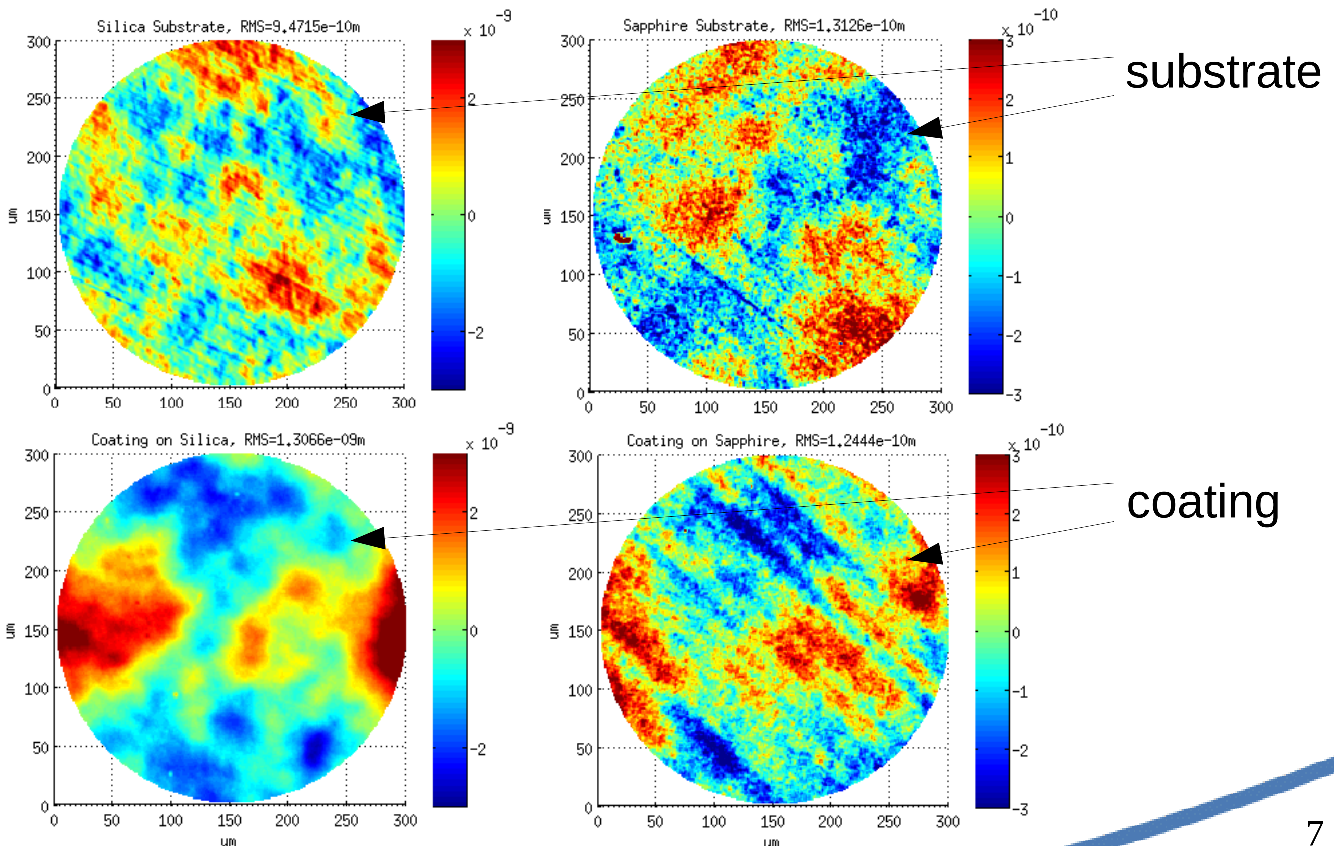


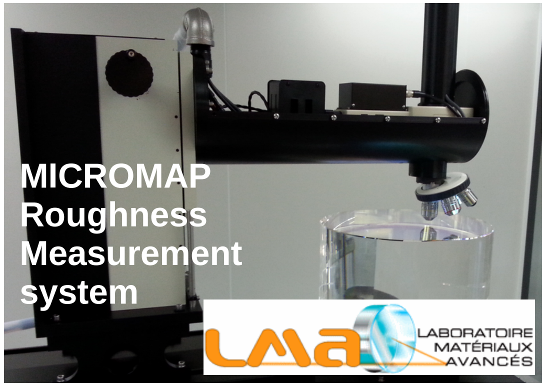
2 inches diameter

We have two samples

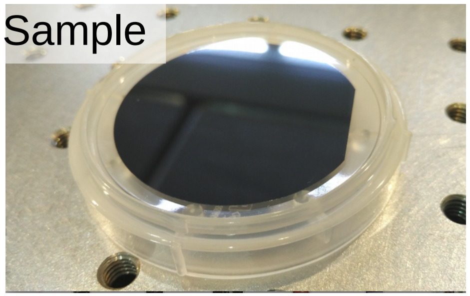
GaAs / $Al_{0.92}Ga_{0.08}As$ transferred on **silica** substrate	GaAs / $Al_{0.92}Ga_{0.08}As$ transferred on **sapphire** substrate

RMS= 1nm | **RMS= 0.1nm**

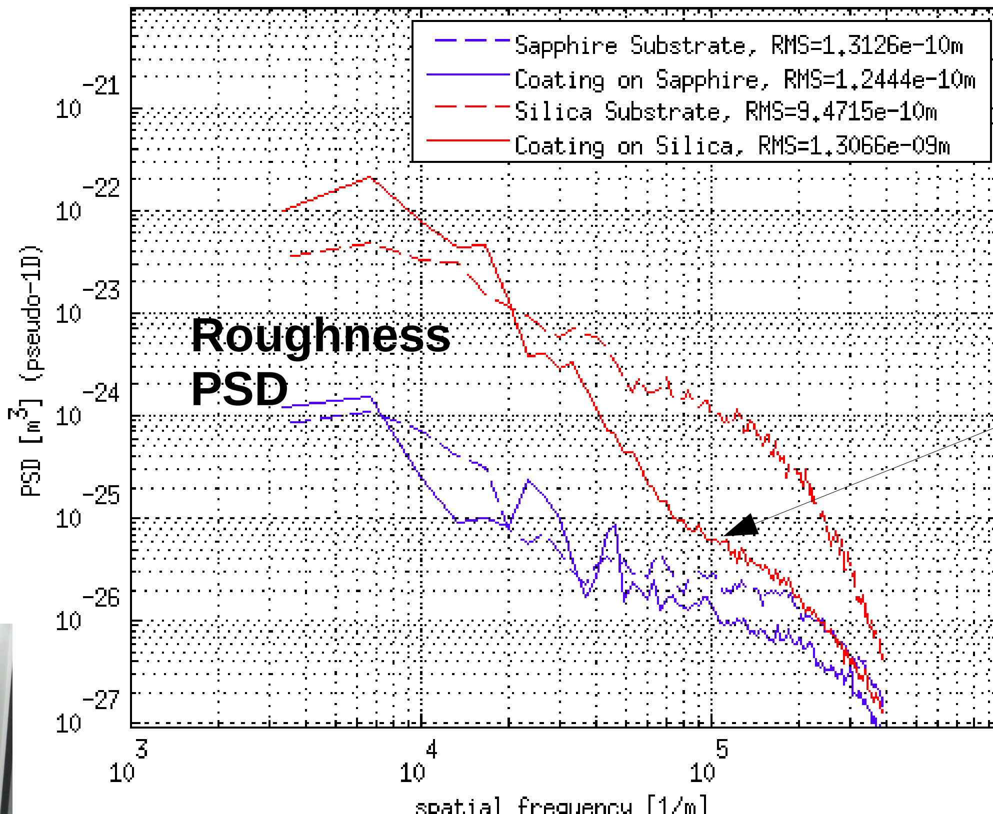




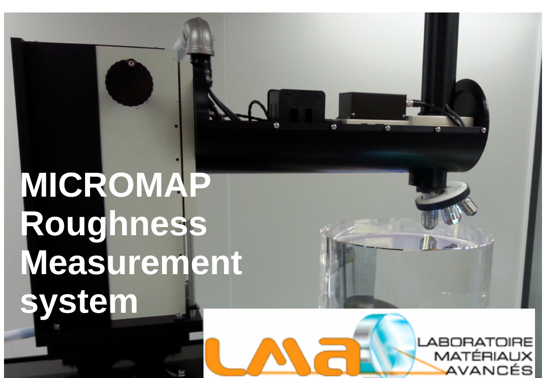
Roughness measurements



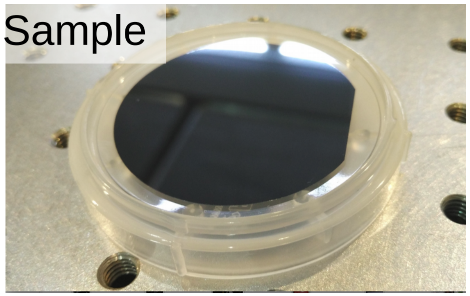
2 inches diameter



- Roughness is limited by the substrate
- Coating roughness (on silica) is lower at higher spatial frequencies



Absorption measurements at LMA



2 inches diameter

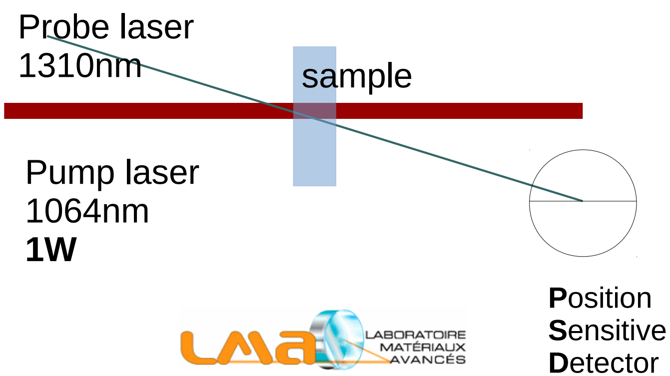
GaAs / $Al_{0.92}Ga_{0.08}As$
transferred on
silica substrate

0.4 ± 0.4 ppm/cm

GaAs / $Al_{0.92}Ga_{0.08}As$
transferred on
sapphire substrate

<below noise level>

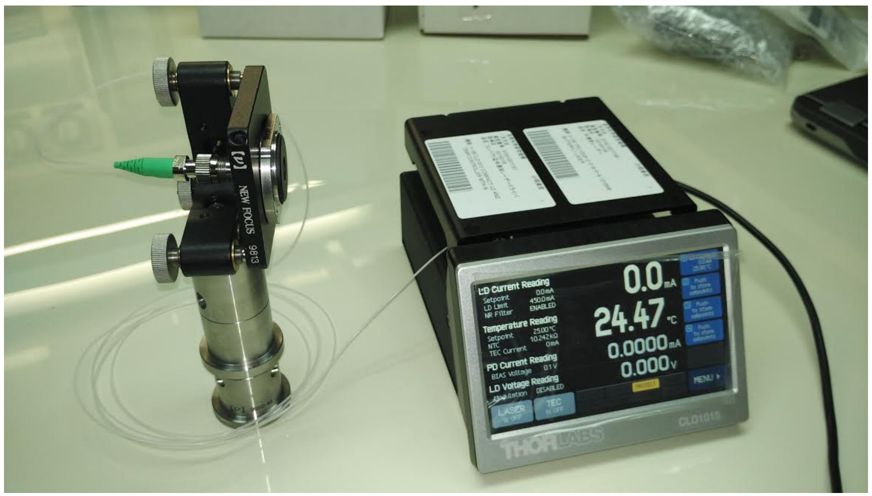
PHOTOTHERMAL
DEFLECTION METHOD



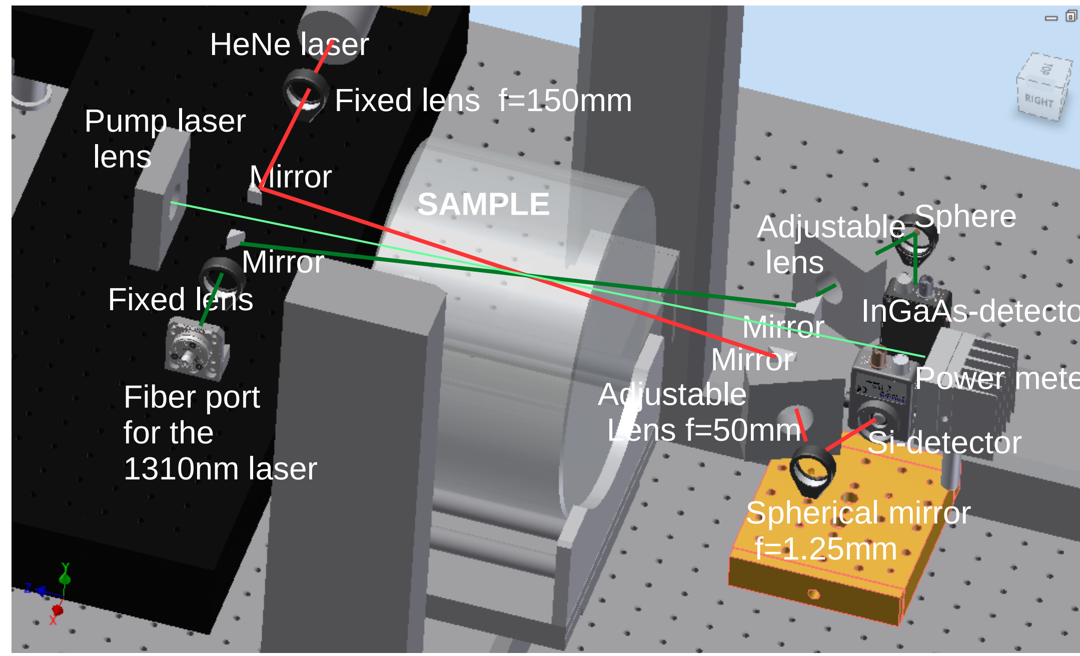
- At LMA we have a different method: instead of the focusing of the probe we measure the beam deflection
- We did single point absorption measurement
- Pump power is only 1W
- Higher thermal diffusivity of **sapphire** makes the signal too small (below the noise level)
- Low SNR → more pump power is needed

Absorption measurements at NAOJ

- 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, so the measurement will be more precise
- We have a translation stage to make maps of the surface absorption



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

Summary

- We have GaAs / $Al_{0.92}Ga_{0.08}As$ coatings made by CMS company
- We did performance tests at LMA:

  Transmission: 6ppm

  Scattering: 6ppm and 9.5 ppm

  Roughness: 0.1nm and 1nm (limited by the substrate)

  Absorption: <1ppm
- We are working at NAOJ to make absorption maps with higher sensitivity
- We are installing a 1310nm probe laser

Thank you for your attention

ありがとうございました