



Development and test of an absorption bench to characterize the KAGRA mirrors: status report

Marchiò Manuel Tatsumi Daisuke Flaminio Raffaele

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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.

OBJECTIVES:

- Measure optical absorption of KAGRA sapphire substrates and coatings
- Investigate new mirror materials for future upgrades – crystalline coatings.

STEPS

Setup absorption experiment

KAGRA

- Calibrations
- Simulations
- Absorption measurements



Absorption measurement system Experimental setup features:



- Scan along the sample depth
- 2D maps of the surface and inside the substrate
- Pump power up to 10W
- Best sensitivity:
 - 1 ppm/cm for bulk absorption
 - 0.1 ppm for surface absorption

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

Absorption measurement system Experimental setup features:



- We want to measure larger samples:
 - size of Tama300 ø100 mm x 60 mm
 - size of KAGRA ø220 mm x 150 mm
- Before replacing the translation stage and disassemble all the parts, we did some test on two Tama300-sized sapphire samples.



- When measuring **thick samples**, there are two important issues:
 - The probe angle in the material (Snell's law)
 - The probe optical path through the material

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



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

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

$$n_0 = 1$$

$$n_1 = 1.76 \text{ Sapphire}$$

$$\alpha_0 = 6^\circ$$

$$X_1 = X_0 \cdot 1.81$$

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





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Moving the detector, the probe size is recovered. We can use the same calibration value.

New detector

Position correction = Sample thickness * (n-1) / n







Measurement of Tama300-size sapphire samples: Scan along the z-axis (propagation of the pump beam)



Next steps for the absorption measurement system

Install a large translation stage to measure larger mirrors



• Install different mounts for different sizes



➔ 1 to 2 inches

 → Ø100mm x 60mm (Tama300 size)



→ Ø220mm x 150mm (KAGRA size)

• Install a 1310 nm laser probe to measure GaAs samples



• Install 1310 nm probe laser



Summary

- We are able to measure thick samples with the right calibration and detector position.

- Ready to upgrade the system for large samples
- We will make maps of large samples

- We will measure crystalline coatings on GaAs substrates





Thank you for the attention

