PCI Technique for Thermal Absorption Measurements

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Absorption Loss Measurements on LIGO Optics

LIGO-G080315-00-Z

Outline

- **Photothermal Common-Path Interferometer**
- **Surface Absorption Measurements on Coated Optics**
- **Transversal scans through mirror: point data**
- **Longitudinal scans: surface inspection**
- **Time scans**

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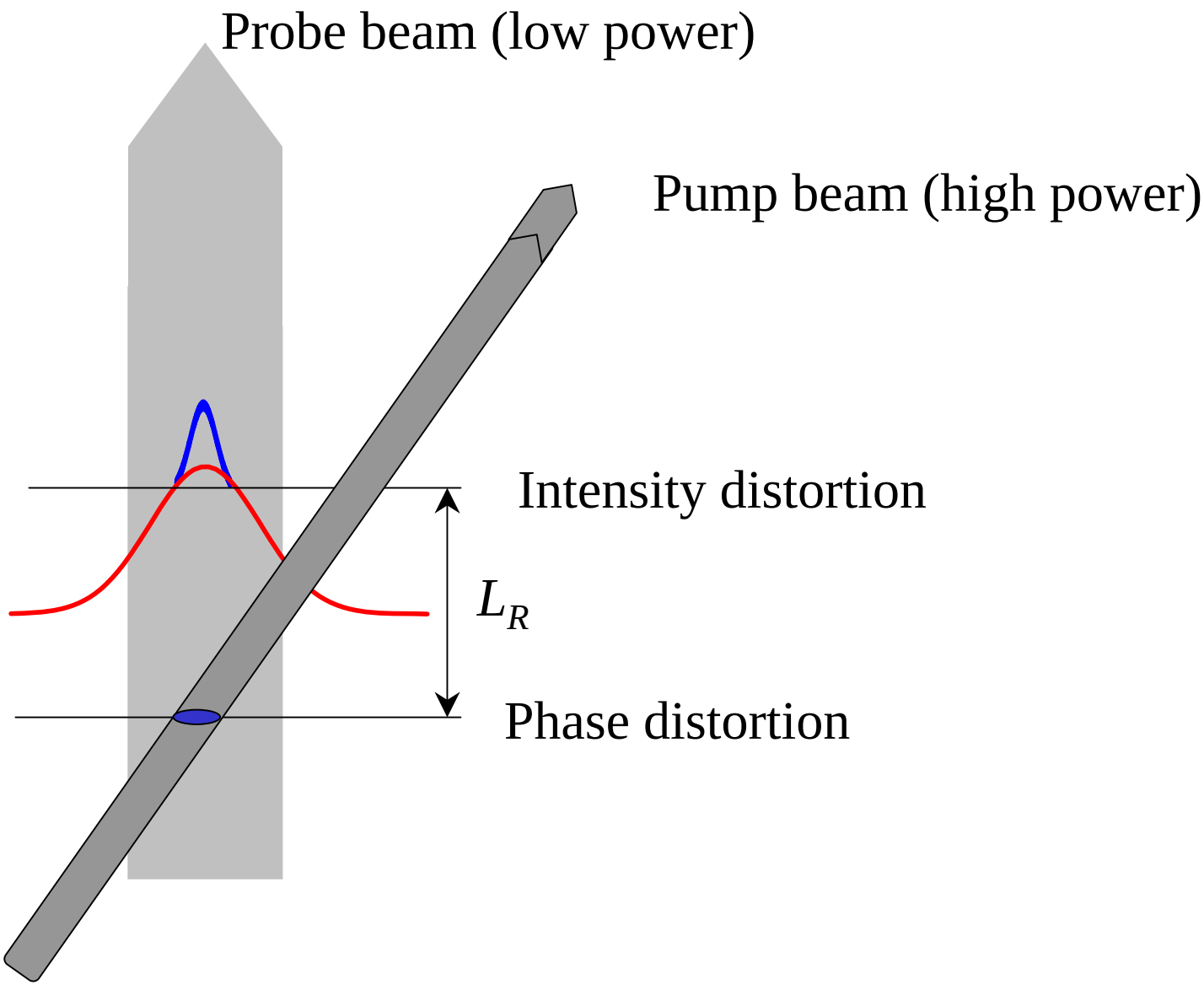
PCI Method (by Alex Alexandrovsky)



PCI Method

The probe phase is distorted due to heating:

$$\Delta\varphi = kL\frac{\partial n}{\partial T}\Delta T$$

$\Delta\varphi$ transforms into an intensity distortion. At the Rayleigh length the intensity modulation is:

$$\Delta I/I_0 = k\delta = (2\pi/\lambda)\Delta nL$$

$$\Delta n = (\partial n/\partial T)\Delta T$$

The simplified formula for α with a "chopped" pump beam of power W_P is:

$$\alpha \approx C(\partial n/\partial T)(\lambda/L)(w_0^2/W_P)(\Delta I/I)\,f$$

PCI Method

RI R-imaging System

PD Photodetectors

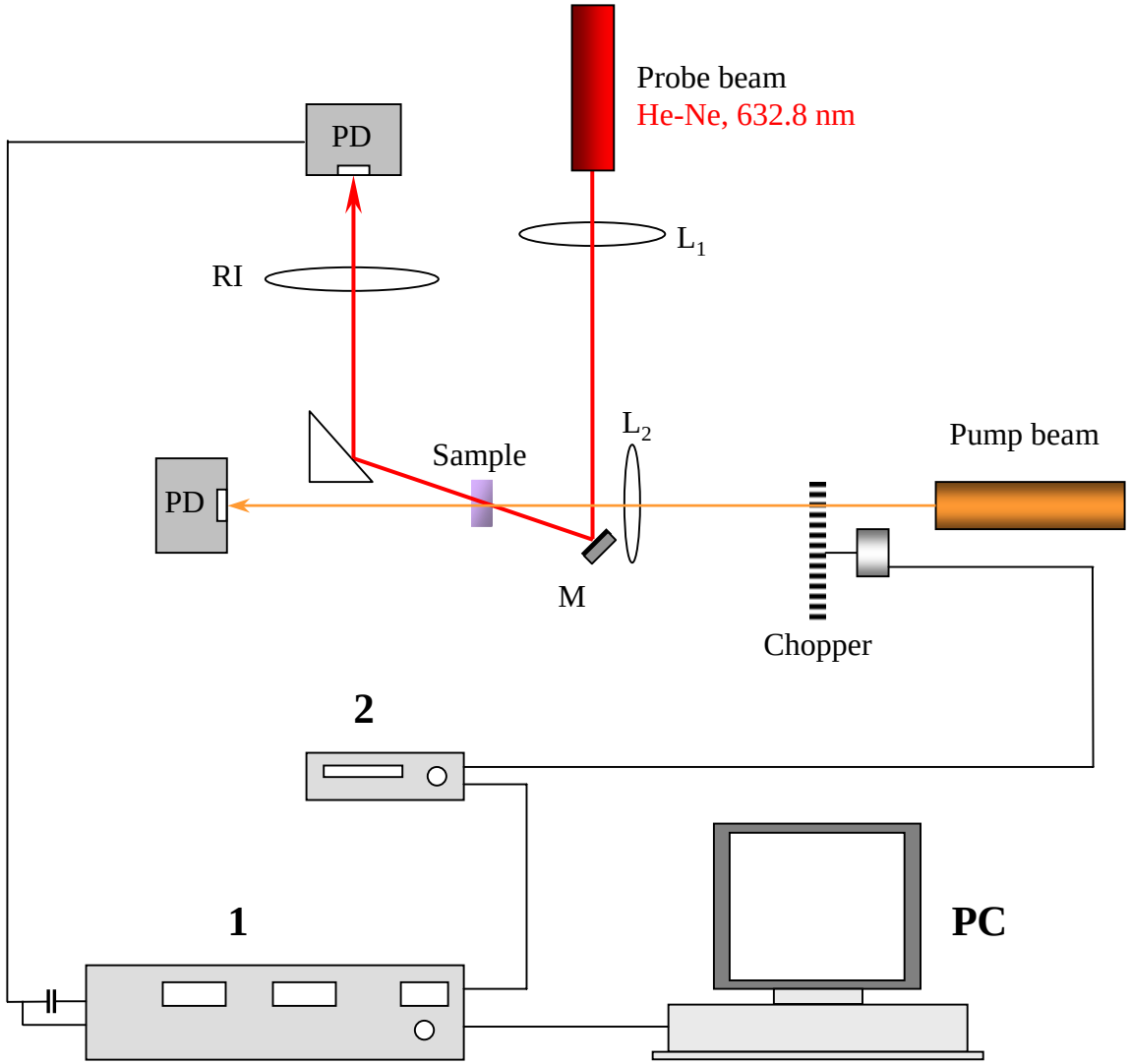
L_i Lenses

M Mirror

1 Lock-in Amplifier
SR830 DSP

2 Chopper Controller
SR340

PC with GPIB-connection
(LabVIEW software)



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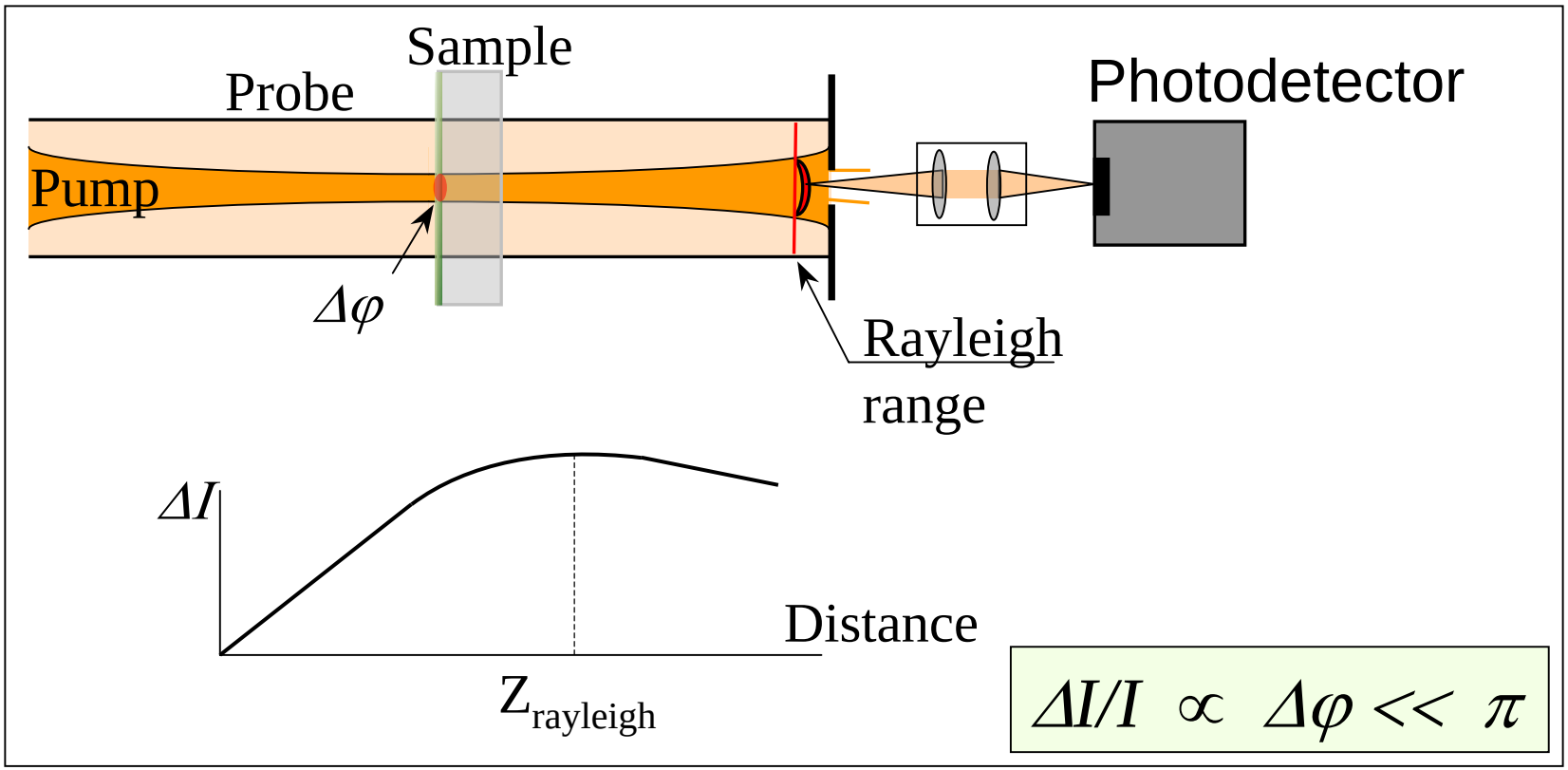
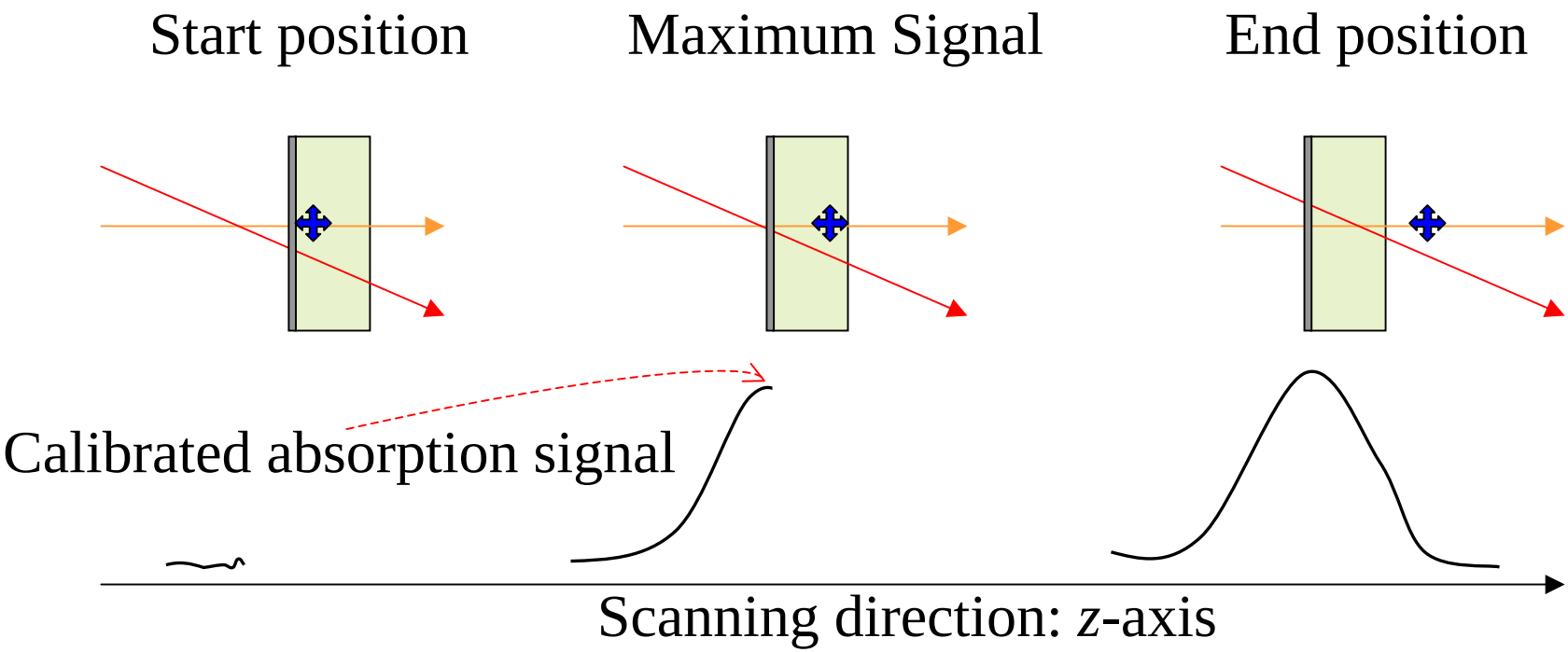


Fig.1. $w_{pump} < w_{probe}$. When the pump is on, the probe experiences phase distortion ($\Delta\varphi$) in the heated area. At some distance, $\Delta\varphi$ transform into ΔI and an effective interference occurs between the central spot (distorted) and outer ring area (undistorted) of the probe

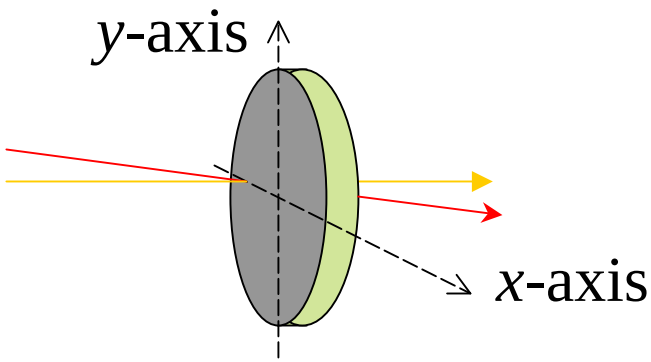
Measurement technique: transversal *z*-scan (through surface)

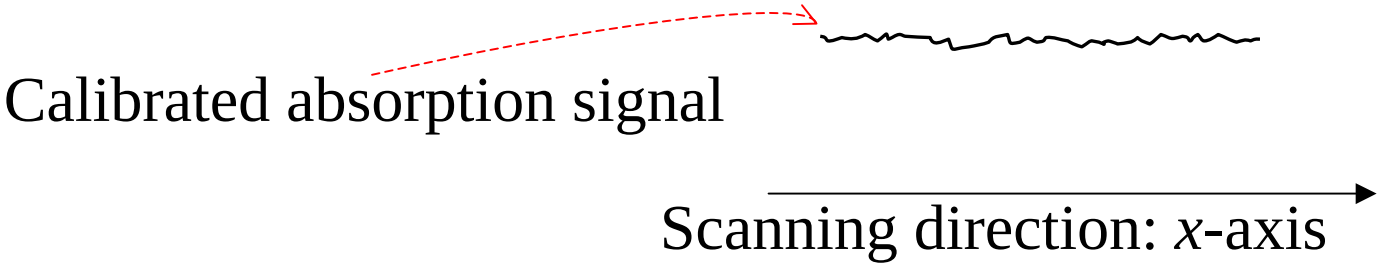


✥ → signal reading point (the focus of the optical system)

Measurement technique: longitudinal *x*-scan (across surface)

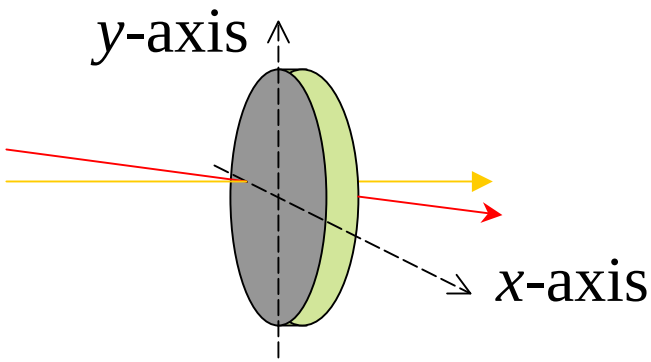
The heated point is positioned at the coated surface

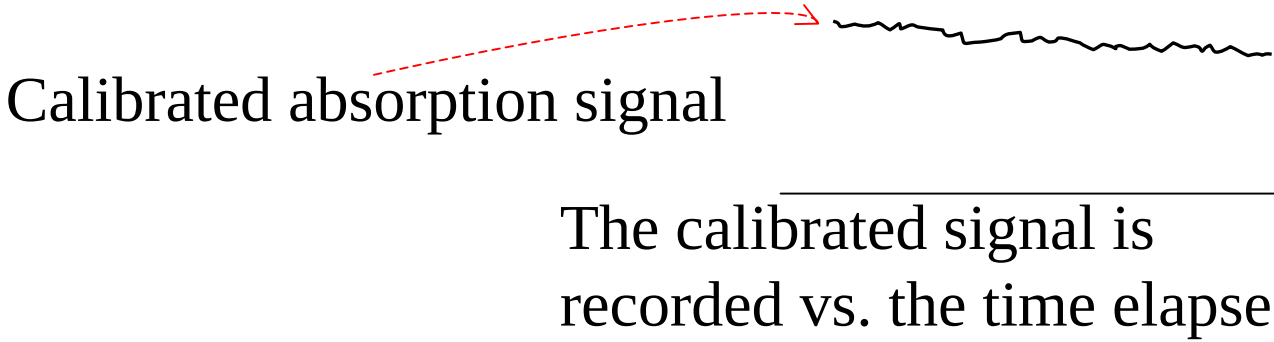




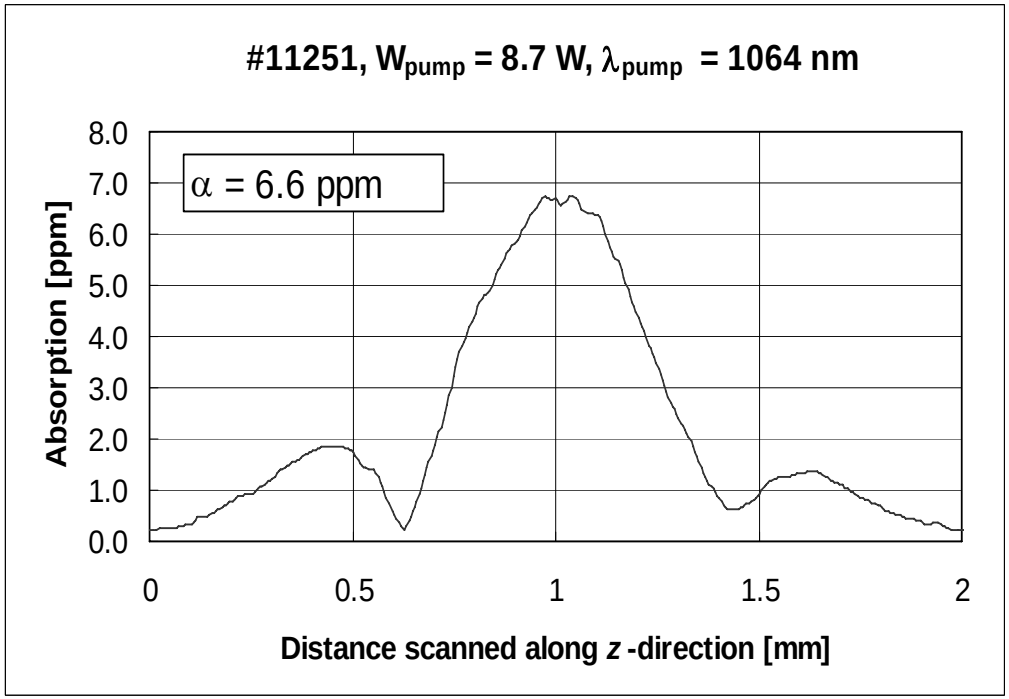
Measurement technique: time scan

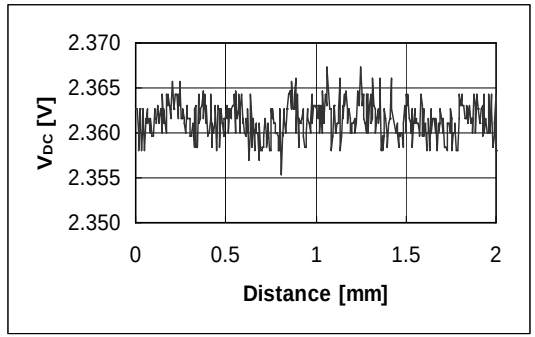
The heated point is focused at the coated surface.
The calibrated signal is recorded vs. time elapsed

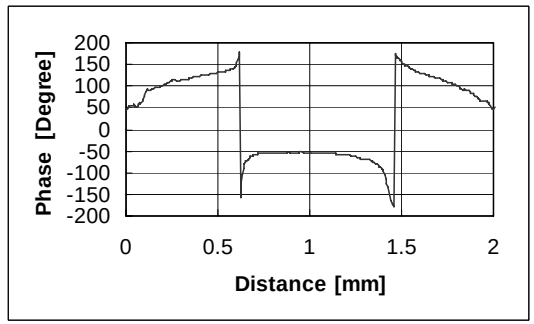




HfO_2-SiO_2/SiO_2 coating, ∅ = 1 inch





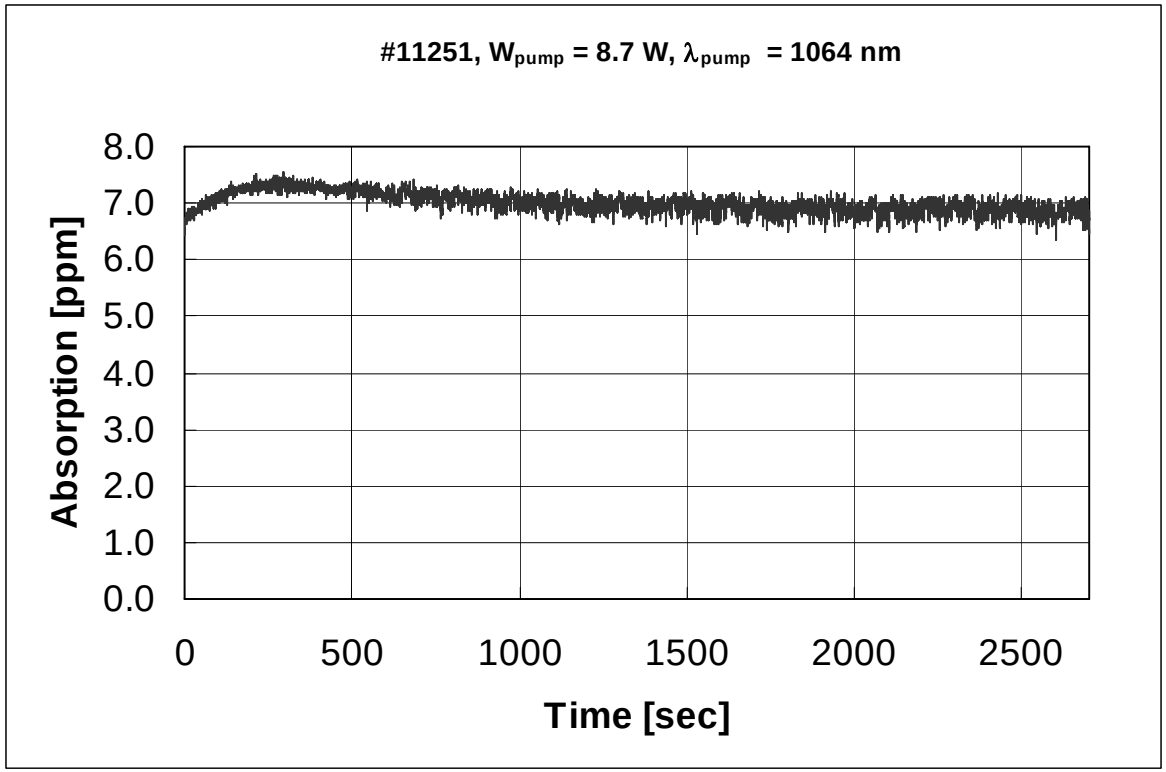


A transversal *z*-scan of sample #11251.

α = 6.6 ppm.

Additionally monitored parameters : *probe beam stability, phase delay with respect to chopper*

HfO_2-SiO_2/SiO_2 coating, ∅ = 1 inch



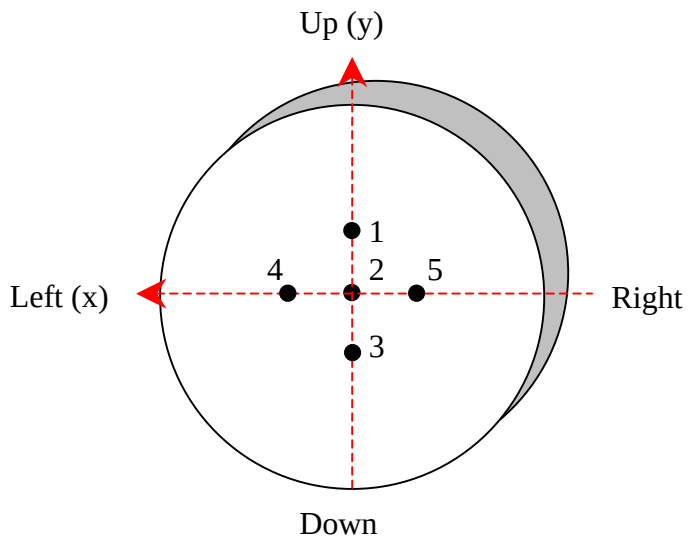
A characteristic time dependent 45 min *t*-scan of sample #11251.

α shows a “bump” (7.3 ppm) at about 5 min.

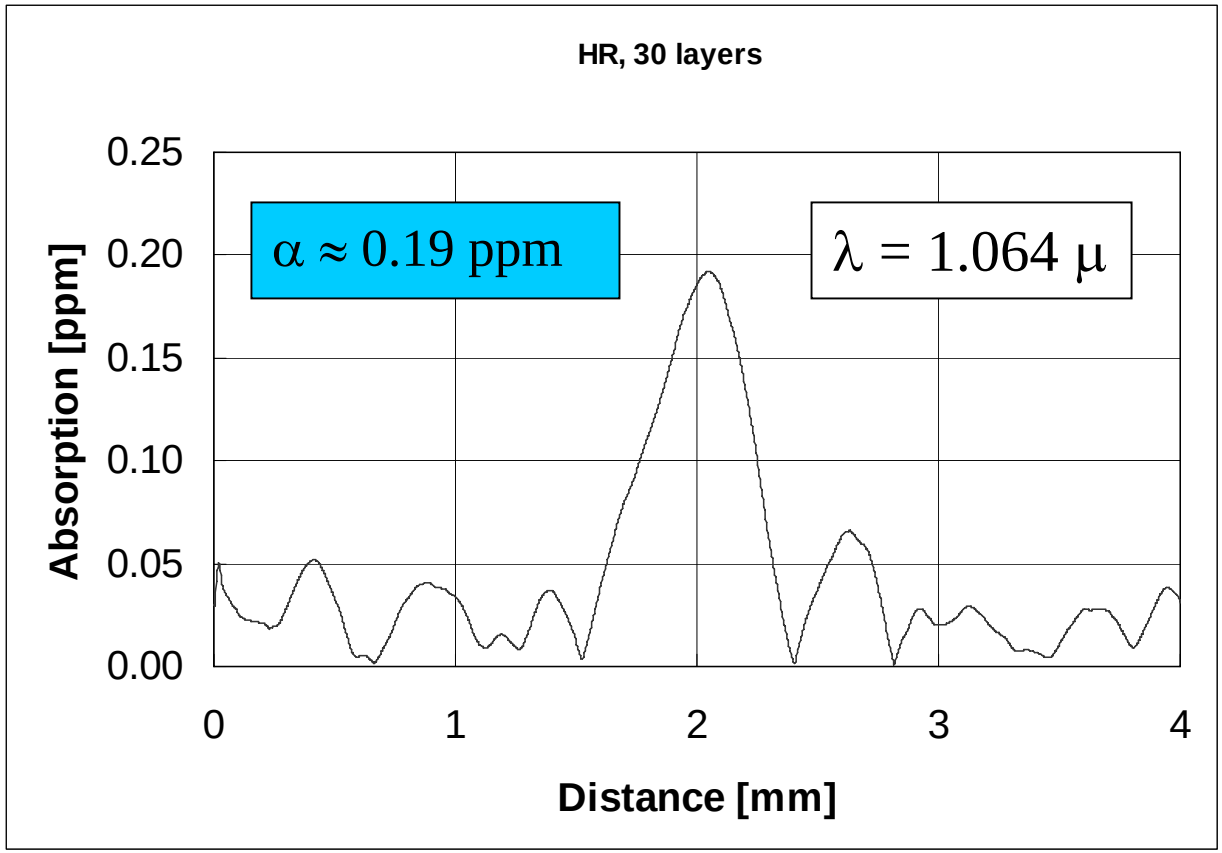
Tabulated data on series of HfO_2-SiO_2/SiO_2 coated samples

Sample #	Absorption (ppm)					
	3 mm above	Center	3 mm below	3 mm left	3 mm right	Average
014-01	7.2	7.4	7.1	7.1	7.2	**7.2**
018-01	8.0	8.0	7.9	8.1	7.9	**8.0**
024-01	6.9	6.7	6.9	6.8	6.9	**6.9**
11251	6.8	6.4	6.6	6.6	6.6	**6.6**

Position of measured points

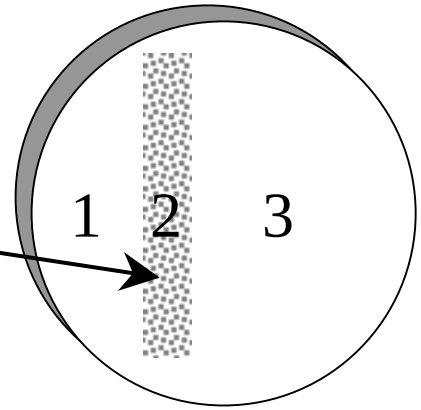


Method's resolution: down to 0.1 ppm with W_{pump} < 10 W

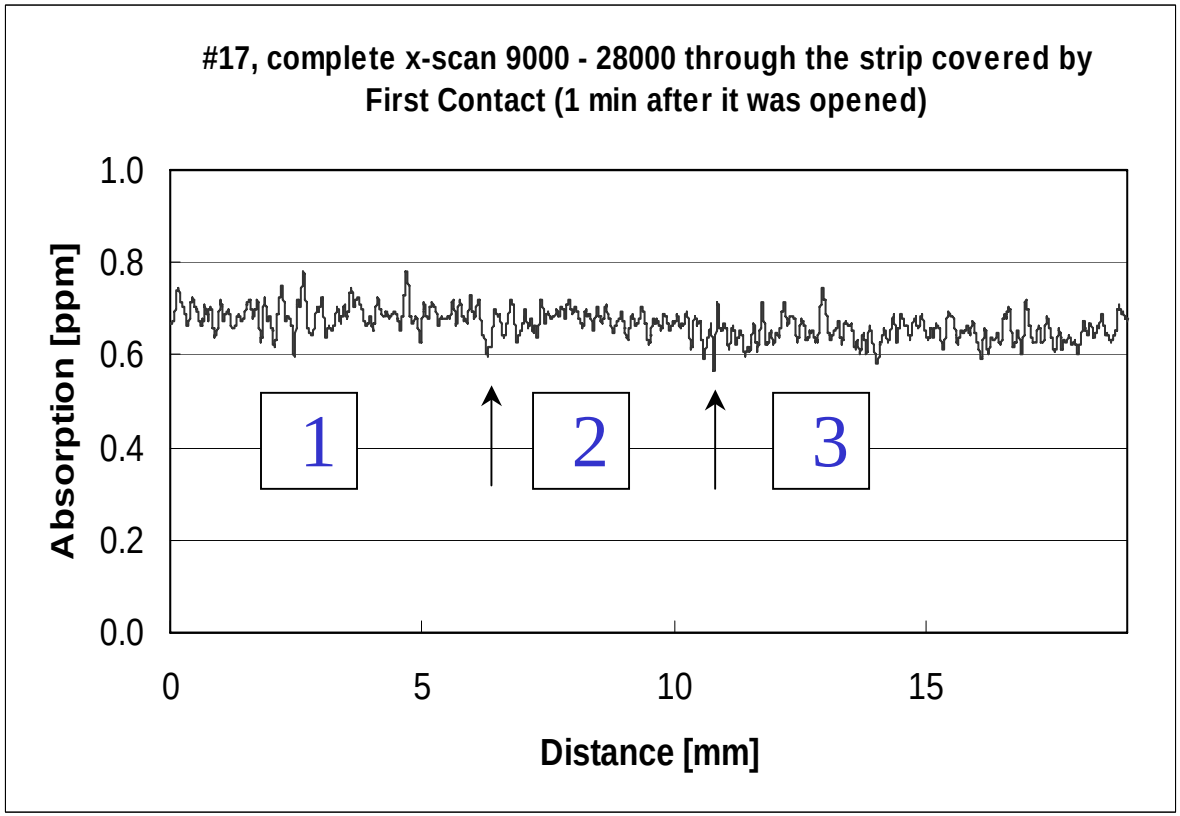


A transversal *z*-scan of a 30 layer HR mirror on a FS substrate.
W_{pump} = 8.8 W, λ = 1.064 μ. Absorption measured = 0.19 ppm.

A coated 3 inch disk marked #17, α = 0.65 ppm.

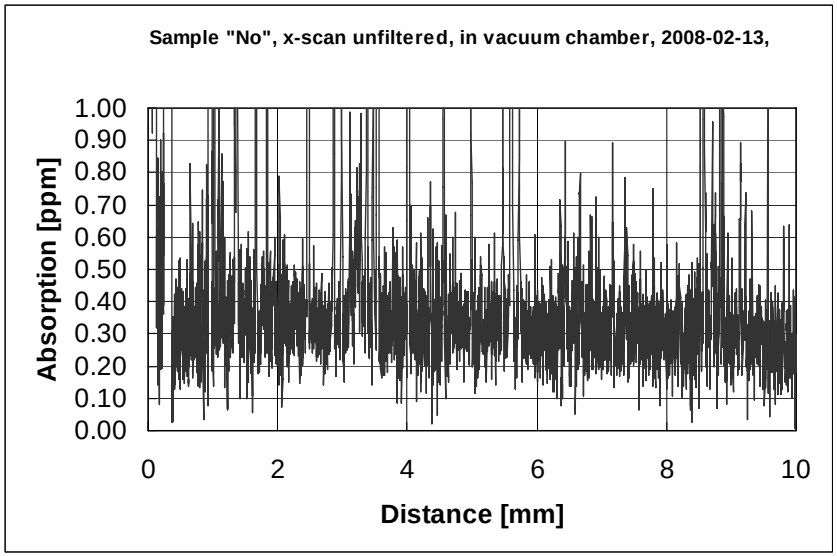


Covered by a First Contact strip for 1 week

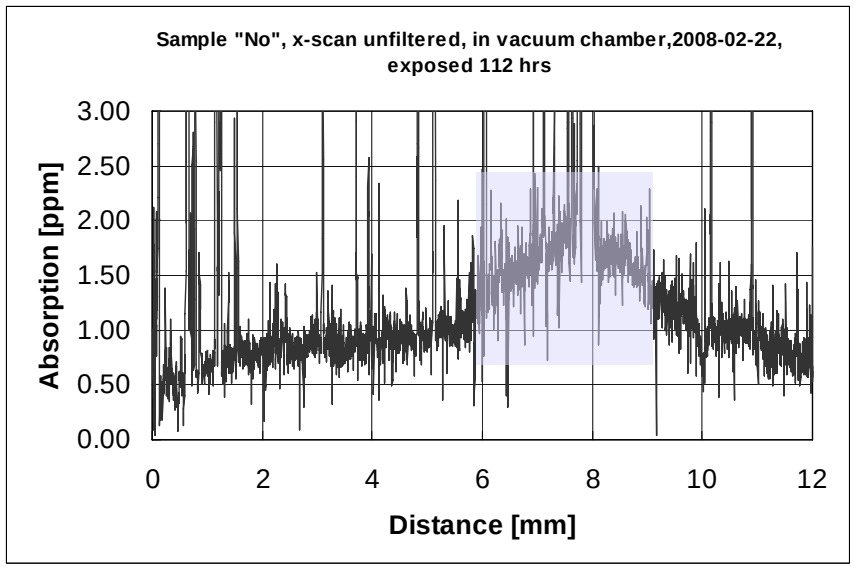


Testing the "First Contact" effect.
α = 0.65 ppm.

Study of the UV illumination effect on LIGO coated mirrors



Characteristic *x*-scans before and after UV illumination *(see Ke-Xun Sun's talk for details)*



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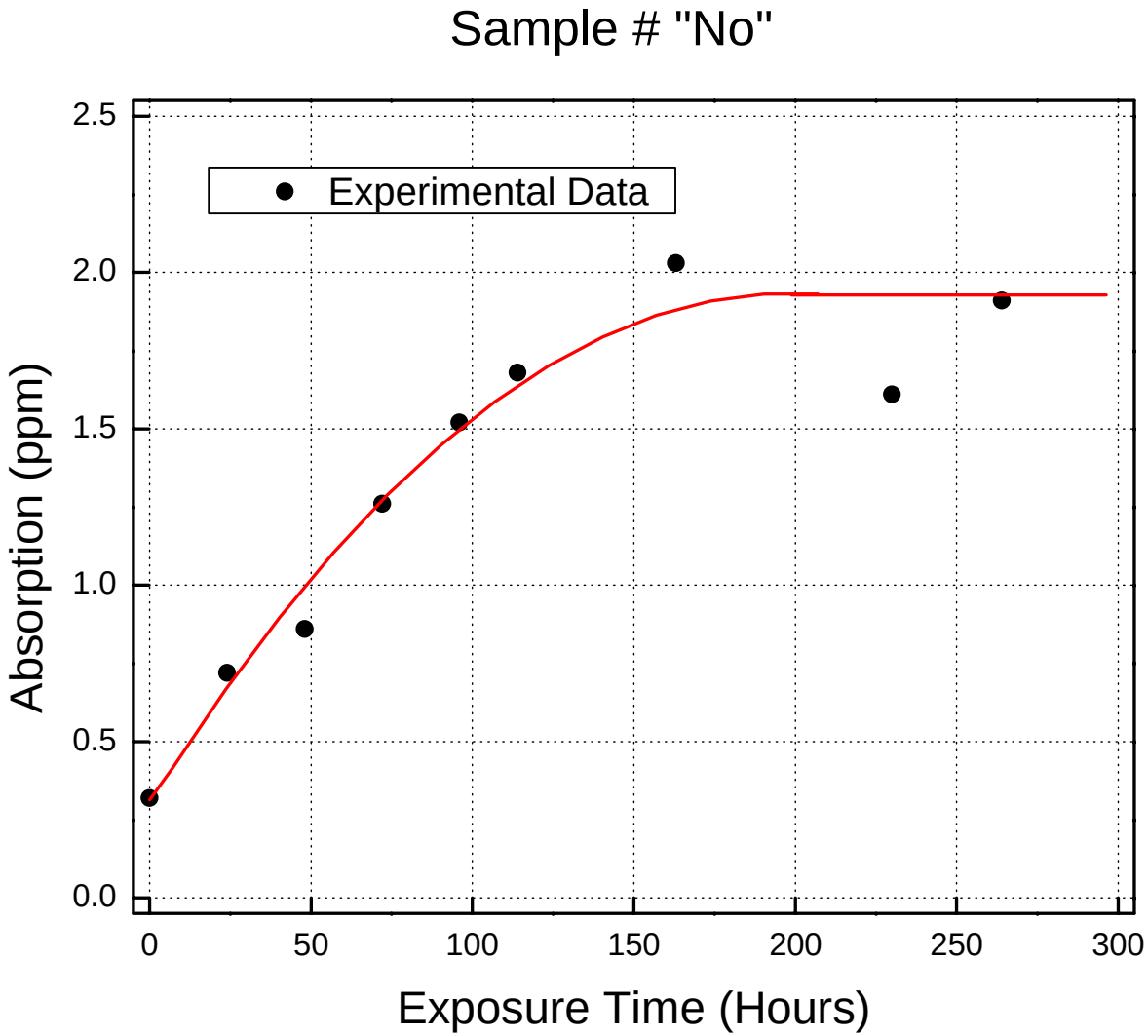

Variation of the absorption loss vs. Exposure Time

Summary

The PCI method is capable to measure thermal absorption losses as low as 0.1 ppm with 8 W incident power

Point by point as well as continuous scan across the coating are possible

The lowest Absorption value measured on LIGO mirrors till now were 0.19 ppm