Recent Results on the Measurement of Transmission and Scattering Structure on Doped and Non-doped Mirrors

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Coatings investigations: motivations and goal

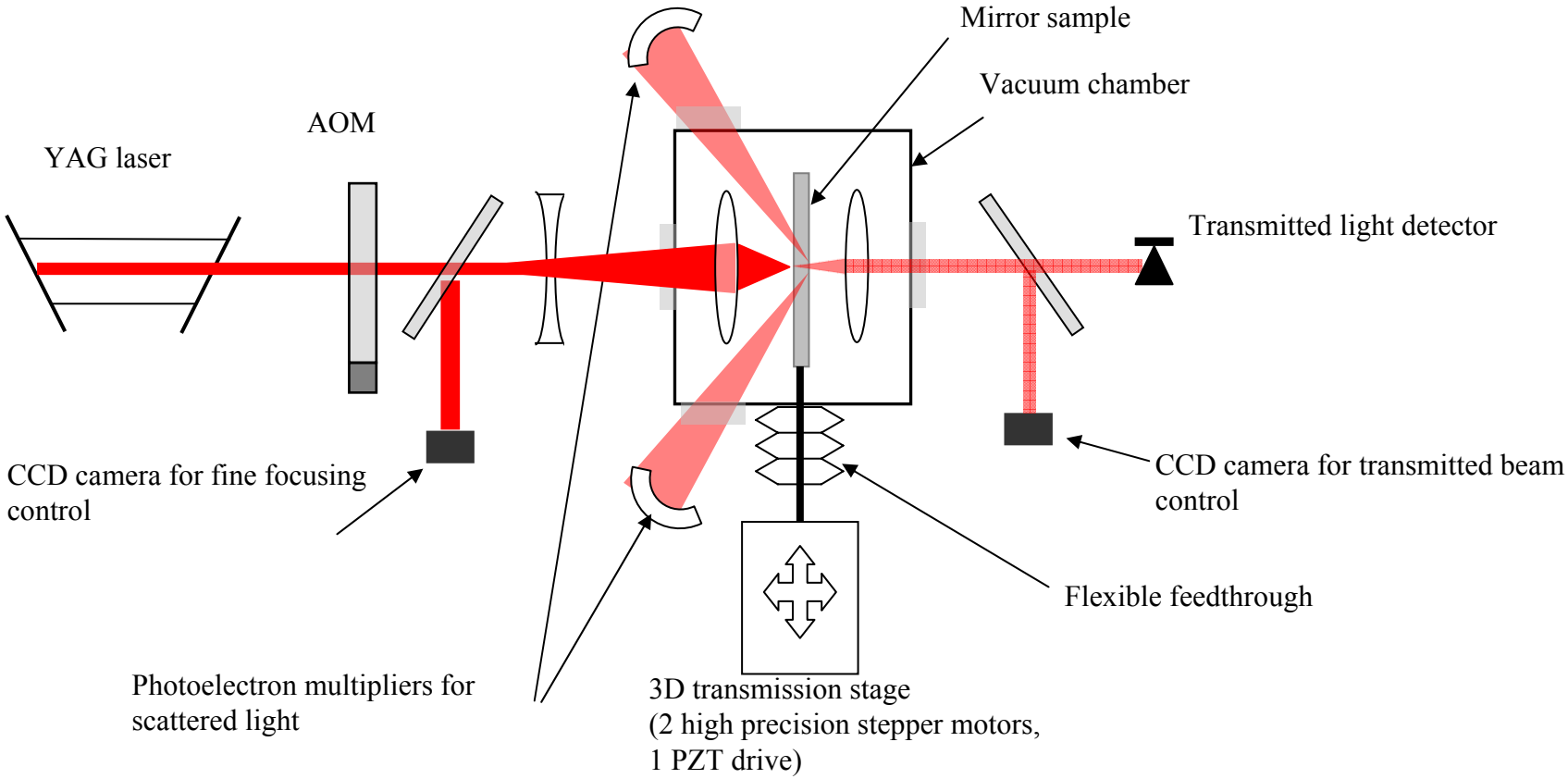
• We decided to test coatings for presence of small (starting from the size compatible to wavelength) **rare** inhomogeneities (defects).

• Such defects may not significantly contribute to the total scattering and absorption budgets nor be visible on the spatial microroughness Fourier spectra.

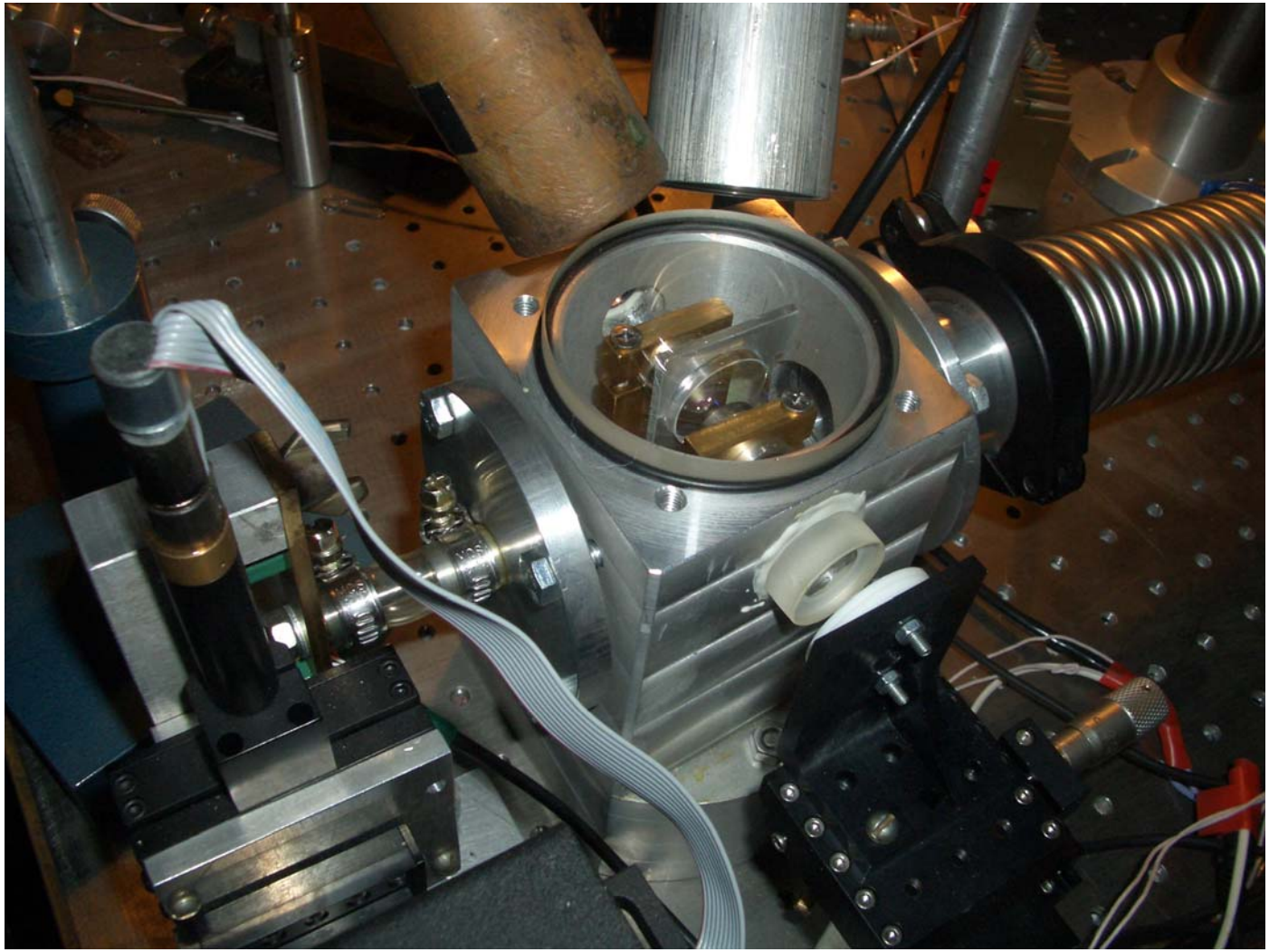
• Such defects may, in principle, became sources of excess mechanical noise because stress release and optical breakdown thresholds could be much lower in that points.

• Simple scanning of transmission and scattering is used as a first step before more sophisticated investigation or direct noise measurements.

Transmission and scattering measurements setup: diagram



Transmission and scattering measurements setup: photo

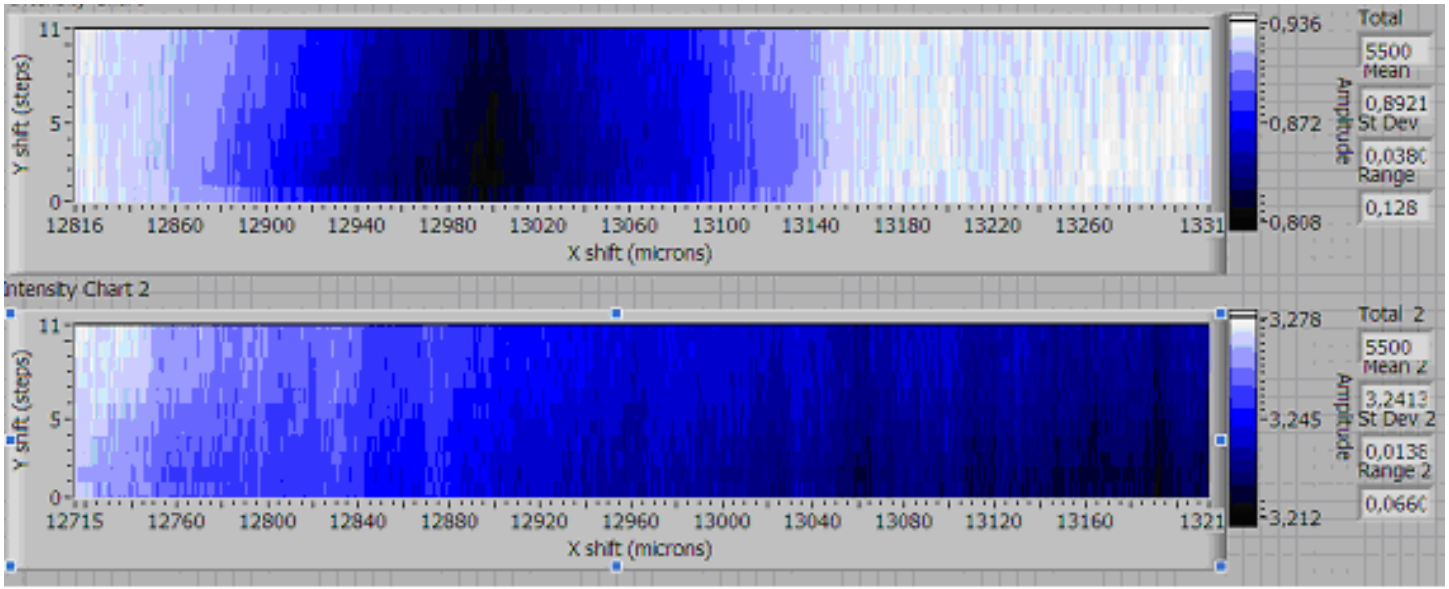


Transmission and scattering measurements setup: features

- 1 μm spatial resolution (close to diffraction limit)
- 1-2 % transmission measurement accuracy for mirrors with $T=10^{-4}$ (10 kHz modulation-demodulation technique is used)
- 0.5-1 % scattering variations measurement accuracy
- Power density up to 300 kW/cm^2
- Permanent focusing control and correction
- Approx. 5 minutes for the single 500x10 μm strip scan

Preliminary measurements: 100 μm plates.

Substrate: Russian SiO_2, deep polishing. Coating: Ta_2O_5/SiO_2, $T=5x10^{-3}$
Caltech order (REO?).

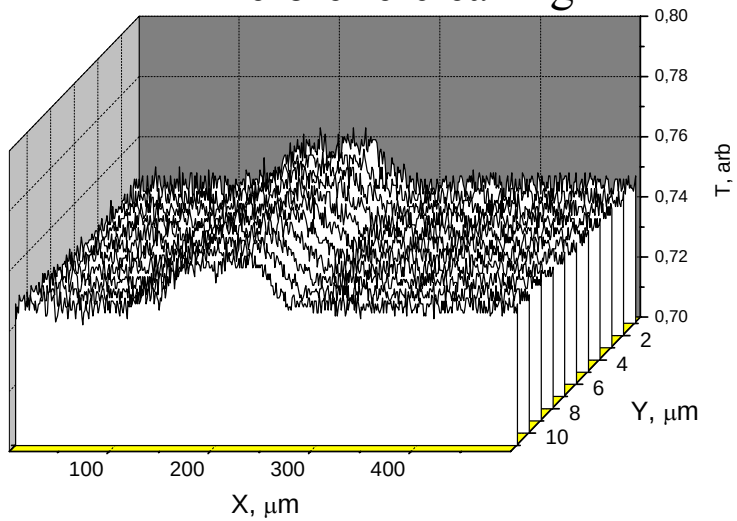


Example of the strip with a "spot" where transmission is 12% below average value (upper chart). No significant changes of scattering in this place (lower chart)

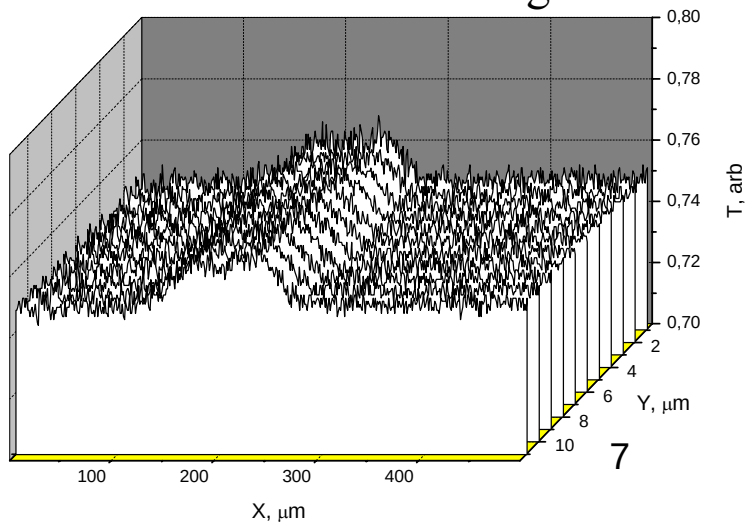
Samples preparation: cleaning

- Ultrasonic pure acetone and methanol bath has been used.
- We also tried CO_2 "snow" cleaner (good results, can be easily applied for the cleaning samples *in situ*)
- In order to prove that the observed "spots" aren't a residual surface impurities, same areas were tested before and after re-cleaning. There is a good evidence that they are not (but still no 100% guarantee).
- Sometimes small (1 micron or less) very bright scattering centers disappeared after the re-cleaning: presumably dust particles.

Before re-cleaning



After re-cleaning

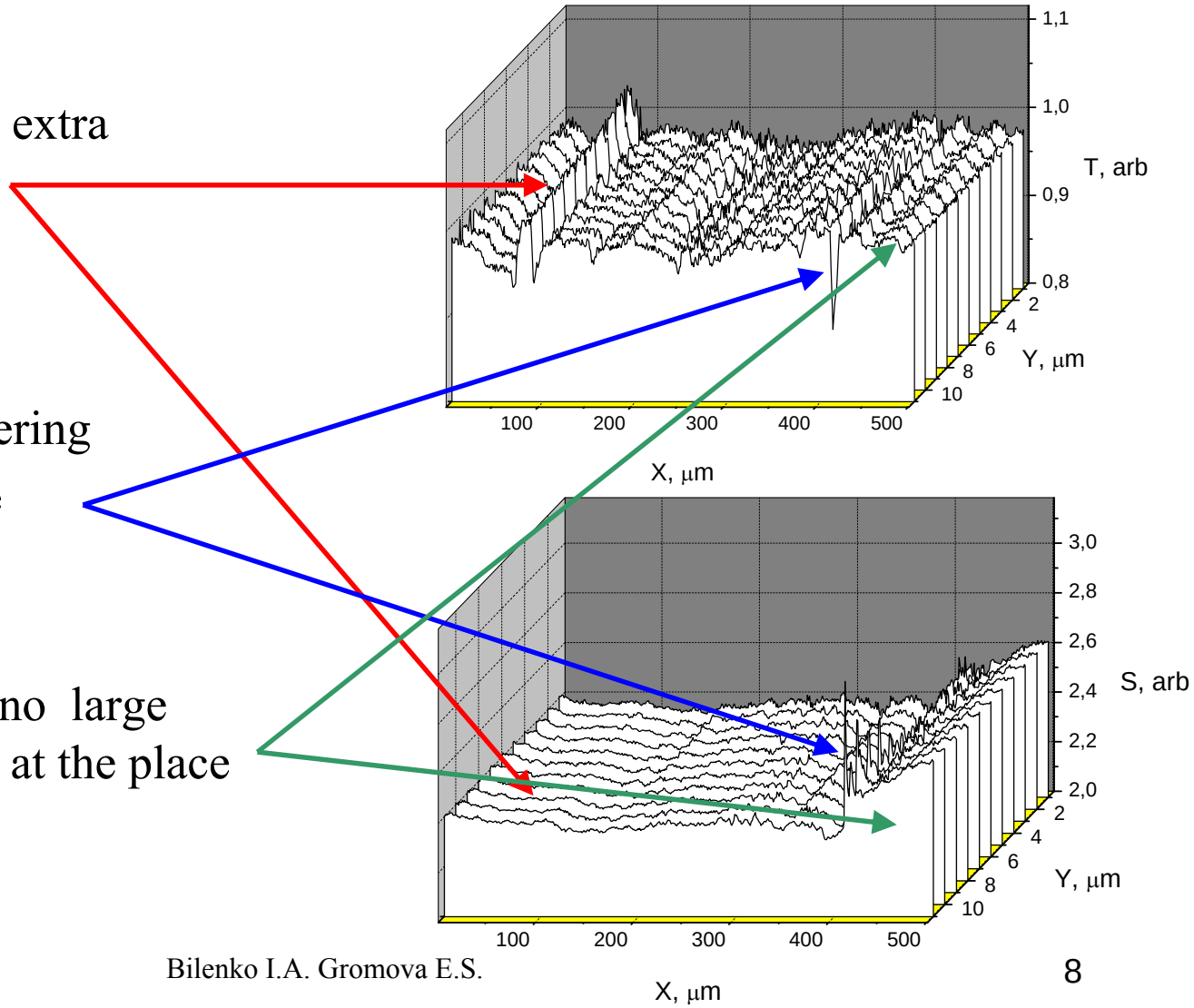


Different types of observed defects

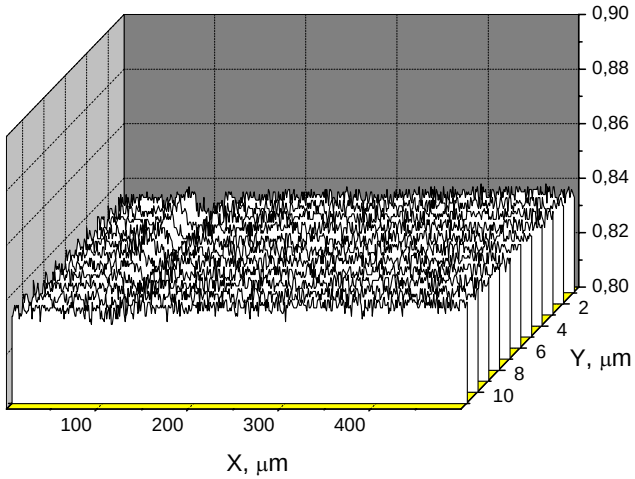
Transmission peak, no extra scattering

Transmission and scattering peaks at the same place

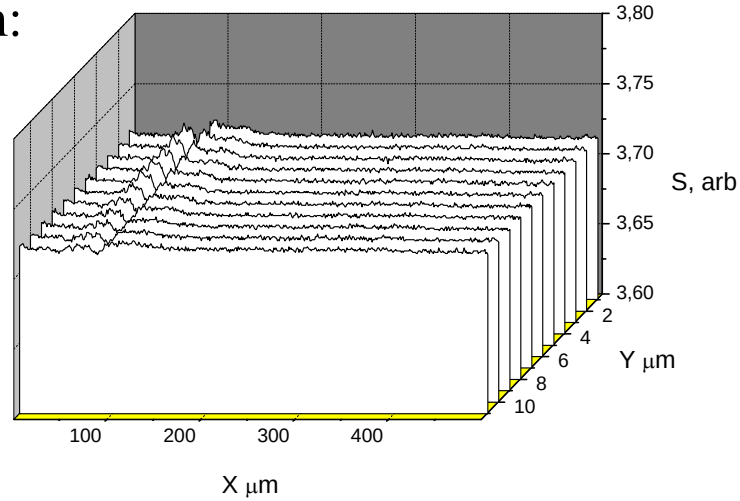
Wide scattering peak, no large transmission variation at the place

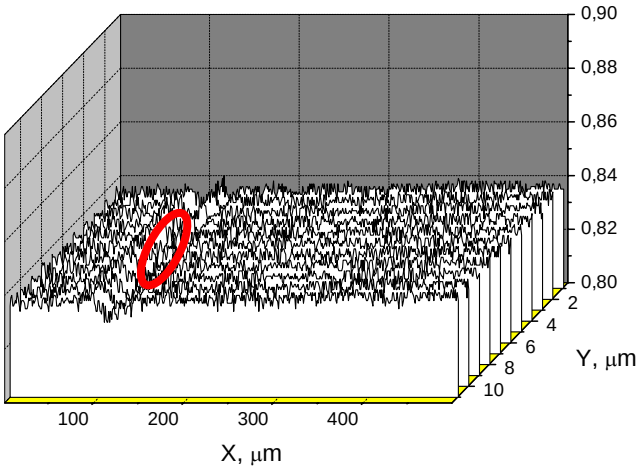


High power density test

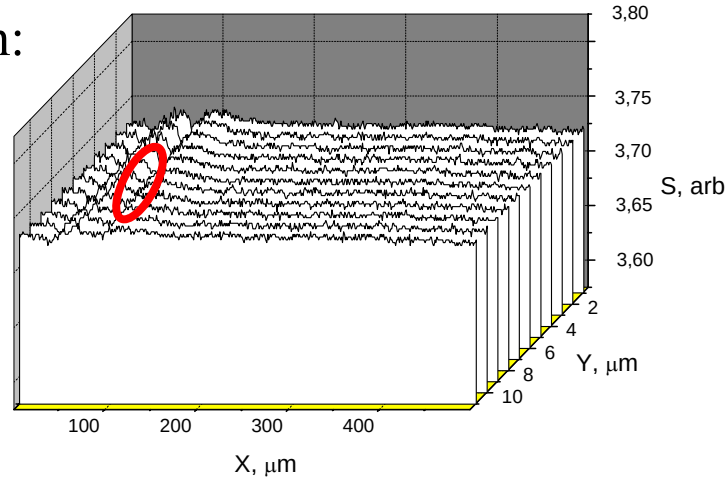


Before exposition:

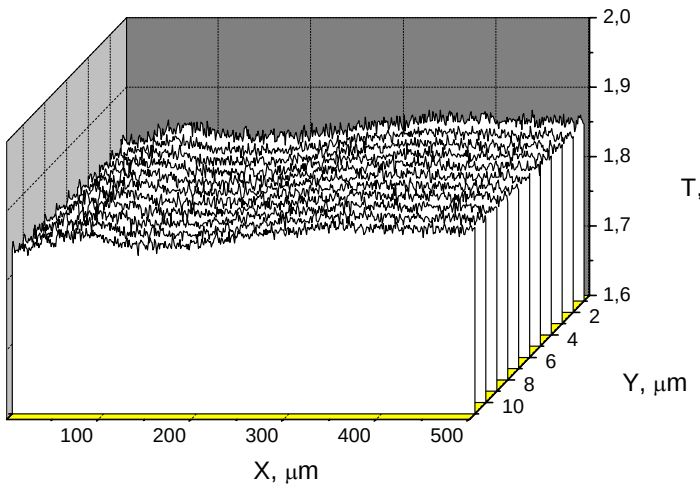




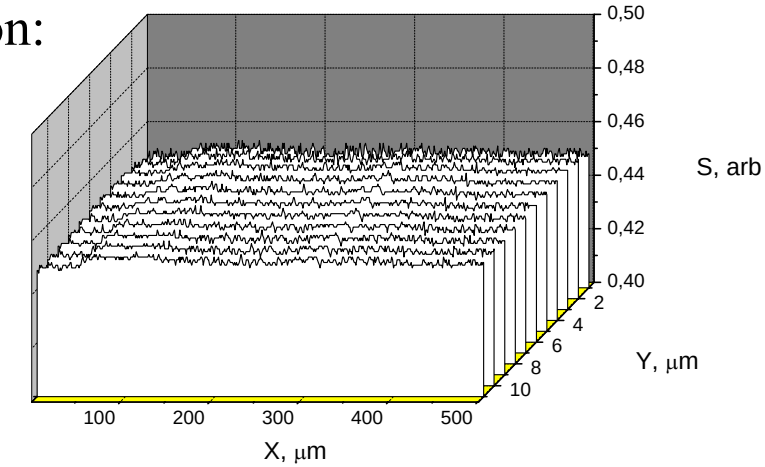
After exposition:
15 mW, 5 μm^2
(~300 kW/cm^2)
for 30 minutes

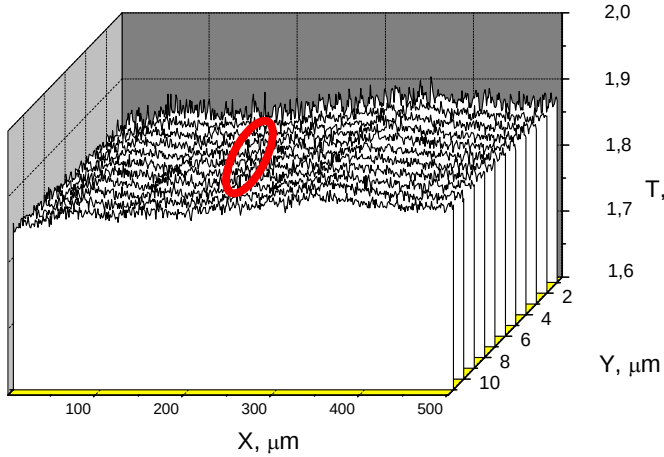


High power density test (Ti-doped Ta_2O_5/SiO_2: C07041121)

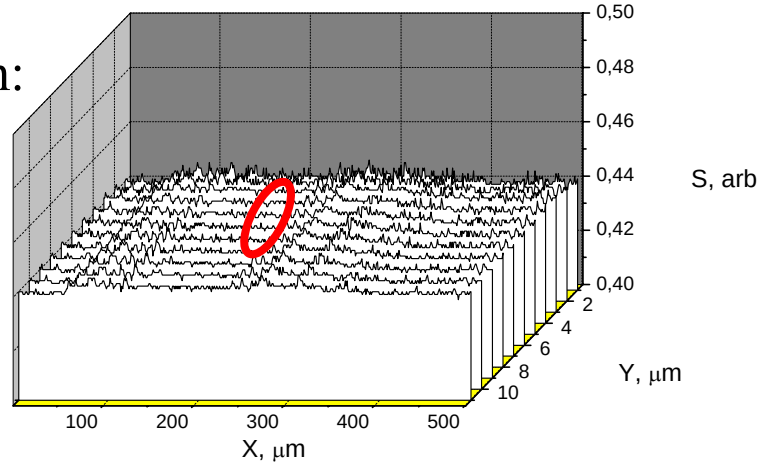


Before exposition:





After exposition:
15 mW, 5 μm² (~300 kW/cm²) for 30 minutes



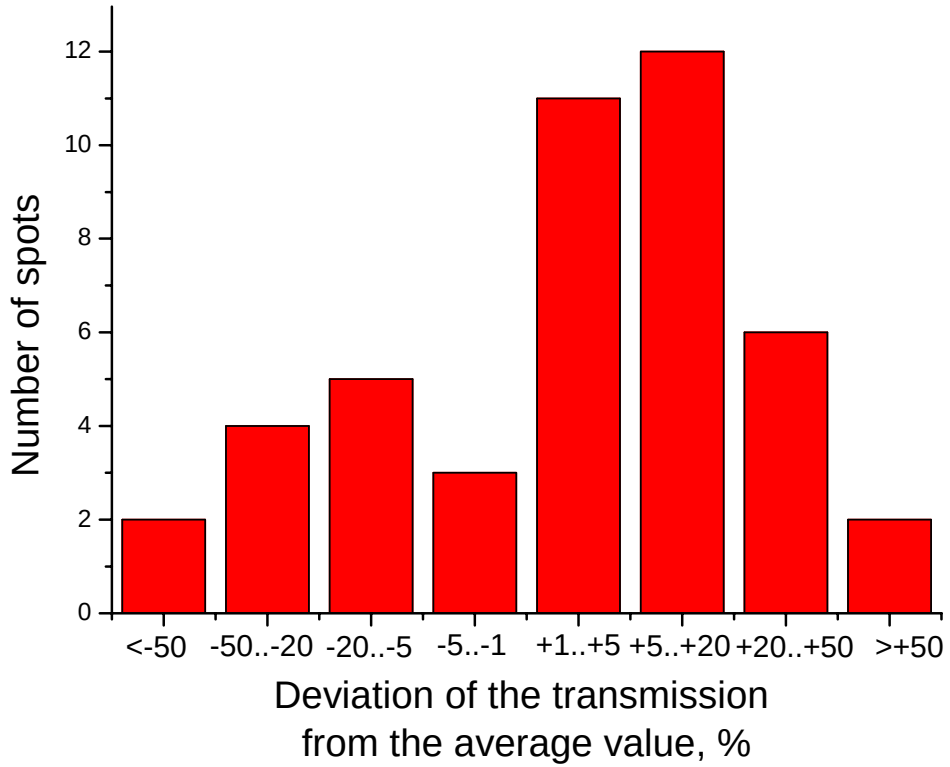
Measurements summary

	Ta_2O_5/SiO_2 on 100 μm plate T=5x10^{-3}	Ta_2O_5/SiO_2 on superpolished 1" SiO_2 substrate. T=1x10^{-4} (LIGO Lab provided)	Ti-doped Ta_2O_5/SiO_2 on superpolished 0.5" SiO_2 substrates. T=1x10^{-4} (LIGO Lab provided: C07041121, C07041122)
Total scanned area	0.5 mm^2 (85 strips)	0.1 mm^2 (20 strips)	0.3 mm^2 (62 strips)
Number of spots observed*	81	7	18
Estimated spots area (% of scanned area)*	0.008 mm^2 (1.5%)	0.0006 mm^2 (0.6%)	0.002 mm^2 (0.6%)
Maximum deviation of transmittance from average value	60%	7%	30%
Maximum deviation of scattering from average value	220%	30%	90%

* Deviation of transmittance and/or scattering from the average value exceeds 2%.

Distribution of the spot number on the transmission value

Histogram for the distribution of the spot number on the transmission value for the 100 μm plates (Ta_2O_5/SiO_2, $T=5x10^{-3}$).



Discussion and conclusion

Assuming that in the case when transmittance in a spot drops due to the additional adsorption, it is possible to estimate upper limit for the spot heating in AdvLIGO case:

$$\Delta T_0 = \frac{W_{ads}}{2\sqrt{\pi k_f d}} \approx 0.06K$$

(W_{ads}=25 μW, k_f=33W/m K, d=10^{-6} m)

Observed defects seems not to be dangerous for mirrors performance …so far.

Future plans

- Make scan area wider (80 microns instead of 10) by installation stacked PZT drive
- Reduce temperature drifts and mechanical backlash for better repeatability.
- Implement an absorption measurement (?)
- Collect more data to obtain statistically significant difference between samples (or to confirm absence of difference)
- Test another coating materials and techniques.