Coating Core Optics for O4

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LIGO-G2200124-v1

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- Waiting to coat ETMs for O4 until we have resolution of point absorber problem - are we there?
  - Progress in limiting particulate in the chamber
  - Still absorbers - but small, significance is uncertain
  - What does small mean???
    - Known IFO points
    - Compare what is seen on witness samples
  - Why not wait?
    - Schedule - first optic arrives for installation 14 weeks from “GO” ~June 1
    - O4
    - Costs - $125k/day to run LIGO, $ 213k to repolish ETM S1
    - Schedule - LMA needs to get on development of Ti:Ge coatings for some project called A+

- Other ETM options
  - Ablation - might start with ETM11/14 - these have high scatter

LMA

LMA Current Status

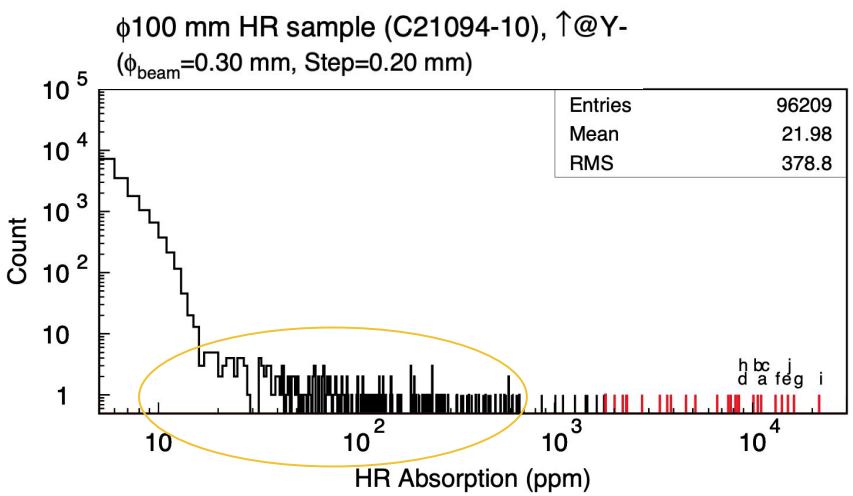
Ready to coat ~mid February

- Waiting on a new target
- Waiting on new mounts
- Waiting on new chamber panels

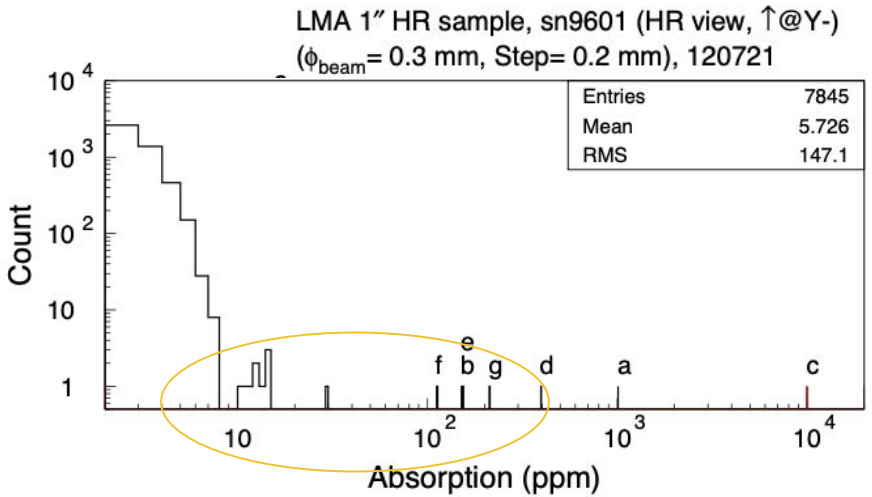
Will receive Ti:Ge targets this month

A noticeable improvement in the chamber

Foil covering sandblasted surfaces

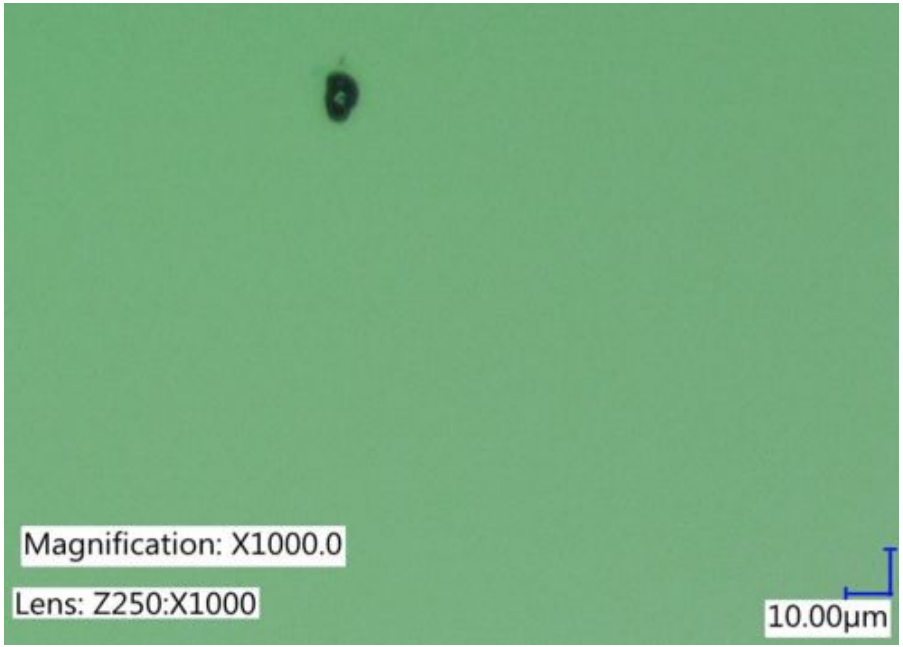


No sandblasted surfaces



Remaining points are small

SN9601 highest absorber on RTS is point c

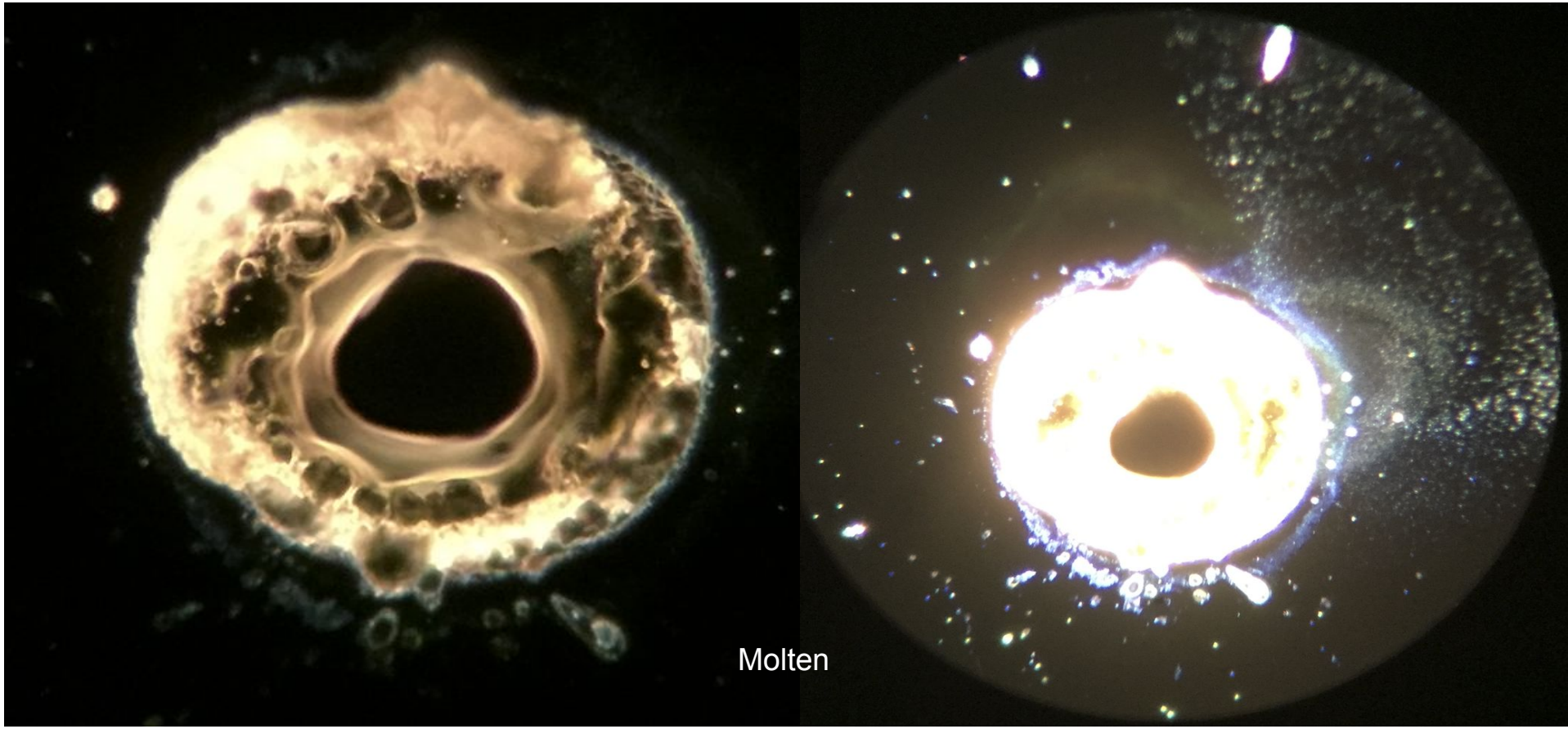


Point Absorber Summary

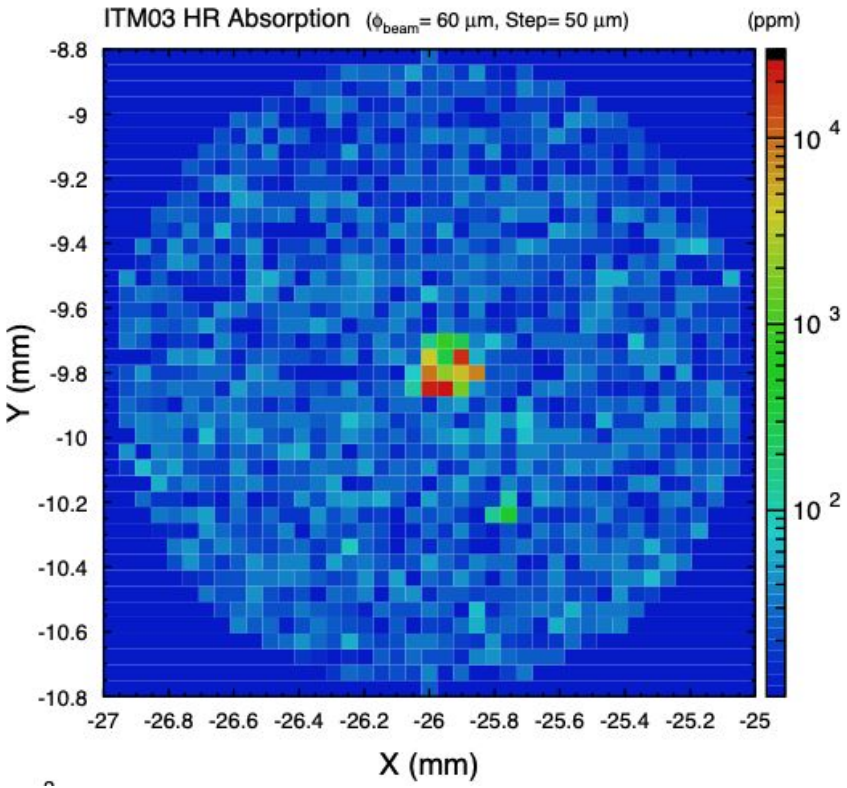
- Possible causes
  - Coating chamber panels are sandblasted and difficult to clean, may shed during coating
  - Re-sputtering from the coating chamber optic mount or shutter
  - First contact residue from in-situ cleaning
  - Exploding dust - we suspect this is minimal
- Identification and characterization
  - Photo-thermal Common-path Interferometery (PCI) absorption tests - Zhang, Catalog at T2000055, E2000079
  - Hartmann Wavefront Sensor (HWS) - Brooks G2001349
  - Material imaging and ID - Appert/Kuns/Gras/Gomez/Kasprzak, Catalog at T2000733
- Possible mitigation
  - Prevention
    - Chamber cleaning - Ananyeva T2100351
    - Masking parts near the optic with clean or new material each run
  - Ablation
    - Demonstrated removal of defects by ablation - Fritschel G2001414 T2100216
      - Residual absorption caused by ablation on clean coatings can be mitigated by annealing in air at 300 C° SN0932
      - Remaining residual absorption of ablated or partially ablated points, improving with annealing, work is ongoing E2100395

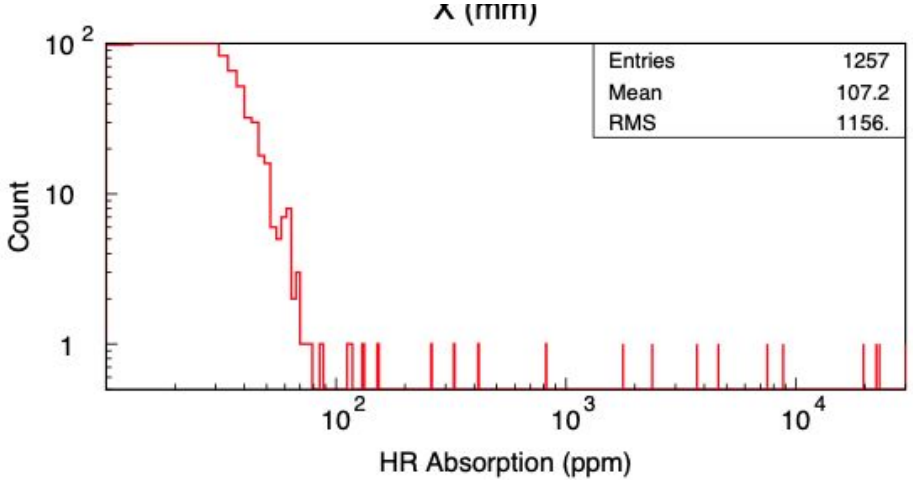
Point Absorbers In Situ
Different causes?

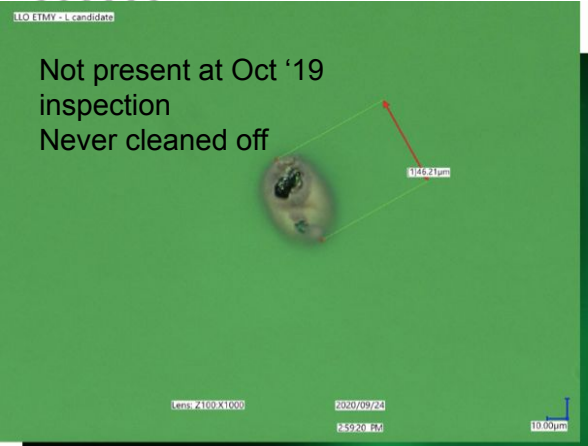
Absorber from O2 LHO ITMx



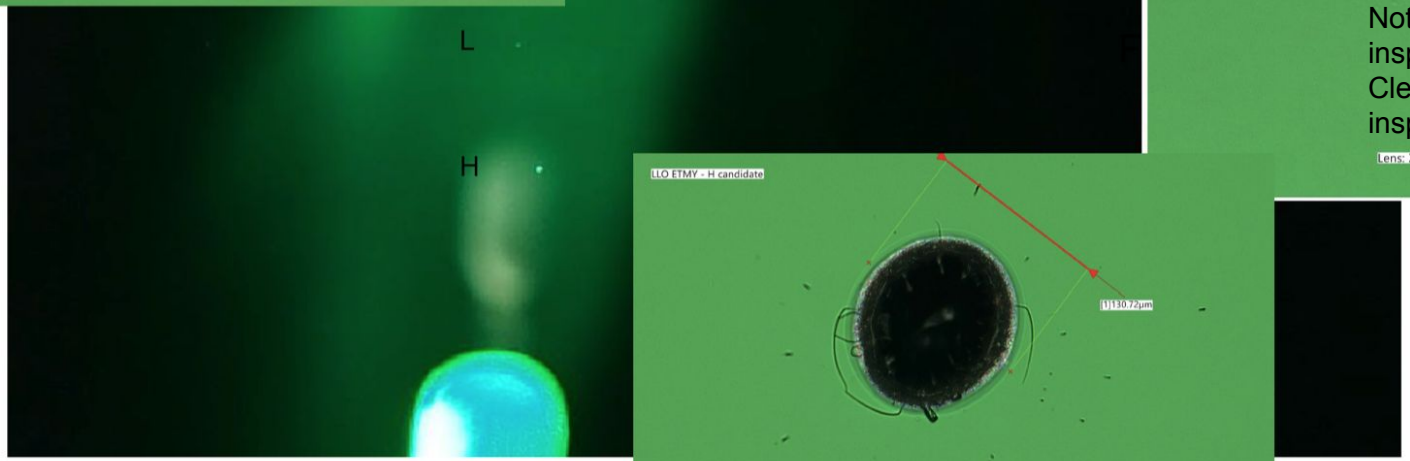
O2 LHO ITMx local absorption map

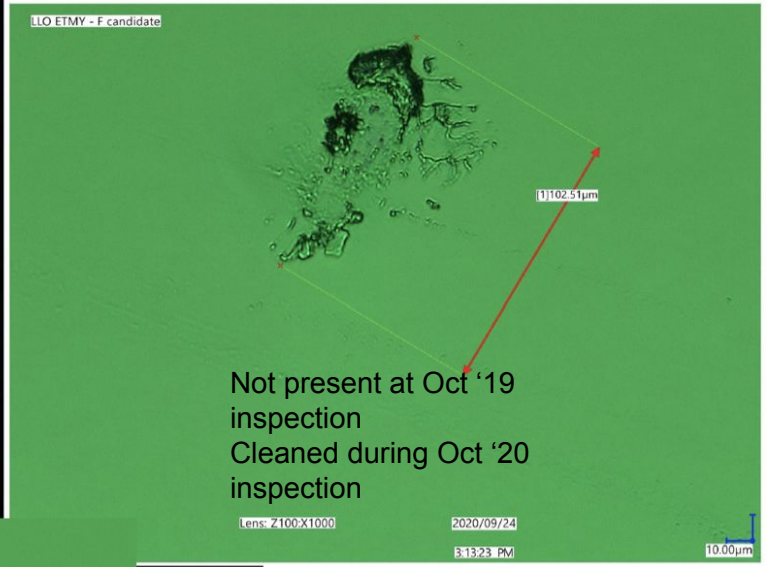






Not present at Oct ‘19 inspection
Never cleaned off



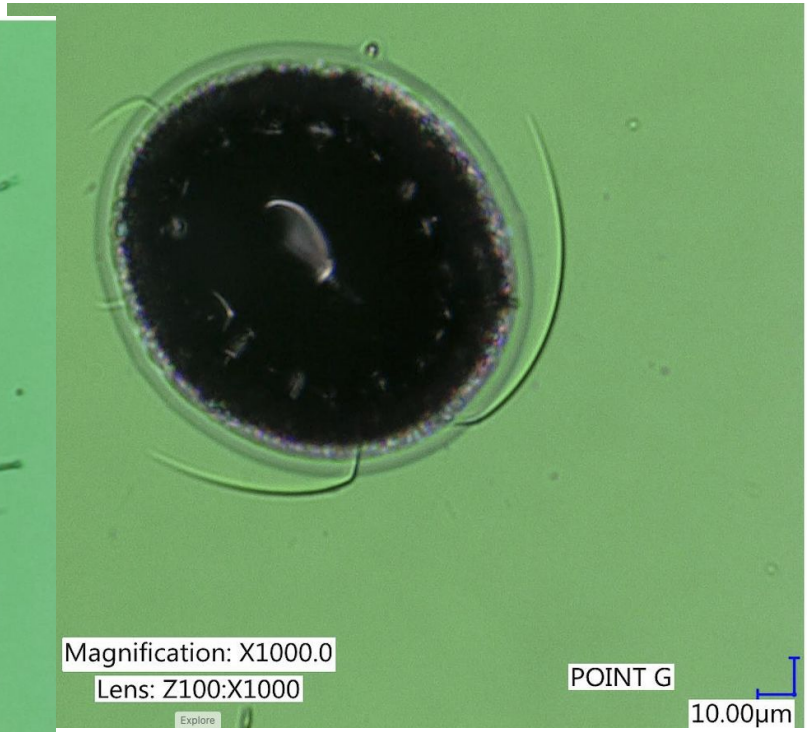


Not present at Oct ‘19 inspection
Cleaned during Oct ‘20 inspection

L1 ETMy Alog [Source]

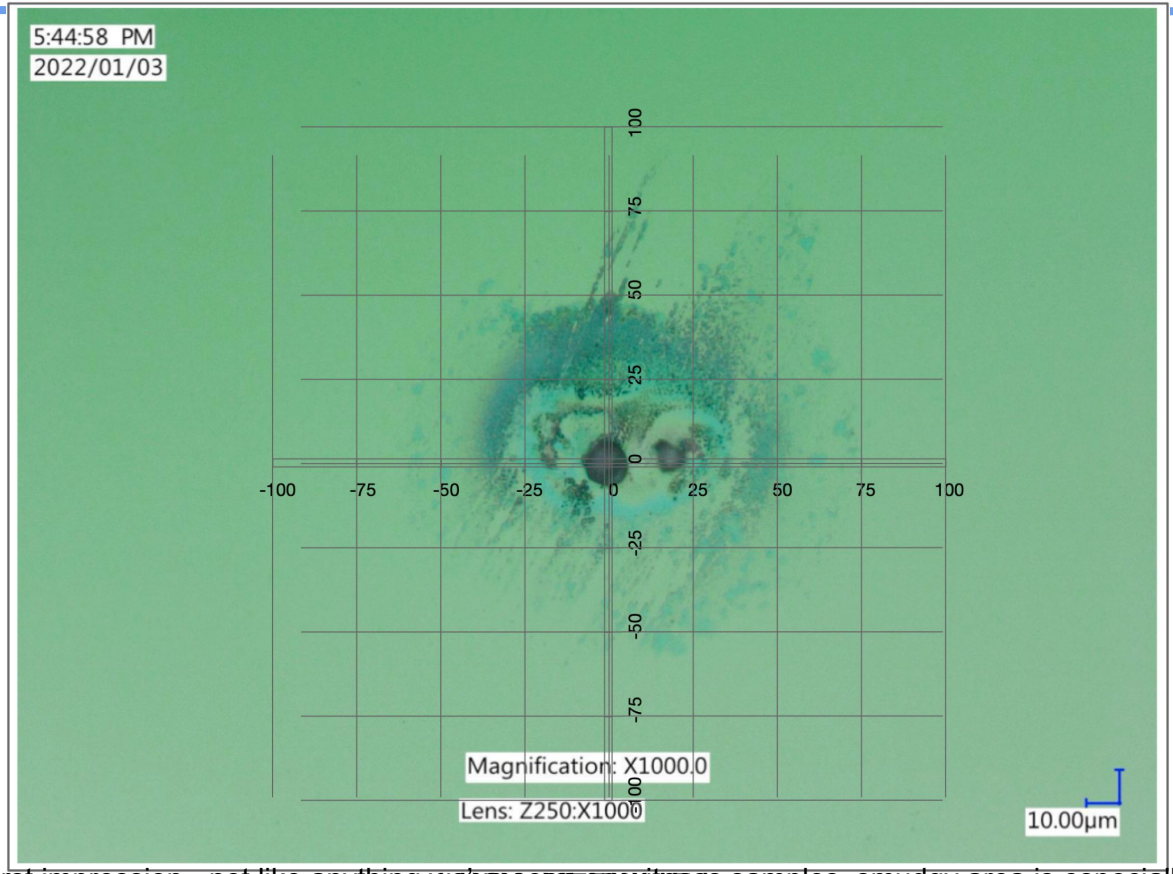
Original absorber candidate found Oct ‘19, “shattered” ~130µm

ETMx inspection October 7, 2019 LLO aLOG 48996, or T1900696



Shattered

LHO O3 ITMY HR Absorber Point-i

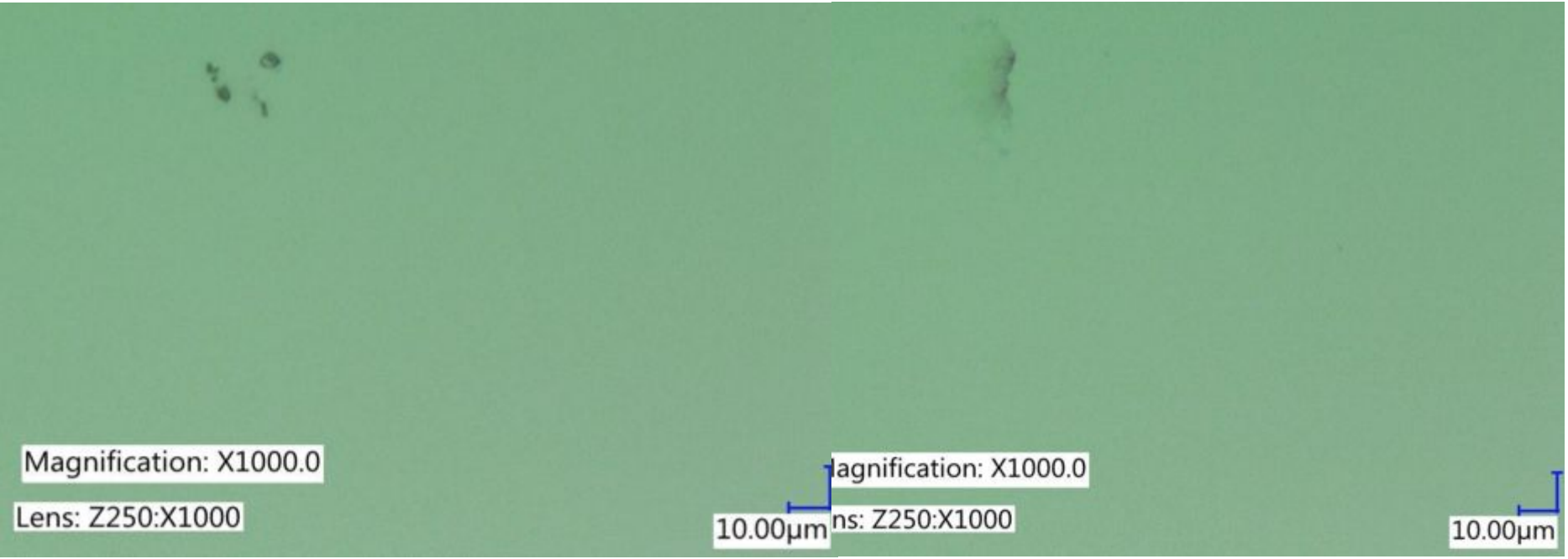


Stephen's first impression - not like anything we've seen on witness samples, smudgy area is especially unusual.

LHO O3 ITMy HR Absorber Points g and f

Point g

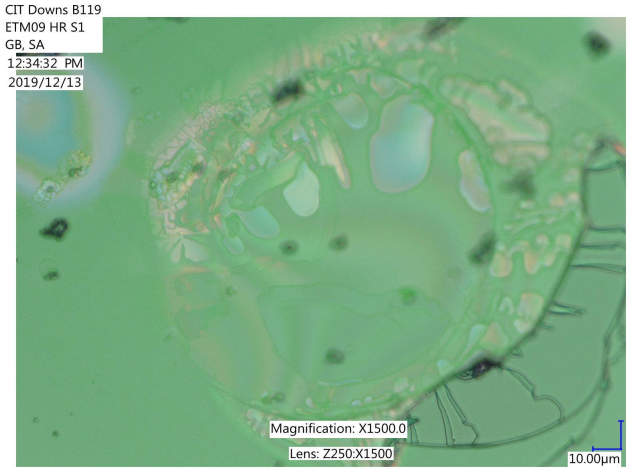
Point f

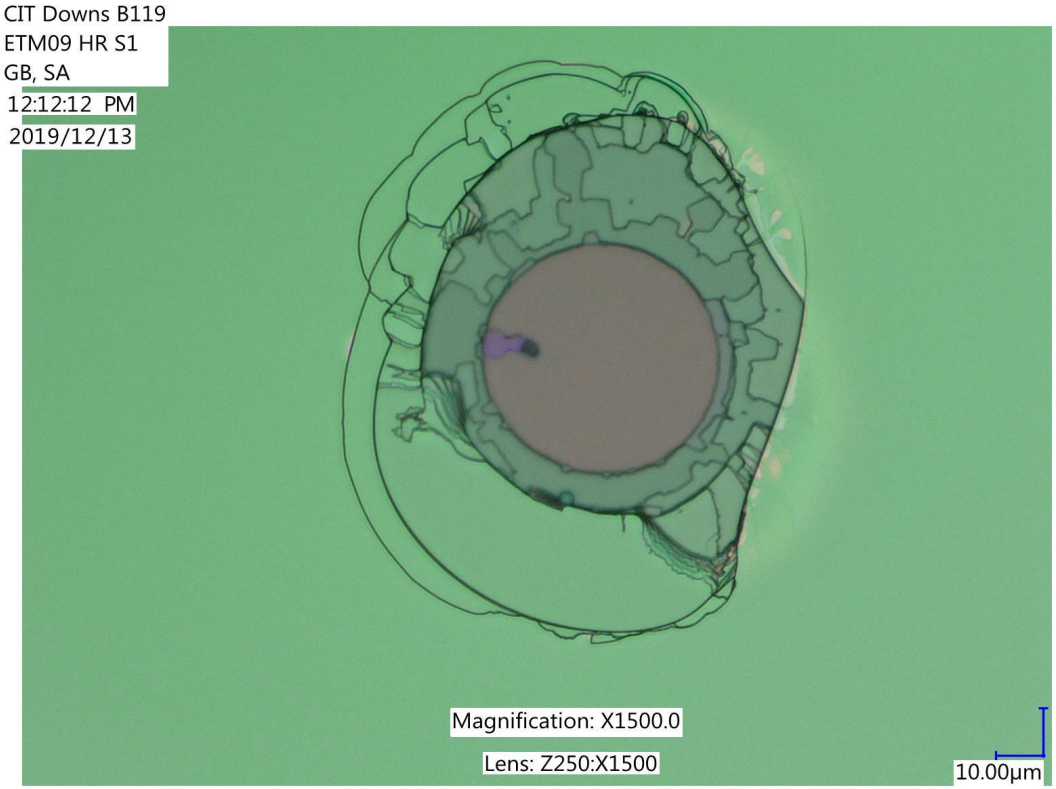


From ETM09 after extraction from LLO-Y

another type of point/bubble, not absorbing

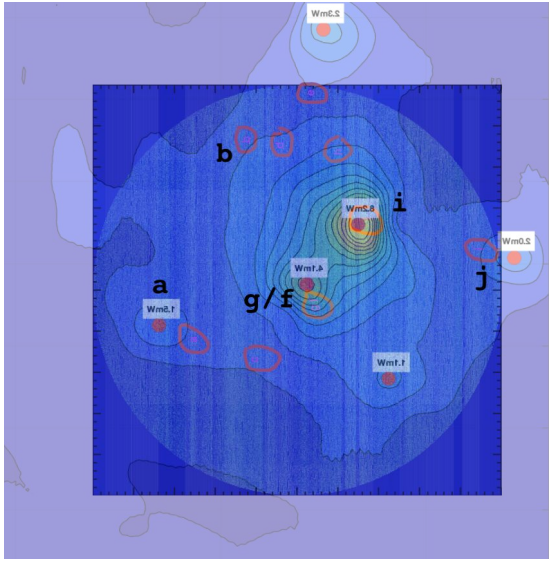
(photographed in lab)





Equivalent point diameters: RTS vs in-situ vs HPAD
LHO O3 ITMY

Point	RTS (μm)*	In-situ LHO (μm)	HPAD (μm)	Visual estimate
i	73 ± 15 μm	31 ± 2 μm	16 - 22μm	50um?
g/f	17.5 ± 4 μm/ 3μm	25 ± 4 μm	5 - 7μm	10um/10um
b	14 ± 3 μm	NA	5 - 7μm	10um
a	7.3 ± 1.5 μm	40 ± 18 μm	NA	5um
j	3.4 ± 0.7μm	27 ± 8 μm	NA	3um



*Based upon heating beam diameter of 300μm see Calibrating thermal lens measurements G2200069 - Brooks

Possible confounding factors:
HPAD (intensity/power, AOI) [wavelength is 1064nm] [ITM11 HR spectrum pg 6.]
Standing wave (ifo) vs. traveling wave (benchtops)
Convection cooling vs. vacuum
IFO beam position uncertainty (especially for features out near edge)

Other Options

Ablation on existing ETMs
Ablation as a backup to newly coated ETMs

Ablation sample annealing to reduce absorption

Feature c partial removal - some metal found in SEM.

Feature i no residual metal found in SEM but possibly some buried under apparent coating blob?

All ablated areas seem to still have features left.

Note that per T2100216 slide 21, we are looking for a factor of 4 to 6 reduction from anneal.

SN1009, Laser Ablation and Annealing Test

ID	Before Ablation (ppm)	After Ablation (ppm)	300C 10hr Annealing (ppm)	400C 10hr Annealing (ppm)	500C 10hr Annealing (ppm)
a	8.8E+04	3.0E+04	2.0E+04	2.2E+04	1.4E+04
c	5.2E+04	1.2E+04	1.5E+04	6.7E+03	4.7E+03
e	2.4E+04	4.2E+04	4.4E+04	2.8E+04	1.5E+04
i	1.9E+04	1.5E+04	1.5E+04	1.2E+04	6.6E+03
#14	3.8E+03	1.3E+04	1.2E+04	8.7E+03	7.1E+03
#35	9.0E+03	7.0E+03	8.2E+03	3.3E+03	1.0E+03

Images and report at E2100395

The State of Ablation Art

SN1009

Cost and Schedule

Schedule 20 weeks

LMA coat/process one - 4 weeks

Measure Figure - 1 week

Measure Scatter - 1 week

Measure Transmission - 1 week

Measure Absorption - 3 weeks

Ship/Bond/Ship - 3 weeks

Install - 7+ weeks

Second optic arrives for installation 5 weeks after the first

ETM Inventory

4 ETMs polished, at LMA ready to coat

ZYGO is under contract to polish 2 more on OPS funding

Zygo is under contract to polish 4 more ETMs on UK funding

Zygo is under contract to polish 2 more ETMs on A+ funding

We hold 2 optics for India (ETM11/ETM14) that have point absorbers found with RTS, also have high scatter (~20 ppm) as measured with an integrating sphere.