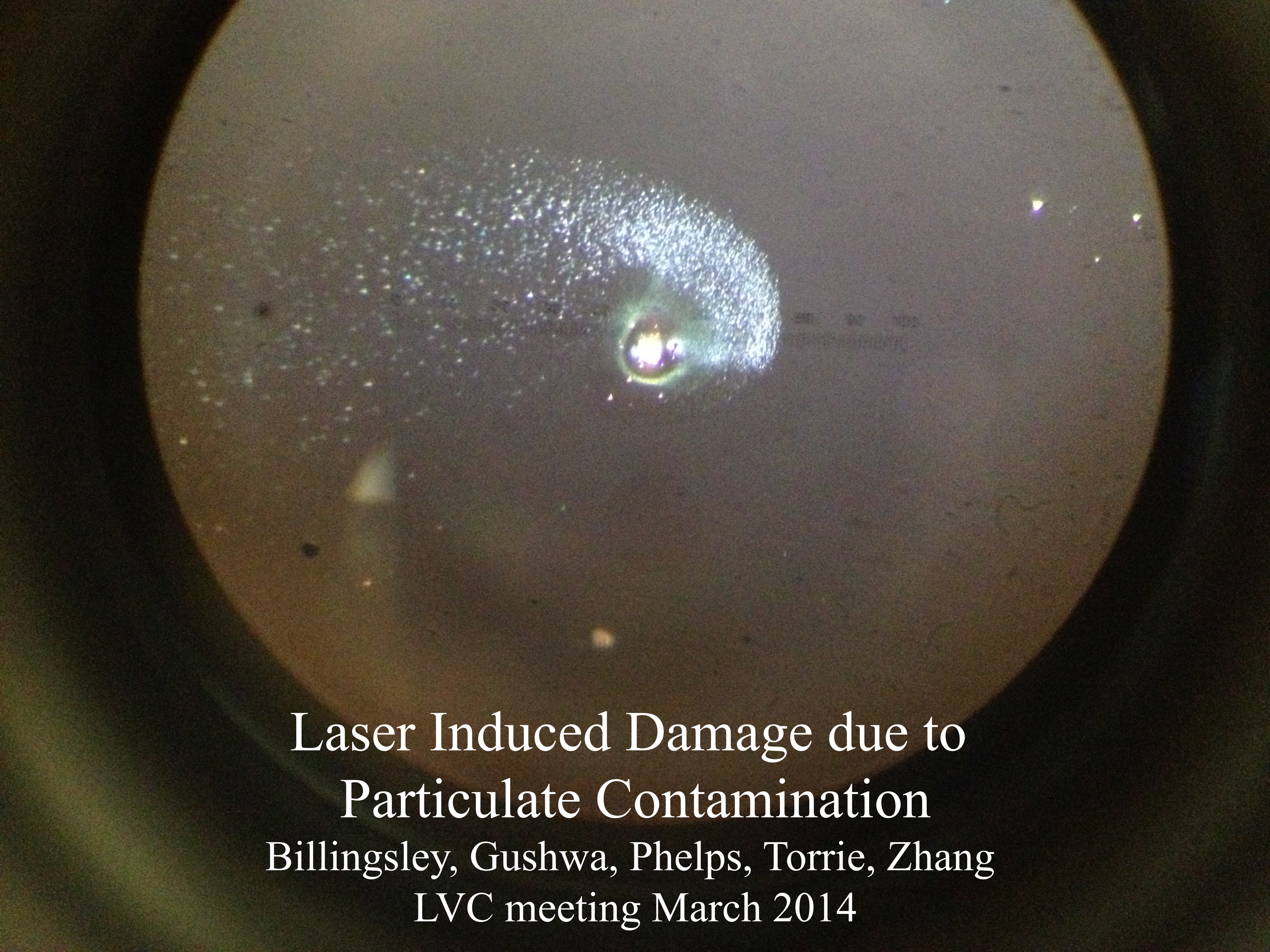
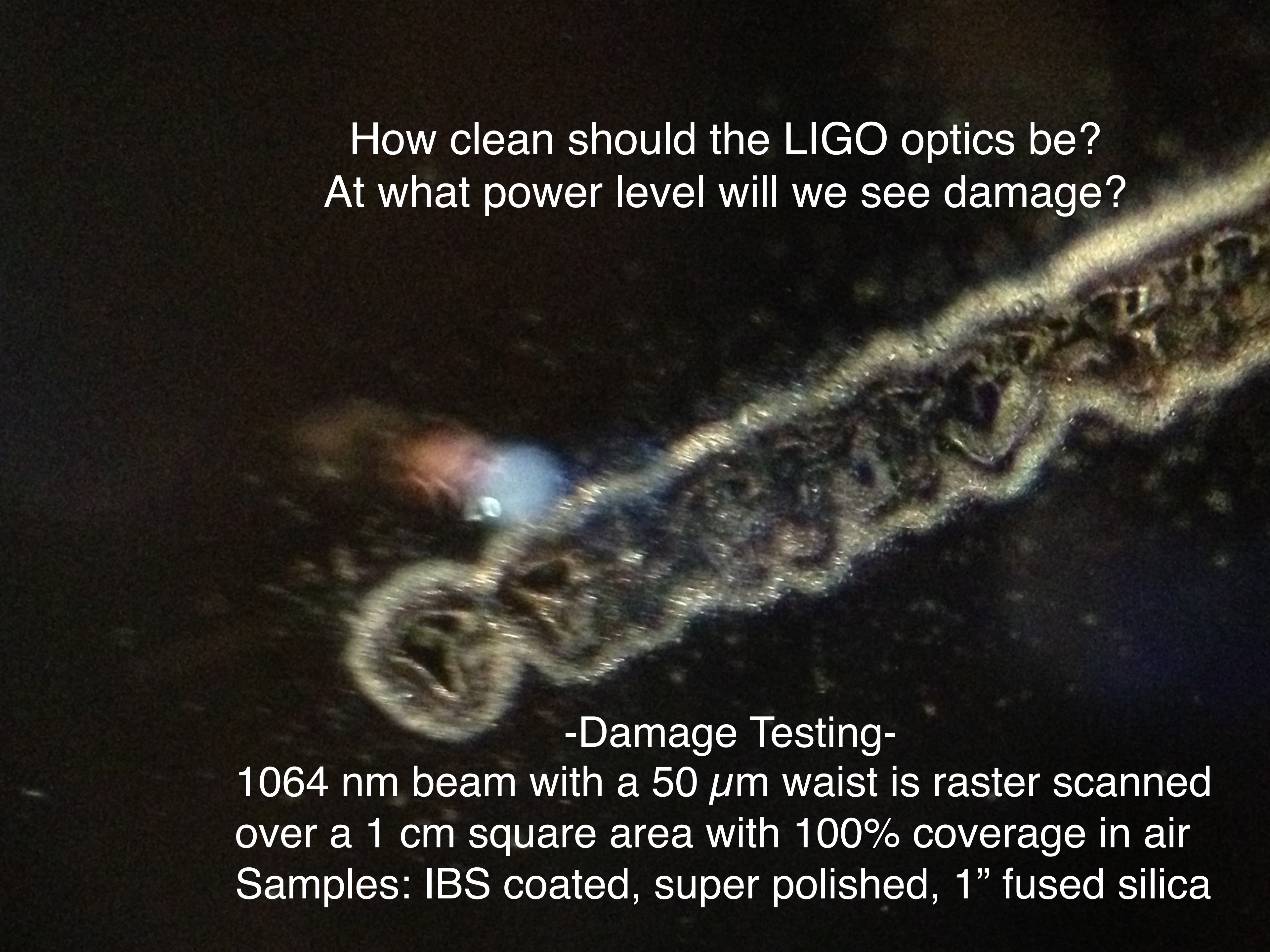


Laser Induced Damage due to Particulate Contamination

Billingsley, Gushwa, Phelps, Torrie, Zhang

LVC meeting March 2014



How clean should the LIGO optics be?
At what power level will we see damage?

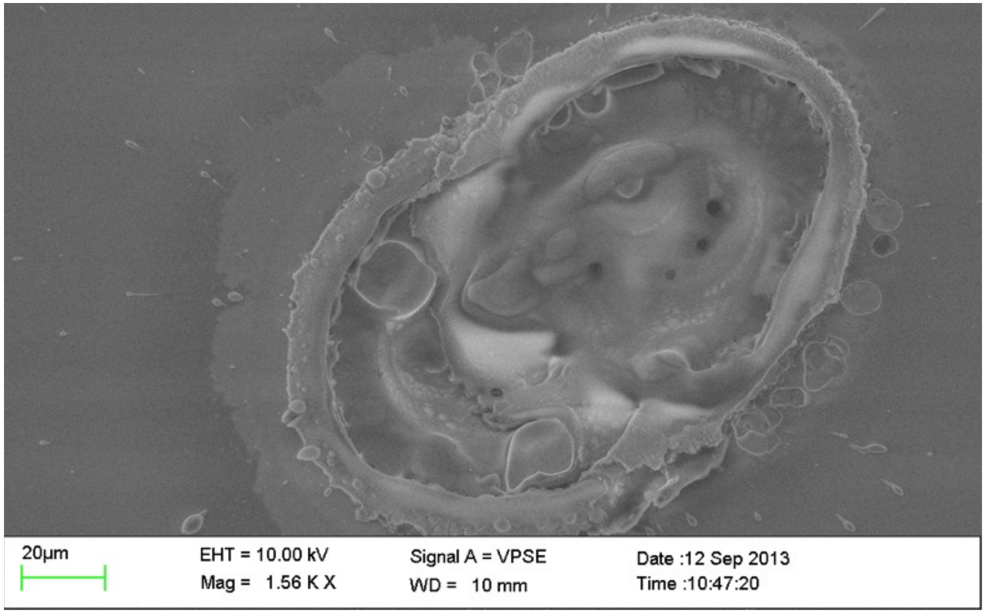
-Damage Testing-

1064 nm beam with a 50 μm waist is raster scanned over a 1 cm square area with 100% coverage in air

Samples: IBS coated, super polished, 1” fused silica

The Pits

- Contamination (dust) melts the coating.
- Onset of this effect at Average ~ 92 W/mm^2
  - » Average power density at full operating power:
    - – Density at the ITM is 96 W/mm^2
    - – Density in the mode cleaner is 2 KW/mm^2



https://services.ligo-wa.caltech.edu/integrationissues/show_bug.cgi?id=198

Observations

- iLIGO – 2 mode cleaner optics have been examined
  - » Pits with center defect surrounded by melted glass dots were found on 1 mode cleaner optic from LLO eLIGO.
  - » The other mode cleaner optic showed a high density of small defects at the center, but no dots surrounded the defects.
- “Safe” level ~ 40 W/mm^2
- Large particles and high power yield bigger pits
  - » Clean room lab dust, blown with ion gun:
    - ~ 240 W/mm2 produces ~100 μm pits
    - ~ 100 W/mm2 produces ~ 2-20 μm pits

Observations 2

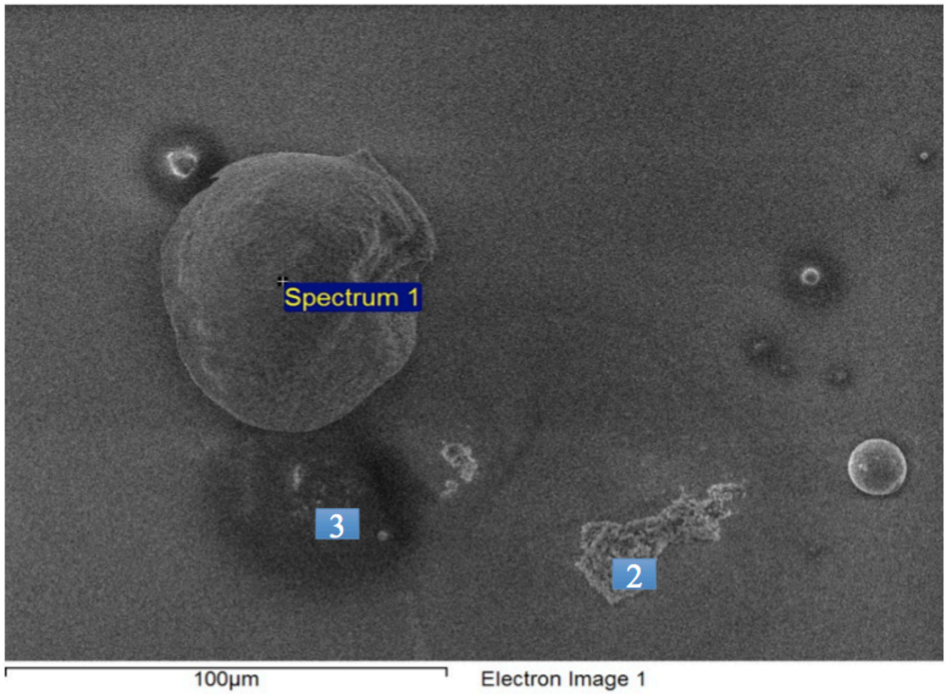
- "Burnt" particles leave a residue that is not always removed by first contact (Plated metals?)
  - » Not all burnt particles cause damage to the optic, some are completely removed by first contact cleaning.
- Ionizing air gun does not remove all particles > 10 μm in size.
  - » Great care must be taken to have a clean air gun system find ion gun reference LIGO-T1300687

A sampling of likely materials

Laser Induced Damage Test (LIDT)

- LIGO-T1300584: LIDT Optic: CIT Lab Dust and Top Gun
- LIGO-T1400162: LIDT Optic: Lab Dust and 160Weq
- LIGO-T1400163: LIDT Optic: FC Clean and Combination Dust
- LIGO-T1400164: LIDT Optic: 5um Al Dust
- LIGO-T1400165: LIDT Optic: 30um Al Dust
- LIGO-T1400166: LIDT Optic: Al Part Dust
- LIGO-T1400167: LIDT Optic: Cu Part Dust
- LIGO-T1400168: LIDT Optic: Ag Part Dust
- LIGO-T1400169: LIDT Optic: SSTL Part Dust
- LIGO-T1400170: LIDT Optic: C3 and cleanroom wipe fibers
- LIGO-T1400171: LIDT Optic: Cleanroom Glove
- LIGO-T1400174: LIDT Optic: Lab Dust and Top Gun
- LIGO-T1400175: LIDT Optic: Top Gun Debris

1 of 30 images at T1300933



SOI 19

1:Element	Weight%
C	5.3
Na	1.05
Al	3.67
Si	16.56
Ti	22.06
O	51.36

2:Element	Weight%
C	12.7
Al	2.11
Si	13.24
Ti	10.86
Ho*	2.68
O	58.42

3:Element	Weight%
C	7.11
Ta	60.57
O	32.33

Material/Features:

- * Holmium is a false positive, its seeing the Tantala in coating.
- 1: Aluminum (and coating)
- 2: Trace Aluminum (and coating).
- 3: Pit into optic's coating.

A start on Theory

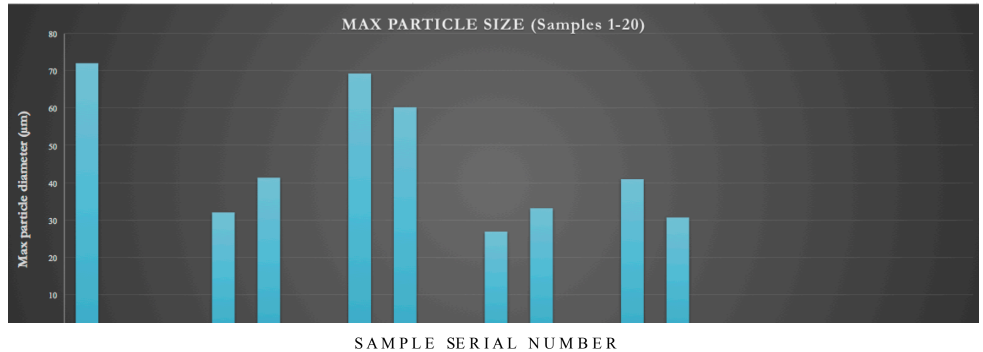
- 10 μm particles and larger are likely to cause damage according to a currently un-archived calculation by E. Gustafson. The damage calculation depends on assumptions of radiative or conductive heat transfer

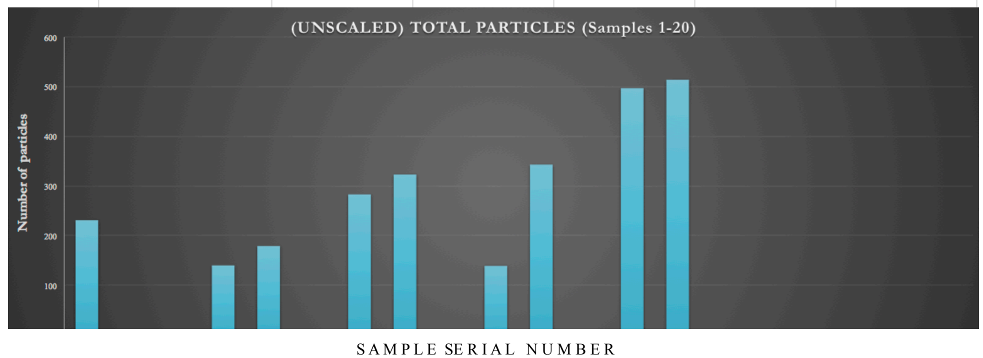
- T1300933 – particle zoo ~ irradiated at 88 W/mm^2
  - » A rich resource for someone interested in modeling this process!

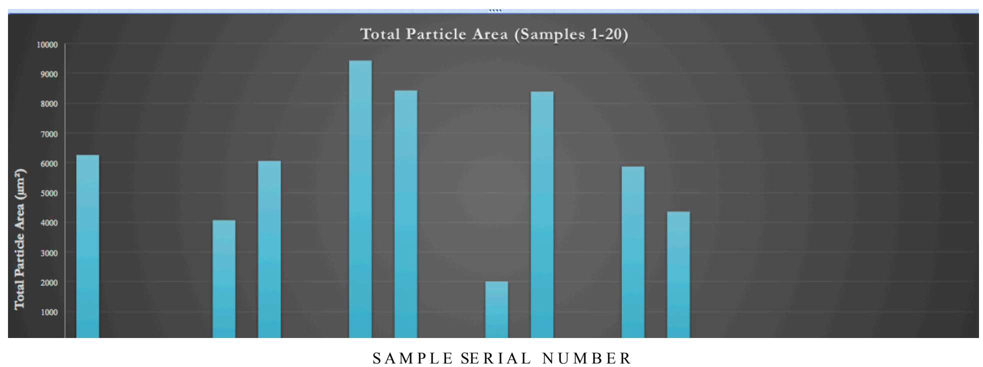
Data base of 1” optics placed in LIGO vacuum chambers

Statistics: LIGO-T1300987

- Initial scan
- Irradiation at 400 W/mm^2
- Post irradiation scan
- First Contact cleaning
- Final Scan



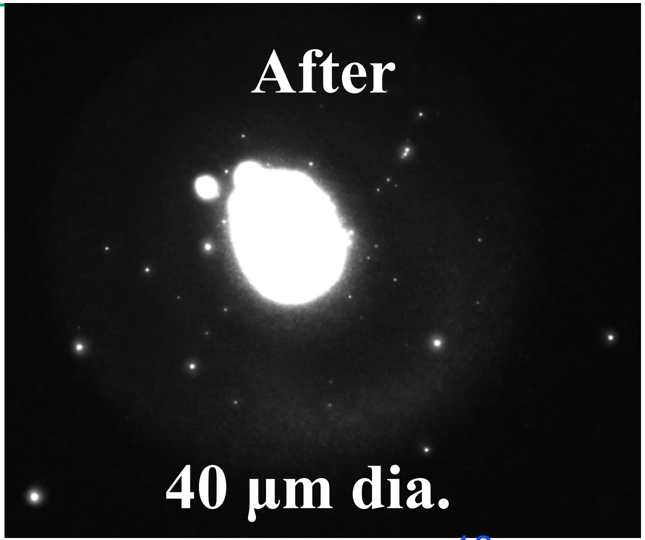




Damage on 1" Optic

- Placed vertically near PR3 at LLO
- Saw 1 cycle + work
- Irradiated 5 mm x 5 mm area at ~400 W/mm^2
- Only 3 particles in 20 – 25 µm dia. range in image scan area (12.8 mm x 12.9 mm)
- Makeup of particle – probably SSTL based on size and shape. Refer to LIGO-E1300147-v12
- Refer to LIGO-T1300851-v2 and LIGO-T1300987-v5

	Initial Scan	Post Irradiation
Min Diameter (µm)	1.0	1.0
Max Diameter (µm)	32.0	41.4
Total Particles	140	179
PCL	207	244
Total Particle Area (µm²)	4,069	6,060
Percent Area Coverage	0.002%	0.004%
Parts per Million	25	37



In Chamber Mitigation

LIGO-G1301249 Contamination Control – Clean as you go!

Tools for testing and reducing the particulate count in vacuum chambers

Progress is quantifiable