Custom polish figure for O4 ETMs

Yamamoto, Billingsley

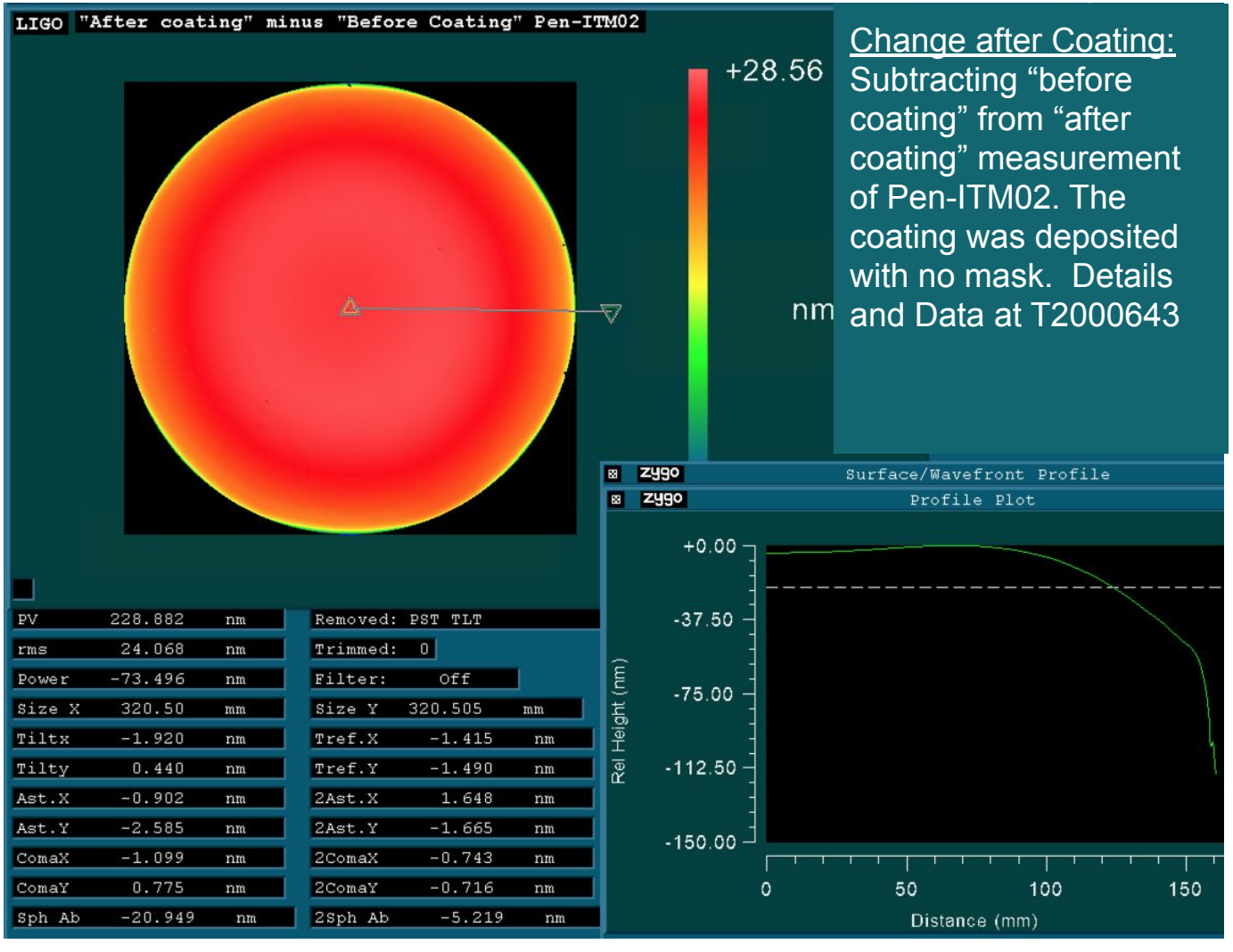
Why a custom figure for ETMs?

- Maximize loss for 7th order mode with minimum impact on round trip losses just in case we still have coating point absorbers. Systems Meeting 9/30/20
    - G2001747 for the study of the best figure for 7th order mode suppression
    - G2001747 pg 22 for the (small) loss penalty we will have in case there are no point absorbers.

Ion Beam Sputtered (IBS) coatings are deposited by placing the optic within a plume of coating material.

aLIGO coatings were deposited in a planetary system using a coating mask that limited the deposition rate in the center of the optic in order to distribute the material evenly. This proved quite difficult to get exactly right.

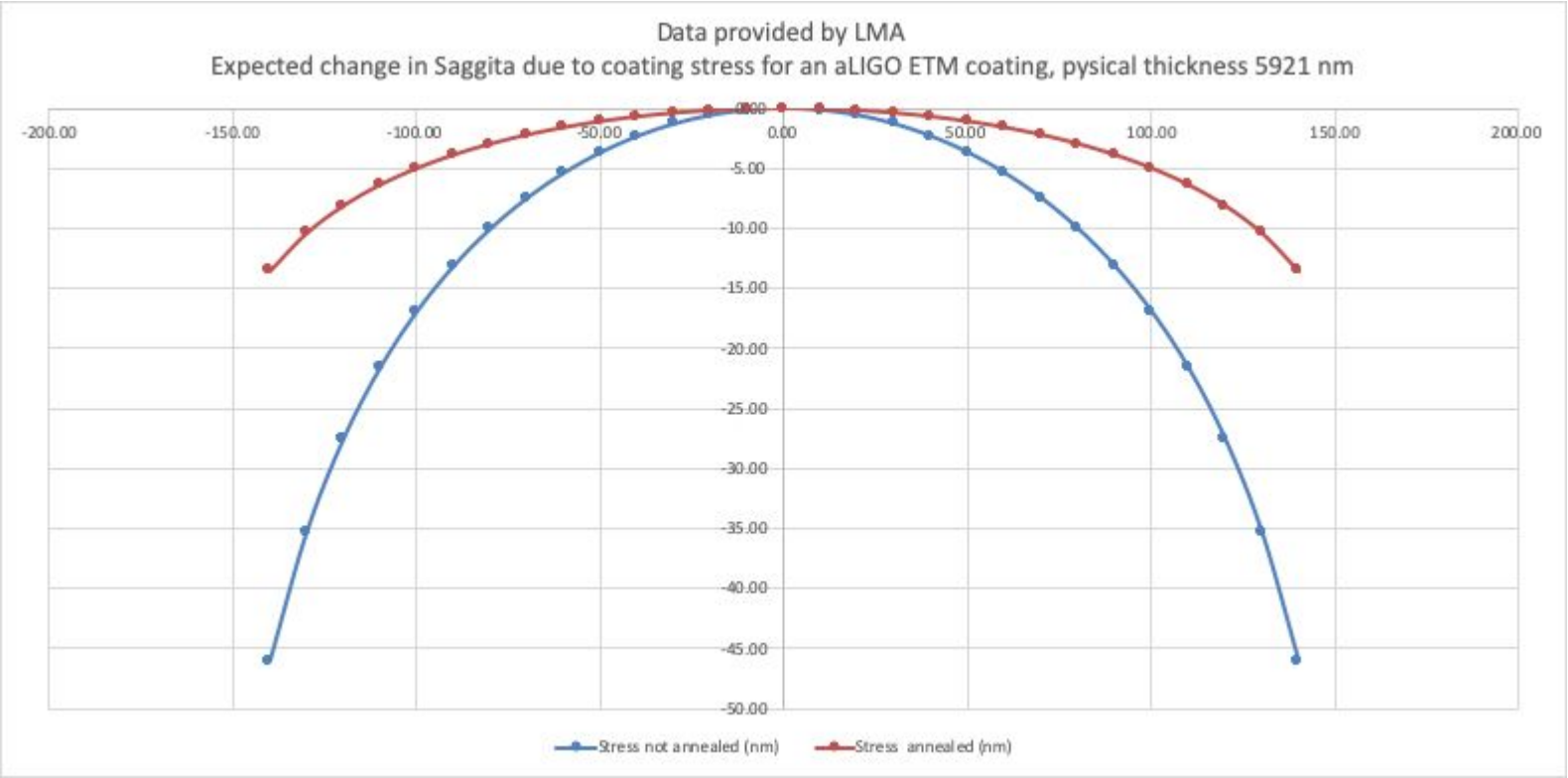
We will use a simple turntable movement for coating deposition.



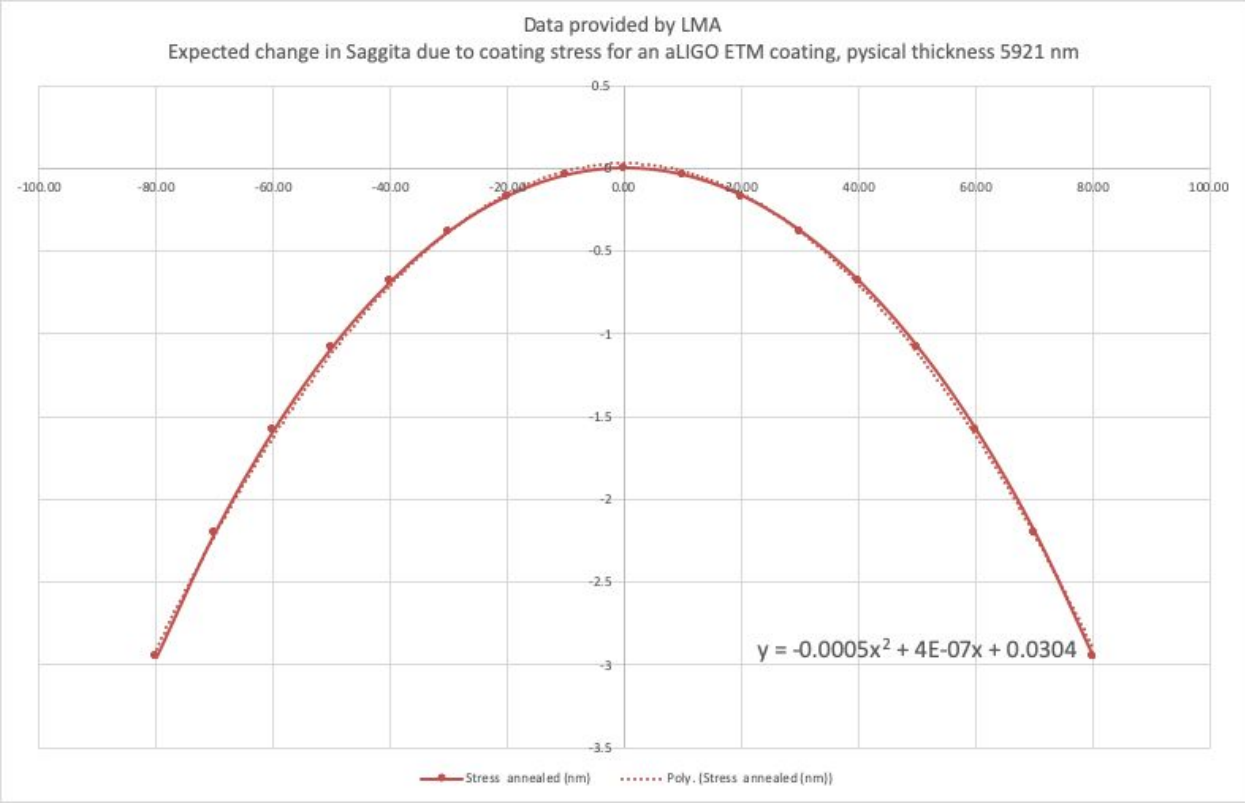
Causes of change in figure after coating

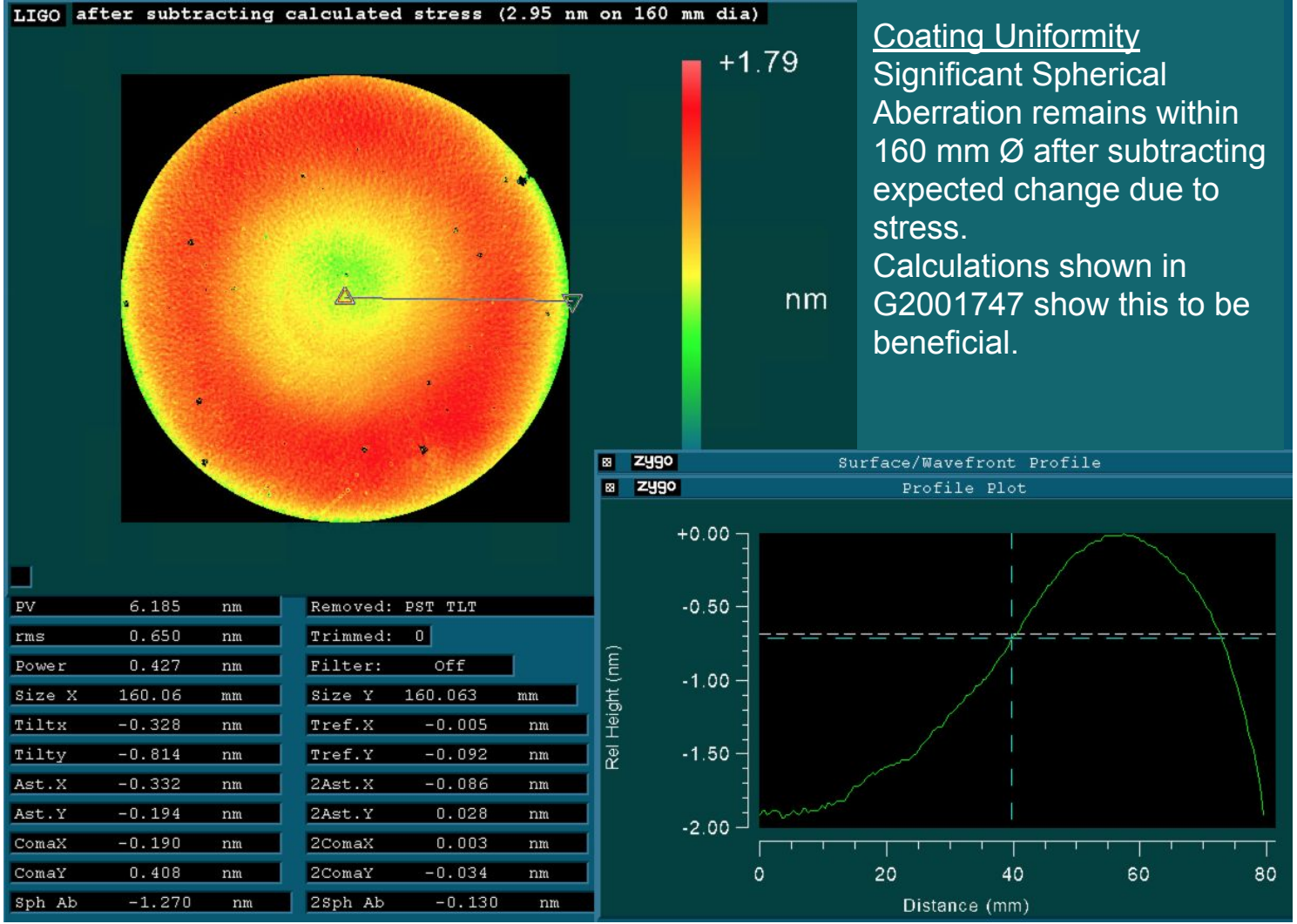
- Compressive coating stress flattens the substrate
- Coating uniformity
- Substrate deformation

Expected deformation due to coating stress LIGO-C2000282



Second order fit to stress prediction is good over the center 160 mm Ø
Saggita is -2.95 nm on 160 mm Ø - equivalent to ~5 m ROC change





Coating Uniformity

Significant Spherical Aberration remains within 160 mm Ø after subtracting expected change due to stress.

Calculations shown in G2001747 show this to be beneficial.

We appear to have a relative uncertainty of ~ 2 meters
Lucky with aLIGO TMs: coating stress/non-uniformity compensate for vendor polish offset

aLIGO Spec 2245 -5, +10 m

T2000644 **All analysis on 160 mm diameter**	**SN**	Uncoated ROC, Polish Vendor (m)	Uncoated ROC, LIGO (m)	∂ ROC LIGO-polish vendor (m)	After Coating ROC, LIGO (m)
mask 1	**ETM07**	2250.8			2240
mask 1	**ETM08**	2249.3			2242
mask 1	**ETM09**	2250.8			2242
mask 1	**ETM12**	2249.0	2246.6	-2.4	2239
mask 2	**ETM11**	2250.6	2248.8	-1.8	2250
mask 2	**ETM14**	2251.0	2248.9	-2.1	2251
mask 3	**ETM10**	2250.1			2248
mask 3	**ETM13**	2249.7	2247.6	-2.1	2244
mask 3	**ETM15**	2249.9	2247.2	-2.7	2245
mask 3	**ETM16**	2249.6	2247.5	-2.1	2247
no mask	**PEN-ITM02**	2498			2491

Each coating mask adds a characteristic amount of power?

T2000644 **All analysis on 160 mm diameter**	**SN**	∂ ROC after coating LIGO-Polish vendor (m)	∂ Saggita after coating LIGO-Polish vendor (nm)	∂ Saggita, stress (calculated by B. Sassolas) (nm)	∂ Sag due to coating uniformity?? (nm)
mask 1	**ETM07**	-11.14	7.1	-2.95	10.0
mask 1	**ETM08**	-7.74	4.9	-2.95	7.9
mask 1	**ETM09**	-8.42	5.3	-2.95	8.3
mask 1	**ETM12**	-10.1	6.4	-2.95	9.4
mask 2	**ETM11**	-0.6	0.4	-2.95	3.3
mask 2	**ETM14**	-0.04	0.0	-2.95	3.0
mask 3	**ETM10**	-2.43	1.5	-2.95	4.5
mask 3	**ETM13**	-5.54	3.5	-2.95	6.5
mask 3	**ETM15**	-4.46	2.8	-2.95	5.8
mask 3	**ETM16**	-2.68	1.7	-2.95	4.6
no mask	**PEN-ITM02**	-7	3.6	-2.95	6.5

~ 2 nm spread within mask 1

~ 2 nm spread within mask 3

Suggestions for ROC Specification Change

Change ROC spec from 2245 -5+10 m to → 2240 ± 10 m

Make the ROC tolerance symmetric ± 10 m (was -5 +15)
this fixes vendor response polish all to ROC = 2250 m

Compensate for stress change (∂ saggita = -2.95 nm, 160 mmØ) which would flatten the surface by ~5 meters (2240 → 2245)

Expected Results

Consistency should be good to ~ 2 m
Absolute accuracy is unchanged/unknown to better than ± 7 meters
Same measurement system - proof of concept working in our IFO now.

Final Polishing figure

- New Center ROC
  - Symmetric tolerance
  - Accounting for coating stress
- Customized figure - use the coating
  - Outside fall off is beneficial, actual coating uniformity is similar to, or better than, the “idealized” fall of proposed earlier “A” - see LIGO-G2001747
  - Polish the optic to a sphere
  - Use the coating fall off to suppress 7th order modes

Comments from Committee - see responses at G2001747

- Recommendation is to go with spherical polish, plus coating shape B (blue curve on slide 5 of G2001747-v3)
- For this case, what is the eigenfrequency for the 6th & 7th order modes (delta_f from the TEM00 mode)?
- G2001747-v3, slide 32, upper right plot. Is there any understanding why the RTL for the solid purple curve is lower than for the solid red curve for offsets greater than 2.5 cm ? Also why is the RTL for the dashed cyan curve higher than for the solid cyan at zero offset? As the beam is moved, does the absorbed power stay the same, or decrease as it's moved away from the PA?
- Can you comment on the benefit of retaining or removing the slight spherical aberration, induced by the coating, using a custom polish?
- From G2001747-v3 page 32 - Are labels swapped? Cyan with corr is worse than without at center alignment. Also plots on slide 2 - are the axes labels swapped?