LIGO

Losses in LHO HR Surfaces

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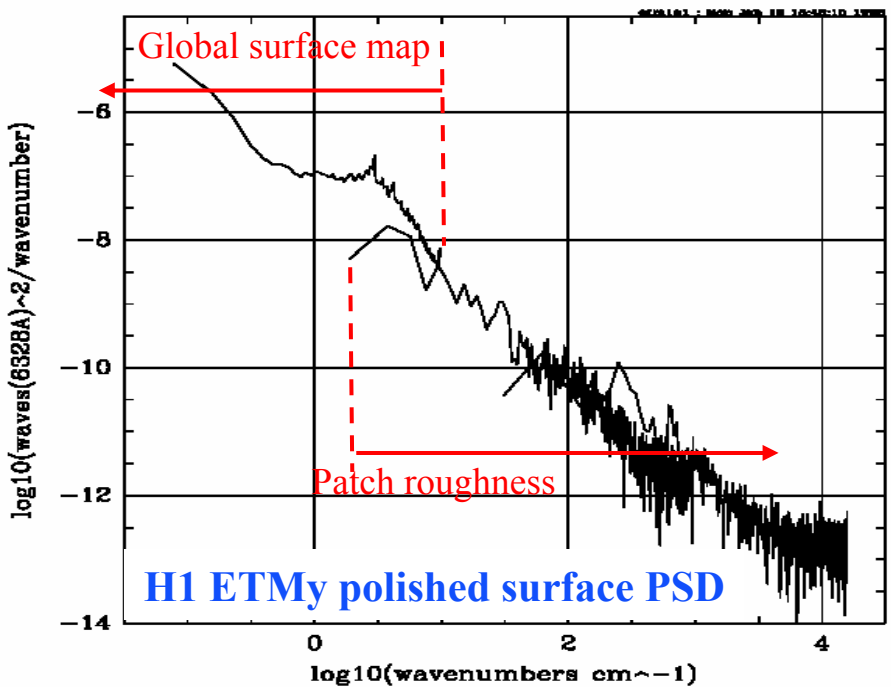
H1: Expectations vs Performance

- Expectations: FFT simulations.
  - » Design era (c '96 → '98). Remarkable agreement with current operations.
  - » "As built" simulations based on bench measurements of actual fabricated optics (c summer '03)

- In Situ measurements (here, fullest story: H1 interferometer)
  - » Scatterometer sampling of in lock beam scatter from HR surfaces.
  - » Arm visibilities (~'00 → culminating 11/02)
  - » Operational performance (recycling gains, contrast defect) (to present).
  - » Comparison with super polished H2 ETMs.
  - » Detailed study of HR surface (Image analysis) "beam spots" (10/03)

Optical Loss Expectations

- SRD ($G_{RC}^{CR} \geq 30$)based on older polish/coating information
- Pathfinder & COC-DRD analysis$\Rightarrow$ slightly better than SRD
  - » Micro roughness σ_{rms} ~.4 -.6 nm$\Rightarrow$ prompt loss ~ $(4\pi\sigma_{rms}/\lambda)^2$ = 30 ppm
  - » "Calflat" aberration maps contributed substantially to G_{RC} limit.
- "As built" fabrication proved substantially better:
  - » Micro roughness σ_{rms} <0.28 nm
  - » prompt loss ~$(4\pi\sigma_{rms}/\lambda)^2$ <10 ppm
  - » Super polished substrates 2 - 3x lower σ_{rms}



"As built" FFT Simulation

- FFT simulation of H1 with *no free parameters*:
  - "Cold" state: no thermal lens (little effect on CR light)
  - G_{RC}^{CR} ~ 92 (observed ~ 41)
- FFT uses *measured* distortion maps,all HR interfaces
  - minor effect on FFT G_{RC}^{CR}
  - ~13% for full as built simulation. Negligible for loss matched case.
  - Consistent with very good ifo contrast defect
    - 6 10^{-4} for H1
    - 3 10^{-5} for L1
- Other in situ observations (e.g H1 arm visibilities) are consistent with arm loss needed to "match" observed G_{RC}^{CR}

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In Situ Optics Performance

- G_{RC}^{CR} ~41, which is:
  - » Consistent with measured arm visibilities
  - » Consistent with total arm loss dominated by prompt scatter.
  - » Scatterometer data extrapolated to absolute loss

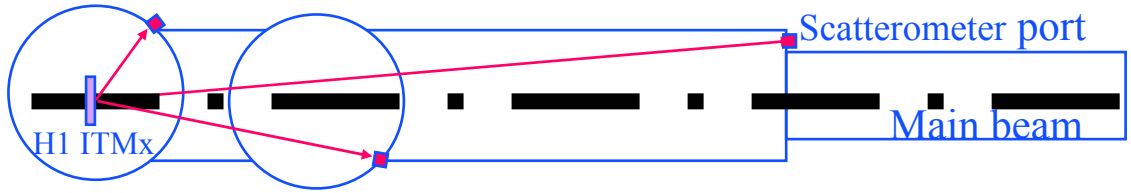
Replaced ITM

CAVITY	V	T_{ITM}	$T_{WITNESS}$	Scatter
2k X	.0222	.0277	.0283	0.85
2k Y	.0211	.0272	.0281	7
4k X	.0241	.0279	.0275	7.5
4k Y	.0214	.0263	.028	8.8

  - » Consistent with lower than anticipated contrast defect (and small FFT dependence on maps)

Scatterometer studies

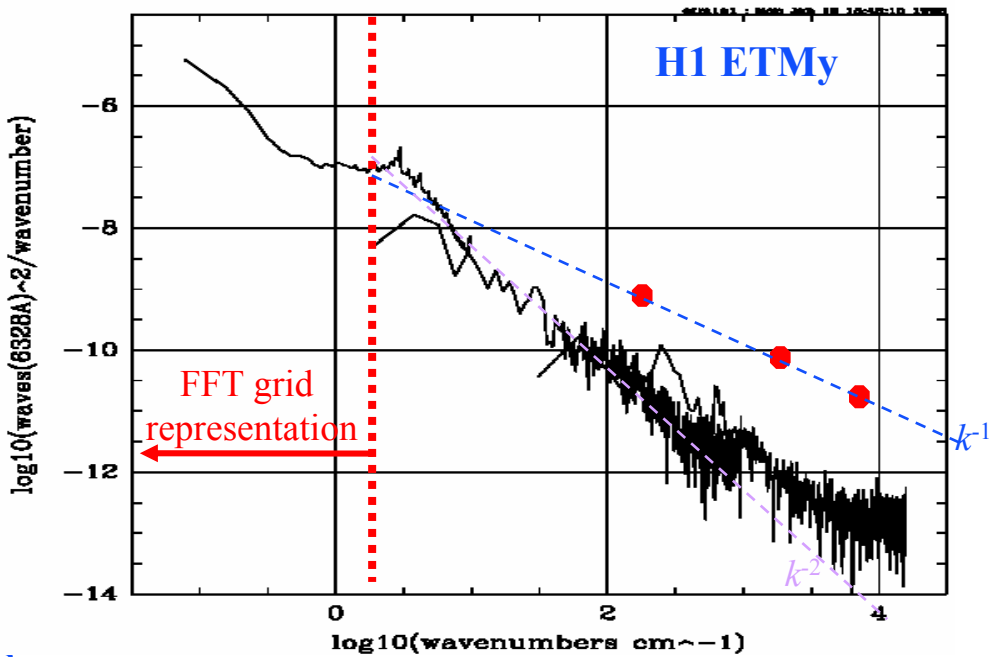
- Some (H1) HR surfaces viewable @ 3 angles:



» Rough integral loss estimate for FFT input: 68ppm "base loss"

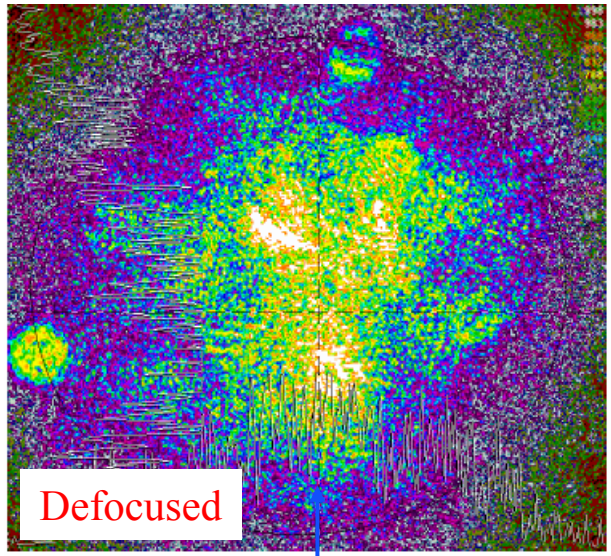
» Angular dependence more "point like".

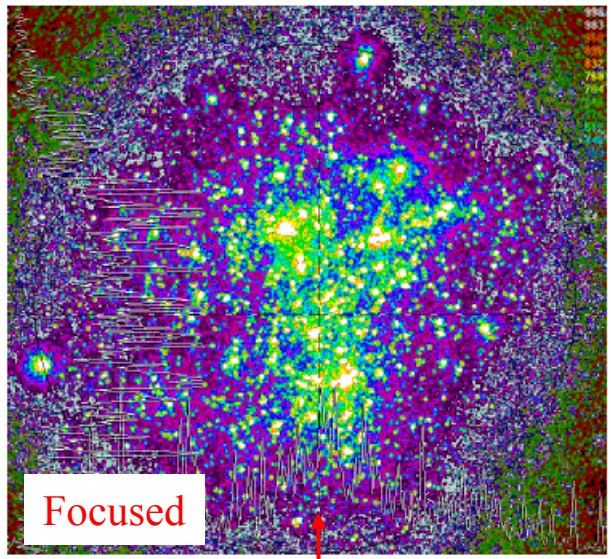
» More accurate ***comparison*** measurement of 2k ETMs (GO super polished) to 2k ITMs, 4kETMs (not super polished): no significant difference

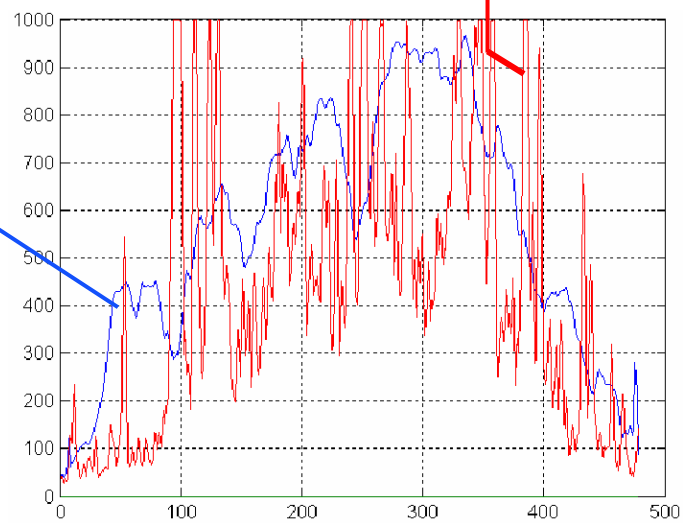


Analysis of the "Globular Cluster"

- Cleanest point scatter image: 2k ETMy:
  - » Grab video stills for detailed analysis:







- ➢ This point defect background ~same for all optics.
- ➢ Diffuse (micro roughness) background contributes < 1/3 of total scatter.
- ➢ Other blemishes don't dominate total (?)
- ➢ Puzzle: Why these point defects missed in Lab. QA?

Conclusions, Direction

- LIGO I optical performance meets design.
- "As built" expectations far exceeded design.
  - » Can be of significant concern for Advanced LIGO, which has initially assumed at least duplicating "as built" performance

- Design OTF tests to understand anomalous scatter:
  - "Frozen" in the coatings ?
  - Surface contamination (~ common to all installed optics !)
  - Also apparent cleaning streaks/defects: significant in terms of loss?