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Advanced LIGO Test Mass Material Selection Status

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LSC

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Downselect – not a word

From Merriam Webster Online……

Suggestions for downselect:

1. downscaled
2. downscales
3. downscale
4. down-easter
5. downstater
6. down-at-heels
7. down-market
8. dulnesses
9. dullnesses
10. doodley-squat

Downselect: Choosing a Test Mass Material

- Committee
  - » David Shoemaker (chair), Jordan Camp, Marty Fejer, Sam Finn, Peter Fritschel, Jim Hough, Peter Saulson, Phil Willems
    - – Input from the COC working group
- Committee objective
  - » Actively direct and support research needed to make a sufficiently informed decision regarding test mass material selection
    - – Figure of Merit – maximize BNS inspiral range?
    - – Trade against cost and complexity in the final analysis?
- Tools
  - » Issues described in the “downselect document”
    - – http://www.ligo.caltech.edu/~gari/LIGOII/Downselect/T020103-05.pdf
  - » Links to back up material at
    - – http://www.ligo.caltech.edu/~gari/LIGOII/Downselect/index.htm

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Background

- Sapphire – Advanced LIGO baseline test mass
  - » Greater Astronomical reach (?)
  - » Thermal characteristics
  - » Mechanical properties
- Fused silica – fall back TM material
  - » Extensive body of knowledge about FS
  - » Large, optical quality sapphire is not yet an “off the shelf” item

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Sapphire - Baseline Status

- Five experimental growth runs Crystal Systems
  - » Two of five 15” boules are considered good optical quality
  - » Two of five are not
  - » LIGO has bought one “good” and one “not” to test for use as transmissive and non-transmissive test masses
    - – Plan to measure absorption, scatter, homogeneity, Q
- Shanghai Institute of Optics and Fine Mechanics
  - » Furnace is in place
  - » No large pieces yet
- Rubicon
  - » Just received 150 mm piece for optical testing, 10 cubes for absorption tests to arrive soon

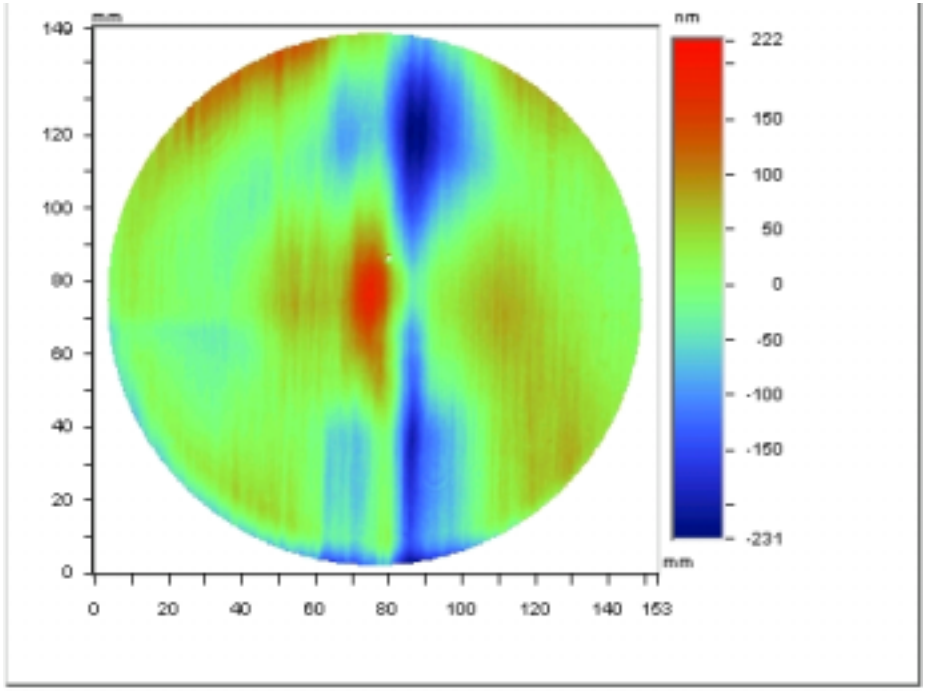
Sapphire optical properties Polishing

- CSIRO and Wave Precision have good results
  - » Microroughness to ~ 1Å
  - » CSIRO better figure (better metrology)

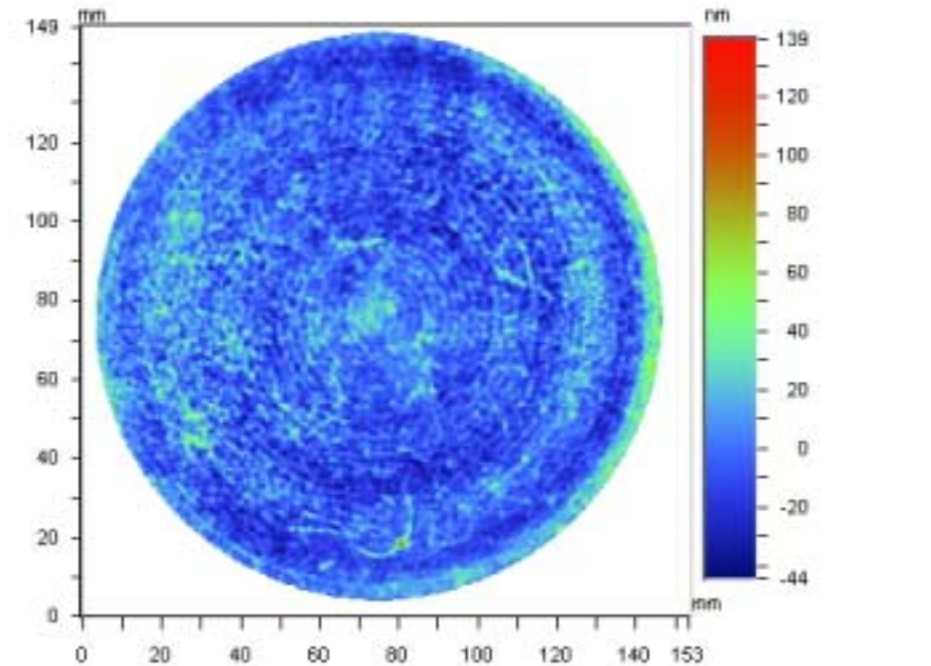
More at http://www.ligo.caltech.edu/~gari/sysmtg.html

Sapphire optical properties Homogeneity

- Compensation studies
  - » CSIRO
    - – Fluid jet polishing
    - – Compensating coating deposition
    - – Ion beam etch
  - » Goodrich
    - – Computer controlled polishing



Homogeneity after Compensating polish at Goodrich



Date: 04/16/2002
Time: 14:37:03
Wavelength: 1.064 um
Pupil: 100.0 %
PV: 183.6397 nm
RMS: 14.6141 nm

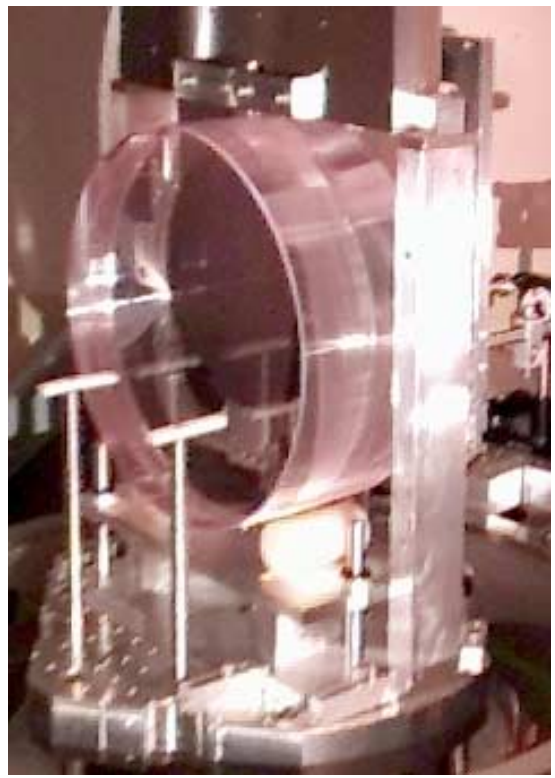
X Center: 282.00
Y Center: 243.00
Radius: 269.89 pix
Terms: Tilt
Filters: None
Masks: Detector Mask

Sapphire optical properties Absorption

- Absorption reduction studied at Stanford (Route, Fejer, et. al.)
  - ~10 ppm/cm required in order to obviate thermal compensation
  - Typically 50 ppm/cm in large samples as received
  - Isolated observations at 10 ppm/cm, existence proof
  - Annealing Studies have produced 20 – 30 ppm/cm to date
- 50 ppm material still useable with active thermal compensation
  - Lower absorption is easier; especially if there is spatial variation
  - Dave Ottaway taking over from Ryan Lawrence at MIT
  - Full cavity experiment at Gin Gin, Western Australia
- Spatial variation? -Measure full size boule at Lyon 3-03
  - Thermal compensation approach depends on these results
    - http://www.ligo.caltech.edu/docs/G/G020502-00.pdf

Sapphire mechanical properties Q

- Q measurement by Phil Willems
  - » Two 314 mm x 130 mm boules measured
  - » Highest Q ~ 260×10^6 radial antisymmetric mode
  - » Lowest Q ~ 28×10^6
- Similar for “good” and “not” substrates
  - » Slightly better for “not!”



Fused silica
A better choice???

- Higher Q in FS → performance ≈ sapphire (Harry)
  - » Best choice for TM material may depend on available coating technology
- Fused Silica surface loss investigations (Penn)
  - » Highest modal Q of a fused silica sample observed to date is approximately 200 million (Syracuse)
  - » Surface loss limit for full size fused silica predicts Q ~ 4×10^9
  - » presume the bulk loss will dominate at some lower value

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Reducing fused Silica surface loss

- Flame polish
  - » Proven to improve Q
  - » Probably will not maintain optical surface quality
- Annealing
  - » Proven to improve Q on FS rod
  - » Significant undertaking for large optics
  - » Not clear what happens to optical surface
- Ion etch
  - » Not tried for Q improvement - not proven
  - » Does maintain surface finish
  - » May maintain surface figure

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Questions

- Is BNS inspiral the right FOM?
- Is scatter, absorption good enough in sapphire?
  - » Testing February-June
- Can we realize 200M Q or better in large FS?
- Can we lower coating losses enough to realize the full potential of either material?
  - » 10x reduction for sapphire
  - » 20x reduction for fused silica

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Timeline

- July 2003 decision needed to maintain LASTI schedule
  - » Ideally resolve coating process first, probably not realistic
  - » Decision needed to allow Suspension design to proceed
- Delivery of first two large sapphire substrates Feb ‘03
  - » Measurements through June ’03
- Need to understand limits on FS Q in this timeframe
  - » substantial progress on large substrates
- Should be able to recommend material selection at next LSC meeting