Sapphire Development Program

Jordan Camp

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LIGO-G960000-00-M

LIGO-G000142-00-D

Sapphire Optics for LIGO II

- Low Internal Thermal Noise
  - ›› $Q \sim 4 \times 10^8$
  - ›› Photoeleastic damping lower limit to low frequency noise (factor ~5 below fused silica)
- Increased Density
  - ›› reduced radiation pressure noise
- Optical performance must satisfy LIGO II requirements
  - ›› $G_{rc} = 100$
  - ›› Arm cavity stored power = 700 kW

Sapphire Development in 2000

- Measure optical and mechanical properties of small sapphire samples
  - Q
  - optical homogeneity
  - ability to polish
  - absorption
  - birefringence of coatings
- Feed back information to Crystal Systems to grow full size pieces for 2001
- An LSC effort: Caltech, Stanford, Glasgow, Syracuse

Q and Loss Measurements

- Measure Q's > 10^8 for a variety of sapphire pieces
  - effect of polish
  - effect of coating, attachments
- Cross check measurements with different groups
  - Caltech, Stanford, Glasgow
- Anelastic low frequency loss studies at Syracuse
  - few x 10^{-7} loss measurement now
  - development proceeding to loss levels of interest for sapphire
  - effect of coating, surface loss

Polish and Optical Homogeneity

- LIGO II recycling gain ~ 100 requires:
  - optics surface figure 1 nm rms
  - microroughness 0.1 nm rms
  - bulk homogeneity 10 nm rms
    - requires compensating polish of back surface
- Polish tests
  - CSIRO
  - General Optics
  - metrology supported by Caltech Fizeau interferometer

Absorption

- Nominal sapphire absorption 40 ppm / cm

  ›› requires factor 30 reduction in bulk distortion through adaptive thermal compensation

  ›› absorption possibly due to Ti impurities

- Program to identify and eliminate sources of absorption

  ›› Stanford Photothermal Common-Path Interferometer

  ›› examine samples from different sapphire starting materials, locations in boule, annealing processes, etc.

Coating Birefringence

- LIGO II requirement: reflected phase shift difference between orthogonal polarizations < 10^{-3} rad
- Measure by probing resonant cavity with transmitted side-band as function of input polarization
- Determine if m-axis sapphire optics are practical
  - c-axis sapphire requires double-size boule

Schedule of Tests

Sapphire Development Tests for 2000

#	Axis	Size	Test	Dates	Place
1	m	15 cm ϕ x 8 cm	Optical Homogeneity and Surface Figure Q	April - June July - Aug	CSIRO Caltech, Stanford
1	m	15 cm ϕ x 8 cm	Optical Homogeneity and Surface Figure Q	April - June July - Aug	GO Caltech, Stanford
2a	m	25 cm ϕ x 10 cm	Q Surface Figure Coating Stress Birefringence Q	June - July Aug - Sept Oct Nov - Dec	Stanford, Caltech - Caltech Caltech, Stanford
2b	m	7.5 cm ϕ x 3 cm	Coating Stress Birefringence	May	Caltech

Tests (cont.)

#	Axis	Size	Test	Dates	Place
3	m,c	1 cm x 1 cm x 1 cm	Bulk Absorption	Mar - Dec	Stanford
4	m,c	2.5 cm ϕ x 1 cm	Coating Absorption Coating Stress Birefringence	April April	Caltech Caltech
5	m,c	3 cm ϕ x 10 cm	Q and Silicate Bonding	May - Aug	Stanford, Glasgow
6	m,c	13 cm ϕ x 6 cm	Q and Coating	April - Aug	Stanford, Glasgow, Caltech

Thermal Distortion in Input Test Mass

	LIGO I	LIGO II
Optic material	Fused Silica	Sapphire
ITM Radius of Curvature	14 km (44 nm)	20 km (53 nm)
Substrate absorption	5 ppm / cm	40 ppm / cm
Substrate circulating power	100 W	6 kW
ROC with thermal lensing (seen outside arm cavity)	22 km (27 nm)	-3.6 km (-290 nm)
Coating absorption	0.6 ppm	0.6 ppm
Coating incident power	12 kW	700 kW
ROC with thermal expansion (seen inside arm cavity)	14.1 km (44 nm)	25 km (43 nm)

Note 1, Linda Turner, 05/17/00 10:40:55 AM
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