Laser and Optics Advanced R&D

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LIGO II Laser Requirements

- Power: 180 W
- Mode Shape: 90% of light in TEM_{00} mode
- Frequency Noise: 5×10^{2} Hz / sqrt (Hz)
- Intensity Noise: 1×10^{-5} / sqrt (Hz)
- Stability: 1%

Path to 180 W Laser

- MOPA (Master Oscillator Power Amplifier)
  - » under development at Stanford University
  - » 30W TEM_{00} output power achieved using LIGO I laser as MO
  - » investigation of intensity noise at various levels of gain saturation
  - » modeling of thermal management key to advance in power
- Injection Locked Stable - Unstable Resonator
  - » under development at Adelaide University, Australia
  - » 30W unstabilized output power achieved
  - » effort to injection lock resonator continuing

Industrial Vendors

- Markets growing for 100 W class IR laser
  - » laser diode price dropping rapidly
- Letter of Solicitation of Interest sent to 12 laser companies
  - » included 180 W laser specifications document
  - » response from Lightwave Electronics (LIGO I laser builder), TRW
  - » verbal response from Laser Zentrum / Hannover
- Time frame for laser fabrication
  - » industrial R&D in 01
  - » fabrication in 02, integration in LIGO II subsystem in 03

Sapphire Optics for LIGO II

- Low Internal Thermal Noise
  - ›› Q ~ 4 x 10^8
  - ›› Thermoelastic noise 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 <u>LSC</u> 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

Bulk Absorption

- Nominal sapphire absorption 40 ppm / cm
  - ›› requires factor 50 reduction in bulk distortion through adaptive thermal compensation
- 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.
  - ›› measured absorption 40 - 120 ppm
  - ›› absorption due to Ti, other impurities

Coating Absorption and Birefringence

- LIGO II coating requirements
  - ›› birefringence < 10^{-3} rad
  - ›› absorption < 1 ppm
- Measure by probing resonant cavity with transmitted side-band as function of input polarization
  - ›› low loss coating possible on c-axis sapphire
- Determine if m-axis sapphire optics are practical
  - ›› m-axis anisotropy may stress coating
  - ››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	May - July July - Aug	CSIRO Caltech, Stanford
1	m	15 cm ϕ x 8 cm	Optical Homogeneity and Surface Figure Q	May - July 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	June	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	May May	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