Core Optics Components (COC)

Polishing Pathfinder Kickoff

Advanced LIGO Project

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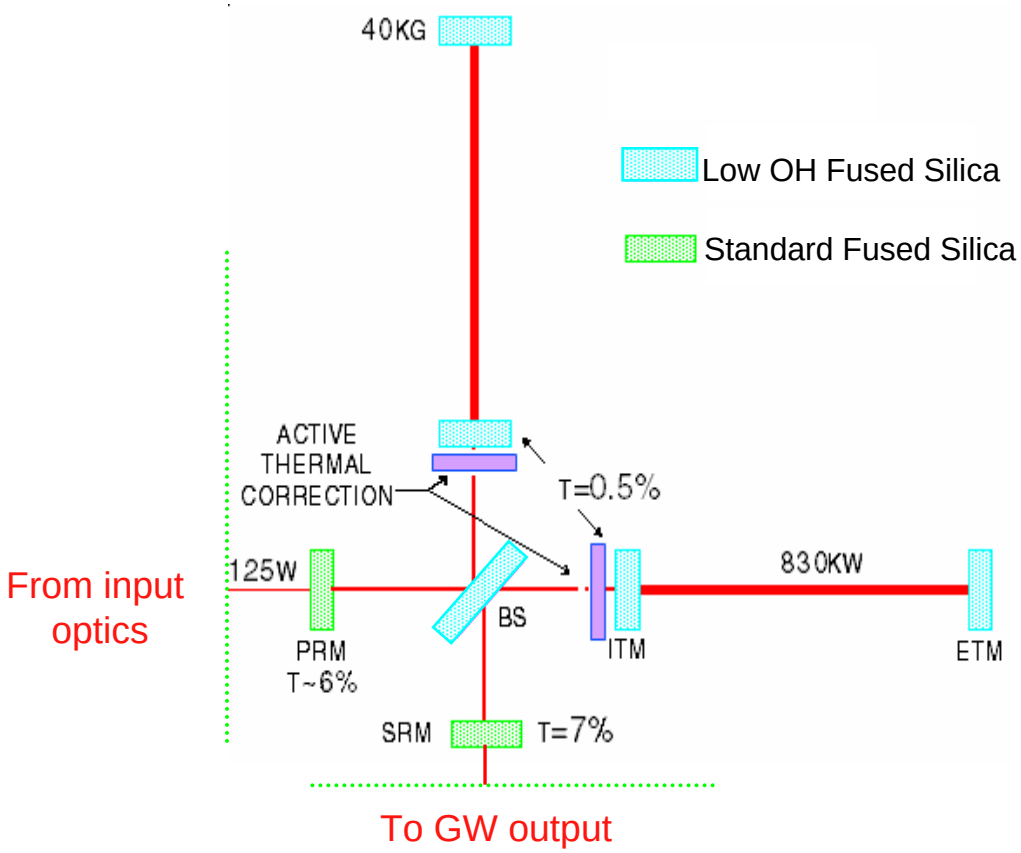
LIGO-G070193-00-D

COC Description & Deliverables



- **Fabricate, characterize and deliver core optics and spares**
- **Provide for cleaning, handling, shipping and storage containers**
- **Complete when all optics and spares are characterized and delivered**

Core Optics Test Mass Requirements

Mass	40 Kg
Dimensions	340 mm x 200mm
Surface figure	< 1 nm rms
Micro-roughness	< 0.1 nm rms
Optical homogeneity	< 20 nm rms, double pass
Bulk absorption	< 3 ppm/cm
Bulk mechanical loss	$< 3\times10^{-9}$
Optical coating absorption	< 0.5 ppm (required) < 0.2 ppm (goal)
Optical coating scatter	< 2 ppm (required) < 1 ppm (goal)
Optical coating mechanical loss	$< 2\times10^{-4}$ (required) $< 3\times10^{-5}$ (goal)
Arm cavity optical loss / round trip	< 70 ppm

Arm cavity loss budget 70ppm/ round trip

	Budget (ppm)	Note
Diffraction Mirror aperture	2 * 1	Will go up to ~10 with heating
Roughness scatter Based on Microroughness theoretical loss at 0.16 nm rms	2 * 3.5	
Defect scatter Scratches and point defects. Requirement < 20k μm^2 over 120 mm dia	2 * 3.7ppm	L1 average 17k μm^2 over 235 mm dia
Coating scatter	2 * 3	Currently 2 * 30?
Figure Based on stretching and scaling our best LIGO 1 data.	2 * 20	See next slide
Absorption	2 * 0.5	typical
ETM Transmission	7	
Total	70.4	

Core Optics Baseline Design

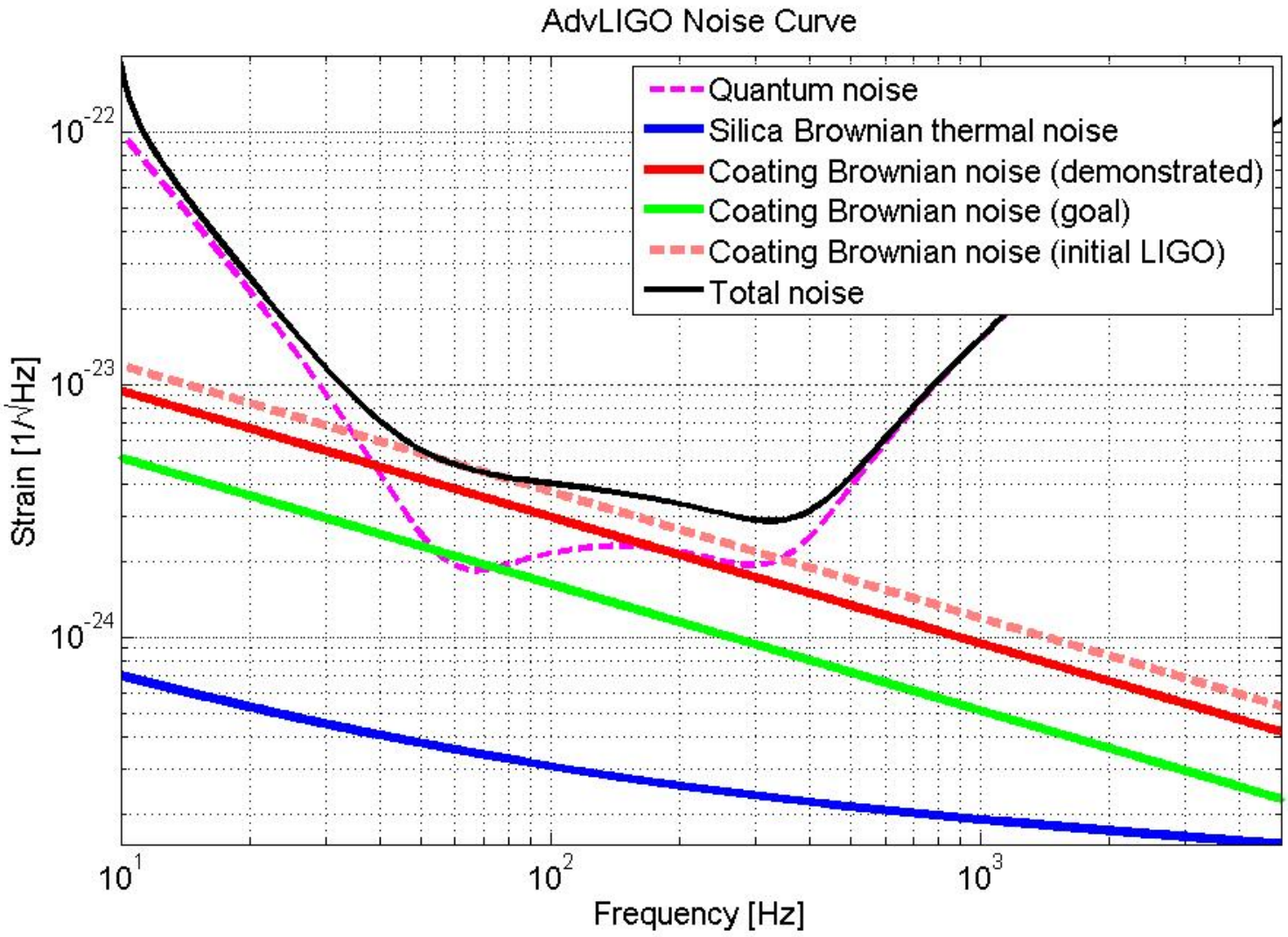


Figure – Radius of curvature

- ROC requirements Surface 1:
  - Astigmatism measured separately (clocked at CIT)
  - ROC absolute ~ within 30 meters, based on diffraction loss
  - ROC relative, model suggests ±2 m…..!
  - Thermal compensation will impact this in an unknown way.
    - Perhaps greater tolerance, probably a different “cold” ROC
  - For Fabrication ROC measurement aperture will be 160mm
- Requirements for Surface 2:
  - Make the bulk look ideal
  - “transmitted” measurement should be S1 ± 15m
  - We are looking for power correction only
    - We don’t anticipate higher order error in the 311 glass, based on LIGO 1 beamsplitter measurements (L1 ITMs were 312 material)
    - Heraeus measured homogeneity of ~6nm PV before final trim

Heraeus certification of ingot 700887000

LIGO-E060006-00

	Specification value	Measured value	Comment
Diameter (mm)	344,0 (+/- 1,0)	344,0 (+/- 1,0)	
Thickness (mm)	204,0 (+/- 1,0)	204,0 (+/- 1,0)	
CA (mm)	Ø 275	Ø 275	
Homogeneity over every Diameter (ppm)	Ø 200 mm ≤ 2,5 x 10*-6 Ø 80 mm ≤ 0,5 x 10*-6	≤ 0,08 x 10*-6 ≤ 0,03 x 10*-6	Inspection thickness 204,5 mm
Residual Birefringence (nm/cm over CA)	Ø 200 mm ≤ 5 Ø 80 mm ≤ 1	≤ 0,527 nm/cm ≤ 0,232 nm/cm	Acc. to ISO 10110
Striae:	Grade 2	no striae detected	MIL-G- 174
Bubble and Inclusion (over CA)	≤ 0,03 mm^2 / 100cm^3 Inclusions with a diameter of 0.06 mm or less are disregarded. Maximum inclusion diameter: ≤ 0.1 mm	no bubbles detected no inclusions detected	
OH – content (ppm)	≤ 250	Average 197 ppm	

Figure – Surface error low freqency to 1/mm

- **Side 1 RMS with TPA removed**
  - **0.7 nm over 150 mm diameter (will be 160 for Adv. LIGO)**
    - **modeling noise in the zone outside: 3x noise of random map ~15% or 3ppm increase in loss**
    - **Random map of 0.5nm rms typically gives rise to ~18ppm loss.**
    - **Roughly 10 ppm loss (1/2 of budget) in the frequency range 0.1/mm to 1/mm**
  - **2.1 nm over 300 mm diameter**
    - **Per T060223, sharp errors of order 20 nm at a position of 3 cm in from the edge have an effect on cavity loss of order ~1ppm**
- **Experience from LIGO 1**
  - **Rms over small areas(1 cm) is consistent across the optic**
  - **Similarity in CIT measurements indicate we generally do not measure the actual optics.**

Microroughness 1/mm to 750/mm

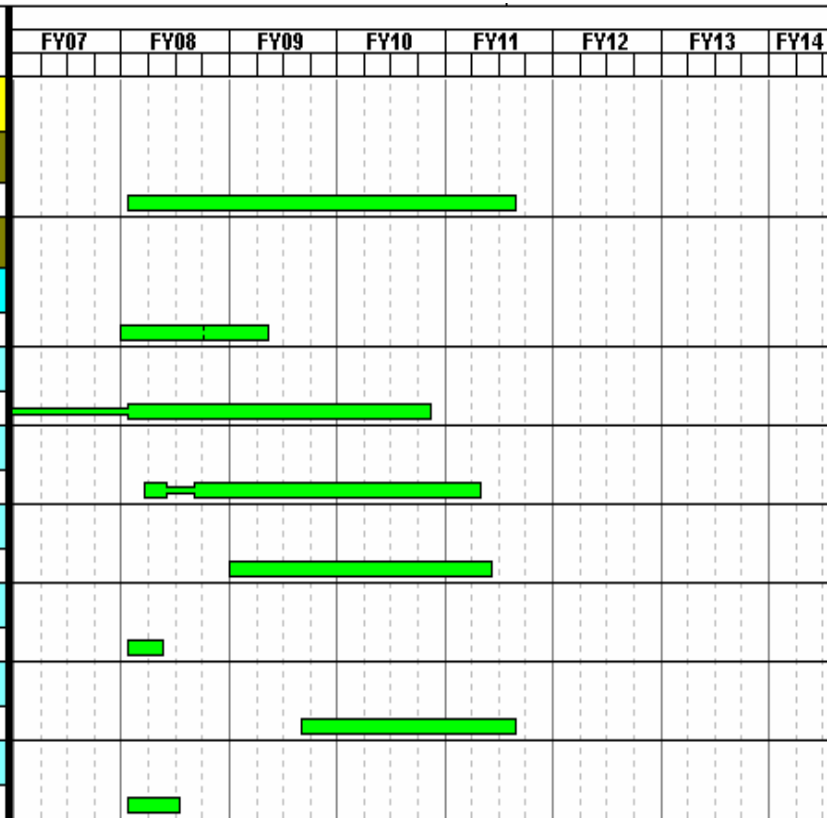
- Outside the normal range of “microroughness” measurements
- The frequency spectrum may be covered by multiple instruments

Advanced LIGO project

- Funding should be available for placing contracts ~Jan ‘08
  - Advanced LIGO is in the President’s budget
  - President’s budget is yet to be approved by Congress
- Anticipate providing the blanks already shaped
  - Wedges
  - Mounting flats
  - Bevels
  - All surfaces polished?
- Due to schedule constraints, anticipate letting two polishing subcontracts.
  - Logical division of optic type is yet TBD and depends on vendor capabilities

Core Optics Schedule Highlights

Activity ID	Activity Description	Funding Agency	Orig Dur	Early Start	Early Finish
LIGO.4.06	Core Optics Components (COC)				
+ LIGO.4.06.1	COC Subsystem Management				
		NSF	895*	23OCT07	24MAY11
LIGO.4.06.4	COC Fabrication				
+ LIGO.4.06.4.2	COC Metrology Fabrication				
		NSF	340	01OCT07	11FEB09
+ LIGO.4.06.4.3	COC Substrate Blanks				
			1,278	01JUL05A	11AUG10
+ LIGO.4.06.4.4	COC Polishing				
		NSF	775	20DEC07	31JAN11
+ LIGO.4.06.4.5	COC Coating				
		NSF	605	01OCT08	08MAR11
+ LIGO.4.06.4.6	COC Cleaning Process Equipment				
		NSF	80	23OCT07	21FEB08
+ LIGO.4.06.4.7	COC Metrology				
		NSF	495	02JUN09	24MAY11
+ LIGO.4.06.4.8	COC Fixture/Handling Fabrication				
		NSF	120	23OCT07	17APR08



Core Optics Spares

	PRM	SRM	BS	FM	CP	1st 2 ifo ITM	3rd ifo ITM (wedge)	ETM
Optic size (mm)	265 x 100	265 x 100	370 x 64	370 x 64	340 x 130	340 x 200	340 x 200	340 x 200
Required 1st IFO	1	1	1	0	2	2	0	2
Spares 1st IFO	2	2	2	0	2	4	0	4
Required 2nd IFO	1	1	1	0	2	2	0	2
Spares 2nd IFO	1	1	1	0	1	0	0	0
Required 3rd IFO	1	1	1	2	2	0	2	2
Spares 3rd IFO	1	1	0	1	0	0	2	0
Total Number 54 (25 of which are spare)	7 (4)	7 (4)	6 (3)	3 (1)	9 (3)	8 (4)	4 (2)	10 (4)