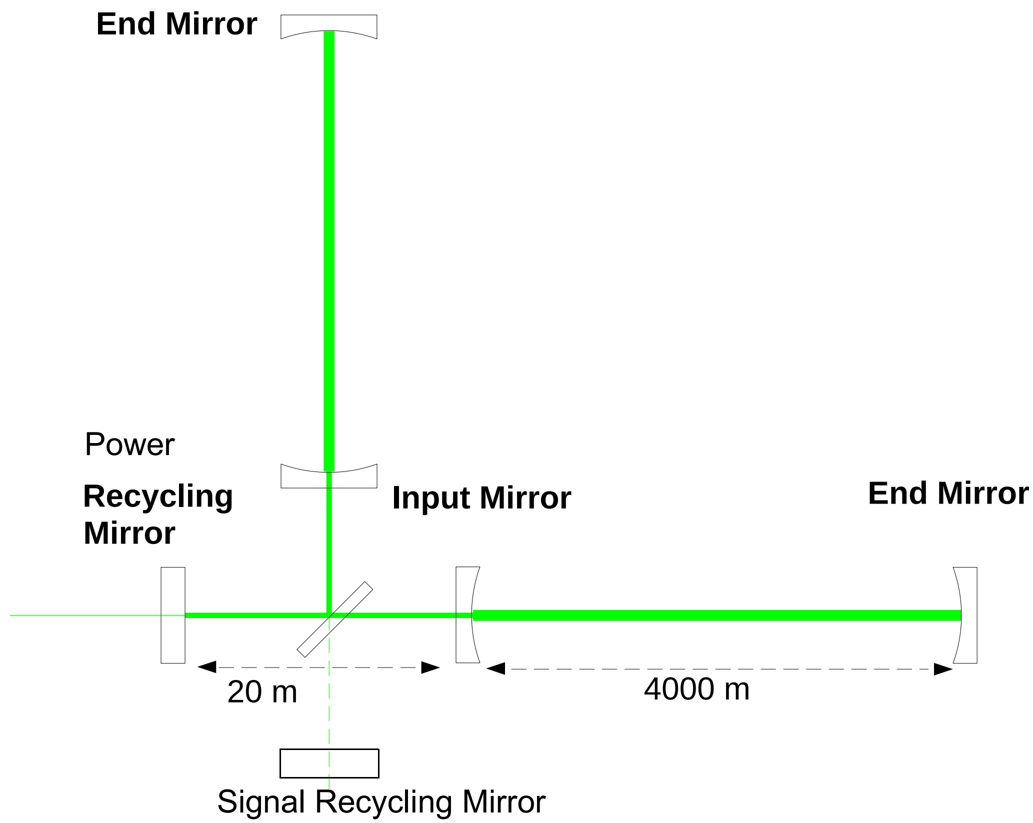
The Core Optics



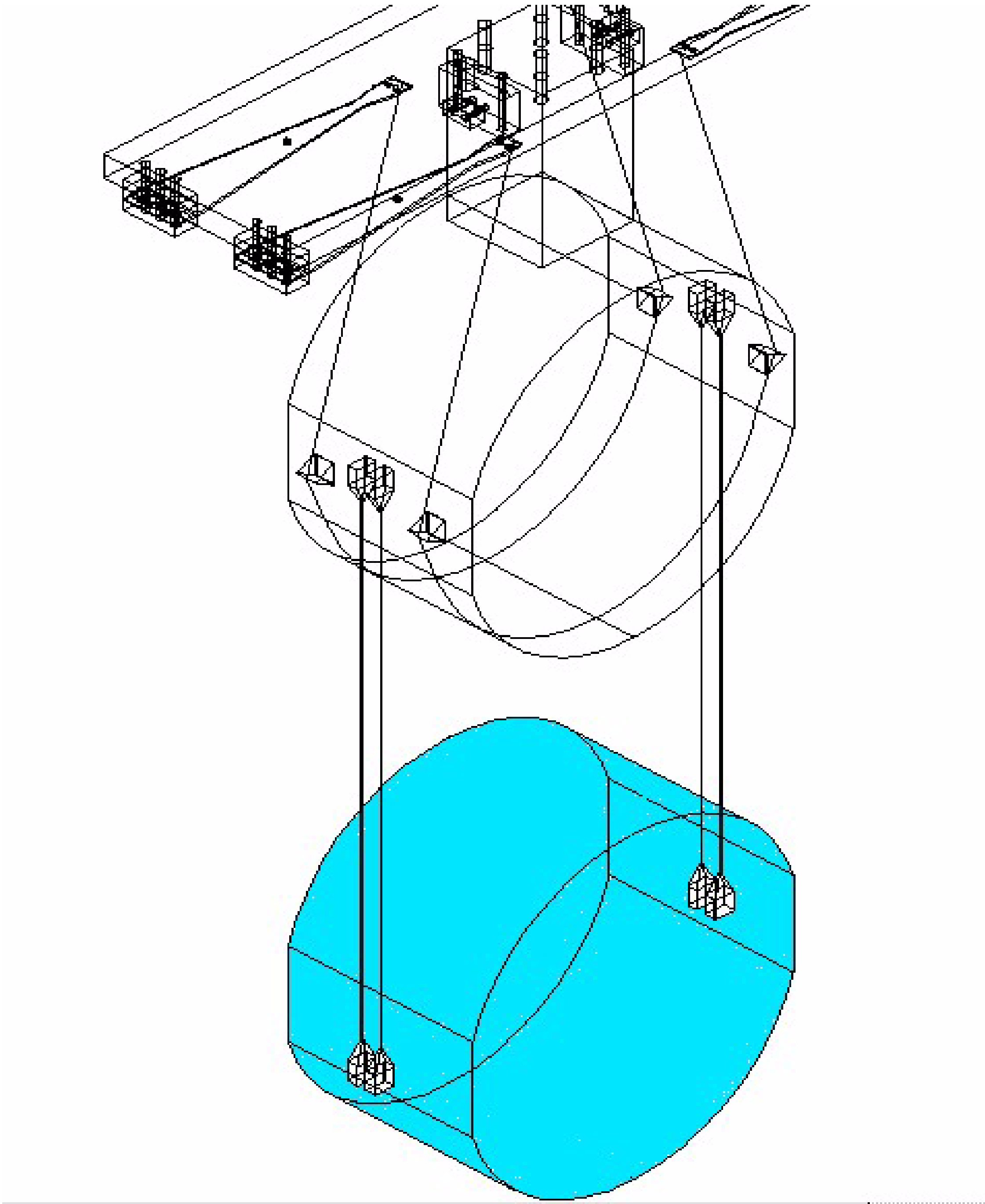
Fold mirrors for the (currently) Washington 2K are also considered core optics

Core Optics Overview

- 3 interferometers
- 23 Core optics
- First installation 2006 - Complete

- Aggressive R&D program - Sapphire, Coating
- Fabrication is subcontracted
- Production Flow
  - Blanks, glass procurement
  - Substrates, polishing
  - Mirrors, coating
  - Final Metrology

COC Boundary



- Interface with SUS, ISC, AOS

Design Parameters
Rely heavily on modeling

	PRM	SRM	BS	FM	ITM	ETM
Baseline Optic size (mm)	254 x 100	254 x 100	350 x 60	350 x 118	314 x 135 (40Kg)	314 x 135 (40Kg)
Baseline Material (fall back material is all FS)	Low inclusion FS	Low inclusion FS	Low absorption FS	FS	Sapphire	Sapphire
Clear Aperture	224	224	330	330	300	300
Sagitta (nm) over central 215 mm dia (2**wo* dia)	240	240	Flat	Flat	165 ± 10	165 ± 10
Surface error -TPA (nm rms) over central 215 mm diameter	< 1.6	< 1.6	< 1.6	< 1.6	< 0.8	< 0.8
Bulk Homogeneity (nm rms)			<10		<10	
Coating Absorption Requirement Goal (ppm)	< 1	< 1	< 1	< 1	< 0.50 < 0.05	< 0.50 < 0.05
Coating Thickness Uniformity (%)			0.1		0.1	0.1

R&D

- Test Mass Material Selection - Decision in '02
  - Which material yields the most sensitivity -
    - Sapphire (the heading for an entire talk by Jordan Camp)
    - Fused Silica
- Coating Development
  - Absorption - Ties in to material selection
  - Uniformity

Pathfinder - Three Phases

- A. Demonstrate polishing of Sapphire to required levels
  - ››Two half size pieces sent to LIGO polishers
- B. Survey several different polishers using a competitive process.
  - ››Half size pieces sent to several polishers
- C. Demonstrate polishing and coating on full size pieces.
  - ››Metrology before and after coating
  - ››Full size pieces go to LASTI after Pathfinder metrology is complete

Production flow

- Blank Fabrication
  - ›› Possible vendors: Crystal systems, Heraeus, Corning...
  - ››QA includes absorption tests to sort Test Mass optics for use
    - –ITM only if using Fused Silica Test Masses
    - –ITM and ETM if using Sapphire Test Masses

Polishing

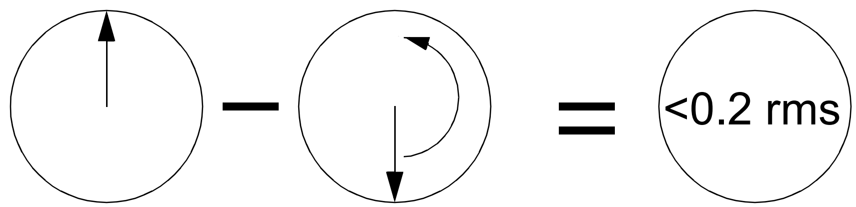
- Machine optics at a high volume facility
- Ship for final polish
  - Possible vendors:
    - CSIRO
    - General Optics
    - Raytheon (formerly HDOS)
    - ....?
- Surface and bulk metrology before coating

Coating

- R&D
  - Uniformity
  - Absorption
- We need to coat with the same vendor who performs the R&D
  - CSIRO
  - General Optics
  - Japan (for TAMA)
  - Max Plank (LZH)
  - MLD
  - REO
  - Virgo
  - Zeiss
- Surface metrology after coating

Metrology

- CIT - Demonstrated repeatability upon rotation of <0.2 nm rms over 80 mm aperture (Initial LIGO beam waist ~ 60 cm diameter)



Decision:

- Beam waist of new design is ~ 120 mm in diameter
  - Current Metrology aperture is 150 mm.
  - Test Mass is 314mm.
  - How to handle the outer 95 mm annulus?
- Goal of Metrology is to certify optics and to support modeling

Metrology options

- Reduce the noise in our current system, stay with the 150mm aperture.
- Increase the current system aperture size to ~200mm with a beam expander/phase shifter.
- Invest in a new ~450mm aperture system.
- Some combination of the above.

Option 1 - Current System

- Build on the work that we have already done.
  - Minimize noise by removing a vibration source, and installing a 10 or 12 bit camera.
  - Isolate the heat source by coupling the laser in through a fiber.
  - Change the pellicle resonant frequency by using a smaller element.
  - Change the phase algorithm to step through different start phases while averaging.
- The small aperture (~150mm) is the drawback to this option.
  - It is the nature of the polishing process to produce a surface which is uniform.
  - Exceptions might be spherical aberration at large diameter, including roll off at the edges.
  - Coating Uniformity is a function of the chamber geometry. As in LIGO I, the uniformity could be verified by elipsometry on large samples and/or spectrophotometry on microscope slides.
- Difficult to extrapolate the data into the correct size for the FFT code.
- Noise level after modifications *should* be better - no guarantee.

Option 2 - Beam Expansion

- Install a beam expander with a phase shifter
- Procure new reference flats.
- Start over in the calibration process.
- Still a fairly "small" aperture (200mm).
- The camera wouldn't change, so we would have less resolution ~.35 mm/pixel, High mag. ~60um/pixel
- Still difficult to extrapolate the data into the correct size for the FFT code.

Option 3 - New 18” system

- There are large aperture systems to be had, WYKO has one at ~$300K
- We might need some modifications to the system in order to attain the kind of accuracy that we are used to.
- We would need to procure 18" reference flats ($100K?).
- Start over in the calibration process.
- The resolution would decrease proportionally.
- We would have the benefit of full aperture metrology to fold into FFT analysis.

Other COC Tasks

- Design and Test of Cleaning Process and Equipment
- Design Handling Fixtures (40 kg!)
- Carriers
- Metrology Fixtures

Number of COC required

Optic Type	First Interferometer		Second Interferometer		Third Interferometer		Total 44
	Required	Spares	Required	Spares	Required	Spares	
Power Recycling Mirror	1	2	1	1	1	1	7
Signal Recycling Mirror	1	2	1	1	1	1	7
Beamsplitter	1	2	1	0	1	0	5
Folding Mirror					2	1	3
Input Test Masses for the first 2 IFOs	2	4	2	0			8
Input Test Masses for the third IFO					2	2	4
ETM	2	4	2	0	2	0	10

One piece fabrication time: ~ 1 year

Fortunately the optics are fabricated in parallel.

COC
Schedule Highlights

- Sapphire-Fused Silica decision - 2Q02
- Deliver prototype test masses to LASTI - 2Q03
- Start Procurements for First IFO - 1Q04
  - ››Fabrication cycle for first IFO (19 optics) ~ 21 mos.
- First IFO optics (all) ready for installation - 4Q05