

LIGO II and Advanced R&D Overview

Gary Sanders Caltech PAC8 Meeting May 2000



LIGO II Reach



LIGO-G000102-00-M

LIGO II



LIGO II Reference Design Parameters / LIGO I Comparison

Subsystem and Parameters	LIGO II Reference Design	LIGO I Implementation
Comparison With LIGO I Top Level Parameters		
Strain Sensitivity [rms, 100 Hz band]	2 x 10 ⁻²³	10 ⁻²¹
Displacement Sensitivity [rms, 100 Hz band]	8 x 10 ⁻²⁰ m	4 x 10 ⁻¹⁸ m
Fabry-Perot Arm Length	4000 m	4000 m
Vacuum Level in Beam Tube, (Vacuum Chambers)	< 10 ⁻⁶ , (< 10 ⁻⁷) torr	< 10 ⁻⁶ torr
Laser Wavelength	1064 nm	1064 nm
Optical Power at Laser Output	180 W	10 W
Optical Power at Interferometer Input	125 W	5 W
Power Recycling Factor	80 x	30 x
Input Mirror Transmission	3%	3%
End Mirror Transmission	15 ppm	15 ppm
Arm Cavity Power Loss on Reflection	1%	3 %
Light Storage Time in Arms	0.84 ms	0.84 ms
Test Masses	Sapphire, 30 kg	Fused Silica, 11 kg
Mirror Diameter	28 cm	25 cm
Test Mass Pendulum Period	1 sec	1 sec
Seismic Isolation System	Active/Passive, 6 stage	Passive, 4 stage
Seismic Isolation System Horizontal Attenuation	10 ⁻⁸ (10 Hz)	^з 10 ⁻⁵ (100 Hz)
Maximum Background Pulse Rate	1 per 10 years, triple interferometer coincidence	1 per 10 years, triple interferometer coincidence



The Real Goals

- Physics "would be surprising if don't see many sources" - Thorne yesterday
- Instrumental quantum limited interferometer across entire sensitive band



LIGO II and LIGO I Sensitivity



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Noise Anatomy of LIGO II



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LIGO II



The Scenario

YEAR	LIGO I	LIGO II
2000	Installation and commissioning	R&D
2001	Installation and commissioning	R&D
2002	Science run starts	MRE/R&D funds start, R&D, design, long lead items
2003	Science run	R&D, design, fabrication
2004	Science run	Fabrication, on-site assembly
2005	LIGO I interferometers removed	Fabrication, on-site assembly, installation into vacuum system
2006		Installation and commissioning



LIGO Laboratory and LSC Role

- LIGO Laboratory will organize and manage the LIGO II project
- LSC participation in the construction of LIGO II will be governed by Memoranda of Understanding (MOU) and specific, periodic Attachments describing tasks, funding, milestones and personnel, with subcontracts
 - » this model used successfully with Univ. of Florida during LIGO I
 - » this model used with LSC for R&D activities, without subcontracts
 - LSC is driving the LIGO II scientific goal and concept
- GEO is proposing a collaborating role and a capital contribution role
- ACIGA role developing (recent)



LSC and Lab Submitted Conceptual Documents

- September White Paper on Advanced Detector R&D
 - » Working Group chairs and spokesperson represented you well
 - this exercise is a success of the LSC structure and governance
- Conceptual Project Book prepared by Lab staff working with the LSC leadership
 - » Assumed all 3 interferometers replaced in 2005-2006 !
 - » Therefore all of LIGO I is turned off
 - » Assumed maximum possible choices of all options
 - intended to get cost envelope bracketed
 - » Cost estimate is MRE request \$94 million + GEO proposed contribution + contribution from LIGO Lab Operations budget!
 - Larger cost than expected due to active isolation, number of control loops and data acquisition/analysis complexity



Major Project Options

- How many interferometers to upgrade?
 - » Assume all 3 interferometers upgraded
- Convert the Hanford 2 kilometer to a 4 kilometer?
 - » Assume length is increased
- Upgrade done in one phase?
 - » Assume all 3 interferometers upgraded in one parallel installation
 - » Decision on this may interact with other gravitational wave detectors to insure that observational coverage is considered
 - » Phasing of upgrade is a major scientific decision



My Summary of NSF Review Recommendations

- LIGO Lab should proceed with full construction proposal for LIGO II to be submitted late in 2000
- NSF should establish a framework for evaluating R&D proposals related to LIGO II in order to assure coordination and monitoring
- LIGO Lab should submit an integrated R&D plan for Lab and LSC research in 2000 and 2001
- Construction proposal should identify Preconstruction R&D to begin in 2002
- Meaningful LIGO I data analysis results should be in hand prior to turning LIGO I off



LIGO Lab's Plan

- Integrated R&D Plan for 2000 and 2001 submitted in March
- Briefing document for NSF MRE selection submitted last month and is under review at NSF
- Full LIGO II Proposal to be submitted near end of 2000, with LSC and GEO participating
- Request R&D \$ increment for 2002
- Request construction \$ for 2003
- Plan first installation in vacuum system in 2005



Phased Funding/Decision Scenario for NSF

FY	2002	2003	2004	2005	2006	TOTAL
Design/Development	\$9M	\$11M	\$4M	\$3M		\$27M
Construction		\$9M	\$21M	\$22M	\$15M	\$67M
Project Total	\$9M	\$20M	\$25M	\$25M	\$15M	\$94M

- Assumption is MRE Design & Development start in FY2002
- Construction start in FY2003
- NSF debating whether MRE budget line should be used for development of projects or only for projects fully ready to construct

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LIGO II



Management of the R&D

- LIGO Lab is working with LSC Working Group Chairs to define and monitor R&D program
- Fully integrated schedule of Lab and LSC activities is in preparation
- MOU's/Attachments B, C, D updated to agree with this plan
- LSC is hosting monthly progress telecons with LIGO Lab participating to assess progress and to identify issues
 - » this is working quite well



Since September, 1999 White Paper

- R&D White Paper failed to fully consider thermal noise sources
- Braginsky et al and Thorne et al papers on thermoelastic damping change sapphire perspective
 - » goal is to work this result into R&D and into LIGO II design choices
 - » increased emphasis on measuring thermal noise limits with suspended sapphire optics
- Some R&D is being curtailed or accelerated to focus on the LIGO II goals
 - » sapphire optical and mechanical properties
 - » thermal compensation
 - » use of test interferometers
- R&D program is undergoing greater discussion and coordination
 - » Aspen workshop was intense.....!
 - » LSC meeting was intense
 - » System design summit scheduled later this month



R&D Questions

- How much risk can we tolerate from limits of our knowledge of the LIGO II thermal noise floor?
 - » How well can we measure thermoelastic noise?
 - Direct measurement in suspended mass interferometers with fine displacement sensitivity (TNI,...)
 - Tabletop measures of damping (anelastic tests,...)
 - » Other contributions to thermal noise
 - Brownian motion noise
 - Young's modulus response to thermal fluctuations (G. Cagnoli)
 - Index of refraction response to thermal fluctuations (B. Kells)
 - intensity noise from thermal compensation via laser
 - others...

• This is not a zero risk endeavor



R&D Questions

Signal tuned configuration research

- » 10 m Glasgow system
 - to prove the principle
- » 40 Meter system
 - to shakeout an engineering implementation
- How come we measured phase sensitivity for LIGO I and no plan to do this for LIGO II is in our White Paper?
 - » Did not consider path length fluctuations induced by thermal fluctuations driving refractive index
 - » ACIGA role?
- How to integrate opportunities from all the test interferometers in the community?

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This Year: Towards Full LIGO II Proposal

- Team forming in LIGO Lab
- Integrated plan being assembled
- Schedule for proposal preparation forming
- Seismic isolation decision MUST be made in April!
- Monthly R&D telecons started for 3 working groups
- Schedule/cost estimating this summer
- Document complete in October
- LSC full participation is crucial
- Lot's of competition pounding the NSF door !
 - » Our field will be held to its own high standards



Issues

• Pressure on key Lab staff is intense

- » LIGO I vs. LIGO II deadlines
- No funding for LIGO II proposal generation and engineering before 2002
 - » using reserve funds for the moment
- Staffing down at end of construction and staffing up for LIGO II
- Early science results from LIGO I engineering runs very important to establish confidence that we will move from instrument builders to investigators of the gravitational wave universe