LIGO Status Report

Barry Barish

LIGO LSC Meeting

March 13-16, 1998

Barish

LIGO

the project

- National Science Foundation
  - » D. Berley (view from the NSF)
- Construction Project (1995-1999)
  - » Facilities and Initial Detector
  - » **presently 78% complete !**
- Commission Facility (1999-2001)
  - » Implement Initial Detectors
    - – $h \sim 10^{-20}$ - Coincidence (Hanford/Livingston)
      - Engineering run (end of 2000)
    - – $h \sim 10^{-21}$ - Initial Design Sensitivity (end 2001)
- Operations (2002 + ...)
  - » Data Taking/Analysis
  - » Enhance Initial Detector
  - » Advanced Detectors

LIGO Schedule

main activities

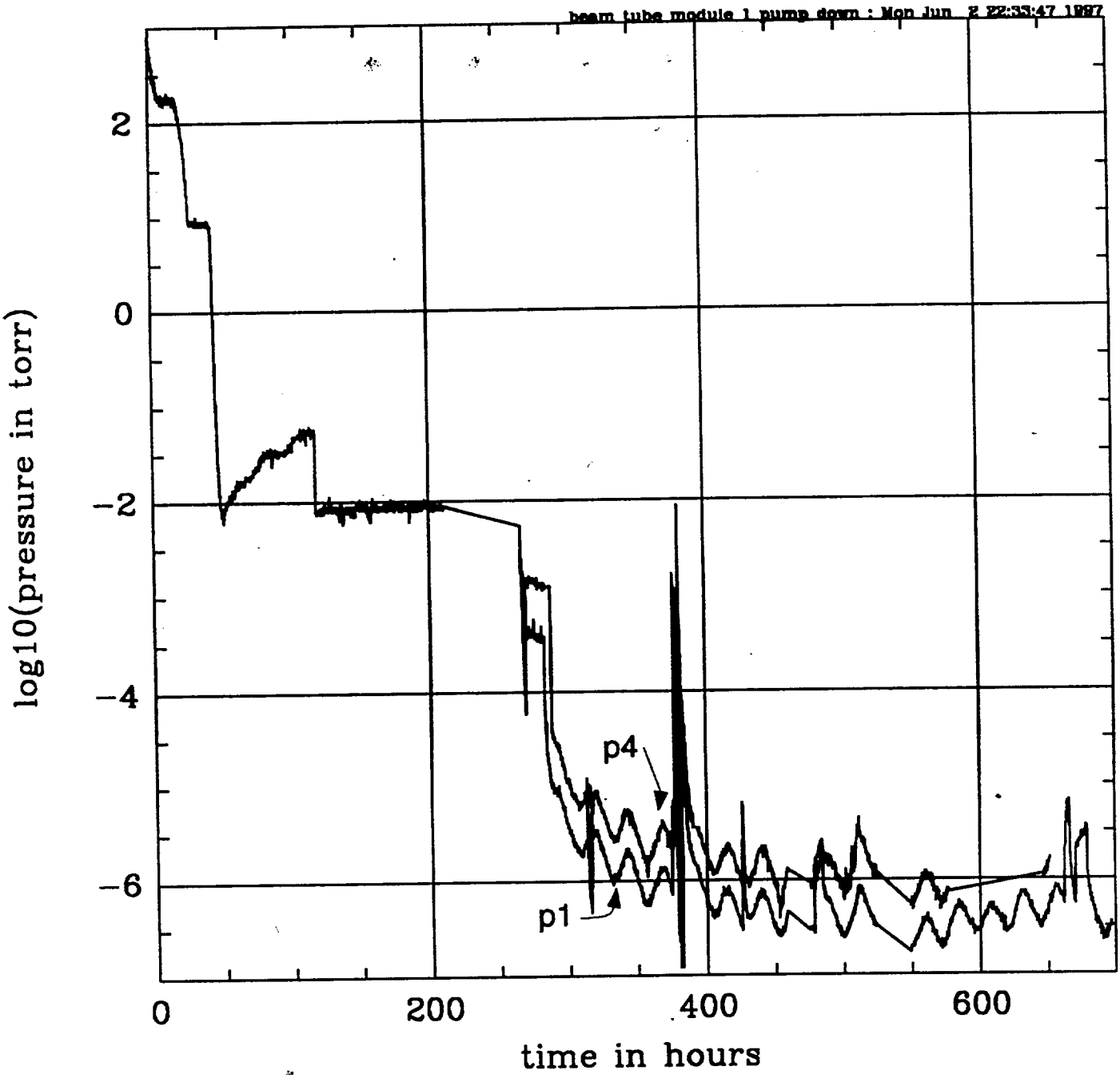
1996	Construction Underway
	-mostly civil
1997	Facility Construction
	-beam pipe & enclosure
1998	Construct Detectors
	-complete vacuum systems
1999	Install Detectors
	-interferometers in vacuum
2000	Commission Detectors
	-first light; testing
2001	Engineering Tests
	-sensitivity; engineering run
2002	Initial LIGO Detector Run
	- $h \sim 10^{-21}$

LIGO Operations

physics/enhancements

- First Physics Run (~2002-2004)
  - » **LIGO I** Development Group
  - » Initial LIGO design sensitivity h ~ 10^{-21}
  - » one year integrated data (~ 2 year run)
  - » data reserved for LIGO I group for two years from collection
- Enhancements/Data Taking (~2004- ?)
  - » Advanced R&D to reach h ~ 10^{-22}
  - » incremental improvements - **LIGO II**
  - » implemented from 2004, mixed with data taking
- Advanced Detector Configurations
  - » development work begins now
  - » implementation within 10 years (eg. 2008)?

Technical Status of LIGO

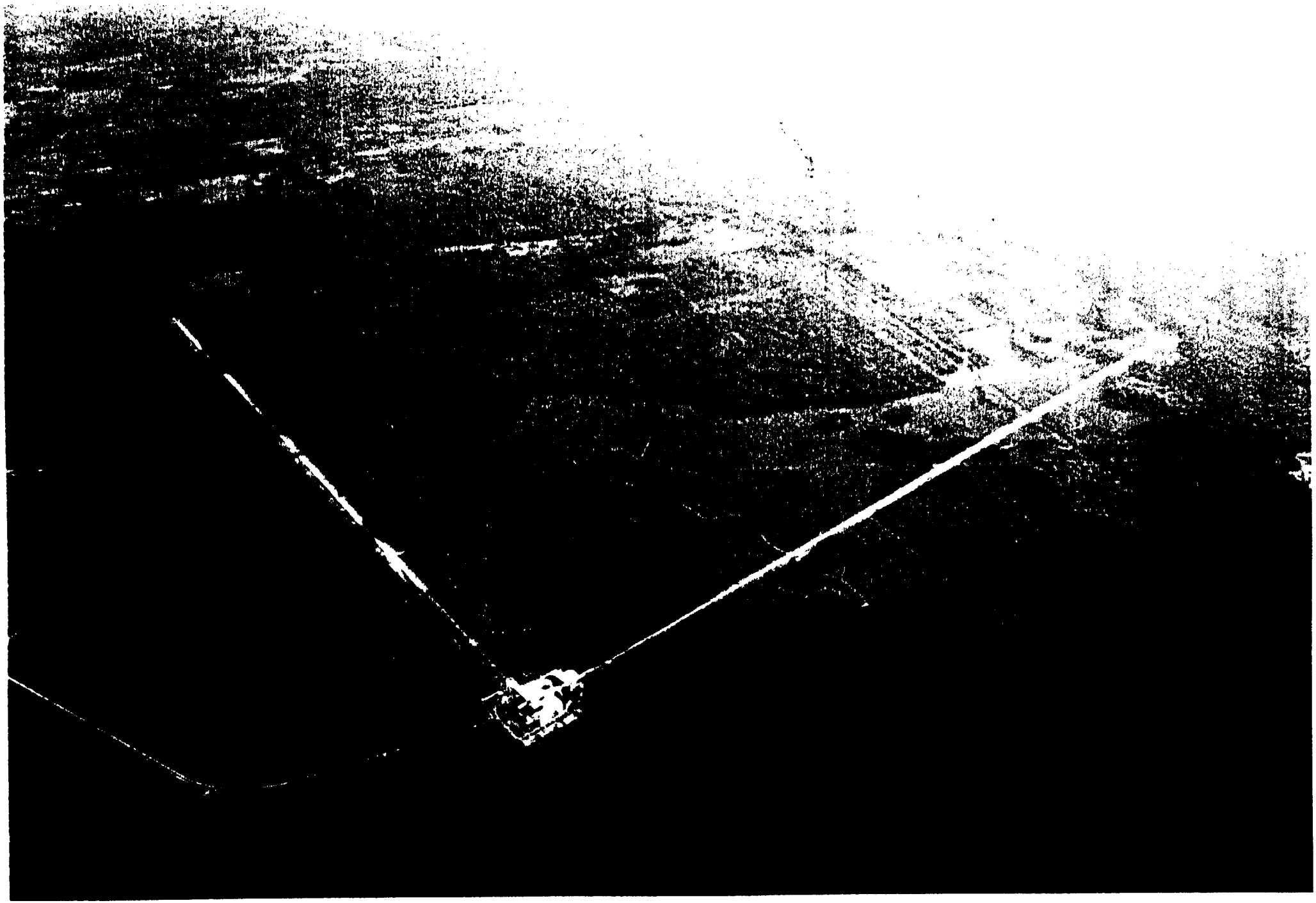

beam tube module 1 pump down : Mon Jun 2 22:33:47 1997
2
0
-2
-4
-6
log10(pressure in torr)
p4
p1
0
200
400
600
time in hours

LIGO Livingston Status

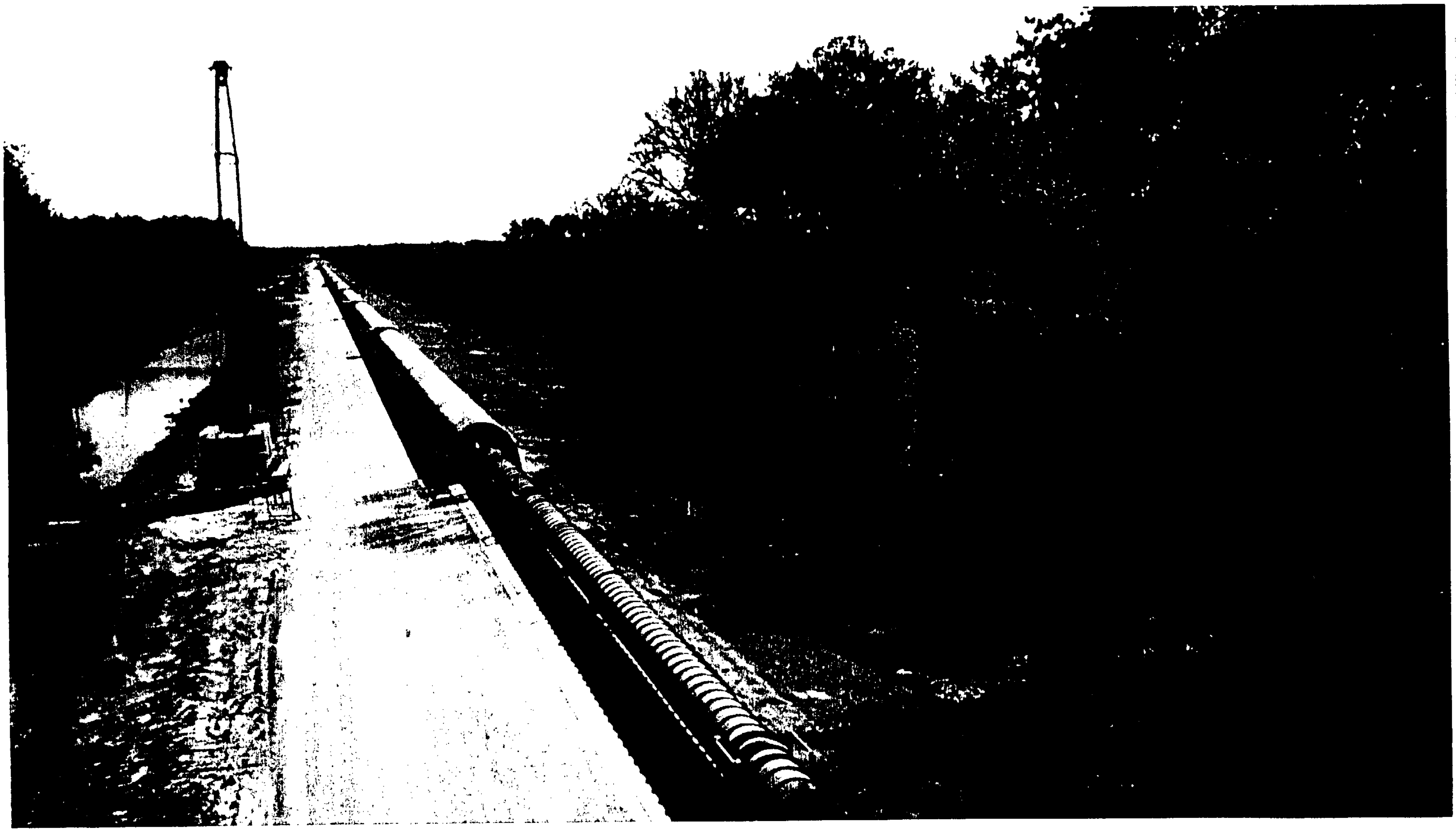
- **Staffing:**
  - ›› Present site staff 7+ 2 Parsons supports construction effort (beam tube, civil, VE, and electrical installation, bakeout)
  - ›› Site head (Coles) resident by end of July.
- **Civil construction:**
  - ›› Joint occupancy of all buildings, final acceptance expected ~ April 1
- **Beam tube:**
  - ›› Right arm completed and all tubes covered
  - ›› Pump down staging underway with pump down to start 3/24.
  - ›› Left arm installation proceeding at 16 tubes week. Expect to complete installation by ~ mid July.
  - ›› Beam tube fabrication will complete by the end of April.
- **Vacuum equipment**
  - ›› Installation readiness review - end of March
  - ›› Begin receiving VE ~ April 1
  - ›› Complete VE installation and check out by year end.

LIGO Livingston Plans

- **1998**
  - ›› Complete construction
  - ›› Prepare support labs (electrical, vacuum, optical) for detector installation activities
- **1999**
  - ›› Detector component installation (Seismic, PSL,IOO, suspensions and core optics, etc.)
  - ›› Data acquisition system installation
  - ›› PSL commissioning
  - ›› Michelson and Recycled Michelson commissioning by year end
  - ›› Physics and Environmental monitoring system installation and integration
- **2000**
  - ›› Add Fabry-Perot arms and bring entire interferometer into operation



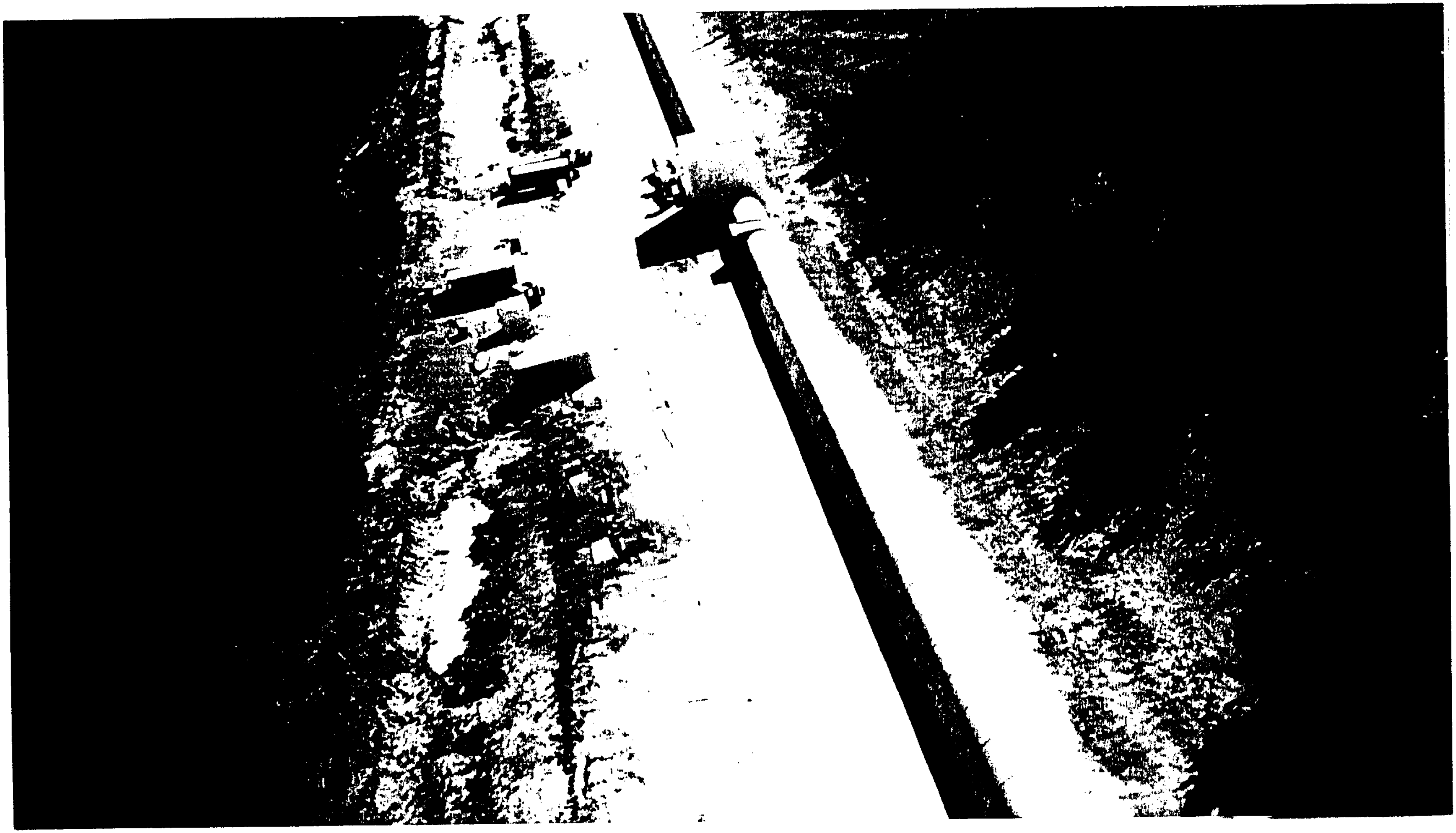
G980014-02-O-V



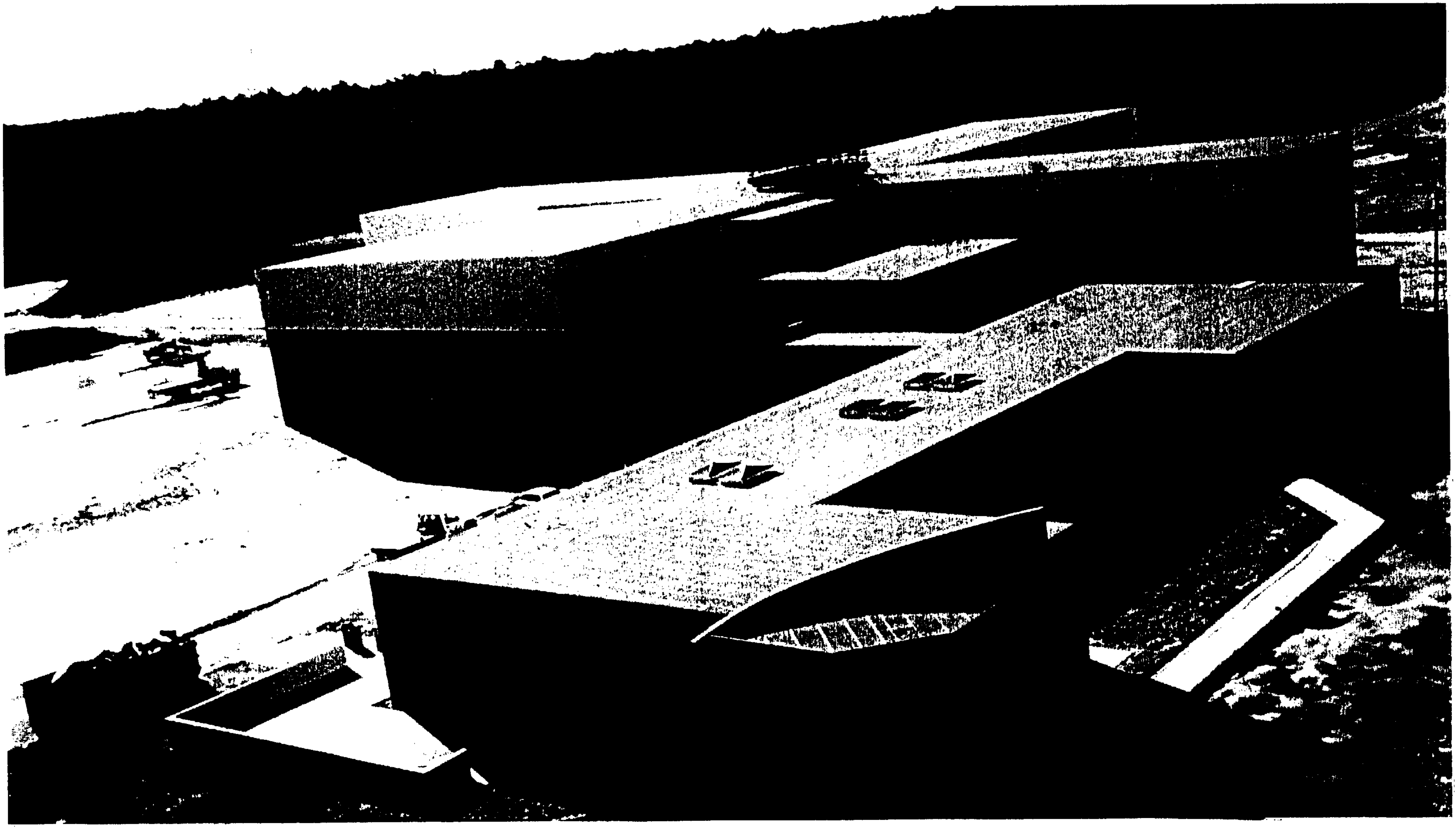
G980014-16-O-V

facilities

- Hanford Construction
  - » building occupied, nearly complete
  - » we own the beam tube !! (prebake ~2 10^{-7} torr)
  - » near term activities - beam tube bakeout, vacuum system implementationl
- Louisiana Construction
  - » buildings recently occupied
  - » 4 km beamtube complete
  - » near term activities - second 4 km beam tube



G980014-08-0-V



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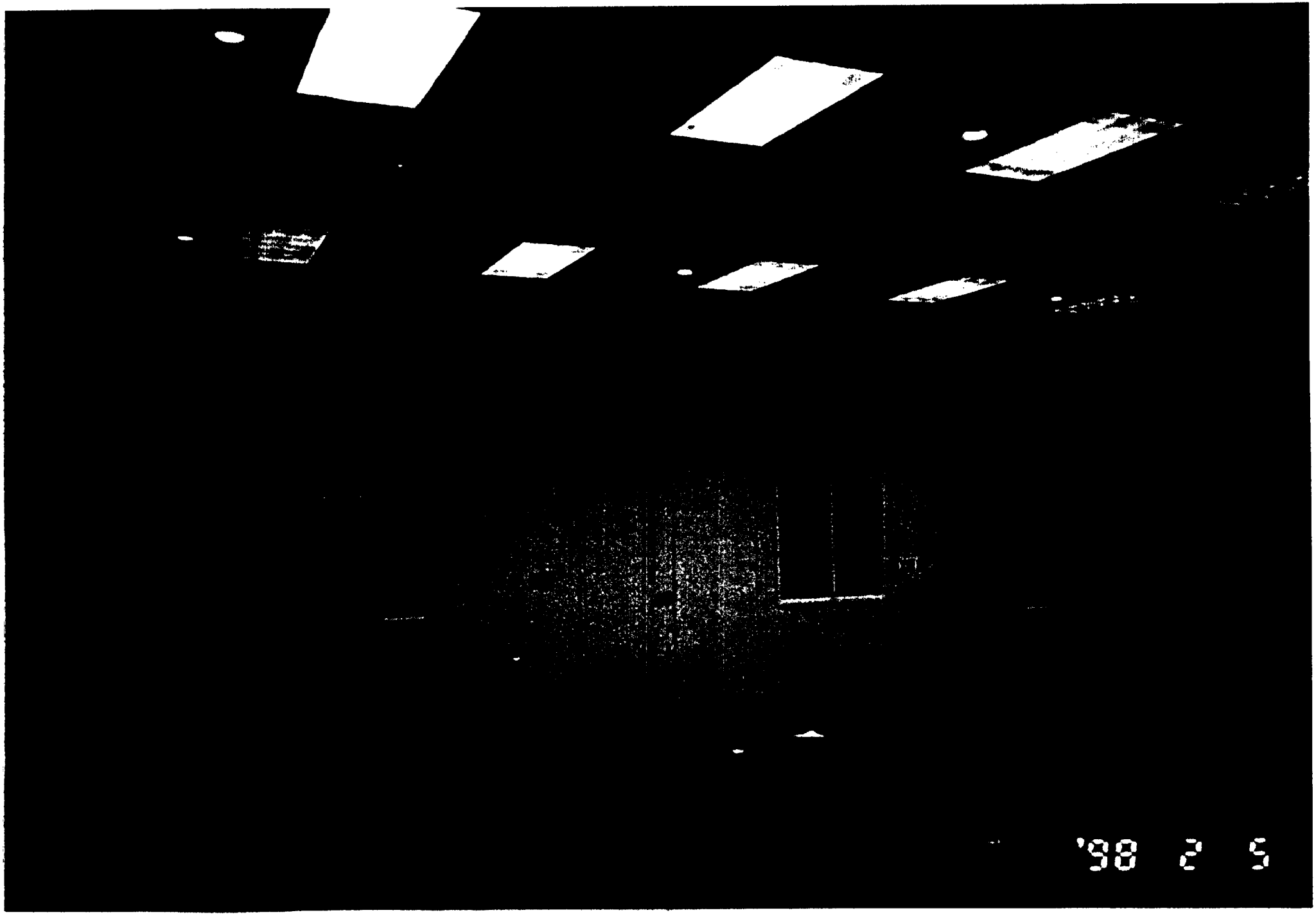
G980013-21-O-V



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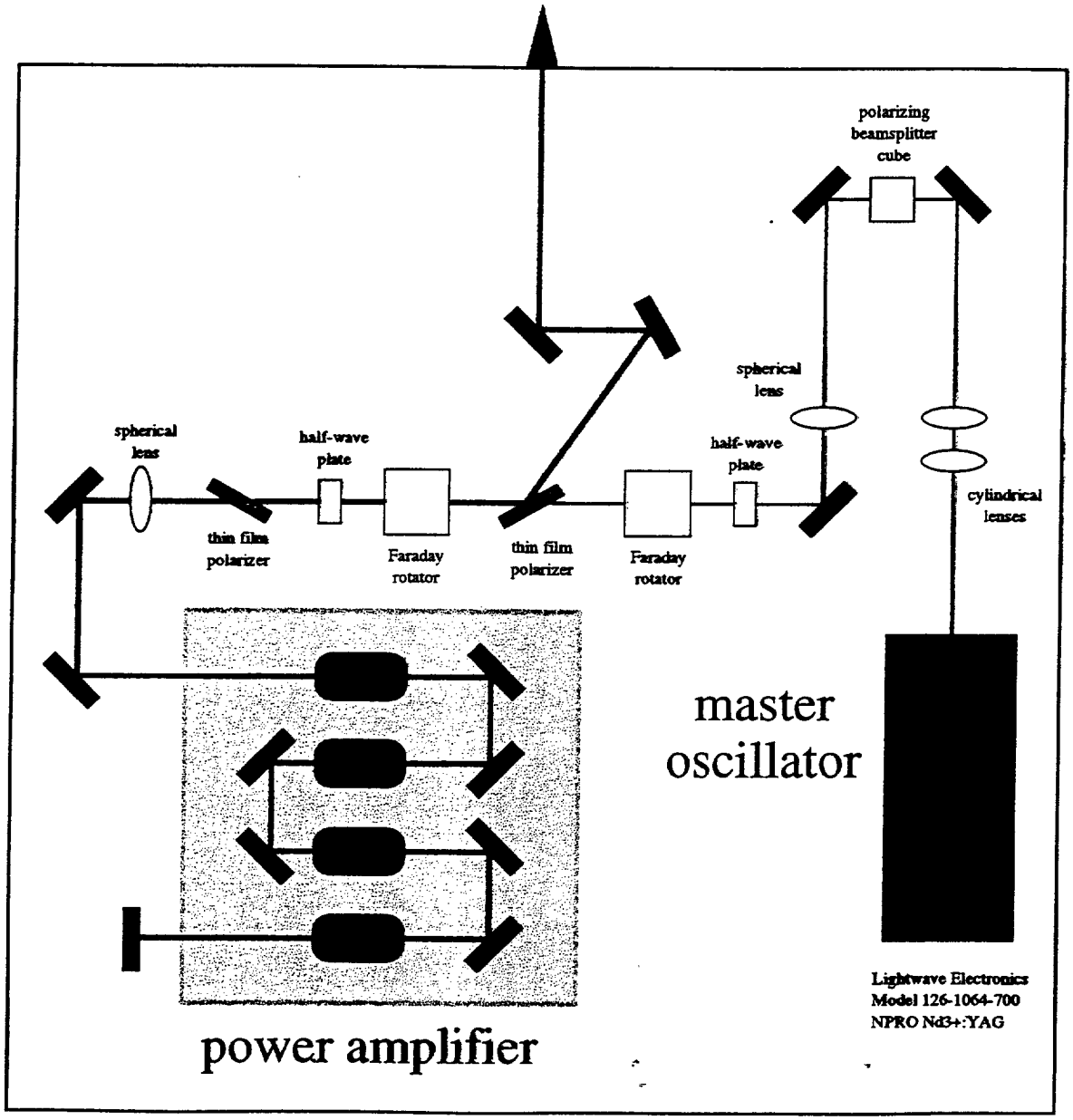
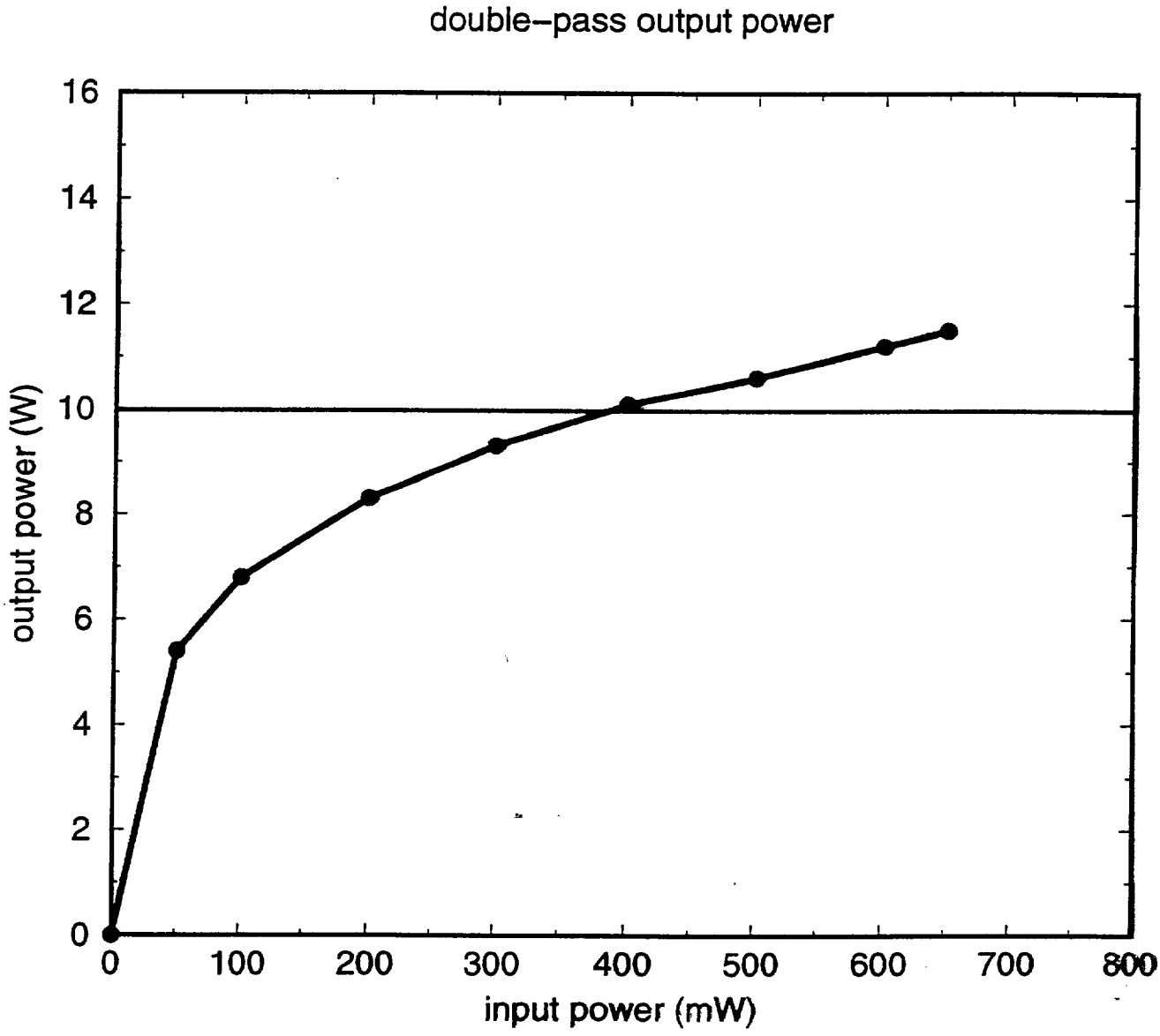
LIGO 10-W Laser Schematic Diagram



LIGO 10-W Laser Brassboard Unit Data



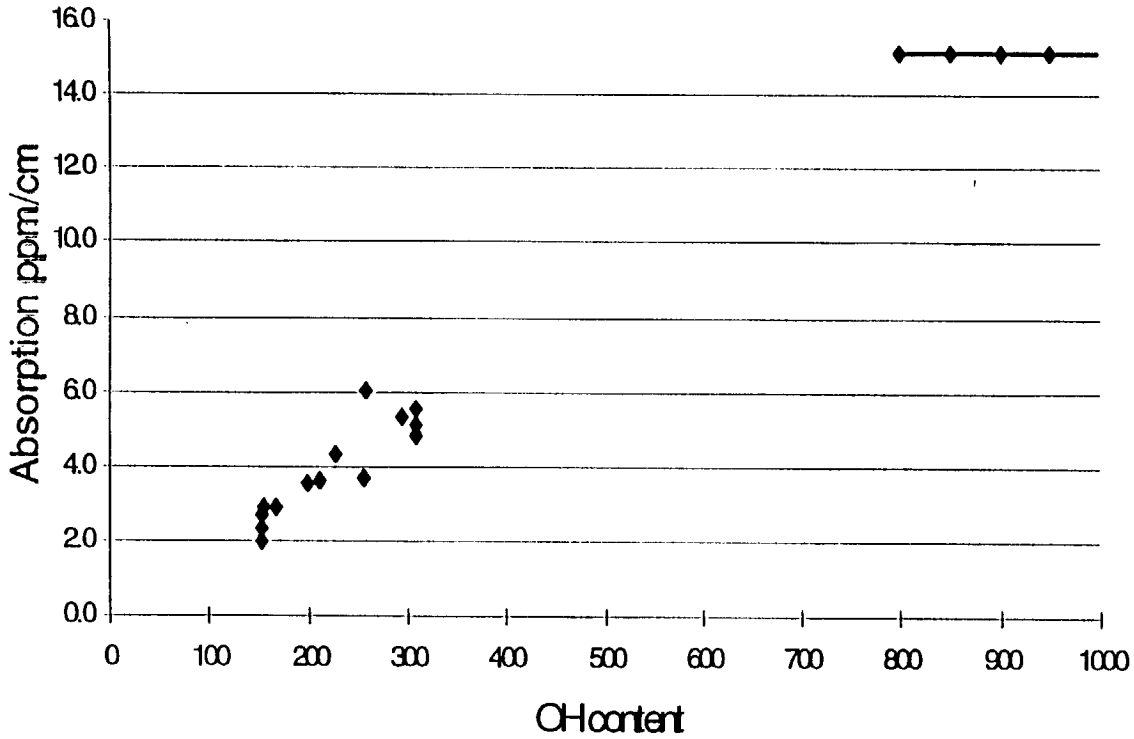
Pre-stabilized Laser Performance Requirements

- Output power
  - >> > 8.5 W in a circular TEM_{00} mode
- Beam quality
  - >> < 100 mW total in all non-TEM_{00} modes
- Relative power fluctuations in the gravitational-wave band
  - >> $< 10^{-7}\ 1/\sqrt{\text{Hz}}$ from 100 Hz to 10 kHz
- Relative power fluctuations above 24.5 MHz
  - >> < 1.005 × the shot noise limit for 600 mW of laser power
- Frequency fluctuations
  - >> $< 0.1 \times (100/f)\ \text{Hz}/\sqrt{\text{Hz}}$ from 100 Hz to 1 kHz
- Beam relative pointing angle fluctuations
  - >> $< 2 \times 10^{-6}\ 1/\sqrt{\text{Hz}}$

Core Optics Requirements

- High purity fused silica
  - ››25 cm diameter x 10 cm thick (except beamsplitter: 4cm thick)
  - ››Beams fill some optics (to ~1ppm level)
  - ››1064 nm HR mirrors and AR second surface coatings.
- Principal performance requirements:
  - ››< 50 ppm loss per surface (limits resonant stored energy: shot noise)
  - ››Surface figure errors to scatter negligible power from TEM_{oo} (best dark fringe)
    - — Similar requirement for bulk inhomogeneity
  - ››High mechanical Q to "suppress" thermal noise ($Q \geq$ few x 10^6)
  - ››Low bulk (<~5ppm/cm) and coating (<2ppm) absorption (thermal lensing limit to beam power and dark fringe contrast).

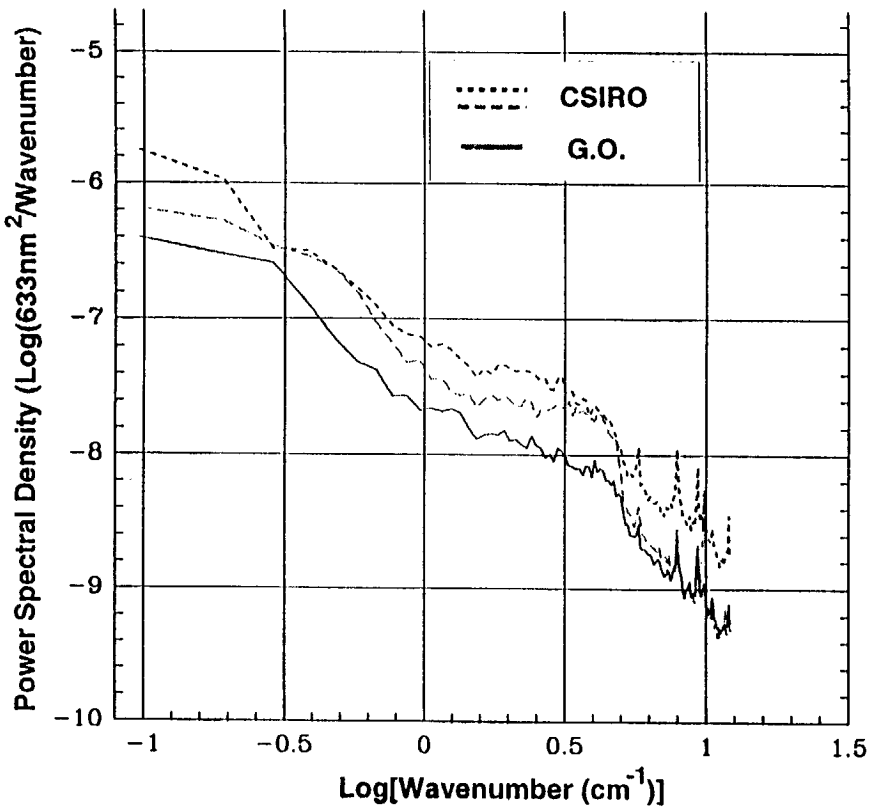
Absorption in Input Test Masses



›› Measured in collaboration with VIRGO

Pathfinder Polishing Surface Figure Results

›› NIST measurements of CSIRO and GO parts



One dimensional power spectra from NIST metrology of curved surfaces. Z(0,0),Z(1,1) Z(2,0),Z(2,2),Z(3,1),Z(3,3),Z(4,0) removed

Detector Status

detector/r&d

- Initial Detector
  - » most subsytems are in final design or under construction

- Detector focus
  - » Laser developed and constructed at Lightwave; prestablization at Caltech (Hanford summer 98)
  - » Input Optics - Florida (Hanford summer 98)
  - » Core Optics - optics, polishing (under construction)
  - » Seismic Isolation - procurements;(first article 98)
  - » Data Acquisition/Data Analysis - (construction)
  - » Length and Alignment Sensing - (design)

- R&D
  - » Phase Noise Interferometer - (near goal)
  - » 40 meter Interferometer - (recycling established)
  - » LIGO Lab advanced R&D program - (initiated)

FIRST COATED PATHFINDER OPTIC.
Inspected by Dale Ness at REO
Photo Courtesy of REO

Shot Noise

$$\delta h(f) \approx \frac{1}{L}\left(\frac{\partial \phi}{\partial x}(f)\right)^{-1} \delta\phi(f)$$

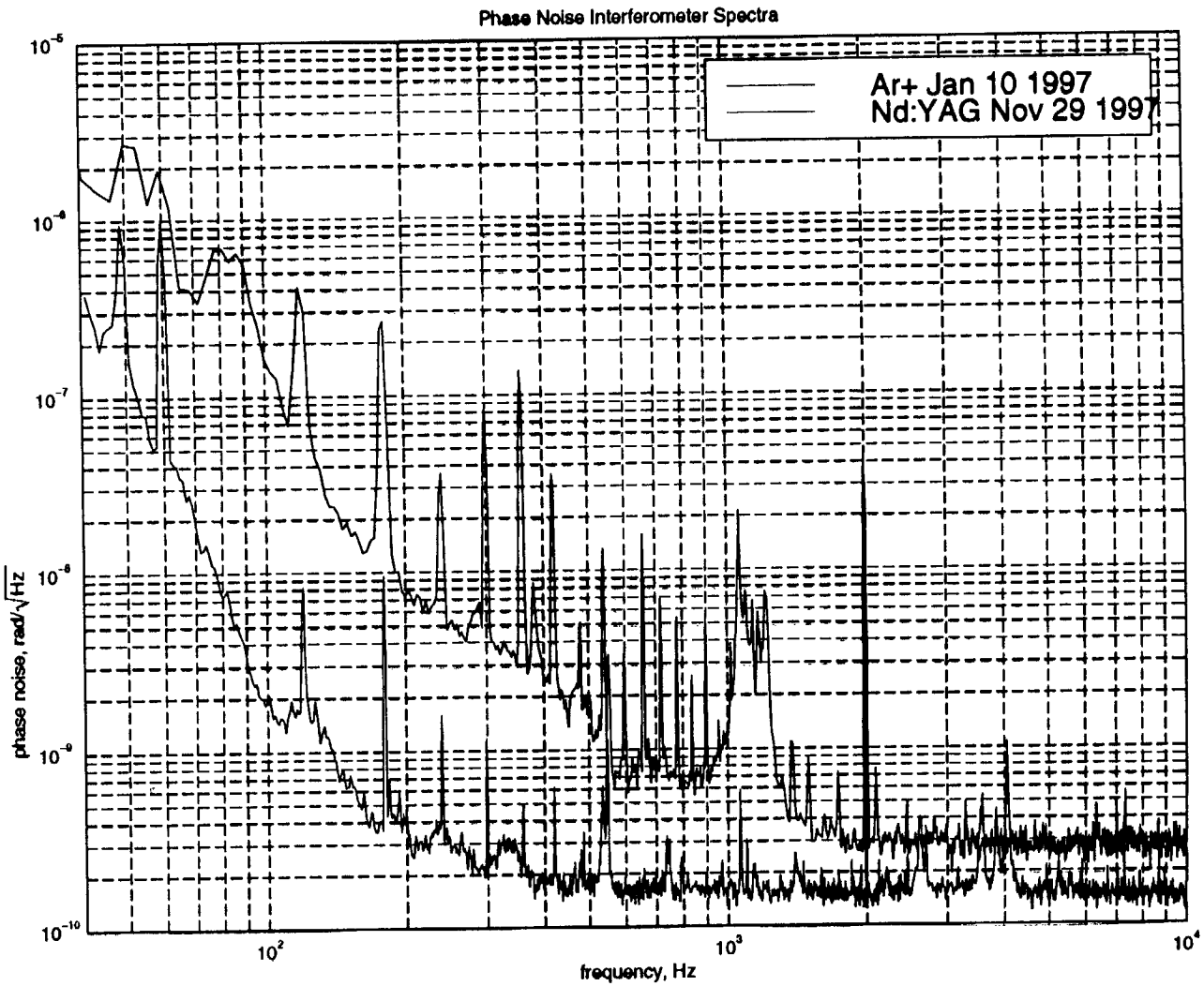
PROPERTY OF INTERFEROMETER OPTICAL CONFIGURATION (MIRROR R's, ETC.)

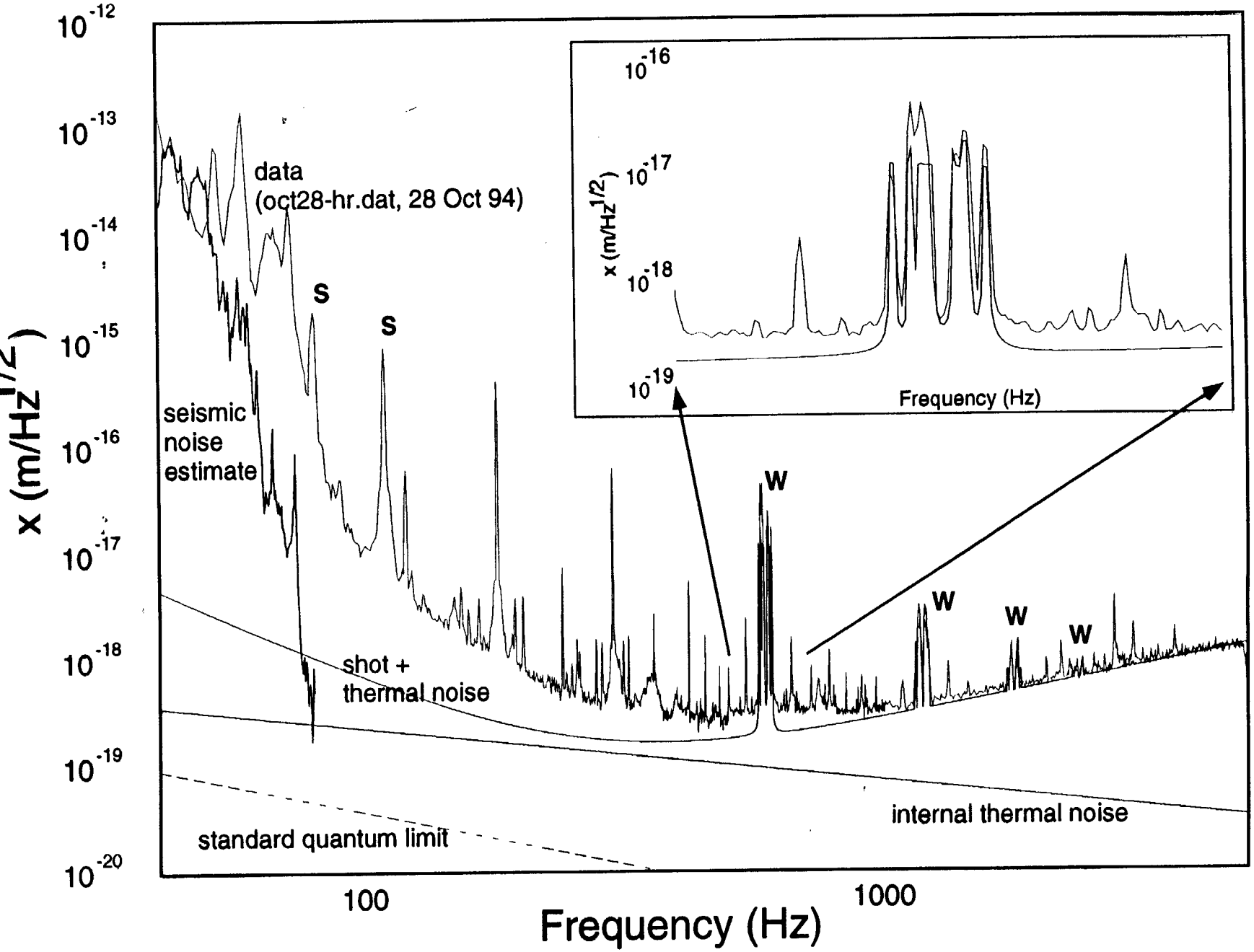
DETERMINED PRIMARILY BY EFFECTIVE OPTICAL POWER

- **Achieving Shot-Noise Limited Phase Sensitivity Requires Understanding and Control of All Other Optical Sources of Noise**
  - **Laser Noise**
  - **Photodiode Uniformity**
  - **Modulator-Induced Noise**
  - **Scattered Light**

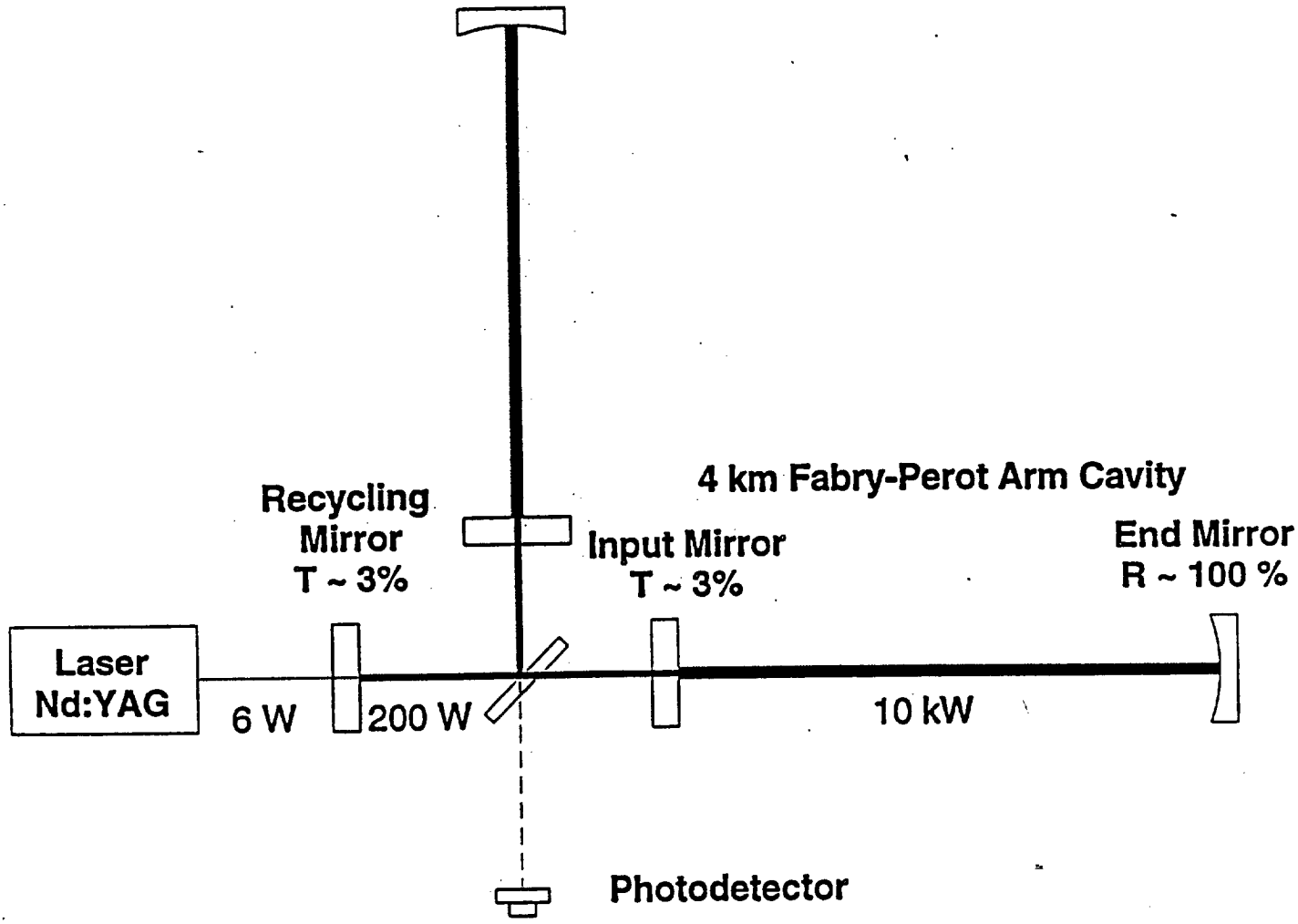
LIGO Requirement	$10^{-10}\ \mathrm{rad}/\sqrt{\mathrm{Hz}}$
Current 40-m Interferometer	$10^{-8}\ \mathrm{rad}/\sqrt{\mathrm{Hz}}$
MPQ Garching	$10^{-9}\ \mathrm{rad}/\sqrt{\mathrm{Hz}}$

PNI Spectrum



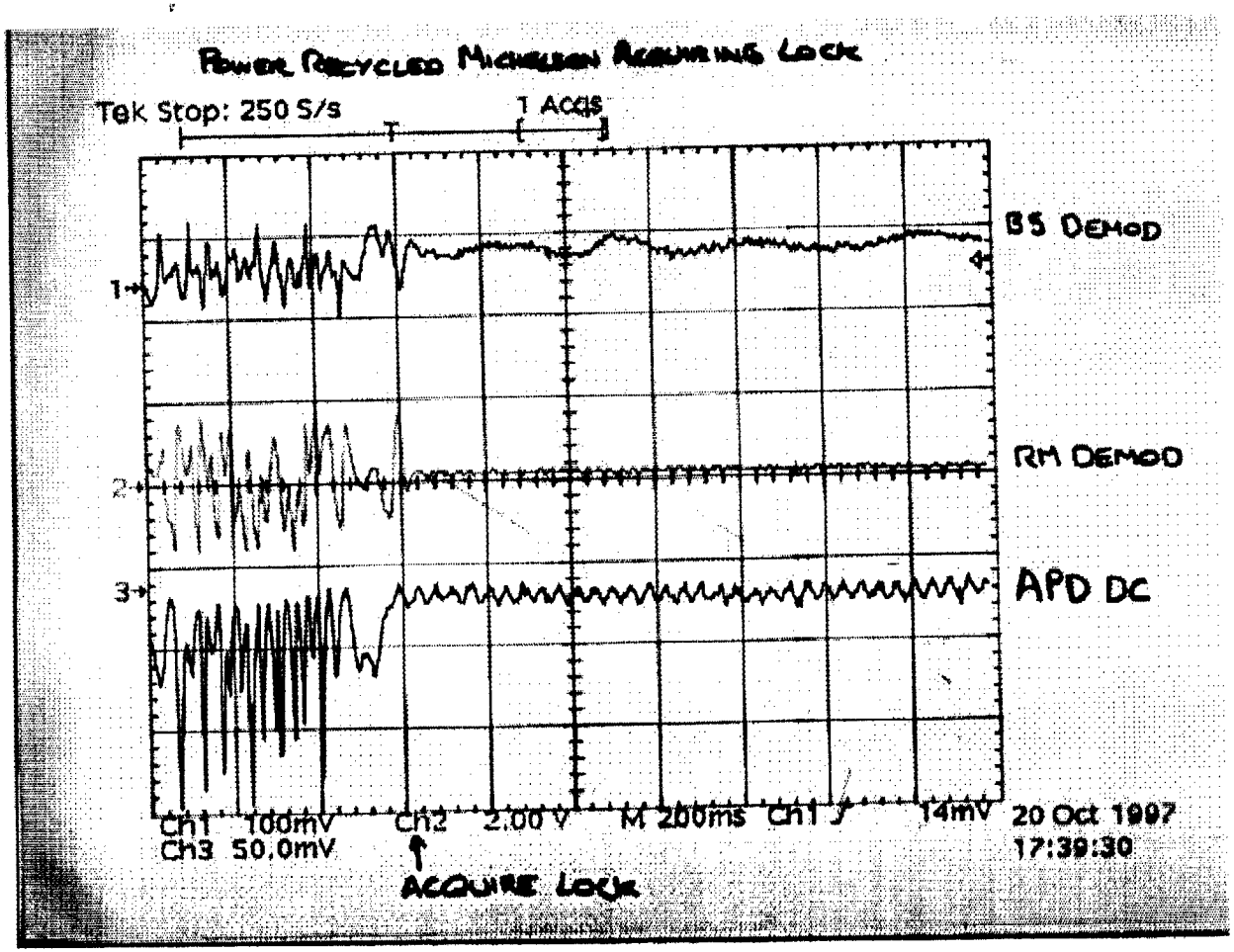

10^-12
10^-13
10^-14
10^-15
10^-16
10^-17
10^-18
10^-19
10^-20
x (m/Hz^1/2)
data
(oct28-hr.dat, 28 Oct 94)
S
S
seismic
noise
estimate
W
W
W
W
shot +
thermal noise
internal thermal noise
standard quantum limit
100
1000
Frequency (Hz)
10^-16
10^-17
10^-18
10^-19
x (m/Hz^1/2)
Frequency (Hz)

Initial Interferometers
Configuration



LIGO

Power Recycled Michelson Acquiring Lock



Technical Status

data and computing

- Detector Diagnostics
  - » concepts and design
- Data Analysis System (DAS)
  - » data formats - frames (VIRGO)
  - » architecture and design
  - » 40 m data to test DAQ/DAS systems
- End to End Simulations
  - » development and 40 m validations

These activities will interface with new LSC development groups

LIGO Laboratory & LIGO Scientific Collaboration (LSC)

LIGO Laboratory
formation

- Mission and Responsibility
  - » operate Hanford and Livingston
  - » assure scientific vitality of these facilities
  - » provide for acquisition of data, and systems for modeling and data analysis
  - » operate research and test facilities at sites and at MIT and Caltech
  - » support engineering design and fabrication of detector upgrades of new detector systems
  - » carry out R&D toward future LIGO program
  - » support LSC in exploitation of scientific goals
  - » review and coordinate new LIGO research initiatives
- Laboratory Charter
  - » approved by Caltech/MIT; final wording being determined with NSF
  - » Directorate, plus functional operational units for Hanford and Livingston Sites; Detector support, Data Analysis and Computing; Advanced R&D; Research Facilities; Technical and Engineering Support and Administration

LIGO Laboratory

MOUs and Attachments

- LIGO Laboratory and each LSC Collaborating Group work defined through an MOU, plus attachments for each activity (updated every 6 months)
  - » the attachments describe the program of the group, the collaborating persons and FTE equivalents; and the requests and responsibilities of the laboratory

- Initial MOUs and Attachments are ALL ready to sign for each institution to be charter members of LSC
  - » 201 collaborators (159 FTEs,)
  - » 19 collaborating groups (including LIGO Labs)
  - » 41 members on collaboration council

19 LSC Groups

Name	# Members	# FTE	# Council
*ACIGA	4	1.9	1
CaRT	7	3,4	1
CEGG	2	1.6	1
FLORIDA	12	10.15	3
GEO	26	13.45	3
*JILA	7	4.05	1
*LSU	5	2.35	1
*MICHIGAN	2	2.6	1
MOSCOW	10	9.0	2
NORTHWESTERN	4	4.0	1
OREGON	6	3.1	1
PENN STATE	1	1.0	1
STANFORD	19	13.05	3
SYRACUSE	4	4.0	1
UW-MILWAUKEE	4	2.25	1
Caltech	56	52.85	11
MIT	19	17.75	4
HANFORD	6	6.0	2
LIVINGTON	7	7.0	2
TOTAL	201	159.4	41

*OLD NUMBERS

LIGO Laboratory

LIGO Science Collaboration

The Laboratory is the responsible institution for LIGO, operated through a cooperative agreement with the NSF, and through an approved structure to Caltech/MIT, including oversight .

The scientific collaboration is created by and will be responsible to the Laboratory

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- LIGO Science Collaboration (LSC) carries out the LIGO science program .
- The LSC communicates with LIGO Laboratory, NSF and the community through the spokesman.
- LSC charter and publication policy under discussion.
  - » interface with Laboratory and Institutional programs must be determined

Note 1, Linda Turner, 04/20/98 03:15:54 PM
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