MIT Group Roles in LIGO R&D and Construction

M. Zucker
11/19/99

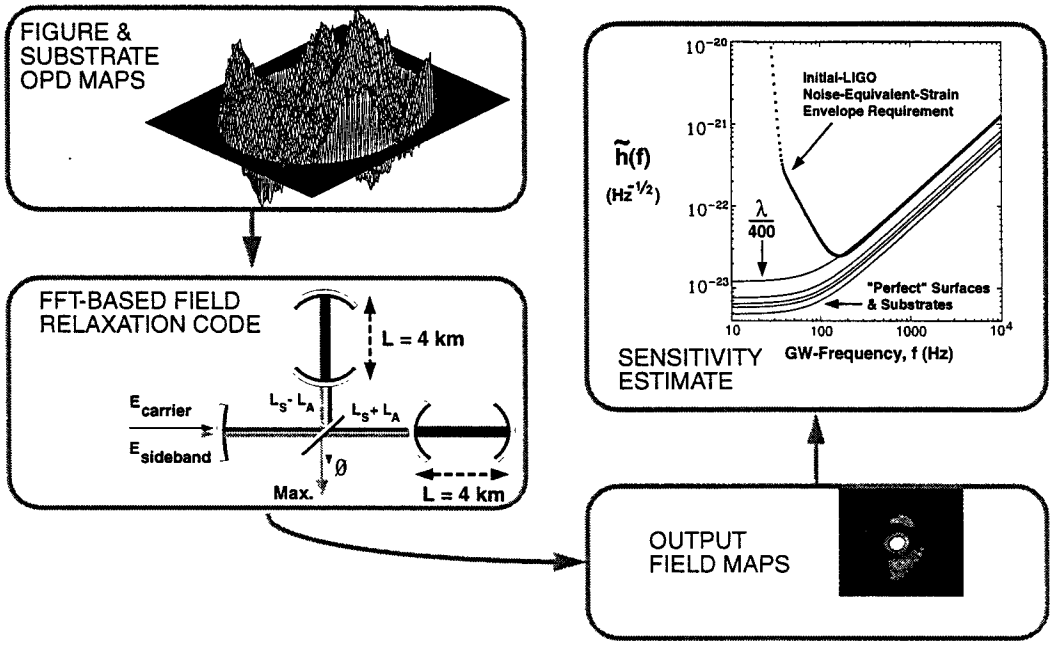
- Interferometer R&D
- Facilities Construction & Management
- LIGO I Detector Design & Construction
- LIGO I Detector Integration & Commissioning*
- Detector Diagnostics & Data Analysis
- Campus Operations & Commissioning Research

* see yesterday's talks by Coyne & Fritschel

Selected MIT Group LIGO I R&D Highlights

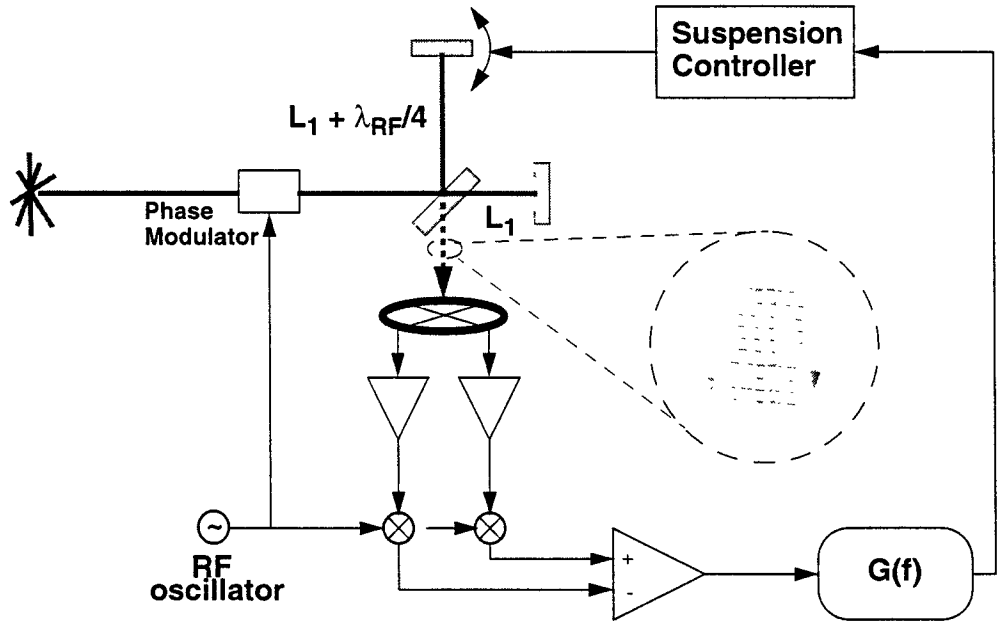
- Early Nd:YAG laser development
- Seismic isolation stack proof of concept
- Beamtube steel outgassing
- Beamtube baffle scattering analysis & experiments
- Tabletop recycling demonstration
- Core optics FFT code modeling & metrology analysis
- Photodetector development
- FMI experiment & wavefront sensing
- Digital control system development & test
- PNI experiment

Optics Simulation & Metrology Analysis

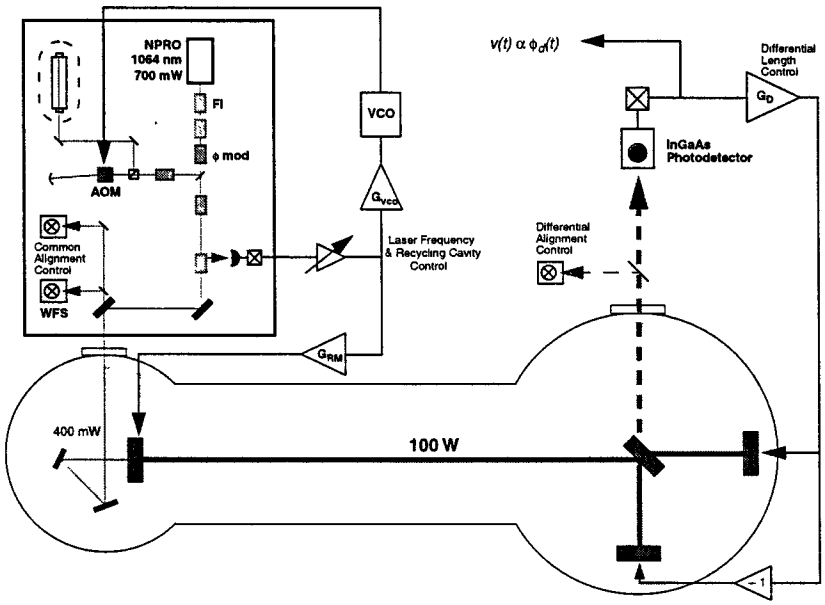


FWI Experiment & Wavefront Sensing

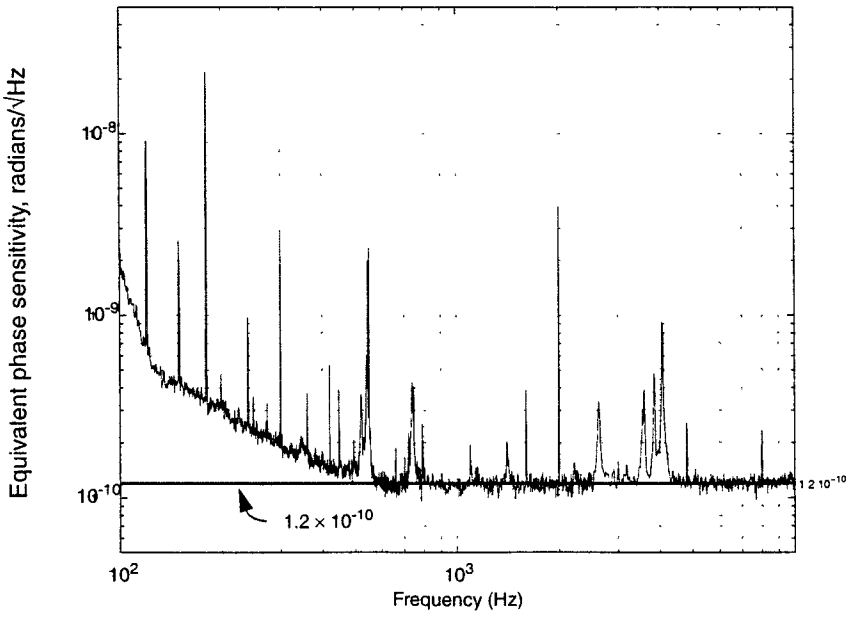
Simple Michelson interferometer with deliberate arm asymmetry



Phase Noise Interferometer



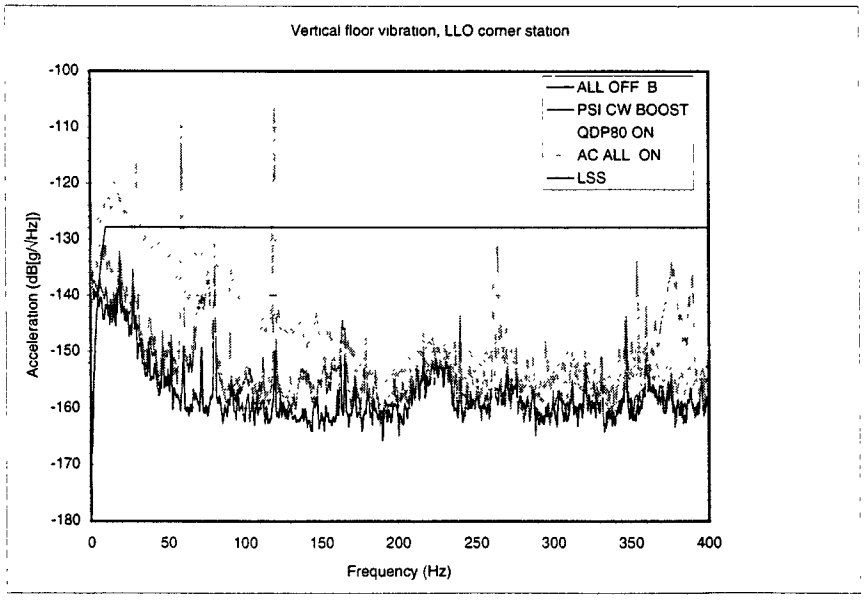
Phase Noise Interferometer



LIGO Facilities Construction & Management

- Integration Scientist: R. Weiss
  - ◊ Facility vibration, acoustic & EMI background characterization of buildings, optical baffling design & testing, ...
- Beam Tube Cognizent Scientist: R. Weiss
  - ◊ Beam tube science requirements, design & fabrication, beam tube bakeout QA, residual gas composition monitoring and modeling
- Vacuum Equipment Cognizent Scientist: M. Zucker
  - ◊ Vacuum equipment science requirements, design & fabrication, detector interfaces, vibration and acoustics analysis & testing , outgassing & contamination investigations

Vacuum Equipment vibration characterization



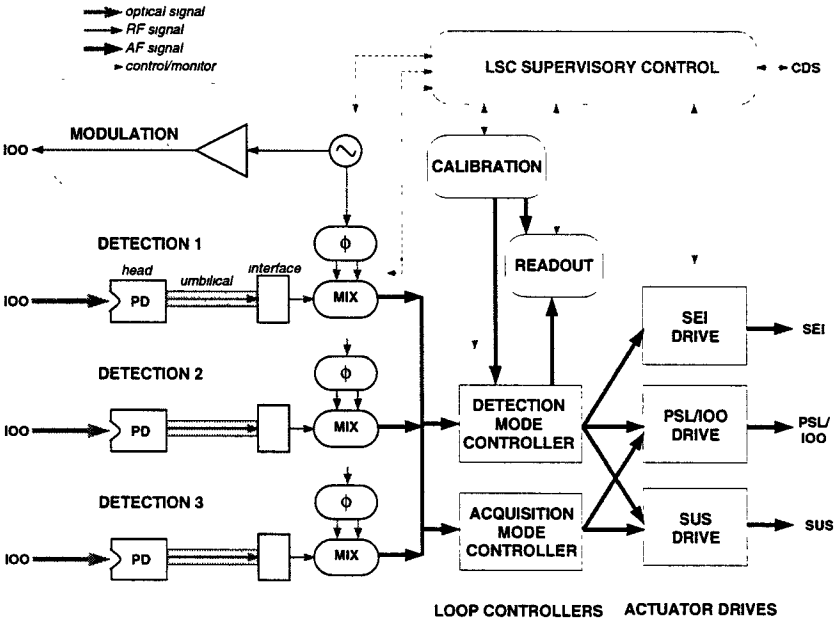
Detector Design & Construction

- D. Shoemaker serves as Deputy Detector Group Leader and Systems Engineer
  - ◊ Responsible for requirements allocation and global interface definition
  - ◊ Evolving now into supervisory commissioning role
- MIT group is responsible for 2 primary LIGO I detector sub-systems
  - ◊ Design
  - ◊ Fabrication
  - ◊ Installation
  - ◊ Commissioning

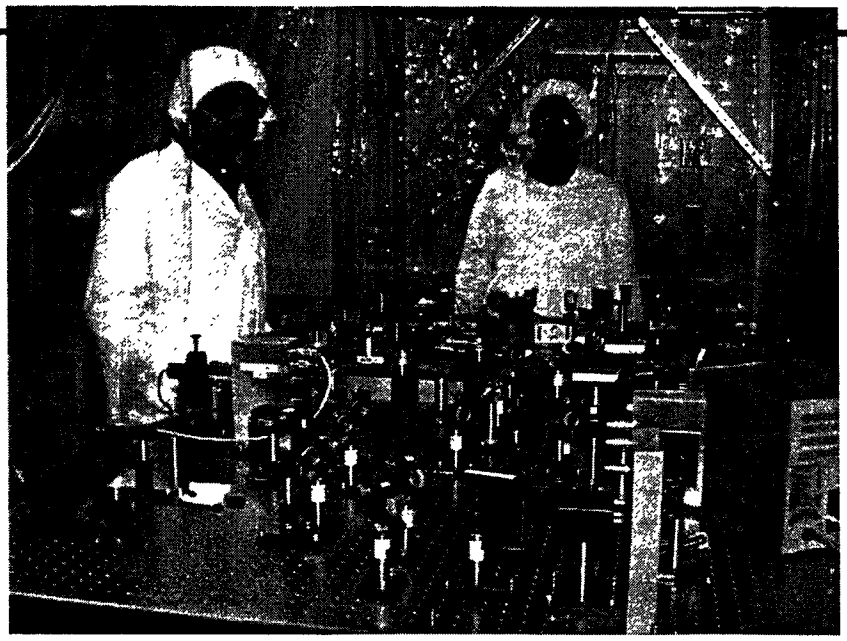
MIT-led Detector Subsystems

- Physics Environment Monitoring (PEM); Seismic, acoustic, vibration, magnetic, electrostatic, RF sensors which permit:
  - ◊ Characterization of sensitivity to local environment (to improve immunity)
  - ◊ Regression of known influences from recorded data
  - ◊ Coincidence veto of false signals induced by environmental disturbances
- Interferometer Sensing & Control (ISC); Photodetectors, feedback controls, digital and analog signal processing, surveying instruments to:
  - ◊ Initialize and maintain alignment & positions of LIGO optics
  - ◊ Sense and control optical phase shift, wavelength and mirror positions to achieve and maintain interference & optical resonance conditions
  - ◊ Provide calibrated readout of gravitational wave strain

LSC Functional Block Diagram



LSC Sensing Table Assembly



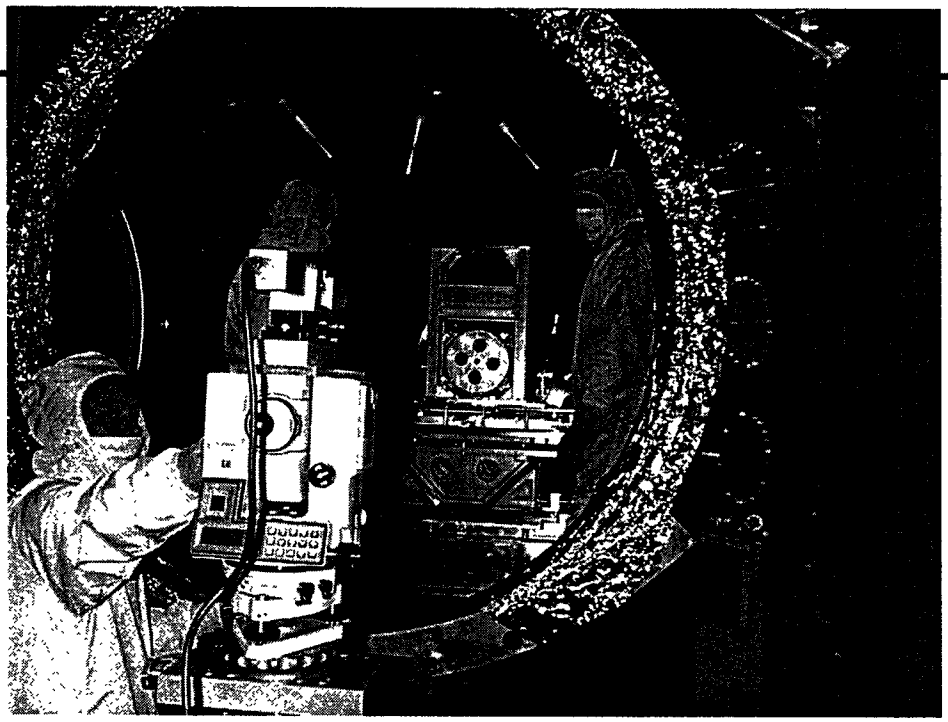
Detector design & construction (cont'd)

- Both ISC and PEM subsystems have broad reach
  - ◊ ISC sensing, conditioning bears "output" of all subsystem effects
  - ◊ PEM (ideally) bears "input" of all (non-gravitational) influences
  - ◊ ISC servos optimize overall operating conditions (mechanical, optical, electronic)
- Natural interplay with Global Diagnostics system
  - ◊ Contribution of working GDS code modules
  - ◊ Testing of GDS software/hardware
  - ◊ Integration of GDS software with ISC digital controls code

Detector Integration & Commissioning

- Initial alignment of each core optic to global references
- Installation & test of ISC, PEM, GDS hardware/software
- Mediation of subsystem interfaces
- Diagnostics & machine-oriented data analysis
- Shoemaker, Fritschel, Weiss have lead roles in commissioning
- Typically 1/4 of total FTE's are currently spent at LIGO sites averaged over group (individuals vary between 15% and 100% depending on responsibilities and current phase of integration)

Initial Alignment of Core Optics



Diagnostics & Data Analysis

- Current emphasis on "detector - out" approach, less on astrophysics-driven aspects
- ISC and PEM have special diagnostic needs
- ISC has strong influence on recorded GW signal characteristics & instrument signature
- PEM key to reducing "accidental" local backgrounds
- Example ongoing investigations:
  - ◊ IInter-site B-field correlations (S. Veatch, S. Chatterji)
  - ◊ IInter-site seismic correlations (S. Chatterji)
  - ◊ Intra-site microseism analysis (E. Daw)

Operations & Commissioning Research (some examples)

- Vacuum contamination & outgassing measurement
- Surface analysis
- Optical scattering analysis
- O-ring material characterization & "sticking" mitigation
- Flourel spring seat outgassing experiments and production processing
- Feed-forward microseismic cancellation
- Inter-site environmental correlations

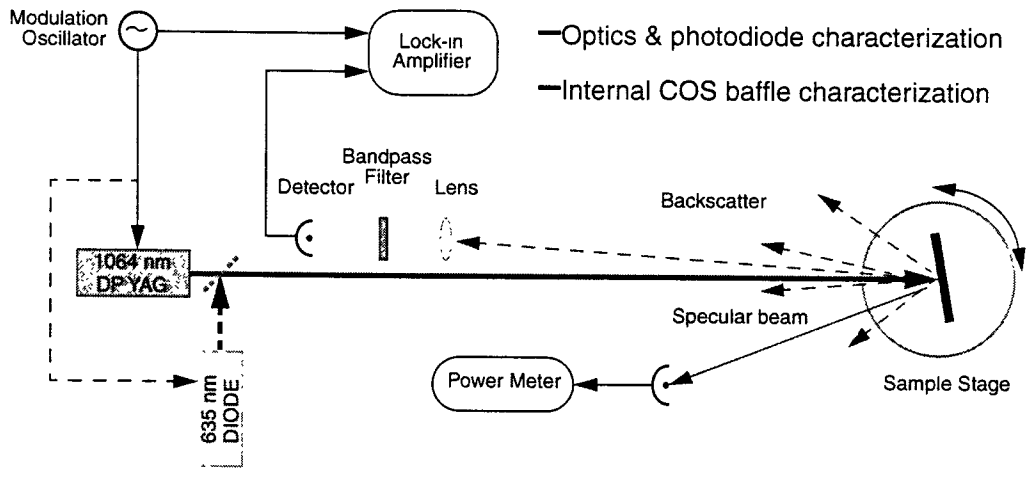
Small-Angle IR/Visible Scatterometer

—Beam tube baffle design & mfg. QA

—Chamber & tube finish evaluation

—Optics & photodiode characterization

—Internal COS baffle characterization



Flourel Spring Seat Outgassing Experiment