LASTI Interferometer Facility at MIT: Program to Support LIGO II Upgrades

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Guiding philosophy:

Upgrading LIGO detectors entails interrupting astrophysical observations.

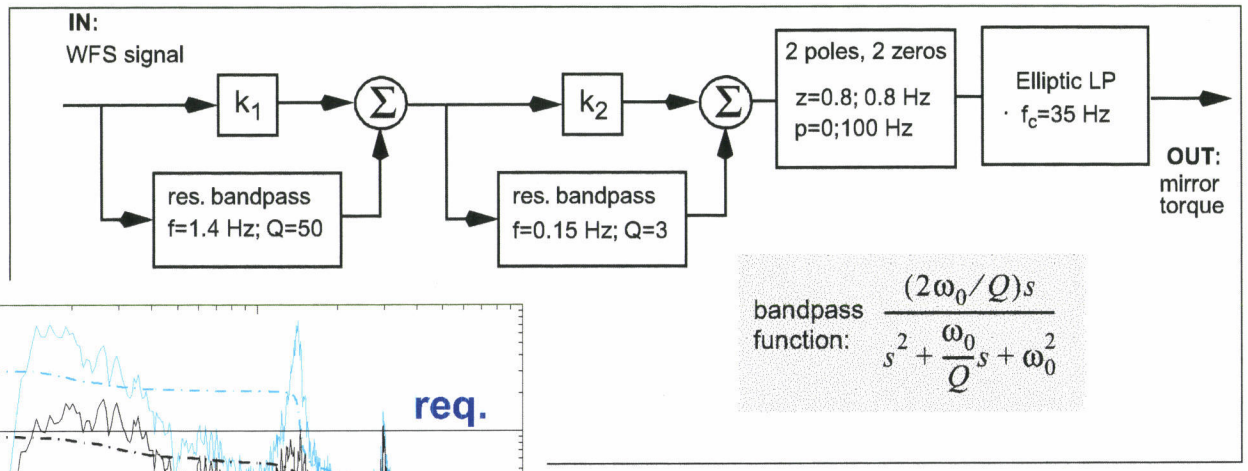
Upgrade technologies must be exhaustively tested offline before integration at the sites.

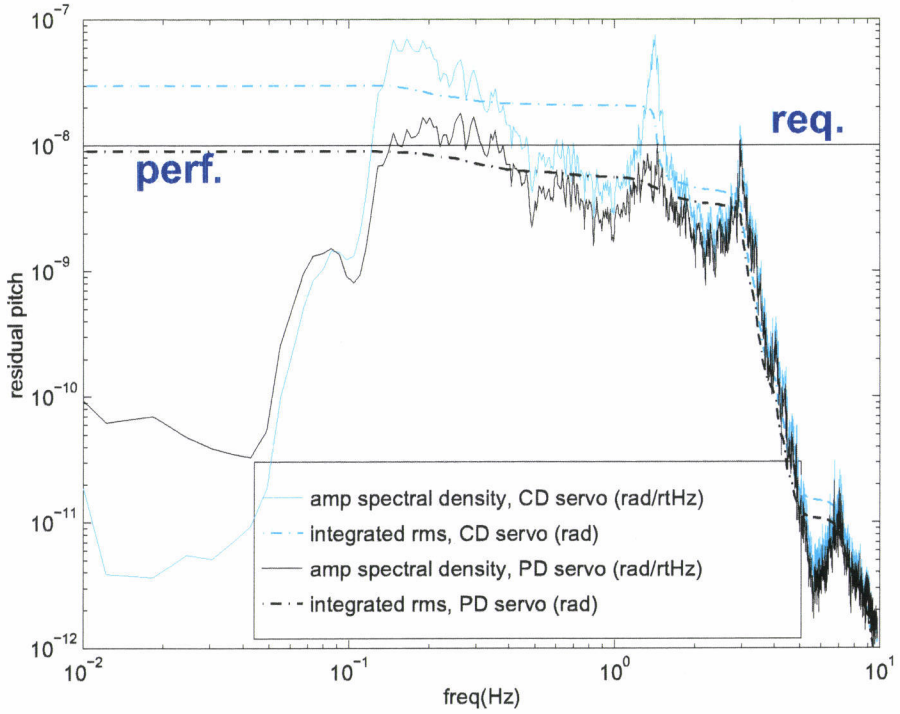
Campus prototypes are agile, flexible and provide key design validation but, until now, none could accommodate full scale suspension and isolation components.

The LIGO Advanced System Test Interferometer (LASTI) at MIT will address this gap; end-to-end integrated testing of optics, mechanics and control systems at final scale is its primary mission.

LIGO I scaling example: alignment control & isolation stack interaction

Equivalent SISO model





Performance vs. RMS residual requirement (end test mass pitch, Livingston seismic noise, Hytec Leaf Spring stack model)

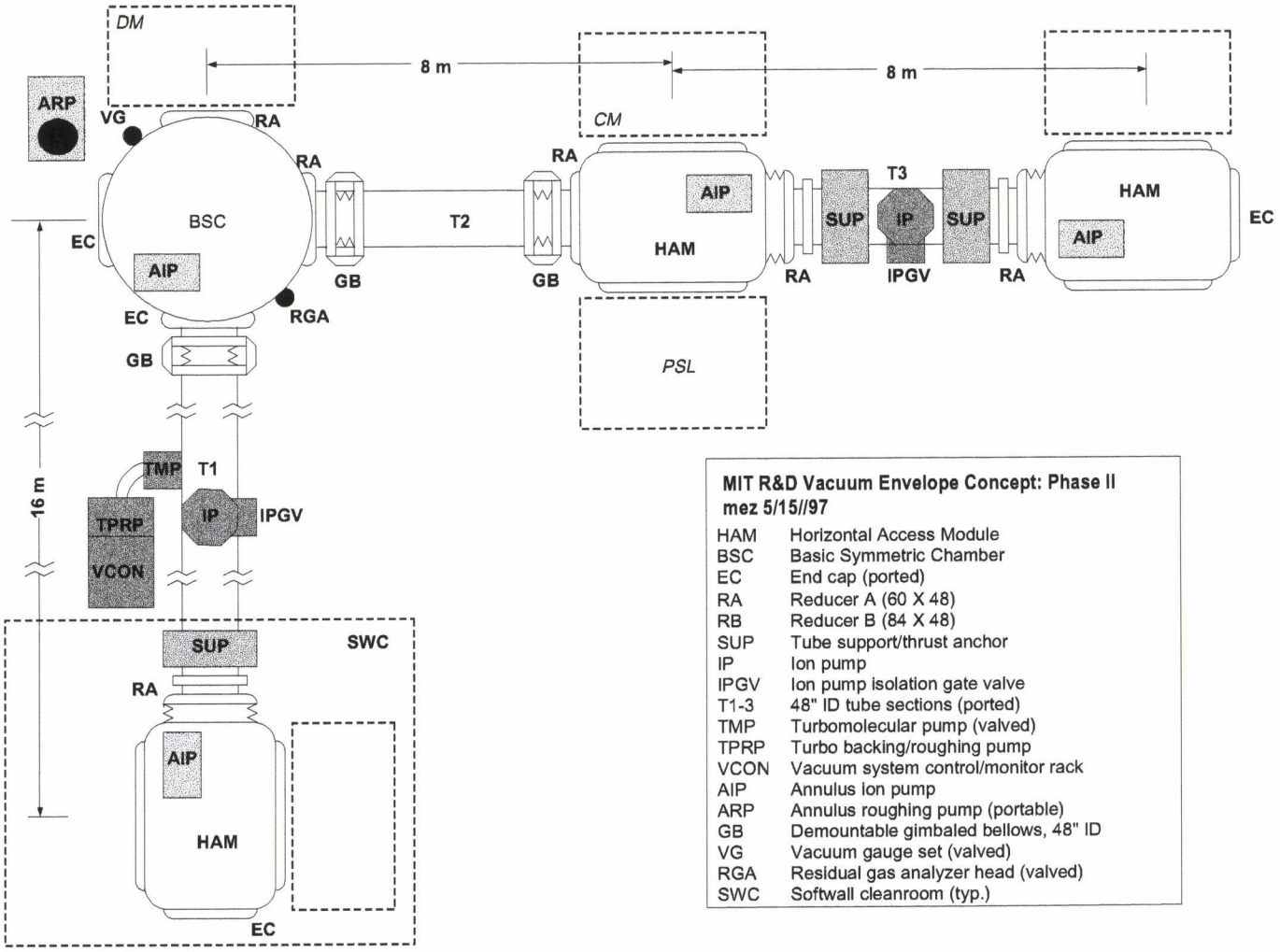
LASTI Laboratory Infrastructure

- New lab space renovated/expanded by MIT as part of LIGO group relocation from Building 20 to NW-17
  - ◊Approx. 14,000 ft^2 of renovated lab/shop space, 4500 ft^2 L-shaped high-bay
  - ◊Dual-hoist bridge cranes, HEPA-filtered HVAC system, 300 kVA electricals, dedicated chiller plant...
  - ◊Completed 9/98
- MIT also allocated $0.5M for active (ex-vacuo) antiseismic system development and installation
- Softwall cleanroom procured from PSI at end of LIGO vacuum equipment contract

LASTI Vacuum Envelope & Basic Internal Structures

- 4 chambers; 1 BSC-type, 3 HAM-type (built by PSI at end of LIGO chamber production run)
- 30" connecting tubes (same design as LIGO mode cleaner tubes)
- Pumping & instrumentation mostly spares from LIGO production (CBI, PSI closeouts)
- 1 complete BSC seismic isolation stack and 1 complete HAM isolation stack (end of LIGO I production)
- Basic seismic support structures in other two HAM chambers

LASTI Vacuum Envelope



MIT R&D Vacuum Envelope Concept: Phase II
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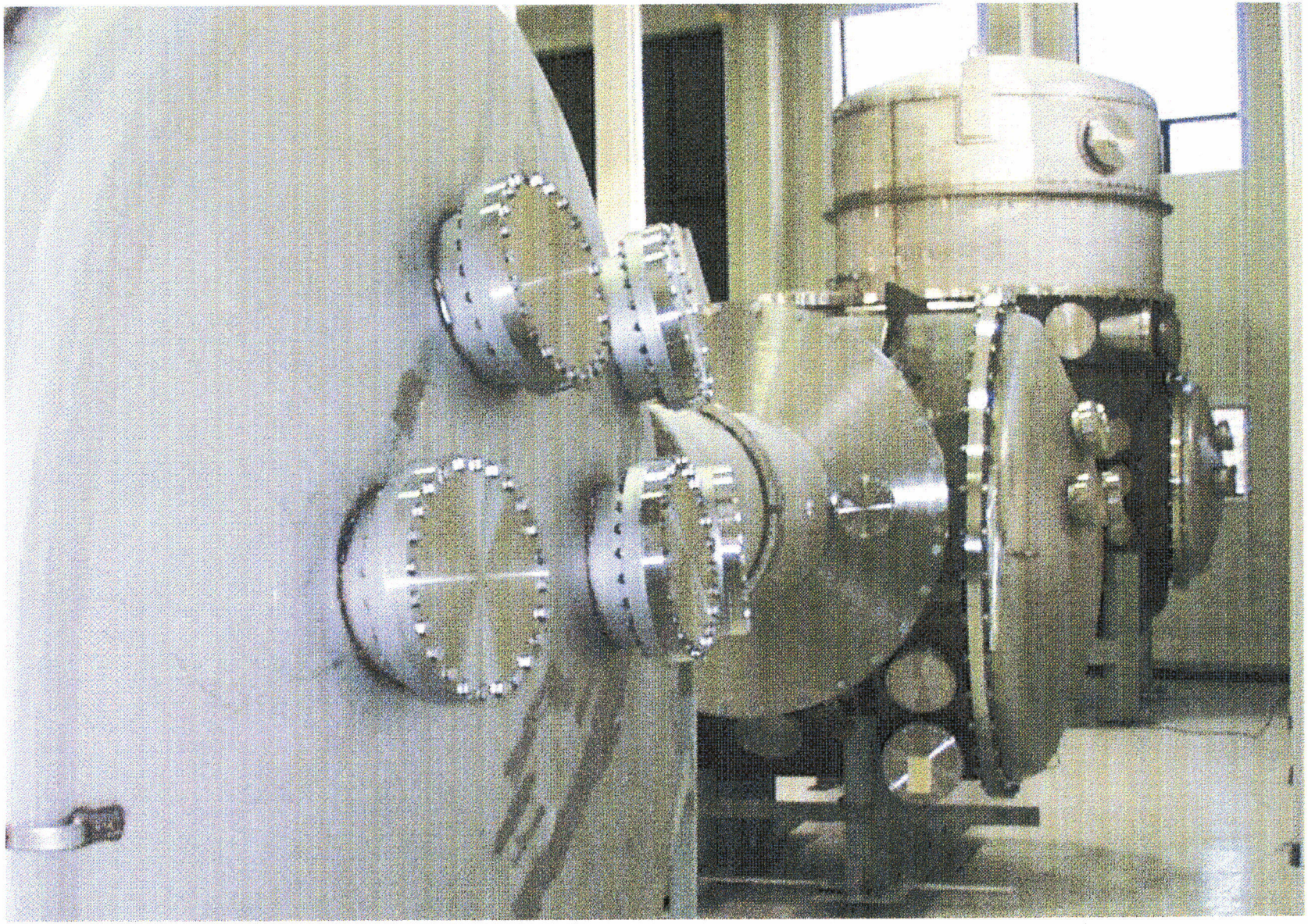
HAM	Horizontal Access Module
BSC	Basic Symmetric Chamber
EC	End cap (ported)
RA	Reducer A (60 X 48)
RB	Reducer B (84 X 48)
SUP	Tube support/thrust anchor
IP	Ion pump
IPGV	Ion pump isolation gate valve
T1-3	48" ID tube sections (ported)
TMP	Turbomolecular pump (valved)
TPRP	Turbo backing/roughing pump
VCON	Vacuum system control/monitor rack
AIP	Annulus ion pump
ARP	Annulus roughing pump (portable)
GB	Demountable gimbaled bellows, 48" ID
VG	Vacuum gauge set (valved)
RGA	Residual gas analyzer head (valved)
SWC	Softwall cleanroom (typ.)



LIGO II Suspension and Isolation Development Plan: Timing Constraints

- Timing set by '04 completion of LIGO I science run
- For integration during late '04, final engineering & start of fabrication is needed in Q2 '02 (earlier for long leads, e.g., core optics)
- Full-scale testing of engineering prototypes should be *completed* by Q1 '02; allow minimum 9 mos.-1 yr. from test start to satisfactory design validation
- Construction & shakedown of campus test interferometers & infrastructure needs to start Q1 of '00 (earlier for long leads, e.g., core optics & laser system)

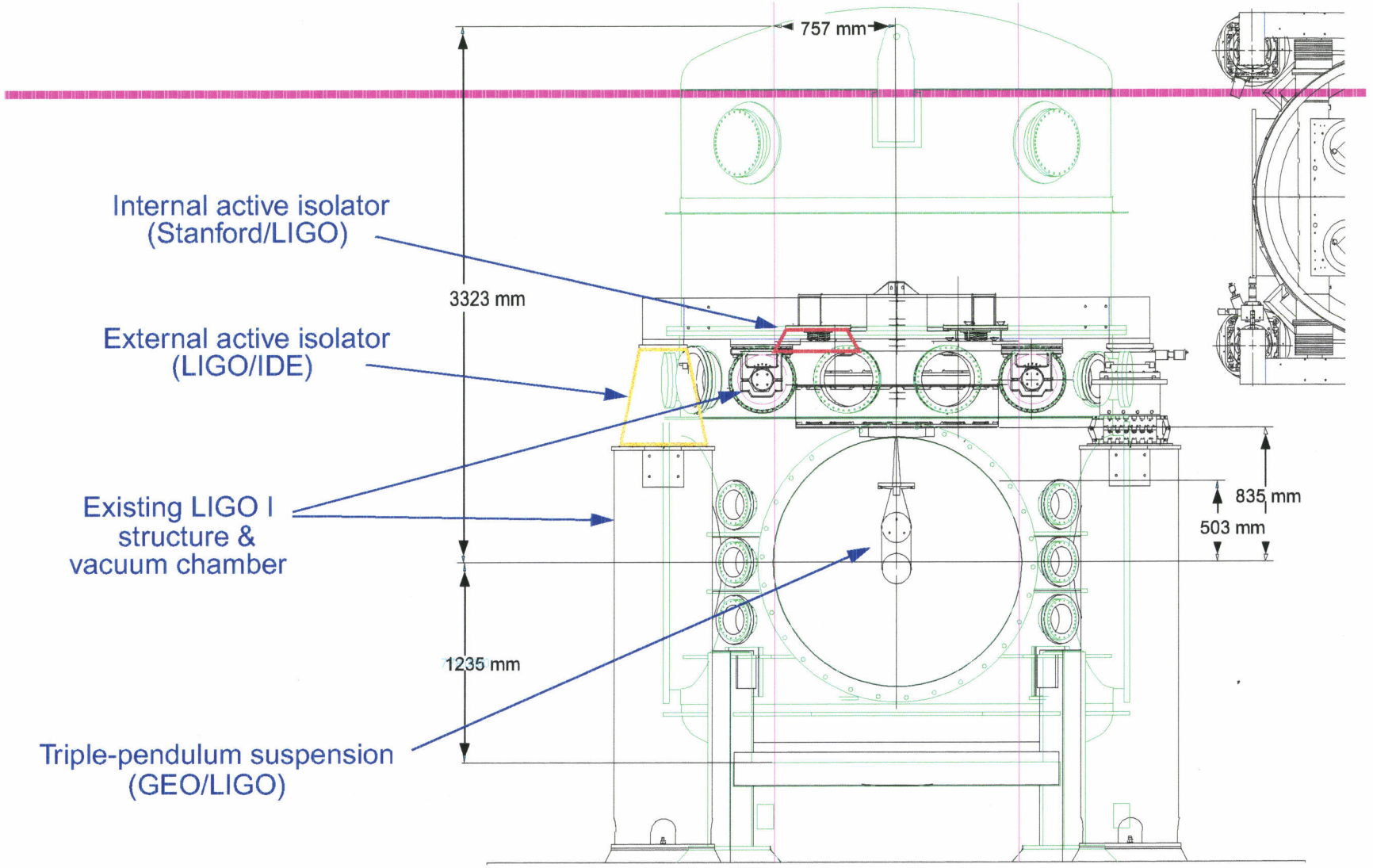
LASTI Instrumentation: Primary Technical Goals

- Prove out controllability, control authority and interactions
  - ◊Scalable allocation of control forces among actuation stages, damping of suspension modes, interaction of active & passive stages
  - ◊Operation with final-stage dynamic reserve of LIGO II design (i.e., μN forces)
- Test for unexpected displacement noise@ high sensitivity
  - ◊Catch & diagnose, or rule out, spurious noise generation at LIGO II displacement noise goal or better (< 10^{-19} $mHz^{-1/2}$ at 100 Hz)
- Comprehensive "secondary" instrumentation
  - ◊Suspension fiber resonance monitors (Syracuse)
  - ◊Vertical "strain release" sensors
  - ◊Network of geophones, accelerometers, magnetometers, etc.

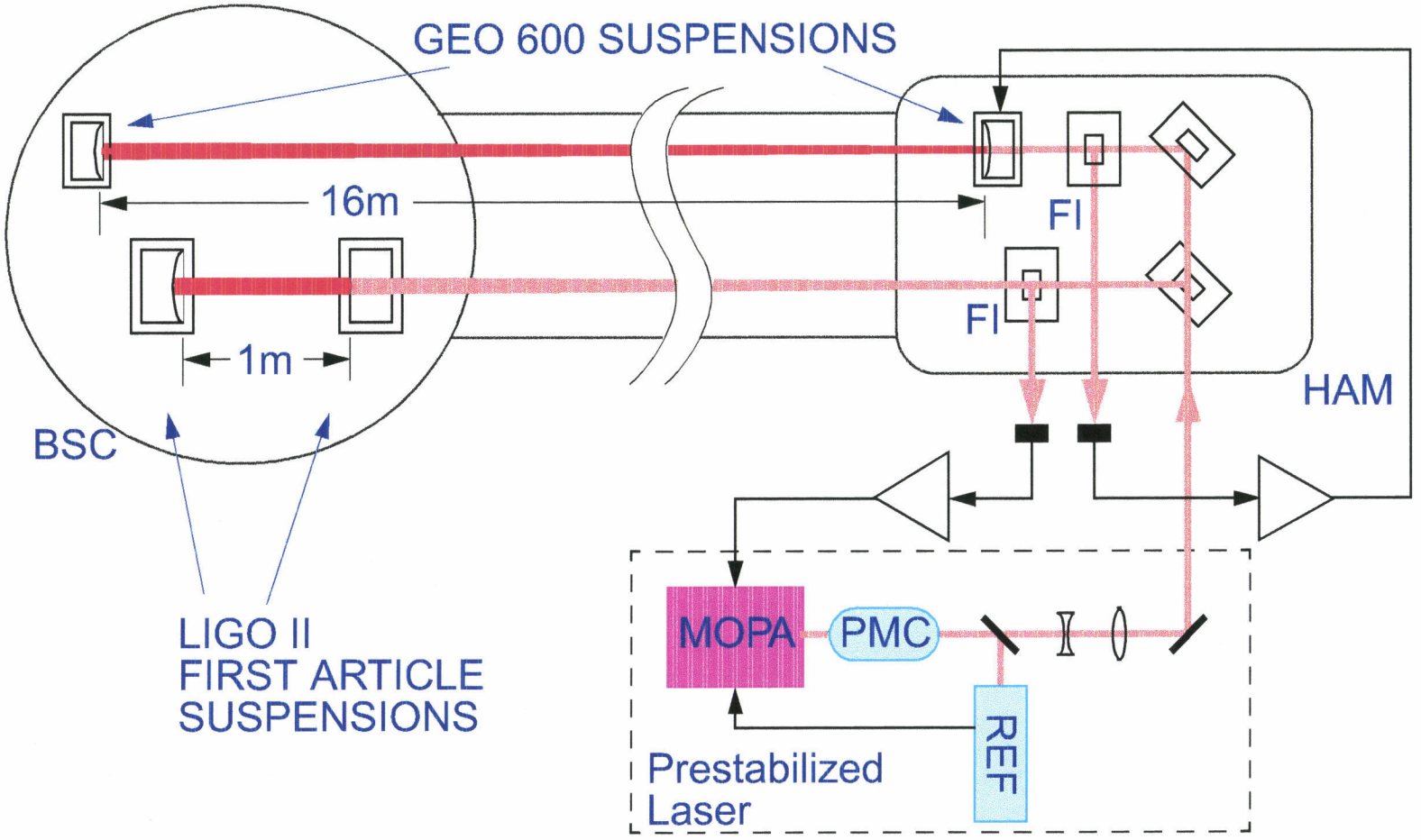
Other LASTI Goals

- Compatible infrastructure
  - ◊Cleanroom & vacuum compatibility exactly as for LHO/LLO installation
  - ◊Handling, assembly and installation techniques to be "proved out" on LASTI => *solutions must migrate easily to LHO/LLO*
- Modular and scalable IFO architecture
  - ◊Final suspension/isolation configuration is not available initially; build up initially with stand-ins (LIGO I stacks + PNI, LIGO I SOS or GEO suspensions)
  - ◊Optical system compatible with measuring final pendula and intermediate stage noise required
  - ◊Ability to match large-diameter beam size and/or scan small beam across mirrors if desired, to explore internal mode thermal noise scaling
  - ◊Flexibility to target specific performance issues discovered in run-up prototype tests & modeling

Possible Test Target (one of a few)



Conceptual design for LASTI interferometer (preliminary)



Proposed evolution of LASTI features

- Phase A (~ '00-'01):
  - ◊Optics/controls: uncoupled independent FP's; NPRO locked to one arm, no mode cleaner
  - ◊Mechanics: PNI or LIGO I SOS suspensions (BS, MMT, FI, TM's) plus two "test article" super-suspensions, LIGO I coil stack (w/active external stage)
  - ◊Objectives: controllability, stage interaction dynamics, residual RMS/peak motion, electrostatic drive, distributed control authority (at FULL SCALE)
- Phase B (~ '01+):
  - ◊Optics/controls: higher finesse FP's, recombined; 10W MOPA; suspended mode cleaner; suspension point IFO; large mode capability
  - ◊Mechanics: Short arm with two "test article" super suspensions & advanced LIGO II seismic system; other suspensions GEO double/triple
  - ◊ Objectives: 10^{-19} $mHz^{-1/2}$ or better at TM; corresponding at susp. pt.

Program timeline

Activity	Dates
Vacuum system commissioning & test	6/99-7/99
Seismic isolation installation	8/99-10/99
LASTI system design review	11/99
Procure core optics	11/99-9/00
Prestabilized laser construction/test	12/99-5/00
Phase A IFO commissioning	4/00-12/00
Phase A suspension testing	1/01-4/01
Phase B reconfig/commissioning	4/01- 9/01
Phase B suspension/isolation qualification	6/01-2/02
Phase B completion	3/02
LIGO II suspension & isolation design review	4/02