Detector Research & Development

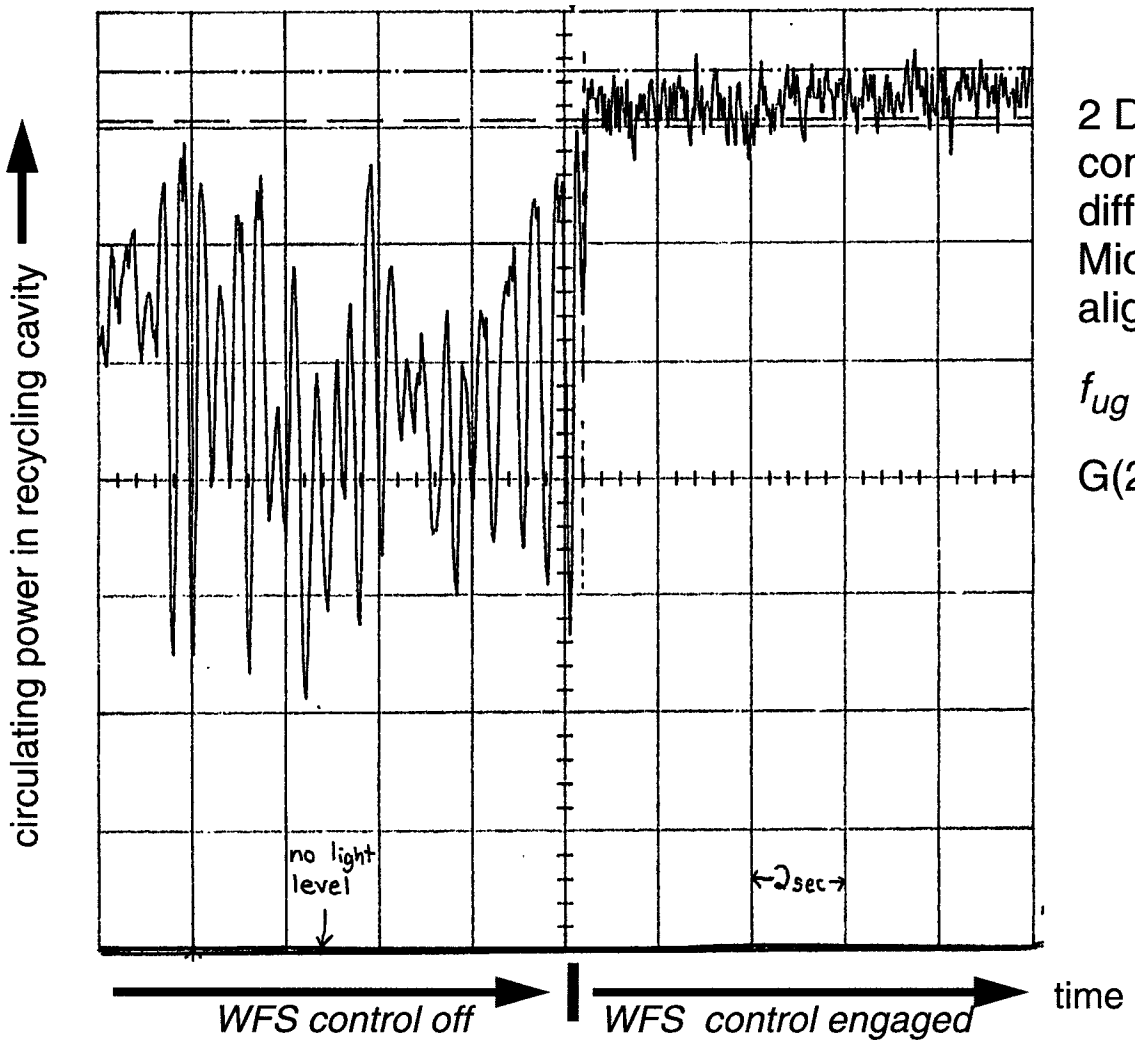
M. E. Zucker

- Phase Noise Interferometer (PNI) program
- 40-meter Interferometer program
- Fixed Mirror Interferometer (FMI) program

Phase Noise Interferometer (PNI)

- Goals: to demonstrate optical phase measurement sensitivity, understand technical sensing noise sources, and test LIGO length sensing/control (LSC) components
- Recent advances:
  - ››Barry STACIS active isolation systems added for second vacuum chamber
  - ››Recycling mirror installed, RF modulation & control systems upgraded
  - ››Wavefront sensing control system installed for differential MI alignment
- Results:
  - ››Recycling gain G = 450
  - ››Power incident on beamsplitter 60 W (carrier only; P_{in} = 200 mW total)
  - ››High-frequency phase sensitivity ~ 3.5 x 10^{-10} rad/$Hz^{1/2}$

PNI: WFS-based Alignment Control

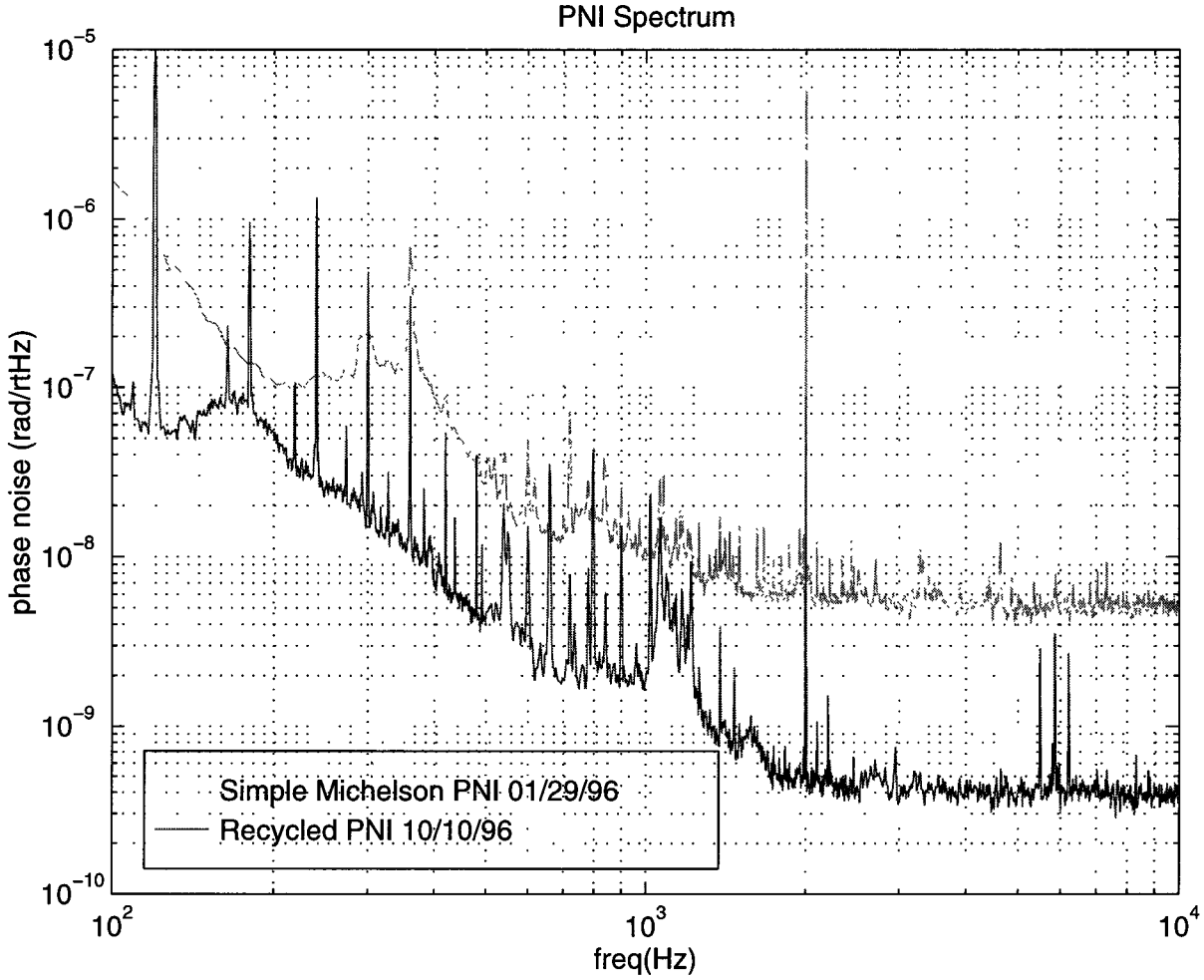


2 D.O.F. WFS control of PNI differential Michelson alignment;

f_{ug} ~ 7 Hz,

G(2 Hz) ~ 20 dB

PNI: Progress on noise spectrum



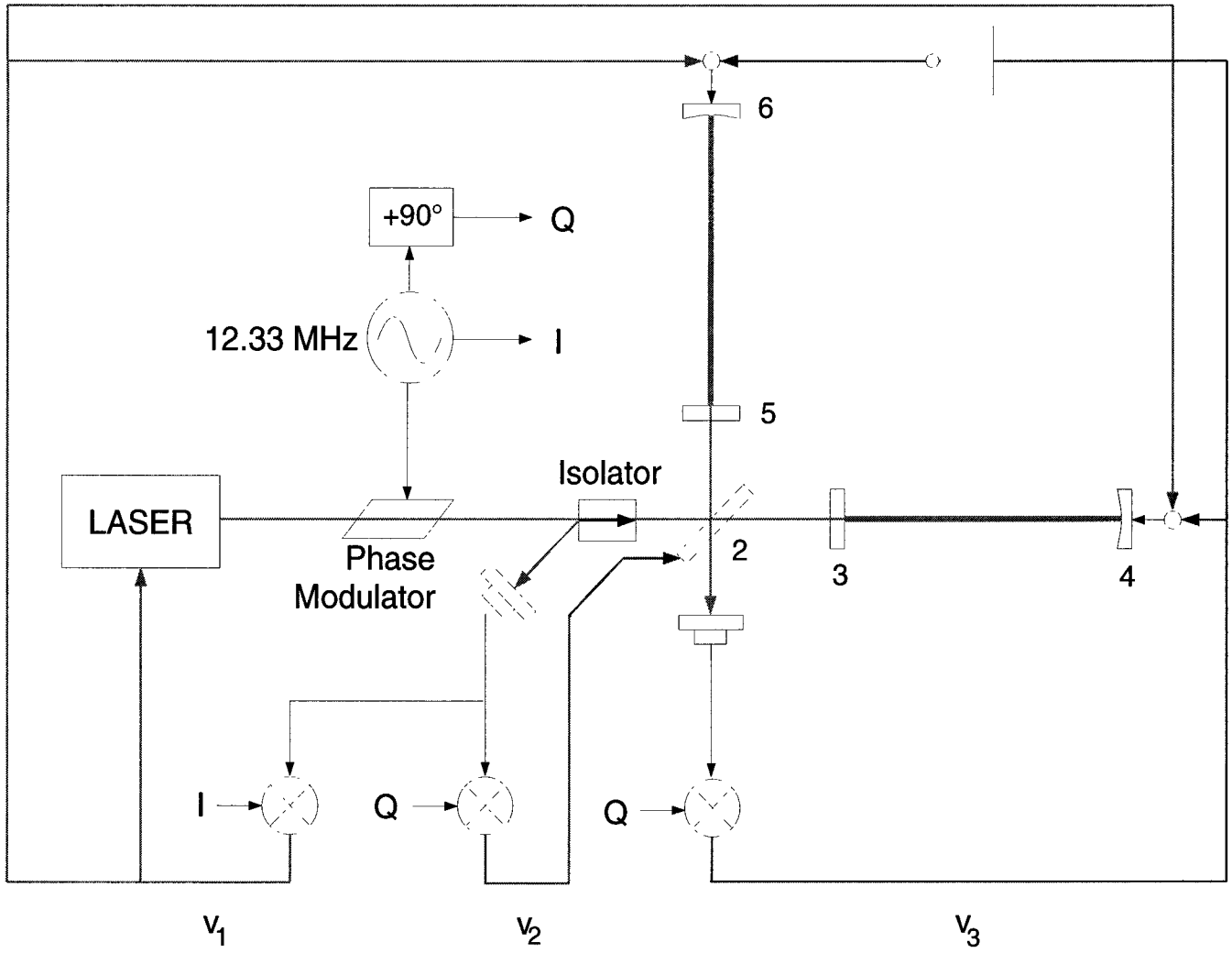
PNI: plan & schedule

- Wrapup of Ar^+ laser experiments next month
- Conversion to Nd:YAG (NPRO, .7 W) starting in December
  - ››optics & laser ready
  - ››laser prestabilization system being assembled/tested at Caltech
- First phase: linear cavity
  - ››test PSL frequency noise
  - ››debug new frequency control servo
- Second phase: Recycled Michelson configuration (as now)
  - ›› prototype test of LSC high-power photodetector
  - ››test of LSC digital controls (still tentative)
- Tests to wrap up last quarter of '97

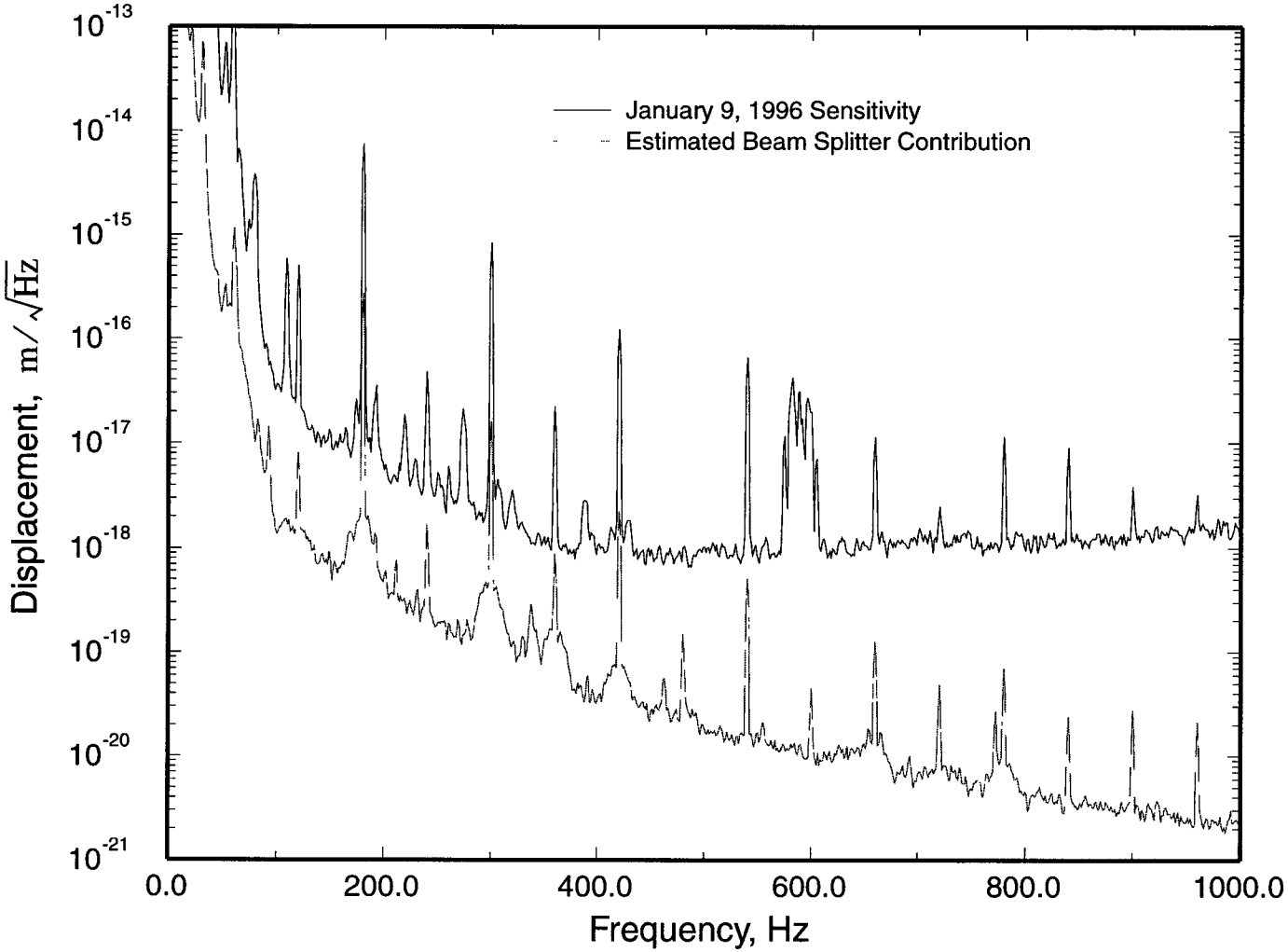
40-m Optical Beam Recombination

- Focus on role as a LIGO configuration testbed; reduced emphasis on displacement noise
- Key first step toward LIGO power-recycled configuration
- Explored new features & noise couplings:
  - ››Coupled control discriminants (nondiagonal readout)
  - ››Sign reversals in Michelson differential readout during lock acquisition
  - ››Greater dependence on uniform mirror figure (new alignment constraint)
  - ››First-order sensitivity to beamsplitter motion
- First test of a recombined Fabry-Perot Michelson interferometer at high sensitivity

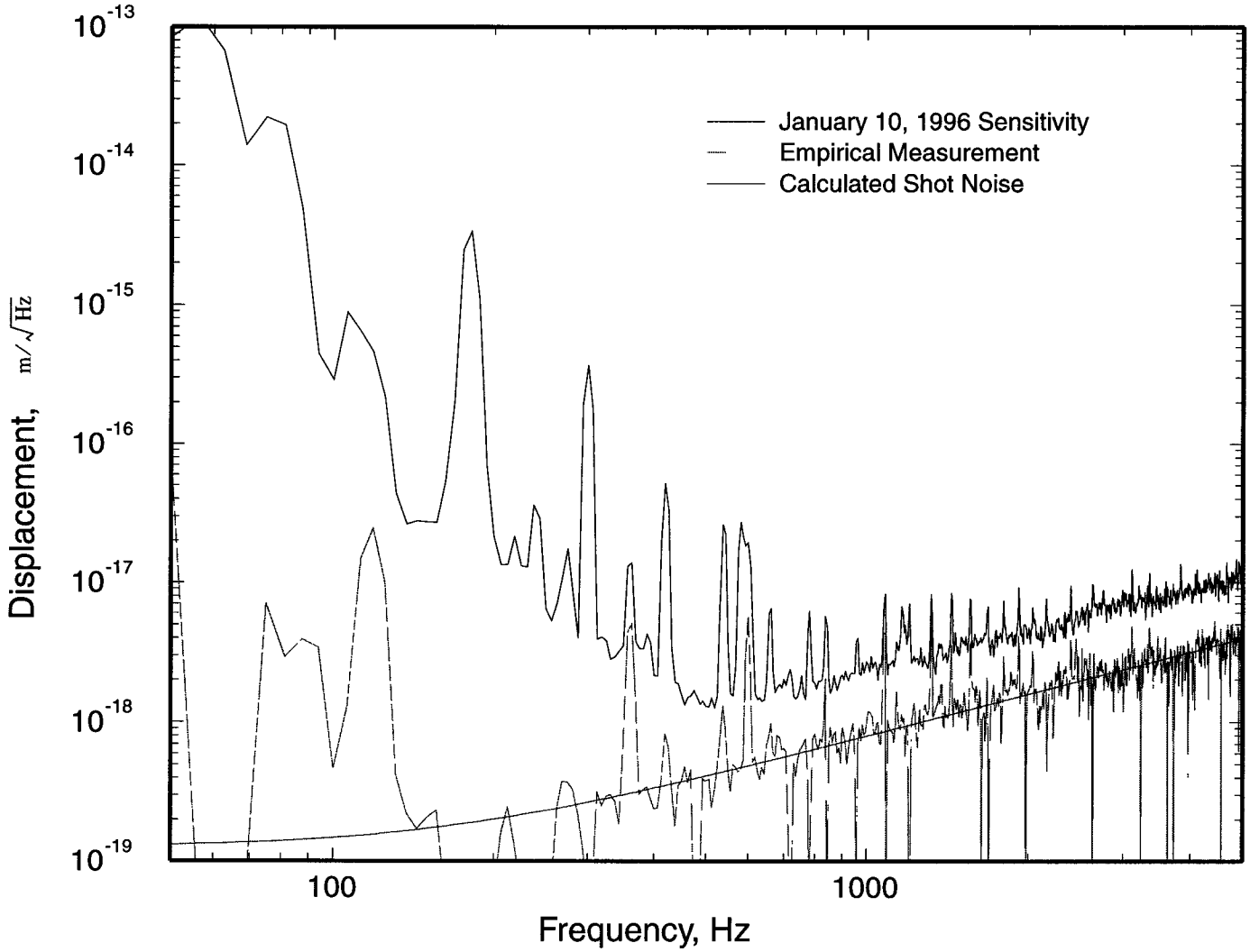
40-m: Recombined Control Topology



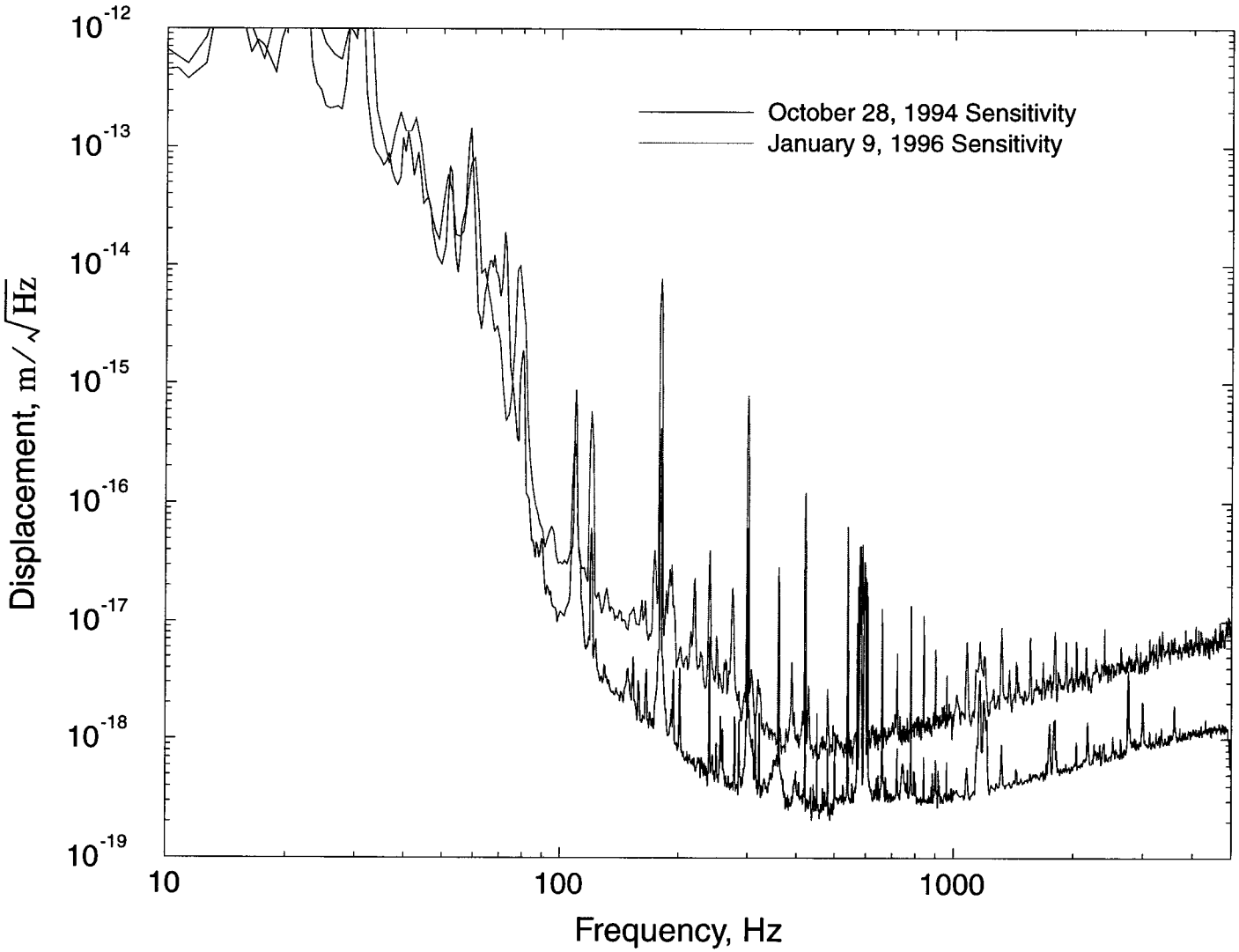
40-m: Beamsplitter Motion Sensitivity



Calculated and measured shot noise



40-m: Sensitivity Comparison



40-m: Suspension prototype test

- Trial of LIGO-type suspension at high displacement-sensitivity
  - ››Single-loop suspension
  - ››Integrated sensor/actuators for pitch, yaw, position
  - ››High-Q attachments
- Integrated test of prototype suspension control electronics
  - ››Dynamic range, noise
  - ››Diagnostics & tuning/setup functions
- Existing 40-m suspensions limit sensitivity, repeatability & ability to generalize other tests (=>other 3 pending)
- Significant impact on SUS Preliminary Design

40-m: Power Recycling

- Program concurrent with LIGO LSC design phase; results support LSC final design
- Focus on validating
  - ››cavity lock acquisition sequence
  - ››alignment technique
  - ››modeling codes and design tools
  - ››control electronics prototypes
- Integrated system tests
- Diagnostics and commissioning exercises
- Training

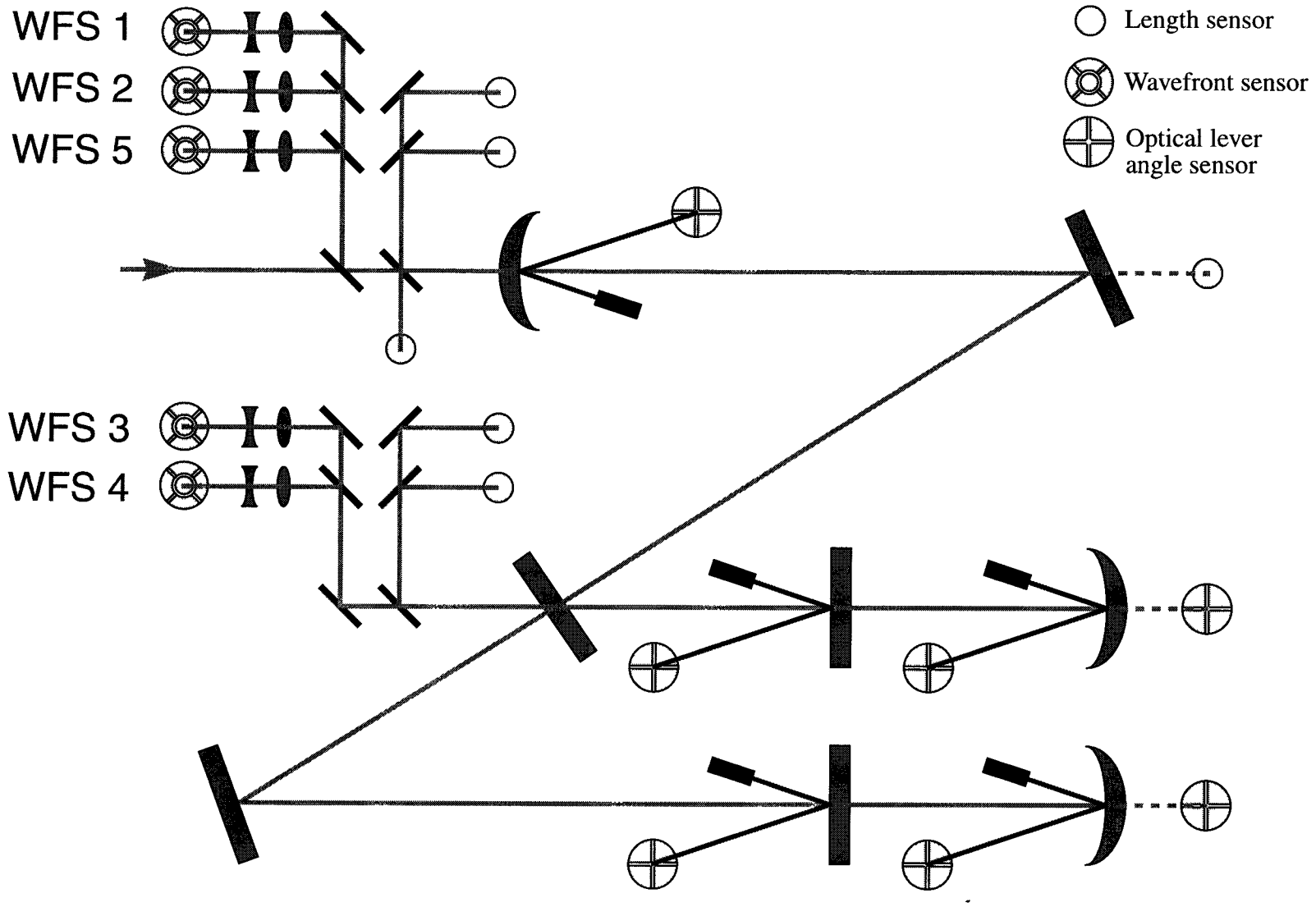
40-m: Recycling Status/Plans

- Installed higher-transmission input couplers
  - ››target recycling factor of 5 (T_{in} = 5600 ppm)
  - ››installation complete, currently shaking down
- Next: reconfigure vacuum envelope & input optics layout
  - ››scheduled to start in November; offline preparations underway
  - ››new side chamber & seismic isolation for expanded input optics
  - ››new beamsplitter to be installed (in LIGO SOS suspension prototype)
  - ››new RF modulation frequency to satisfy resonant condition in final stage
- Final stage: install recycling mirror
  - ››Currently on track for March

FMI: Wavefront Sensing Research

- Goals:
  - ››Validate Modal Model and its predictions for sensitivity of Wavefront Sensing (WFS) angle readouts, a critical technology for LIGO
  - ››Develop WFS sensor and signal processing hardware and software
  - ››Test concepts on a "full-configuration" power-recycled Fabry-Perot michelson
- Apparatus now complete
  - ››Prestabilized Ar^+ laser, LIGO-like RF length control
  - ››Multifrequency phase modulation + frequency-shifted subcarrier generator
  - ››Tabletop interferometer with PZT tip/tilt and fast/slow piston mirror actuators; aux. laser diode optical lever angle calibrators
  - ››5 WFS prototype heads & demodulator modules, VME digital signal processing system

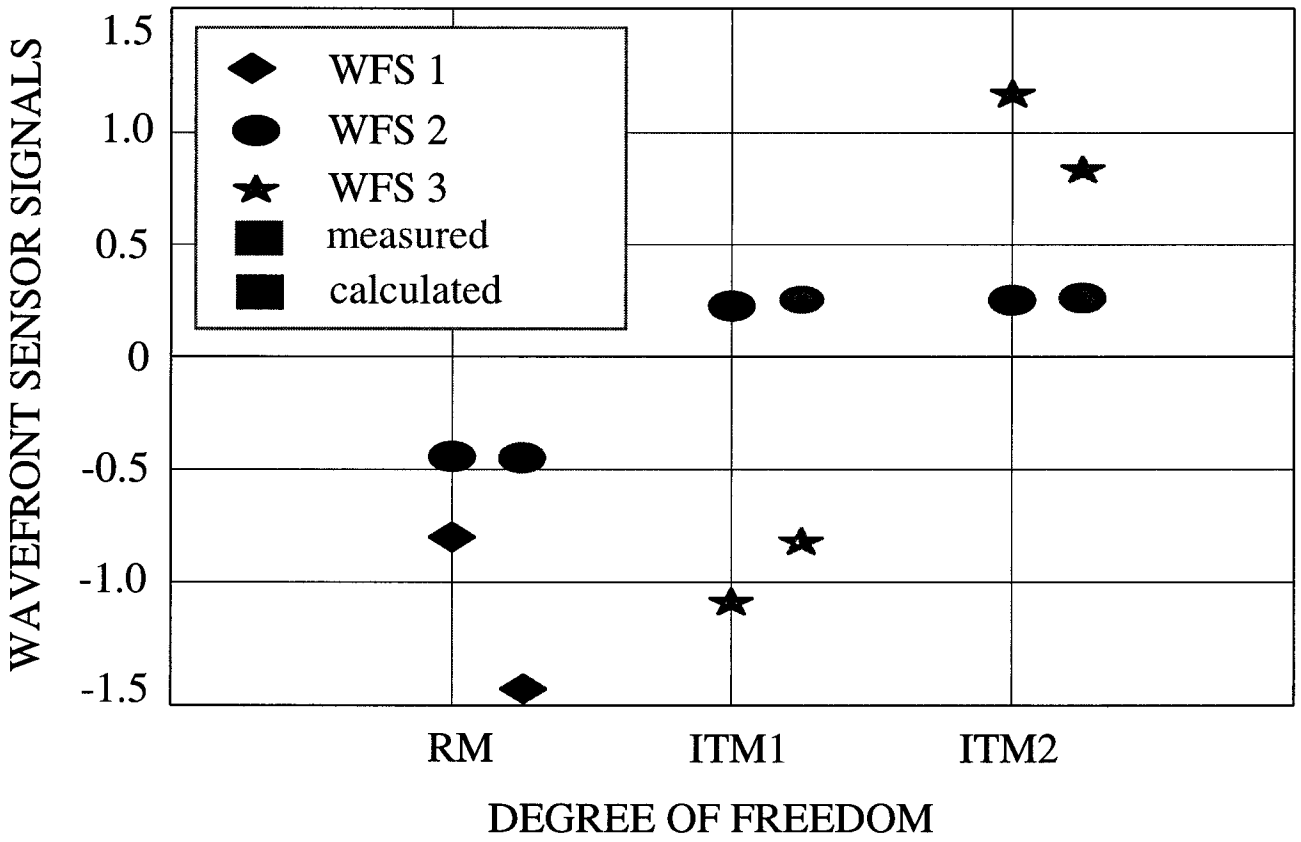
FMI Configuration (schematic)



FMI: Status

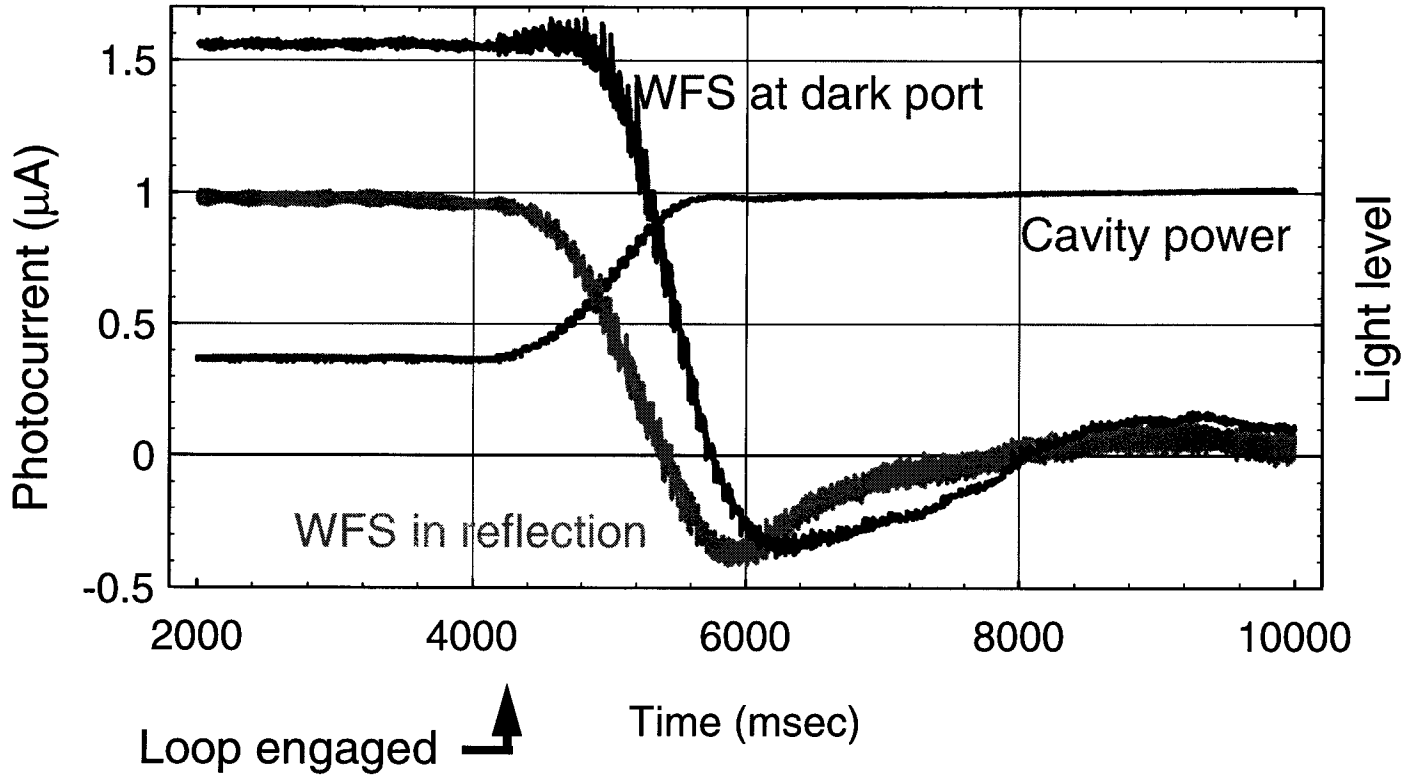
- Good preliminary results with arm cavities disabled (power-recycled simple Michelson only)
- WFS prototype hardware performance consistent with LIGO ASC requirements
- Successful trial of digital MIMO control system; correctly optimized all 6 degrees of freedom (d.o.f.)
- Now bringing arm cavities online for complete data run with all 10 d.o.f.

FMI: Preliminary Results vs. Model



FMI: Digital WFS Control Test

- Closed Loop Control of a Recycled Michelson Interferometer



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LIGO-G960219-D-00-M