Commissioning Plan

for the LIGO Interferometers

NSF Review

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What Drives the Commissioning Approach?

- **Building three detectors on staggered schedule**
  - **Finding problems with first detector more important than a complete characterization**
- **Scale of device makes changes to optical configuration time-consuming**
  - **Example: Opening a chamber to turn an adjustment screw takes about 3 days, and involves about 2 person-weeks of effort**
- **Limitations of angular adjustment ranges, modulation frequency/length matching, etc.**

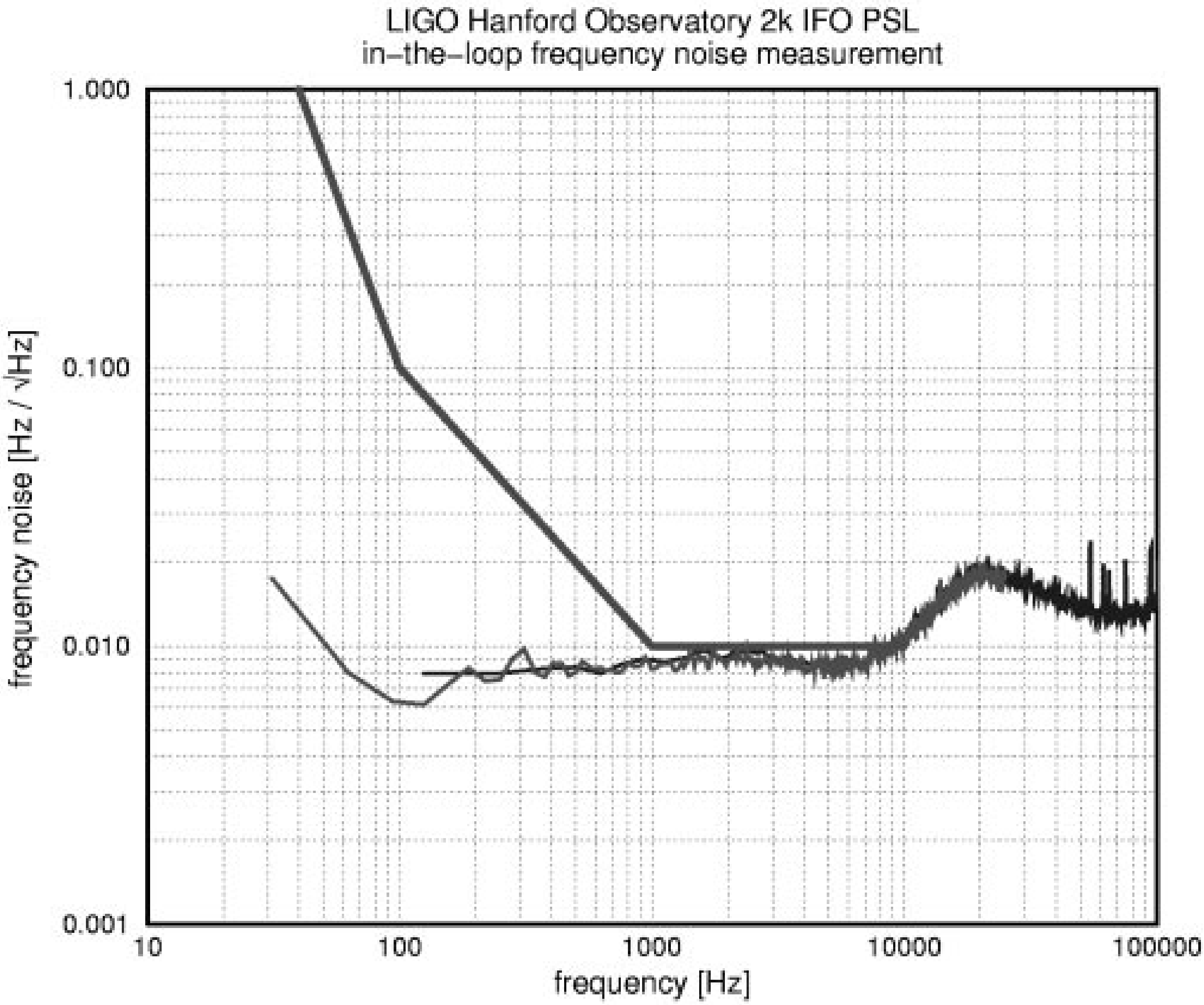
HAM Door Removal

Starting Point for Commissioning

- **Installed and tested subsystems**
  - ››**Physical installation complete**
  - ››**Basic functionality demonstrated**
  - ››**Independent subsystem performance demonstrated**
- **Example: 2km Prestabilized Laser**
  - ››**Installed and operating at LHO**
  - ››**Tested:**
    - **Ability to hold lock for long periods**
    - **Frequency noise stabilized to reference cavity**
    - **Intensity noise stabilized by photodiode after premodecleaner**
  - ››**Not tested:**
    - **Ability to hold lock as interferometer transitions from state to state**
    - **Frequency noise stabilized by L+ loop**
    - **Intensity noise stabilized after modecleaner**

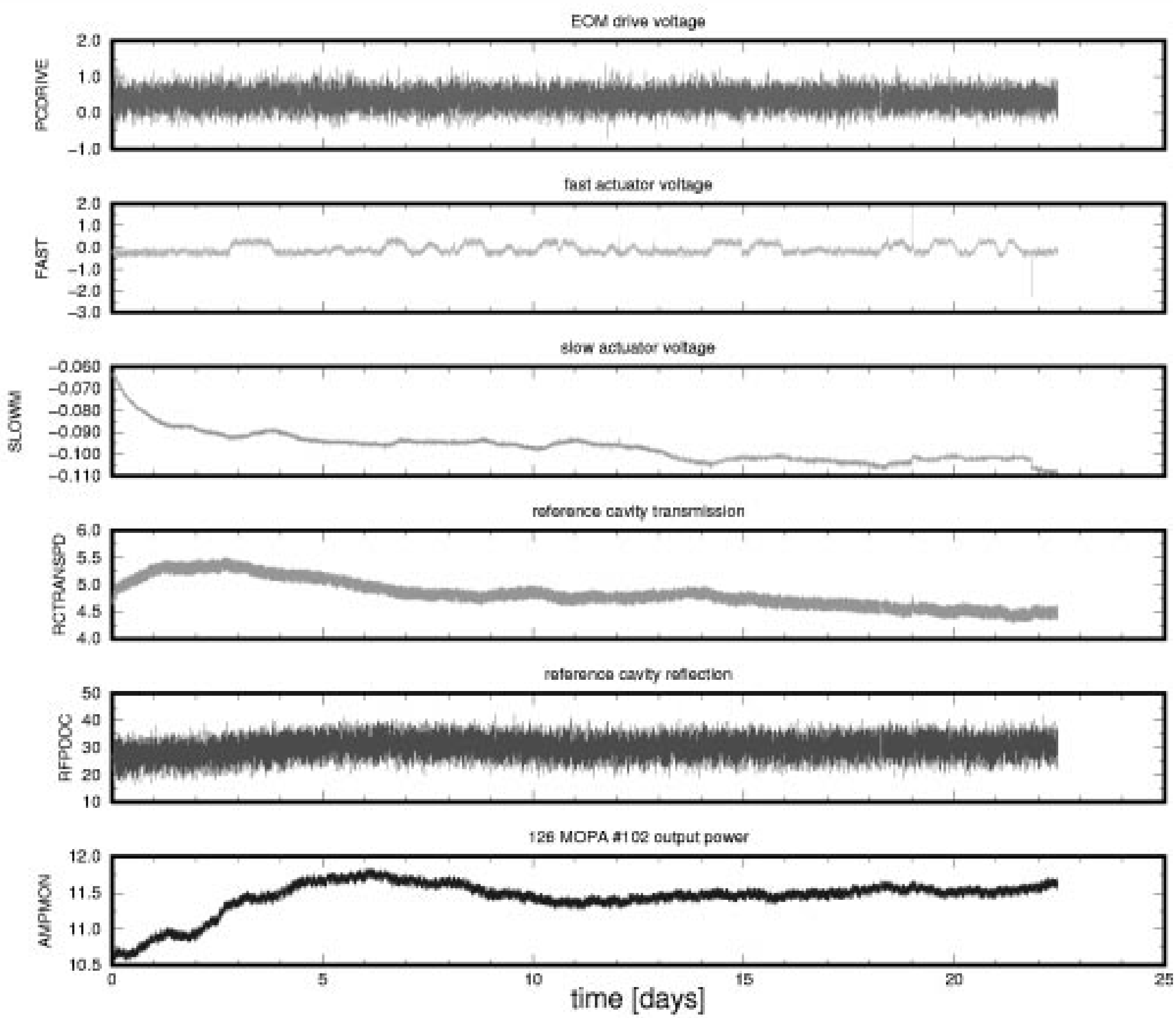
From the PSL Test Review:

- **Frequency noise when stabilized to reference cavity**



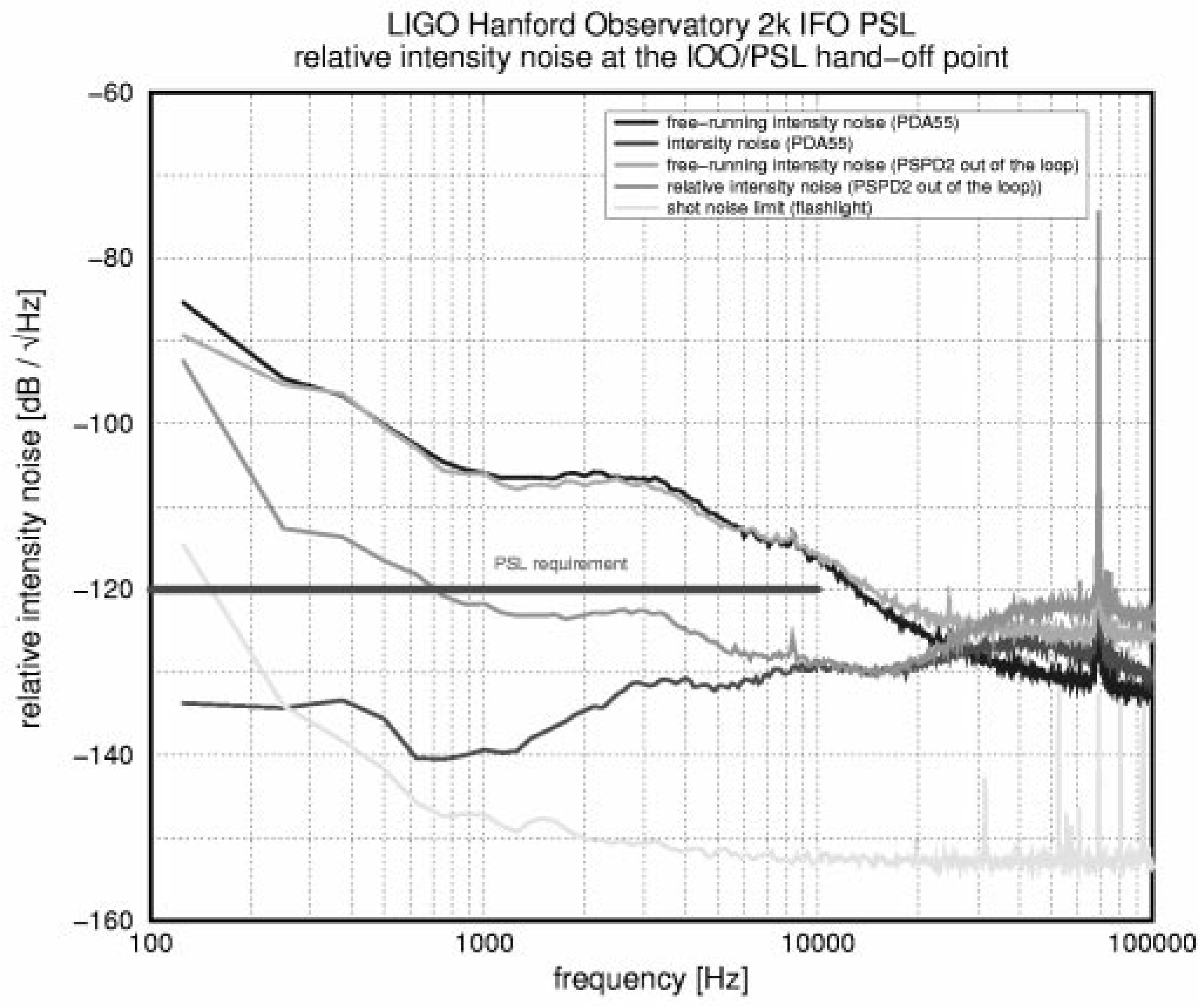
From the PSL Test Review:

- **Locked continuously for 23 days**



From the PSL Test Review:

- **Intensity noise measurements compared inside and outside the stabilization loop**

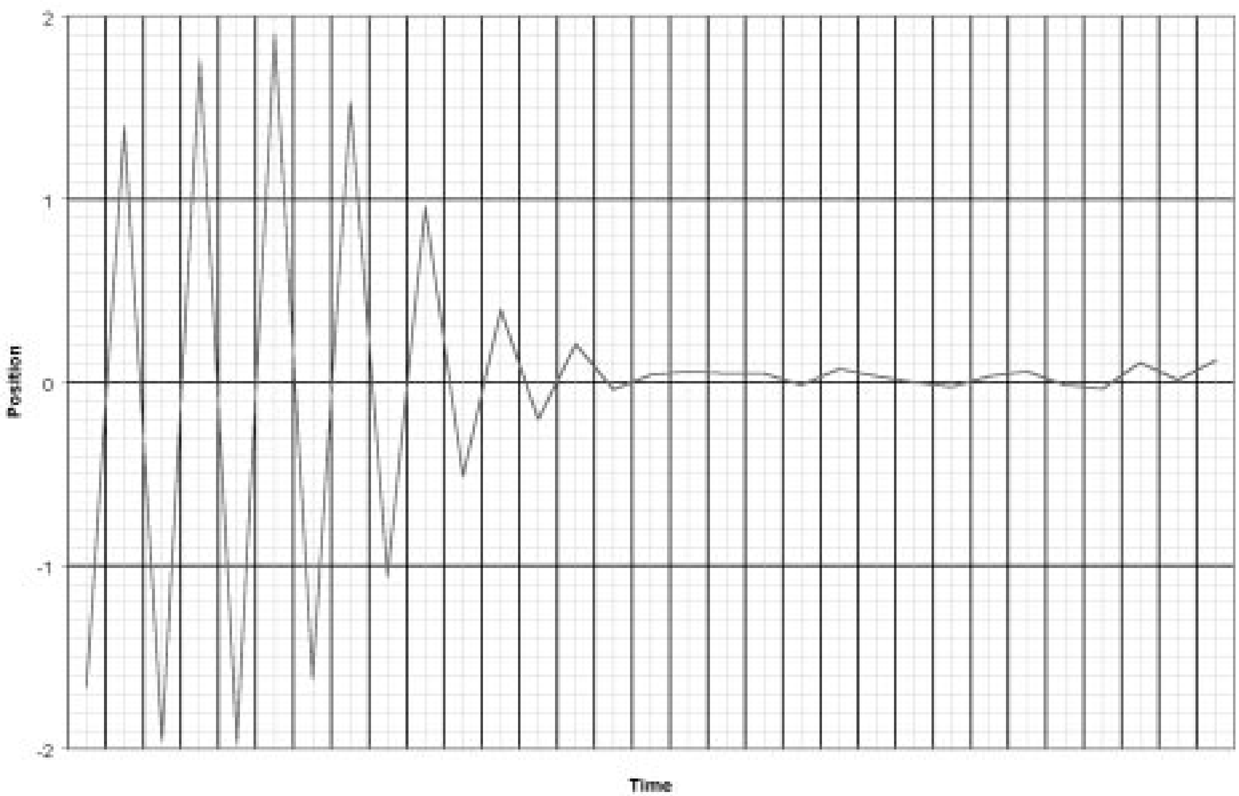


Integration/Test of Suspended Optics

- **Combination of 5 major subsystems (Core Optics, Suspension, Seismic Isolation, Initial alignment, CDS)**

Integration/Test of Suspended Optics

- **EPICS data showing damping of Recycling Mirror**



Major Phases for 2km IFO

- **Integration of PSL and Modecleaner (5-9/99)**
  - ››First integration of intersubsystem servo-loops
  - ››Test robustness of laser servos, performance of laser stabilization
- **Single Arm Cavity (8-10/99)**
  - ››Optical properties of arm cavities
  - ››Correlation of seismic noise over site, adequacy of servos for suppressing microseismic peak
  - ››Opportunity for moderate sensitivity tests of performance of seismic isolation, suspensions)
- **Power-recycled (short) Michelson (10/99-2/00)**
  - ››Marginally stable cavity
  - ››Mixed digital/analog servos
- **Recycled Fabry-Perot Michelson (2-11/00)**
  - ››Lock acquisition
  - ››Stability of length and alignment servos with strongly coupled degrees of freedom

Integrating the PSL and Modecleaner

- **Align MC in air and adjust modulation frequency to match length (using low power)**
- **Pumpdown and align external detection optics**
- **Test length/frequency and alignment controls; set phase shifts, Guoy phases**
- **Optimize suspensions, mode-matching, final modulation frequencies**
- **Characterize performance**
  - **Servo gains, offsets**
  - **Power spectra of noise at various points**
  - **Calibrate error signals**
  - **Investigate robustness**
  - **Length /alignment coupling**
  - **Modulation depth, spurious amplitude modulation**

Single Arm Cavity

- **Align arm cavity (in vacuum) and external detection optics**
- **Test length and alignment controls, adjust phases**
  - ››**Investigate lock acquisition**
  - ››**Investigate robustness of lock (esp. due to microseismic peak and tidal motions)**
- **Optimize suspensions (length/alignment)**
- **Characterize performance**
  - ››**Optical parameters of arm cavities (Finesse, mode matching, scattering,...)**
  - ››**Lock acquisition servos**
  - ››**Power spectra of noise, correlate w/ other parameters**
  - ››**Length/alignment coupling sensitivity**
  - ››**Characterize seismic isolation and suspensions (moderate sensitivity)**

Power-recycled Michelson

- **Align in interferometer air and check alignment of COS telescopes**
- **Pumpdown and align external detection optics**
- **Test length and alignment controls, adjust phases**
  - ››**Investigate lock acquisition**
  - ››**Investigate robustness of lock**
- **Optimize suspensions (length/alignment)**
- **Characterize performance**
  - ››**Optical parameters (Finesse, contrast defect, beam quality) in marginally stable cavities**
  - ››**Servo gains, offsets**
  - ››**Power spectra of noise, correlate with obvious sources**
  - ››**Calibrate error signals**
  - ››**Test capabilities to monitor/debug digital/analog servos**

Power-recycled Fabry-Perot Michelson

- **Align interferometer (in vacuum) and external detection optics**
- **Test length and alignment controls, adjust phases**
  - ››**Investigate lock acquisition/nonacquisition**
  - ››**Investigate robustness of lock (esp. due to microseismic peak and tidal motions)**
- **Optimize suspensions (length/alignment)**
- **Characterize performance**
  - ››**Optical parameters of full interferometer**
  - ››**Servo gains, offsets, gain/phase margins, variability**
  - ››**Power spectra of noise, correlate w/ other parameters**
  - ››**Calibrate error signals**
  - ››**Length/alignment coupling sensitivity**
  - ››**Characterize seismic isolation and suspensions**

Tools

- **Global Diagnostic System (GDS)**
  - ››Part of the detector, linked with data acquisition system to give near real-time feel for accessing data and running tests
  - ››Ability to monitor, display, and correlate many internal signals in the detectors
  - ››Excitation tool for stimulus-response testing
- **LIGO Data Analysis System (LDAS)**
  - ››System used for LIGO data analysis to be a basic tool for commissioning
  - ››Provides important testbed for analysis routines
  - ››Schedules coordinated so that LDAS supports each phase of detector commissioning
- **Simulations**
  - ››End-to-end model planned to be ready for comparison with real detector performance
  - ››Have involved hardware developers in teams with modelers to strengthen links

Organization and Staffing

- **Will structure commissioning organization on successful installation model**
  - ››**Overall coordination by commissioning director**
    - – **Whitcomb**
  - ››**Commissioning co-leaders to handle day-to-day activities, “always” one at each site**
    - – **Fritschel, Saulson, Shoemaker, Weiss, Whitcomb**
  - ››**Site liaison is site head**
    - – **Coles, Raab**
- **Will rely heavily on staff from MIT, CIT**
  - ››**Even more than during installation (at least for the first detector)**
    - – **Largest reservoir of experience with full interferometers**
    - – **Commissioning process is more “interactive” than installation**
  - ››**As detectors start to work should have no trouble getting people to travel to sites**

Final Remarks

- **The hardest part of commissioning the detectors will be getting the required performance (particularly sensitivity) from the full interferometer**
  - ››**The tests we have thought of are designed to ferret out noise mechanism that we have thought of, and since we have thought of them, we have designed the relevant subsystems so that they are not dominant**
- **We must remain flexible to any discrepancies, any unexpected results; evaluate all results to anticipate when changes in “the plan” are required; and adjust “the plan” as appropriate**