IO simulation status

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Outline

- Hanford 2k interferometer simulation program
- e2e architecture of IOO
- Status and Plans

LIGO-G990079-37-M

Minute of the End to End model meeting on May 18th, 1999

viewgraphs of the presentations on May 17

On the second day of the End to End model simulation meeting, the schedule of the PSL and IOO subsystem development schedule were discussed.

1. Subsystem development will be focused to make its inputs and outputs function correctly with minimal ingredients, and details of the subsystems will be included later.
2. The architecture design (designing the arrangement of e2e components to simulate the subsystem) of PSL is completed, and IOO architecture design will be completed by June 2.
3. All necessary parameters will be gathered by the week of June 14.
4. The shakedown (make sure subsystem simulation runs) will be completed by the week of June 21.
5. The validation, individual and combined, will start from July 1.
6. At the end of June, Hiro and Sergei will go to Hanford and work together to connect "PSL" and "IOO" subsystems.
7. The two subsystems with minimal ingredients will be completed by August.

The resources and activities for the subsystem development until the end of July are discussed and followings are confirmed.

1. Rick will work 1/2~1/3 of his time for PSL development.
2. Biplab will work 1/3~1/2 of his time for PSL development.
3. Hiro will work 2weeks.
4. Sergei will work 1/2 of his time for IOO.
5. Malik will help Sergei to implement the control system of IOO.

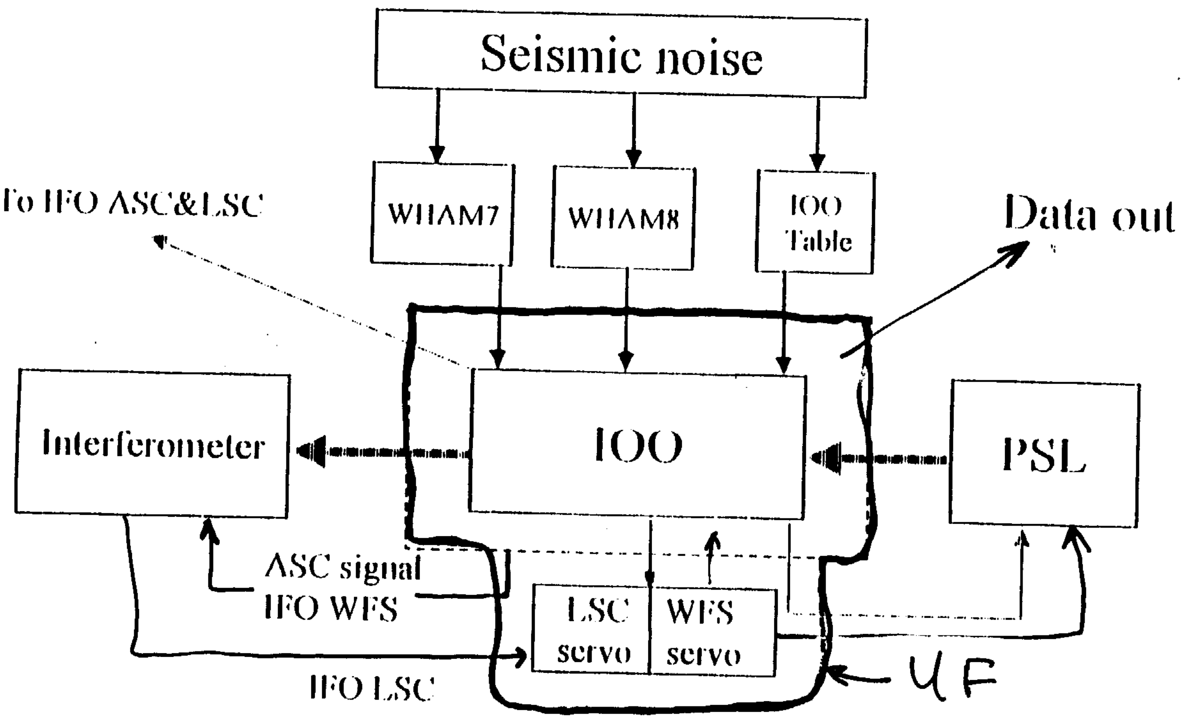
Other near term activities are

1. Hiro will work with Soumya and Mark to build mechanical system, which will be used in IOO and COC.
2. Bill Kells will build COC related part of e2e, after recycling mirror with a very simplified laser source model. Later, the source will be replaced by PSL/IOO models. He cannot predict how much time he can work on this.
3. Biplab and Matt will work to improve the optics/field implementation - see below.

There was a discussion about the implementation of the e2e primitive mirrors. Now, there are two architectures are used in implementing mirrors, one used in ioo subsystem and the other in all the rest. It is desirable to have one universal architecture to implement mirrors in the entire e2e framework. Also discussed was a stream-lined architecture of the optics system based on the experience of the past work. It is proposed that this new stream-lined architecture will be used to implement mirrors for the entire LIGO system - it will take about 1-2 months - and if it turns out that this implementation cannot handle the physics for ioo, a hybrid model will be adopted.

Hanford 2k interferometer simulation program

- Hanford
- Caltech
- UF



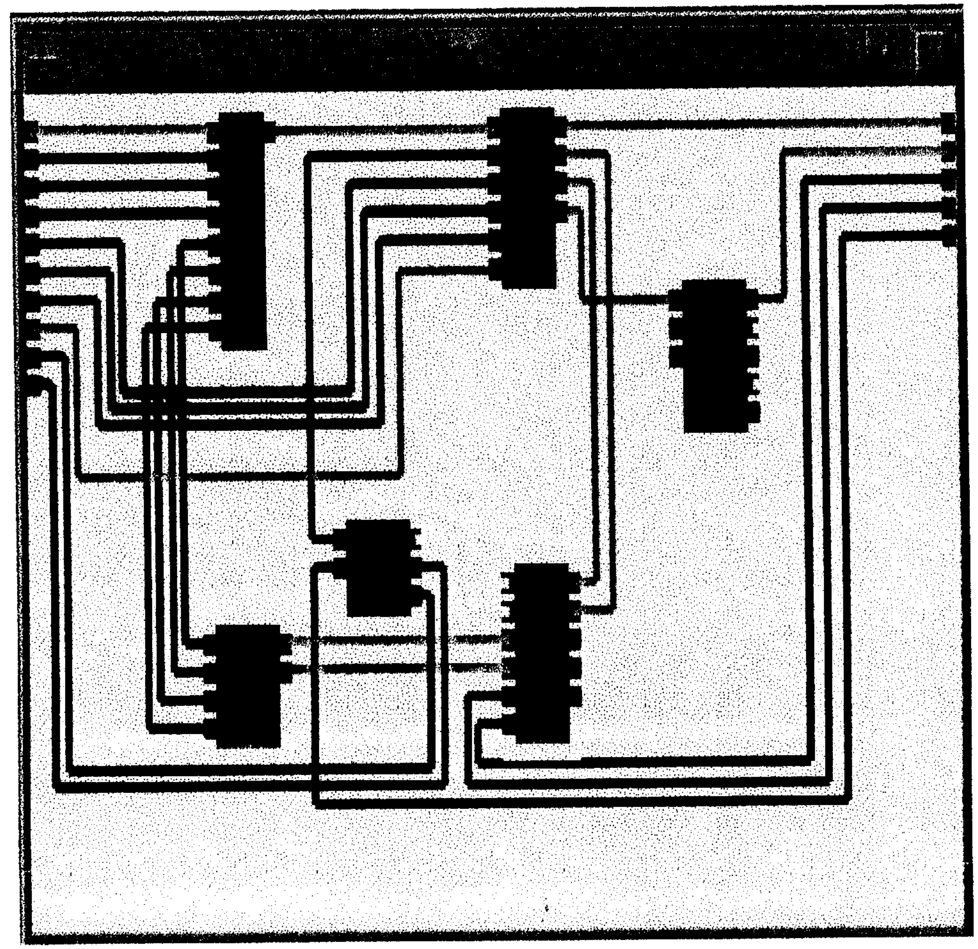
Goal: build a program to help detector diagnostics.

IO Subsystem:

- use e2e model
- development of IO primitives (MC, thick lens)
- developmet of IO subsystem box
- integration with PSL & COC

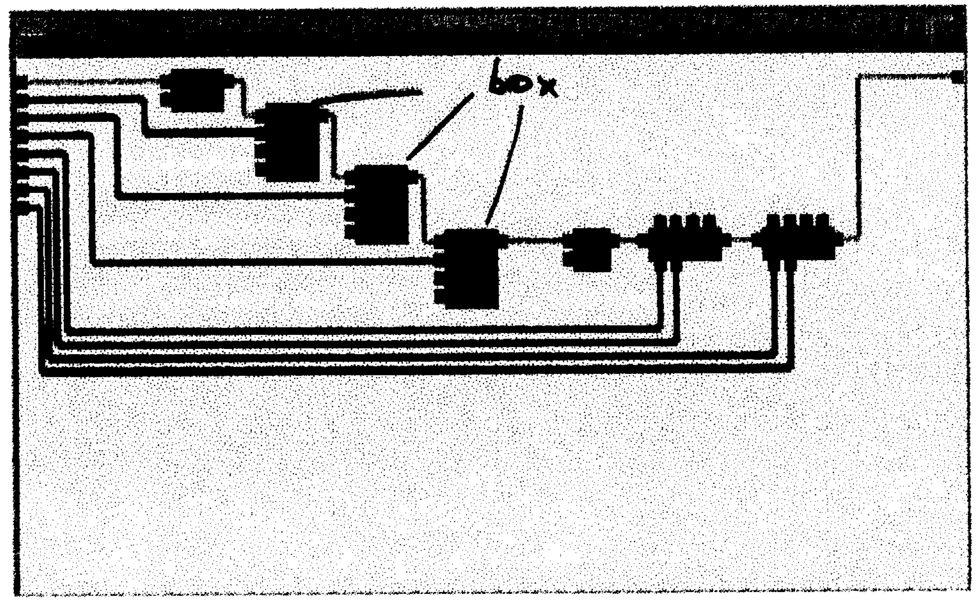
ioo.box

- Input signals
  - psl_beam (field) - input field
  - k1 (real) - EOM-1 mod. frequency
  - k2 (real) - EOM-2 mod. frequency
  - k3 (real) - EOM-3 mod. Frequency
  - Add_Off (real) - additive offset
  - VME (real) - VME control
  - MMT3_yaw (real)
  - MMT3_pitch (real)
- Output signals
  - io_beam (field) - output field
  - ifo_rl (field) - ifo reflected light (FI)
  - psl_iss (real) - psl intensity stabilization
  - MC_noise (real) - MC noise monitor
  - WBS (real) - wideband servo



ioo.out.box

- Input signals
  - in (field) - input field
  - k1 (real) - EOM-1 mod. frequency
  - k2 (real) - EOM-2 mod. frequency
  - k3 (real) - EOM-3 mod. Frequency
  - TM5_yaw (real)
  - TM5_pitch (real)
  - PM2_yaw (real)
  - PM2_pitch (real)
- Output signals
  - out (field) - output field

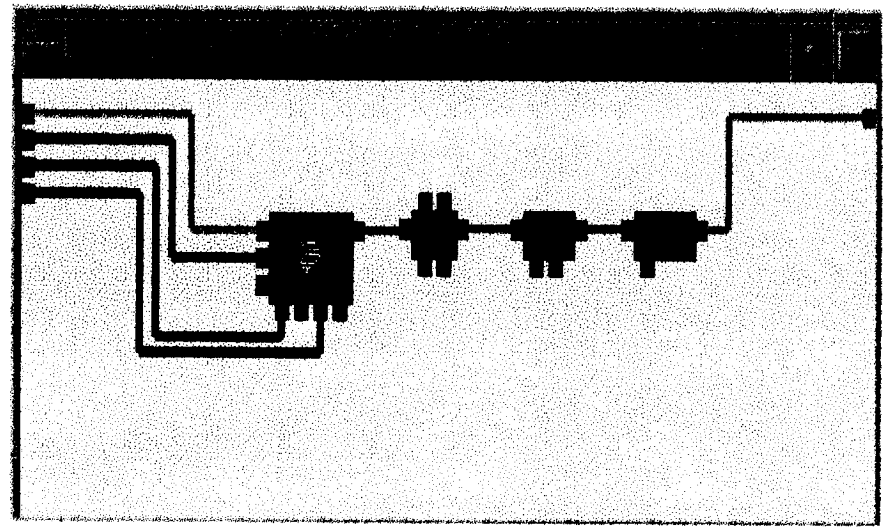


- MMT - now use the periscope module. Using

  thin lens module we could describe static misalignment of the MMT lenses that makes beam elliptic.

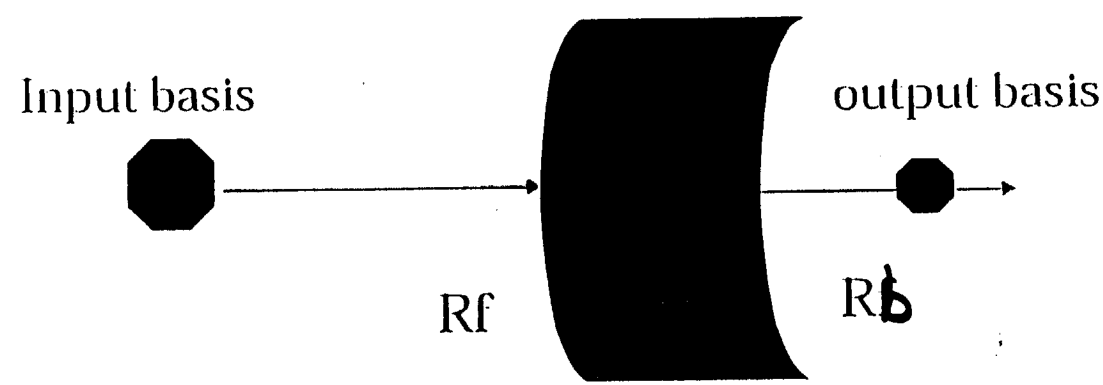
ioo.out.eom.box

- Input signals
  - ➢ in (field) - input field
  - ➢ k (real) - modulation frequency
  - ➢ gamma (real) - frequency mod. depth
  - ➢ gA (real) - amplitude mod. depth
- Output signals
  - ➢ out (field) - output field
- EOM - side-band generator
- TL - thick thermo-lens
- Iris - EOM aperture



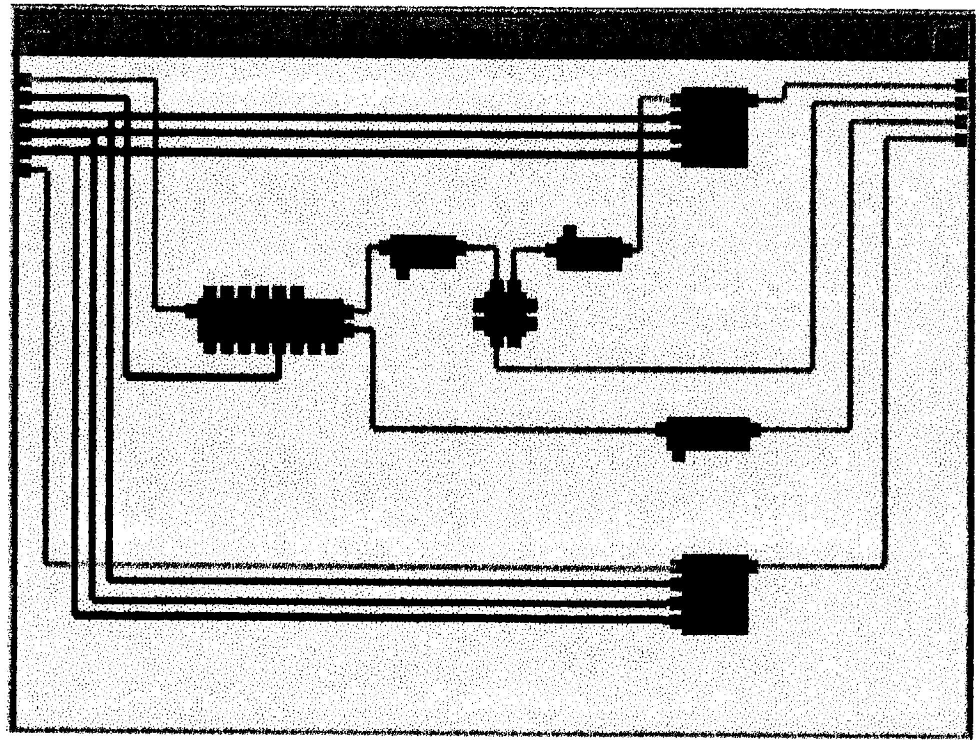
Lens-duct module

- Thick lens $(t, n, dn, R_f, R_b, (dx, dy), (pitch, yaw))$
- thermo-lensing: $\Delta n(r) = \alpha r^2 + \beta r$, r - radius
  - ➤ duct term - add effective focal length
  - ➤ linear term - mode decomposition
- beam basis conversion



ioo.ham7.box

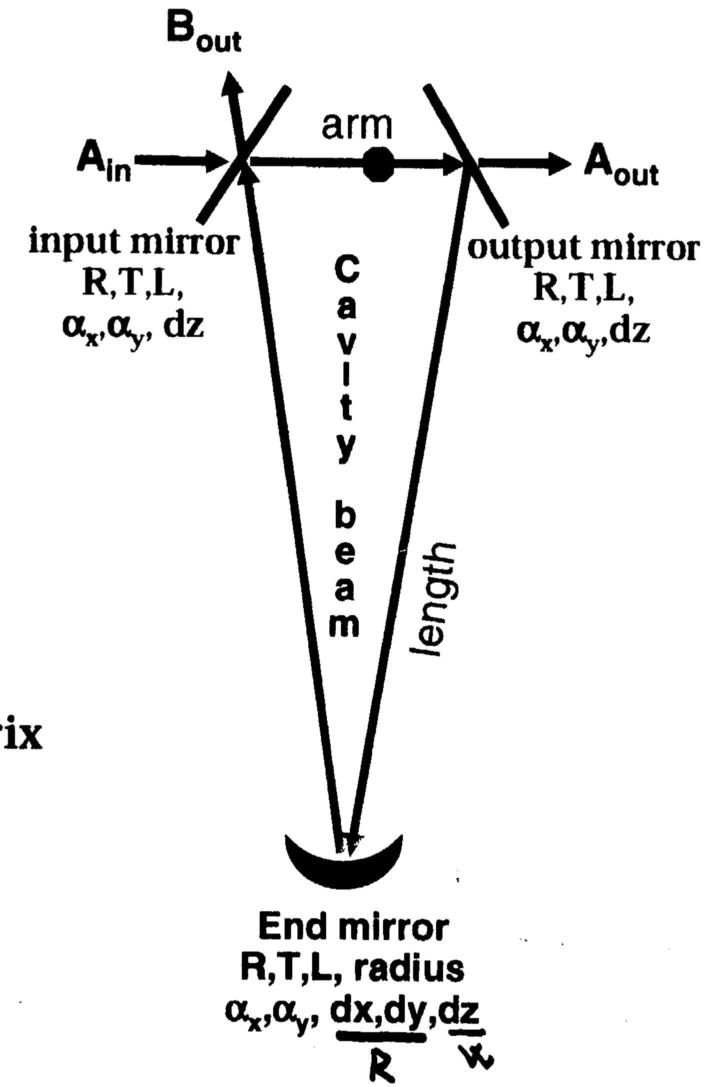
- Input signals
  - ➢ in (field) - input field
  - ➢ ifo-ref (field) - IFO reflected light
  - ➢ MCVM_LS (real) - MC vertex mirror length servo
  - ➢ MMT3_yaw (real)
  - ➢ MMT3_pitch (real)
  - ➢ MMT3_LS (real) - length servo
- Output signals
  - ➢ out (field) - output field
  - ➢ MC_out (field) - MC field
  - ➢ MC_ref (field) -MC reflected light
  - ➢ FI_ref (field) - FI reflected light



- mmt_rm - ioo beam path
- rm_mmt - ifo reflected beam path

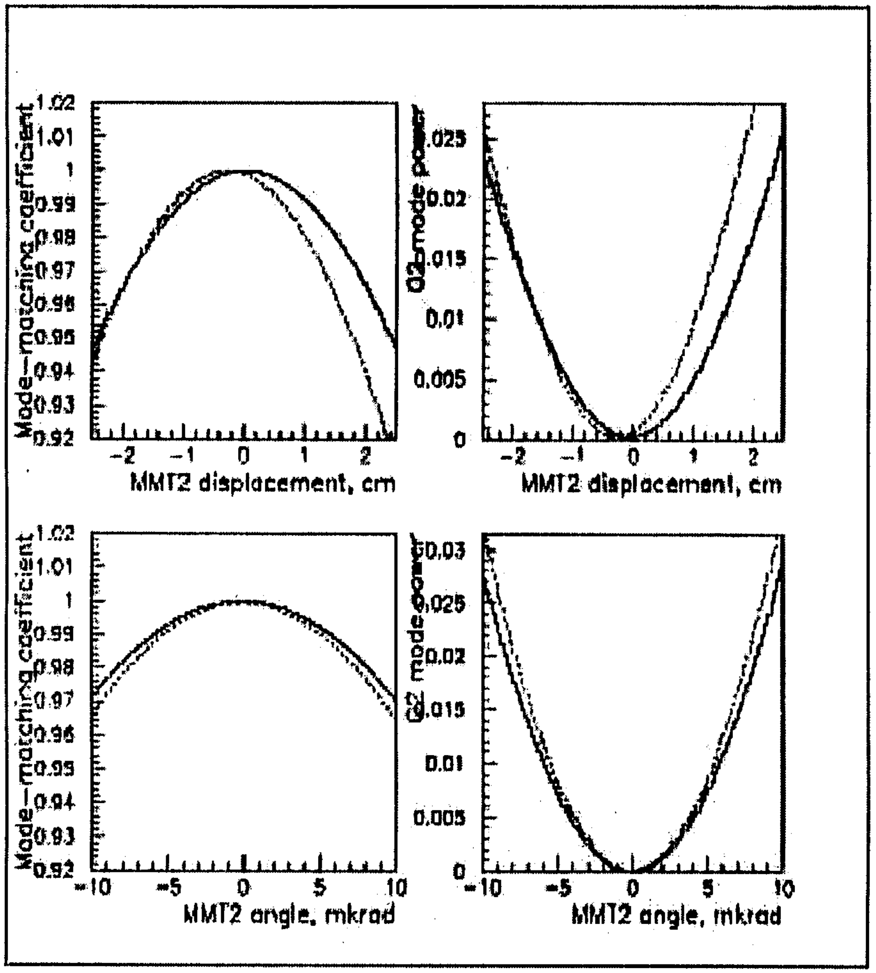
IOO Mode Cleaner

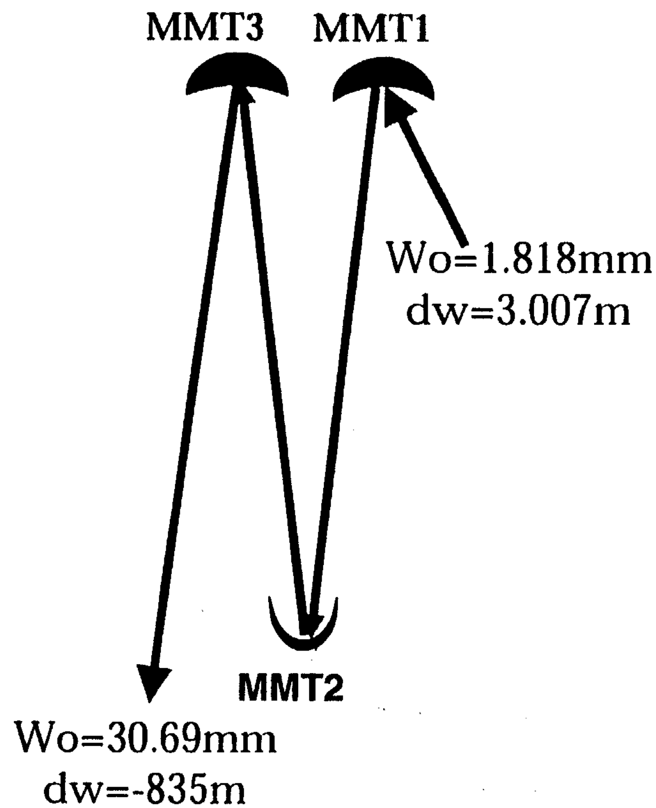
- Simulation time step $\Delta T < 1$ns required if MC is a compound module
- RT time $T_{RT} \sim 85$ns $\ll \Delta T$ ($\Delta T > 1\mu s$)
- High finesse ~ 1500: long memory for perturbations ~ 0.1ms
- Summation Cavity
  - 1 RT: $E(t)=U(t)*E(t-T)+t_a*E_{in}(t)$
  - n RT: $E(t)=U^n(t)*E(t-nT)+S_n t_a*E_{in}(t)$
    $n=\Delta T/T_{RT}$, $S_n=(I-U^n)(I-U)^{-1}$, I - **unit matrix**
  - round trip matrix $U = M_1*M_2*M_3*Guoy$
  - M - mode decomposition matrix
  - use FCD method to calculate M for each mirror



IOO-2kCO mode-matching coefficient

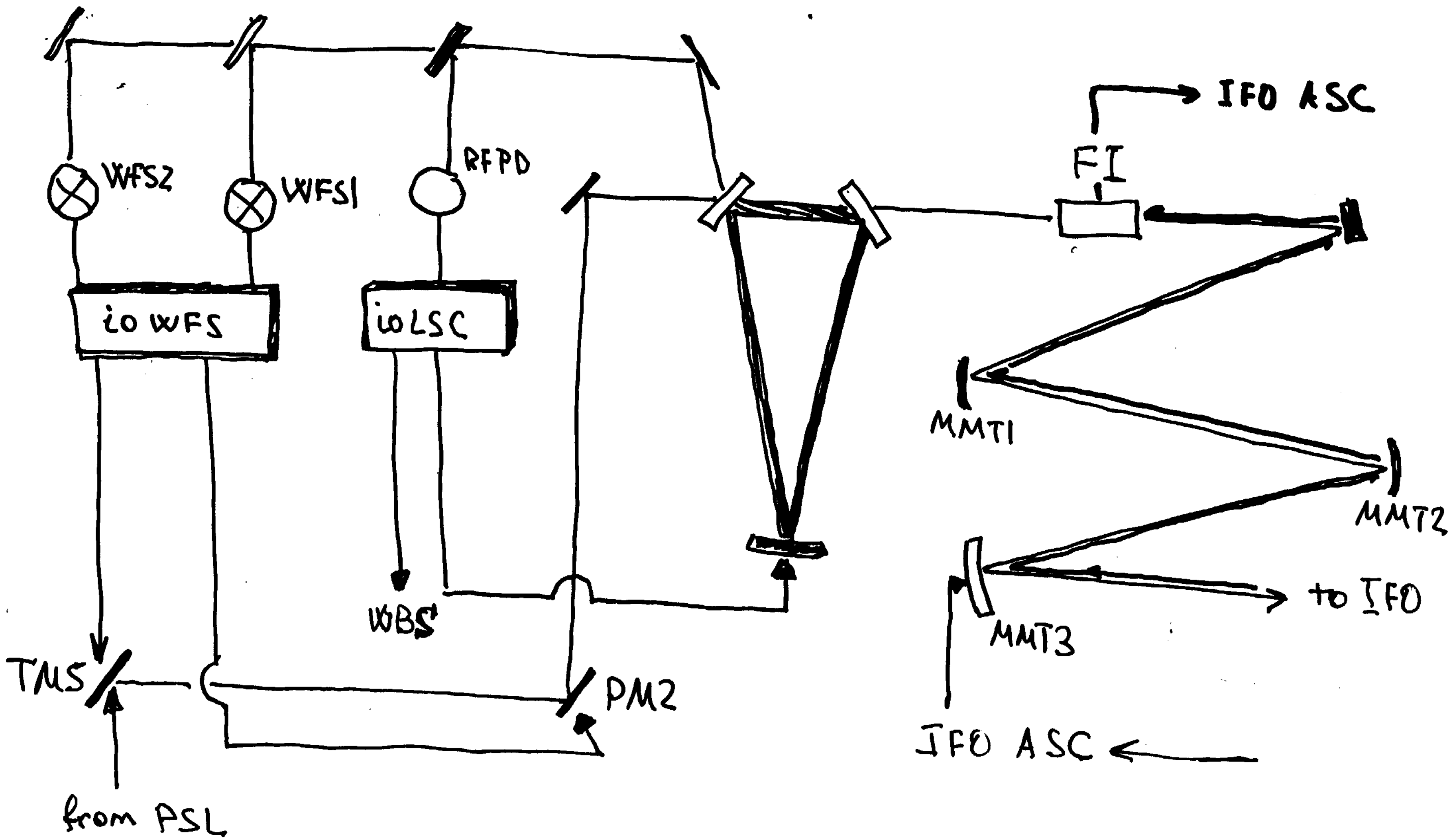
- Use mode-matching mirrors for MMT
- Use duct lens to simulate Faradey Isolator: effective focal length = 60m

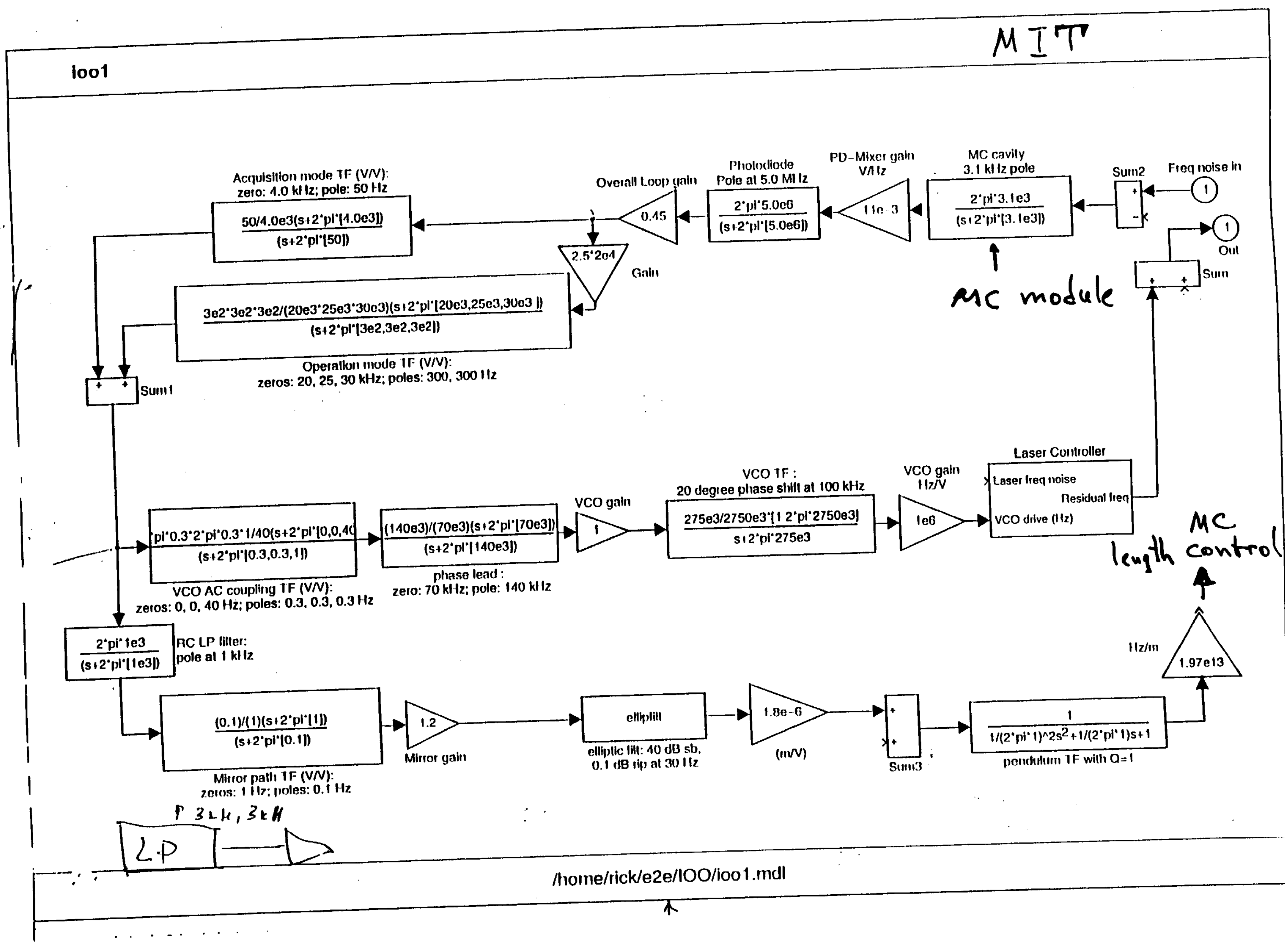




e2e meeting, May 17, 1999

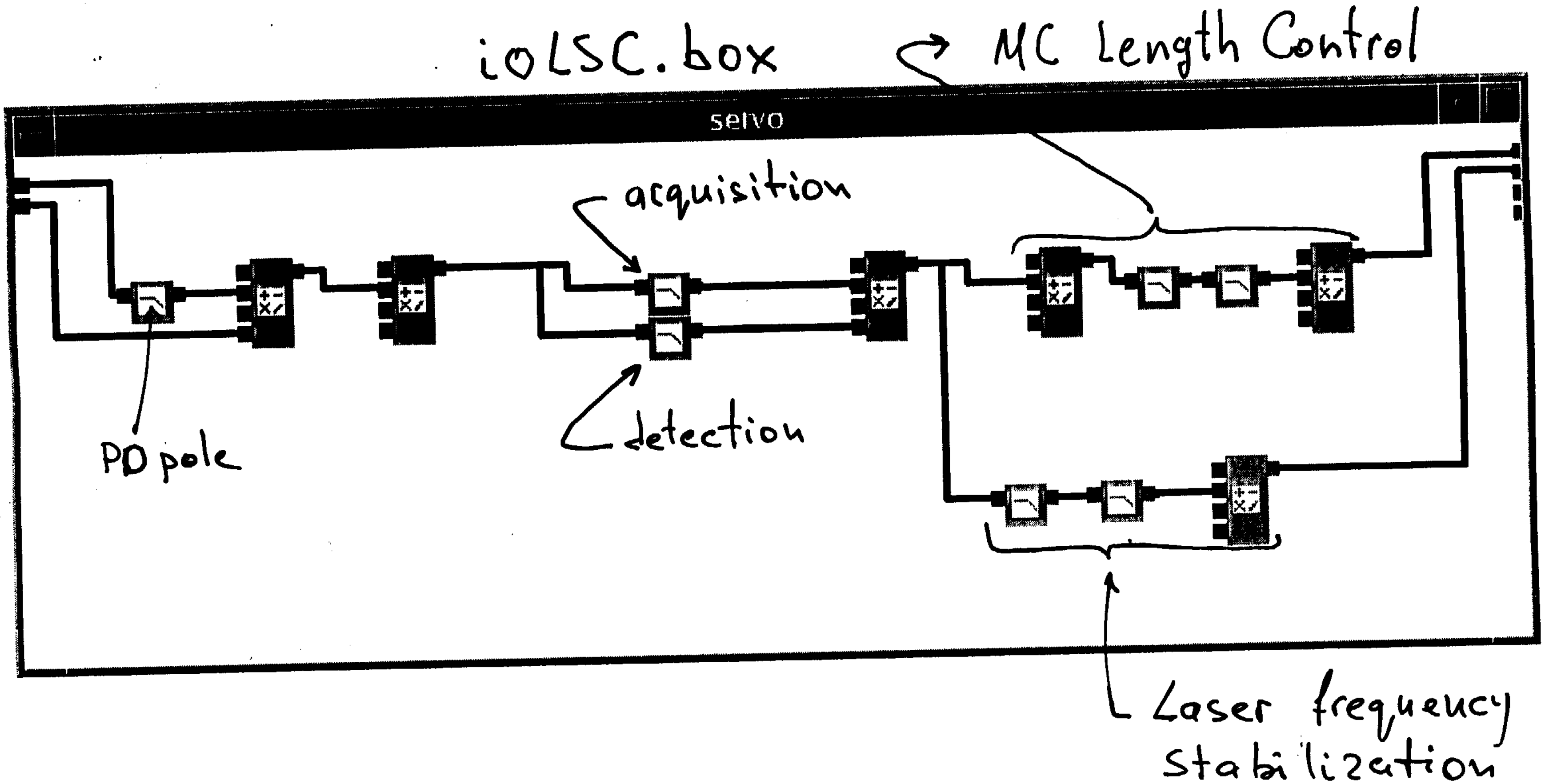
IO Control loops (MIT)



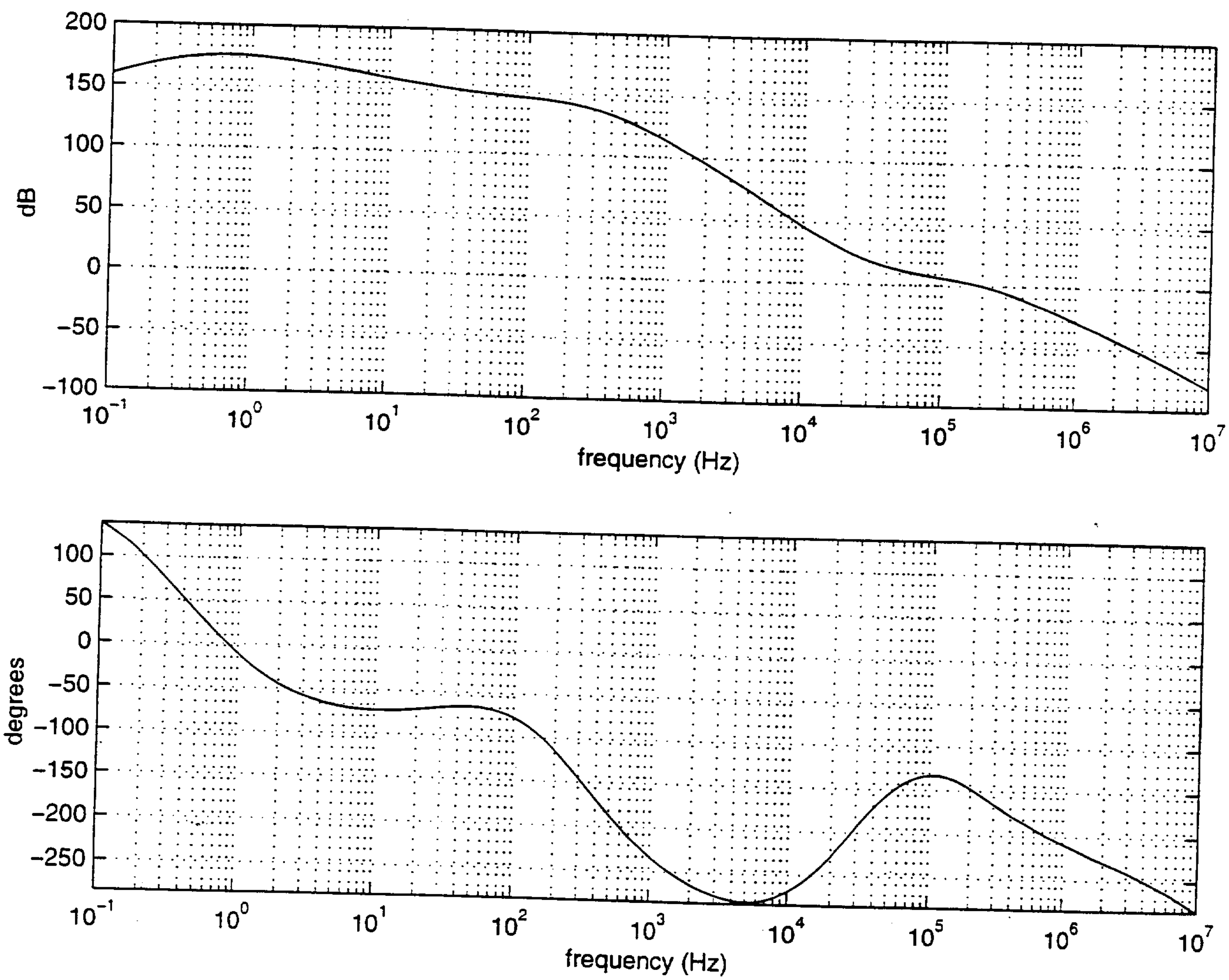


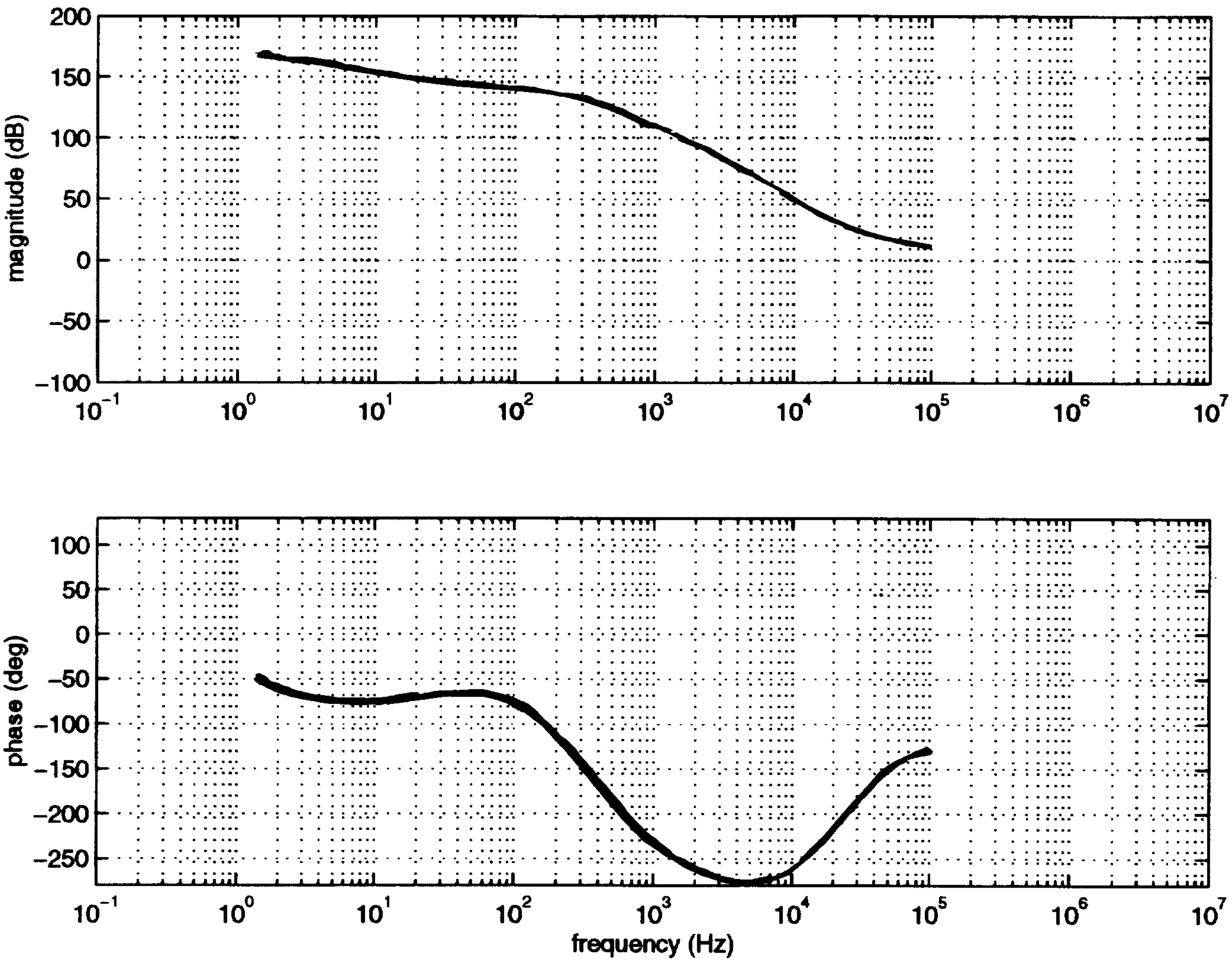
MIT
ioo1
Freq noise in
1
Sum2
MC cavity
3.1 kHz pole
2*pi*3.1e3
(s+2*pi*[3.1e3])
MC module
PD-Mixer gain
V/Hz
1e-3
Photodiode
Pole at 5.0 MHz
2*pi*5.0e6
(s+2*pi*[5.0e6])
Overall Loop gain
0.45
2.5*2e4
Gain
Acquisition mode TF (V/V):
zero: 4.0 kHz; pole: 50 Hz
50/4.0e3(s+2*pi*[4.0e3])
(s+2*pi*[50])
3e2*3e2*3e2/(20e3*25e3*30e3)(s+2*pi*[20e3,25e3,30e3])
(s+2*pi*[3e2,3e2,3e2])
Operation mode TF (V/V):
zeros: 20, 25, 30 kHz; poles: 300, 300 Hz
Sum1
Out
Sum
pi*0.3*2*pi*0.3*1/40(s+2*pi*[0,0,40
(s+2*pi*[0.3,0.3,1])
VCO AC coupling TF (V/V):
zeros: 0, 0, 40 Hz; poles: 0.3, 0.3, 0.3 Hz
(140e3)/(70e3)(s+2*pi*[70e3])
(s+2*pi*[140e3])
phase lead :
zero: 70 kHz; pole: 140 kHz
VCO gain
1
VCO TF :
20 degree phase shift at 100 kHz
275e3/2750e3*[1 2*pi*2750e3]
s+2*pi*275e3
VCO gain
Hz/V
1e6
Laser Controller
Laser freq noise
Residual freq
VCO drive (Hz)
MC
length control
2*pi*1e3
(s+2*pi*[1e3])
RC LP filter:
pole at 1 kHz
Hz/m
1.97e13
(0.1)/(1)(s+2*pi*[1])
(s+2*pi*[0.1])
Mirror path TF (V/V):
zeros: 1 Hz; poles: 0.1 Hz
1.2
Mirror gain
ellipfilt
elliptic filt: 40 dB sb,
0.1 dB rip at 30 Hz
1.8e-6
(m/V)
Sum3
1
1/(2*pi*1)^2s^2+1/(2*pi*1)s+1
pendulum TF with Q=1
P 3kH, 3kH
LP
/home/rick/e2e/IOO/ioo1.mdl

MC Length & Frequency Control



MC Length & Frequency control
servo TF (open loop)
(Simulink)





200
150
100
50
0
-50
-100
magnitude (dB)
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
100
50
0
-50
-100
-150
-200
-250
phase (deg)
frequency (Hz)

e2e TF

Status and Plans

- optics part of IO is completed
- currently working on the implementation of MC length control servo
- integration of the IO and PSL systems
- implementation of the MC WFS servo
- complete development of IO subsystem by beginning of September.

Note 1, Linda Turner, 08/17/99 09:05:49 PM
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