Length Control System Modeling

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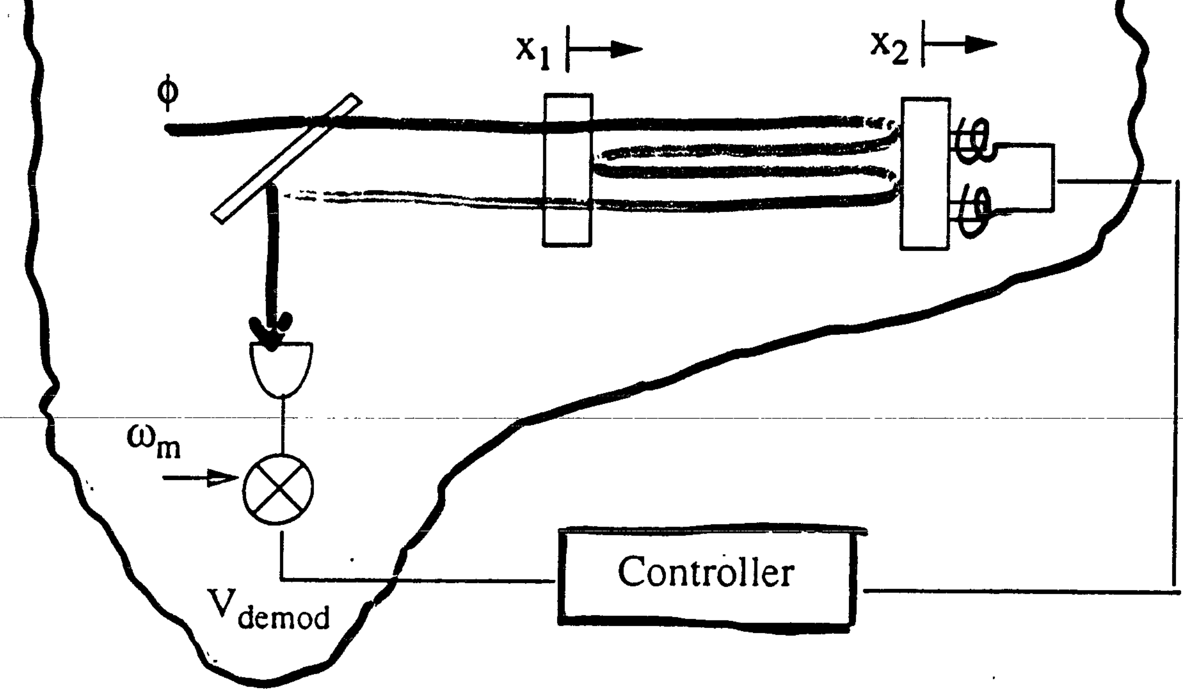
Optical Response Model:

Model showing response at V_{demod} due to moving x_1 and x_2, or changing ϕ



Feedback Model:

Model of how light intensity on photodetector is transfomed into a force that drives test mass or changes laser phase

Length Control System has 2 Modes of Operation

1. **Operations Mode:** $|x_1 - x_2| < \frac{n\lambda}{2} \pm \frac{\text{(fringe width)}}{2}$

   a. Linear optical response model

   b. Linear feedback model (saturations not important)

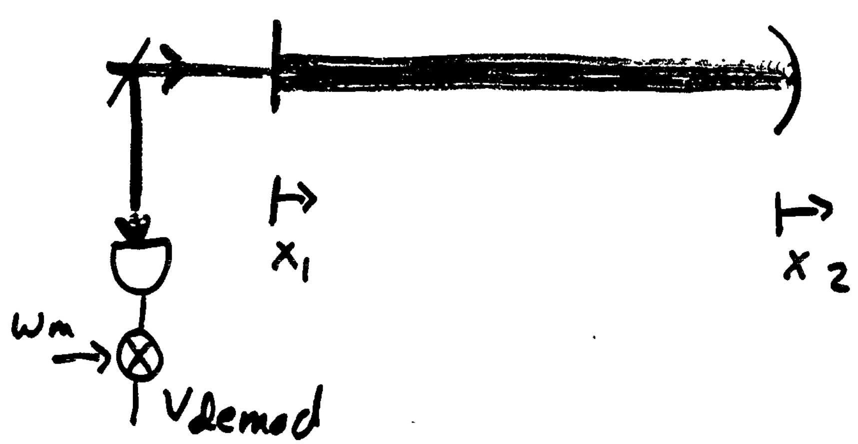
   c. Feedback design "more straightforward" since frequency domain techniques can be used (i.e bode plots valid)

2. **Acquisition Mode:** $|x_1 - x_2|$ traverses through fringes

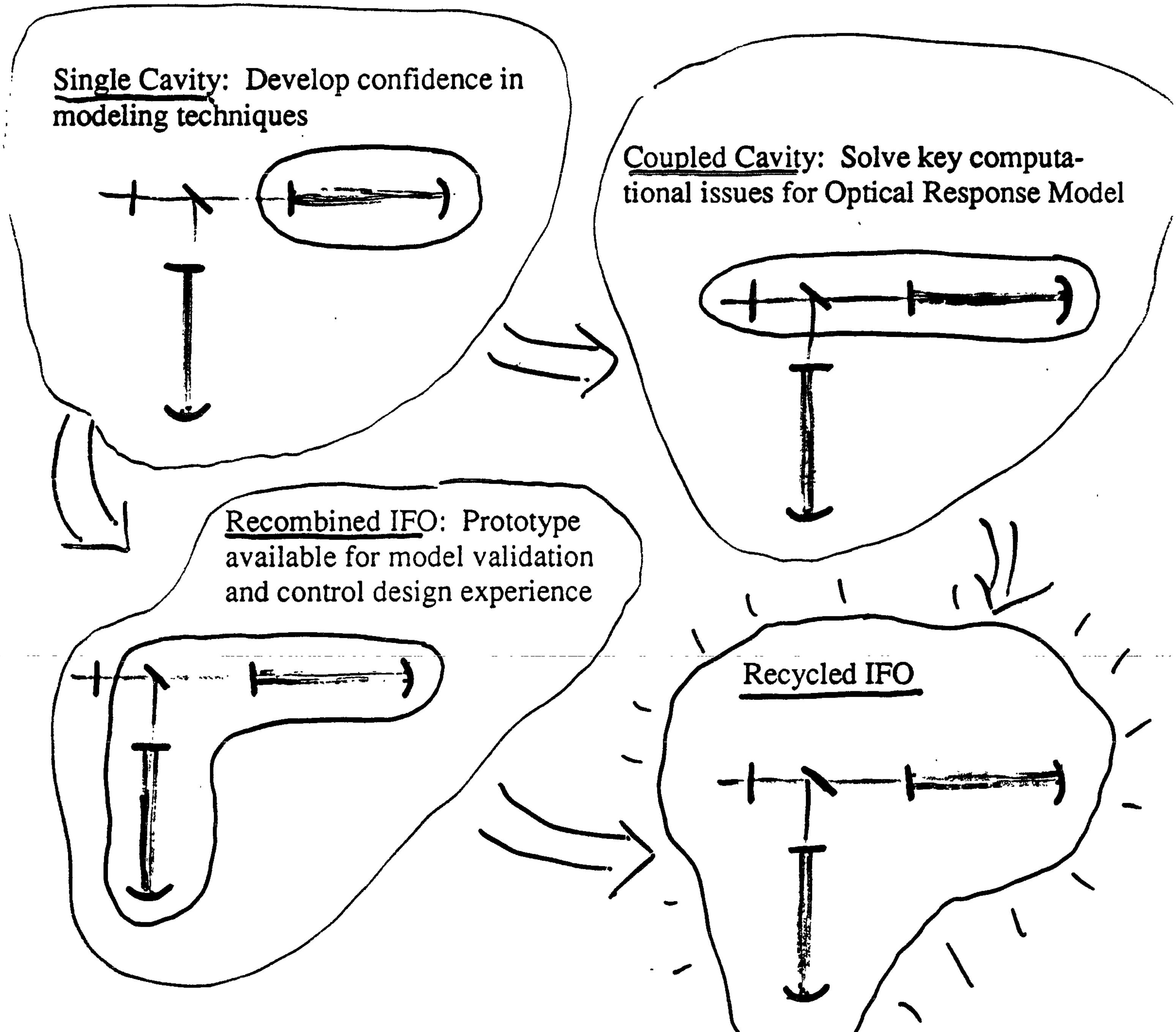
   a. Nonlinear optical response model

   b. Nonlinear feedback model if saturations important

   c. Feedback design and analysis must be done in time domain since frequency domain techniques not valid



Building Blocks Needed for Acquisition Model of LIGO Recycled IFO



4 Goals associated with each block:

1) Completion of optical response model
2) Completion of feedback model
3) Model Validation
4) Use of model as design/analysis tool for prototype/LIGO IFO

Status of Single Cavity Acquisition Modeling

1. Optical Response Model (complete)

   a. Model matched with experimental data

2. Feedback Model (complete)

   a. Simulations showing threshold velocity observed in second arm of 40 M ($F_1 \approx 15000$): $v_{th_1} = .2 \frac{\text{microns}}{\text{sec}}$

   b. Simulations showing predicted threshold velocity of 4 Km cavity assuming LIGO parameters (F_2=200). $v_{th_2} = 15 \frac{\text{microns}}{\text{sec}}$

   c. Prediction that threshold velocity ratio scales inversely with the Finesse ratio:

$$\frac{F_1}{F_2} \approx \frac{v_{th_2}}{v_{th_1}}$$

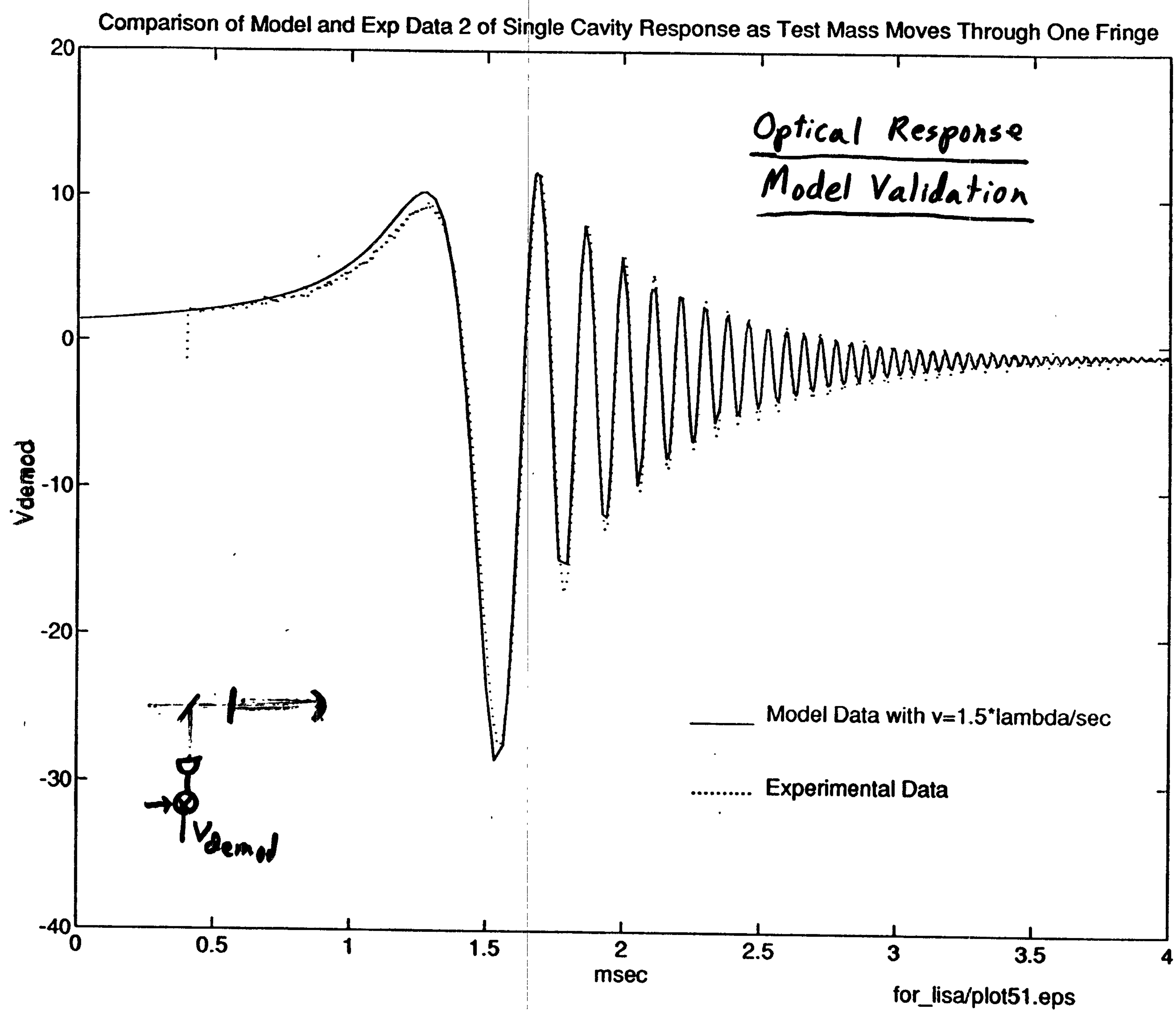
3. Model Validation (in progress)

   a. Use output of coil driver to predict test mass velocity as lock acquired (i.e. measurement of v_{th}). Use test mass velocity as input to model to simulate waveform as lock is acquired

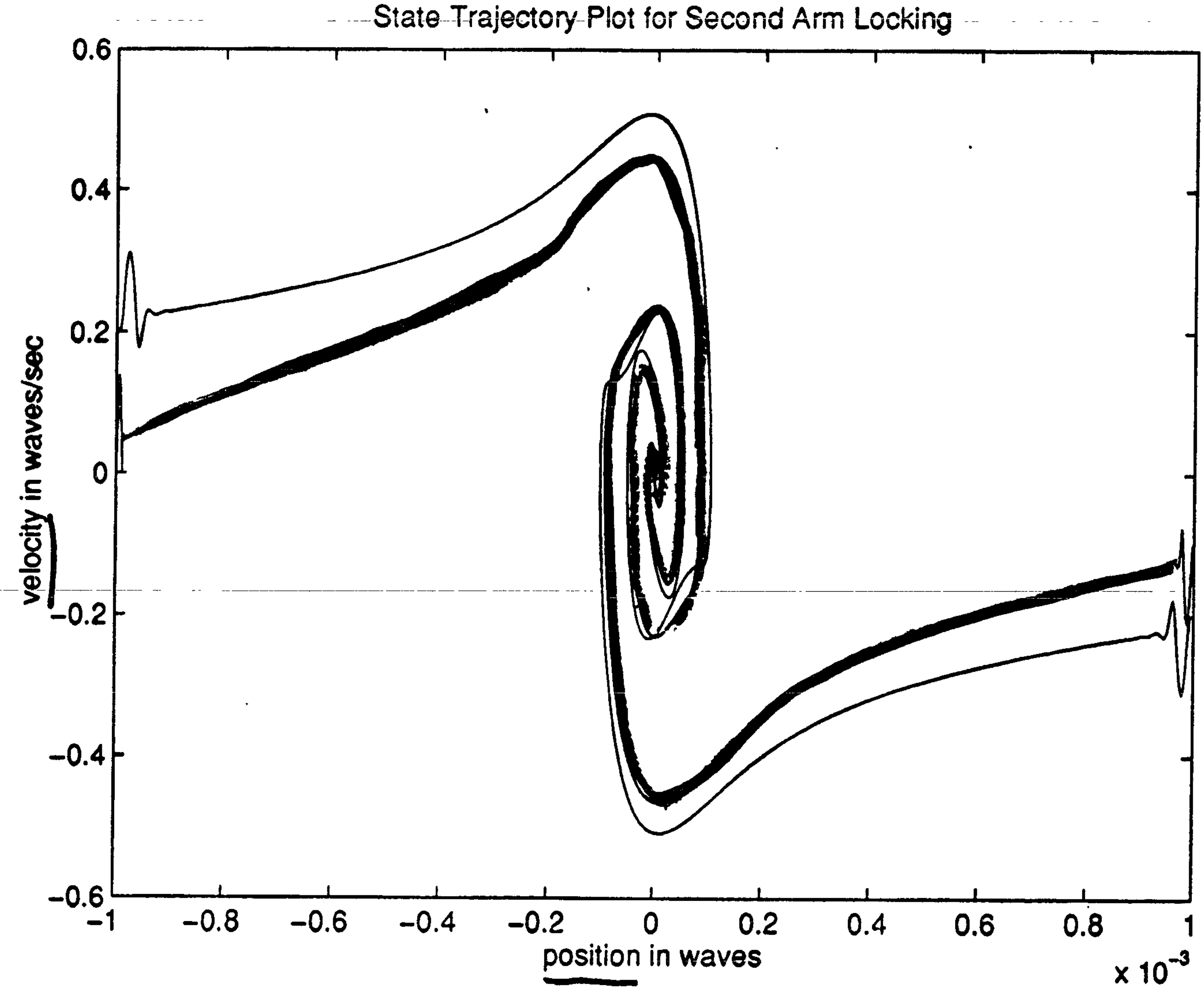
4. Use of Model as Design/Analysis Tool for prototype/LIGO IFO (in progress)

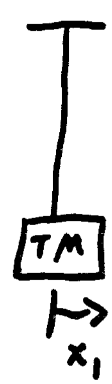
   a. Design of alternate feedback design to increase speed of acquisition of 2nd arm in 40 m lab

↑ Need experience with 1 deg of freedom systems before go to 2 + 4 coupled degrees of freedom LS.

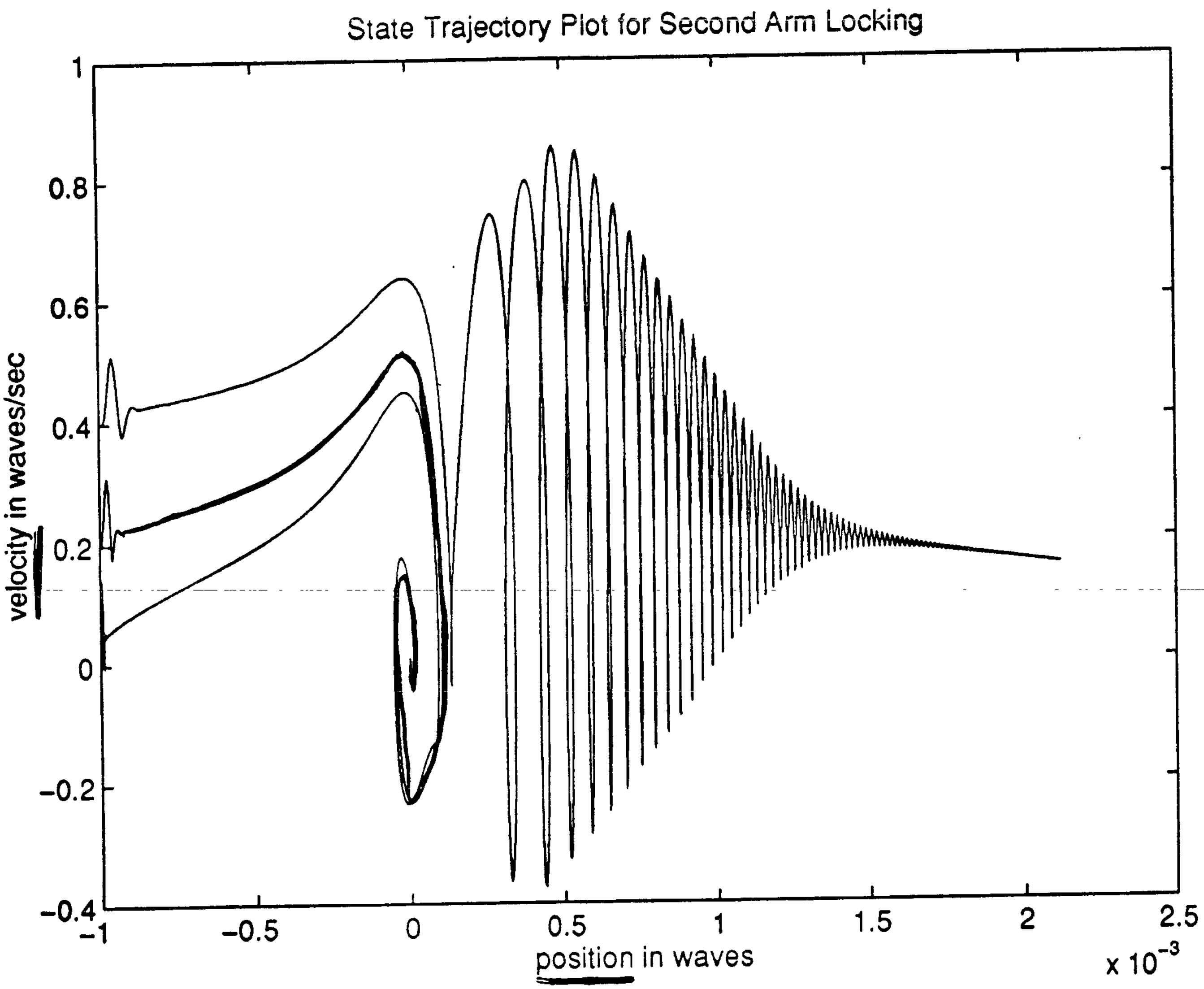

Comparison of Model and Exp Data 2 of Single Cavity Response as Test Mass Moves Through One Fringe
Optical Response
Model Validation
Vdemod
msec
Model Data with v=1.5*lambda/sec
Experimental Data
for_lisa/plot51.eps
20
10
0
-10
-20
-30
-40
0
0.5
1
1.5
2
2.5
3
3.5
4

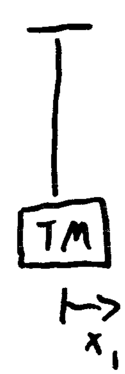
40 M Locking Trajectory



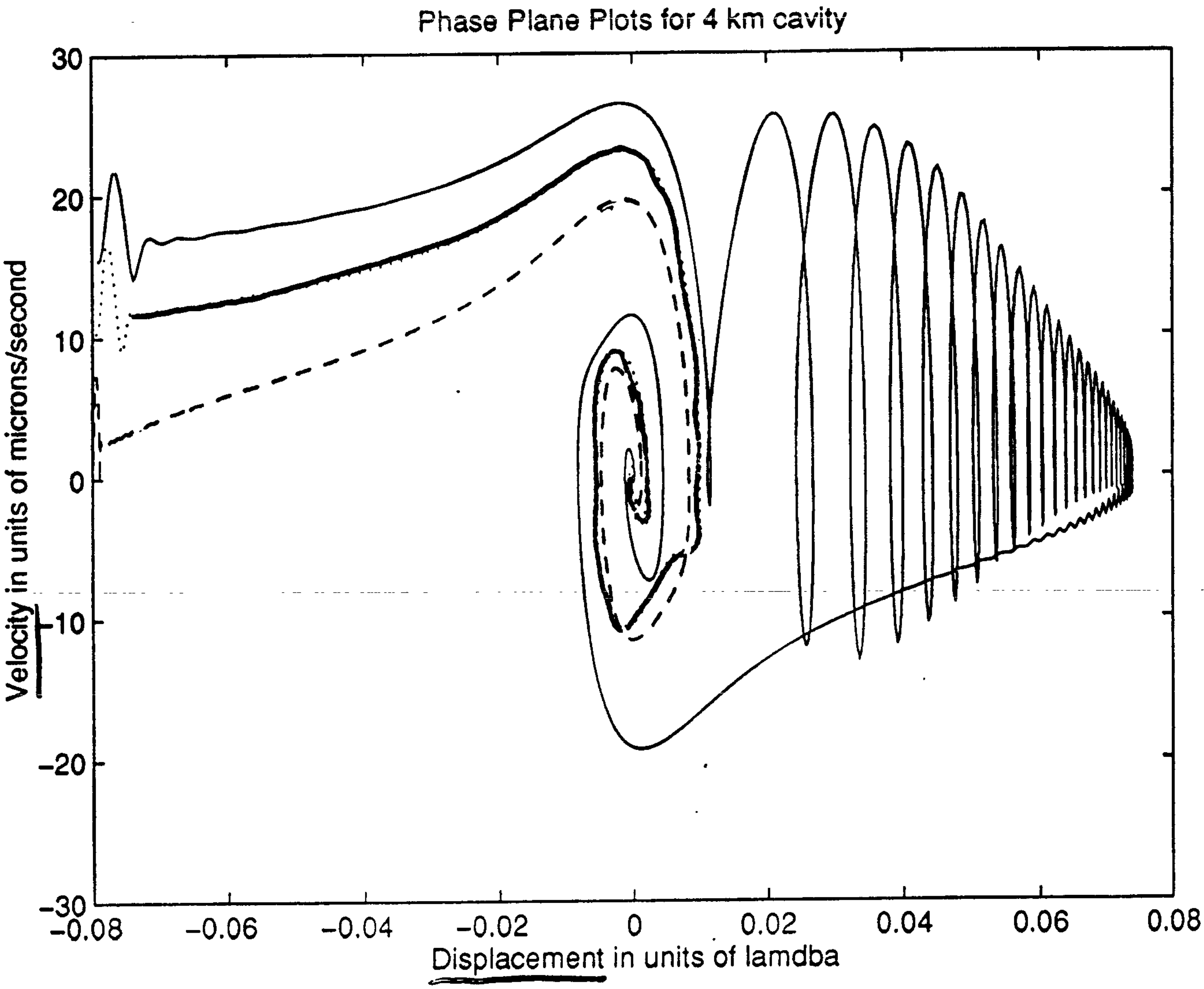


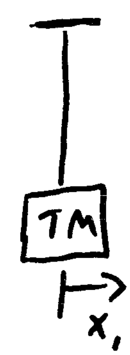
40 M Locking Trajectory



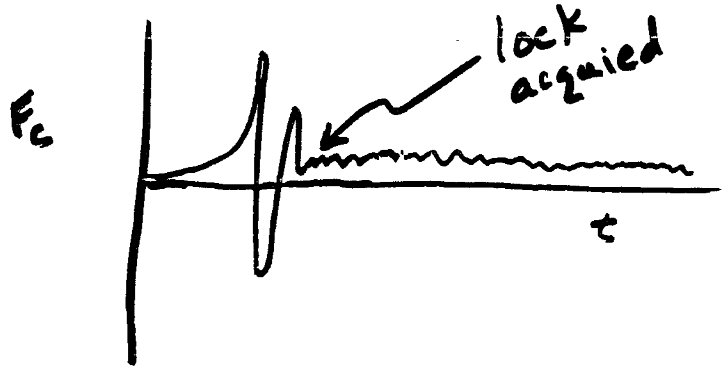


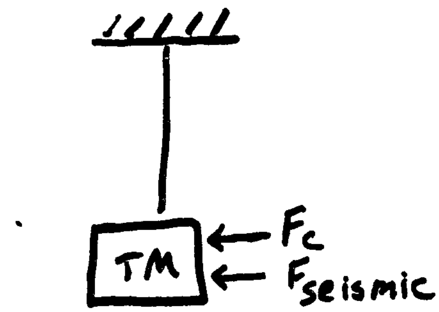
4 KM Locking Trajectory





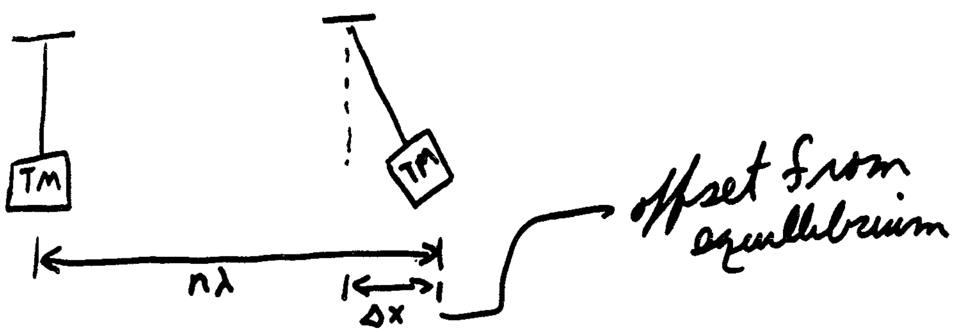
Closed Loop Model Validation for Single Cavity





1. Measure coil driver output voltage, and calibrate to determine control force on test mass, F_c.

2. Can determine offset from pendulum equilibrium using DC offset of F_c



3. Can predict velocity at moment of acquisition from F_c (look at many acquisitions to get threshold velocity)

4. Can predict F_c waveform as lock acquired using model (need velocity from (3))

Status of Coupled Cavity Acquisition Modeling

1. Optical Response Model (complete)
2. Feedback Model (will commence work on this when Single Cavity complete)
3. Model Validation (in progress)
   a. Optical Response Model: Generate transfer functions by driving model with small amplitude signals around resonance. Compare with transfer functions generated from Martin's model of coupled cavity in Operation Mode
4. Use of Model as Design/Analysis Tool for prototype/LIGO IFO (not applicable)

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