Signal Extraction for Frontal Modulation in RSE

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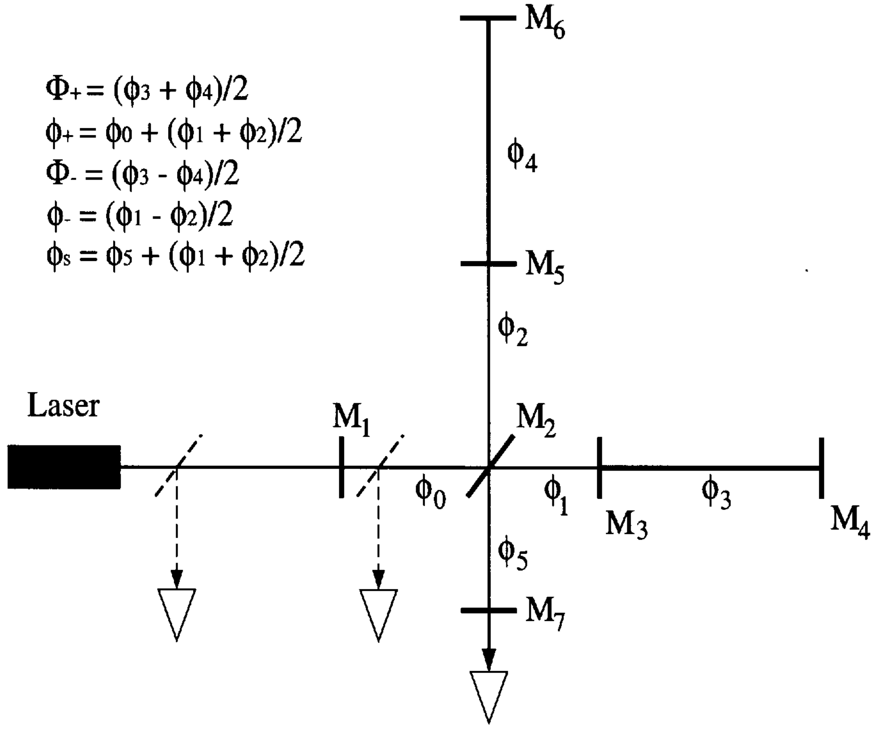
LSC-LLO meeting

March 16-18, 2000

LIGO-G000055-00-D

Resonant Sideband Extraction



- Assumptions I'll make

  ››3 PD's

  – **Transmission pd's have bad snr?**

  ››Modecleaner after modulation

  – **Is this needed or not? Modulating after MC frees up alot of constraints**

  ››Entirely optically heterodyned signal extraction

  – **Regarding offset locking, where is the beamsplitter signal?**

What these assumptions mean

- Extra dof + same pd's in use would imply the need for an additional modulation frequency on the input light.

  ››Exist signals using higher order sidebands, but these are typically small.

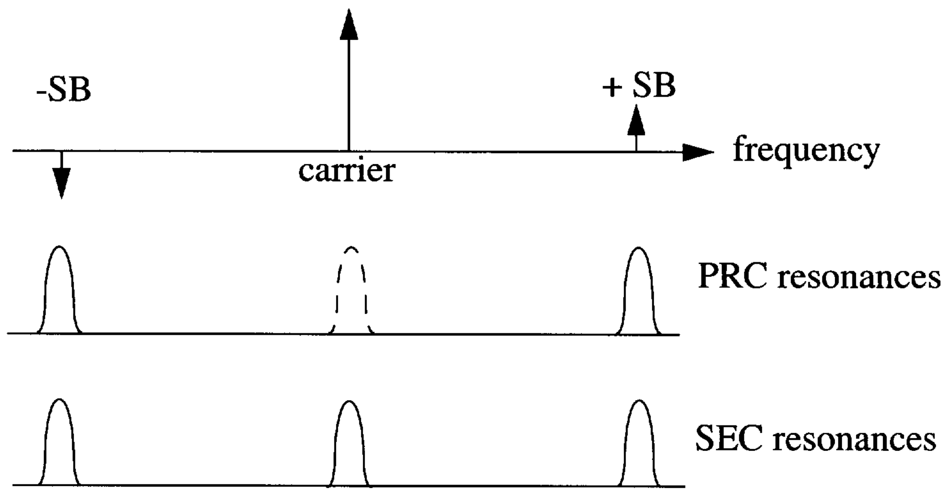
- Modecleaner implies that all these frequencies need to be integer multiples of MC's fsr

  ››Base frequency can be tunable, but this implies not only a change in length of the MC, but possibly also of the power recycling cavity.

- What else?

Broadband signal extraction

- In broadband mode, high transmission for both sidebands
  - ››Symmetry of sidebands about carrier matches symmetry of FSR



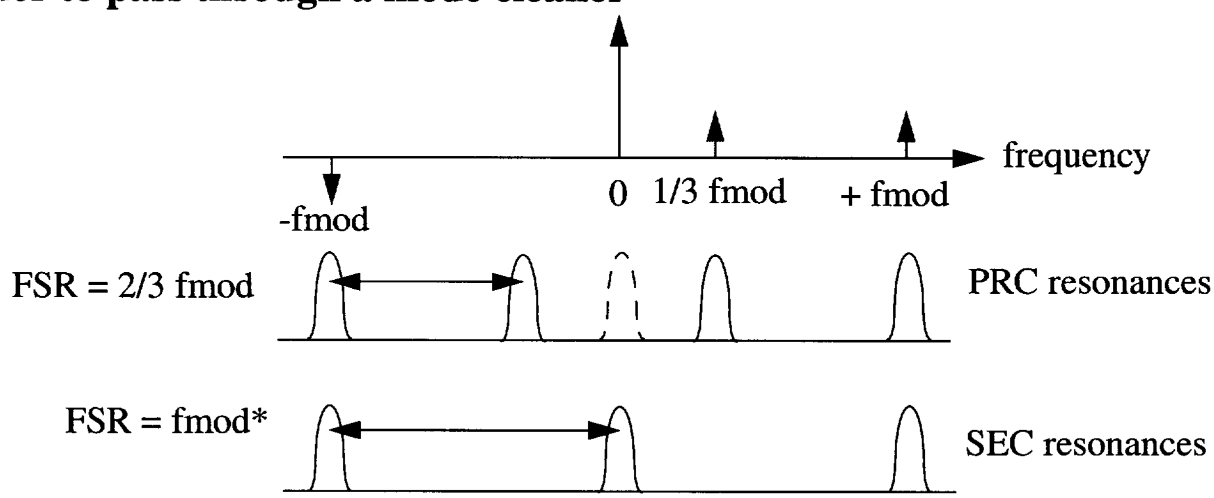
  - ››Set up GW LO frequency to resonate in both PRC and SEC

Length control : SSB

- Need an independent LO to measure RF sideband phase variation in SEC

  ››Add subcarrier at fmod/3 or some integral odd fraction of fmod

  – **Taken as a constraint that all frequencies are integer multiples, in order to pass through a mode cleaner**



  – **Using AM modulated sidebands at fmod/3 would probably be better for only broadband operation**

  ››Use [fmod-fmod/3] beatnote at existing signal ports (PRC pickoff, for example) for control of SEC

  ››All other signals could be the same as initial LIGO

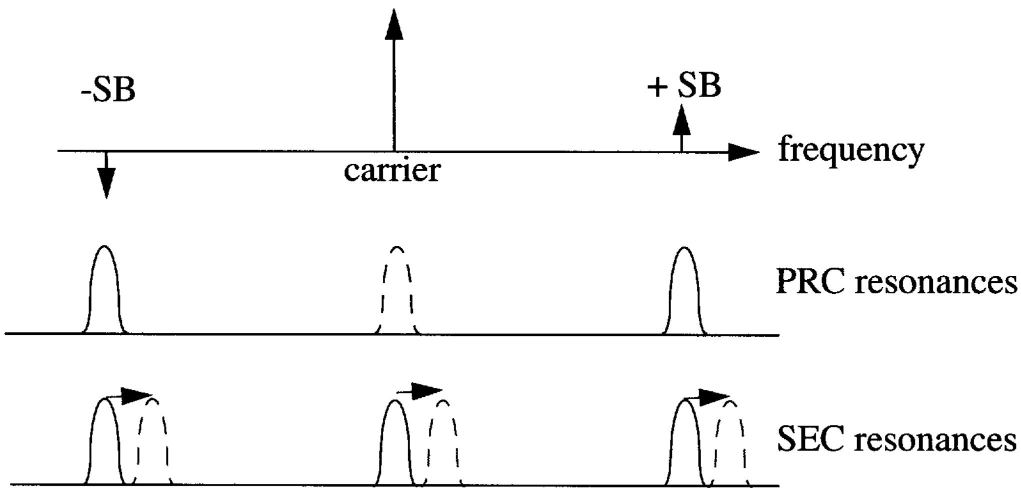
  – **More cross-couplings**

- This breaks down when...

Detuning

- Detuning introduces a problem

  ››Both GW LO sidebands no longer resonant in coupled-cavity system



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Option : SSB transmission

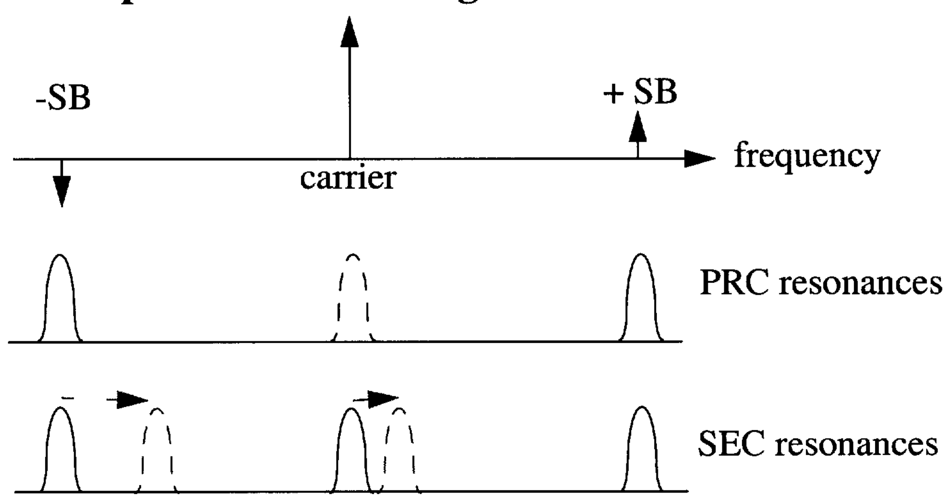
- Macroscopically detune length of SEC

  ››Only one RF sideband gets out

  ››SEC length changes on the order of centimeters

  ››Once a macroscopic length change is made, there exists a range of microscopic detuning for which there is still significant RF sideband power transmitted to the dark port

  – **This can encompass the entire range of interest**



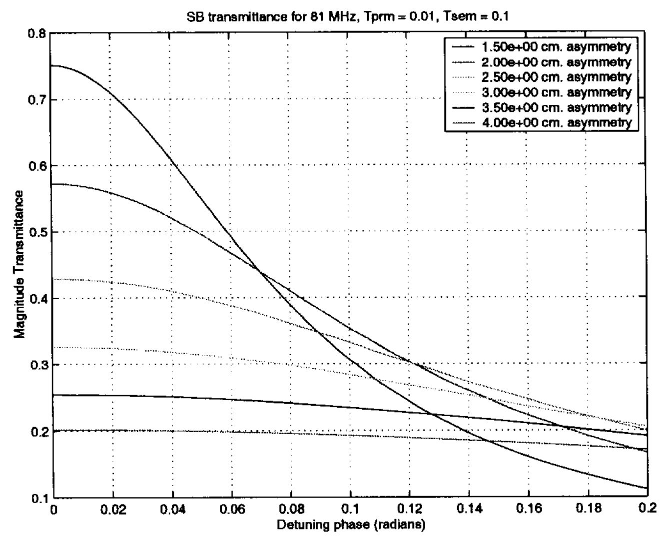
- What about change in fmod?

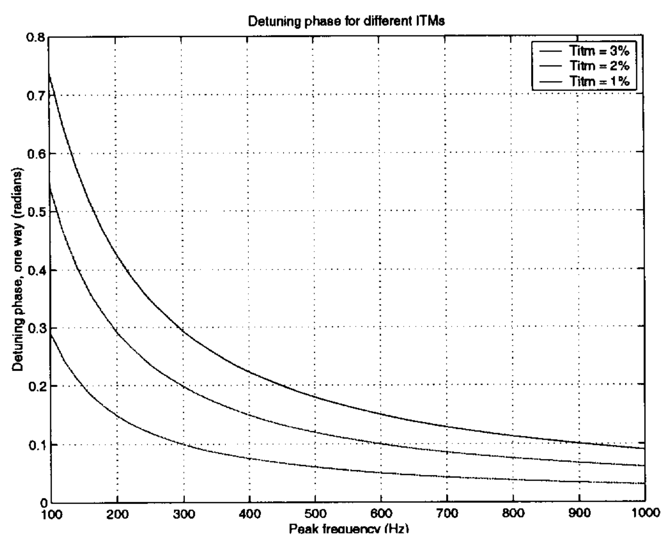
  ››Would have to change both fmod and fmod/3, plus the modecleaner length, plus the power recycling cavity length in order to maintain resonance of fmod/3, which in turn iterates the desired change in fmod.

Asymmetry

- Chosen for good transmission of GW LO sideband.

  ››Typically quite small.. 1-4 cm for ~80 MHz.



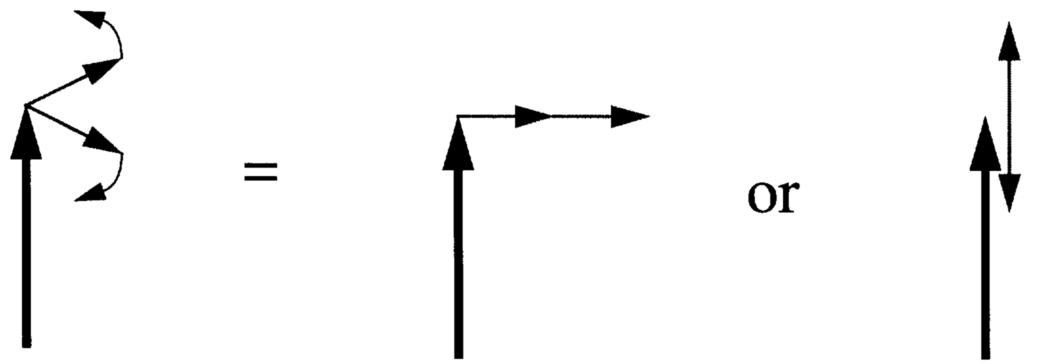


  ››Pick an asymmetry with strong transmission a 0 detuning, but consider the range of "microscopic detuning" desired.

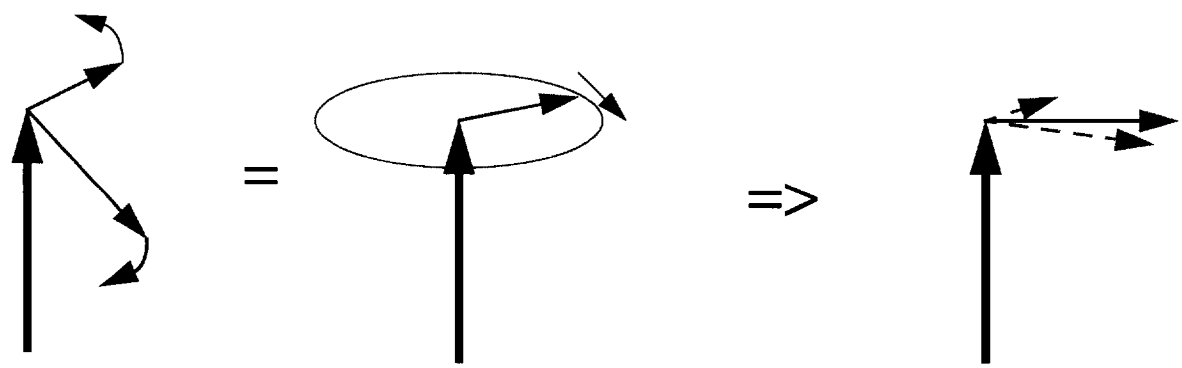
Detuning control

- GW LO sidebands are now unequal in magnitude and phase inside the interferometer

  ››This means that for other signals which use those sidebands, there exists only one demodulation phase which has no offset, per photodiode



  – **Both give independent signals with 0 offset**



  – **Only one demodulation phase has zero offset!**

  ››What did we lose here? The “independence” of the Michelson ϕ_- signal

Implications (with some assumptions)

- The GW signal Φ_- is just fine at the dark port

  ››No carrier means no offset, regardless of demod phase.

- The other 4 d.o.f.'s come out of 2 pd's

  ››If you use the GW LO sidebands to detect the other signals, then in order to get 4 signals, you must have 2 different demodulation frequencies at both pd's.

  ››If you don't use the GW LO frequency, then you must look at how the additional sideband frequency is affected by the off-resonant signal cavity

  — **Can be a small effect, but is it negligible? How much DC offset is ok? "Safer" to assume one demodulation phase per photodiode per demodulation frequency.**

  ››6 signals (2 pd's x 3 demod frequencies), 4 d.o.f.'s.

  — **Dark port photodiode doesn't get good signals for anything but** Φ_-

  — **Carrier-AM modulation beatnote exists for detuned operation, but is non-existent for broadband.**

  — **Pretty fully cross-coupled**

RSE detuned matrix

%DOF 1 = F+, DOF 3 = f +, DOF 4 = f –,DOF 5 = f s

```
In[95]:= dof = 88m4, 1, m6, 1<, 8m1, 1<, 8m3, 1, m5, - 1, m4, 1, m6, - 1<, 8m7, 1<<;
         outindex = 8index@m1, 1, 2D, index@m1, 2, 1D, index@bb1, 1, 1D<;
         DCMatrix@dof, outindex, 0.14, 3 mfreq, .1D
         DCMatrix@dof, outindex, - .01, 2 mfreq, .1D
         DCMatrix@dof, outindex, 1.002, mfreqD
```

0.219911 demodulation at 81. MHz

	DOF 1	DOF 2	DOF 3	DOF 4
PD 1	- 871.789	36.1086	- 0.81204	0.712219
PD 2	- 657354.	- 3840.6	243.758	- 213.794
PD 3	0	0	0.470631	0

- 0.015708 demodulation at 54. MHz

	DOF 1	DOF 2	DOF 3	DOF 4
PD 1	0	- 11.8966	0.106232	- 0.510697
PD 2	- 9.33543	1104.65	1.53611	- 121.269
PD 3	0	0	0.263903	0

1.57394 demodulation at 27. MHz

	DOF 1	DOF 2	DOF 3	DOF 4
PD 1	2128.4	- 45.5014	0.156322	0.000604216
PD 2	504917.	4948.48	- 46.9246	- 0.181373
PD 3	0	0	- 0.000262508	0

- Issues (unresolved)

  ››Is it stable? Probably. Signals aren't linearly dependent.

  ››How would the cross-coupling degrade system performance? Is there a gain hierarchy which can be established that works?

  ››Alternatively, is there a robust diagonalization matrix?

  – **Might be difficult, due to the several orders of magnitude between signals**

  ››By the way, it doesn't look that bad.. (same matrix works for broadband as well)

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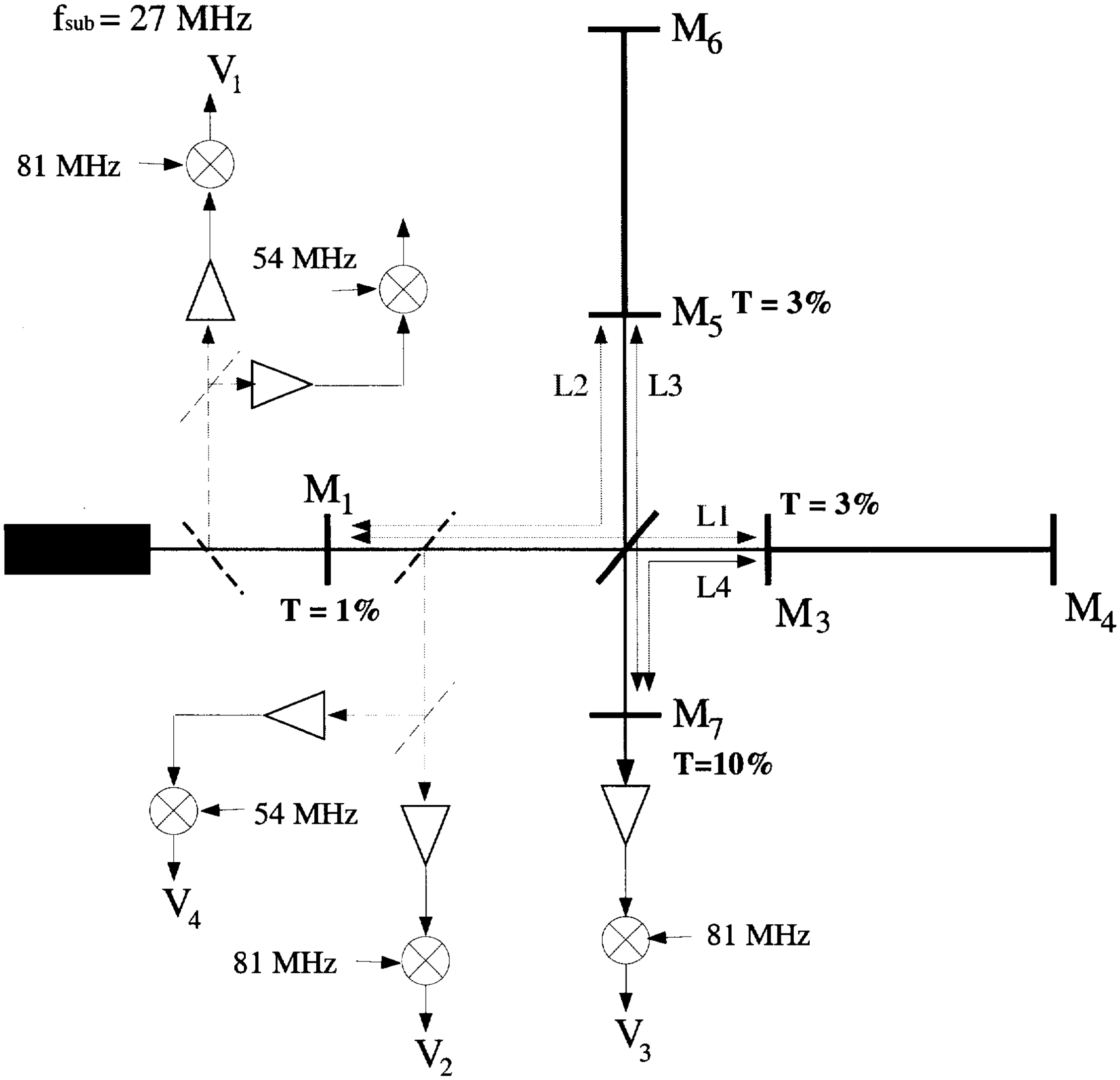
RSE - SSB design

$L_{PRC\ avg} = (L1 + L2)/2 = 2.776$ m.
$L_{SEC\ avg} = (L3 + L4)/2 = 1.851$ m.
$\delta = L2 - L1 = 0.03$ m.
$f_{mod} = 81$ MHz
$f_{sub} = 27$ MHz



››Cavity lengths can be some multiples of lengths spec'd

Other issues

- AM sidebands vs. subcarrier

  ››Subcarrier actually gives better signal separation of Michelson and signal cavities

  ››Signal cavity signal has 2 zero crossings with AM sidebands due to sensitivity to the "other" GW LO sideband.

  ››Demodulation at AM sideband frequency (carrier-AM sideband) doesn't give any signal unless the relative phase of the AM sidebands are messed up (e.g., in detuning).

  ››Sub-carrier demodulation always requires precision demod control (even in broadband operation)

  ››Generation of input spectrum

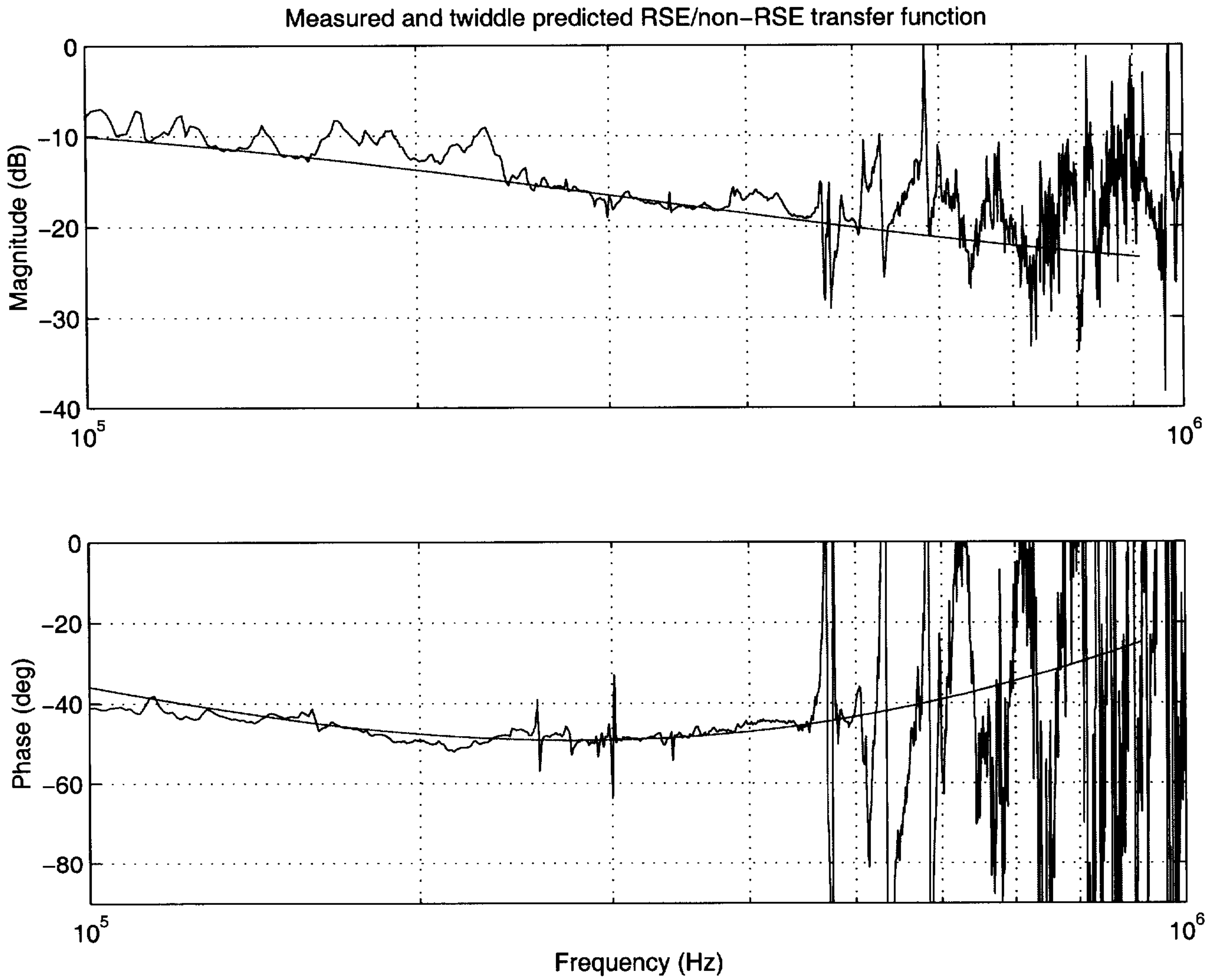
  – **Subcarrier: I use a Mach-Zender, which implies another control loop to maintain good fixed phase relationship, and this would also require alignment control. Is there a better way?**

  – **AM sidebands: Can probably be done in series (sideband on sideband issues, perhaps).**

- Modecleaner, arm finesse limitations, does the ideal signal extraction method change with different signal mirrors, will broadband ever be used.... ?
- Noise couplings...

Experimental results (so far)

- Locked full RSE, broadband



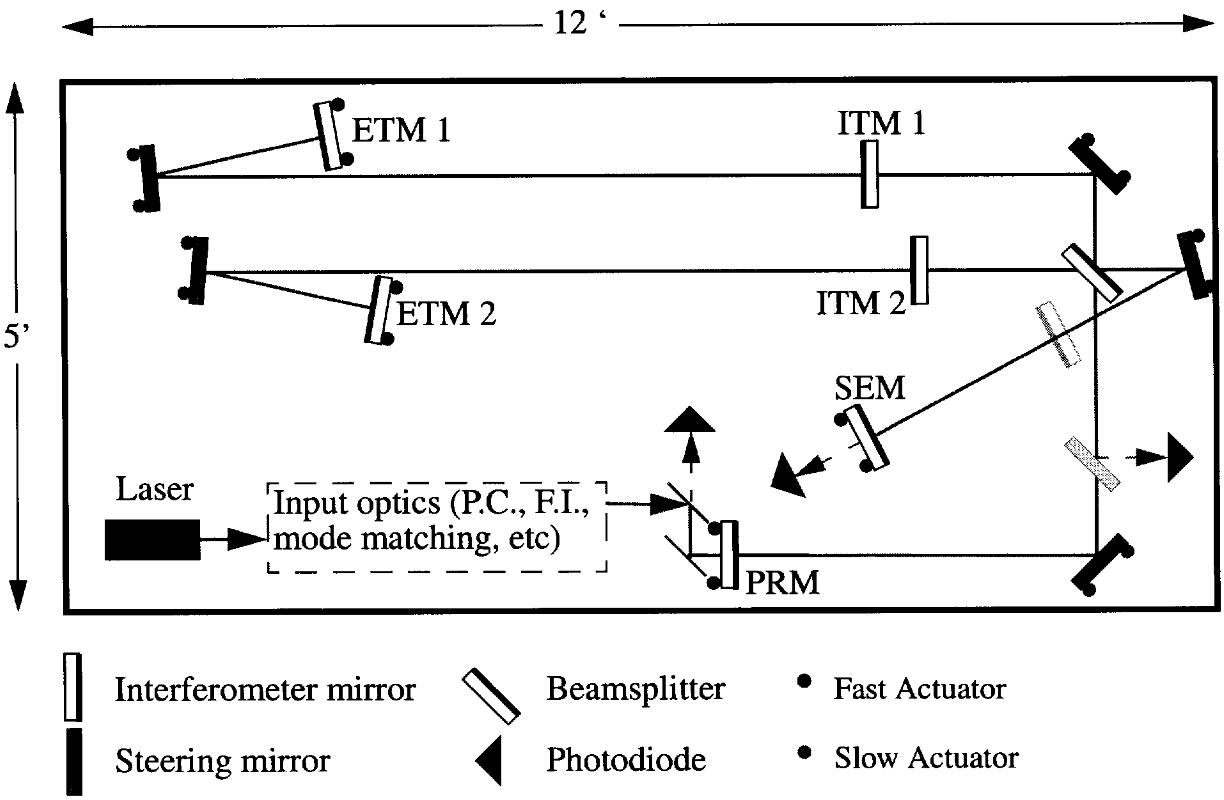
››Somewhat simplified optics - 60% PRM, 37% SEM. Arm cavity finesse of 300 (cavity pole roughly 200 kHz).

Experimental Work (in progress)

- Goals :

  ››Implement more aggressive signal extraction (SEM of 10%).

  – **Better phase shifters, have to modify RF electronics**



  ››Lock and measure detuned transfer functions.

Note 1, Linda Turner, 05/09/00 02:05:40 PM
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