LIGO

Modeling the 40m

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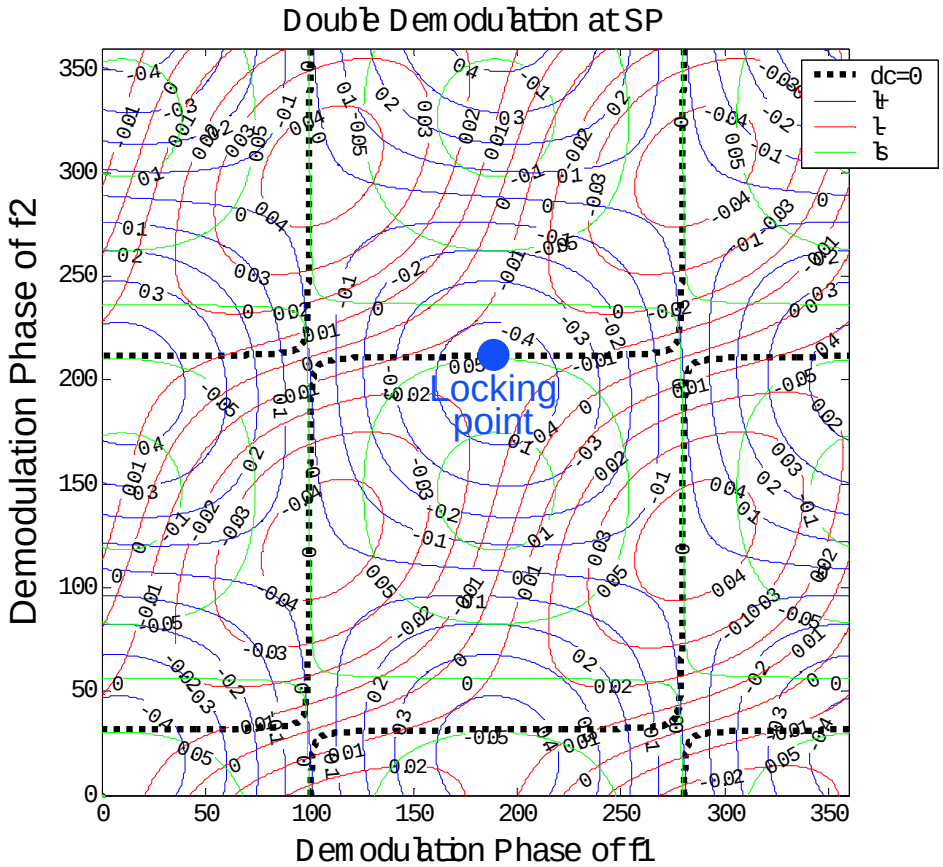
Modeling tools used at the 40m

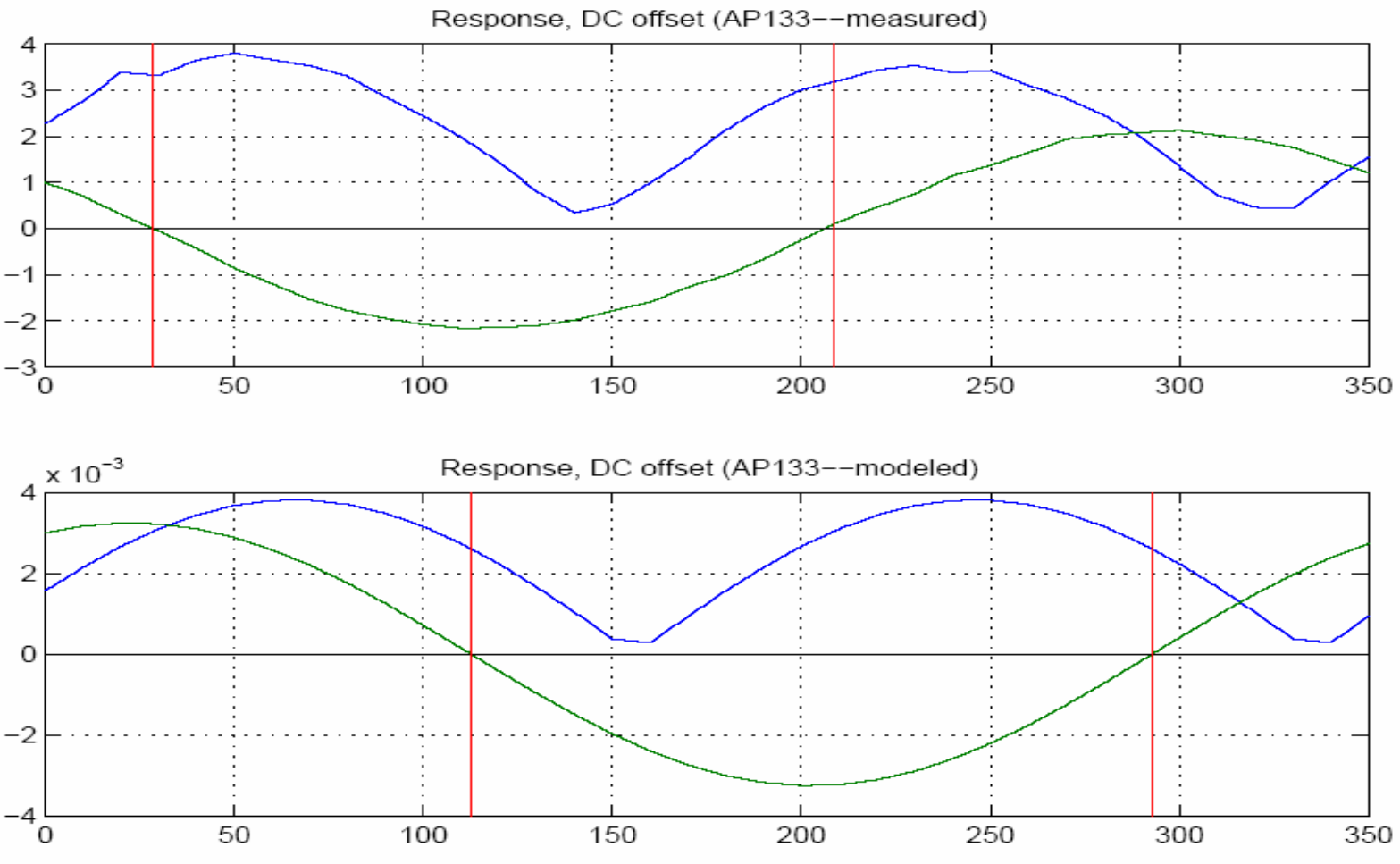
- Twiddle
  - » Frequency domain, analytical, no radiation pressure
- Finesse
  - » Frequency domain, no radiation pressure
- E2E
  - » Time domain, now with classical radiation pressure
- TCST (Thomas Corbitt Simulation Tool)
  - » Two-photon formalism, frequency-domain
- Optickle
  - » Frequency domain, Matlab, two-photon formalism

Finesse

- Finesse used extensively at the 40m lab 2004-2005
- Seiji Kawamura modeled the DRMI very thoroughly using Finesse
- Very useful for investigating quirks of double & differential demodulation

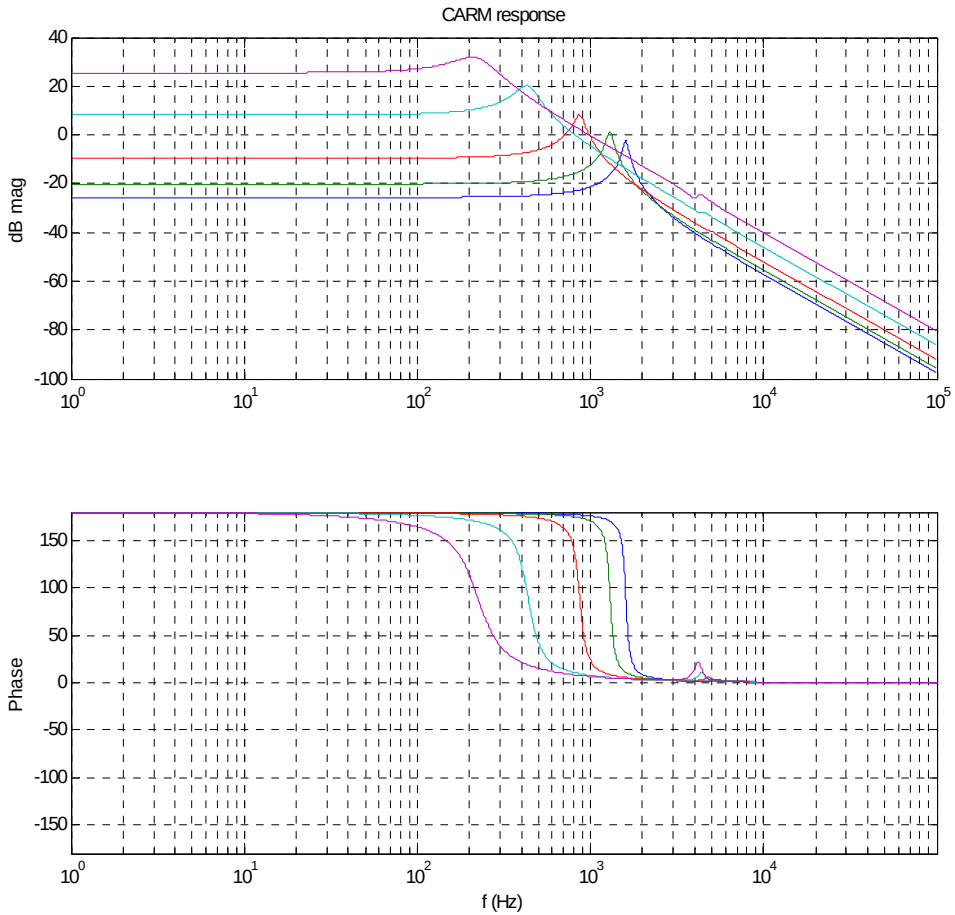


Differential Demodulation: offset vs gain



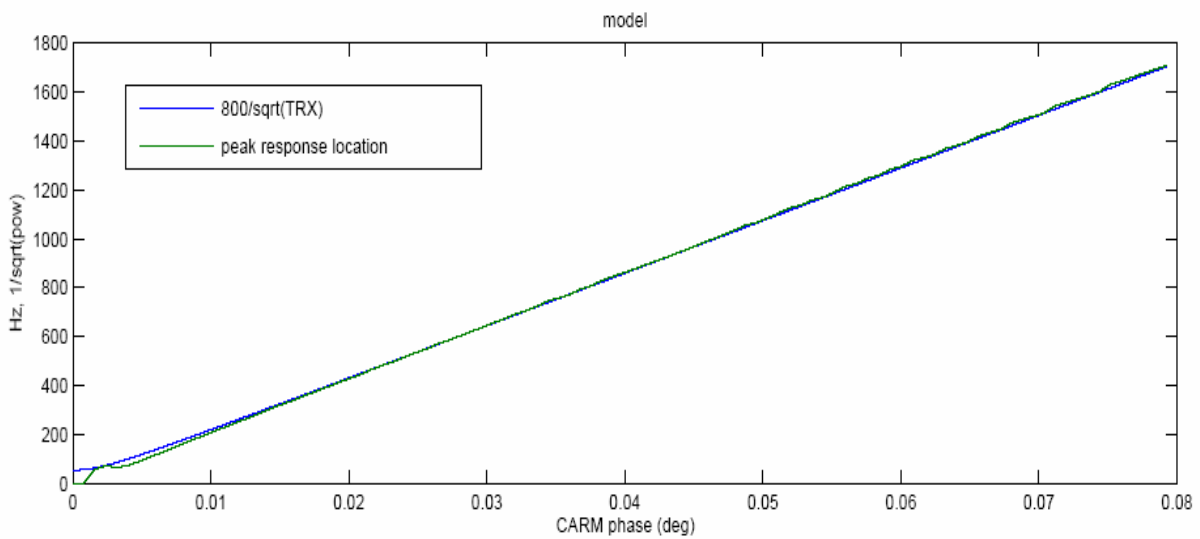
Finesse

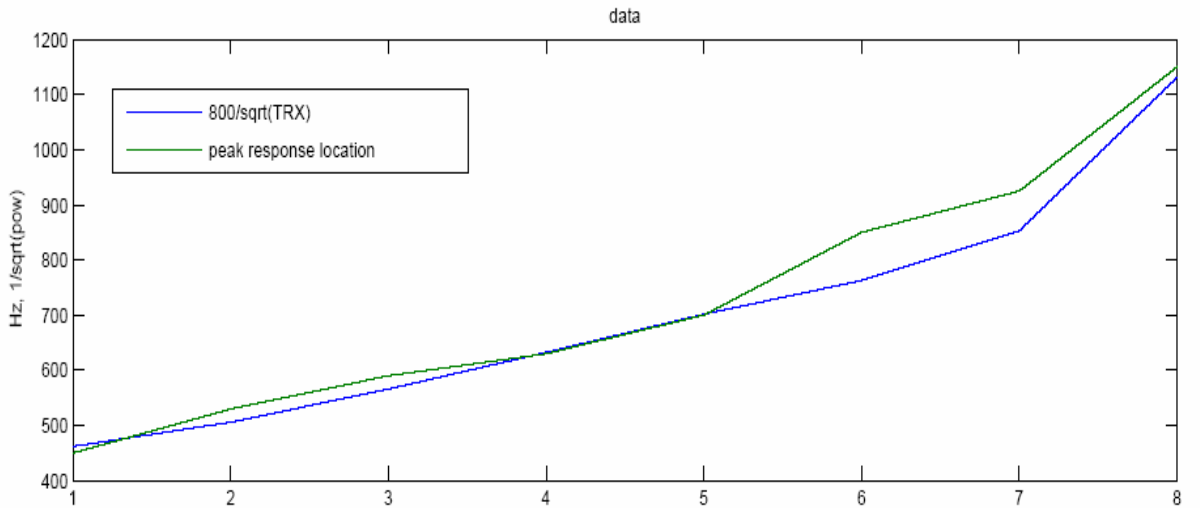
- Also used to investigate the coupled cavity response in our offset CARM state, and design compensation.
- Unfortunately has no radiation pressure effects



Straight from the ilog

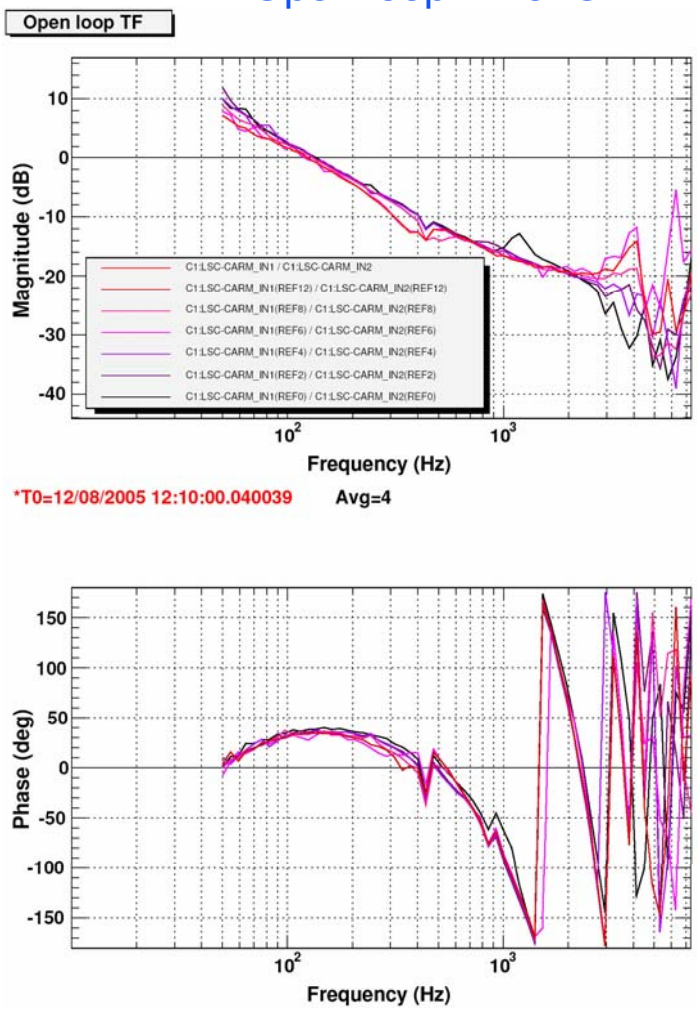
- Location of peak RSE response (in CARM) as a function of offset, modeled in Finesse, and then measured.



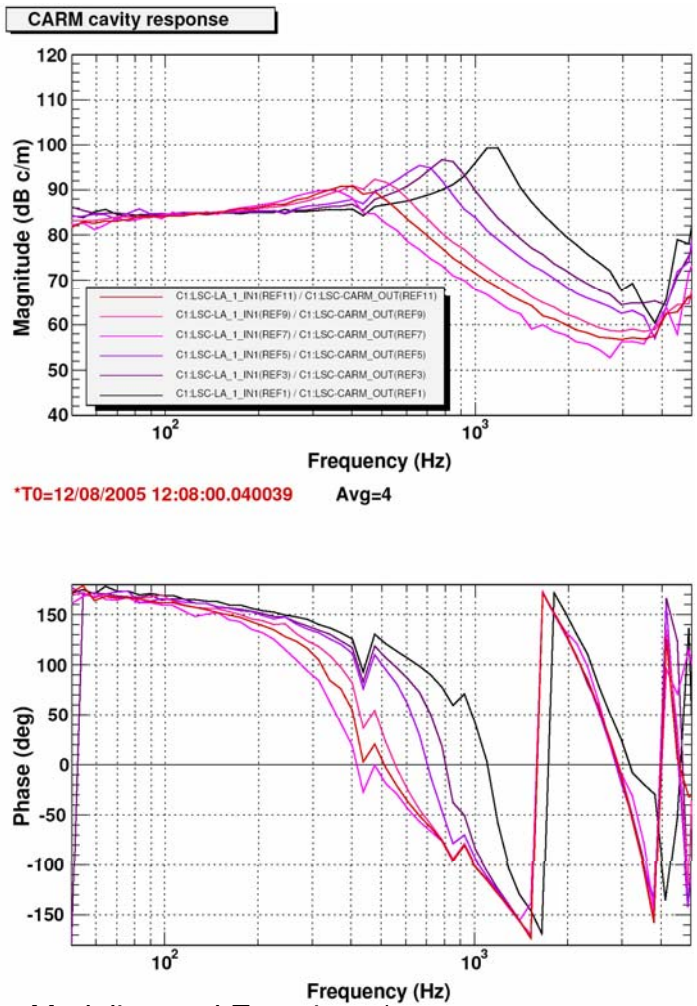


Dynamic compensation filter for CARM servo

Open loop TF of CARM



Optical gain of CARM

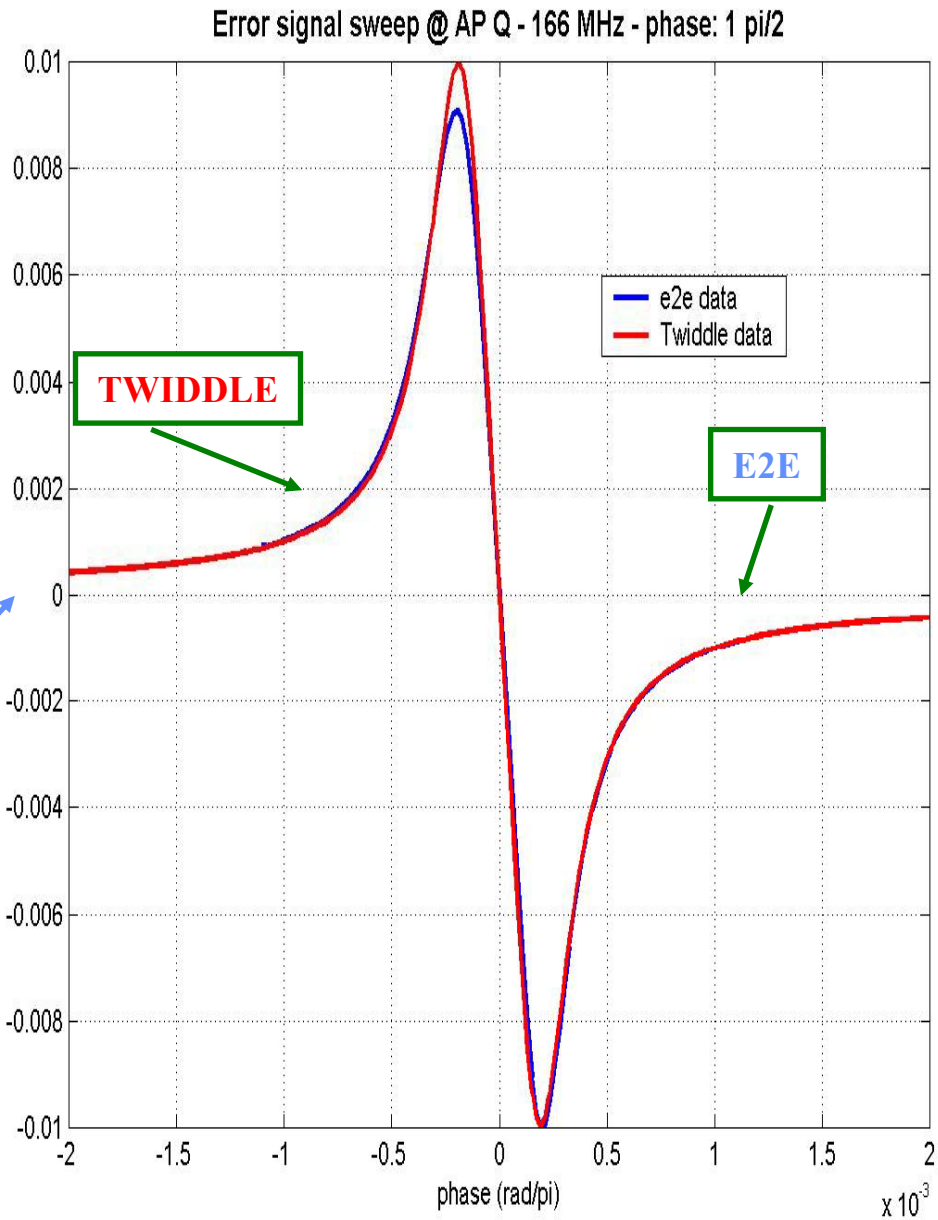


- Optical gain (normalized by transmitted power) shows moving peaks due to reducing CARM offset.
- We have a dynamic compensative filter having an nearly the same shape as optical gain except for upside down. Designed using FINESSE.
- Open loop transfer function has no phase delay in all CARM offset.

e2e SIMULATION:4Om/AdvLIGO package

Error signal sweeps at 10^{-9} m/s for the 40m IFO obtained in E2E framework and compared with TWIDDLE predictions

Example:
DARM @ **AP 166 MHz**
TWIDDLE and E2E comparison



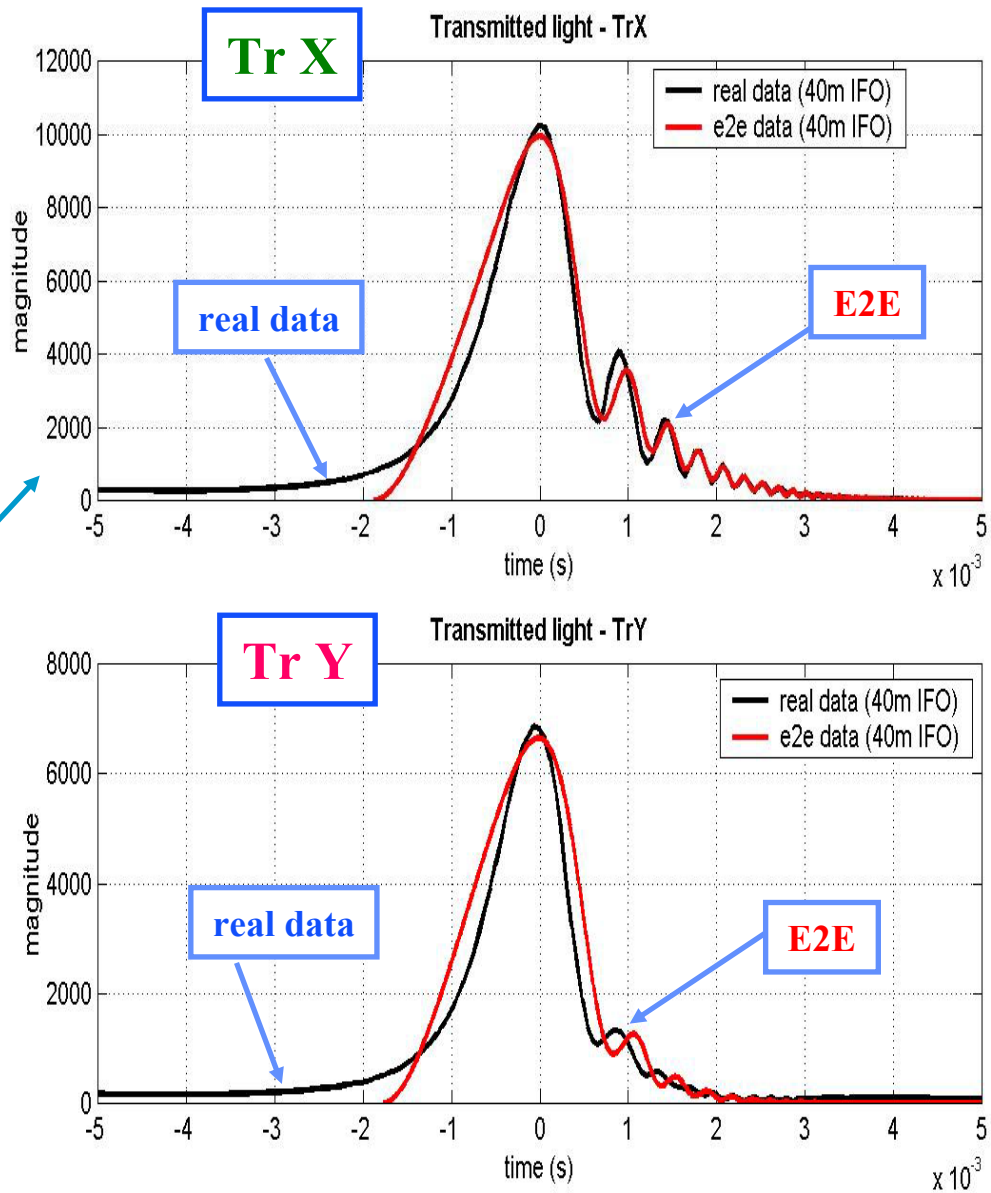
e2e SIMULATION: 4Om/AdvLIGO package

Real data have been used to estimate relative mirror velocity for both the arms:

$V_{xarm} = (0.35 \pm 0.13)$ µm/s

$V_{yarm} = (0.26 \pm 0.13)$ µm/s

Comparison between real data (black) and e2e simulated data (red) of the transmitted light for both the arms (full IFO): the mirror velocities used in E2E simulation are the values obtained fitting the real data



e2e SIMULATION: 40m/AdvLIGO package

Comparison between real data , e2e simulated data and the theoretical prediction **V(t)** of the SP error signal @ 166 MHz

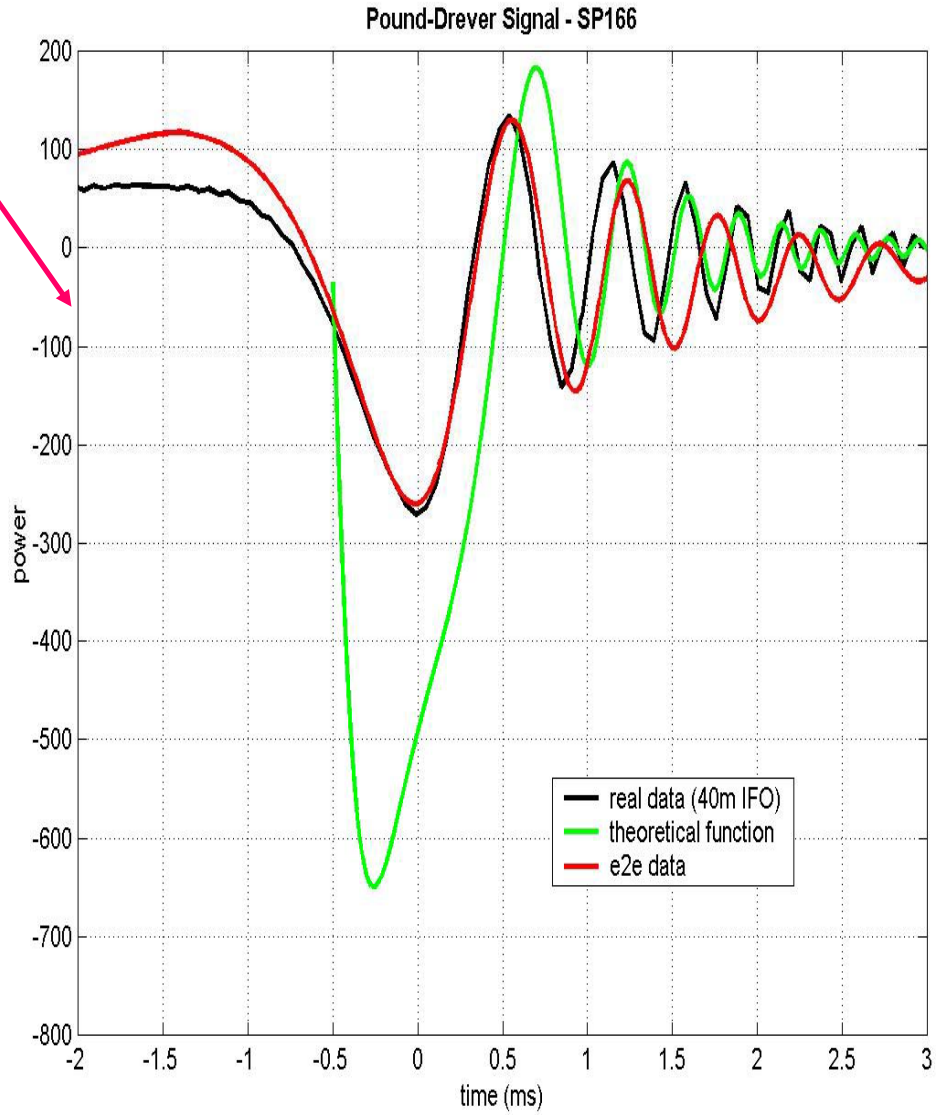
$$V(t) \sim \exp(t/\tau) \sin(a\, t^2)$$

with $a = (k\, v) / (2\, T)$

The **τ** and the velocity **v** is the value obtained fitting real data

τ = 0.7 ms

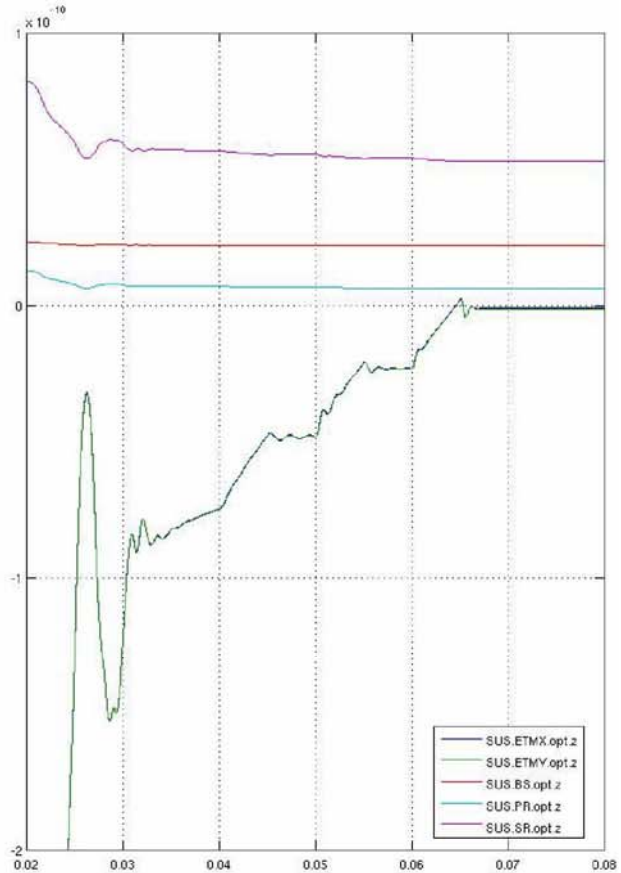
v = 0.26 μm/s



E2E: 40m Lock Acquisition

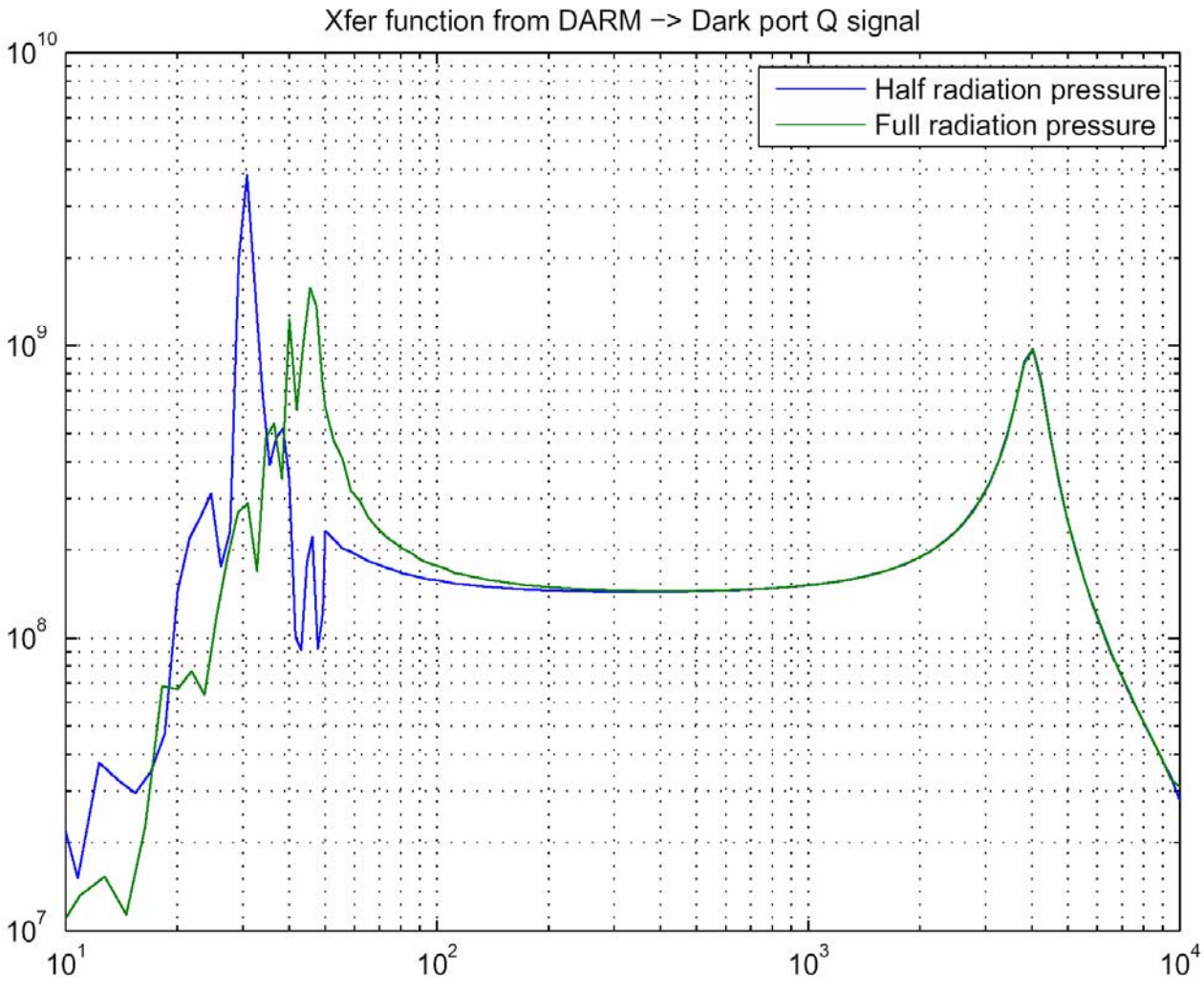
E2E simulation by Matthew Evans in June 2005

- CARM moved to RF signal
  - » Not yet done at 40m
  - » REFL port HF demod (a.k.a., SP166)
  - » Normalized by arm power
  - » Offset and gain matched at hand over
  - » Offset swept to zero slowly
  - » Coupled-Cavity pole compensation required
    - – Pole (actually more complicated) moves down as resonance is approached
    - – Compensation filter uses sum to make a “moving zero”
    - – More detail may be required for 40m



- Simulation indicates that controlled reduction of CARM offset should work.

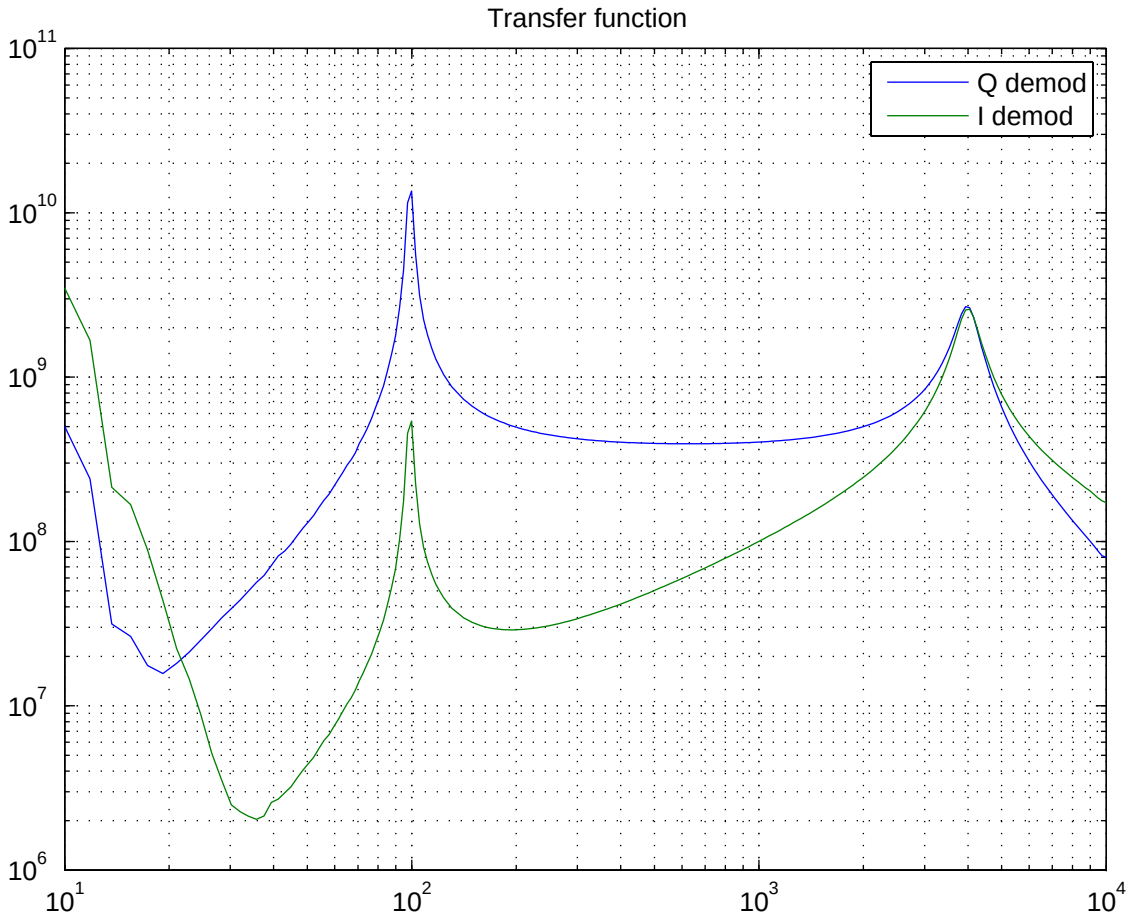
Optical spring in E2E



- Calculated by time domain simulation
- No length control
- Lock lasts ~0.7sec, so statistics at low frequency is not good.
- Simple length control required
- Calculation time ~5min using DRMI summation cavity

Hiro Yamomoto

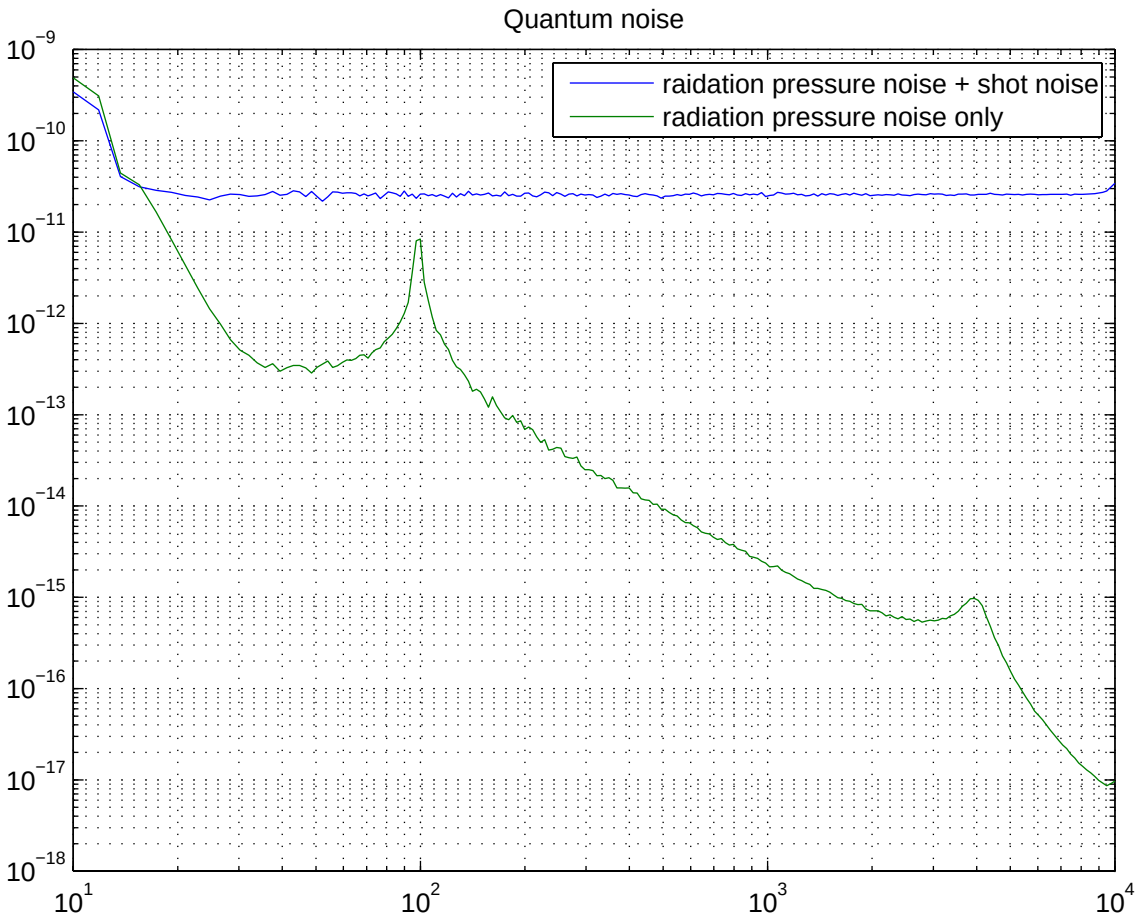
E2E DARM TF to I and Q



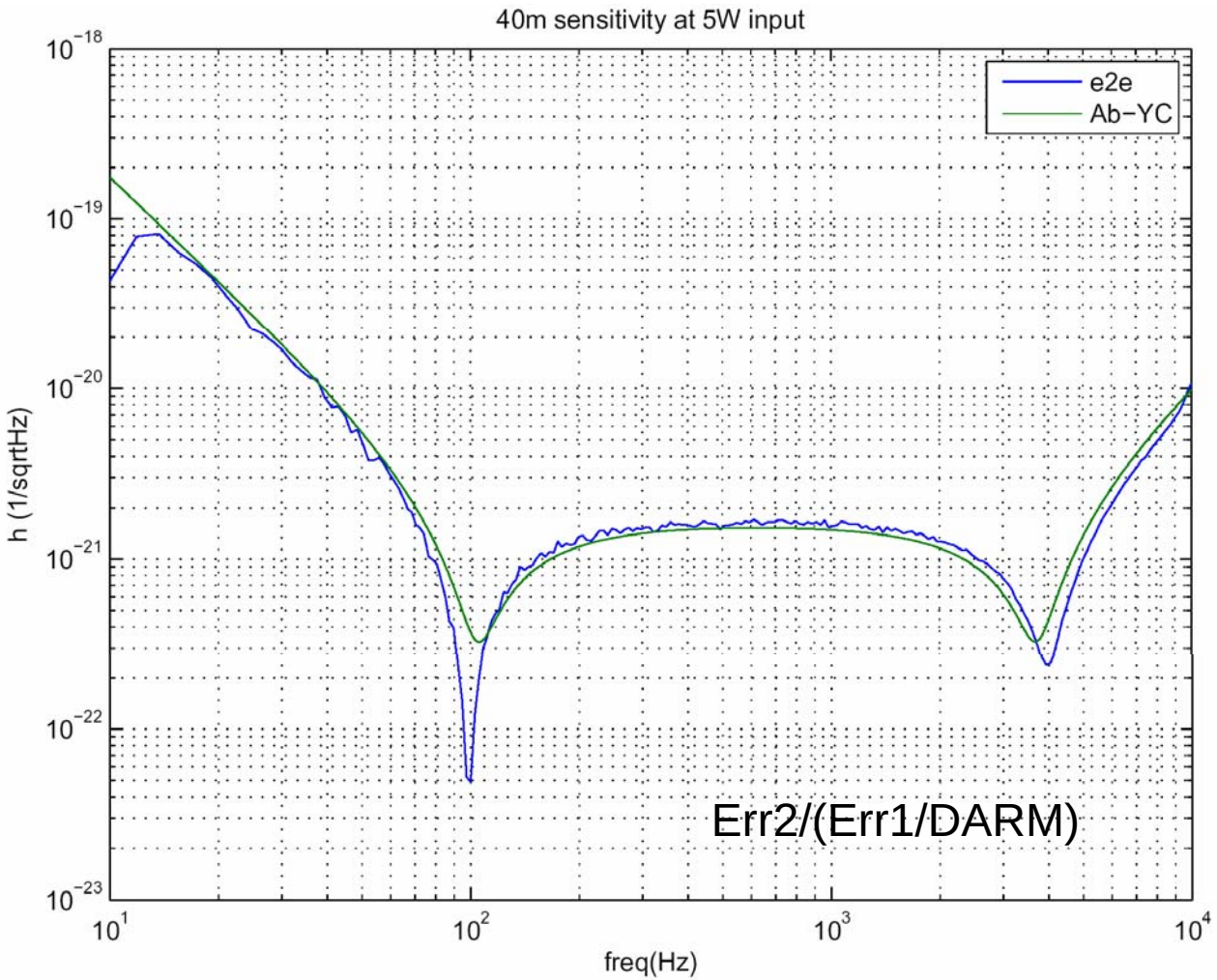
- 5W Input
- Arms controlled with POX, POY (no DARM)
- no MICH control

Hiro Yamomoto

E2E Optical Noise



Optical noise of 40m in E2E



- Simple length control (UGF~100Hz)

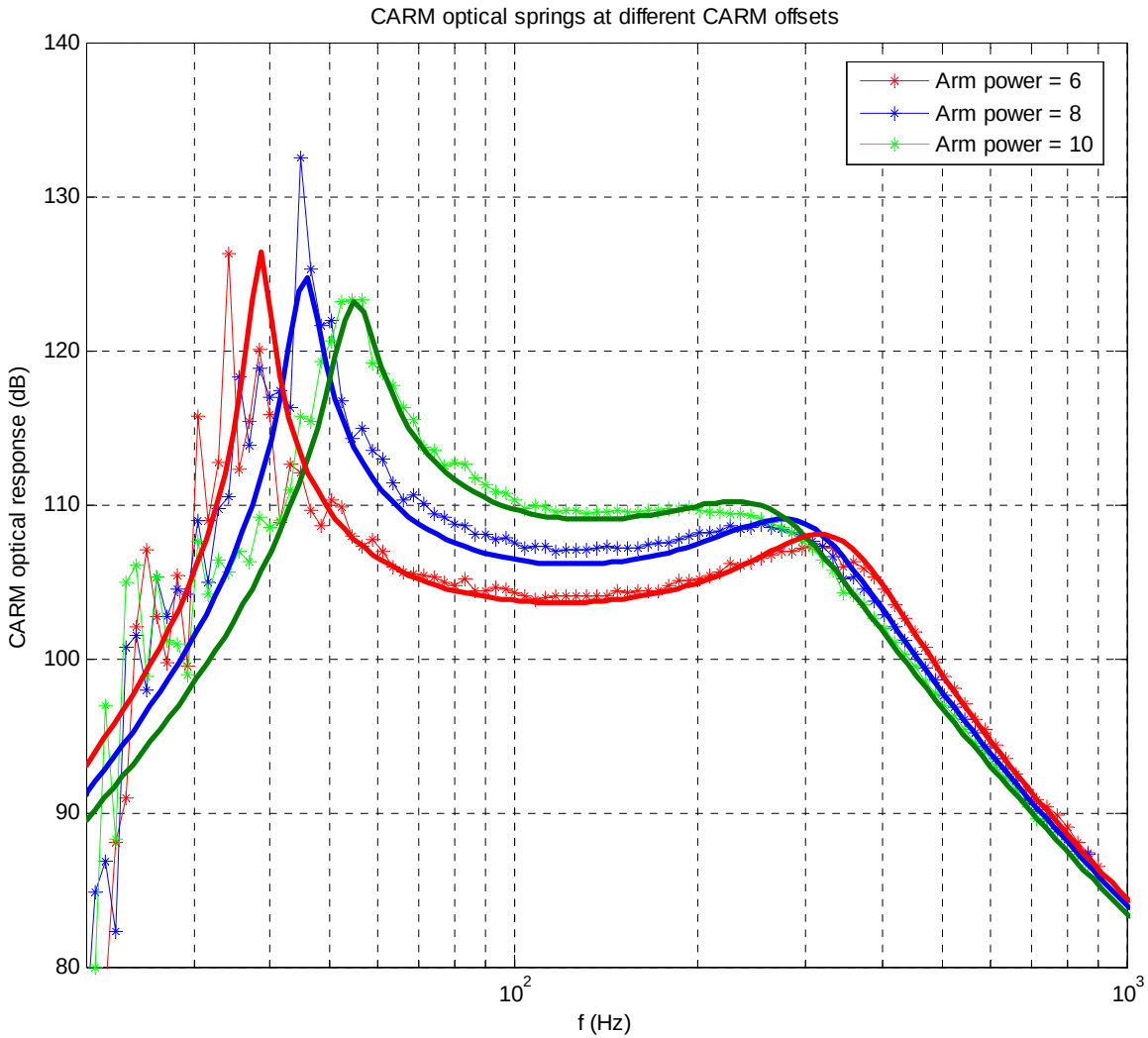
- Err2/(Err1/DARM)

DARM: DARM excitation on mirrors
Err1: error signal with DARM excitation
Err2: error signal with optical noise

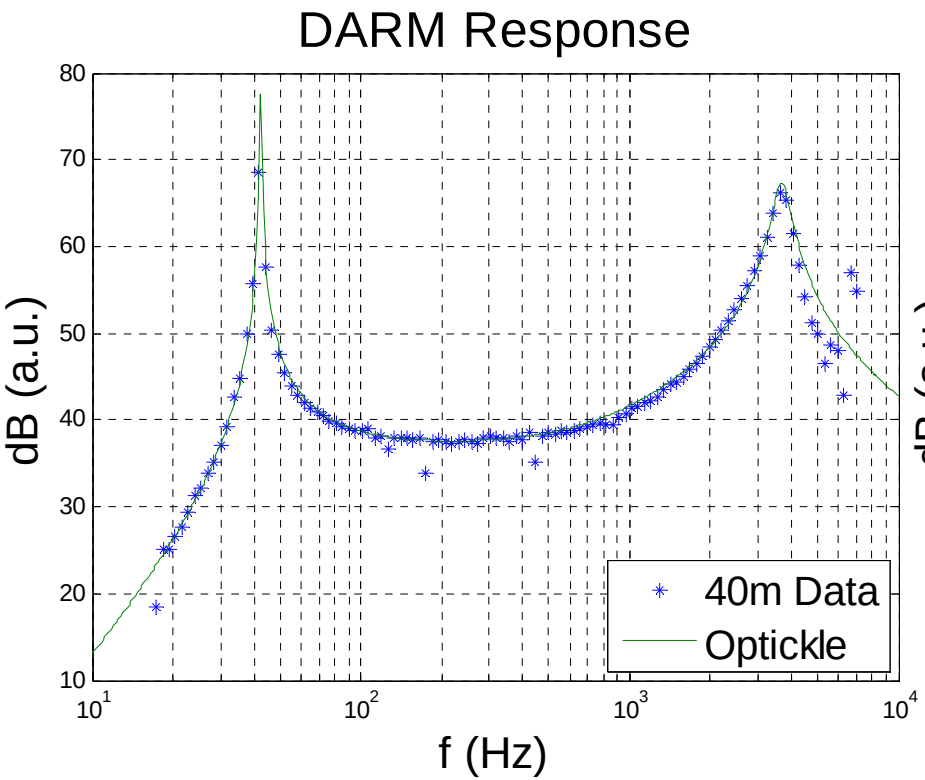
- How much further does E2E need to go? 2-photon?
- input vacuum?
- Quantum control?
- Or just classical physics + shot noise + radiation pressure noise ?

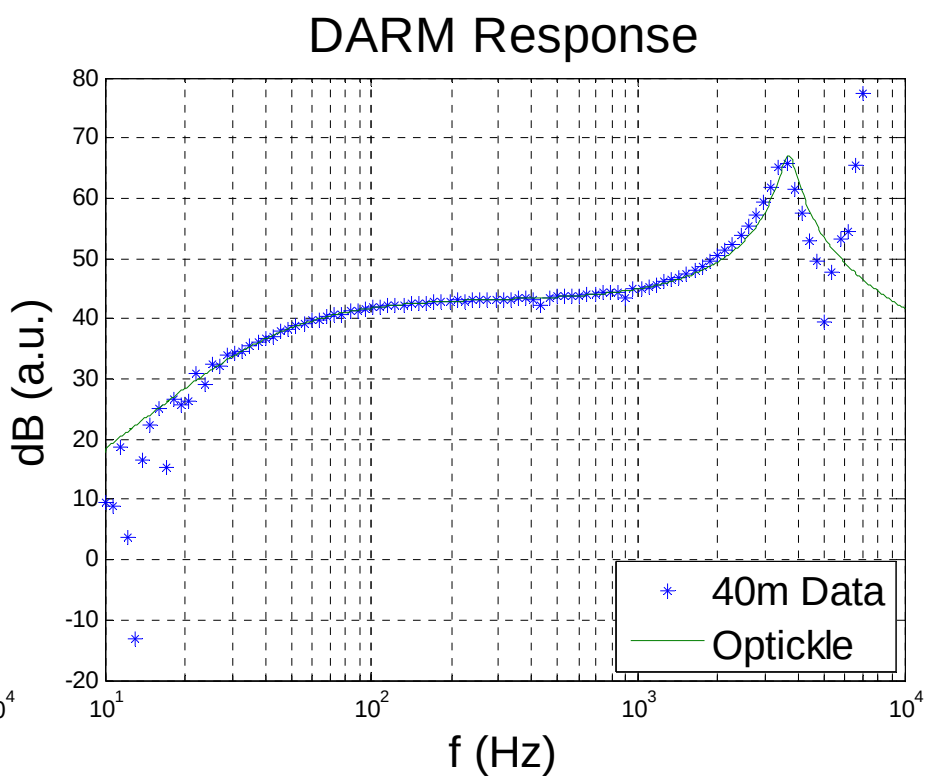
TCST

- Solid lines are from TCST
- Stars are 40m data
- Max Arm Power is ~80
- Also saw CARM anti-springs, but don't have that data



Optickle


DARM Response
dB (a.u.)
f (Hz)
40m Data
Optickle


DARM Response
dB (a.u.)
f (Hz)
40m Data
Optickle

CARM optical springs, with no offsets (TCST)