LHO 2K Core Optics Characterization

William P. Kells
California Institute of Technology

Presented at PAC8 Meeting
May 1-2, 2000

DCC Document number LIGO-G000125-00-D

LHO 2K core optics characterization

- Michelson contrast
- Cavity mode parameters & match to input beam
- Cavity storage time: ring downs & free swinging transients
- Cavity macroscopic length: SB locking
- Cavity loss: visibility measurements

Special Thanks: D. Barker, M. Barton, G. Billingsly, J. Camp, D. Cook, D. Coyne, J. Heefner,M. Landry, P. Fritschel,G. Mueller, N. Mavalvala, L. Matone, T. Nash, D. Ottaway, D. Reitze, H. Rong, P. Saulson, R. Schonfeld, D. Sigg, M. Smith, R. Weiss, S. Whitcomb, H. Yamamoto, M. Zucker,.....

Michelson Contrast

- Observe Bright/Dark fringes at Asymmetric port: how dark is dark for carrier?
- Method 1: RF SB lock Michelson via feedback to one ITM (other ITM, BS free swinging)

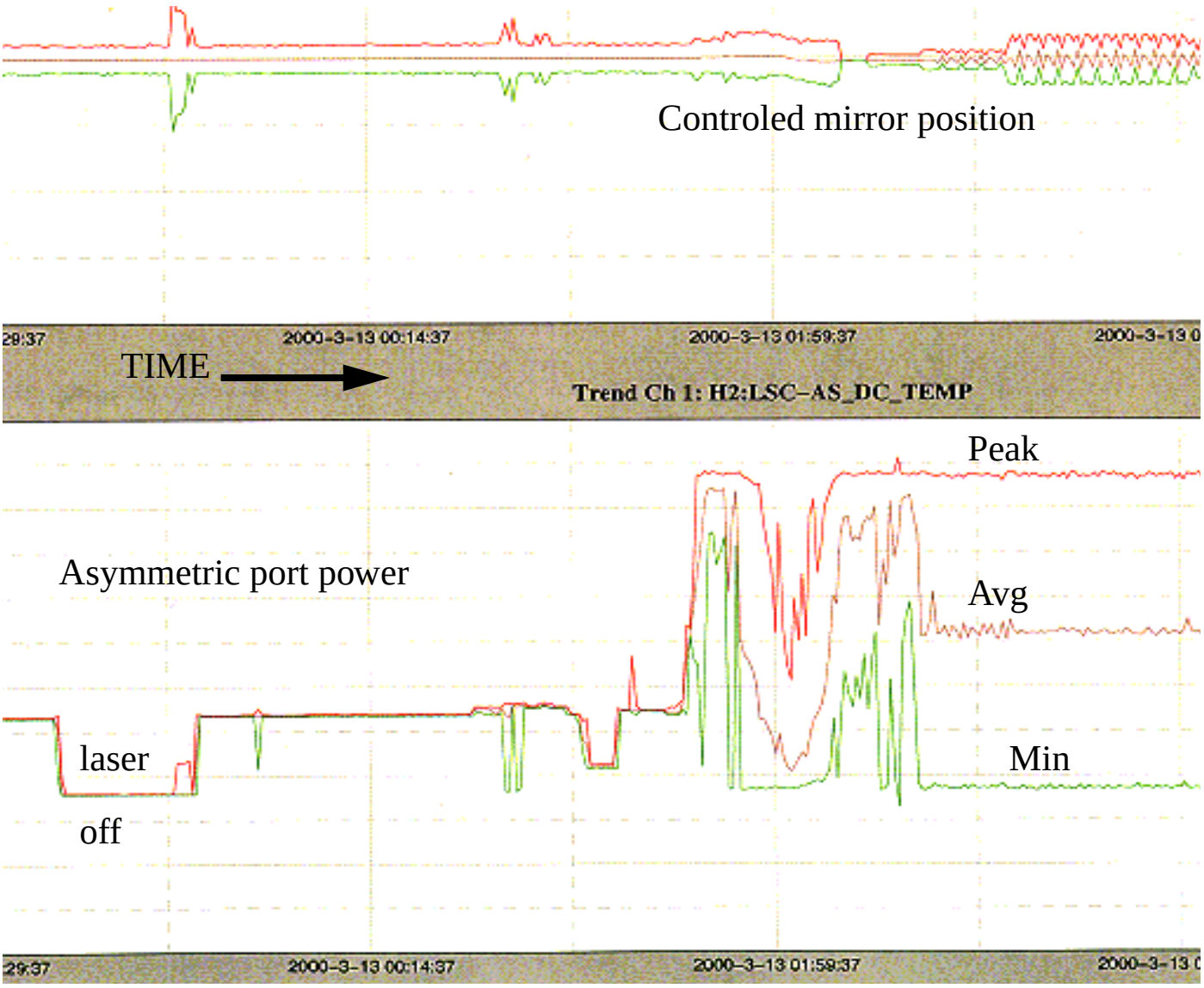
1-C = Dark Fringe Power/(Bright Fringe + Dark Fringe Power)

(all powers corrected for SB light component)

››Result : 1-C = 0.0032

- Known tolerances of ITMs (reflectivity, ROC, Schnupp Asymmetry give $1\text{-}C < 10^{-4}$
- Defects: misalignment, beam clipping, frequency noise on light source, OPD distortion
  - Mirror metrology=> λ/50 residual OPD for each ITM substrate. For two double pass contributions this can dominate observed 1-C
  - This ITM OPD effect ameliorated with arm cavities locked.
- Method2: Ramp one ITM longitudinal position: no SB light necessary (no servo lock)

Michelson Contrast (Cont'd)



- Result: 1-C = .005

Cavity Mode & Matching

- Beam spot video images of non-specular scatter for locked cavity & dumped input beams
  - BRDF scatter model of mirrors allows estimate of micro-roughness loss consistent with design and mirror metrology.
- Calculated mode from mirror ROC metrology.

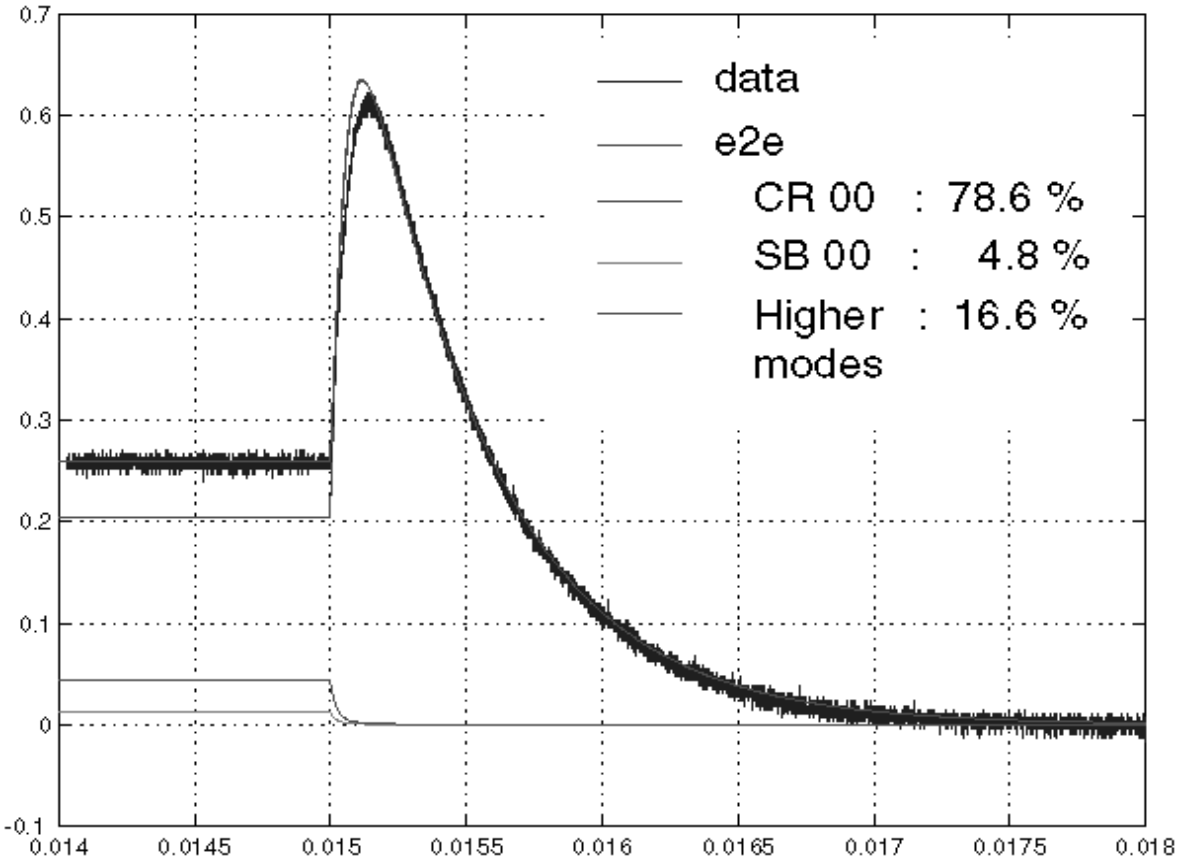
Summary of mode parameter measurements LHO 2K cavities

	ITM (0 m)		Waist	ETM (2009 m)	
	w	**R.O.C**		***w***	**R.O.C.**
Cavity design	.0320	14560	.0313 @600m	.03478	7400
X arm mirrors	.03293	14189	.0321 @680m	.03502	8380
Y arm mirrors	.03275	13523	.0319 @700m	.03477	8210
Y input beam video	.0287	8000	.0275 @680m	.032	5052
X input beam (reflection)	.0293	6800	.0275 @830m	.0311	5386

- Cavity reflection in/out of lock => input beam parameters relative to cavity mode.
  - determines matching = 0.96, consistent with other methods

Cavity Storage Time

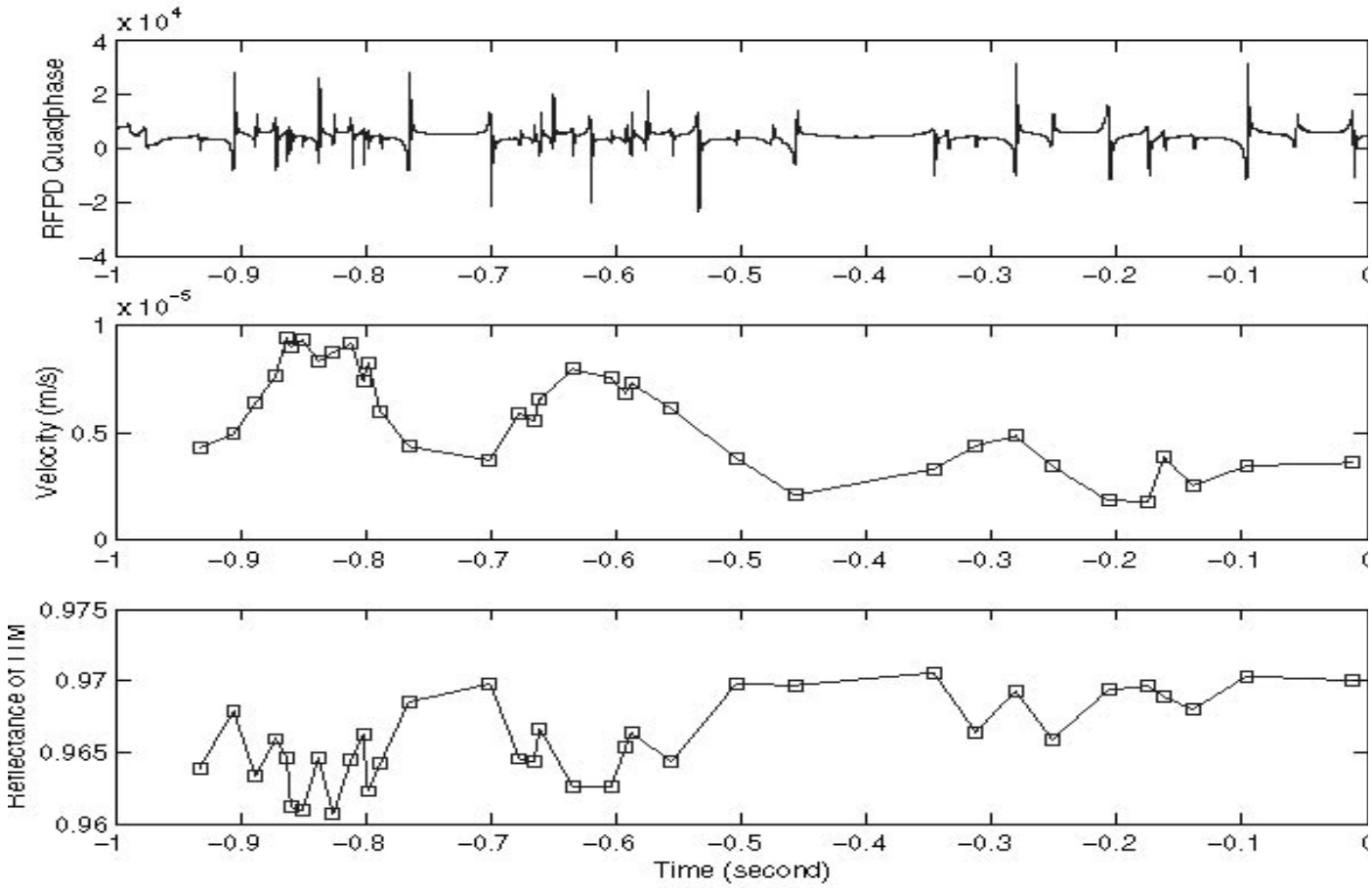
- Cut input beam (fast). Fit decaying intensity of light from ITM.
- Multi-mode “end to end” (e2e) dynamic model



- Fit: T+Loss=.0281 (nominal design=.030)

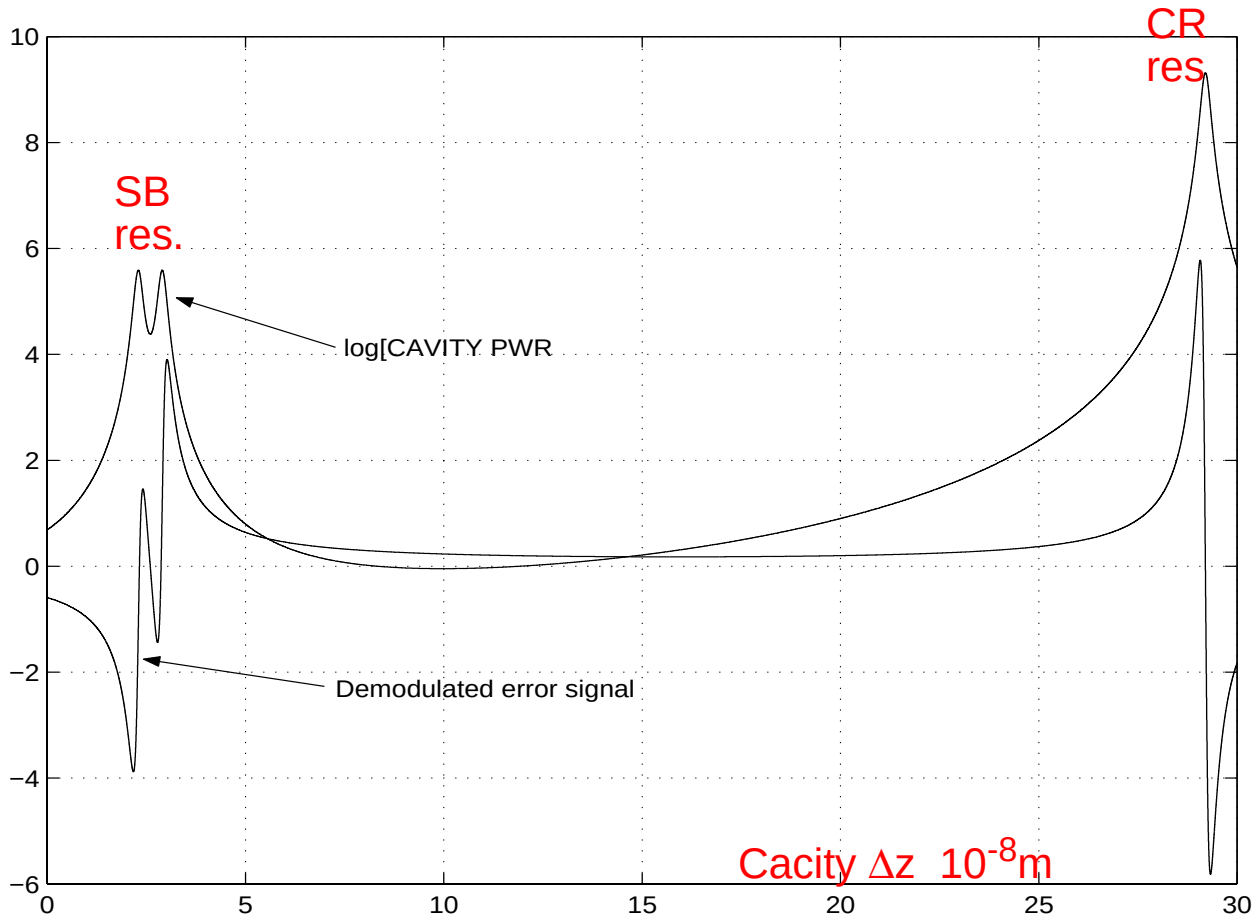
Cavity Storage Time

- e2e fit of un-locked cavity reflectivity with constant source beam:



Cavity Macro Length

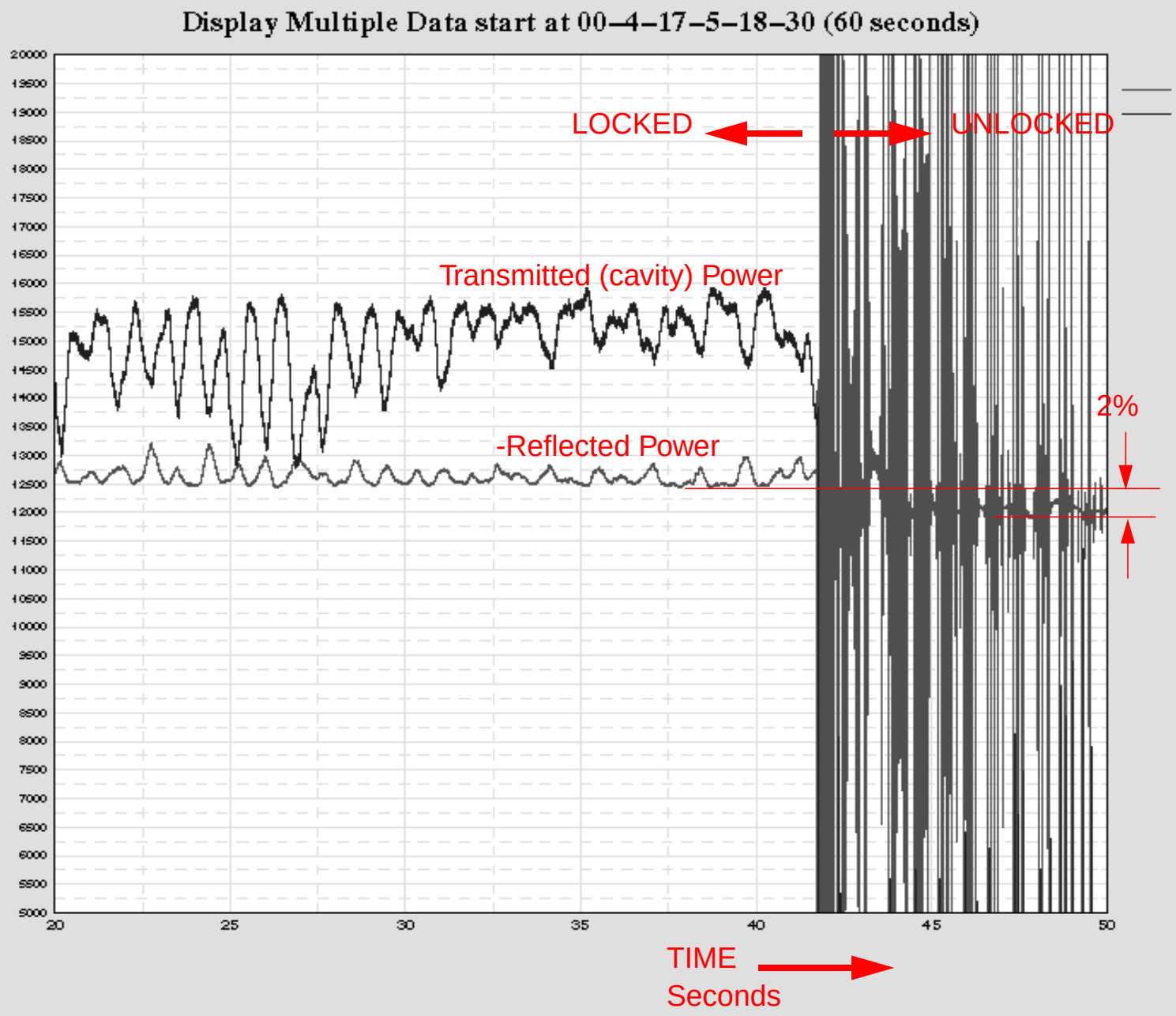
- SB+/- resonance spacing sensitive to L_{macro}



- Best model fit to free cavity demod fringes
  - L_{mcro}= 2009.11 m at f_{sb}= 29.508 Mhz (agrees with survey)
  - error signal OK to lock at carrier anti-res: SB resonance seen.

Cavity Loss: Visibility

- Deficit of In/out of lock cavity reflected power for aligned & matched cavity is direct measure of cavity loss
  - Measured mismatching insignificantly affects visibility
  - Beams observed ~centered on mirrors: no edge loss
  - ETM transmission insignificant
- Expect ~1% level: experimentally difficult:
  - Large beams fill optics: large systematic errors from clipping
  - Requires careful mean alignment as well as good WFS servo
  - Slow improvement of observed visibility as experience is gained in operating and tuning optics and servos.
- Best results (X arm): visibility = 0.020 (corresponds to 70 ppm average per mirror)
  - Optics fabrication prediction below 30ppm (0.01 visibility)
  - Reflected beam still clipping=> measurements are upper limits
  - With some interpretation (of fluctuations) best visibility = 0.015


Display Multiple Data start at 00–4–17–5–18–30 (60 seconds)
LOCKED
UNLOCKED
Transmitted (cavity) Power
-Reflected Power
2%
TIME
Seconds

CLIPPING DOMINATED