PERFORMANCE of LIGO 2km LARGE OPTICS

W. Kells

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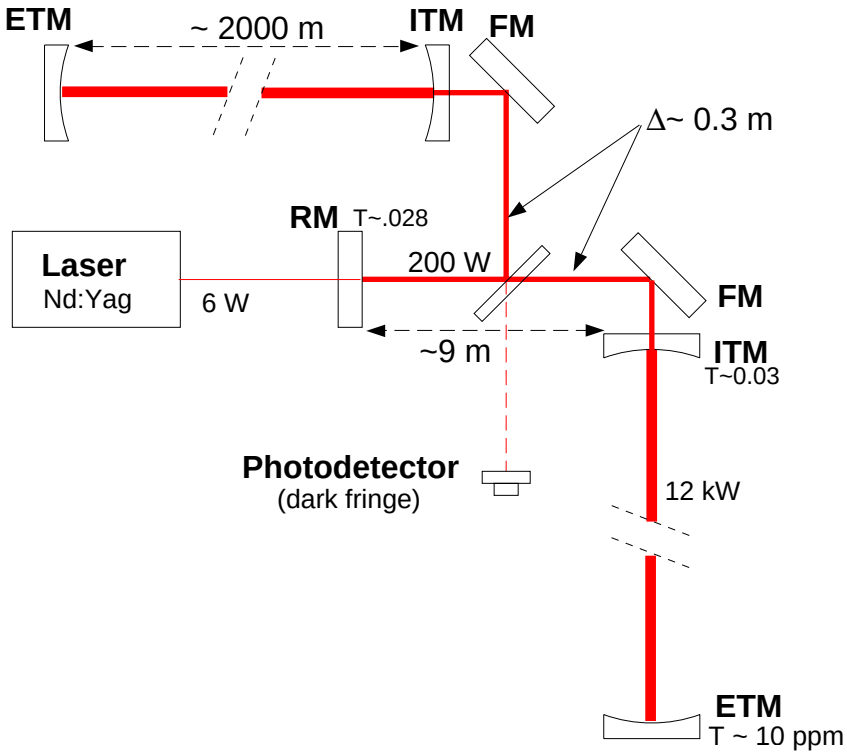
LIGO-G010255-00-D

LHO 2K core optics performance

- Michelson contrast
- Cavity mode parameters & match to input beam
- Cavity storage time: ring downs. Free swinging transients: arm lengths & SB operating point.
- Interferometer loss: arm visibilities & recycled 'missing' power.
- SBs in ~degenerate (cold start) recycling cavity



LIGO-G010255-00-D

Michelson Contrast

- Observe Bright/Dark fringes at Asymmetric port: how dark is dark for carrier?
- 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

–Post fabrication mirror metrology=> $\lambda/50$ residual OPD for each ITM substrate. Combining metrology OPD maps predicts residual rms dark port power ~ 0.0018. Beam splitter OPD may contribute remainder

–This ITM OPD effect ameliorated for carrier field with arm cavities locked.

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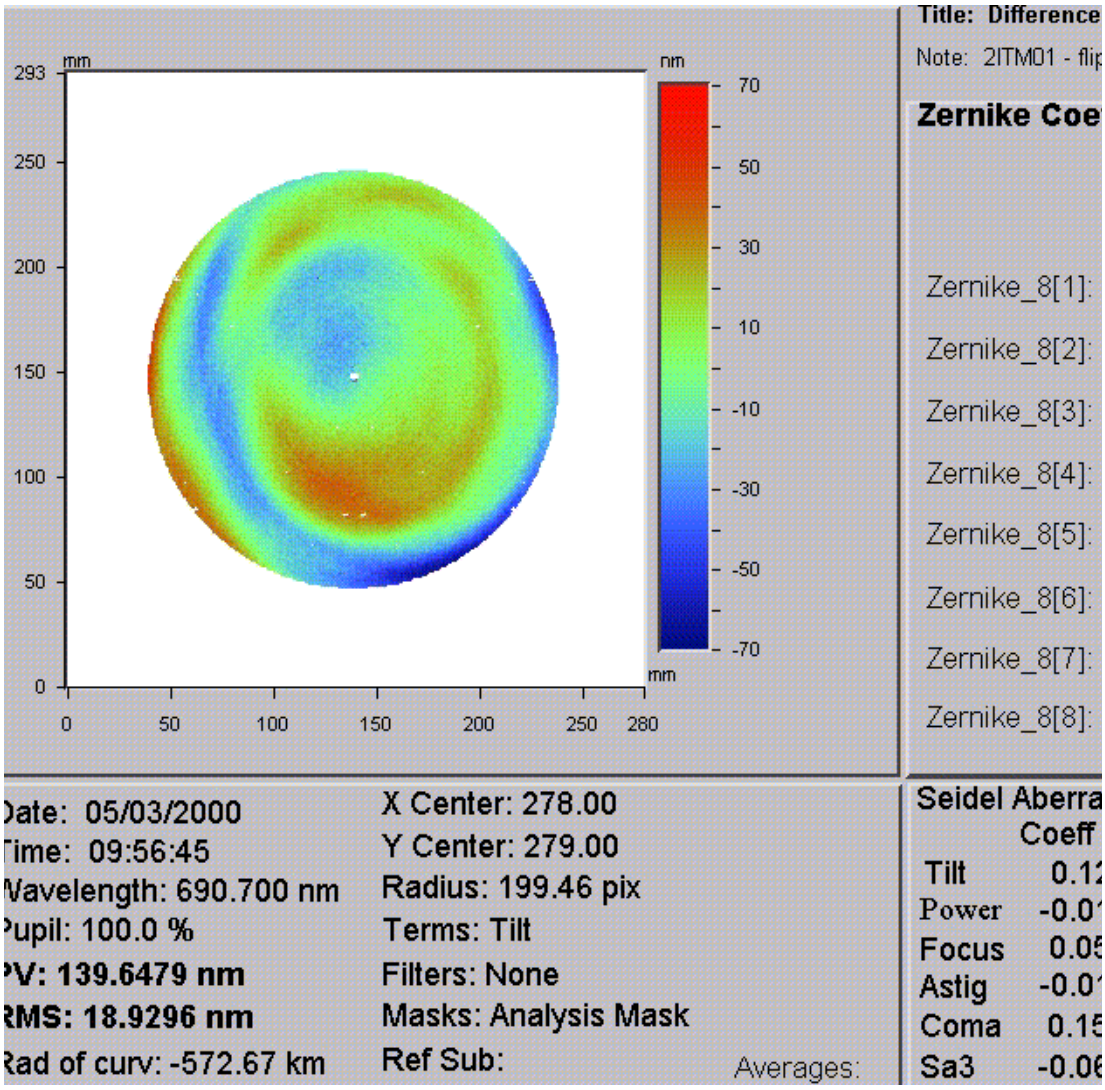
Michelson Contrast(Cont'd)



- Difference map of 2km ITM back reflections
- Beam weighted rms ~7.5 nm

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 metrology.

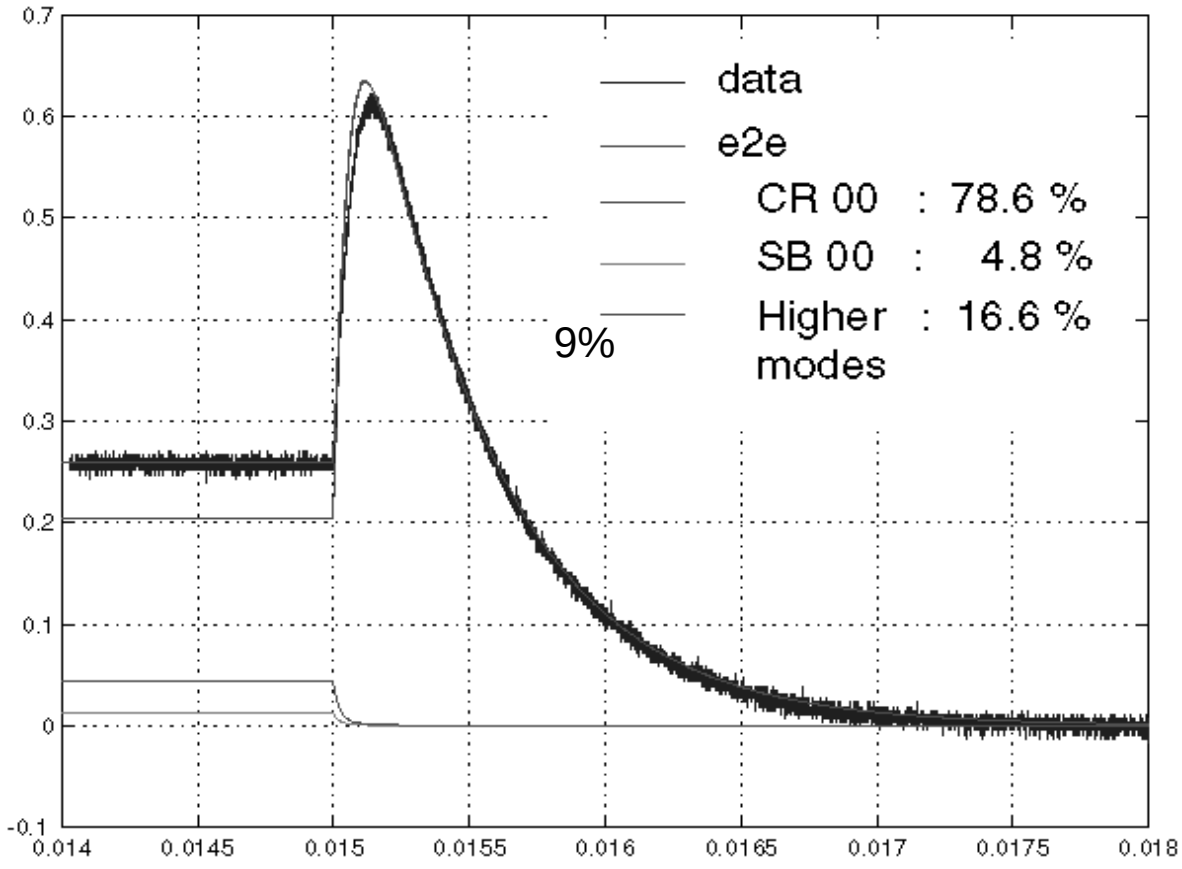
Summary of mode parameter measurements LHO 2K cavities

	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 observation of arm cavity locked vs unlocked reflections.

Cavity Storage Time

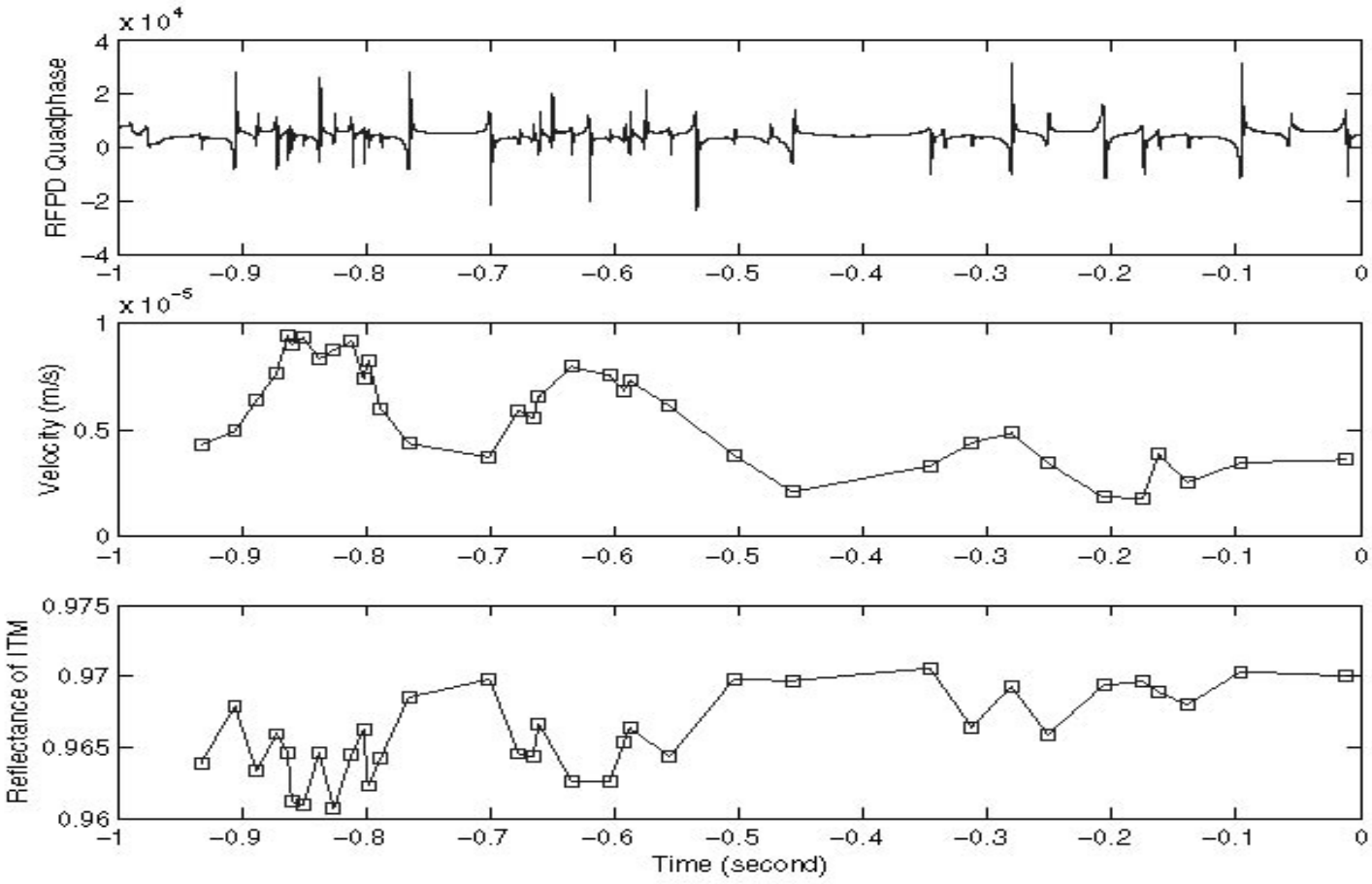
- Cut input beam (fast). Fit decaying intensity of light from ITM.
- Multi-mode “end to end” (e2e) dynamic model



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

Cavity Storage Time

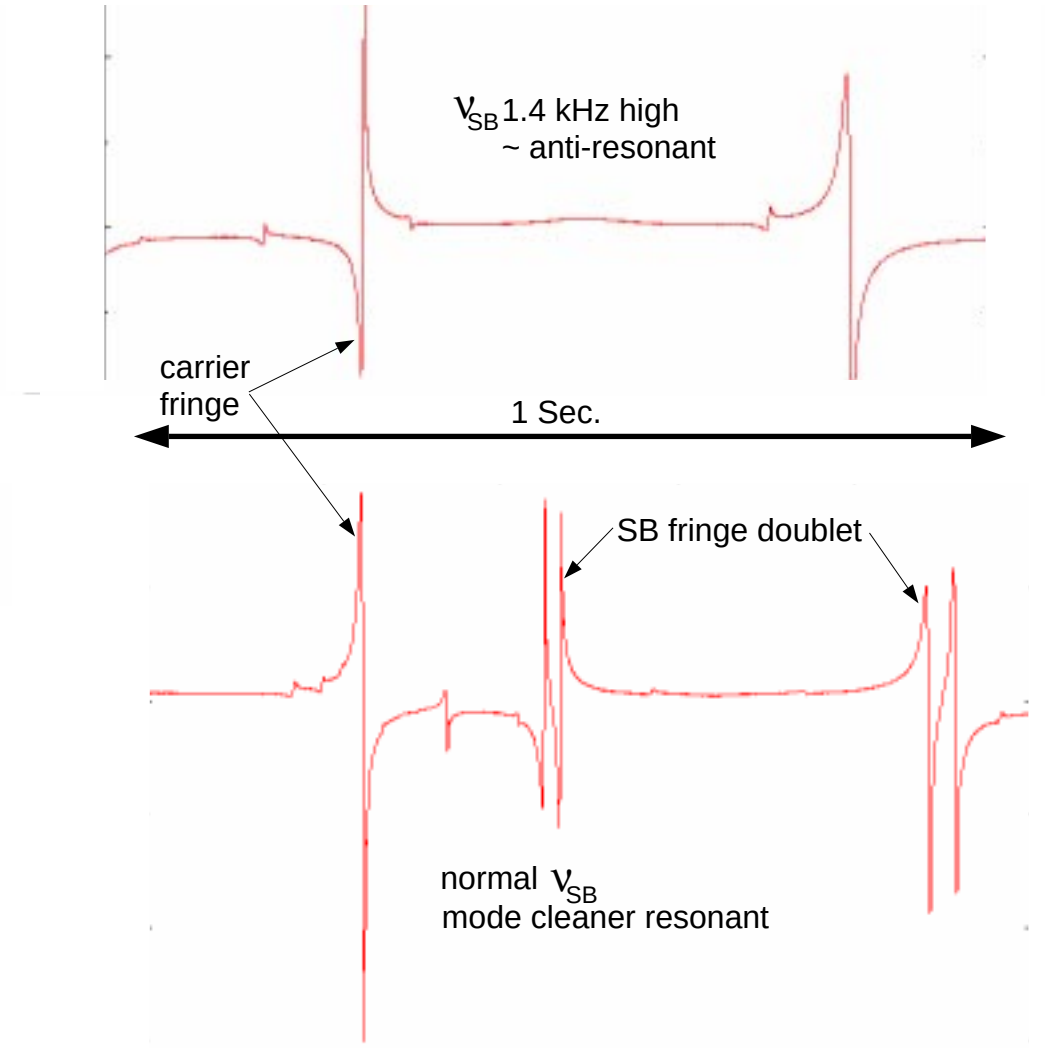
- e2e fit of un-locked cavity reflectivity with constant source beam:



Arm length & SB de-tuning

- Design calls for ν_{SB} slightly off arm anti-res.

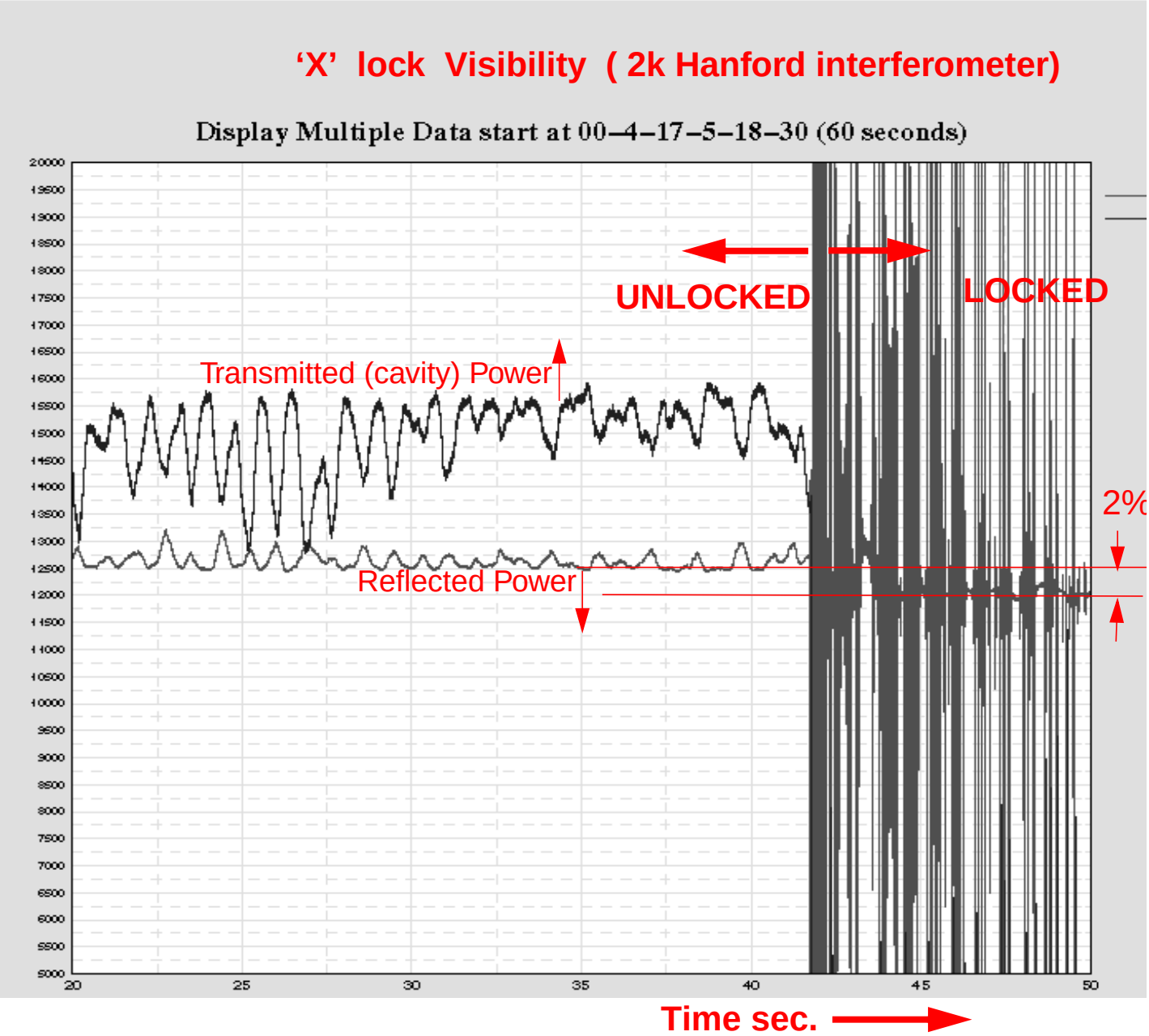
  ›› 1.4 kHz offset (ν_{SB}=29.50588 MHz => L_{arm}=2009.11 m) from free fringes, or locked arm $2\nu_{SB}$ resonance.



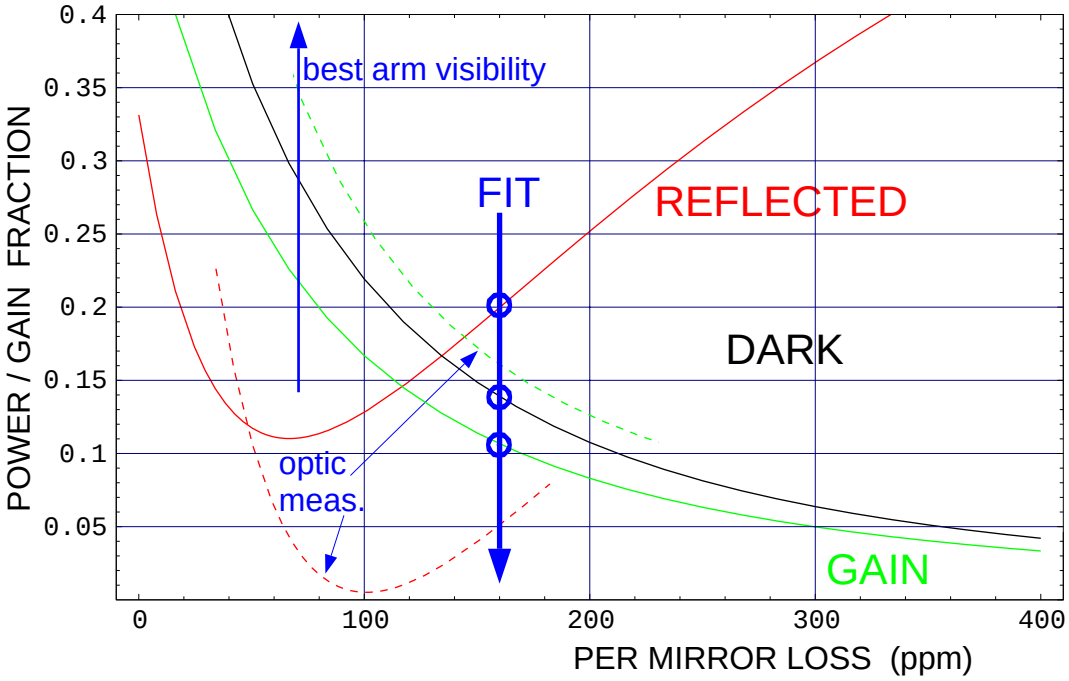
Cavity Loss: Visibility

- 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 small (include as net effective loss).
- Expect ~1% level: experimentally difficult:
  - Large beams fill optics: systematic errors from clipping
  - Requires careful mean alignment as well as good WFS servo
- Best results ('X' arm): lock deficit <0.020 (corresponds to 70 ppm average per mirror)
  - Fabrication metrology results in FFT simulations predict 60ppm (0.018 deficit) equivalent loss/mirror. Recycling gain > 45 plausible.
  - Reflected beam still clipping=> upper limits.
  - With some interpretation (of fluctuations) best visibility = 0.015
  - 'Y' arm measurements not refined: lock deficit < 0.04

Cavity Loss: Visibility

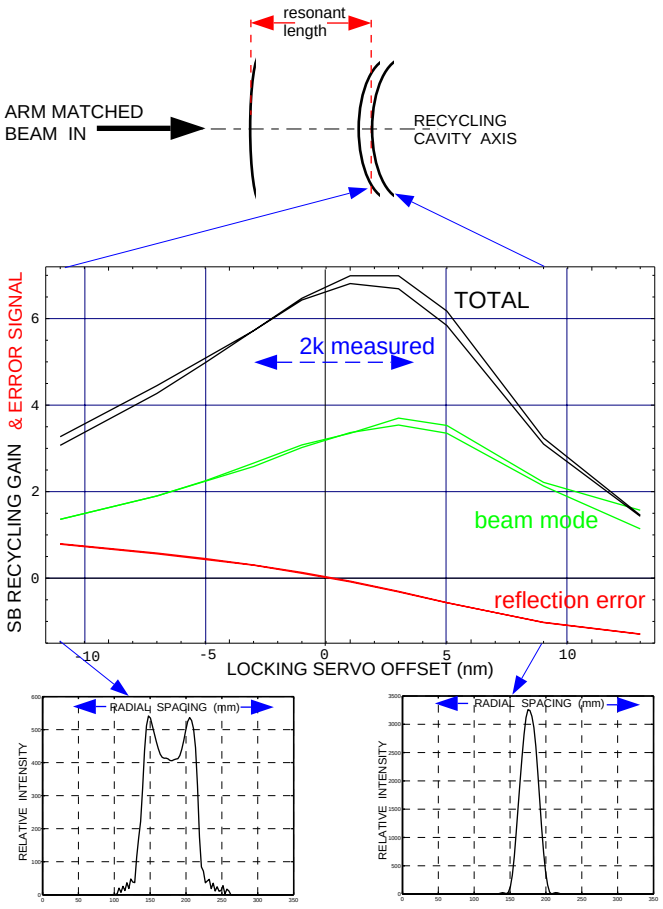


POWER BUDGET



- Measure: 'visible power'=P_{refl} +P_{dark}
  - ››Correct for P_{SB}=0.10
  - ››Missing (Lost) carrier power ~0.65 at G^{RC}=15-18.
  - ››Loss is integral over interferometer
  - ››Fit requires significant mismatch (0.1 power) to arms (~2x beam and optics conclusion).

Degenerate (cold start) Recycling cavity



- Recycling cavity ~unstable at low power
  - ››No well defined mode or matching
  - ››Observe characteristic variation of cavity profile with length
  - ››Observe offset of SB peak gain from natural lock point.