LIGO

The Thermal Lens in LIGO I

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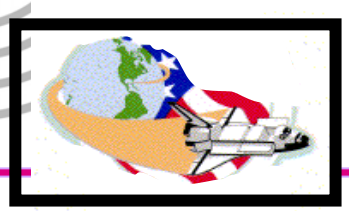
GWADW Aspen, February 2003

G030021-00-D



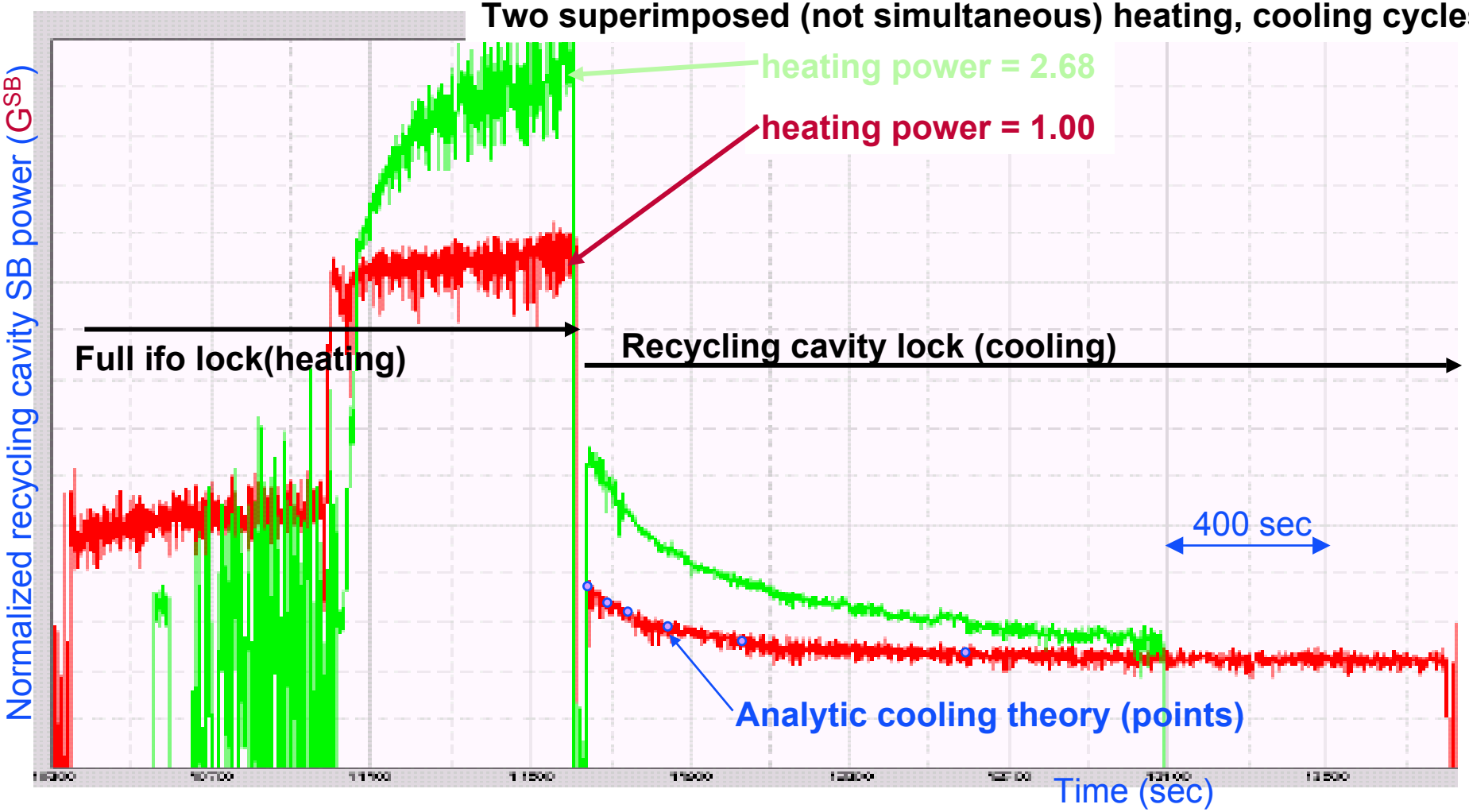
- Lensing due to absorption in Silica was long ago predicted to seriously alter interferometer optical performance ($G_{RECYCLE}$)
  - TL Proportional to *total* absorbed power (hence ifo input power).
    - Part from absorption of beam power through optic bulk.
    - Part from absorption of beam power in optic coatings.
  - Proportional to β/κ where $\beta = dn/dT$; $\kappa =$ thermal conductivity.
  - At LIGO I power levels only SB fields (G^{SB}) significantly degrade.
    - At higher power levels (LIGO II) G^{CR} can degrade if not compensated.
- LIGO I strategy: estimate lensing at design power (6w input).
  - Compensate for this by optimizing recycling mirror (RM) R.O.C for hot state.
  - Validated by FFT modeling of exact (non-spherical) TL in ITMs and BS plus ROC (spherical) optimization of RM.
- Report here first actual TL measure/analysis (LHO 4k).

Measurement strategy

- LIGO interferometers now stable enough to reproducibly distinguish heating/cooling effects.
- >95% heating via stable ifo carrier Gaussian field ($\propto P_{in} G^{CR}$)
  - 0.6 ppm ITM HR coating absorption
  - 3 ppm/cm silica bulk ITM/splitter absorption

  ⇒ Comparable heatings
- Reach Temp. equilibrium for long full interferometer locks.
- Cut off carrier heat source (break full lock), then record cooling curves of:
  - G^{SB} vs time in remnant (arm cavity ends misaligned) locked recycling cavity .
  - Optical (demodulation) gain vs time.
  - Measure for various carrier heating levels (ifo input beam powers).

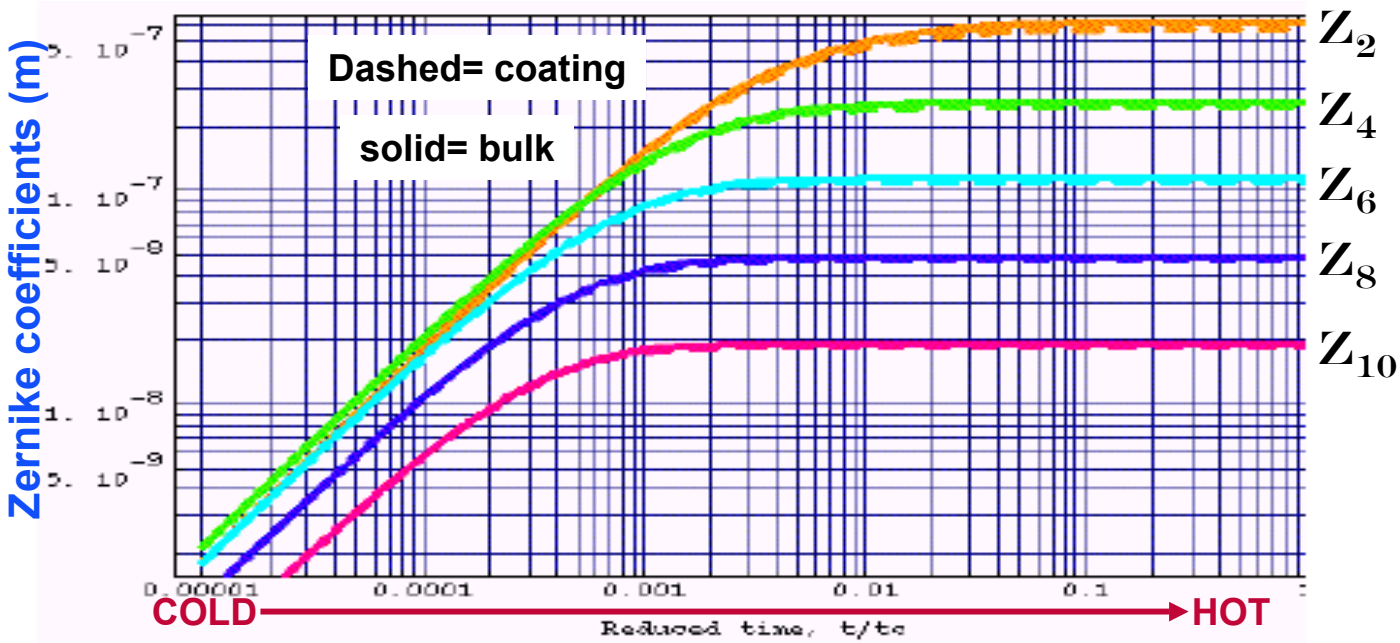
The Thermal lens, Experimental



Bulk vs Coating absorption

- Original analytic analysis of silica beam heating (Hello/Vinet) shows remarkable property that TL is ~same for bulk or coating heating for = absorbed power.

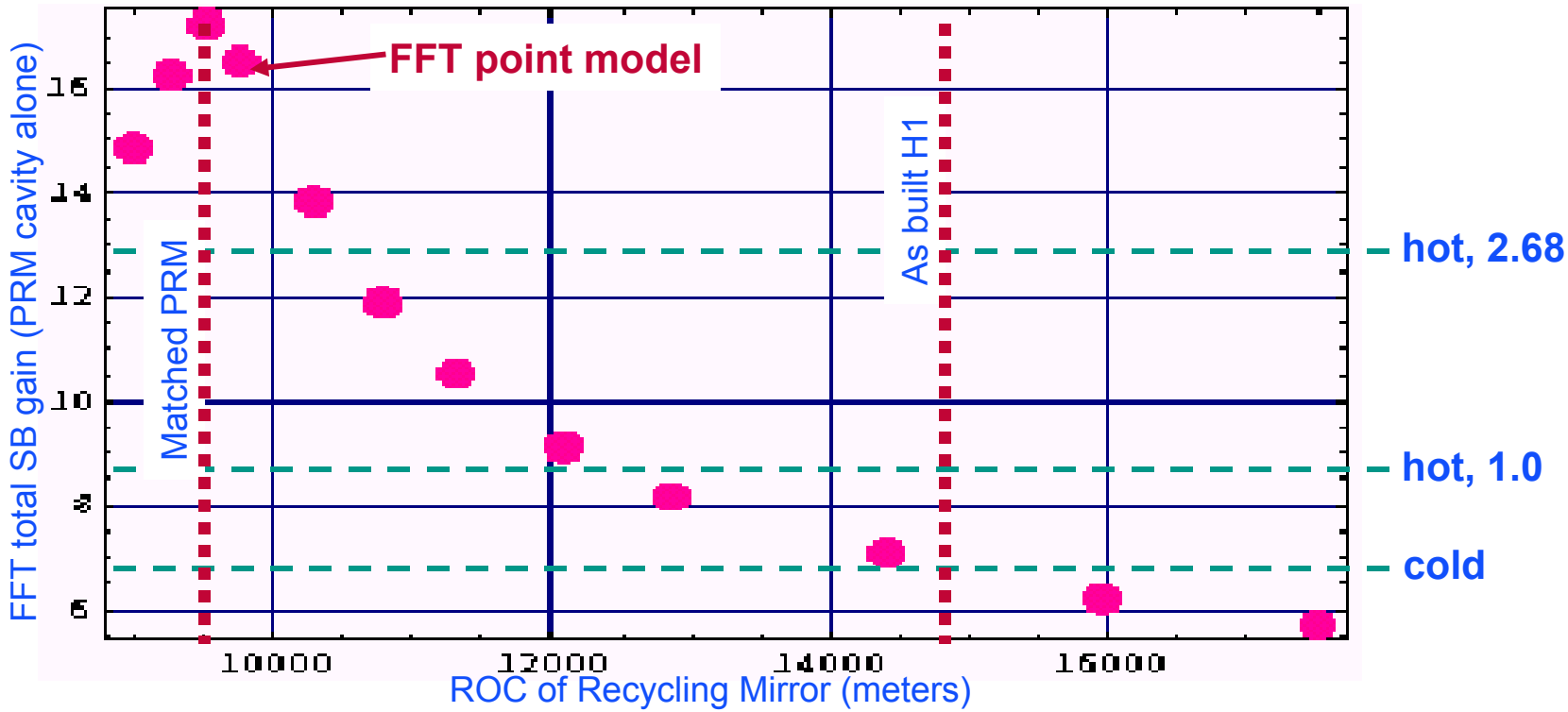
For LIGO/VIRGO
Like test mass and
Beam proportions



- Allows fit to single beam power scaled TL distortion for unknown bulk to coating absorption ratio.

FFT model of TL thin lens equivalent

- SB resonant recycling cavity modeled vs RM R.O.C.
- Normalize FFT "as built" G^{SB} to experimental curve cold value



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Conclusions

- Thermal lensing has been identified and measured in one of the LIGO I interferometers (LHO 4k).
- It is confirmed that the "cool-cold state" (operations to date) significantly degrades G^{SB}
- Scaling of lens vs ifo input power ⟹ extrapolation to $ROC_{optimum}$
  - Analysis to be used for fabrication of retrofit RM (ifo specific).
  - ~Independent of [unknown] bulk/coating absorption coefficients.
- Accurate compensation of thermal distortion helps all extensions of optical detectors: particularly ⟹ high f_{GW}
  - **Low arm finesse; higher laser power and G^{CR} implies stronger lensing**