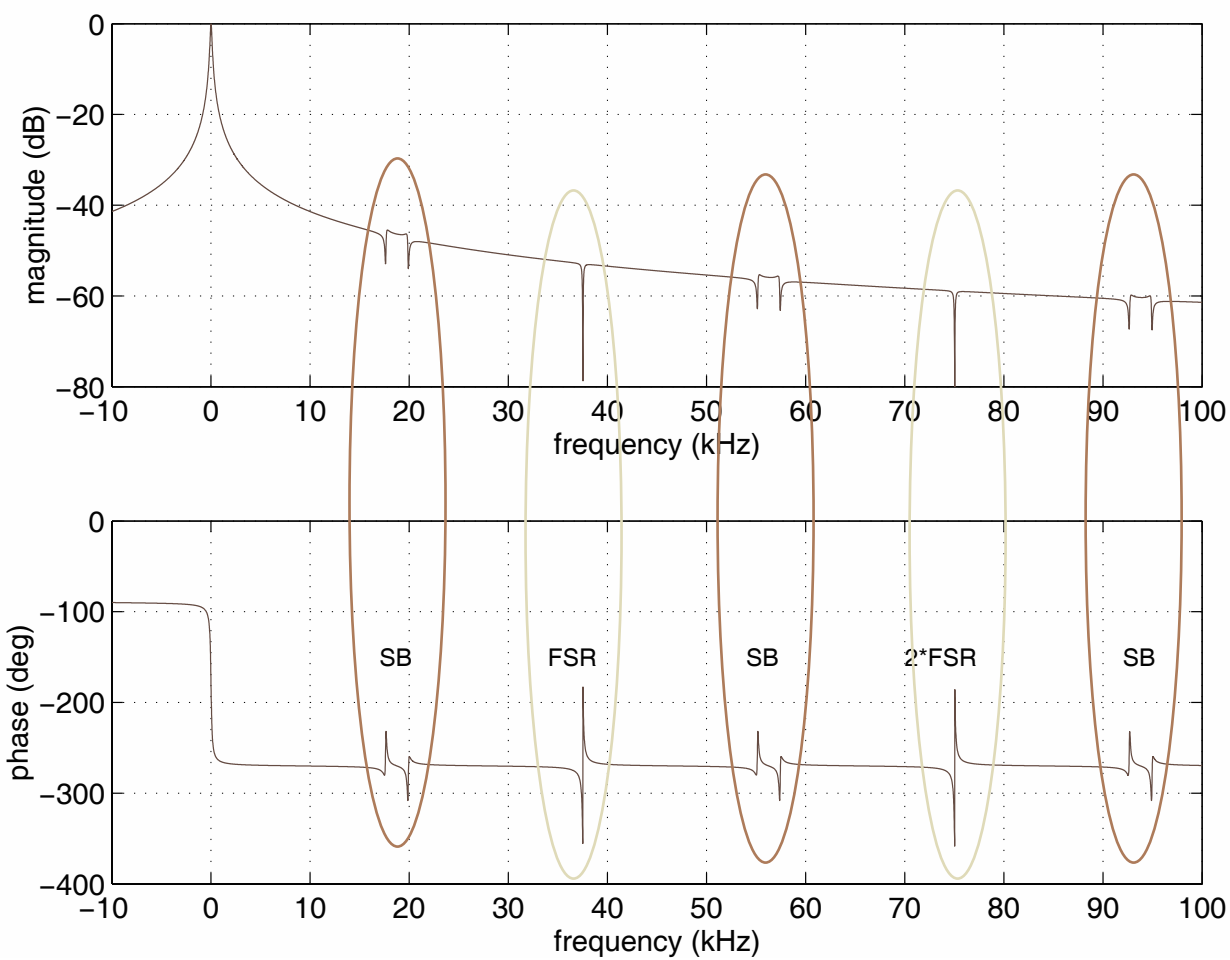
LIGO

Summary of recent measurements of g factor changes induced by thermal loading in the H1 interferometer.

Rick Savage, Malik Rakhmanov, Keita Kawabe,
and Joe Betswieser

Measurement Technique

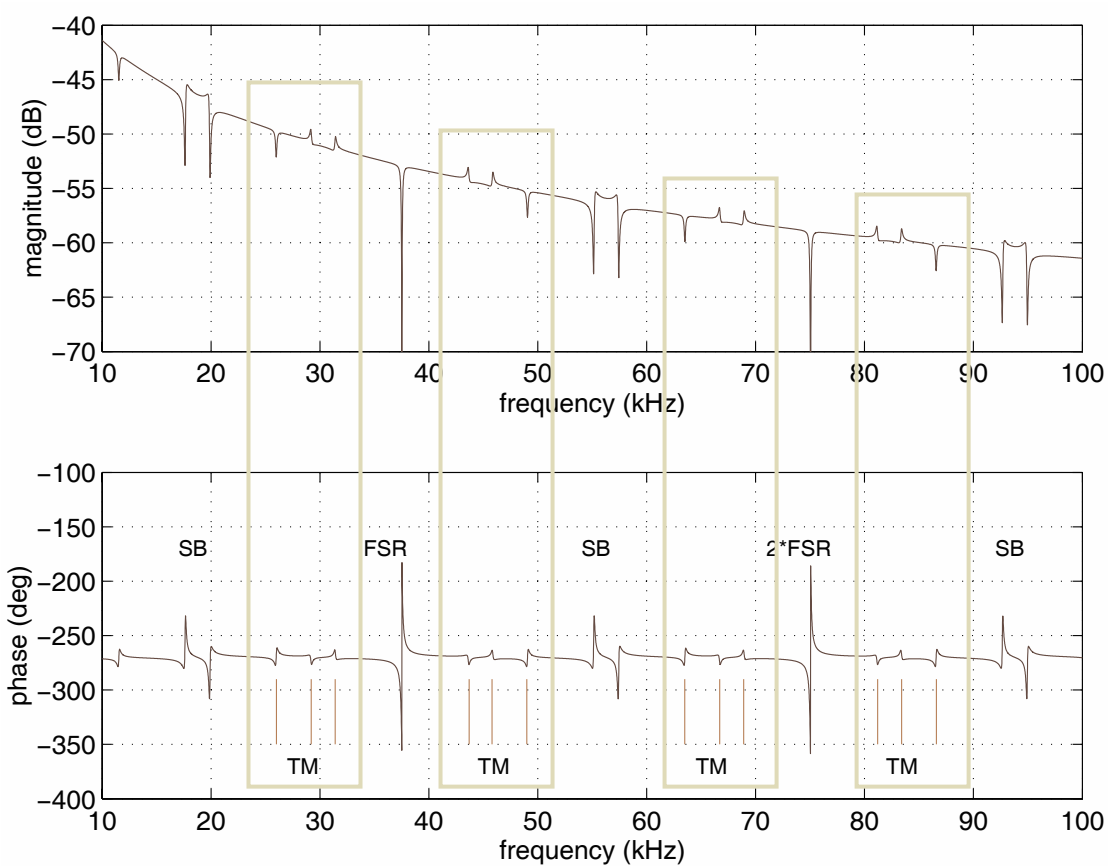
- Dynamic resonance of light in Fabry-Perot cavities (Rakhmanov, Savage, Reitze, Tanner 2002 *Phys. Lett.* A, **305** 239).
- Laser frequency to PDH signal transfer function, $\mathbf{H_\omega(s)}$, has cusps at multiples of FSR and features at freqs. related to the phase modulation sidebands.



Misaligned cavity

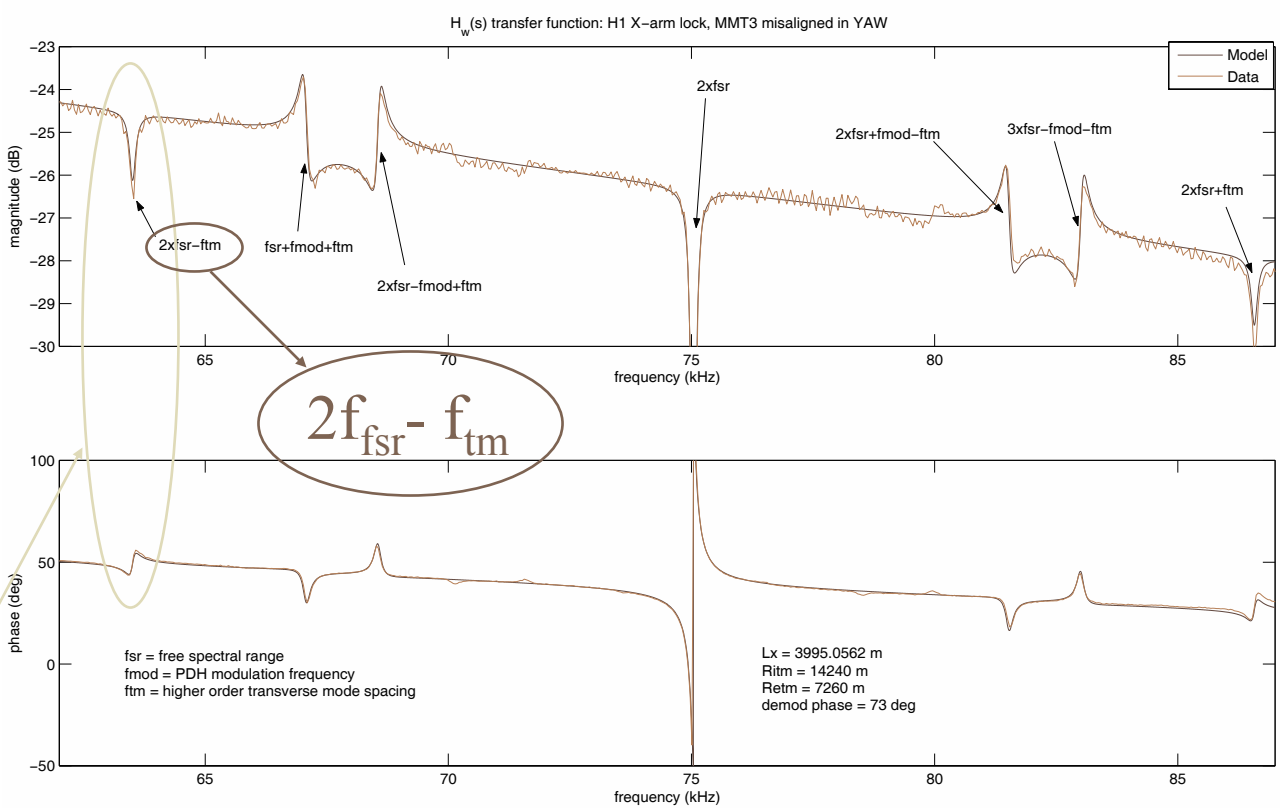
- Features appear at frequencies related to higher-order transverse modes.
- Transverse mode spacing: $\mathbf{f_{tm} = f_{01} - f_{00} = (f_{fsr}/\pi)\ \mathrm{acos}\ (g_1 g_2)^{1/2}}$
- $\mathbf{g_{1,2} = 1 - L/R_{1,2}}$
- Infer mirror curvature changes from transverse mode spacing freq. changes.
- This technique proposed by F. Bondu, Aug. 2002.

Rakhmanov, Debieu, Bondu, Savage, *Class. Quantum Grav.* **21** (2004) S487-S492.



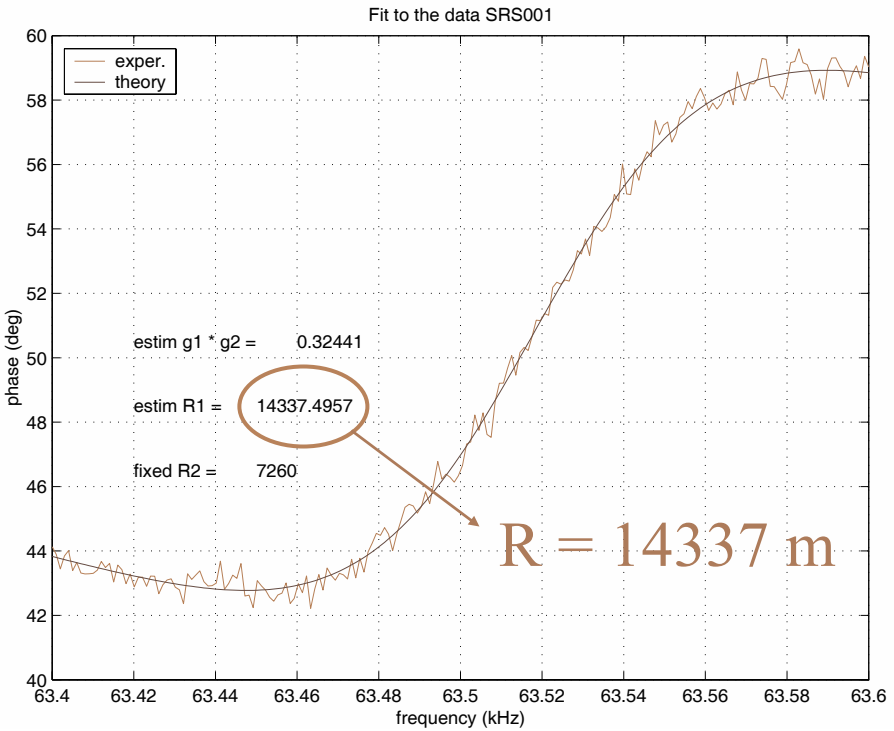
H1 data – Sept. 23, 2003

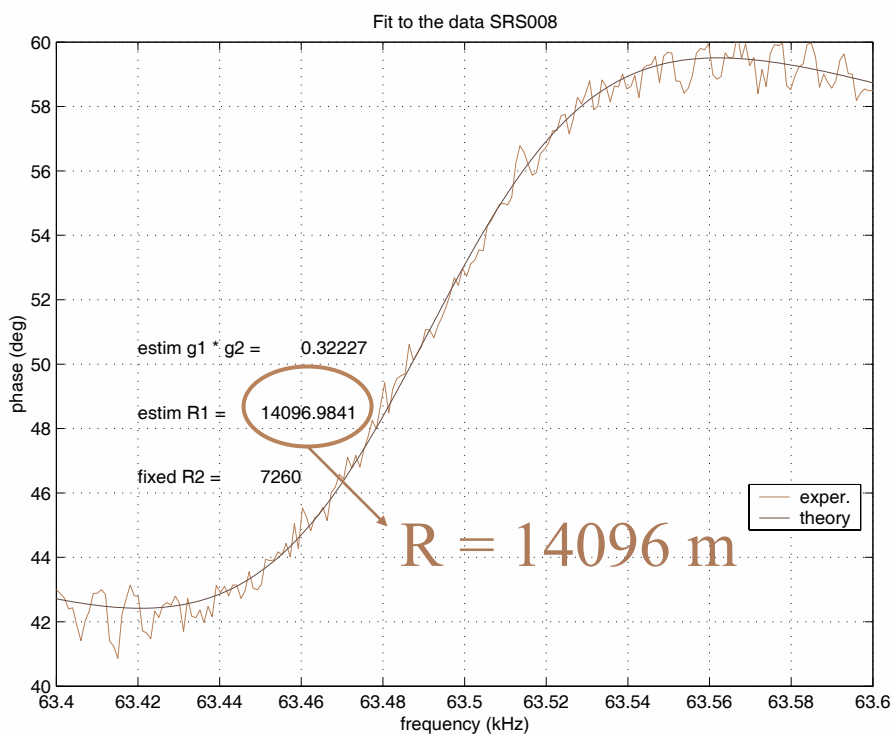
- Lock a single arm
- Mis-align input beam (MMT3) in yaw
- Drive VCO test input (laser freq.)
- Measure TF to ASPD Q_{mon} or I_{mon} signal
- Focus on phase of feature near 63 kHz



Data and (lsqcurvefit) fits.

ITMx TCS annulus heating → decrease in ROC (increase in curvature)



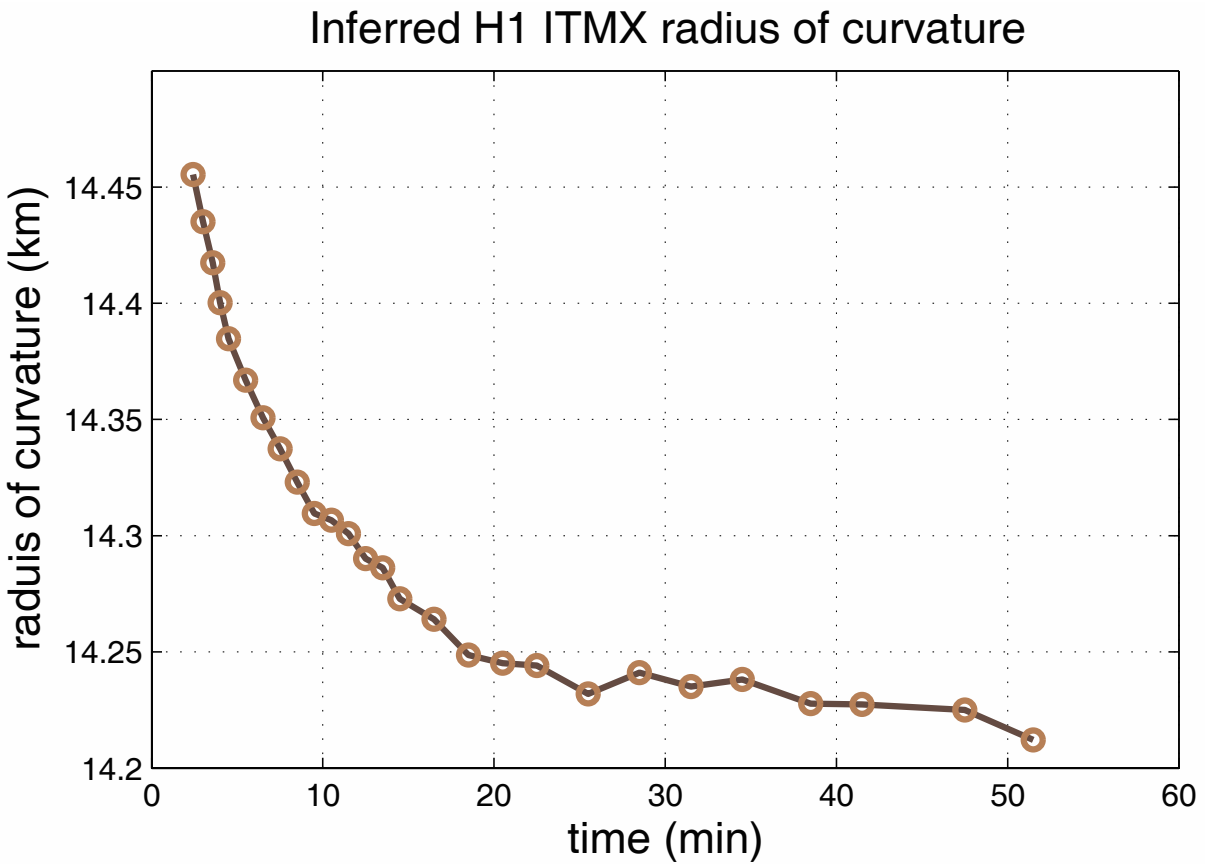


Assume metrology value for R_{ETMx} = 7260 m
Metrology value for ITMx = 14240 m

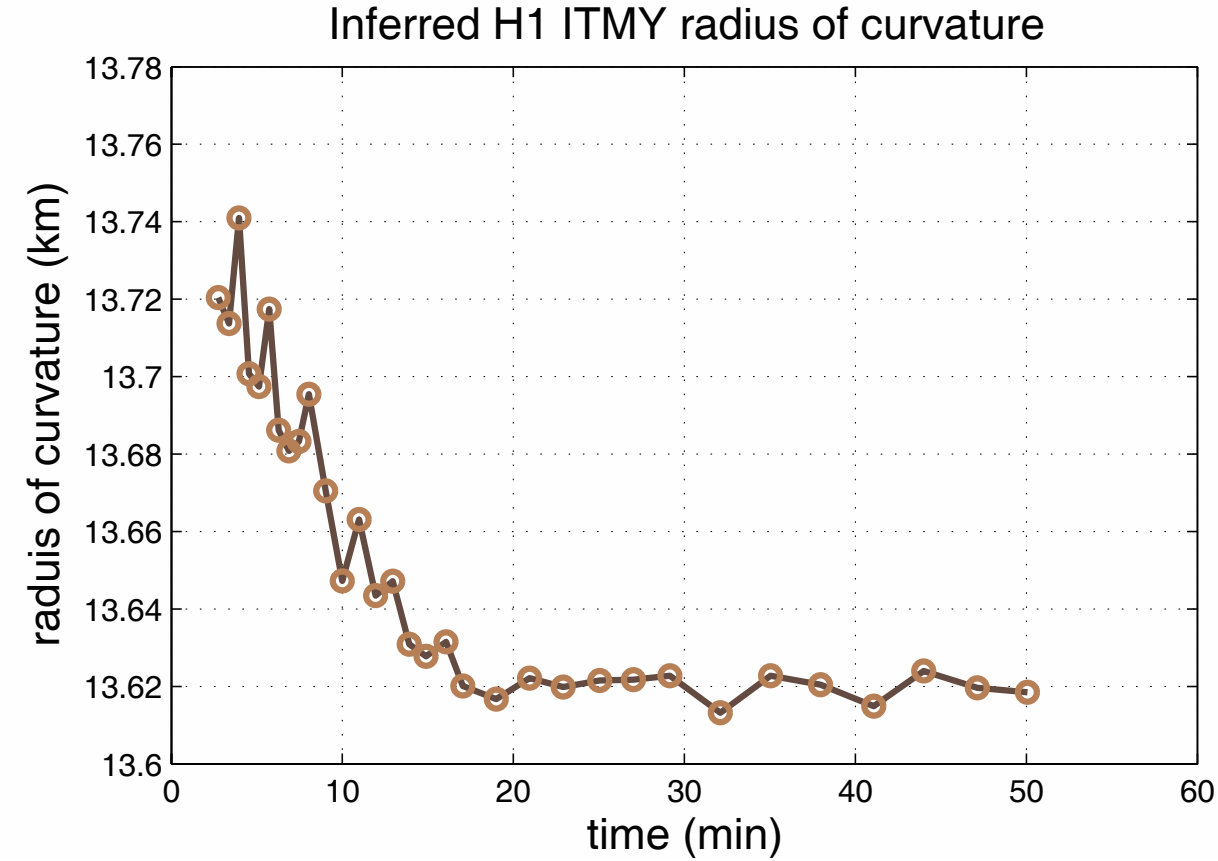
To investigate heating via 1 μm light …

- Lock ifo. for > 2 hours w/o TCS; P_{laser}= 2 W
- Break full lock (t = 0) and quickly lock a single arm.
- Misalign input beam (MMT3) in yaw
- Measure temporal evolution of $\mathbf{H_{\omega}(s)}$
- Note: 1μm light heats both ETM and ITM

- H1 Xarm data Feb. 18, 2005

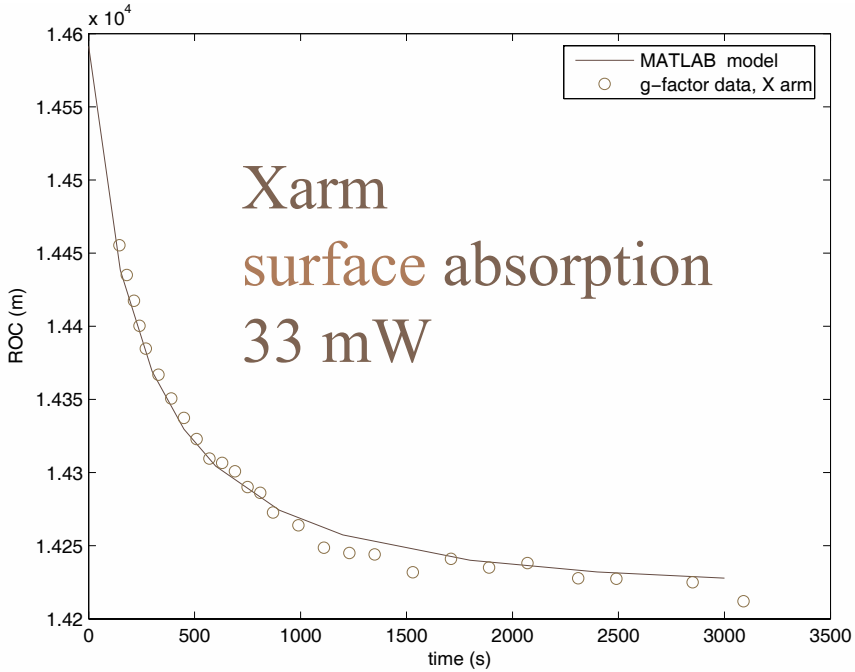


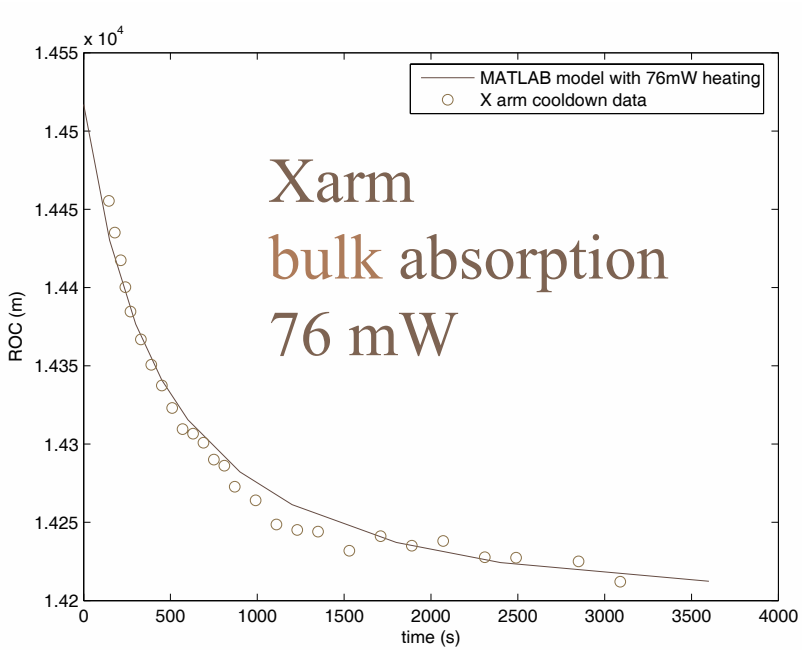
Yarm measurement Feb. 19, 2005



Comparison with model – Phil Willems

- Time-dependent model based on Hello-Vinet formalism (*J. Phys. France* 51(1990) 2243-2261)
- Free parameters: "cold" radius of curvature and power absorbed
- Fits by eye (+,- 20%)



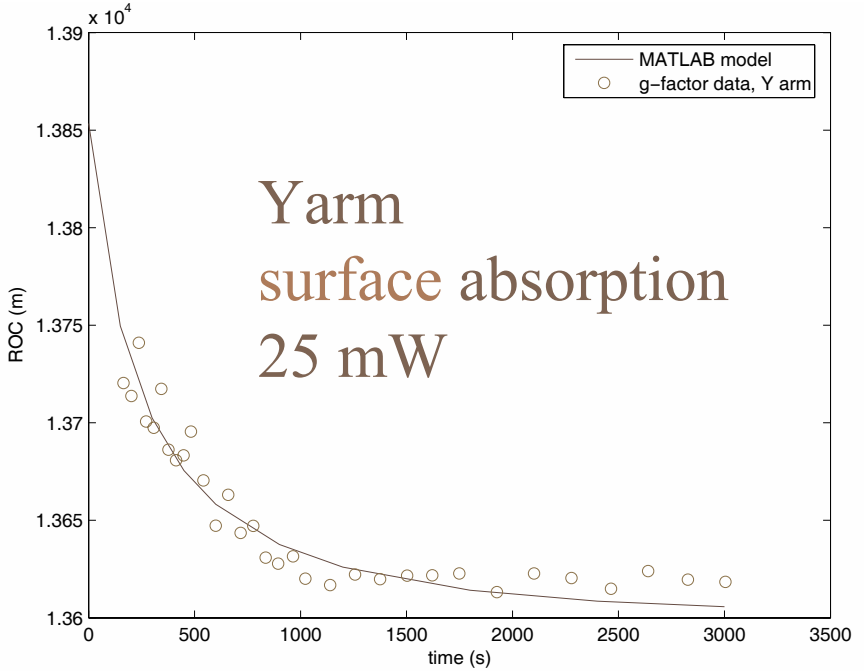


ΔR ~ 370 m

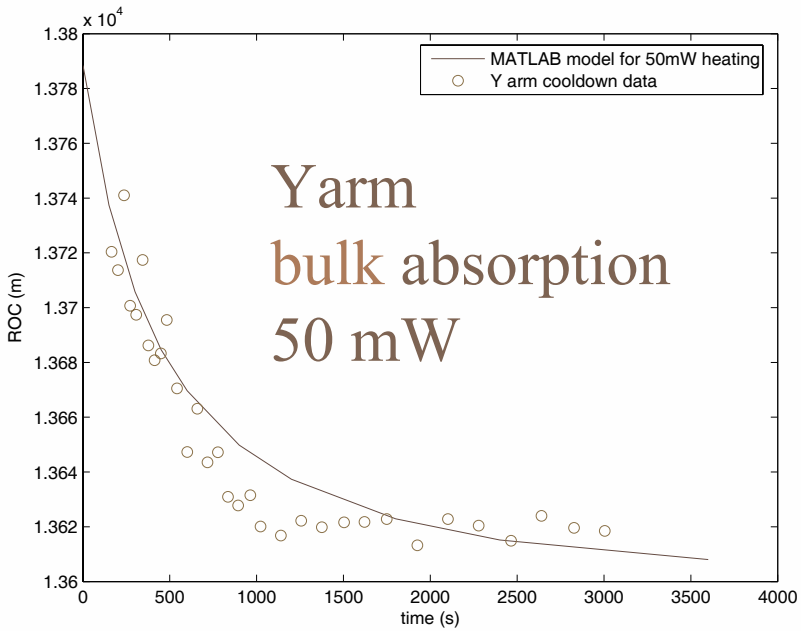
ΔR ~ 320 m

Comparison with model - Yarm

- Phil Willems – time-dependent Hello-Vinet model

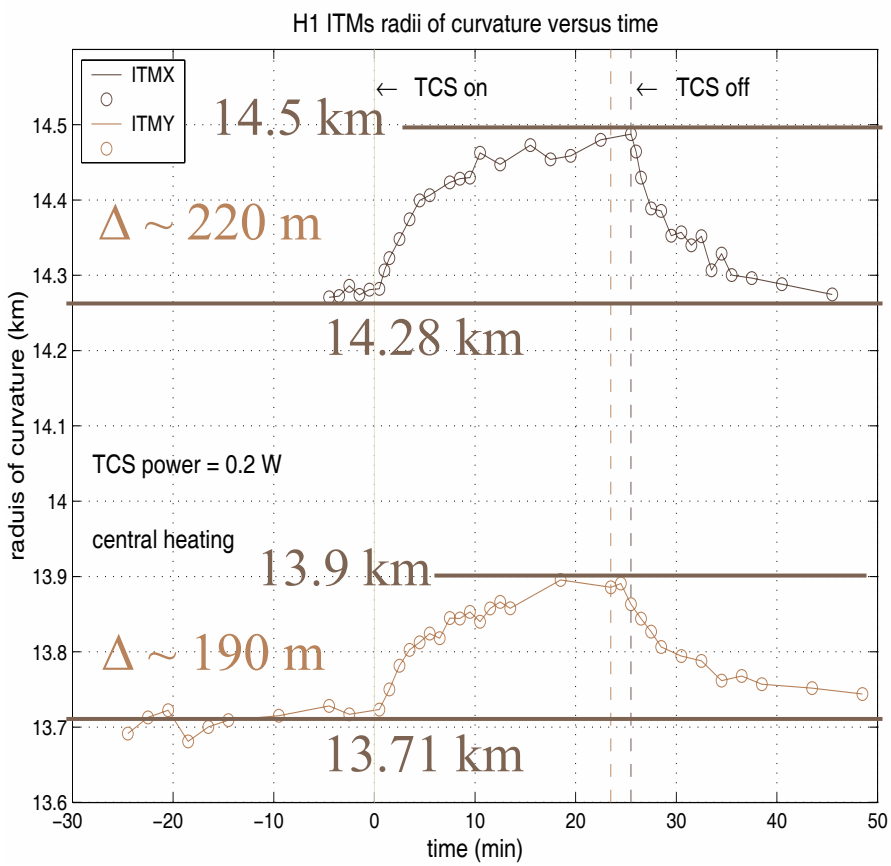


ΔR ~ 250 m



ΔR ~ 190 m

Calibration using TCS heaing results



- TCS calibration
  Xarm: 220m / 37mW = 5.9 m/mW
  Yarm: 190m / 45mW = 4.2 m/mW
  - » Surface (not bulk) absorption

- 1064 nm heating

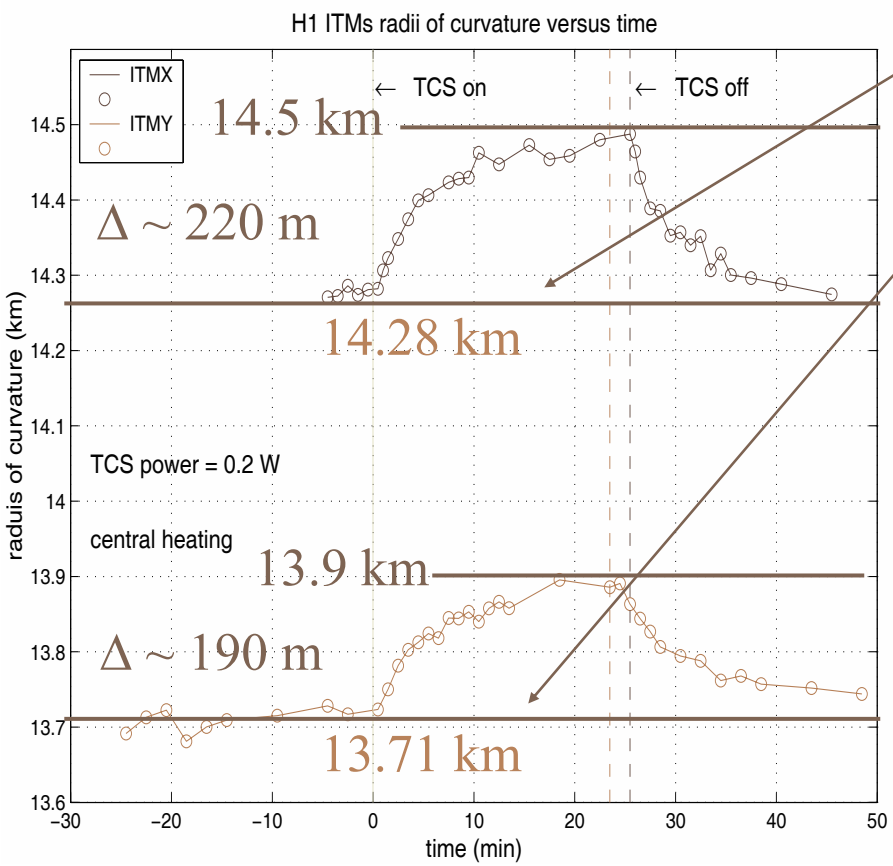
  Xarm: 293m / 5.9 m/mW = **49mW**

  Yarm: 177m / 4.2 m/mW = **42 mW**

  Assumes all heating on *surface* and no absorption in ETMs

- *Surface-equivalent, ITM-only absorption calibration*

Issues – "cold" curvature differences



- "Cold" values from 1064 nm meas.
  ITMX: 14.226 km
  difference ~ 50 m
  ITMY: 13.615 km
  difference ~ 100m
- Systematic errors?
  - » Alignment drifts – sampling different areas of TM surfaces
- More complex, time-dependent behavior of surface distortions?
  - » Phil Willems studying with time-dependent model of surface distortions
  - » g factor measurements and reduced data available in LIGO-T050030-00-W