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Summary of H1 g factor measurements

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1 Introduction

In February 2005, a series of measurements were made at the LIGO Hanford Observatory as part of ongoing efforts to understand heating effects in the input test masses of the H1 (4-km) interferometer. The measurements summarized in this document recorded the temporal evolution of the arm cavity g factors resulting from heating with either the 1064 nm interferometer laser light or the 10 μm light of the Thermal Compensation System (TCS).

From the g factor measurements, we infer the ITM radius of curvature by assuming the metrology value for the ETM radius of curvature. $g = g_1 g_2$; $g_{1,2} = 1 - L/R_{1,2}$ where L is the length of the arm cavity.

The individual measurements and results are described in LHO elog entries on Feb. 9¹, Feb. 11², Feb. 18³, and Feb. 20⁴. Slides for the presentation on this topic given at the LIGO detector commissioning meeting on Monday, Feb. 14, 2005 can be found in the LIGO DCC⁵.

The nominal test mass radii of curvature are from metrology performed by the fabricator. They are:

ITMX – 14240 m

ITMY – 13600m

ETMX – 7260

ETMY - 7320

The reduced data from these measurements, which was used to generate the plots in this document, can be found at the end of this document. Once this document is available in the DCC, one should be able to cut and paste the data from the .doc file for comparison with thermal models, etc.

Descriptions of the measurement technique can be found in:

LIGO- P030044-00-W⁶, Characterization of the LIGO 4km Fabry-Perot Cavities Via Their High-Frequency Dynamic Responses to Length and Laser Frequency Variations, M. Rakhmanov, F. Bondu, O. Debieu, and R. L. Savage, Jr., Classical and Quantum Gravity, Vol. 21, No. 5, pp. S487-S492, 2004

¹ http://blue.ligo-wa.caltech.edu/ilog/pub/ilog.cgi?group=detector&date_to_view=02/09/2005&anchor_to_scroll_to=2005:02:09:18:20:59-rick

² http://blue.ligo-wa.caltech.edu/ilog/pub/ilog.cgi?group=detector&date_to_view=02/11/2005&anchor_to_scroll_to=2005:02:11:11:37:51-rick

³ http://blue.ligo-wa.caltech.edu/ilog/pub/ilog.cgi?group=detector&date_to_view=02/18/2005&anchor_to_scroll_to=2005:02:18:18:27:46-rick

⁴ http://blue.ligo-wa.caltech.edu/ilog/pub/ilog.cgi?group=detector&date_to_view=02/20/2005&anchor_to_scroll_to=2005:02:20:16:23:59-malik

⁵ LIGO- G050076-00-W in the LIGO DCC or <http://apex.ligo-wa.caltech.edu/~rick/Talks/050213CommGfactor.pdf>.

⁶ <http://www.ligo.caltech.edu/docs/P/P030044-00.pdf>

2 TCS annulus heating

2.1 Xarm

This measurement began at approximately 11:56 AM PST on Feb. 9, 2005. A nominal 1.0 W of TCS annulus heating was applied to ITMX. A direct measurement of the TCS output power in this heating mode was not made, but C. Vorvick was confident in the calibration.

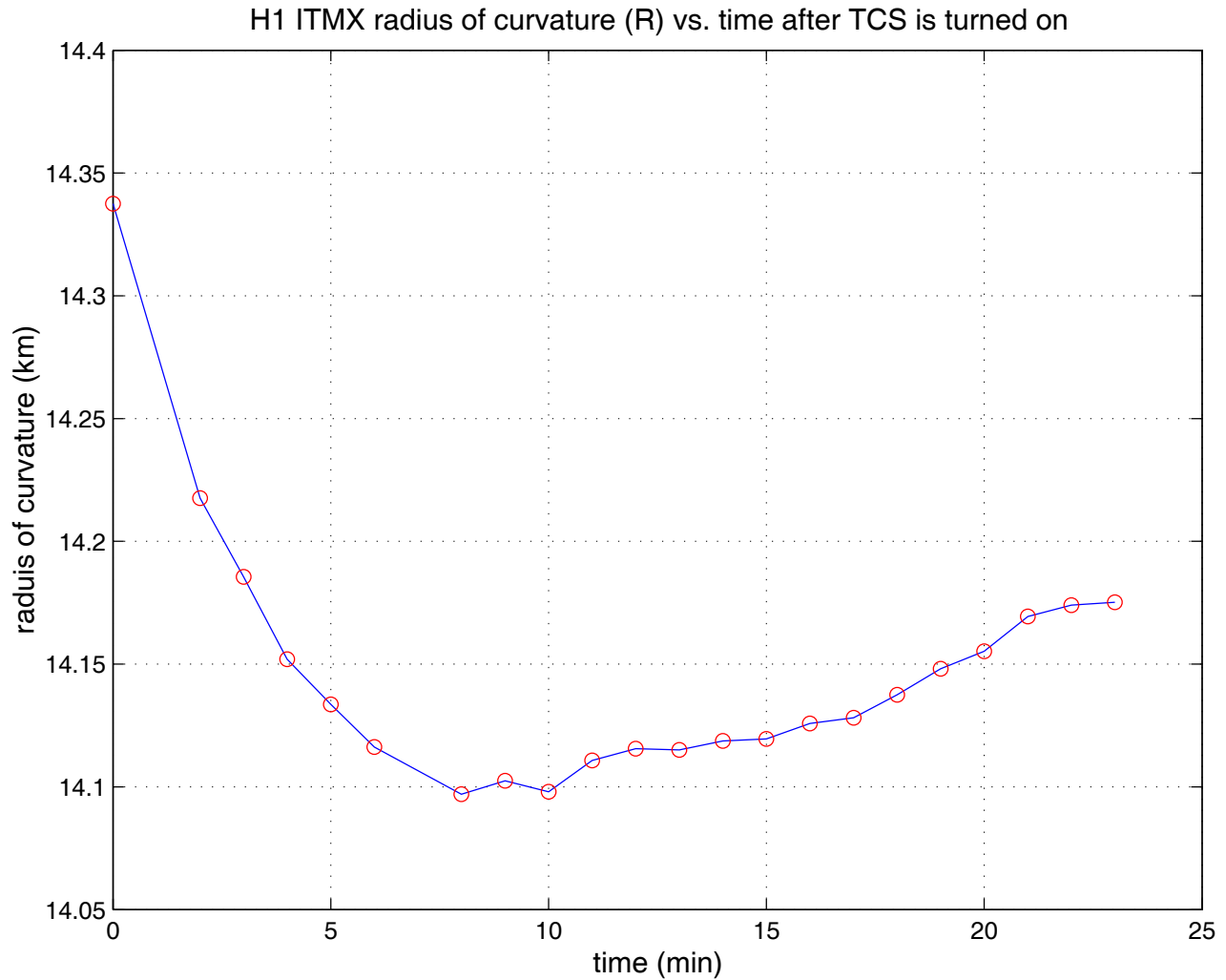


Figure 1 H1 ITMX; 1.0 W of annulus TCS heating.

2.2 Yarm

This measurement began at approximately 5:15 PM PST on Feb. 9, 2005. Unlike the Xarm measurement, immediately preceding this measurement the interferometer had been locked in the full “power up” mode (3 W) with the TCS compensation fully active.

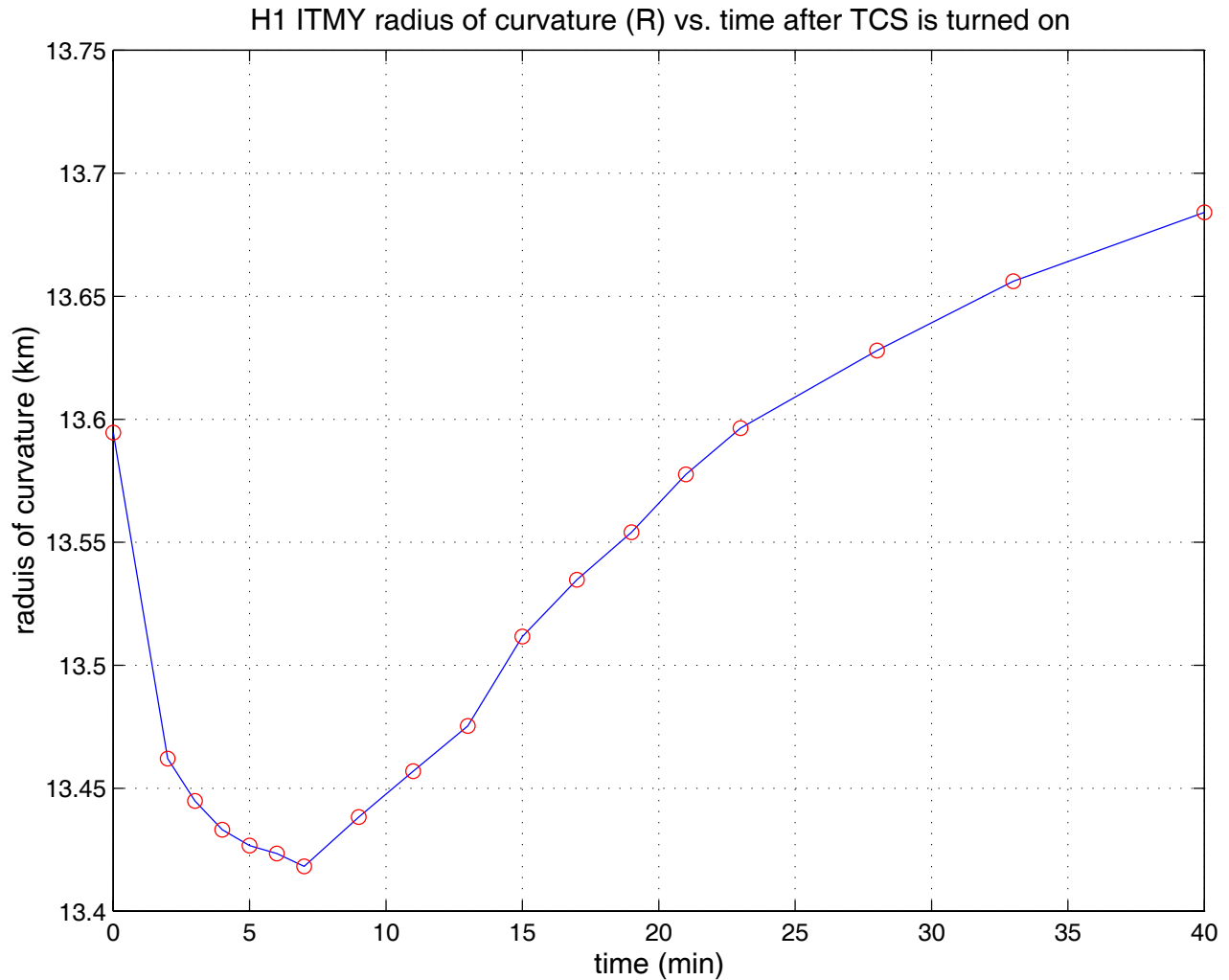


Figure 2 H1 ITMY; 1.0 W of annulus TCS heating.

3 TCS central heating

For these measurements, the interferometer had been out of lock for approximately six hours and the TCS system had been off. Thus we are reasonably confident that the optics started in their “cold” state.

3.1 Xarm

This measurement began at approximately 12:10 PM PST on Feb. 10, 2005. The TCS heating was turned on at $t = 0$ and turned off at $t = 25.5$ minutes.

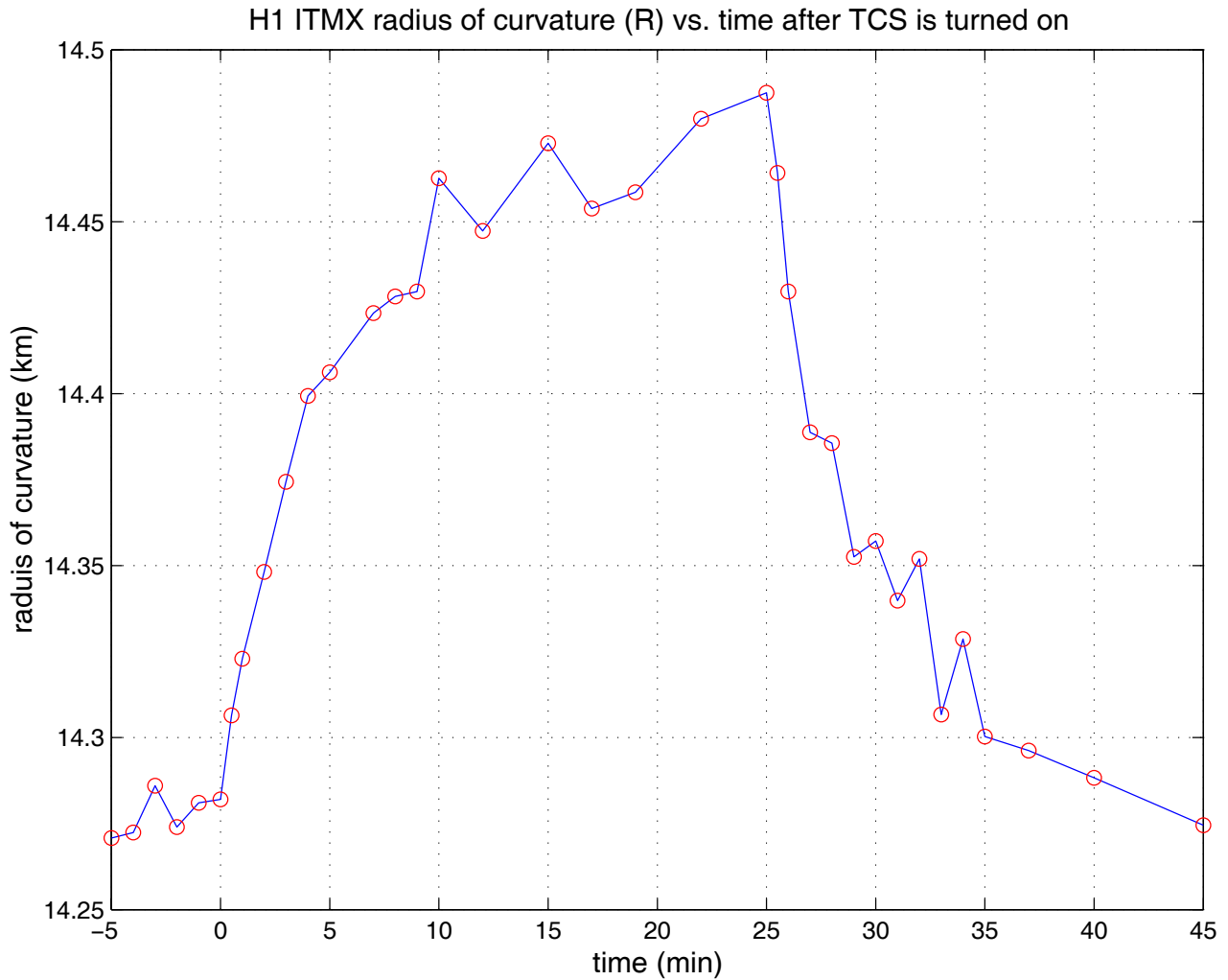


Figure 3 H1 ITMX; 37 mW of central TCS heating (nominal 0.2 W).

3.2 Yarm

This measurement began at approximately 10:42 AM PST on Feb. 10, 2005. The TCS heating was turned on at $t = 0$ and turned off at $t = 24.0$ minutes.

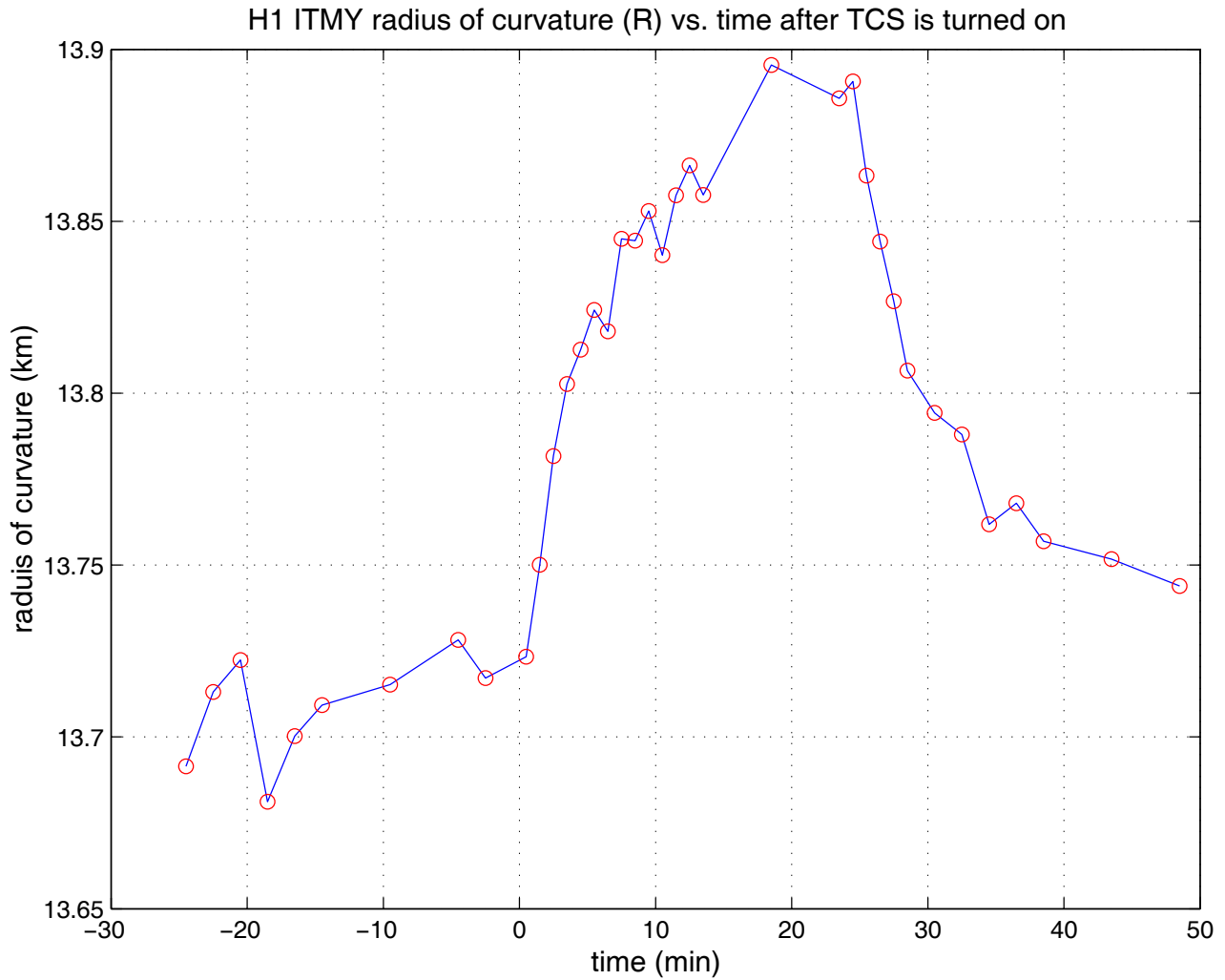


Figure 4 H1 ITMY; 45 mW of central TCS heating (nominal 0.2 W).

4 Interferometer (1064 nm) heating

For these measurements, the full interferometer was locked at with 1.9 W of input power and the TCS heating turned off on both arms. The ifo. was locked in this configuration for at least two hours before breaking the lock to begin the measurements. The locks were broken at $t = 0$.

4.1 Xarm

This measurement began at 12:05 PM PST on Feb. 18, 2005. The interferometer was locked with 1.9 W of input power and no TCS heating immediately prior to this measurement.

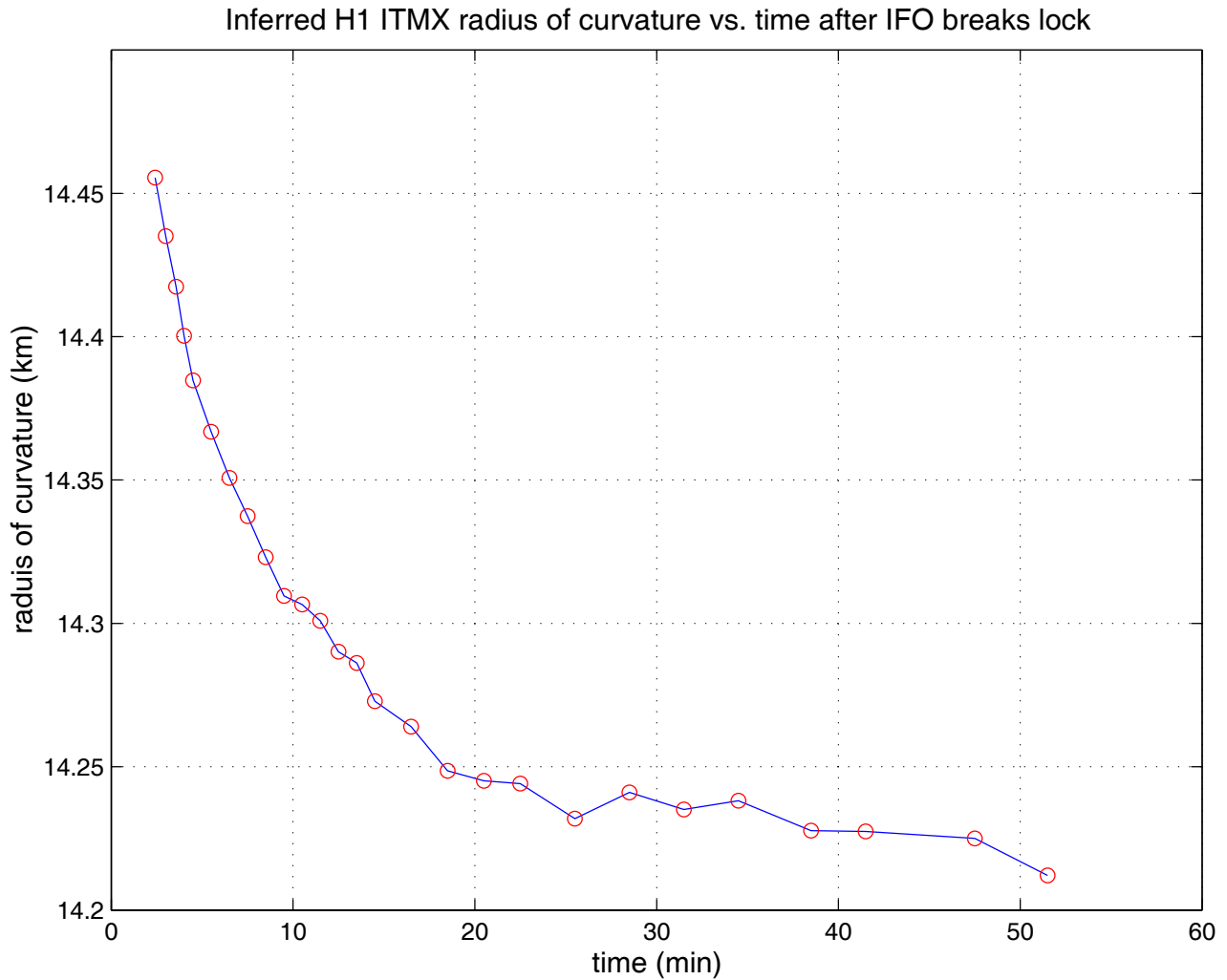


Figure 5 H1 ITMX; after 2 hours full ifo. lock at 1.9 W input power with no TCS heating.

4.2 Yarm

This measurement began at 2:40 PM PST on Feb. 19, 2005. The interferometer was locked for 2.5 hours at 1.9 W of input power with no TCS heating immediately prior to this measurement. Before that the ifo. was locked for about one hour at full power (3W) with full TCS heating active.

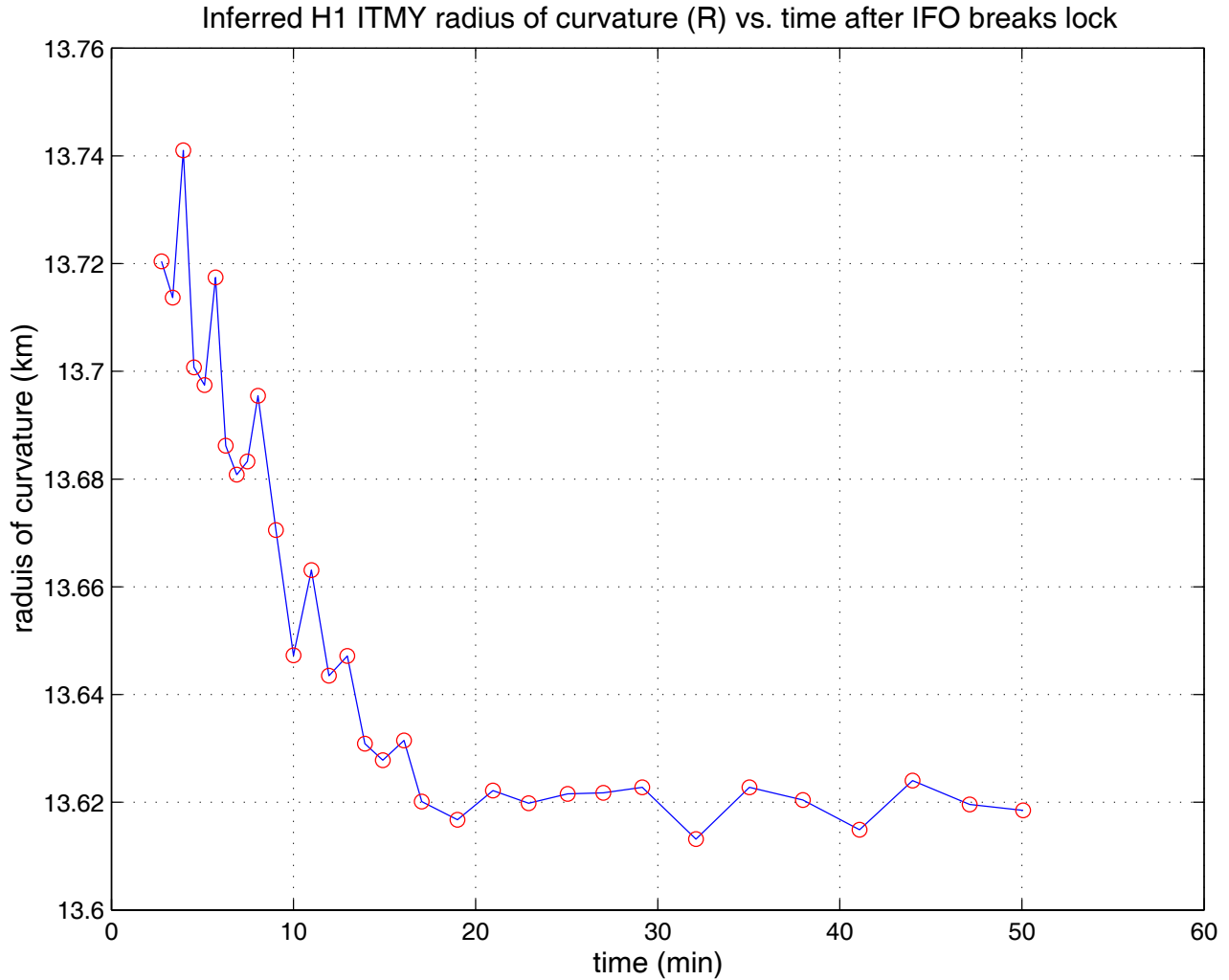


Figure 6 ITMXY; after 2 hours full ito. lock at 1.9 W input power with no TCS heating.

5 Data for plots

format: time (minutes), g factor, radius of curvature (km)

ITMX annulus TCS heating

=====

0.00	0.324406	14.3375
2.00	0.323349	14.2176
3.00	0.323063	14.1855
4.00	0.322763	14.1520
5.00	0.322598	14.1336
6.00	0.322441	14.1162
8.00	0.322268	14.0970
9.00	0.322317	14.1024
10.00	0.322277	14.0980
11.00	0.322392	14.1108
12.00	0.322435	14.1155
13.00	0.322431	14.1151
14.00	0.322464	14.1187
15.00	0.322471	14.1195
16.00	0.322528	14.1258
17.00	0.322549	14.1282
18.00	0.322633	14.1375
19.00	0.322728	14.1481
20.00	0.322792	14.1552
21.00	0.322919	14.1694
22.00	0.322960	14.1740
23.00	0.322971	14.1752

ITMY annulus TCS heating

=====

0.00	0.320741	13.5946
2.00	0.319427	13.4621
3.00	0.319254	13.4448

4.00	0.319137	13.4332
5.00	0.319072	13.4267
6.00	0.319039	13.4235
7.00	0.318987	13.4183
9.00	0.319188	13.4383
11.00	0.319375	13.4569
13.00	0.319559	13.4753
15.00	0.319922	13.5117
17.00	0.320151	13.5348
19.00	0.320342	13.5541
21.00	0.320574	13.5776
23.00	0.320759	13.5964
28.00	0.321068	13.6280
33.00	0.321342	13.6561
40.00	0.321614	13.6841

ITMX central TCS heating

=====

-5.00	0.323820	14.2708
-4.00	0.323834	14.2724
-3.00	0.323954	14.2860
-2.00	0.323848	14.2740
-1.00	0.323910	14.2810
0.00	0.323919	14.2820
0.50	0.324134	14.3065
1.00	0.324278	14.3229
2.00	0.324499	14.3482
3.00	0.324727	14.3744
4.00	0.324944	14.3994
5.00	0.325003	14.4062
7.00	0.325152	14.4234
8.00	0.325194	14.4283
9.00	0.325206	14.4297

10.00	0.325490	14.4627
12.00	0.325358	14.4473
15.00	0.325577	14.4728
17.00	0.325414	14.4538
19.00	0.325455	14.4586
22.00	0.325638	14.4799
25.00	0.325703	14.4875
25.50	0.325503	14.4642
26.00	0.325206	14.4297
27.00	0.324852	14.3888
28.00	0.324825	14.3856
29.00	0.324537	14.3525
30.00	0.324577	14.3571
31.00	0.324426	14.3398
32.00	0.324532	14.3520
33.00	0.324136	14.3067
34.00	0.324328	14.3286
35.00	0.324080	14.3003
37.00	0.324044	14.2962
40.00	0.323974	14.2883
45.00	0.323853	14.2745

ITMY central TCS heating

=====

-24.50	0.321685	13.6914
-22.50	0.321894	13.7131
-20.50	0.321984	13.7224
-18.50	0.321585	13.6811
-16.50	0.321770	13.7002
-14.50	0.321857	13.7092
-9.50	0.321915	13.7152
-4.50	0.322040	13.7282
-2.50	0.321933	13.7171

0.50	0.321993	13.7233
1.50	0.322250	13.7501
2.50	0.322553	13.7817
3.50	0.322753	13.8027
4.50	0.322848	13.8126
5.50	0.322958	13.8242
6.50	0.322899	13.8180
7.50	0.323154	13.8449
8.50	0.323149	13.8444
9.50	0.323231	13.8530
10.50	0.323109	13.8401
11.50	0.323274	13.8576
12.50	0.323356	13.8663
13.50	0.323275	13.8577
18.50	0.323631	13.8955
23.50	0.323540	13.8858
24.50	0.323586	13.8907
25.50	0.323328	13.8633
26.50	0.323147	13.8441
27.50	0.322982	13.8267
28.50	0.322790	13.8065
30.50	0.322673	13.7943
32.50	0.322613	13.7880
34.50	0.322363	13.7618
36.50	0.322422	13.7680
38.50	0.322316	13.7569
43.50	0.322266	13.7517
48.50	0.322191	13.7439

ITMX ifo. heating

=====

2.42	0.325428	14.4554
3.00	0.325253	14.4351

3.57	0.325100	14.4174
4.00	0.324952	14.4003
4.50	0.324817	14.3847
5.50	0.324662	14.3669
6.50	0.324521	14.3507
7.50	0.324405	14.3374
8.50	0.324279	14.3230
9.50	0.324161	14.3096
10.50	0.324135	14.3066
11.50	0.324085	14.3009
12.50	0.323990	14.2901
13.50	0.323956	14.2862
14.50	0.323838	14.2728
16.50	0.323760	14.2640
18.50	0.323624	14.2486
20.50	0.323593	14.2451
22.50	0.323584	14.2441
25.50	0.323476	14.2319
28.50	0.323557	14.2411
31.50	0.323504	14.2351
34.50	0.323531	14.2381
38.50	0.323439	14.2277
41.50	0.323436	14.2274
47.50	0.323415	14.2250
51.50	0.323300	14.2121

ITMY ifo. heating

=====

2.75	0.321965	13.7204
3.37	0.321900	13.7137
3.95	0.322163	13.7410
4.53	0.321775	13.7007
5.12	0.321743	13.6974

5.72	0.321936	13.7174
6.28	0.321634	13.6862
6.88	0.321582	13.6808
7.47	0.321606	13.6833
8.05	0.321724	13.6955
9.03	0.321482	13.6705
10.00	0.321256	13.6473
10.98	0.321410	13.6631
11.95	0.321219	13.6435
12.95	0.321255	13.6472
13.92	0.321096	13.6309
14.90	0.321066	13.6278
16.07	0.321102	13.6315
17.05	0.320991	13.6201
19.00	0.320958	13.6168
20.95	0.321011	13.6222
22.92	0.320988	13.6198
25.05	0.321005	13.6216
27.02	0.321007	13.6218
29.15	0.321017	13.6228
32.10	0.320923	13.6132
35.03	0.321017	13.6228
37.97	0.320994	13.6204
41.08	0.320940	13.6149
44.00	0.321029	13.6240
47.13	0.320986	13.6196
50.07	0.320975	13.6185