LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Technical Note **LIGO-T1200280-v1** Date: 6/4/2012

Quad Monolithic Prototype Q Measurements

Brett Shapiro

California Institute of Technology
LIGO Project, MS 18-34
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project, Room NW22-295
Cambridge, MA 02139
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

LIGO Hanford Observatory
Route 10, Mile Marker 2
Richland, WA 99352
Phone (509) 372-8106
Fax (509) 372-8137
E-mail: info@ligo.caltech.edu

LIGO Livingston Observatory
19100 LIGO Lane
Livingston, LA 70754
Phone (225) 686-3100
Fax (225) 686-7189
E-mail: info@ligo.caltech.edu

http://www.ligo.caltech.edu/

1 Introduction

The purpose of this document is to compile Q (quality factor) measurements and references from the LASTI monolithic quadruple pendulum modes into a single document. The LASTI ilog includes most of these measurements: `http://emvogil-3.mit.edu/ilog/pub/ilog.cgi?group=lasti`. Read-only access for the ilog is obtained with a username of 'reader' and a password of 'readonly'.

The suspension longitudinal modes were measured by Brett Shapiro and are presented here in Section 2. The fiber violin modes were measured by Matt Evans and are presented briefly in Section 3. More details on the fiber violin modes can be found in the following documents:

1. T1000468
2. T1000514

The test mass acoustic modes were measured first by John Miller and later by Slawek Gras and will not be presented here. The following documentation details these measurements:

1. G1001023
2. P1000032
3. J. Miller, M. Evans, L. Barsotti, P. Fritschel, M. Macinnis, R. Mittleman, B. Shapiro, J. Soto, C. Torrie. Damping Parametric Instabilities in Future Gravitational Wave Detectors by Means of Electrostatic Actuators. Physics Letters A. 2011. Vol. 375, n 3. pgs. 788-794.

2 Suspension Longitudinal Modes

This section presents the quadruple pendulum noise prototype measured Qs of the four longitudinal (x) suspension modes. These Qs were measured by exciting each of the modes individually with a sine wave tuned to the mode frequency. The mode was allowed to ring up for a period of time, at which point the excitation was turned off. The Q was measured by fitting an exponential curve of the form in Eq. (1) to the subsequent decay.

$$Ae^{-Bt} \tag{1}$$

A is the amplitude of the decay, B is the positive time constant of the decay, and t is time in seconds. For a mode of frequency f_n in units of Hz, the Q factor is determined from the measured time constant B as

$$Q = \frac{\pi f_n}{B} \tag{2}$$

There are two groups of measurements presented here. The first, in Section 2.1 presents the measurements from the quad in the configuration of a glass test mass hung from a loop of stainless steel wire. The second in Section 2.2 presents the results from the quad in a full monolithic configuration where the glass test mass was hung from welded glass fibers.

Each section first presents an undamped longitudinal transfer function measured from the top mass to the top mass using the OSEMs. On this transfer function the measured Q values are labeled for each mode. The ringdown measurements for the four modes are then plotted with the exponential decay fit superimposed.

The results from these two configurations are very similar, though in general there was a slight decrease in Q after the transition to the monolithic state. The Qs for these two configurations are summarized in the Table 1.

Table 1: Summary of the four longitudinal mode Q measurements.

Mode #	Wire Frequency (Hz)	Monolithic Frequency (Hz)	Wire Q	Monolithic Q
1	0.433	0.44	1015	1007
2	0.98	0.982	774	578
3	2.018	1.986	321	262
4	3.421	3.38	453	428

These measurements are also presented in the LASTI ilog: `http://emvogil-3.mit.edu/ilog/pub/ilog.cgi?group=lasti&task=view&date_to_view=02/01/2010&anchor_to_scroll_to=2012:02:15:23:30:07-brett`.

2.1 Glass Optic on Metal Wires

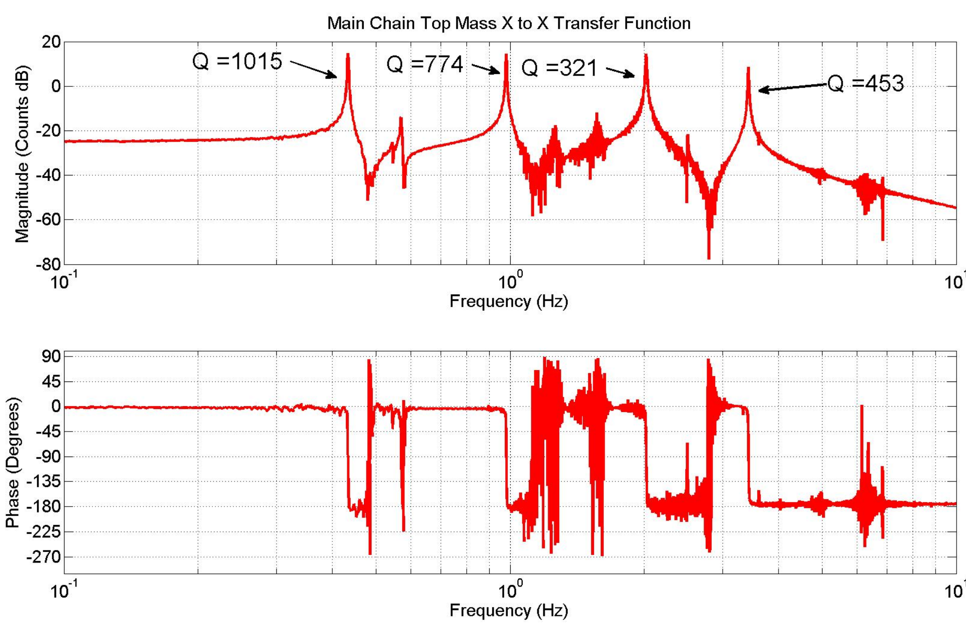

Figure 1: Quad top mass force to top mass displacement transfer function.

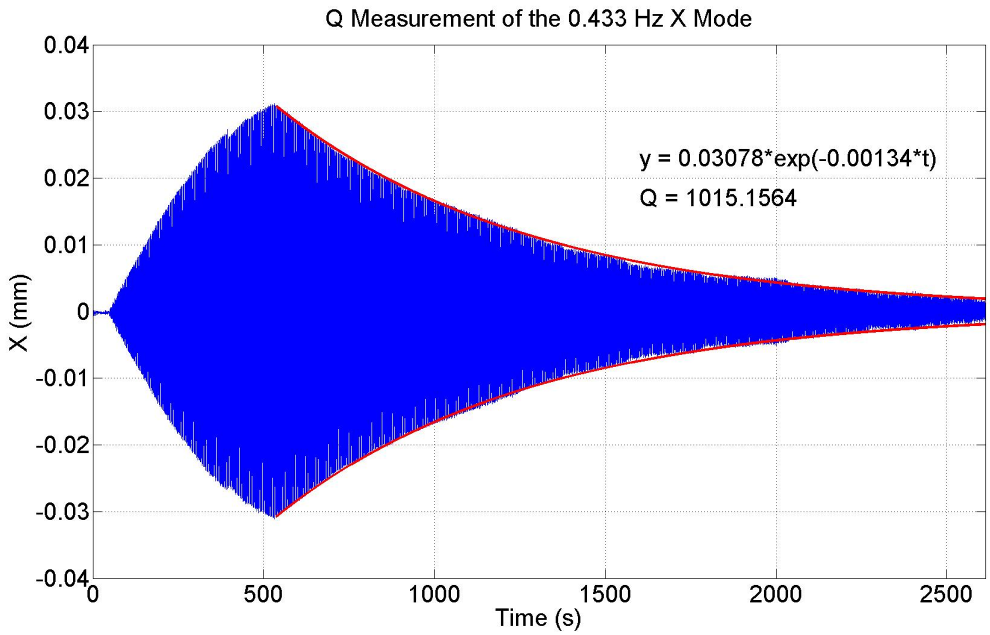

Figure 2: Ringdown Q measurement of the 0.433 Hz mode.

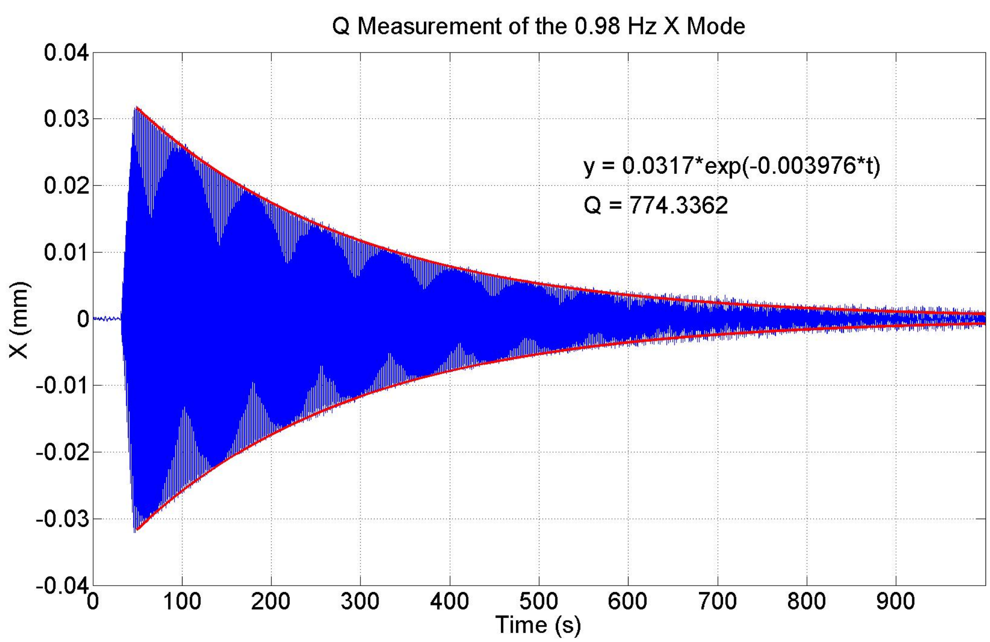

Figure 3: Ringdown Q measurement of the 0.98 Hz mode.

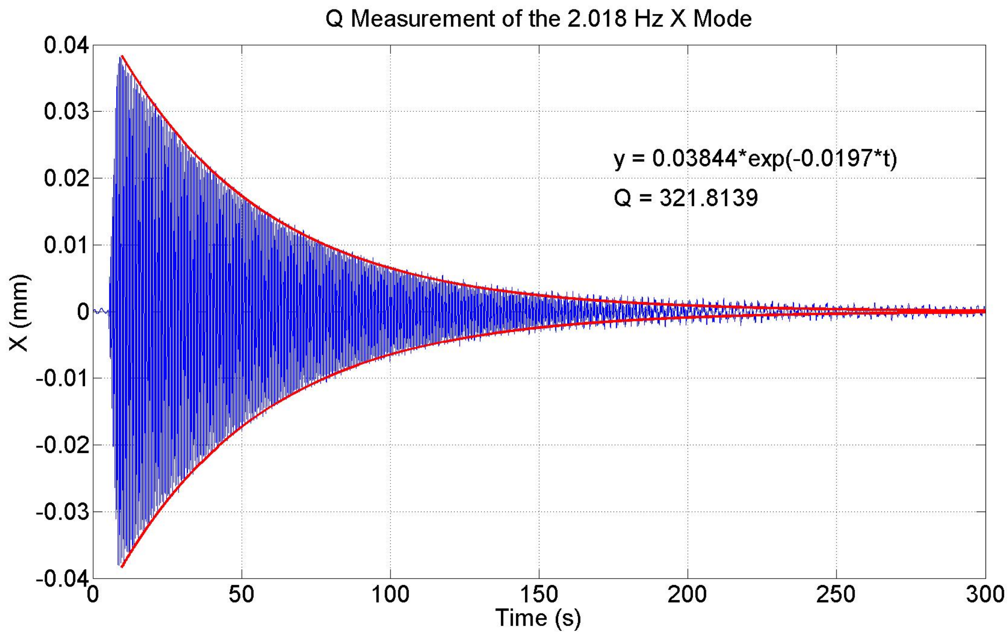

Figure 4: Ringdown Q measurement of the 2.018 Hz mode.

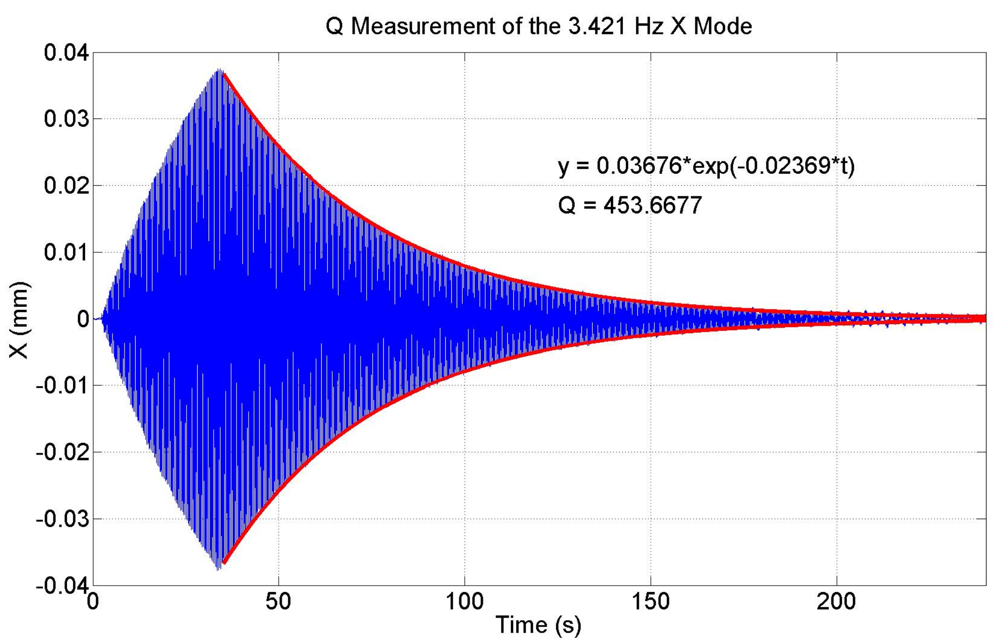

Figure 5: Ringdown Q measurement of the 3.421 Hz mode.

2.2 Full Monolithic Quad

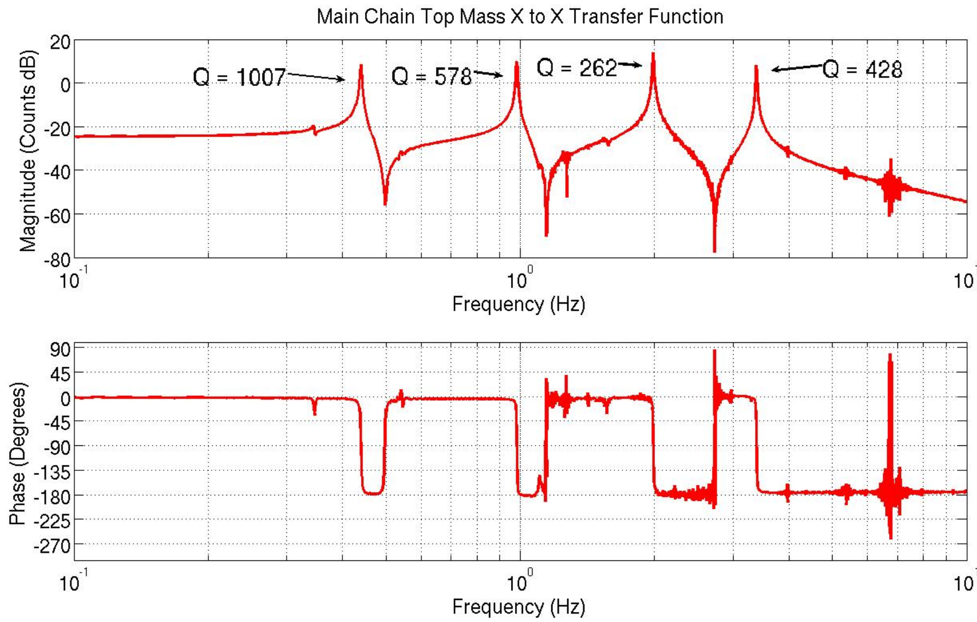

Figure 6: Quad top mass force to top mass displacement transfer function.

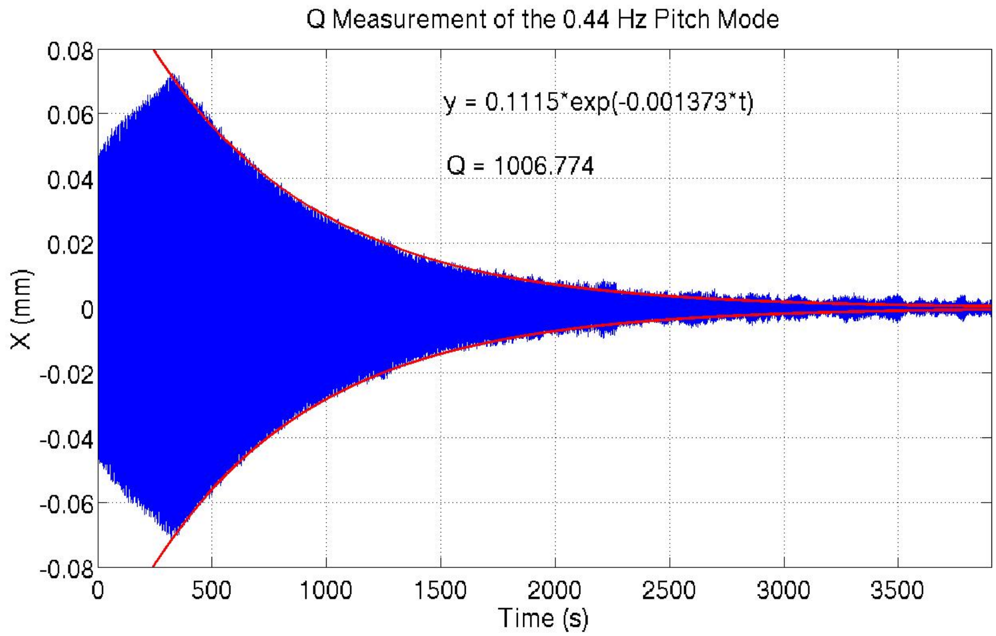

Figure 7: Ringdown Q measurement of the 0.44 Hz mode.

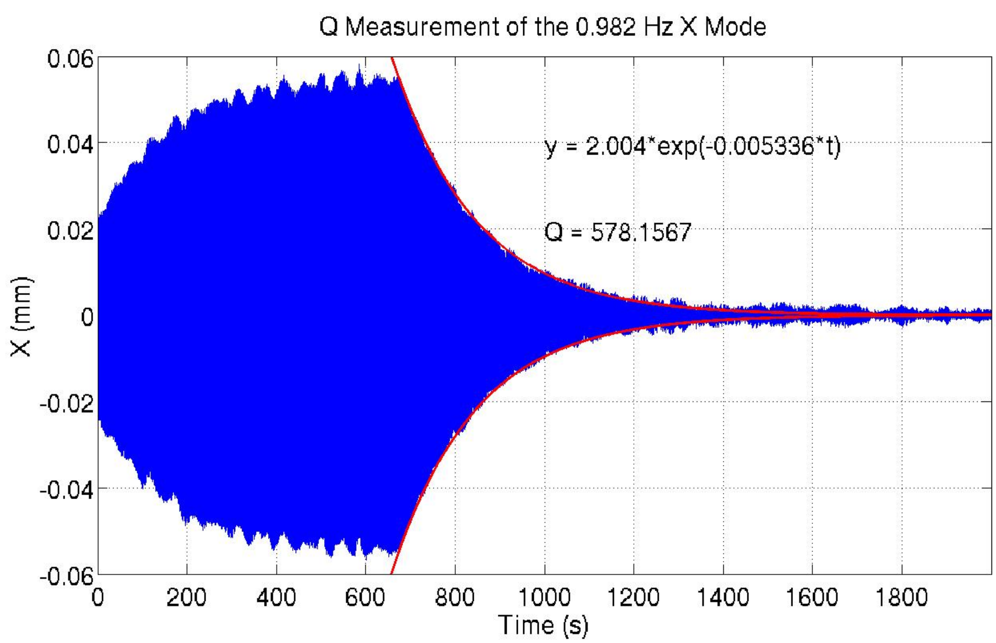

Figure 8: Ringdown Q measurement of the 0.982 Hz mode.

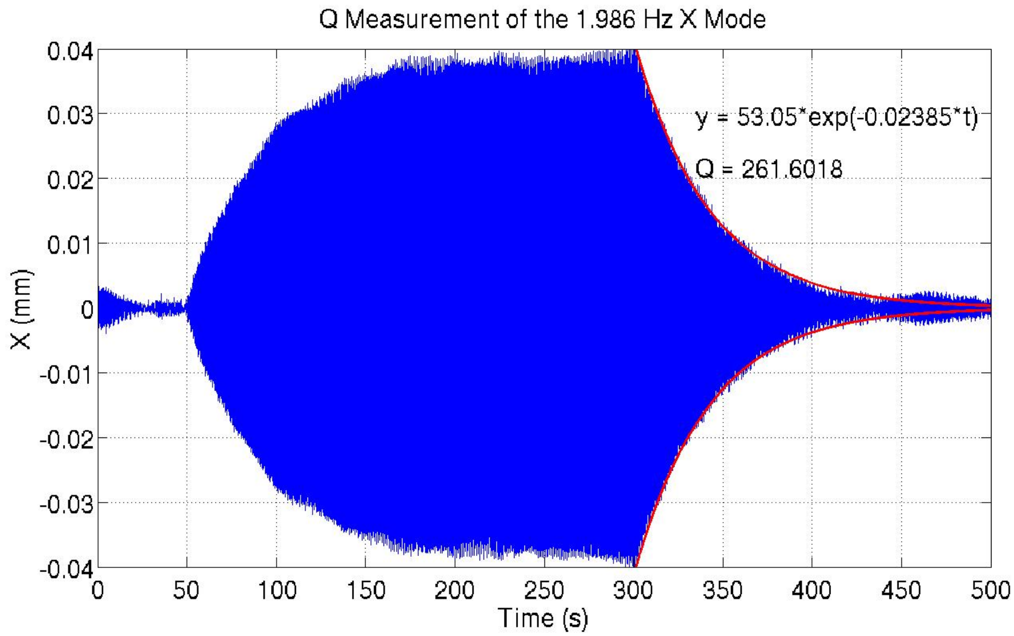

Figure 9: Ringdown Q measurement of the 1.986 Hz mode.

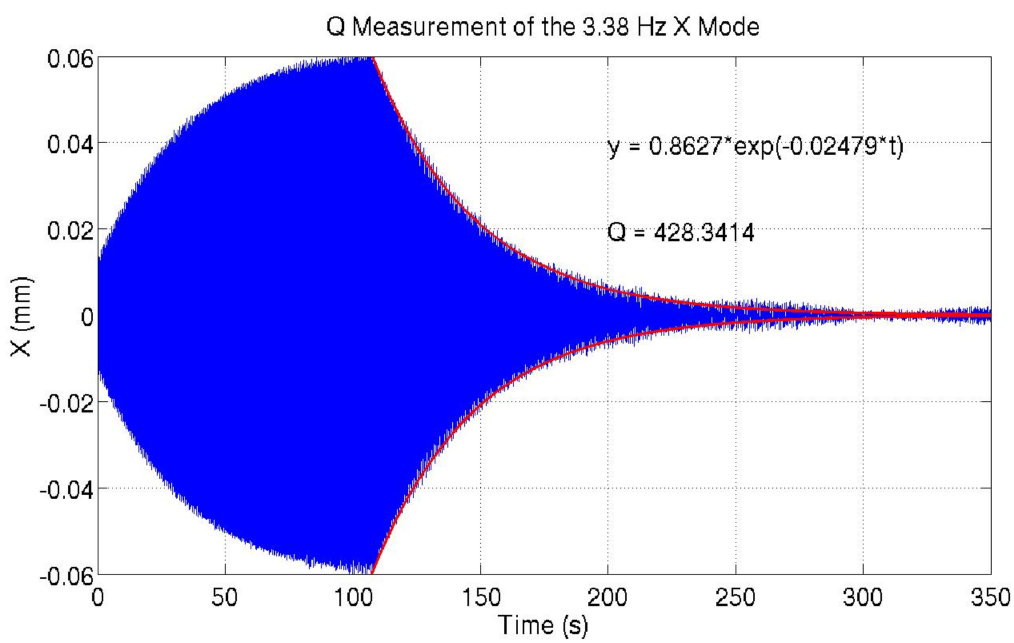

Figure 10: Ringdown Q measurement of the 3.38 Hz mode.

3 Fiber Violin Modes

The violin modes of the fibers were excited by driving the OSEMs at the penultimate mass (PUM). Figure 11 plots the ringdown of the fundamental modes for two of the fibers. These modes frequencies are 511.3 Hz and 520.9 Hz. The Qs for these modes were measured at 599×10^6 and 623×10^6 respectively. A single second harmonic at 1019.9 Hz was measured with a Q of 455×10^6. Figure 12 plots this measurement. These measurements agreed well with the theoretical predictions in T1000514.

The violin mode Qs are listed on the LASTI ilog at `http://emvogil-3.mit.edu/ilog/pub/ilog.cgi?group=lasti&task=view&date_to_view=07/31/2010&anchor_to_scroll_to=2010:07:31:03:10:31-mevans`.

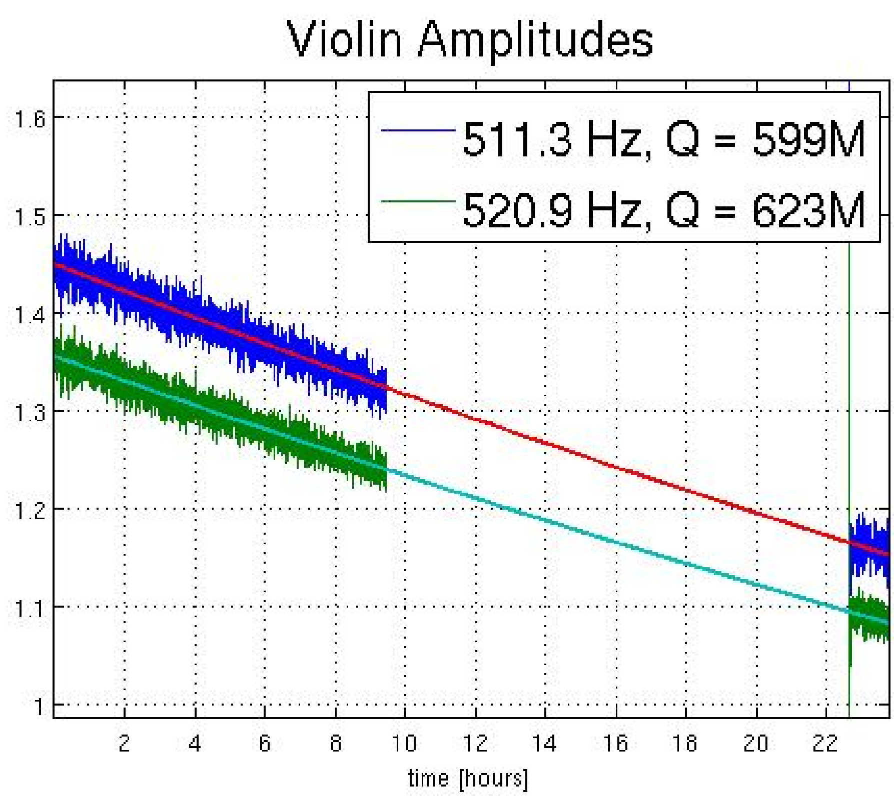

Figure 11: Ringdown of the fundamental violin mode for two of the fibers.

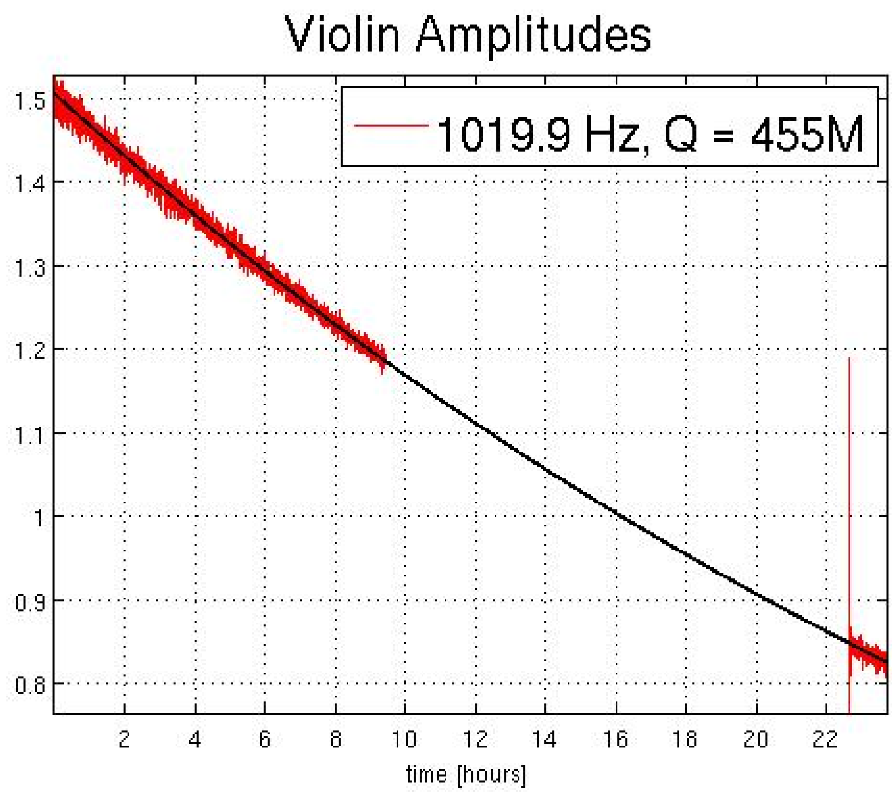

Figure 12: Ringdown of the second harmonic violin mode for one of the fibers.