BTO Data from 22 September, 2005
Observations and Comments
C. Shelton 10/4/2005

For the 22 September, 2005 LGS engineering run, a new computer (bto), data acquisition and cabling were installed on the laser beam transfer optics, and the laser itself had been mounted on stiffer, isolated supports.

The intent of these changes was to implement the Q3 safety interlock, reduce laser pointing jitter, implement synchronous (laser-triggered) data acquisition, and improve both speed and signal quality of the quad cell data acquisition. All of these were done.

In addition, John Angione had time to create a data logging feature, which writes all raw data to a tab-delimited text file readable by both IDL and Matlab. I have written Matlab routines to reduce the data and do some analysis. A data reduction routine performs background subtraction, computes centroids, and converts centroids to calibrated beam motion in millimeters. An analysis routine provides power spectra and cross-correlation, including a sharp-edged filter function for isolating individual jitter frequencies.

Figures 1 and 2 show power spectra of Q2 x and y, at laser power levels of 6.4W and 0.1W. The ND filters were in place for both power levels. While there is still excess activity in the 55-62 Hz area, the magnitude as seen in a time-domain plot is far lower than that of the 62 Hz vibration seen in the previous run. Other good news is that the dynamic range is vastly improved; the normalized peak heights of the 55-62 Hz lines are essentially identical, even with a 64:1 change in laser power. There is a change in the noise floor, but basically the 0.1W level with an ND filter in place is perfectly useable. The fact that the signals scale with optical power plus the lack of lines at exactly 60, 120 or 180 Hz indicates that the electrical signal quality is now very good, and that the 55-62 Hz activity is real pointing jitter.

For these data, the x centration was good on all quad cells, while the y centration was marginal. On Q1, y was off enough to saturate the y signal and weaken the x signal. As Q2 had the cleanest signal, and no corrections for a double-image beamsplitter, its data is used here.

The cluster of lines around 62 Hz can be cleanly separated out by a suitable filter, with the bandwidth set to just encompass all the lines, as shown in Figure 3. Figure 4 is a calibrated time-domain plot where one can estimate the total jitter due to this cluster. There appears to be about 0.3mm peak-to-peak in Q2x and a similar amount in Q2y. Notice the dropouts in the y ac signal, which correspond to negative y excursions visible in the y dc signal that take the detector out of its linear region. The fourth trace in Figure 4 is a running estimate of the best fit y/x slope. This is useful when an individual frequency is isolated, but is not too meaningful on a mix of them.

Figure 1. Power Spectra of Quad Cell Data, 6.4W

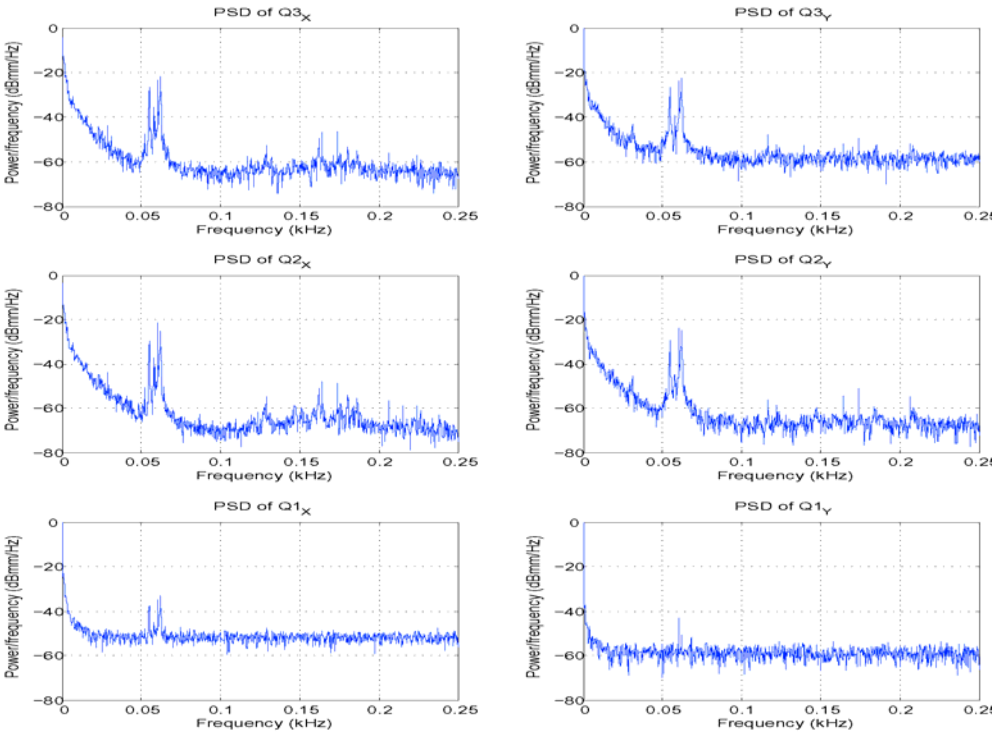


Figure 2. Power Spectra of Quad Cell Data, 0.1W

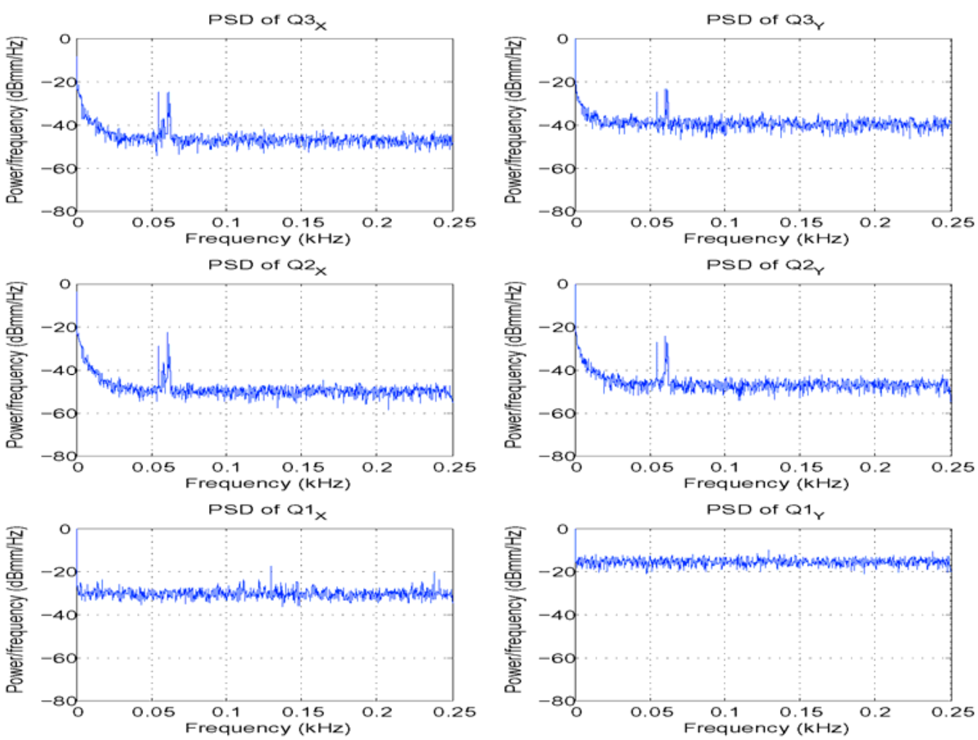


Figure 3. Power Spectra with Filtering

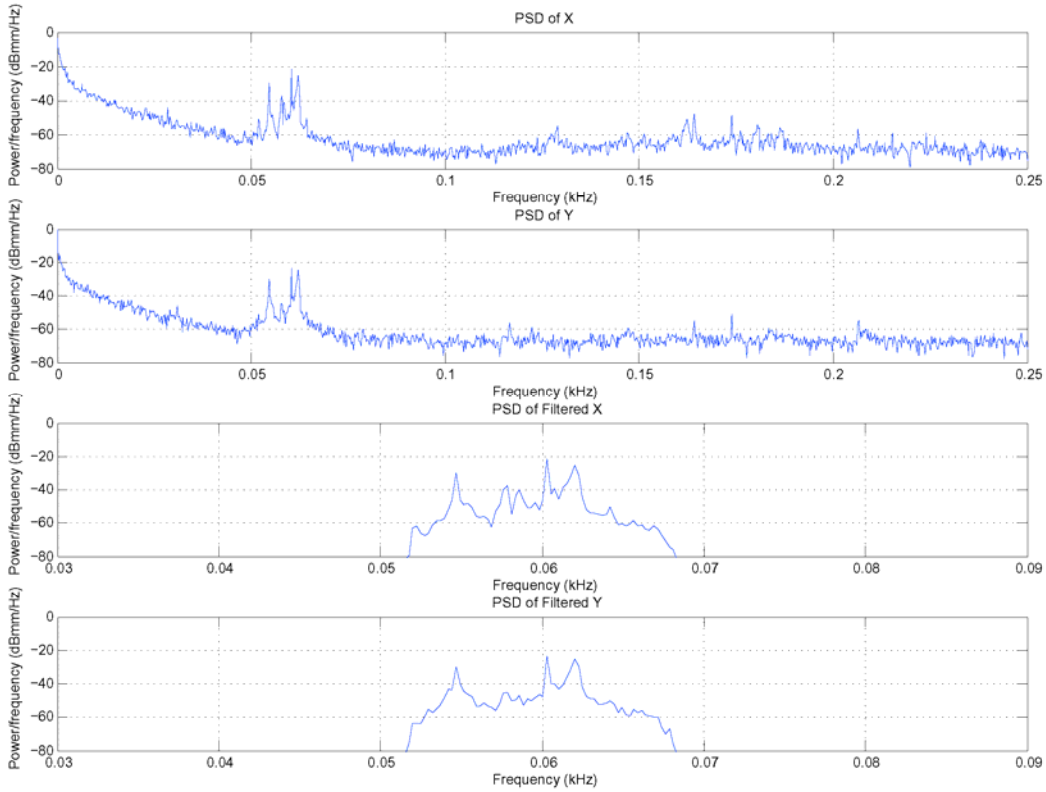
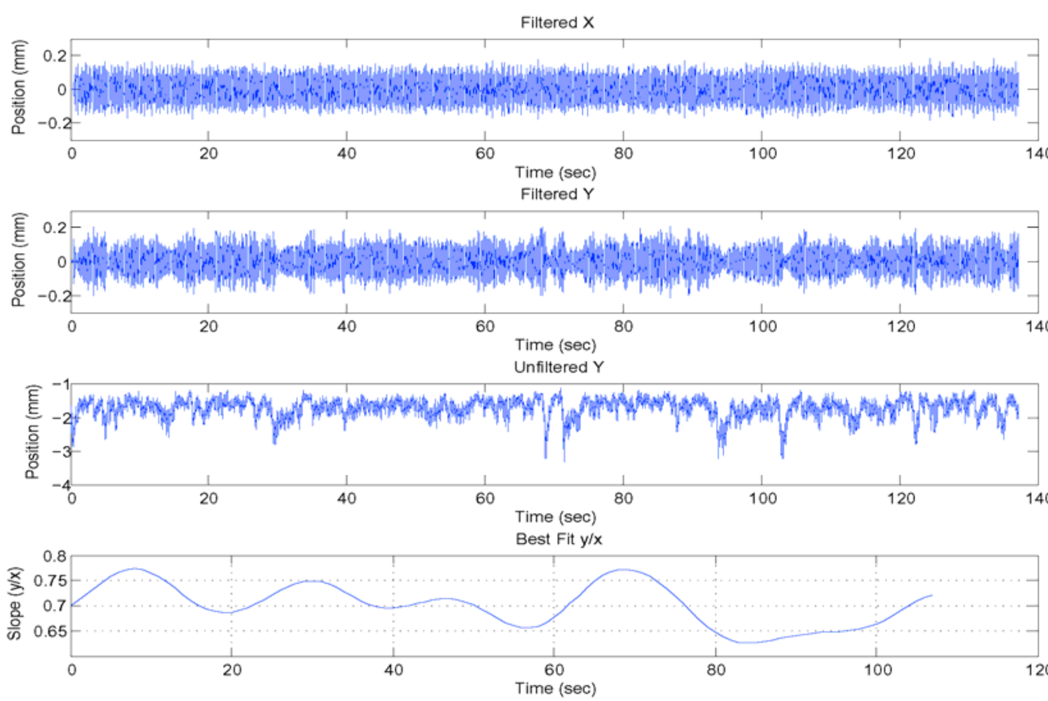
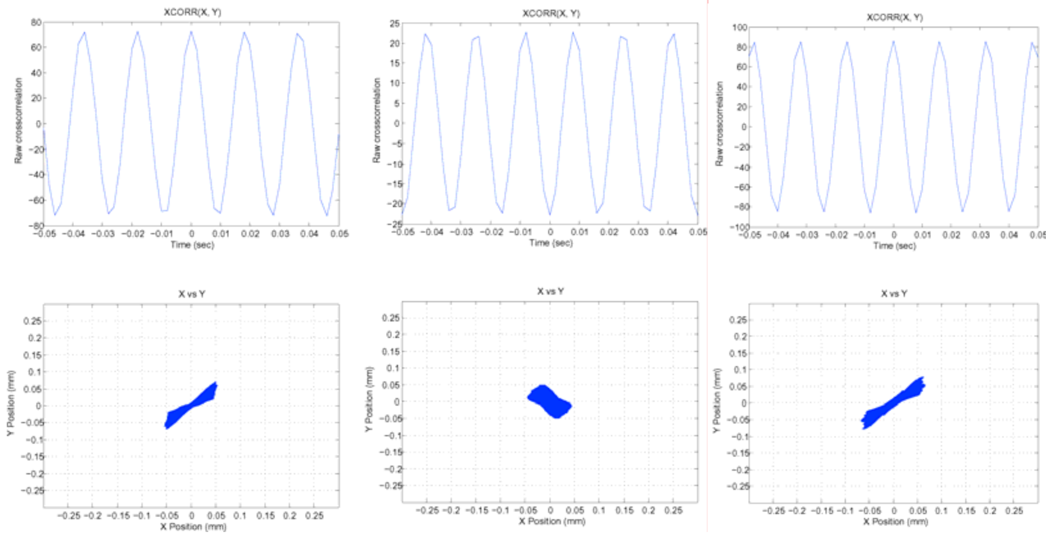


Figure 4. Filtered Position vs Time



By dropping the bandwidth to 0.5 Hz and increasing the order of the finite-impulse-response (FIR) filter to 1024, the filter becomes sharp enough to pick out the individual lines of the jitter spectrum for further analysis. Setting the center frequency to the three main lines of the cluster, at 54.6, 60.2 and 62.0 Hz, shows an interesting phenomenon, as seen in Figure 5.

Figure 5. Correlation of X and Y for 54.6, 60.2 and 62.0 Hz



It turns out that the motion at each frequency is in a straight line on an x, y plot, but the motion at the first and third frequencies is at right angles to the motion of the middle frequency. Notice that for each frequency, there is no phase shift between x and y. The x, y motion is a line, not an ellipse, and the cross-correlation plots at the top show maximum (or minimum) correlation at t=0. To me this is strong evidence that the mirrors in the mirror train are not the source of these beam motions. A motion at these angles of any of the mirror mounts would surely give rise to a large and frequency dependent phase shift between x and y components.

One simple explanation for all this is that these motions are vertical and horizontal on the laser bench, but are rotated to the angles seen, by the oblique reflections from laser to M1a to M1b. This could be confirmed easily enough with zemax, or more simply, by casting a shadow in the laser beam on the bench with a ball driver or the like.

The calibrations of the quad cells in millimeters in these graphs are a best effort, but have not yet been verified by other means. It does appear safe to conclude, though, that the magnitude of the 55-62 Hz motions is greatly reduced, and are no longer large enough to worry about at this time. Another conclusion is that the quad cells and their data acquisition hardware and software are working quite well.