Frequency and Stroke Response of the Membrane Mirror

Purpose:
   To measure the resonant frequency of the membrane mirror, and calibrate its focal length for various driving voltages

Date: On or about May 20, 2004

Procedure:
   Since the larger 10mm cone was installed on May 12, 2004, these tests were done with the larger cone in place. First, I measured the frequency response of the membrane mirror near 2kHz and its stroke. Too measure the frequency response, I drove the membrane mirror with a 5Vpp sine wave (later measured to be 3.6Vpp with an oscilloscope). The mirror was illuminated with a laser. The path of the laser was folded twice across the optical bench so that the beam would fill the aperture of the mirror. A measured scale was laid down on the bench. A white sheet of paper on a square wood block served as the screen. The screen was moved back, away from the mirror until a focused spot was first seen. Since the mirror is vibrating near 2kHz, a light is getting focused at various places and also diverged, I wanted to find the focus nearest to the mirror, which would correspond to the focal length when the mirror was most concave. For this test I scanned from 2kHz to 2.5kHz in steps of 50Hz.
   Second, I calibrated the stroke of the membrane mirror for various driving voltages. I measured the focal length of the mirror in the manner described above. The driving voltage was measured by an oscilloscope to show the actual voltage that was being applied, rather than what I told the function generator to deliver.
   Third, I took the membrane mirror to Subaru. There Olivier Guyon and I installed our membrane mirror in their membrane mirror testing set-up. The membrane mirror was connected to a function generator and an amplifier. The function generator scanned through frequencies from 90Hz to nearly 6000Hz in steps of about 1Hz. The membrane mirror was illuminated by a laser hitting the mirror off center, so that the reflected spot would translate across the face of a position sensitive diode. This diode measured the x anf y position of the spot in real time. Thus, we could also measure the phase difference between the spot's motion and the signal given to the membrane mirror.
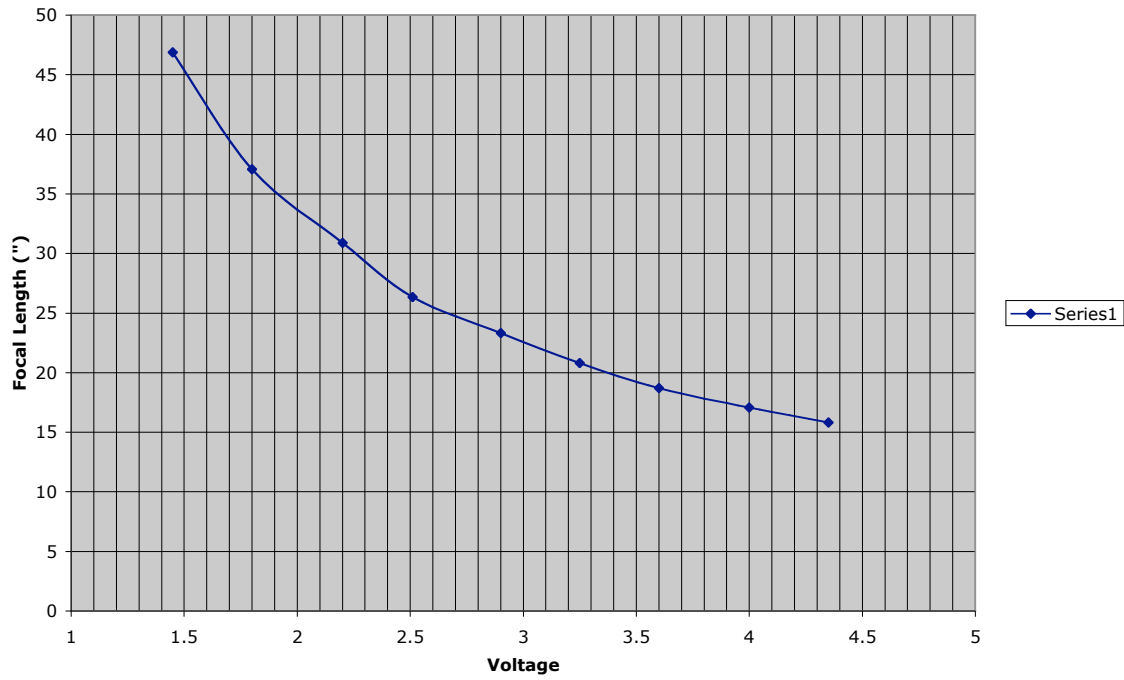
Results
   The results of the first two tests are given in the next three plots. The first shows the calibrated frequency response near 2kHz. The next two show the calibrated stroke response, in linear and log-log scalings. Since the stroke response is a straight line on the log-log plot, it follows a power law relationship with index of –1.01 (i.e. this is the slope of a best fit line through the log-log data points).
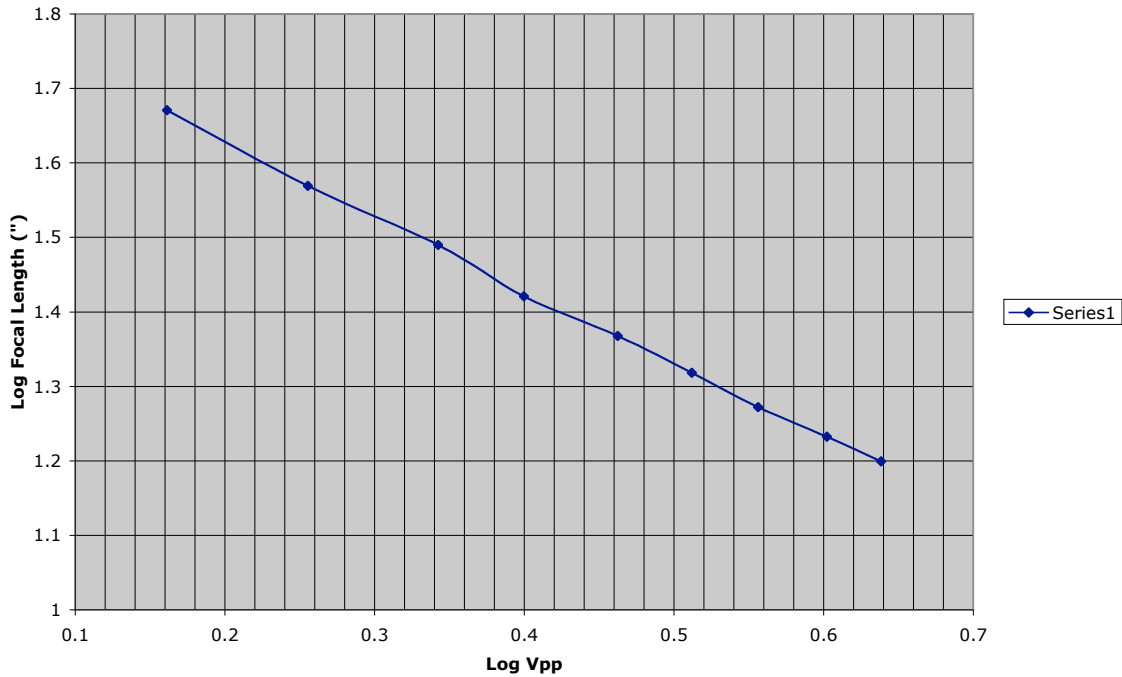
Membrane Frequency Response
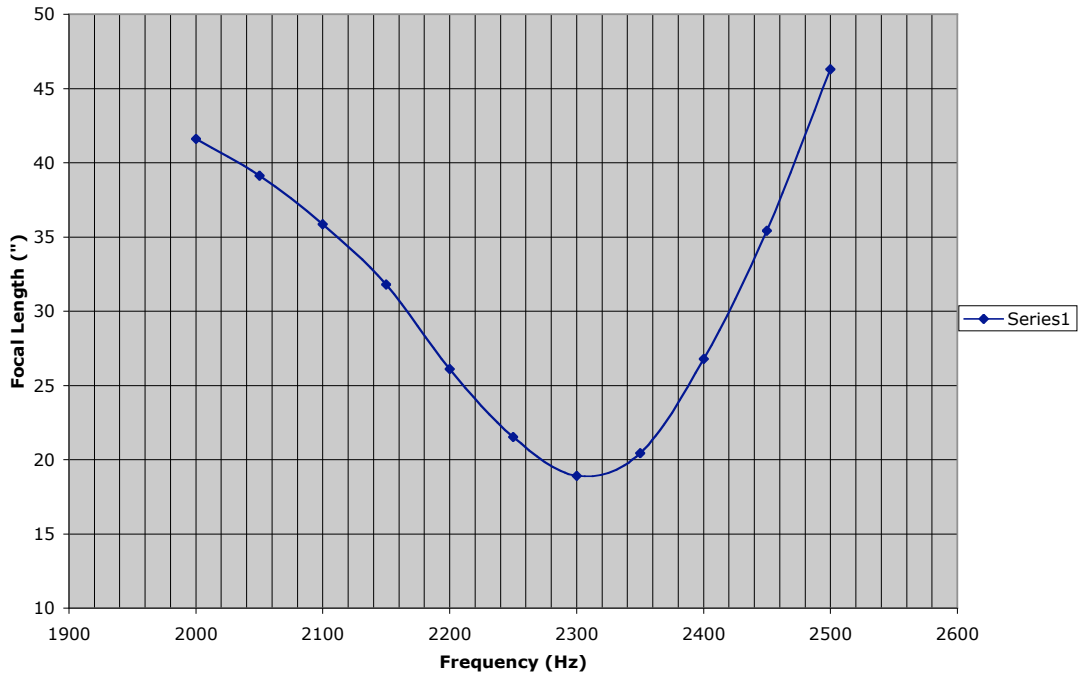

Stroke Response

Log Stroke Response

The next three plots show the results from the tests at Subaru. The first shows the Y amplitude of the reflected spot's motion vs. frequency, and the second plot has the phase (in radians) overplotted. We see a broad peak near 2.3kHz that we saw before, but a double-peaked resonance near 1.15Khz, and sharper resonances near 3.2kHz and 4.8 kHz. At each of these resonance peaks there are large increases in phase. There is even a small bump at 1.5kHz with its own phase increase. The corresponding plots for X amplitude and phase are similar to those shown here. Although we do no know the scale of the amplitude, it can be calibrated with our own measurements of focal length vs. frequency near 2kHz. At each resonance feature the phase is near π or 2π, although the phase at the 4.8kHz resonance is at ~4.15 radians, which is near $4/3\pi$.

The third plot shows the Y amplitude and the derivative of the Y phase with respect to frequency. The phase derivative data has been smoothed over 5Hz wide bins to improve the S/N of the plot. The phase derivative is very similar to the amplitude, i.e. they have peaks and troughs in the same places. There are significant differences, however. First, the peaks do not have the same relative strengths. In Y amplitude, the 4.8kHz peak is stronger than the 3.2kHz peak, but the reverse is true in the phase derivative. Also, the phase derivative is greatest near the double-peak at 1.1kHz, which is not a particularly strong resonance in Y amplitude. Second, the resonance features are sharper in the phase derivative than in Y amplitude. There are features in the Y amplitude that are more easily seen in the phase derivative plot, such as the small bump at 3.5kHz. There is a feature in the phase derivative plot at 1.65kHz that does not appear to have a corresponding feature in the Y amplitude plot. It should be noted that although the phase changes rapidly near the resonance features, it is well behaved (i.e. the derivative is smooth and continuous).
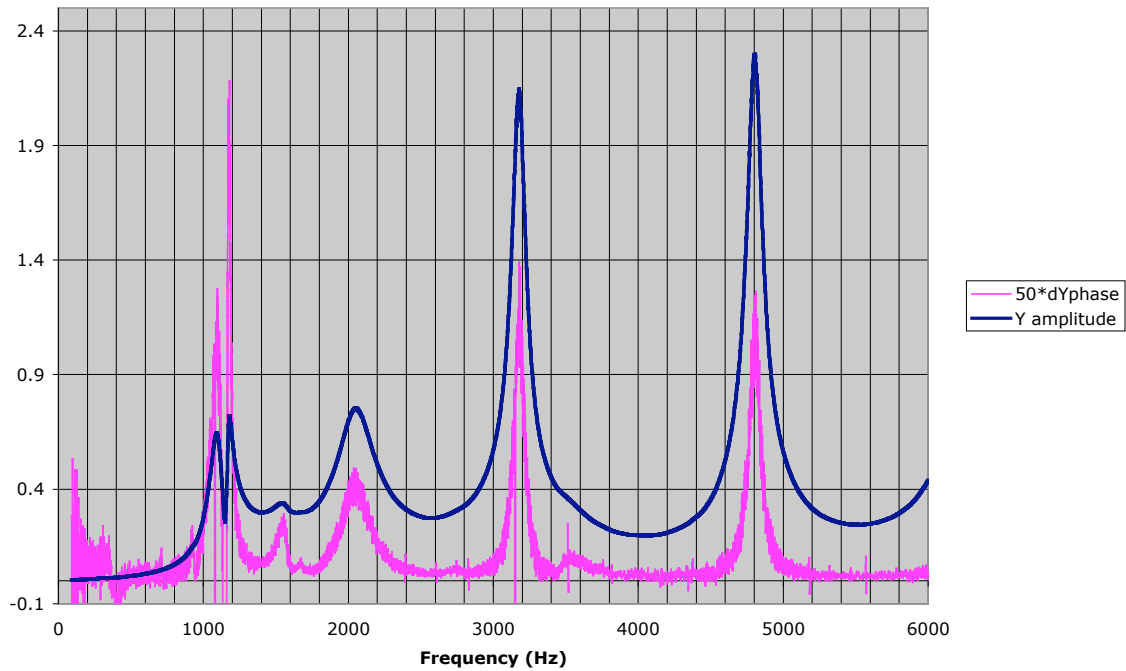
Y amplitude vs. Frequency
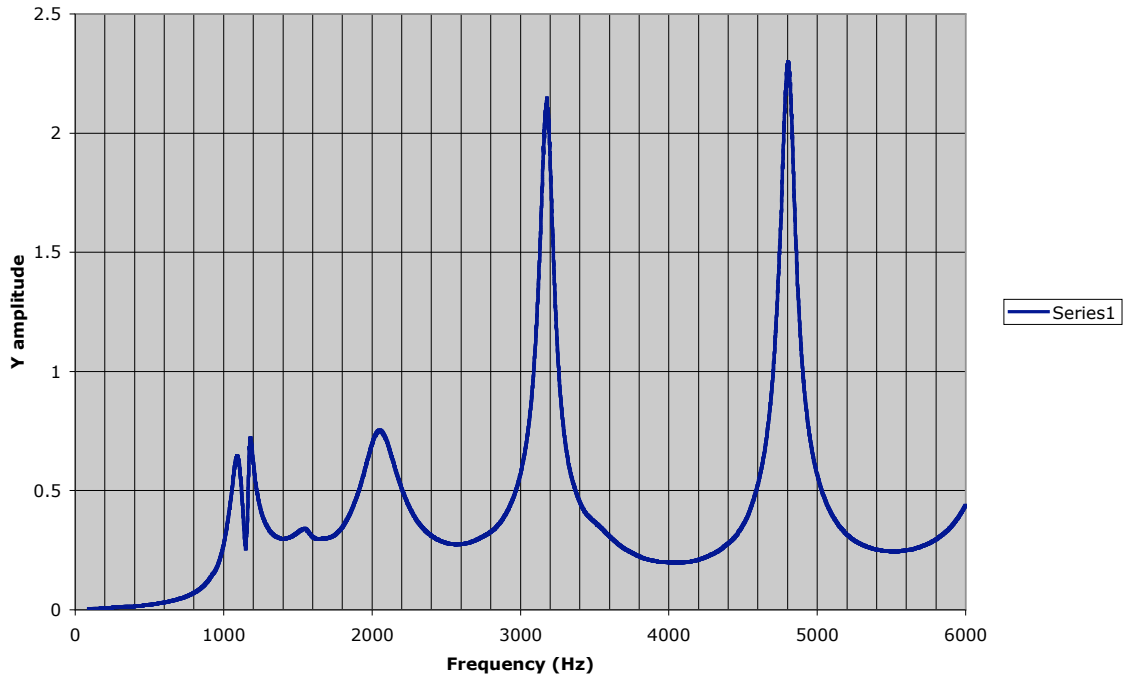
Y amplitude and Phase
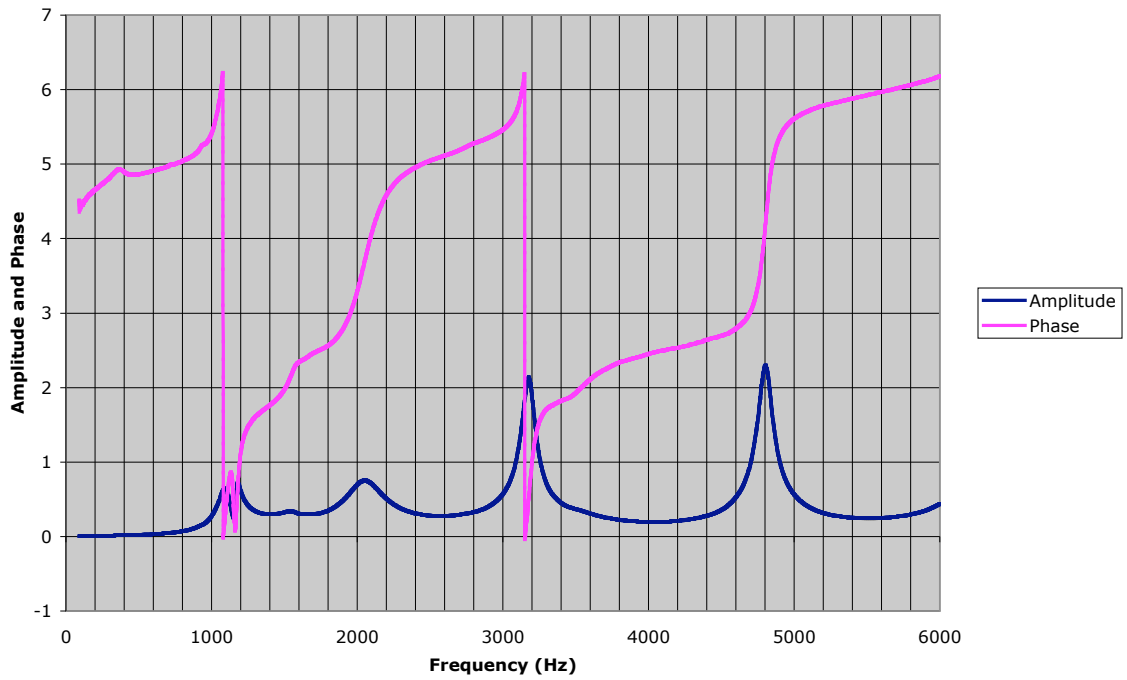
Y amplitude and dY phase

Conclusions:
1) In addition to the well known resonance at 2.3kHz, there are several other resonances. Some are much sharper, and one is double peaked. Each resonance feature has a corresponding increase in the phase of the mirror. At each resonance feature, the phase is at or near pi or 2pi.
2) The phase derivative closely traces the amplitude of the membrane stroke. The resonance peaks are shaper in the phase derivative than it is in the amplitude, and the peaks in the phase derivative do not have the same relative power as they do in amplitude. The phase derivative is well behaved.
3) The stroke of the mirror follows a power law relation with index=-1.