IR Upper-End Resonance

Recent sky observations using the IR upper end have verified that mechanical resonances excited by the mirror chop frequency can profoundly affect image quality.

Square-wave Harmonic Content

The Fourier series of an ideal square wave with no DC component shows that: (a) only odd harmonics exist; (b) the amplitudes of the harmonics are related to the amplitude of the fundamental by the inverse of the harmonic number. Figure 4 graphs the spectrum of a square wave with a frequency of 2.727 Hz. The strength of the higher square wave harmonics exacerbate the interaction between low-frequency chops and high-frequency structural resonances. Since the separation between harmonics is a constant, equal to twice the fundamental frequency, the higher square-wave harmonics seem to crowd together since the difference between them becomes a smaller fraction of their absolute value.

Sky observations with the IR upper end produced a list of disturbing chop frequencies which correlates with a primary structural resonance at about 29 Hz. Assuming that a structural resonance is unavoidable, it is desirable to evade the detrimental effects as much as possible. Even though the amplitude of the higher harmonics may be small, the chops with the widest throws are done at low frequencies, tending to offset the decrease in harmonic amplitude size. The 13th harmonic of a 120 arcsecond throw at 2 Hz would have the same harmonic energy at 30 Hz as the 3rd harmonic of a 10 Hz, 24 arcsecond throw.

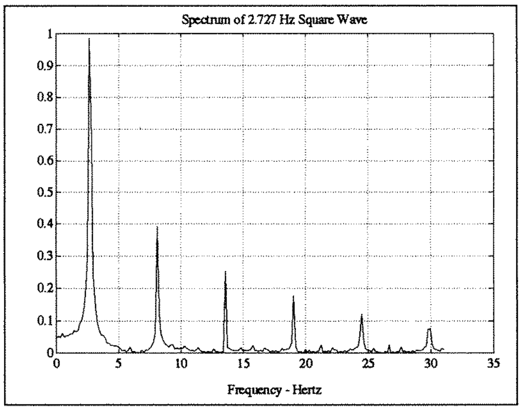

Figure 4: Spectrum of jittered 2.73 Hz square wave showing energy smearing.

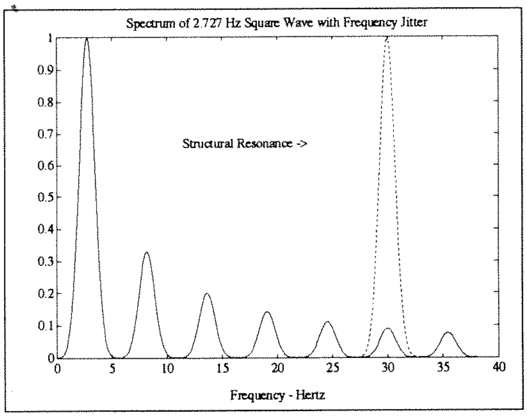

Figure 5: Chopping spectrum with 11th harmonic at 30 Hz.

Structural Resonance Frequency

The sky observations indicated a strong disturbance at 29 Hz based on the relationship between the magnitude of the vibration and the frequency of chop. The actual frequency of mechanical vibration was not measured. Previous accelerometer measurements of vibration in the support trusses show a resonance at about 14.5 Hz. Only very small image disturbances were noticed for chop frequencies around 14.5 Hz. This could imply that the disturbance is caused by a resonance in the tip-tilt collimation stages above the chopper back plate. Further measurements will be required using sinewave chopper excitation to probe structural resonance.

Avoiding Structural Resonance Excitation

Currently, the data indicates that the safest chop frequencies are those which are not equal to 29 divided by an odd integer. For example, frequencies between 29 and 29/3 Hz should be fairly clean with regard to the 29 Hz disturbance. However, the accuracy of the chopping frequency is also important. A recent observing program used the exposure control process to produce the mirror chopping signal. Even with a nominally "safe" chop frequency, there was phase jitter on the chopping signal which resulted in image deterioration due to structural vibration. Figure 5 graphs a square-wave spectrum with broader spectral components due to frequency or phase jitter. The increased harmonic energy spread decreases the safe range of fundamental chop frequencies.

Characterization

Before planning to remedy the existing problem, it must be admitted that our characterization is limited. Sky observations were made near zenith with a particular rotational orientation of the chopping stage. We need to know how stage orientation and low angle stresses affect the frequency and width of structural interaction with chop. Driving the mirror with a sinusoid would permit precise determination of structural interaction at various pointing angles and stage rotation positions. Plans call for coordination with observers to prevent image deterioration and further characterize resonance excitation.

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The New F/35 IR Secondary Mirror

The IR secondary mirror originally delivered shortly after the telescope was commissioned, and used very successfully until its replacement this fall, was known from early days to suffer from a strongly turned-down edge which spred light into image wings. Accordingly, in 1989 both the SAC and the Infrared Working Group, with an eye toward the approaching shift of emphasis away from aperture photometry and toward high resolution imaging, recommended that the mirror be replaced by one with improved optical quality. Since, at that time, the future path of Adaptive Optics and array detectors was not clear, it was decided that the optical parameters for the new mirror would essentially copy those of the old one - except for improved optical quality - and that the mirror would be attached to the existing chopping mirror mount. The optical parameters for the new mirror are given in Table 1. After the initial effort to locate a fabricator capable of producing a mirror which would fit both our optical and financial budgets faltered, Contraves U.S.A., located in Pittsburgh, was finally selected. It was a good choice.

The new mirror, although functionally similar to the older one, differs in detail. The optical coating on the older mirror was initially a sapphire-silver-sapphire coating applied by NOAO, and more recently bare silver applied at CFHT. The new mirror was coated by Denton Vacuum with their FSS-99 protected silver coating.

Both old and new mirrors contain light-weighting structures to minimize the moment of inertia about the chop axis, and thus