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.

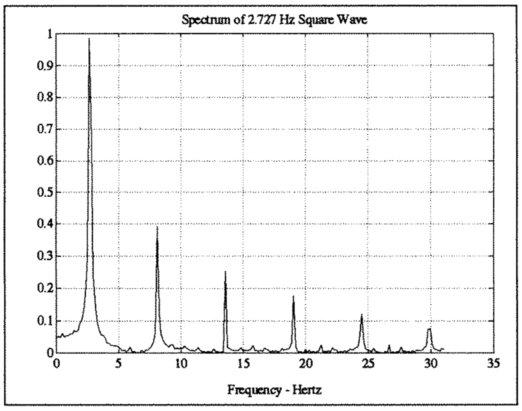

Figure 4: Spectrum of jittered 2.73 Hz square wave showing energy smearing.

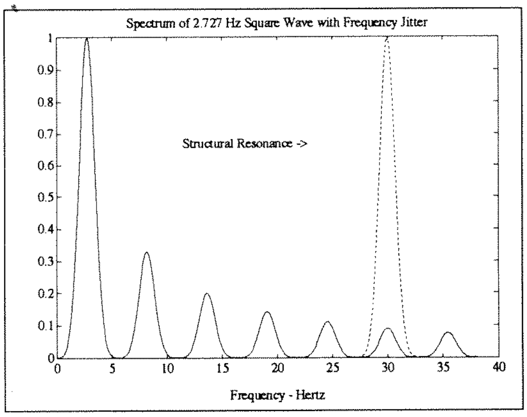

Figure 5: Chopping spectrum with 11th harmonic at 30 Hz.

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.

J. Horne and E. Stokes

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

Table 1: Optical Characteristics of the New f/35 IR Secondary Mirror

final output f/ratio	34.8
back focus (from the primary mirror vertex)	1991 mm
beam diameter on primary	3450 mm
material	Zerodur standard
clear diameter	400.4 mm
magnification	8.882
vertex radiusa	3535.8 mm
figure	hyperboloid
conic constant ($K = -e^2$)	-1.5709
back finish	acid etched
vertex thickness	38.9 mm ±2. mm

minimize chopping power requirements. In the old mirror this was accomplished by building the blank from top and bottom halves into which cavities were ground. The halves were then cemented together with the weight reduction cavities sandwiched inside the resulting structure. Unfortunately, these cavities printed through to the optical surface. The new mirror has 18, 38 mm diameter circular cores bored out of the back side of the otherwise solid, monolithic mirror to within 6 mm of the front surface. This approach we were assured by Contraves would not produce measurable print-through to the optical surface - a fact which was confirmed during acceptance testing in Pittsburgh.

The outer wall of the new secondary mirror is bevelled at 6 degrees so that the vertical edge is not exposed to the line of sight while chopping - the older mirror had simple vertical edges. In an additional effort to help minimize telescope emissivity, the edge of the optical surface has no bevel whatsoever and comes to a knife-sharp edge where it meets the outer mirror wall. The manufacturer was able to keep the corner sharp and at the same time maintain the high optical quality right to the edge.

CFHT took delivery of the finished and coated secondary mirror in mid-September this year, just over a year and a half after the initial agreement with Contraves. It was already evident from earlier acceptance tests in Pittsburgh that Contraves had delivered a first-class optic. In-shop interferometric tests showed a slope-based encircled energy distribution of 82.9% within a circle of 0.2 arcseconds diameter, 94.9% within 0.3 arcseconds, and 99.9% within a 0.5 arcseconds diameter. Still the optical performance needed to be established on the sky in concert with the primary mirror. These tests have just been completed, and although the analytic results are not yet available, we can say that sub 0.5 arcsecond CCD images were obtained immediately. A lateral shearing interferogram indicative of the mirror quality is shown in Figure 6.

John Horne, Ed Stokes, Stéphane Béland, and the daycrew came together, took the glass as delivered and made it into an operating telescope system in one short month.

S. Béland and D. Salmon

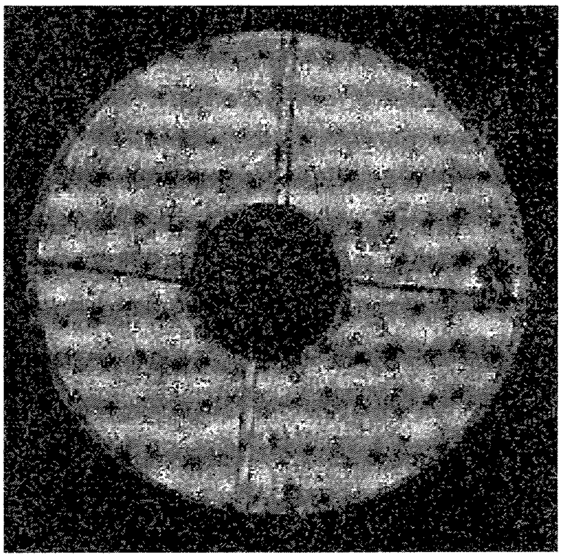

Figure 6

Detector News

During the spring and summer of this year the detector group has been working in several different areas; supporting our existing CCDs, developing the new CCD controller, acquiring new detectors, and making plans to operate the NICMOS3 IR arrays with the new controller.

New Controller

Development of the new controller has, as of this summer, moved into the operational and testing phases. We have successfully operated 2 different CCDs in the lab, and have completed a successful engineering run at the telescope using the engineering version of the JPL1 1024x1024 CCD. We are currently finalizing controller packaging designs and construction, and plan to move the Lick1 2048x2048 CCD on to the new controller in October. Our long term plan is to complete the first phase of the controller and release it for general use in the beginning of 1992.

New Chips

JPL1E, the engineering version of the 1024x1024 12 µm JPL1 chip, is in operation and under test in the CCD lab with the new controller. Numbers regarding the performance and characteristics of the science-grade device, JPL1, will be released as soon as possible. Another 1024x1024 18 µm pixel device, SAIC3, has been acquired from SAI Corporation. This device has not yet been operated at CFHT, however, factory data shows it to be cosmetically superior to the SAIC1 device now used on many focal reducer and HRCam runs. We are investigating the possibilities of having a blue-enhancing coating put on it before it replaces SAIC1 and goes into service early next year. Discussion are underway with SAI Corporation to explore the options for acquisition of a thinned, coated 1024x1024 18 µm device. The specifications for such a device call for a physically flat (< 25 µm bow or ripples), high QE (< 40% @ 3000Å) imager that offers noise performance equal to or better than the thick SAIC1 device. We are hopeful that a device will become available to us in the next 3-4 months.

NICMOS3 Detector

A preliminary design has been completed for operation of the NICMOS3 multiplexer array (first test phase) using the new controller. This design will allow all four quadrants to be controlled independently to allow for the highest readout rates possible with this array. We anticipate being able to reach readout rates of less than 0.3 seconds per frame in the initial development phases.

C. Clark and S. Massey