Shearing Interferometry and Seeing

The telescope optics together with atmospheric turbulence combine to establish the ultimate limiting resolution of the telescope. Measurements of their respective contributions to the final image size can help to establish where efforts should be concentrated if image quality is to be improved. As described in another article in this bulletin, the Hartmann test provides an atmosphere-free measurement of the quality of the optics. A complimentary test, shearing interferometry, can provide an optics-independent measurement of image degradation caused by atmospheric turbulence.

Claude and Francois Roddier pioneered the use of rotation shearing interferometry for seeing measurements. With their expert guidance — and their spare set of interferometer optics — we fabricated a shearing interferometer for seeing measurements at the side-port of the cassegrain bonnette. It was first used during a joint 10 night University of Hawaii-CFHT-NOAO seeing studies program.

A bit of theory

The rotation shearing interferometer is a classical Michelson interferometer with the retroreflectors replaced by roof prisms. The interferometer is used with an image of the telescope pupil (usually the primary mirror) imaged at the prism roofs so that fringes are superimposed on the pupil image. A narrow interference filter which passes a few tens of Angstroms limits the spectral bandwidth.With the two beams of the interferometer perfectly aligned, (except for a very slight lateral displacement), a uniform set of straight-line fringes is visible across the pupil. If one of the roof prisms is rotated slightly, the two pupil images rotate with respect to each other. Through the telescope, because of atmospheric turbulence, a long (60 second) exposure of the pupil produces an image over which the region of fringe visibility is reduced to a small circular patch centered on the intersection of the prism roofs. A typical interferogram with the pupil images rotated 20 degrees is shown in Figure 14.

Theory predicts that the envelope enclosing the fringes, the so-called fringe visibility function, or fringe contrast, will provide a direct measurement of the angular size and intensity distribution of the source, which in our case is a star image blurred by atmospheric turbulence. Aberrations in the telescope optics change the shape of the fringes, but not their visibility. According to seeing theory fringe visibility should decrease as the separation between interfering points on the pupil increases according to the relation :

$$V = \exp[-3.44 (d/r_0)^{5/3}]$$

where :

- **V** is the fringe contrast (normalized to unity at the center of rotation)
- **d** is the shear distance (linear displacement) between pupil points
- $\mathbf{r_0}$ also known as Fried's parameter, is a characteristic distance which describes the seeing. $\mathbf{r_0}$ is related to the seeing disk full width at half maximum (in

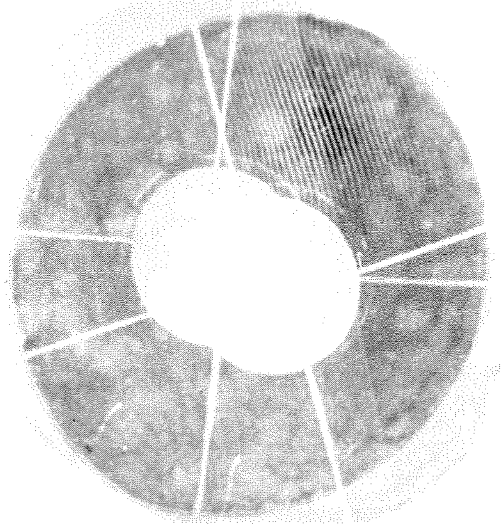

Figure 14: A shearing interferogram recorded with a CCD. The region of fringe visibility is reduced to a small patch at the intersection of the images of the two prism roofs because of atmospheric turbulence. A measure of the shear angle and the size of the fringe patch provides a measure of the seeing.

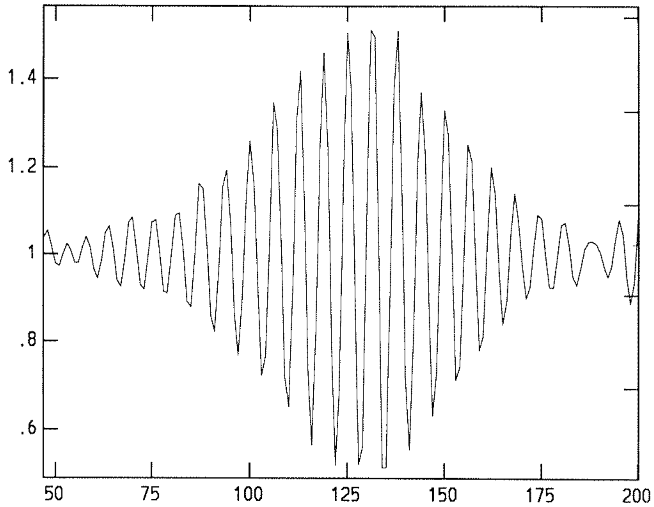

Figure 15: An intensity profile across the fringes.

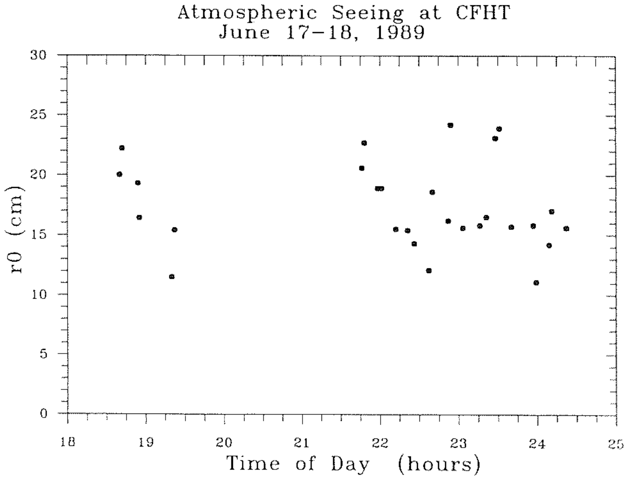

Figure 16

arcseconds) by the relation :

$$FWHM = (0.987\ \lambda/r_0) \times 206265$$

The rotation shearing interferometer is particularly well suited to fringe visibility measurements since in a single frame a full range of shear distances is covered. Shear lengths increase linearly with distance from the center of shear rotation, starting from zero shear at the center, and extending to some upper limit, which depends on pupil size and shear angle, at the edge of the pupil.

A typical fringe profile is shown in Figure 15. A fit of the predicted fringe visibility to the fringe envelope provides the seeing measurement.

Some results

During the June, 1989 seeing campaign we observed fringes at the f/36 infrared focus for a few hours on each of 10 nights while sharing the telescope with the FTS. Many hundred interferograms were recorded. To date, after writing the data reduction routines, we have reduced a small fraction of the data. The very preliminary graph in Figure 16 shows r_0 values for the night of June 17-18, 1989. The FWHM ranges between 0.5 arcseconds and 1.1 arcseconds at 6563 Å with 85% of the seeing better than 0.67 arcseconds. These are very preliminary data. A report on the complete data set will be published later. It is noteworthy that, by combining the Hartmann-derived optical image size and the seeing data given here in quadrature, the image FWHM should have been better than 0.7 arcseconds more than 80% of the time at the naked prime focus.

Some words of thanks

Many individuals have been involved in the shearing interferometry program. Claude and Francois Roddier have given generously of their time in showing us how to attack the problem and given us innumerable hints for the data reduction procedures. Stephane Beland wrote most of the data reduction software and participated in much of the observing, as did Steve Hill. Wiley Knight designed a beautiful set of mechanics based on the Roddiers' interferometer, and Dan Sabin did his usual first-class job in fabricating and assembling the instrument.

Derrick Salmon

The Dome Systems Control Project

A new system is being implemented in the observatory to allow remote control and status monitoring of the shutter, the windscreen and other devices located on the rotating part of the dome.

At present, the only information transfer between the fourth floor observing area and the moving dome level is a radio link transmitting weather data from a number of sensors to a computer. It is almost at capacity and cannot be expanded to meet our needs.

Design

The originality of the design resides in the use of the power lines to establish a communication path between the operator's console, on the fourth floor and the controller, located on the dome catwalk. This controller is an industrial-grade, PC-AT clone programmed in C language and interfaced to its environment through a bank of opto-isolated relays. It can also receive analog signals from encoders and sensors. The system is expandable and flexible enough, so that it could be accessed via a terminal, a dedicated manual console or a computer through the network. The final system will control and display status of the shutter and windscreen absolute positions, as well as important status signals.

Devices Controlled and Monitored

This systêm will allow control of the weather tower heater, dome louvers, windscreen and shutter positioning, and flat field lamps. In addition it will monitor the status of the catwalk gates, dome crane, windscreen slack cable sensor, and the weather station .

Conclusion

This new CFHT equipment should help provide a smoother, more efficient and safer operation of our telescope. This has also been the pilot project using STD-Bus controllers. Future projects including the new Coude spectrograph and MOS/SIS may be based on this technology.

Philippe Papasian

Telescope Tape Policy Changes

With the successful switch to optical disk for CFHT's permanent record of telescope observations we can now allow observers to take home their original telescope data tapes. Observers have the following options for taking their data home:

- You need only pay for CFHT supplied tapes which are removed from CFHT.
- You may purchase tapes at CFHT or bring your own.
- You may take the telescope data tapes home. You are no longer required to make a copy and leave the originals at CFHT.

We also offer the following options in Waimea after the run is over:

- You may concatenate telescope data tapes and you will not be charged for the telescope data tapes used.
- You may make copies of tapes.

We wish to thank our visiting observers for their patience over the years and hope that this new arrangement will be of benefit to all. Users with questions or requirements outside of those described above should contact their support astronomer.

Bob Link and Rick McGonegal