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Direct measurement of the throughput of the Herschel Telescope's ISIS spectrograph

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Abstract

Measurements of the throughput of ISIS have been made using laboratory sources. They show a fault in the red fold, but the instrument is otherwise functioning as expected.

Introduction

In Technical Note no. 87, Jenkins et al. described careful spectrophotometric measurements made with ISIS plus CCD detectors. These showed a marked discrepancy between the actual and predicted throughput of the system, and suggested strongly that the problem was in ISIS itself, rather than in the telescope or the detectors. Accordingly we decided to measure the throughput of ISIS itself by a direct method in the laboratory. This Note records our experiments and our conclusions.

Experimental arrangement

The measurements were made at the end of 1992 March, when ISIS was in the aluminizing area of the WHT. We used a Melles-Griot 5 mW HeNe laser to direct light into the spectrograph; the laser was mounted on the optical bench used for alignment and the light was directed in through a wide slit using a 45-degree flat. It was possible to mount a rotatable Polaroid above the slit. The detector was a United Detector Technologies photodiode, with a neutral density filter and diffusing screen mounted in front. The diode was operated in the linear range of intensity. It was held in an Ealing x-y-z stage which was clamped at the camera outputs (using parts of the ISIS alignment microscope) or at the position of the collimator mirrors. The input intensity was measured just above the slit, with the diode held in a lens holder resting on the metal crossmember which normally holds the alignment mirror. The output of the diode was measured with a picoammeter.

After warming up for 30 minutes, the laser showed a remarkably stable output, with fluctuations at the 0.1% level at most. The diffusing screen in front of the diode made it very insensitive to the exact location of the laser spot on the input window. Peaking up with the x-y-z stage showed a broad plateau in response. The diode was also insensitive to the distance between it and the laser, at least over two meters.

The laser beam cannot be sent into the system axially because it runs into the baffling shielding the hole in the cameras' folding flats. Accordingly we worked some distance off axis.

To examine vignetting, a diffuser was placed just above the slit. The scattered laser light illuminated the grating and camera with a beam close to f/11 so that the pupil could be examined.

Results

Three types of measurements were made. First, we used the dummy silvered mirror in place of the grating and measured the throughput at the collimator and at the camera. Next, we used the 158B and R gratings which were employed during the original spectrophotometric measurements, and repeated the measurements at the camera. Last, we used the Polaroid to produce light polarized perpendicular to, and parallel to, the slit, and once again measured the total throughput.

The measurements at the collimator are measurements of the reflectivity of the folds, at the wavelength of the laser light (630 nm). The blue fold was not the prism, but the aluminized flat; its reflectivity was 0.85, a value assumed by Jenkins et al. The red fold immediately showed a problem; its reflectivity was only 0.60, much lower than would have been expected from a silver coating. David Jackson cleaned the flat, but its reflectivity did not improve.

The results are summarized in the Tables below. The column 'Expected' is obtained by multiplying together the measured reflectivities of the folds, David Jackson's spectrophotometric measurements of the reflectivities of the optimized coatings on the collimator and camera mirrors, a factor of $(0.98)^4$ for air-glass surfaces, and the efficiency of the dummy mirror or grating. The gratings' efficiencies were taken from Mike Lowne's original measurements at Herstmonceux. The value for the red channel's optimized mirrors was 0.97 and for the blue, 0.80. The latter value is low because the laser light is much redder than the blue channel would normally expect. The dummy mirror is silvered and should have a reflectivity of 0.97.

Repeated measurements suggest that reflectivities can be measured by our technique to ±0.02.

Channel	Fold	Expected	Measured
red	0.60	0.49	0.51
+grating	0.60	0.38	0.41
blue	0.85	0.39	0.42
+grating	0.85	0.17	0.14

Channel	Perpendicular	Parallel
red	0.39	0.41
blue	0.13	0.13

Examination of the pupil images showed them to be symmetrical, unshadowed and unobstructed.

Conclusions

1. The red folding mirror is faulty and should be replaced as soon as possible. This will improve throughput on the red channel by two-thirds. The poor reflectivity of this mirror explains completely the results of Jenkins et al. for this channel.

2. Apart from the red fold, both channels have exactly the throughput expected. There is therefore no explanation for the low values found by Jenkins et al. for the blue channel by spectrophotometry. These values were not confirmed by subsequent imaging through ISIS. The spectrophotometric discrepancy is well-determined and is close to a factor of two, a coincidence which may point at a rogue Hartmann shutter.

3. Instrumental polarization with the 158 gratings is very low, consistent with the data reported by Jenkins et al.

Reference

Jenkins C.R., Sinclair J.E., Clegg R.E.S., 1992, ING La Palma Technical Note no. 87