WAVELENGTH OFFSETS AMONG INTERNAL LAMPS AND EXTERNAL SOURCES

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Abstract

Offsets between spectral features from the internal direct Pt–Cr–Ne and an external Pt–Cr–Ne calibration lamp are determined from G270H spectra for both Digicons and show an offset of less than 0.1 diode on the blue side and a non–constant offset with a range of 0.35 diode on the red side. Offsets between the cross–strapped and direct internal lamps vary with wavelength over a range of about 0.2 diode on both sides. There is evidence that the amount of offset as a function of wavelength is independent of the choice of apertures. A calibration test procedure to establish the repeatability of the internal/external offsets as a function of diode number for all dispersers is outlined in § IV. If these offsets repeat and can be reliably calibrated, the accuracy of FOS wavelength scales should be an order of magnitude better, in the range of 0.03 diode.

I. Introduction

In the FOS Wavelength Calibration report (Sirk and Bohlin, 1986a) a description of how the FOS is calibrated for the 0.1 arcsec apertures with the internal Pt–Cr–Ne calibration lamps is outlined. The Aperture Offset report (Sirk and Bohlin, 1986b) describes a procedure to determine a wavelength scale of a science spectrum obtained through any aperture, assuming that any shift of spectral features between an internal Pt–Cr–Ne lamp and an external source is a constant. The internal RMS error of an FOS wavelength calibration is typically 0.03 diode. The error in an absolute wavelength scale will only be as accurate as the uncertainty in the internal/external offset. At present the offsets between internal and external sources are known for the G270H grating only, and are non–linear as a function of diode number on the red side. Data for other gratings are non–existent except for the case of G650L on the red side, where the offset is in good agreement with the G270H case over diodes 0 to 350.

II. Spectral Offsets

a) *Internal–External*

During the March, 1983 and August, 1984 ambient tests at Martin Marrietta Corp. data for determining internal/external offsets were obtained for both detectors in 1983 and for the red detector 1984. However, during the 1984 *ambient* test the external lamp was wired with the wrong polarity, which reduced the flux of the Pt and Cr lines to the point where only about half a dozen Pt–Cr lines can be located on G270H and G570H. (During the 1984 *vacuum* test the time separation was at least 7 hours between external Pt–Cr–Ne spectra and internal Pt–Cr–Ne spectra so that the thermal drifts of 0.3 diode observed by Sirk and Bohlin (1986a) Fig. 6 would be confused with internal/external offsets). The 1983 external lamp data show much more flux than the 1984 data, but many of the Pt and Cr lines have less than 100 peak counts making their centroids uncertain by 0.03 diode. To reduce this error, the spectrum through the upper aperture of the 0.1-Pair is resampled to match the scale of the lower aperture by performing a least squares linear fit of lower aperture line centroids *vs.* upper aperture line centroids. The two spectra are then added together. Lines showing less than 100 peak counts are rejected.

In October of 1986 a special test was run on the FOS using the internal Pt–Cr–Ne lamps and an external Pt–Cr–Ne lamp for gratings G270H and G160L on the blue side, and G270H and G650L on the red side. The apertures were 0.1-Pair, 0.5-Pair, 1.0-Pair, 0.3 circular, and 1.0 circular on both sides. For a given grating and aperture combination, three spectra were obtained, one each from the two internal lamps and one from the external lamp, without moving either the filter–grating wheel (FGW) or the aperture mechanisms. Thus, a shift in one spectrum relative to another cannot be ascribed to any lack of repeatability of the mechanisms.

For the 0.1-Pair upper and lower apertures, the spectral offsets are determined by comparing the measured line centroids of sharp, unblended spectral lines of one spectrum with the centroids of the same lines of another spectrum, as described in Sirk and Bohlin, 1986a, § IV. The offsets between the direct internal and the external Pt–Cr–Ne lamps from spectra taken with G270H and the 0.1-PairL aperture for the blue tube are shown as Figures 1 and 2 for the 1983 and 1986 data, respectively. The red side offsets are likewise shown as Figures 3 and 4 with an additional 1983 case for G570H shown as Figure 5. The blue side data show an offset with a range of about 0.1 diode in 1983 and a zero offset in 1986. For G270H the red side shows a non–linear offset with a range of 0.1 diode in 1983 and 0.35 diode in 1986.

Spectra through the 0.5 arcsec and larger apertures have wide lines that are too blended for determining line centroids, so the cross–correlation technique described in Sirk and Bohlin (1986b) § II is used to determine the offsets. Since the internal and external spectra of 1986 through the 0.1-Pair, 0.5-Pair, 1.0-Pair, 0.3 circular, and 1.0 circular apertures for G270H show no average differences larger than 0.03 diode on either tube among the 5 sets, the internal/external offsets seem to be independent of aperture. However, the cross–correlation technique does not yield the same results on the 0.1-Pair and 0.3 circular apertures as the line centroiding method does over diodes 0 to 100 on G270H for the red tube. The deviation of the cross–correlation and line centroiding results can be attributed to the differences between the spectra of the two lamps.

b) *Internal–Internal*

Offsets between the cross–strapped and the direct lamps are non–linear on both sides as shown in Figure 6 and 7 for the blue and red side, respectively. The upper plots in each figure show two cases, one for G400H and the other for G270H from the July 1984 thermal vacuum tests. The lower plots show the offsets measured for G270H from the October 1986 tests. The curvature of the 1986 data is similar to that of 1984. The offsets do not change with aperture, as shown for a typical example comparing the upper aperture of the 0.1-Pair to the 0.3 circular aperture in Figure 8.

III. Discussion

To adequately determine spectral offsets, 30 to 40 unblended spectral lines are required over the diode array. None of the HST Standard Wavelength Sources that are the external astronomical standards possess the density of lines that are necessary to parameterize the internal to external offsets as a function of diode number for all of the FOS dispersers. Therefore, internal/external offsets must be dealt with while the FOS is still on the ground, where a Pt–Cr–Ne lamp can be used as the external source. Although there is no guarantee that the offsets will not change after launch, an understanding of the source of the non–linearity and its stability is essential for planning flight calibration strategies.

One possible cause of the non–linearities is that non–uniform illumination of the FOS optical components within the *f/24* beam will cause shifts of spectral features in the case that the spectrum is also out of perfect focus on the Digicon. The external lamp is used with a diffuser to provide uniform illumination. However, the internal lamps are known to illuminate only part of the gratings. In addition to spectral shifts, a defocus will cause a broadening of the lines, in the case that the optics are fairly well filled. Table 1 lists FWHMs measured from red tube spectra obtained before and after the installation of the red detector F-8 and the target acquisition (TA) LEDs in December 1985. There are three values of FWHM in Table 1 that are significantly larger than the 0.92 FWHM measured by Kinney and Ford (1985). The G650L width of 1.31 diode may well be an out of focus grating. The values of 1.18 diode for the cross–strapped G400H in 1985 and 1986 are difficult to explain. In general, the line widths in Table 1 do not prove or disprove the theory that spectral shifts are caused by defocused and non–uniform illumination of the optics. However, any contribution of the LEDs to non–uniform illumination from the internal lamps is *not* the main problem, since Figures 6 and 7 demonstrate that the spectral shifts remained constant from 1984 to 1986.

IV. Calibration Test Procedure

The goals of the laboratory test program are: 1) to verify that there are repeatable non–linear offsets between internal calibration lamps and an external source, 2) To measure the offsets as a function of diode number for each disperser, and 3) To verify more completely the independence of the effect on aperture.

Since the preliminary indications are that offsets are independent of aperture, only the 0.3, 0.5-Pair, and 1.0-Pair apertures will be used to verify the primary set of 0.1 arcsec offsets. The calibration test procedure starting with the red Digicon should be as follows:

1) Select grating in the order G270H, G190H, G570H, G400H, G650L, G780H, G270H and the 0.1-Pair aperture. Obtain both upper and lower spectra. Do G270H first and last to verify short term repeatability.

2) Take three spectra using the internal direct, cross–strapped, and the external Pt–Cr–Ne calibration lamps without moving the FGW or aperture wheel.

3) Repeat using 0.3 circular, 0.5-Pair, and 1.0-Pair apertures for G270H and G400H.

4) Repeat entire procedure for the blue Digicon, except omit G780H.

The internal exposure times are given in Sirk and Bohlin (1986c). The external lamp should be used in conjunction with a MgF_2 diffuser at the entrance port to ensure uniform illumination of the FOS optics. The diffuser should be moved twice to get a set of 3 G270H spectra without moving any mechanisms to verify the uniformity of the diffuser.

The test outlined above should be conducted twice, once as soon as possible to understand the problem, and once again after the actual flight components have been installed.

References

Kinney, A. and Ford, H. 1985 *FOS Line Widths (FWHM) as a Function of Aperture Size* CAL/FOS–018, STScI.

Sirk, M., and Bohlin, R. 1986a, *FOS Wavelength Calibration* CAL/FOS–026, STScI.

Sirk, M., and Bohlin, R. 1986b, *FOS Entrance Aperture Offsets* CAL/FOS–029, STScI.

Sirk, M., and Bohlin, R. 1986c, *FOS Wavelength Calibration Exposure Times* CAL/FOS–028, STScI.

Table 1

FWHM of Spectral Features Measured for the 0.1-Pair Aperture on the Red Digicon*

Grating	Lamp	FWHM†	σ	# Lines	Date	File
G270H	X–Strap	0.96	.02	11	Jul–84	YAX0034
G270H	Direct	0.96	.04	11	Jul–84	YAX0042
G400H	X–Strap	0.93	.03	10	Jul–84	YAX0035
G400H	Direct	0.95	.02	9	Jul–84	YAX0043
G650L	X–Strap	0.99	.07	7	Jul–84	YAX0039
G270H	Ext Hg	1.02	.06	5	Dec–85	YBH0121
G400H	Ext Pt–Cr–Ne	.99	.04	10	Dec–85	YBH0124
G400H	X–Strap	1.18	.09	10	Dec–85	YBH0342
G400H	Direct	0.97	.03	9	Dec–85	YBH0490
G400H	X–Strap	1.18	.08	11	Aug–86	YDF0097–0105♡
G400H	Direct	0.90	.07	13	Aug–86	YDG0053–0062♡
G270H	Ext Pt–Cr–Ne	1.05	.07	11	Oct–86	YDJ0051
G270H	X–Strap	0.99	.03	10	Oct–86	YDJ0050
G650L	Ext Pt–Cr–Ne	1.31	.10	6	Oct–86	YDJ0039

*The 1984 data were obtained with the (F3) Digicon and the 1985 and 1986 data were obtained with the (F8) Digicon. F3 replaced F4 in March 1984, and F8 replaced F3 in dec 1985. The TA LEDs were installed in December 1985 starting with file YBH0342.

†FWHM and σ are in units of diodes.

♡Several consecutive, short exposure spectra are added together.

Figure Captions

All spectra were obtained with G270H and the 0.1-PairL aperture unless otherwise noted.

Figure 1. Spectral offsets between the external and direct internal lamps for the blue side 1983 ambient data.

Figure 2. Spectral offsets between the external and direct internal lamps for the blue side 1986 ambient data. The average offset is zero and there is no curvature.

Figure 3. Spectral offsets between the external and direct internal lamps for the red side 1983 ambient data.

Figure 4. Spectral offsets between the external and direct internal lamps for the red side 1986 data. The range of the offset is 0.35 diode and there is a non–linearity.

Figure 5. Spectral offsets between the external and direct internal lamps for the red side G570H 1983 data.

Figures 6 and 7 Spectral offsets between the cross–strapped and direct lamps for the blue and red tubes, respectively. The upper plots show offsets for G270H and G400H determined from the July 1984 vacuum data. The lower plots show offsets from the October 1986 ambient data. In all cases, the aperture is the 0.1-Pair lower.

Figure 8. Typical spectral offsets between the cross–strapped and direct lamps for the 0.1-PairU and the 0.3 centered apertures on the red side showing nearly identical curvature. Note how similar all the plots are in Figures 6, 7, and 8. The other apertures that were analyzed (0.5-Pair, 1.0-Pair, and 1.0 centered) show similar offsets between the cross-strapped and direct lamps on both detectors.

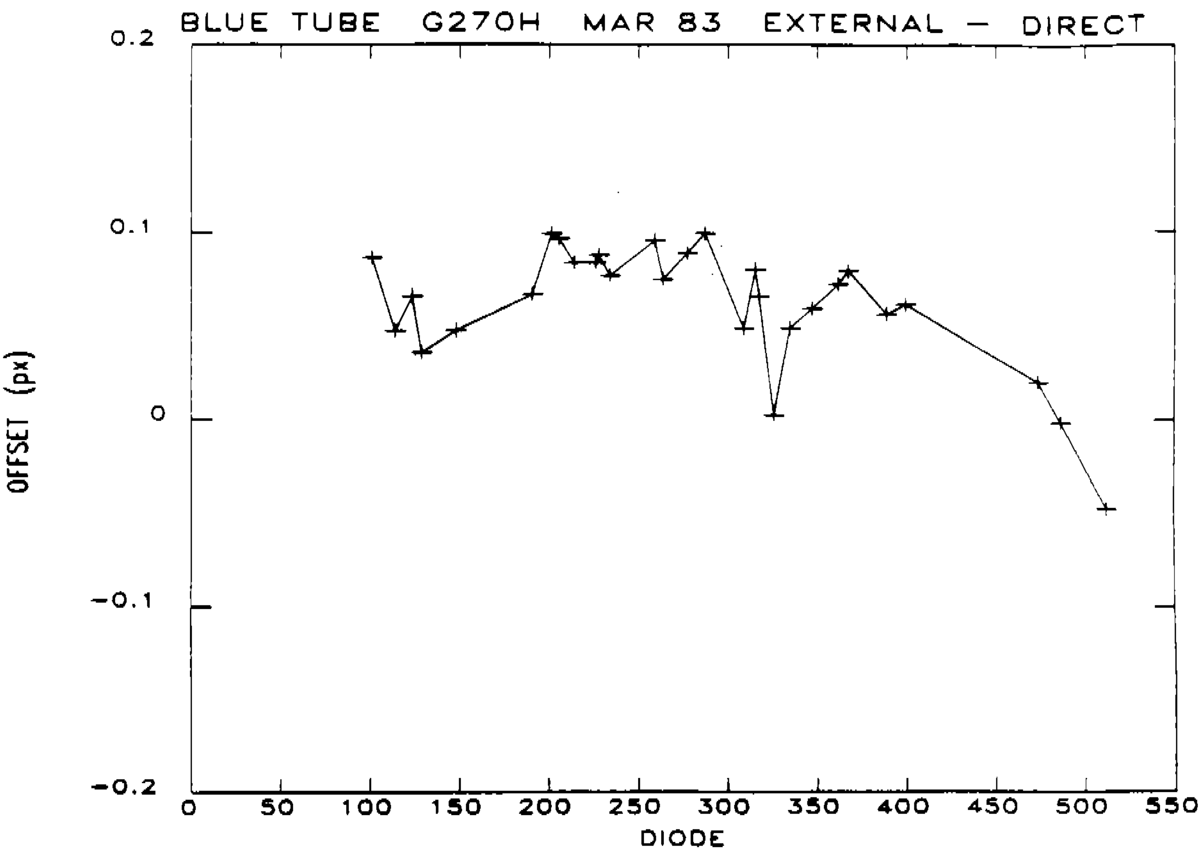


Figure 1.

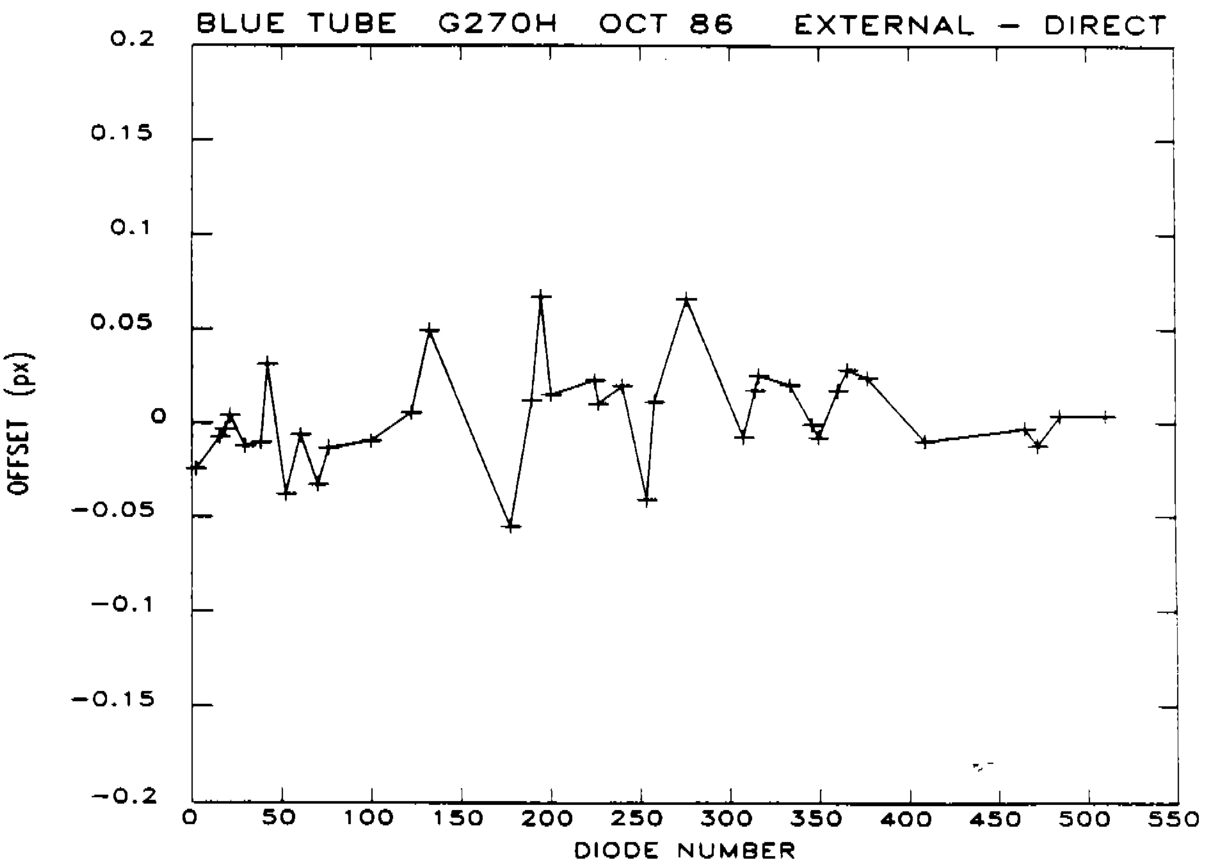


Figure 2.

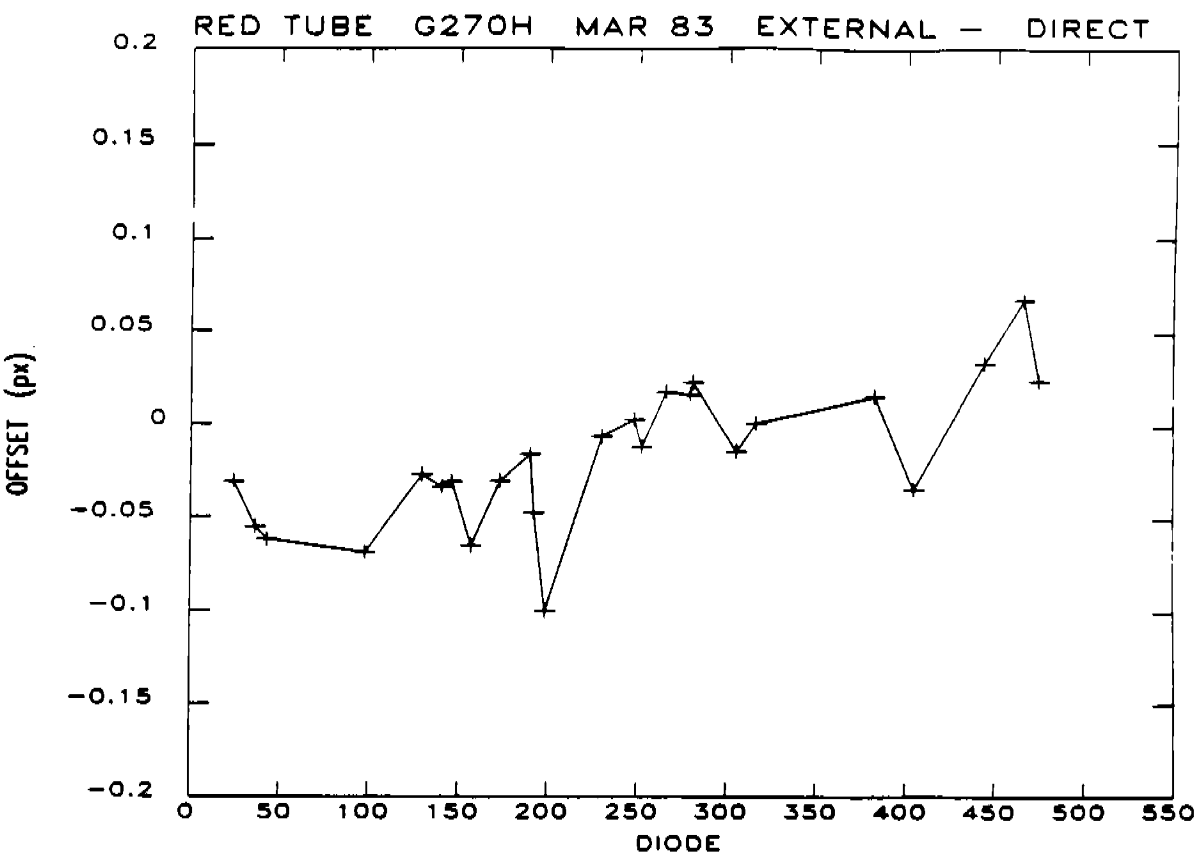


Figure 3.

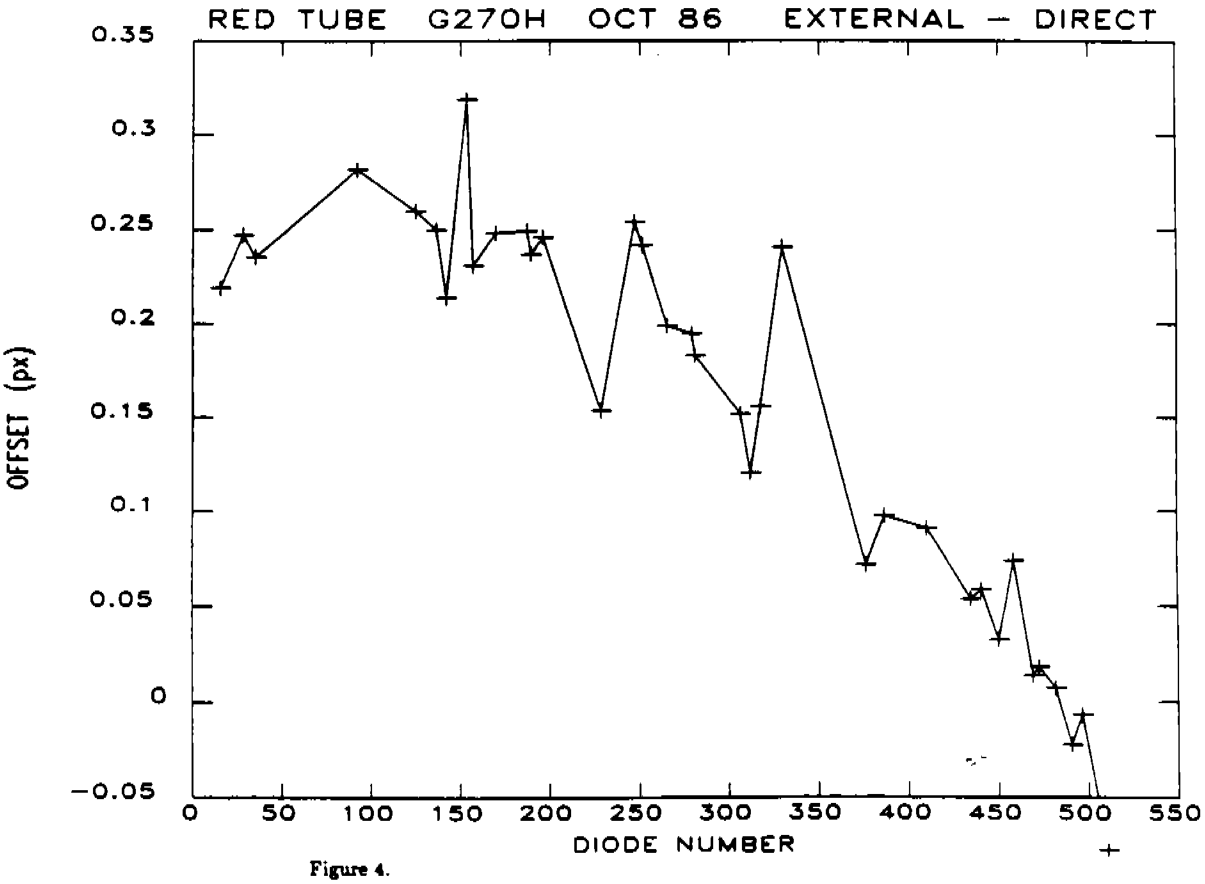
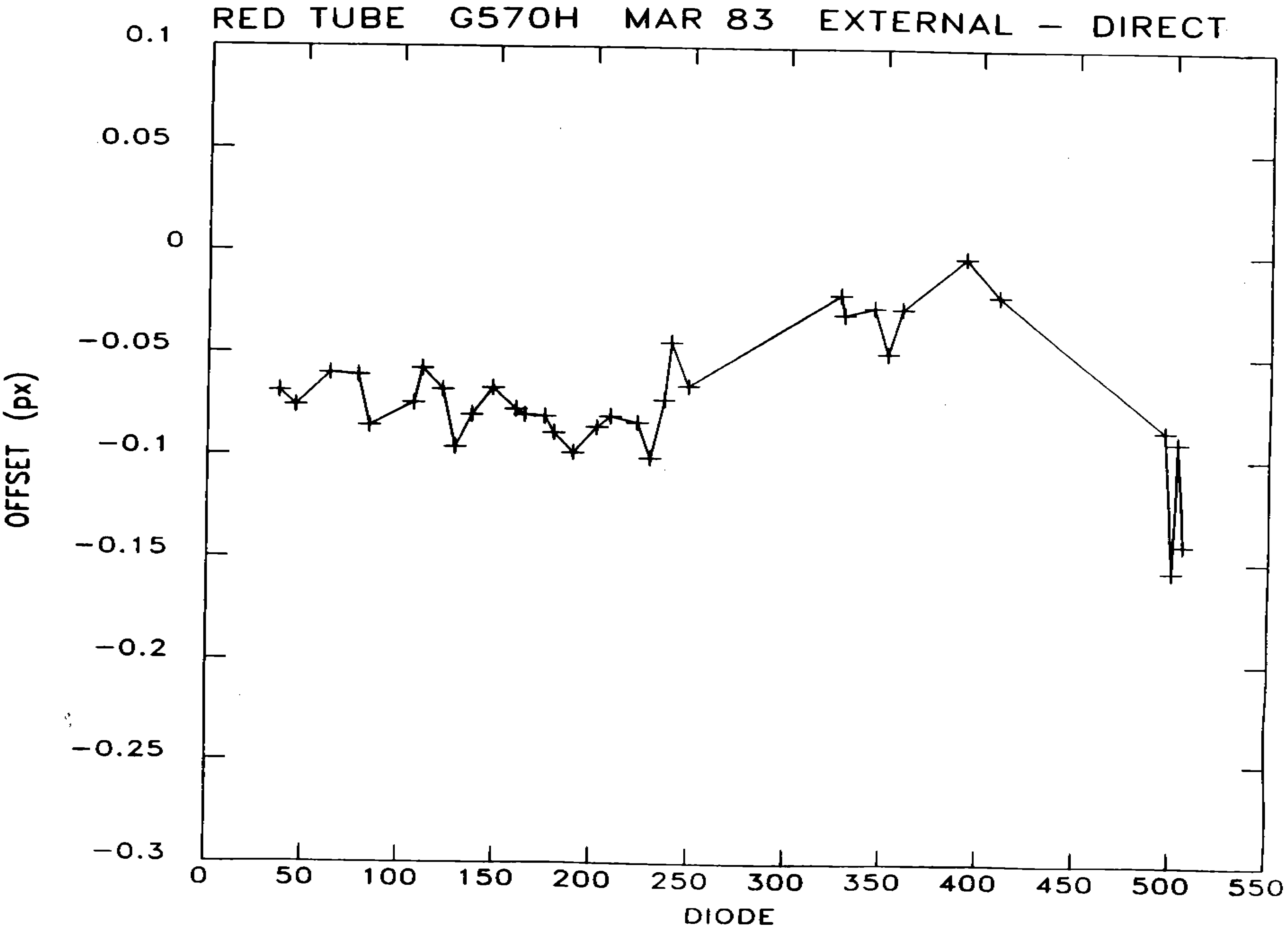


Figure 4.


RED TUBE G570H MAR 83 EXTERNAL – DIRECT
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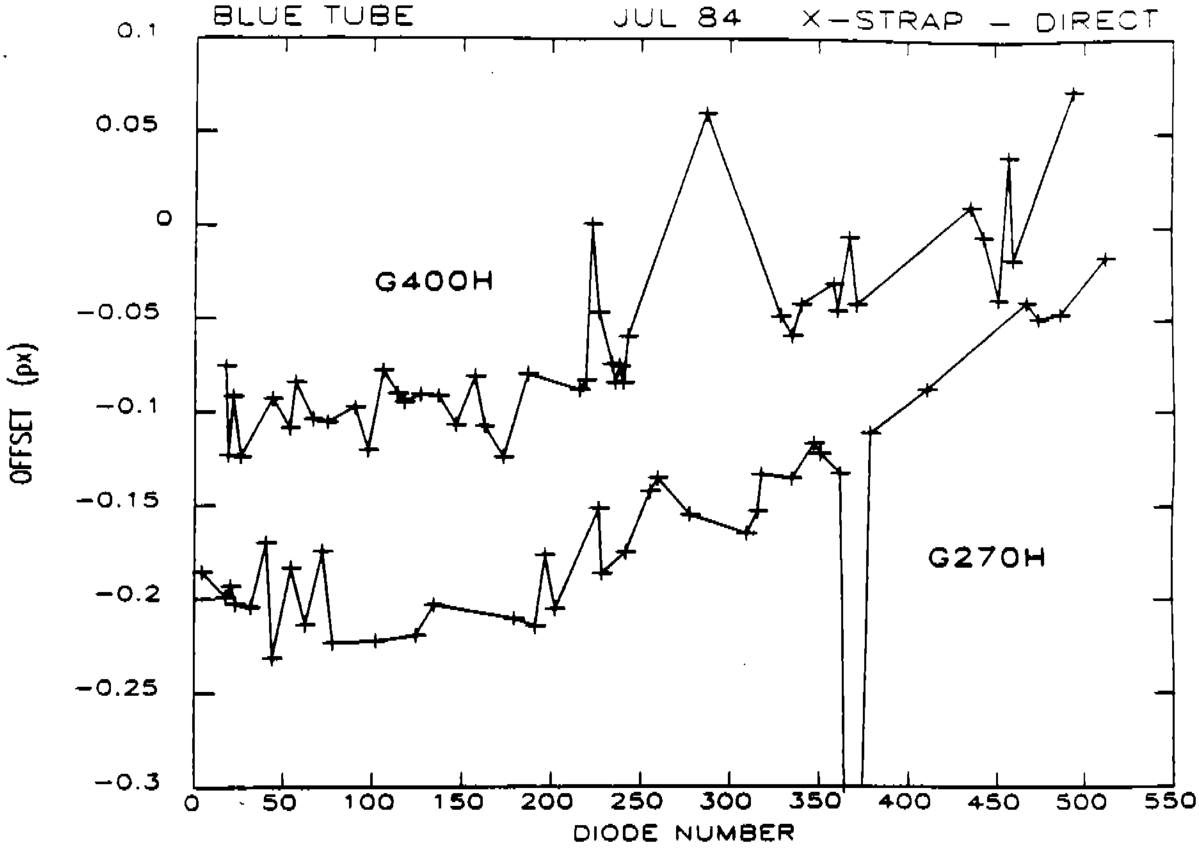
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
−0.25
−0.3
0
50
100
150
200
250
300
350
400
450
500
550
DIODE

Figure 5.


BLUE TUBE JUL 84 X-STRAP - DIRECT
G400H
G270H
OFFSET (px)
DIODE NUMBER
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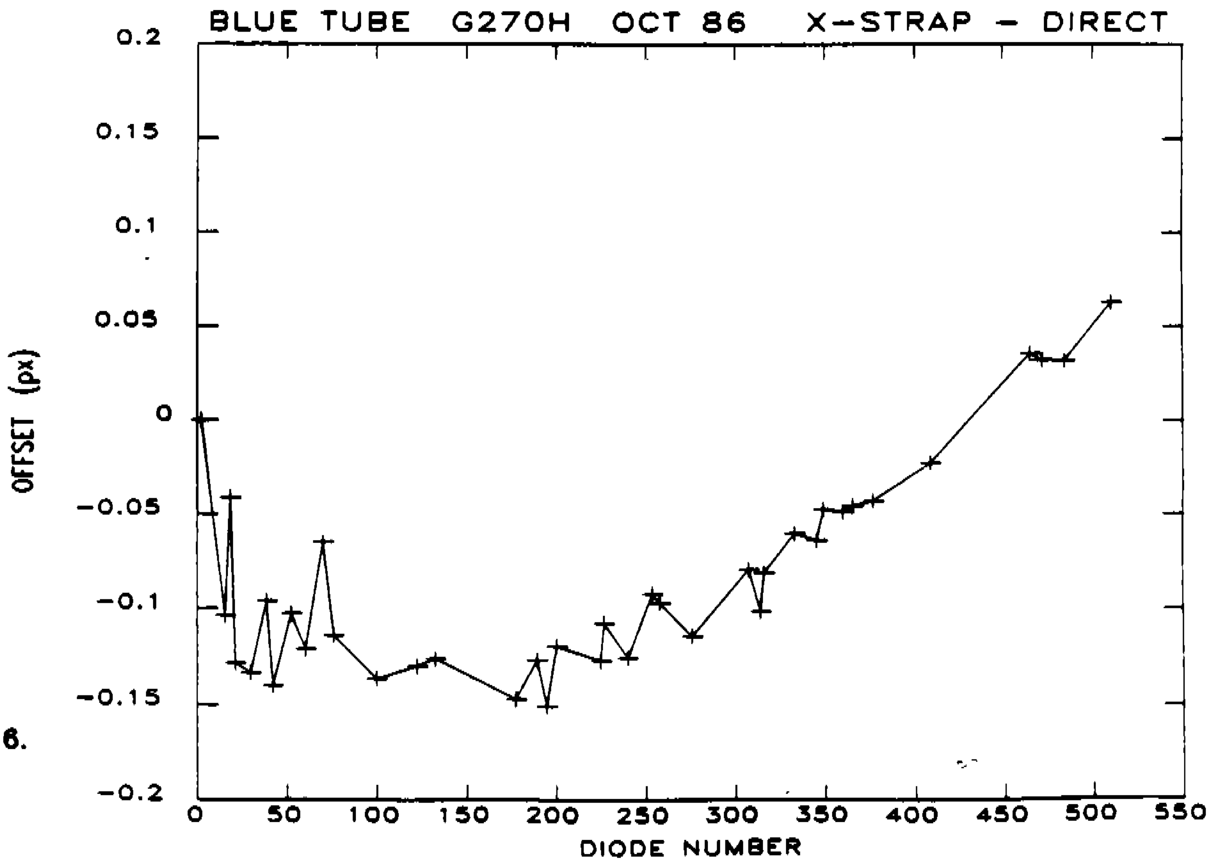
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
0 50 100 150 200 250 300 350 400 450 500 550


BLUE TUBE G270H OCT 86 X-STRAP - DIRECT
OFFSET (px)
DIODE NUMBER
0.2
0.15
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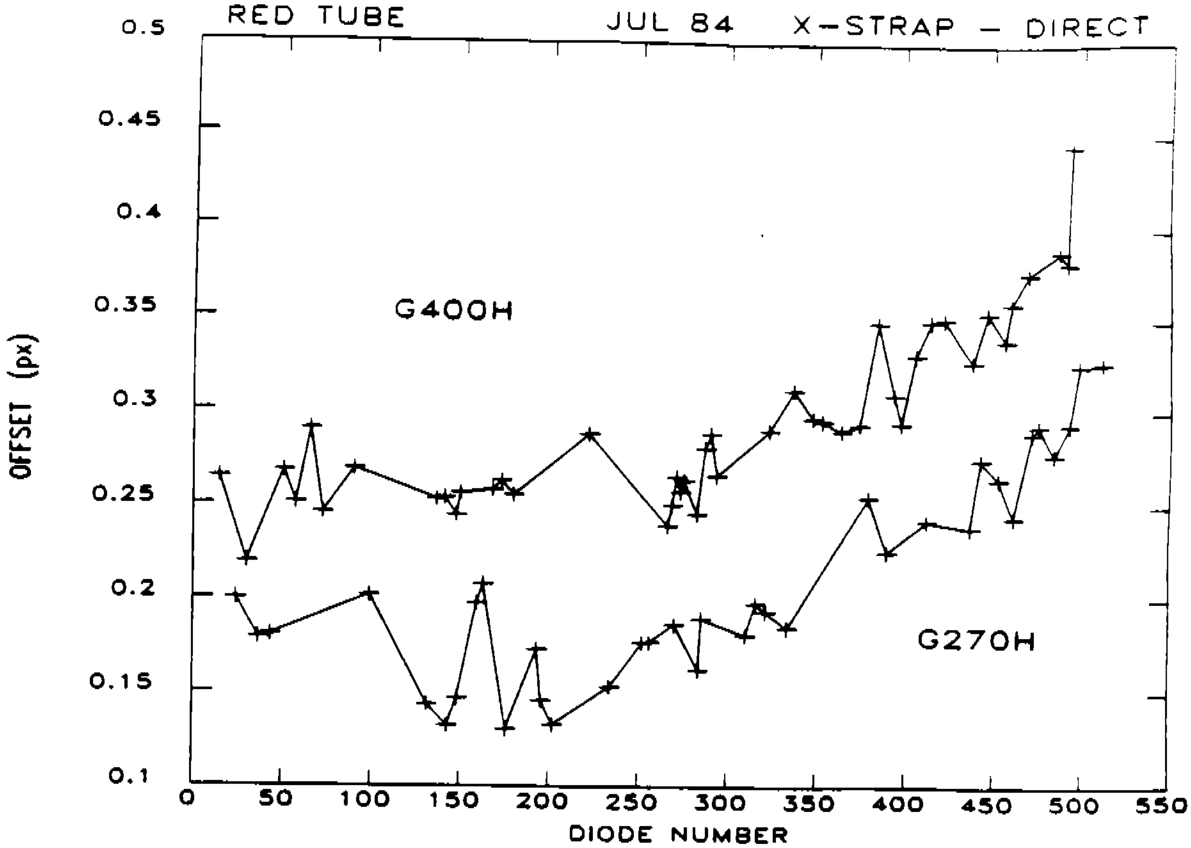
0
-0.05
-0.1
-0.15
-0.2
0 50 100 150 200 250 300 350 400 450 500 550

Figure 6.


RED TUBE
JUL 84
X-STRAP - DIRECT
G400H
G270H
OFFSET (px)
DIODE NUMBER
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0.3
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0.1
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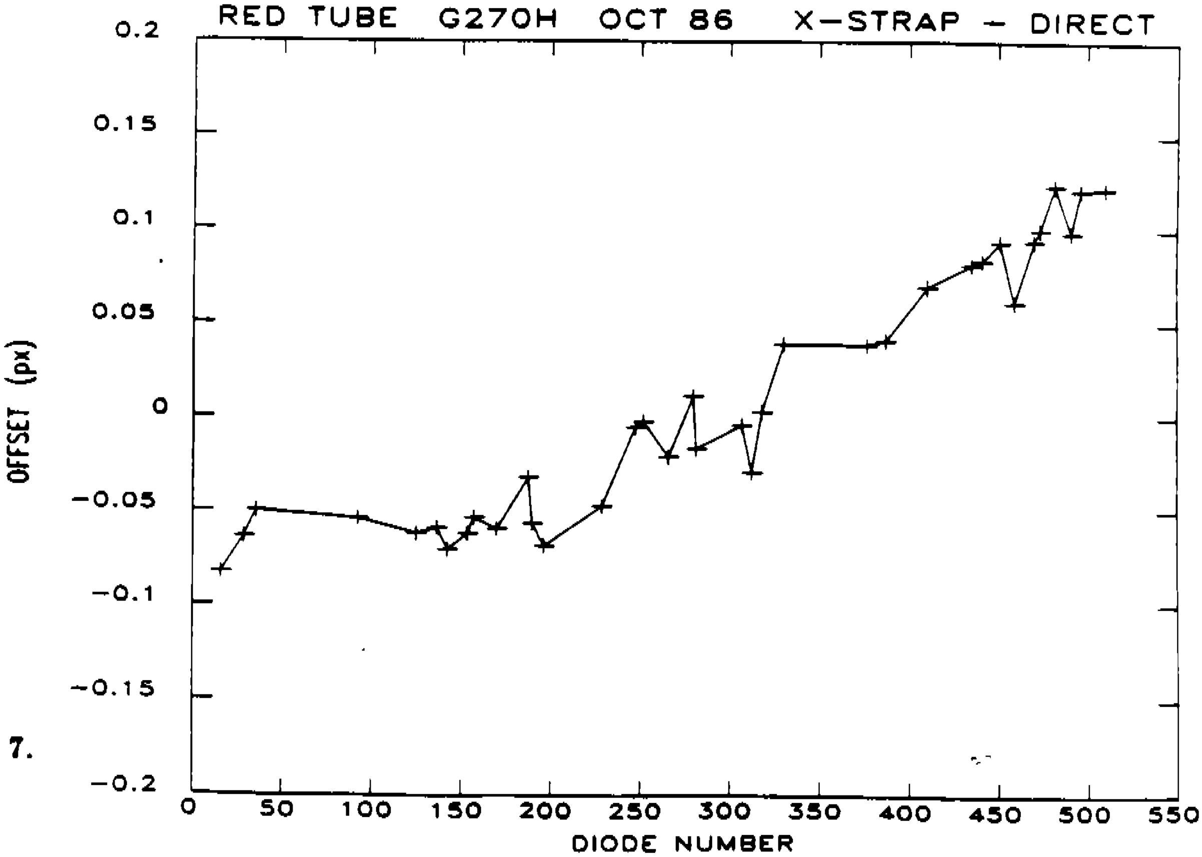
450
500
550


RED TUBE G270H OCT 86 X-STRAP - DIRECT
OFFSET (px)
DIODE NUMBER
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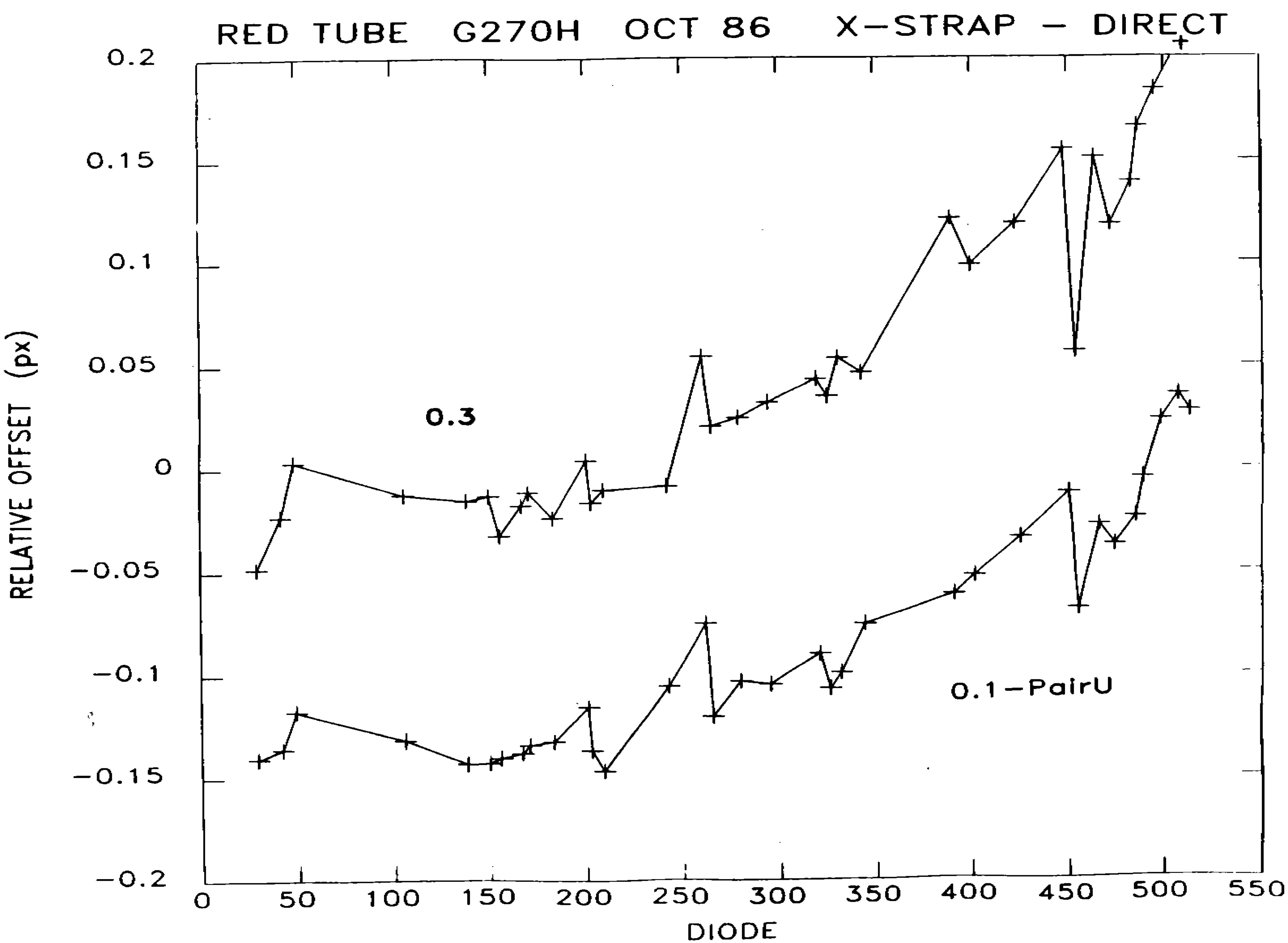
0.05
0
−0.05
−0.1
−0.15
−0.2
0
50
100
150
200
250
300
350
400
450
500
550

Figure 7.


RED TUBE G270H OCT 86 X-STRAP - DIRECT
RELATIVE OFFSET (px)
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0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
0.3
0.1-PairU
0
50
100
150
200
250
300
350
400
450
500
550
DIODE

Figure 8.