Scattered Light Perpendicular to the Dispersion in the FOS

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ABSTRACT

Measurements of scattered light perpendicular to the FOS dispersion axis are presented. The data were obtained through a variety of apertures using many of the FOS dispersers during a March 1988 calibration session at Lockheed. The fraction of scattered light present 1500μ from the spectrum is always less than or about 0.3%. These results are nearly identical to a calibration report presented by Lindler and Bohlin four years ago [1].

1. INTRODUCTION

Lindler and Bohlin [1] measured the scattered light perpendicular to the dispersion axis of the FOS for all dispersers through a variety of different spectrograph apertures. The performance of the spectrograph was good, with typical scattered light levels of 0.2% a distance of 1500μ from the dispersion axis. This report presents new measurements from the 8–24 March 1988 calibration run at Lockheed.

2. OBSERVATIONS AND REDUCTIONS

Observations of continuum lamp sources (deuterium or tungsten incandescent lamp) were made at 16 Y-deflection positions, spaced at 200μ intervals (one diode height) using the *YCPSCT* procedure. The 16×516 element arrays were reduced using the usual IDL routines, correcting for paired-pulse events and interpolating bad diodes. Dark count corrections were not applied because they were never significant. Table 1 shows the results; the measurements of Lindler and Bohlin [1] at 1500μ away from the spectrum are also tabulated for comparison.

Table 1–Scattered light (%)at 500 and 1500μ

Disperser	Tube	Aperture	500μ	1500μ	L&B*	Fig.
Prism	Red	2.0-Bar	0.2	0.20	0.1	1
Prism	Blue	2.0-Bar	0.2	0.05	0.1	2
G270H	Red	0.7 × 2.0-Bar	0.5	0.30	0.5	3
G270H	Blue	2.0-Bar	0.5	0.30	0.2	4
G400H	Red	0.3 Hole	0.4	0.20	0.2	5
G400H	Blue	1.0 Hole	0.2	0.10	0.1	6
G570H	Red	0.3 Hole	0.5	0.20	0.2	7
G570H	Blue	1.0 Hole	0.2	0.06	0.2	8
G650L	Red	0.1-Pair	0.5	0.10	0.2	9
G650L	Blue	0.5 Hole	0.3	0.10	0.1	10
G650L	Red	Blank	—	—	—	11
G650L	Blue	Blank	—	—	—	12

* L&B - Lindler and Bohlin [1] measurements at 1500μ from the spectrum.

Detailed results are presented in Figures 1–12, each divided into 4 parts. Parts A and B are 3-d perspective surface plots from two different angles to provide full coverage of the spectrum. The intensity scale (Z-axis) is logarithmic. For presentation purposes, the short dimension (Y-step) was expanded from 16 to 80 elements by linear interpolation using the IDL REBIN function.

Part C of Figures 1–10 (all except the blank aperture observations) show representative spectral distributions extracted from the 16 × 516 element array. The upper curve in Part C is the spectrum extracted from the bright portion of the photocathode while the lower curve is a representative sample some distance from the spectrum (a constant distance was not used since the observations were made through apertures of varying sizes; a distance suitable for the largest aperture would not be appropriate for the smallest). To improve the signal-to-noise ratio, several Y-step samples were averaged after individual examination verified that none of those to be included was significantly different from the others.

Part D of Figures 1–10 are representative cuts across the dispersion axis showing the typical slit profile. Because light is scattered in all directions away from the spectrum and not just perpendicular to the dispersion axis, there will sometimes be regions where the incident signal is low while the scattered light contribution from other spectral regions is high (see, for example, Figures 1 and 2). Because of this, only a fraction of the spectral range was used to determine the slit profile. The range of wavelengths (diodes) included in Part D of Figures 1–10 was determined by examination of Part C where representative scattered light performance in regions of high incident intensity could be chosen. For example, diodes 400–490 were chosen from Figure 1C because scattered light in that region is constant and representative of usual observing conditions. At each diode position, the 16 points of the slit profile were normalized to the largest value and averaged with the rest to improve the signal-to-noise. In this manner, an accurate indication of the perpendicular component of scattered light was obtained.

Similar diagrams were displayed by Lindler and Bohlin [1], although the normalization they used was different and they included all diodes in the final result instead of selecting portions of the spectrum. A quantitative difference between their method and the current one is that they measure the scattered light as a fraction of the total integrated flux while we measure it as a fraction of peak intensity in the slit profile. For small apertures this makes little difference, but for wider slits the current scattered light estimates may be somewhat larger.

3. CASE DESCRIPTIONS

3.1 PRISM

Figures 1 and 2 show the deuterium lamp observations through the 2 arcsecond aperture with an occulting bar (2.0-Bar) using the red and blue detectors. Performance with the blue tube is distinctly better than with the red detector.

The red system shows a component of scattered light that illuminates much of the observed portion of the photocathode. This is most easily seen in Figures 1A and 1B where in the regions away from the bright light of the lamp spectrum, a constant excess signal is seen. In Figure 1C, diodes 1–150 show the signal level at 0.3 Hz. This signal rises to about 1 Hz at diodes 200–300, which are nearer the spectrum. The blue detector observations show a similar excess of light in diodes 200–300. Since observations with the blank (dark) aperture do not show this feature, it is not likely light leaks into the detector photocathode area are the cause. This component of scattered light in the red detector observations was also mentioned by Lindler and Bohlin [1].

3.2 G270H

Figures 3 and 4 summarize the scattered light properties of the G270H grating through a 2.0 arcsecond square aperture with an occulting bar (2.0-Bar) illuminated by the tungsten FEL lamp.

A disturbing effect seen in both detectors is a significant increase in scattered light at the short wavelength end of the spectra. The problem is easily seen in Figures 3A–C and 4A–C. In Figure 3, the red tube observations show a large increase in off-spectrum light at diode positions greater than 300. A similar increase is seen in the blue detector observations for diodes 0–100. In these regions, the scattered light can account for more than 10% of the light on the spectrum. Presumably, the source of the excess light is the strong, broad portion of the incandescent lamp spectrum further to the red.

3.3 G400H

Figures 5 and 6 show the results of observations of the FEL lamp with the 0.3 arcsecond slit using the G400H grating. The scattered light characteristics are good, with the blue detector being somewhat better than the red.

3.4 G570H

Figures 7 and 8 show observations of the FEL lamp with the 0.3 arcsec slit and the G570H grating. Again, performance with the blue detector is better than the red. A small bump centered around diode 460 about 30 diodes wide can be seen in Figure 8C. This bump is off the dispersion axis (Figures 8A–B) and consequently is probably not a spectral feature. The maximum intensity is small, being only 0.1% of the peak intensity of the observed spectrum. Both the location and low intensity make this bump of little consequence in most situations.

3.5 G650L

Figure 9 shows the red tube observations of the incandescent lamp with the G650L low dispersion grating. This observation was made through a paired 0.1 arcsec aperture so none of the measured points were as far as 1500μ from the peak intensity. However, 1500μ from the center of the pair of apertures, the scattered light intensity is 0.1% of the peak intensity. A distance of 500μ from the peak of one of the two maxima shows scattered light at the 0.5% level.

Because the dual apertures are separated by a distance that is larger than the diode height, an observation centered between the two apertures will include only light scattered from the two adjacent holes. Figure 9D shows this observation at Y-offset 8. It is reassuring but unremarkable that the intensity of scattered light at position 8 is about twice that at positions 6 and 10, which are each an equal distance from the apertures but away from the center.

Figure 10 shows the blue tube observations with the G650L grating taken through a 0.5 arcsec aperture. At 1500μ the fractional scattered light is the same as with the red tube (0.1%). At 500μ from the spectrum, the scattered light level is 0.3%.

3.6 BLANK

Figures 11 and 12 show the results of 10 second exposures taken with the blank (opaque) slit position, grating G650L in place, and the tungsten light source on. Parts C and D of these two figures show the spectra at the extreme Y-step values. The results are the same as reported in *CAL/FOS-011,* that is, light is seen near diode 200 in the red detector and around diode 490 in the blue detector, both far from the dispersion axis (Figures 11C and 12C). Figure 11 also shows sporadic counts between diodes 216–265 inclusive, which are attributable to a bad diodes in that range.

4. CONCLUSIONS

The perpendicular scattered light performance of the FOS spectrograph is good, with less than 0.3% of the peak intensity being seen in regions 1500μ from the spectrum with most gratings. Generally speaking, the blue side of the spectrograph is better than the red side. The most serious anomaly is the excess light seen at the blue end of the spectrum when using grating G270H with either the blue or red detector. Less serious problems are the generally high level of background scattered light seen when using the prism, and the light leaks seen at large Y-deflections when using the blank aperture position.

Comparing these results with those of Lindler and Bohlin, we see that 4 observations showed better performance, 2 were worse (one of these–G270H/blue–only marginally so), and 4 were the same at 1500μ from the spectrum (Table 1). On the whole, the scattered light performance of the FOS perpendicular to the dispersion is probably slightly better now than it was in 1985 when Lindler and Bohlin measured it.

REFERENCES

[1] Lindler, D., and Bohlin, R. 1985, *CAL/FOS-011, Scattered Light Background Perpendicular to the Dispersion—Preliminary Version* (FOS Calibration #19).

FIGURE 1

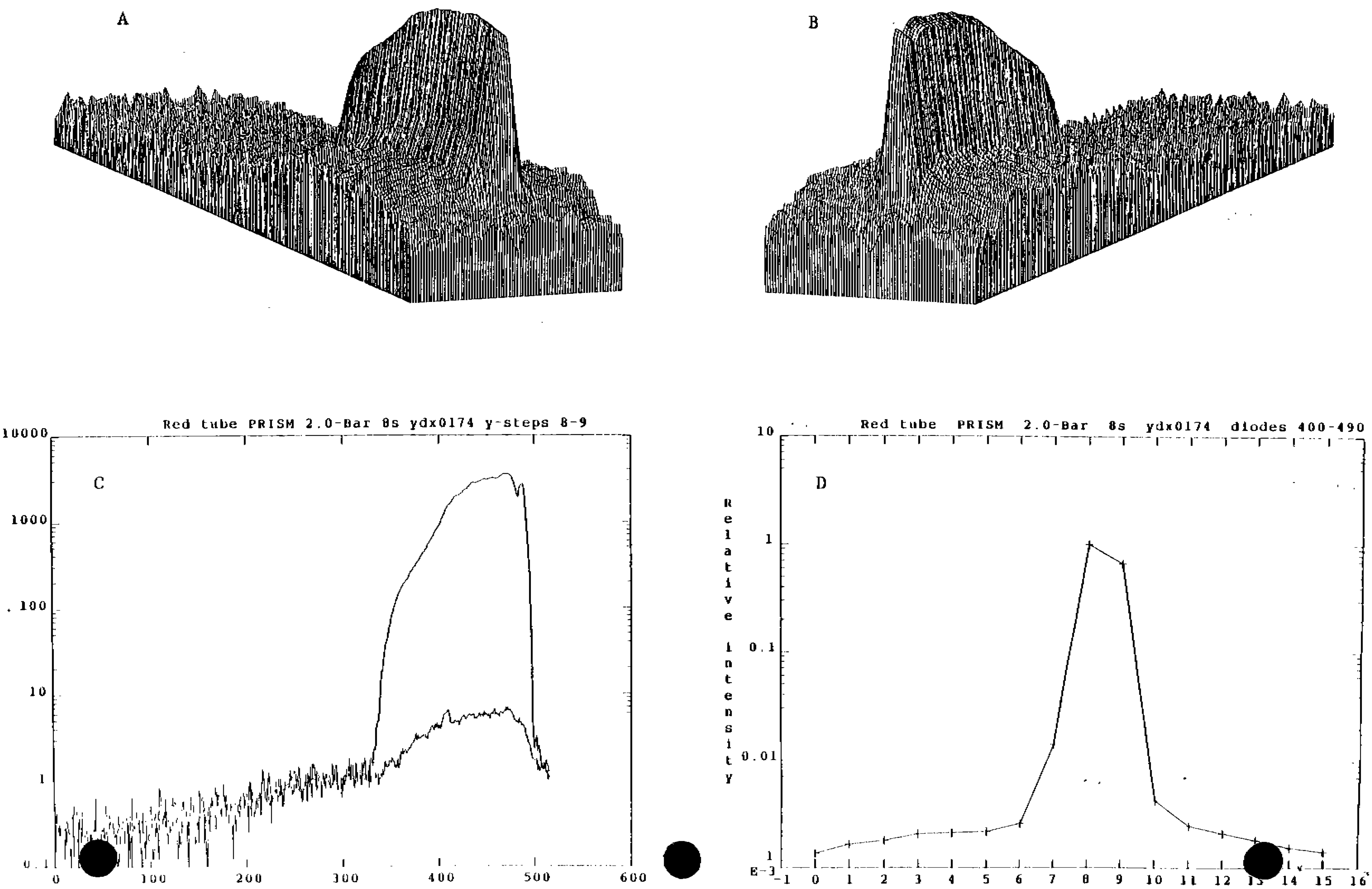
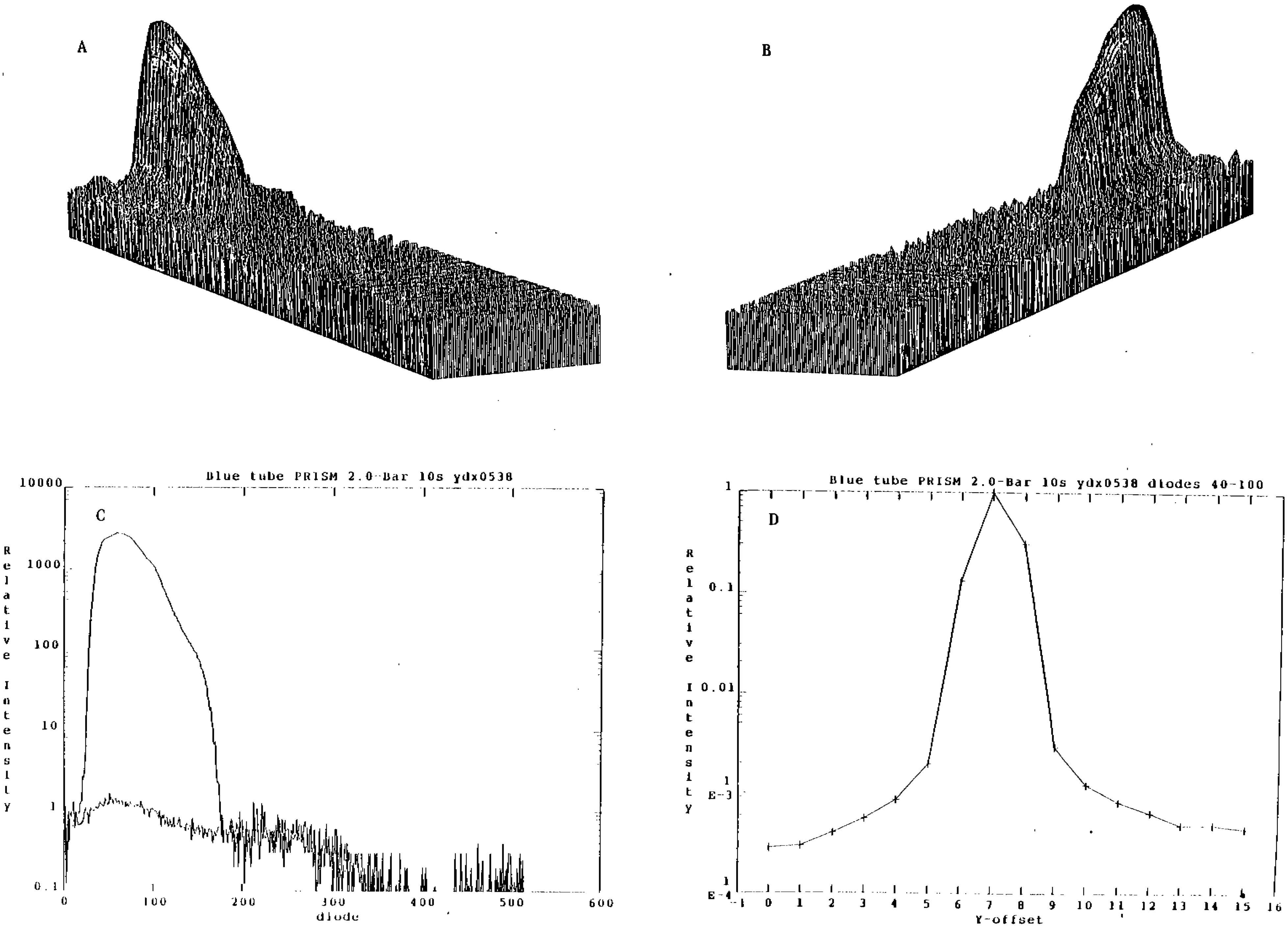

A
B
C
Red tube PRISM 2.0-Bar 8s ydx0174 y-steps 8-9
Relative intensity
10000
1000
100
10
1
0.1
0
100
200
300
400
500
600
D
Red tube PRISM 2.0-Bar 8s ydx0174 diodes 400-490
Relative intensity
10
1
0.1
0.01
1 E-3
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

FIGURE 2



A
B
C
Blue tube PRISM 2.0-Bar 10s ydx0538
Relative Intensity
diode
D
Blue tube PRISM 2.0-Bar 10s ydx0538 diodes 40-100
Relative Intensity
Y-offset

FIGURE 3

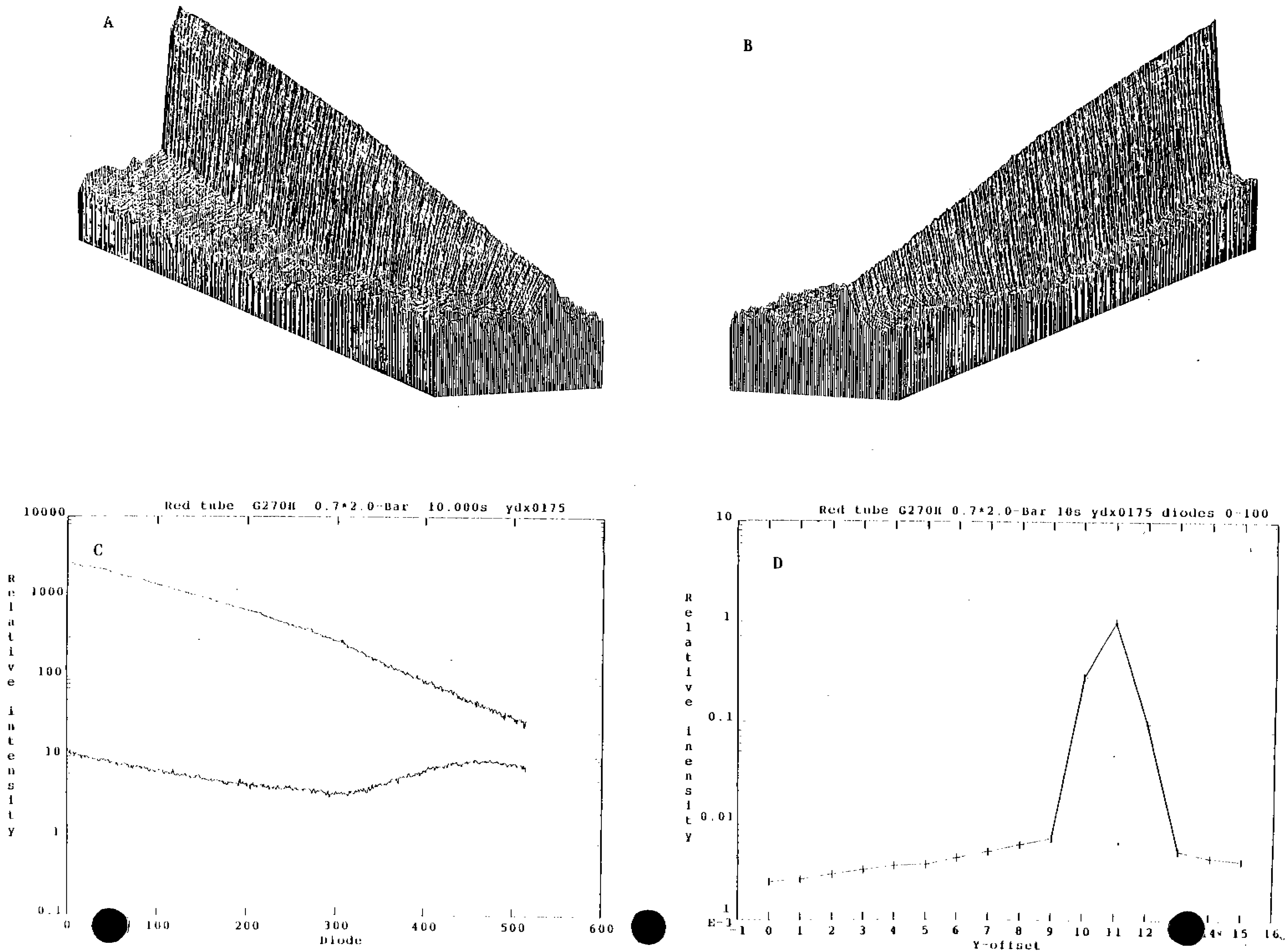

A
B
C
Red tube G270H 0.7*2.0-Bar 10.000s ydx0175
10000
1000
100
10
1
0.1
Relative intensity
0
100
200
300
400
500
600
Diode
D
Red tube G270H 0.7*2.0-Bar 10s ydx0175 diodes 0-100
10
1
0.1
0.01
Relative intensity
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
15
16
Y-offset

FIGURE 4

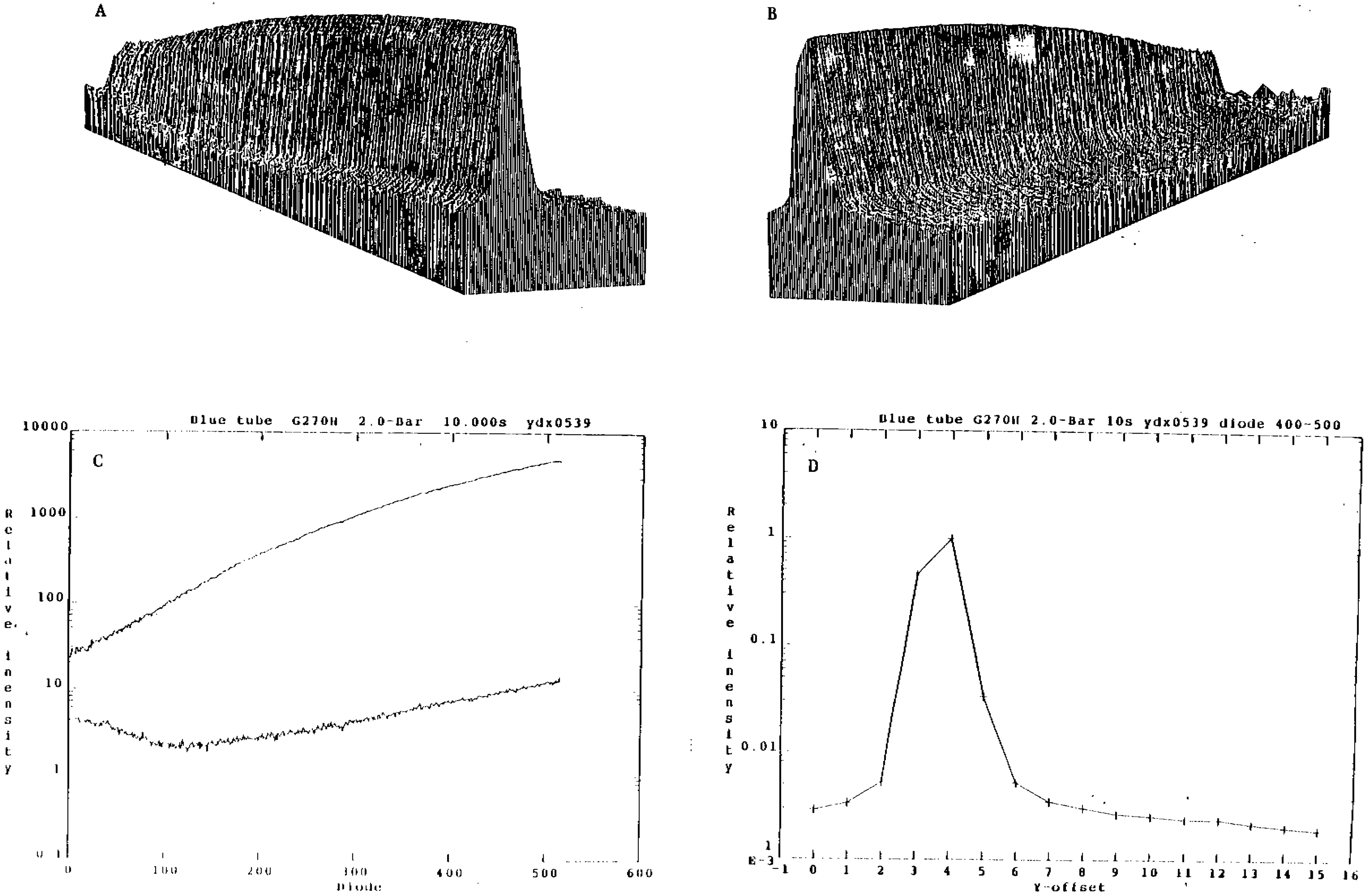

A
B
C
Blue tube G270H 2.0-Bar 10.000s ydx0539
Relative intensity
10000
1000
100
10
1
0.1
0
100
200
300
400
500
600
Diode
D
Blue tube G270H 2.0-Bar 10s ydx0539 diode 400-500
Relative intensity
10
1
0.1
0.01
1 E-3
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Y-offset

FIGURE 5

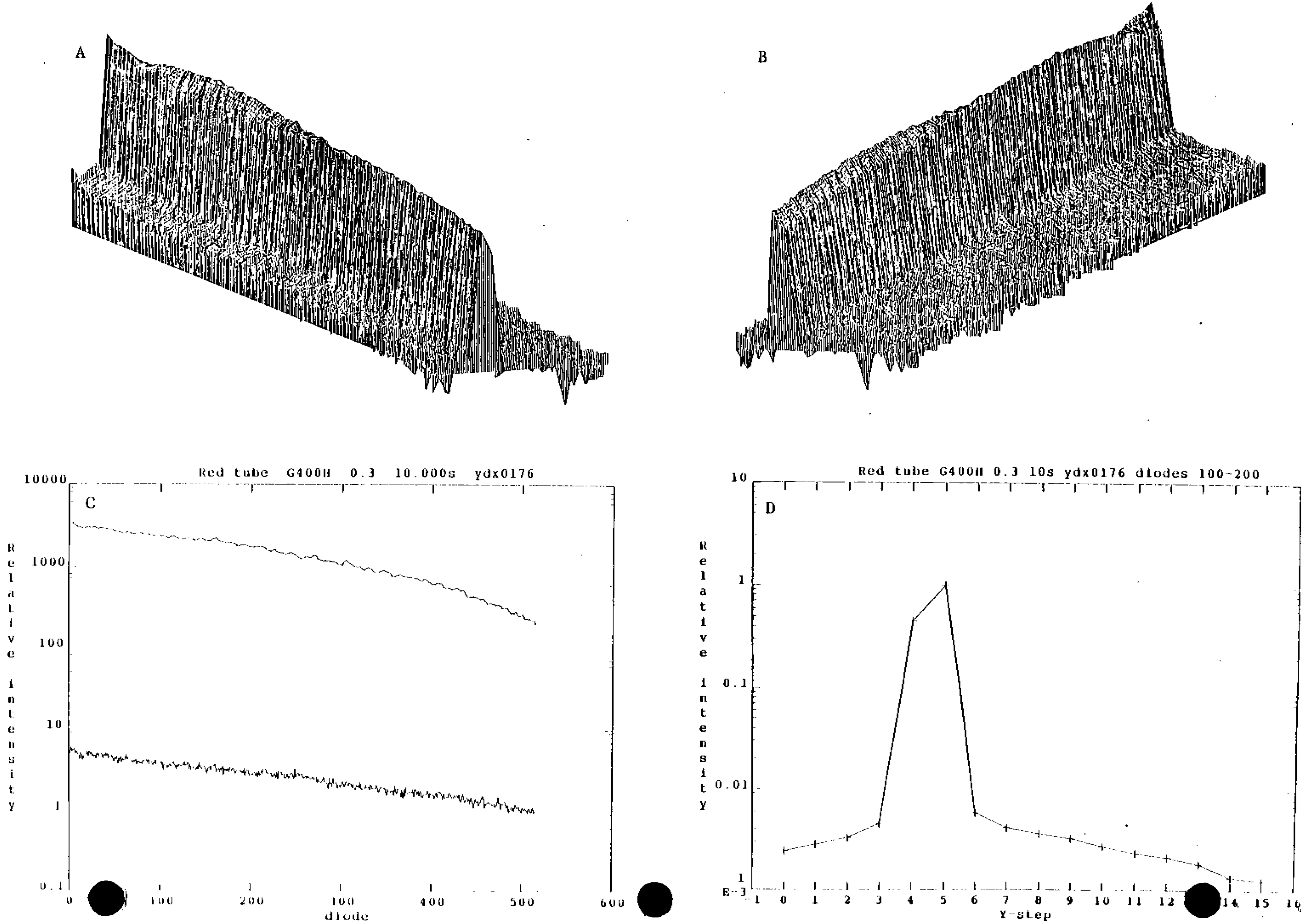

A
B
C
Red tube G400H 0.3 10.000s ydx0176
Relative intensity
10000
1000
100
10
1
0.1
0
100
200
300
400
500
600
diode
D
Red tube G400H 0.3 10s ydx0176 diodes 100-200
Relative intensity
10
1
0.1
0.01
1 E-3
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
14
15
16
Y-step

FIGURE 6

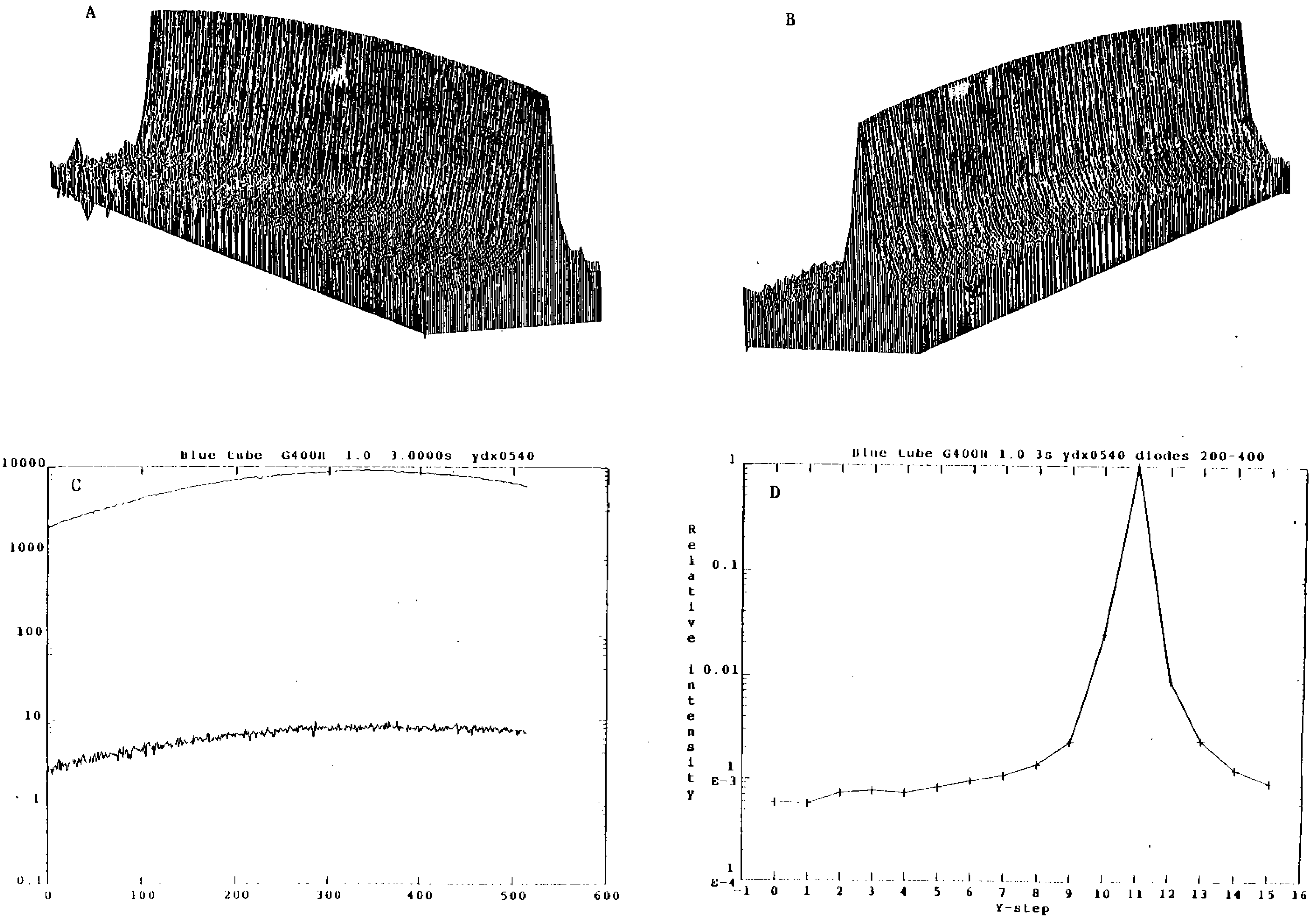
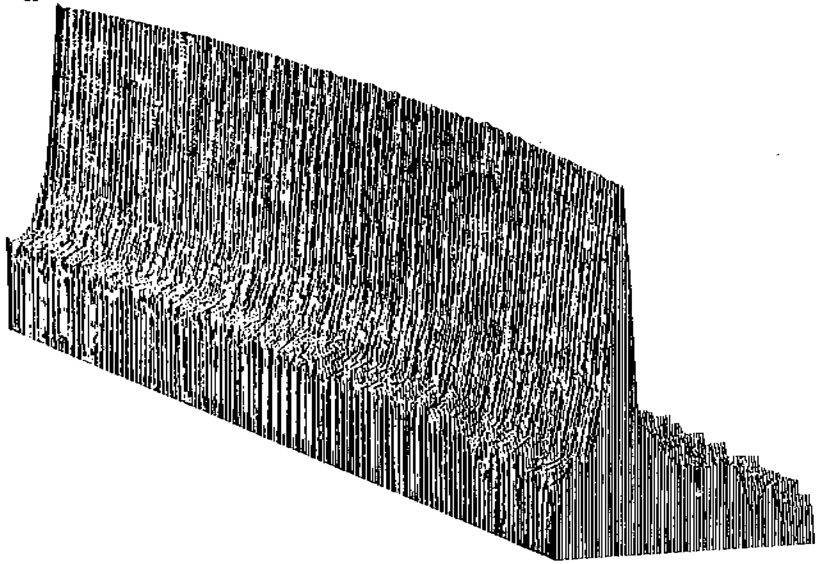
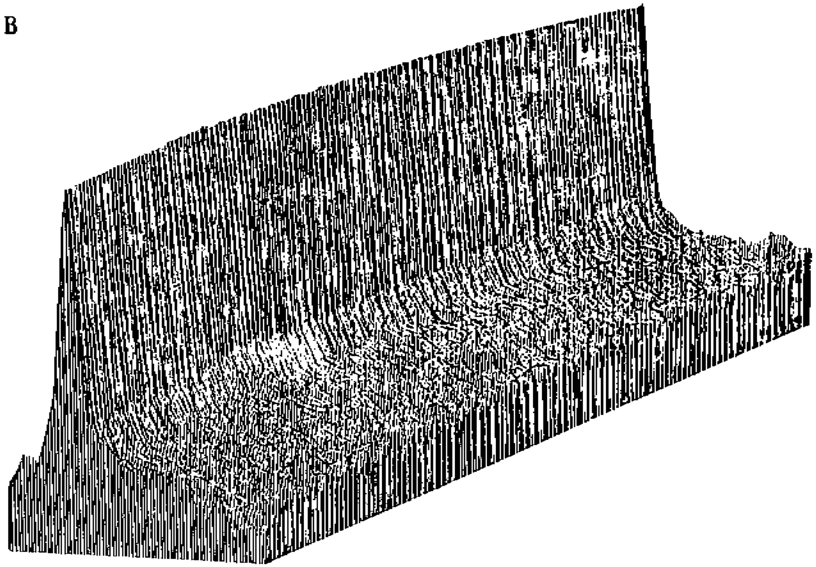

A
B
C
Blue tube G400H 1.0 3.0000s ydx0540
10000
1000
100
10
1
0.1
0
100
200
300
400
500
600
D
Blue tube G400H 1.0 3s ydx0540 diodes 200-400
Relative intensity
1
0.1
0.01
1 E-3
1 E-4
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Y-step

FIGURE 7

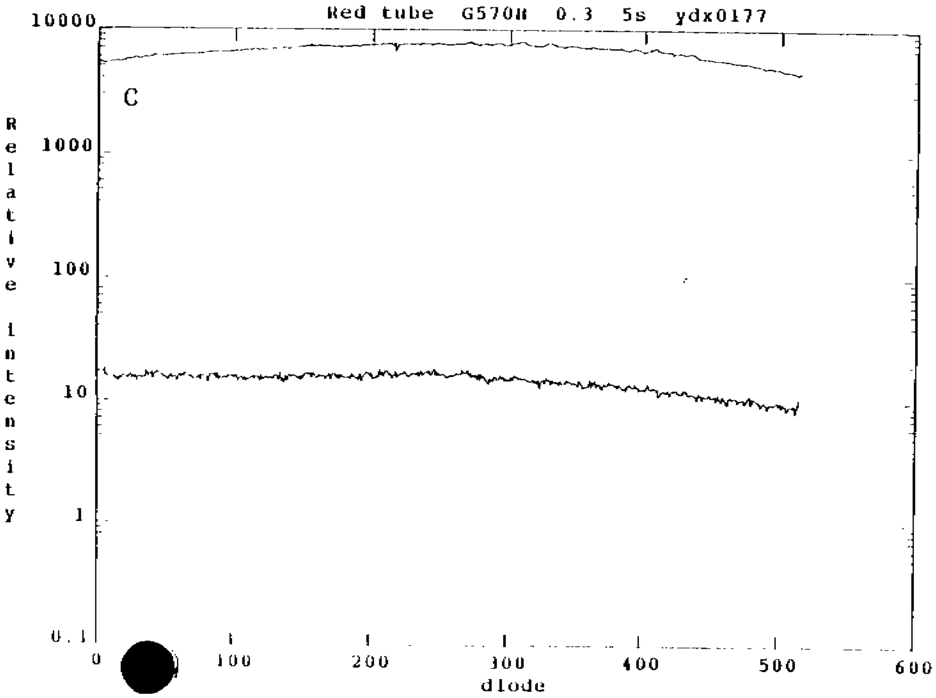
A



B



C



D

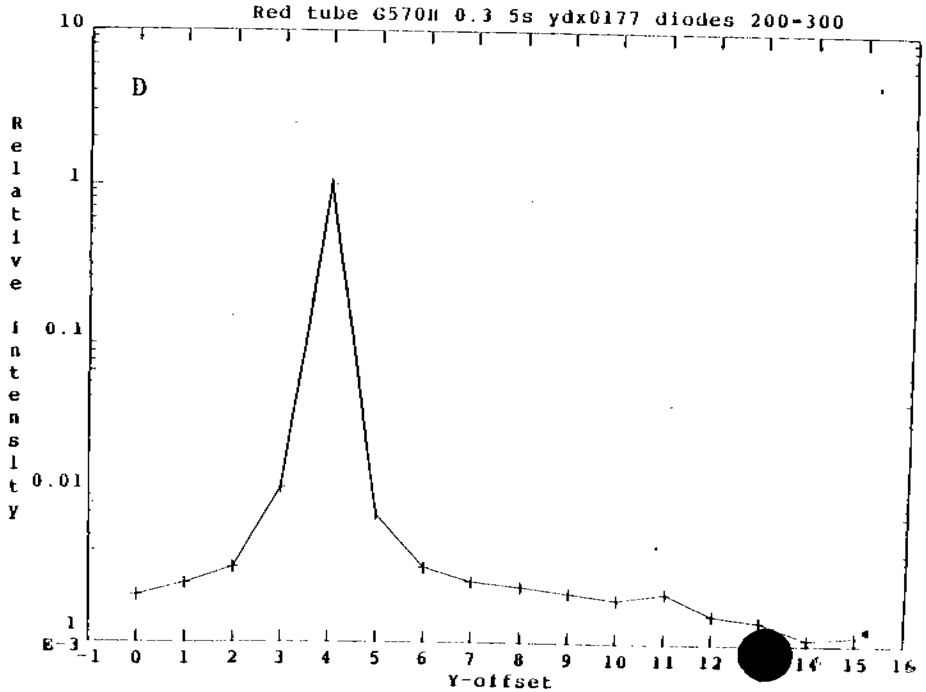
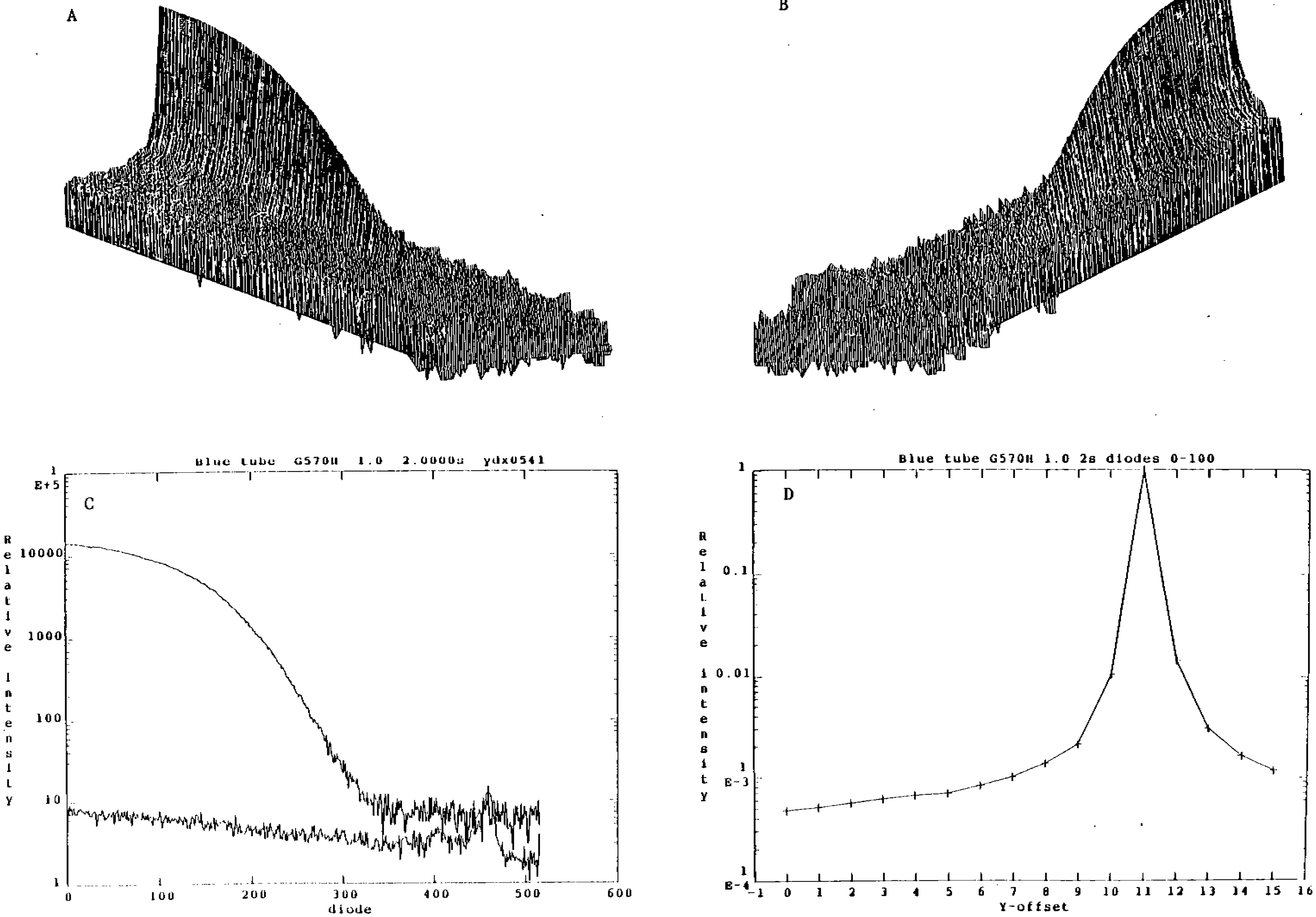


FIGURE 8



A
B
C
Blue tube G570H 1.0 2.0000s ydx0541
Relative Intensity
1 E+5
10000
1000
100
10
1
0
100
200
300
400
500
600
diode
D
Blue tube G570H 1.0 2s diodes 0-100
Relative intensity
1
0.1
0.01
1 E-3
1 E-4
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Y-offset

FIGURE 9

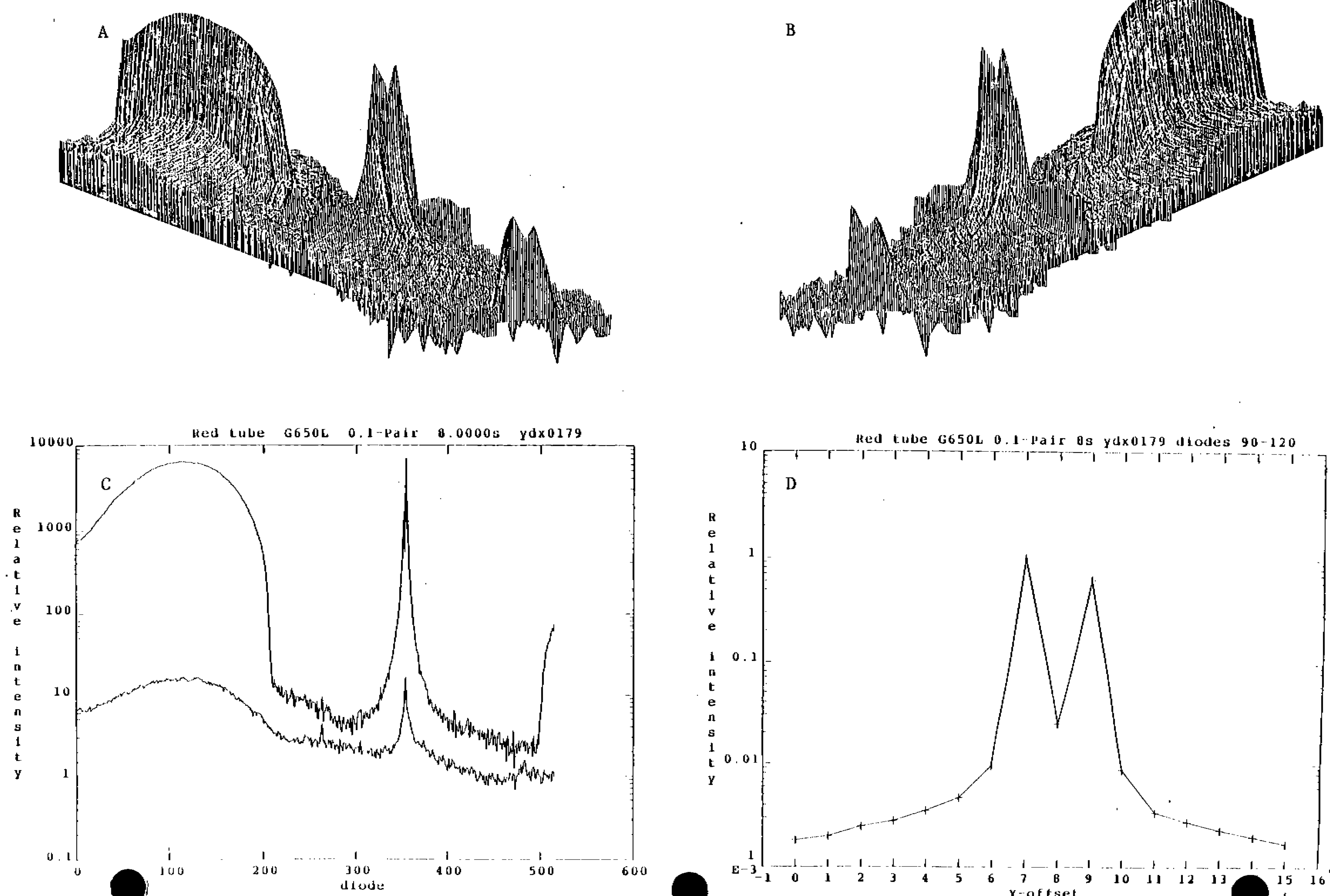

A
B
C
Red tube G650L 0.1-Pair 8.0000s ydx0179
Relative intensity
10000
1000
100
10
1
0.1
0
100
200
300
400
500
600
diode
D
Red tube G650L 0.1-Pair 8s ydx0179 diodes 90-120
Relative intensity
10
1
0.1
0.01
1 E-3
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Y-offset

FIGURE 10

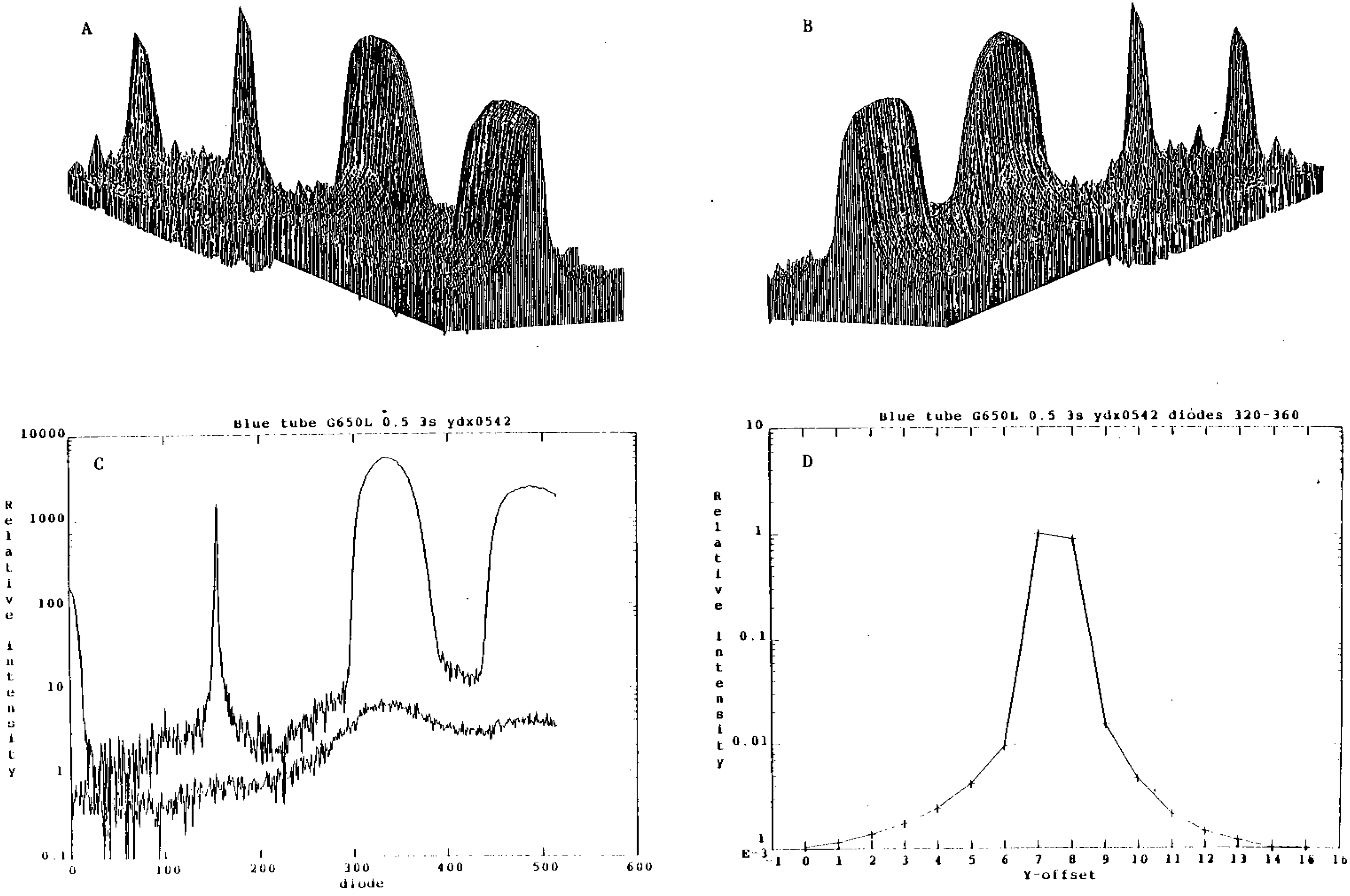
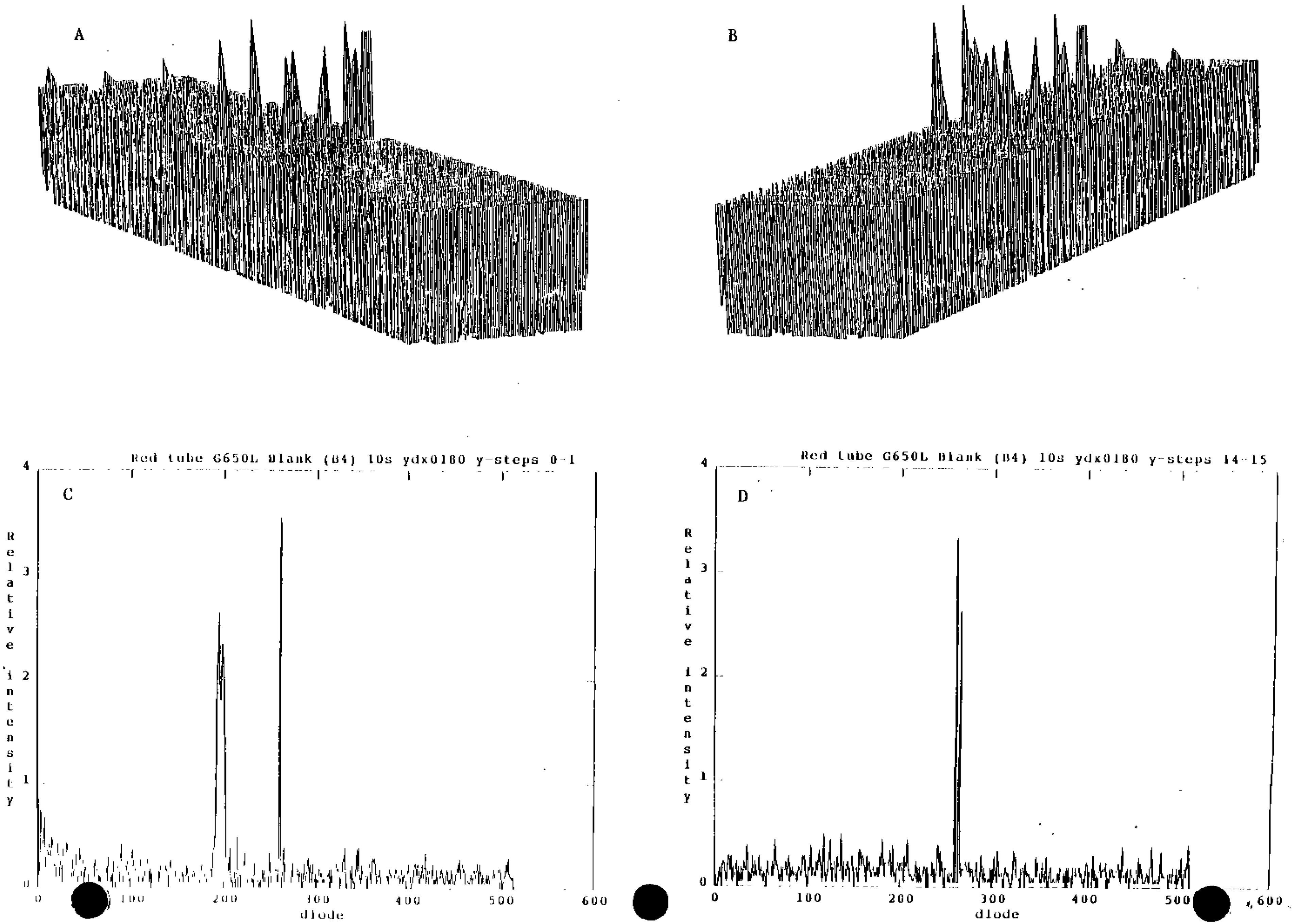
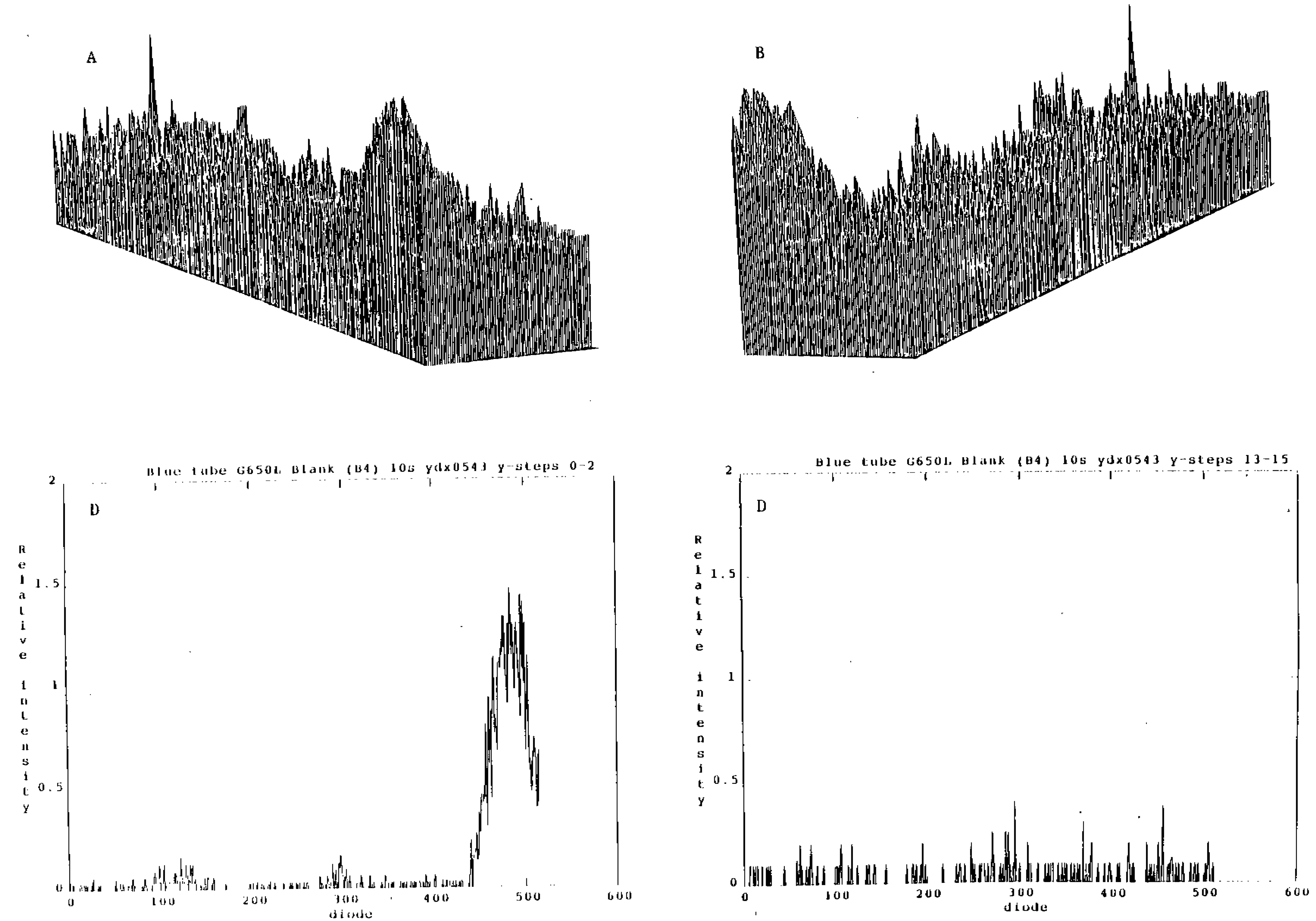

A
B
C
Blue tube G650L 0.5 3s ydx0542
Relative intensity
10000
1000
100
10
1
0.1
0
100
200
300
400
500
600
diode
D
Blue tube G650L 0.5 3s ydx0542 diodes 320-360
Relative intensity
10
1
0.1
0.01
1
E-3
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Y-offset

FIGURE 11



A
B
C
D
Red tube G650L Blank (B4) 10s ydx0180 y-steps 0-1
Red tube G650L Blank (B4) 10s ydx0180 y-steps 14-15
Relative intensity
diode
0
1
2
3
4
100
200
300
400
500
600

FIGURE 12


A
B
Blue tube G650L Blank (B4) 10s ydx0543 y-steps 0-2
D
Relative intensity
0
0.5
1
1.5
2
100
200
300
400
500
600
diode
Blue tube G650L Blank (B4) 10s ydx0543 y-steps 13-15
D
Relative intensity
0
0.5
1
1.5
2
0
100
200
300
400
500
600
diode