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# Current Schemes for National Synchrotron Light Source UV Beamlines*

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## ABSTRACT

We describe in some detail four beamlines proposed for the National Synchrotron Light Source UV ring at Brookhaven National Laboratory. Three grazing-incidence instruments, one of the plane grating Mijake type and two with toroidal gratings at grazing angles of $2\frac{1}{2}^\circ$ and $15^\circ$ are described. Two normal incidence instruments, one using the source as entrance slit and accepting 75 milliradians horizontally are also discussed. In each case we have estimated the output fluxes expected from such beamlines.

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## 1. Introduction

This paper describes four beamlines devised for installation on the National Synchrotron Light Source (NSLS) UV ring. Three of the four lines (U2, U3, and U4) use normal incidence monochromators, U4 having access to the synchrotron radiation through a LiF window. Beamline U1 incorporates three grazing incidence instruments, one using a plane grating and two using toroidal gratings. The NSLS UV ring which is designed to run at 0.7 GeV with 1 amp. stored current has a bending radius of 1.91 meters giving it a critical wavelength of about 32Å. Up to 90 milliradians (horizontal) x 10 milliradians (vertical) of radiation opening angle are available from each of the 16 beamlines. Since the light source has such a small vertical beam size (FWHM ~ .2mm) and high brightness, it is often attractive to use the source itself as a monochromator entrance slit. The savings in beamline hardware and reflection losses are often very considerable. Three of the four beamlines described employ this approach. The high brightness remains an advantage even if a collection mirror is used, however, helping to minimize the losses at entrance slits for instruments of high resolution.

## 2. Grazing Incidence Beamline U1

This line is divided into three, one of which (20 milliradians) is spare. It is shown schematically in Fig. 1. U1A intercepts 5 mradians horizontally with an 86° angle of incidence pre-mirror at 10 meters from the source. This mirror is made up of four segments of spherical figure and focuses mainly in the horizontal plane. Detailed ray tracing indicates that such a mirror will give adequate image quality and large cost saving compared to an aspheric mirror some .75 meters long. The horizontal focus is arranged to occur at the sample position i.e. 150mm after the monochromator exit slit and is < 1mm wide. 2.5 meters from the pre-mirror the radiation is dispersed downwards in the vertical plane by a plane grating(1,2). The dispersed beam is then collected and focussed on the (horizontal) exit slit by a parabolic mirror.

The gratings have a rectangular profile(2,3). These so-called "laminar" gratings have a "wavelength of maximum efficiency" ($\lambda_m$) very like a blaze. $\lambda_m$ can be chosen at will by correct choice of the groove depth and angle of incidence for a given groove density. Once the groove depth has been chosen $\lambda_m$ becomes a function of $\alpha$. It turns out by good fortune that in negative order with a gold coated 600 lines/mm grating, $\lambda_m$ is roughly the same function of $\alpha$ as $\lambda_j$, where $\lambda_j$ is the typical wavelength covered by range j over which reflection filtering of second and higher orders occur, and which extends from $\lambda_j/2$ to $2\lambda_j$. The instrument is designed to work in several "ranges" and the above discovery means that one grating can cover several such ranges and never be far off blaze. Within a given range the post-mirror remains stationary and the grating is rotated with a sine bar arrangement such that the linear position of a drive rod is directly proportional to wavelength.

Six ranges are envisaged for the instrument and their properties are listed in table 1. The best resolution with the source as entrance slit is .013Å. Estimated fluxes for the various ranges are presented in Fig. 4.

Beamline U1B (Fig. 1) houses two toroidal grating monochromators (TGM's) one vertically above the other and sharing a common target point. The upper TGM has an 87.5° angle of incidence and collects 3 milliradians horizontally. The source is used as entrance slit and the grating is the only beamline optical component. The resolution is intended to be 2eV. The lower TGM has unit magnification pre and post mirrors and collects 15 milliradians horizontally. Two gratings are used to give a wavelength range from 80-320Å with .25Å resolution and from 320 - 1680Å with ~ 1Å resolution. Estimates of the output fluxes from these instruments are shown in Figs. 5 and 6.

Depending on the requirements of a particular experiment it is possible that different TGM configurations will be required. For example for some experiments such as photoemission it may be desirable to design the instrument for constant energy, rather than wavelength resolution. Fig. 6 compares fluxes from two TGM's, one designed for constant energy and one designed for constant wavelength resolution. It turns out that if the grating from the $\Delta\lambda$ instrument were masked down to achieve $\Delta E = 0.1$eV, the output flux would be much lower than the $\Delta E$ instrument(4). Clearly any choice of instrument must involve considerations of flux and resolution.

The general philosophy regarding TGM's is to design these instruments in such a way that slit to grating distances and angles of incidence may fairly readily be changed to accommodate different optimization schemes. The designs presented here should therefore be regarded as illustrative examples.

## 3. Normal Incidence Beamlines U2 and U3

The two beamlines U2 and U3 are identical. Each has a 3.5 meter normal incidence monochromator which uses the source as an entrance slit(5). The beam is collected by three plane pre-mirrors which superpose their respective sources to a common source point. Since the total number of milliradians collected is 75, the tri-mirror arrangement is necessary to reduce the effective source size and maintain resolution. As shown in Fig. 2, the pre-mirrors also serve to direct the emerging beam away from the storage ring. With a .2mm source and a 3600$\ell$/mm grating, the resolution is ~ .2Å. Some flux estimates are shown in Fig. 7.

## 4. LiF Windowed Beamline U4

This line is divided into two, each of which has a commercial Czerny-Turner 0.5 meter monochromator installed (Fig. 3). In each case the radiation is intercepted by a plane mirror which collects some 40 milliradians. This light is focussed through a LiF window onto the entrance slit of the monochromator with a magnification of 0.5. Beamline U4A has the monochromator installed with vertical dispersion, while U4B has horizontal dispersion(6), the choices being made solely on the basis of convenience for the experimental chambers. Estimated fluxes are presented in Fig. 8.

## References

(1) K. P. Mijake, R. Kato and H. Yamashita, Sci. Light 18, 1, 39 (1969).

(2) M. R. Howells, D. Norman, G. P. Williams and J. B. West, J. Phys. E 11 199 (1978).

(3) A. Franks, K. Lindsey, J. M. Bennett, R. J. Speer, D. Turner and D. J. Hunt, Philos. Trans. A277 503 (1978).

(4) W. R. McKinney and M. R. Howells, This Conference Proceedings.

(5) E. L. Ederer, B. Cole and J. B. West, This Conference Proceedings.

(6) J. C. Sutherland, E. J. Desmond and P. Z. Takacs, This Conference Proceedings.

Table 1. NSLS UV beamline Schemes and Parameters.

| | U1(A)[7] | U1(B) | U1(C) | U2 | U3 | U4(A) | U4(B) |
|---|---|---|---|---|---|---|---|
| 1. # of horizontal mradians HORIZ | 5 | 30 | 20 | 75 | 75 | 40 | 40 |
| VERT | ≤1.4 | 10 | 10 | 10 | 10 | 10 | 10 |
| 2. Type of experiment | High resln. solid state | ARPES, SEXAFS[3] | SPARE mradians<br>AT PRESENT | None at present | Mol beam chemistry | Time resolved fluor | Biology[16] |
| 3. Type of monochromator(s) | Mijake | Double TGM[4] | | Normal incidence | Normal incidence | 0.5m Czerny-Turner[14] | 0.5m Czerny-Turner |
| 4. Wavelength range(s) Å | R1:30-65 R2:40-110<br>R3:90-240 R3:150-475<br>R5:400-1200 R1(A):25-50 | M1:8-100<br>M2:80-1600[5]<br>G1:80-120 G2:320-1600 | | 300-3000 | 300-3000 | 1050-12000 | 1050-12000 |
| 5. Limitation on resolution | Source size | M1 mostly source M2 Aberr | | Source size[8] | Source size[8] | Abberations | Aberrations |
| 6. Best resolution (Å) | R1:.016 R2:.022<br>R3:.039 R4:.062<br>R5:.1 R(A):.013 | M1:2eV<br>M2:G1 ~ .25<br>G2 ~ 1.0 | | 0.25[10] | 0.25[10] | 0.3 | 0.3 |
| 7. Special features | | 2 Mon'rs feed 1 sample | | | | Window, no fast valve | Window, no fast valve |
| 8. Plane of dispersion | Vertical | Vertical | | Vertical[9] | Vertical[9] | Vertical | Horizontal |
| 9. Dispersion (Å/mm) | [2]R1:1.20 R2:1.90<br>R3:3.4 R4:5.7<br>R5:9.1 R1(A):0.91 | G1 ~ .55<br>G2 ~ 2.2 | | 1.19 | 1.19 | 16.7 | 16.7 |
| 10. Angular acceptance(mr)(H × V) | Nominally parallel light | M1:3 × .25 M2:15 × 10 | | (75 × 10) | (75 × 10) | (115 × 115) | (115 × 115) |
| 11. Entrance slit | None | M1:No M2:Yes | | None | None | Yes | Yes |
| 12. Blaze wavelength (Å) | R1:45 R2:60<br>R3:135 R4:225<br>R5:600 R1(A):35 | M1:12<br>M2:G1:120<br>G2:480 | | 500 (say) | 1000 (say) | 1500 (say) | 1500 (say) |
| 13. Grating type | Plane, laminar | Toroidal, lamina[6] | | Spherical[11] | Spherical[11] | Plane[13] | Plane |
| 14. Groove density gr/mm | 600 and/or 1200 | M1:600 G1:1800 G2:450 | | 2400 | 2400 | 1200 | 1200 |
| 15. Ruled area (mm × mm) | 50 × 19 | M1:27 × 14 M2:75 × 25 | | 264 × 72 | 264 × 72 | 52 × 52 | 52 × 52 |
| 16. Grating/slit distance(mm) ENT | | M1:4498 M2:1151 | | | | | |
| 17. Grating/slit distance(mm) EXIT | | M1:4336 M2:1930 | | 3500 | 3500 | | |
| 18. Scanning method | Simple rotation | Simple rotation | | Rot & translation | Rot & translation | Simple rotation | Simple rotation |
| 19. Admittance at best resln. (mradian.mm)(Horiz × vert) | (≥5) × (≤0.28) | | | | | | |
| COLLECTION MIRROR DETAILS | | | | | | | |
| 20. Size (mm × mm) | 800 × 35 | M1:None M2:66 × 106 | | 248 × 32[12] | 248 × 32[12] | Two A & B[15] | Two A & B[15] |
| 21. Shape [radius(m)] | Spherical (80) | Ellipsoidal | | Plane | Plane | A Plane B Sphere | A Plane B Sphere |
| 22. Angle of incidence | 86° | M1:87.5° M2:75° | | 7.5° | 7.5° | A 5° B 5° | A 5° B 5° |
| 23. Magnification | 0.25 | 1.0 | | 0.5 | 0.5 | A - B 0.5 | A - B 0.5 |
| 24. Focal length(m) | 2.8 | | | | | A - B 0.77 | A - B 0.77 |

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Footnotes

[1] Using 1200 gr/mm grating.

[2] Using 600 gr/mm grating which gives best order sorting

[3] ARPES = Angle resolved photoelectron spectroscopy
SEXAFS = Surface extended x-ray absorption fine structure

[4] Called M1: 175° included angle and M2: 150° included angle
M1 has one grating M2 has two called G1 and G2
Note that NSLS TGM's will be configured so that the slit distances and included angle can be chosen at will. This allows a choice of the wavelength range of best resolution and of the low wavelength threshold. To change from one configuration to another would involve a resurvey.

[5] This is achieved with two gratings G1 and G2

[6] Without aberration correction

[7] See Brookhaven informal report #26027

[8] A slit can be placed with some difficulty near the source so that better resolution can be achieved.

[9] Has horizontal beam coming away from the storage ring.

[10] With 2400 gr/mm grating

[11] Special shape to 'match' shape of SR beam. Rulings are parallel to longest direction.

[12] In three segments each at the same distance from their own sources.

[13] Al/MgF$_2$ coating. Should be 80% reflection efficient at Lyman α

[14] Acton Research instrument is suggested.

[15] A double reflection is used, first a plane mirror then a spherical mirror both at near normal incidence. The latter images the source on to the monochromator entrance slit.

[16] Existing monochromator and experiment.

## Figure Captions

1. Schematic layout of NSLS beamline U1.
2. Schematic layout of NSLS beamline U2.
3. Schematic layout of NSLS beamline U4.
4. Estimated output flux from the Mijake type plane grating monochromator in beamline U1. The numbers refer to the ranges defined in table I.
5. Output flux estimated from the 2.5° TGM in beamline U1.
6. Output flux estimated from 15° TGM's in beamline U1. Solid line - instrument designed for constant energy resolution. Dashed line - instrument designed for constant wavelength resolution.
7. Estimated output flux from beamlines U2 and U3 for two gratings.
8. Estimated output flux for three gratings for beamline U4.

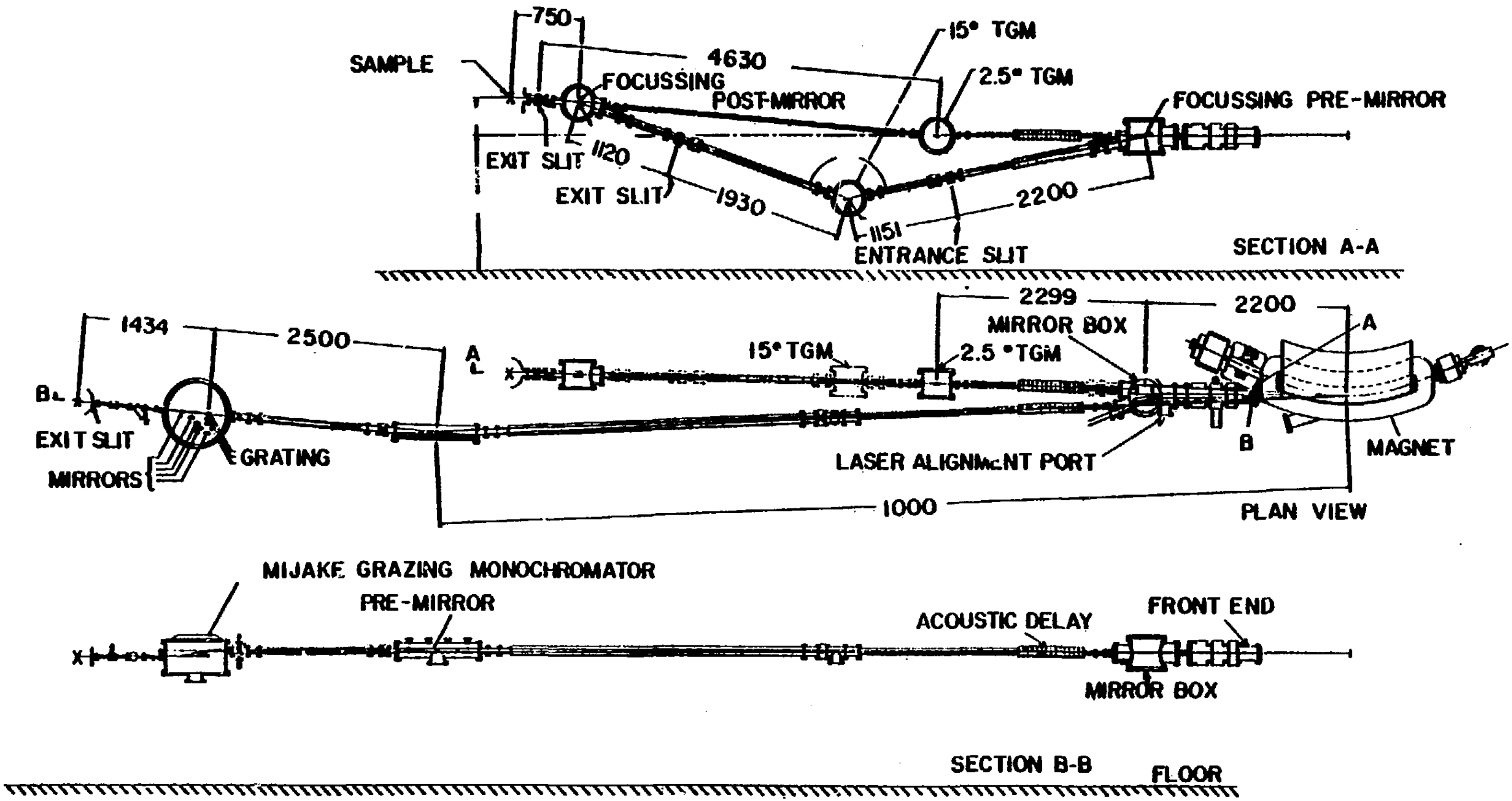

750
4630
15° TGM
SAMPLE
FOCUSSING
POST-MIRROR
2.5° TGM
FOCUSSING PRE-MIRROR
EXIT SLIT
1120
EXIT SLIT
1930
2200
1151
ENTRANCE SLIT
SECTION A-A
1434
2500
A
2299
2200
MIRROR BOX
A
15° TGM
2.5 °TGM
B
EXIT SLIT
MIRRORS
GRATING
LASER ALIGNMENT PORT
B
MAGNET
1000
PLAN VIEW
MIJAKE GRAZING MONOCHROMATOR
PRE-MIRROR
ACOUSTIC DELAY
FRONT END
MIRROR BOX
SECTION B-B
FLOOR

Figure 1.

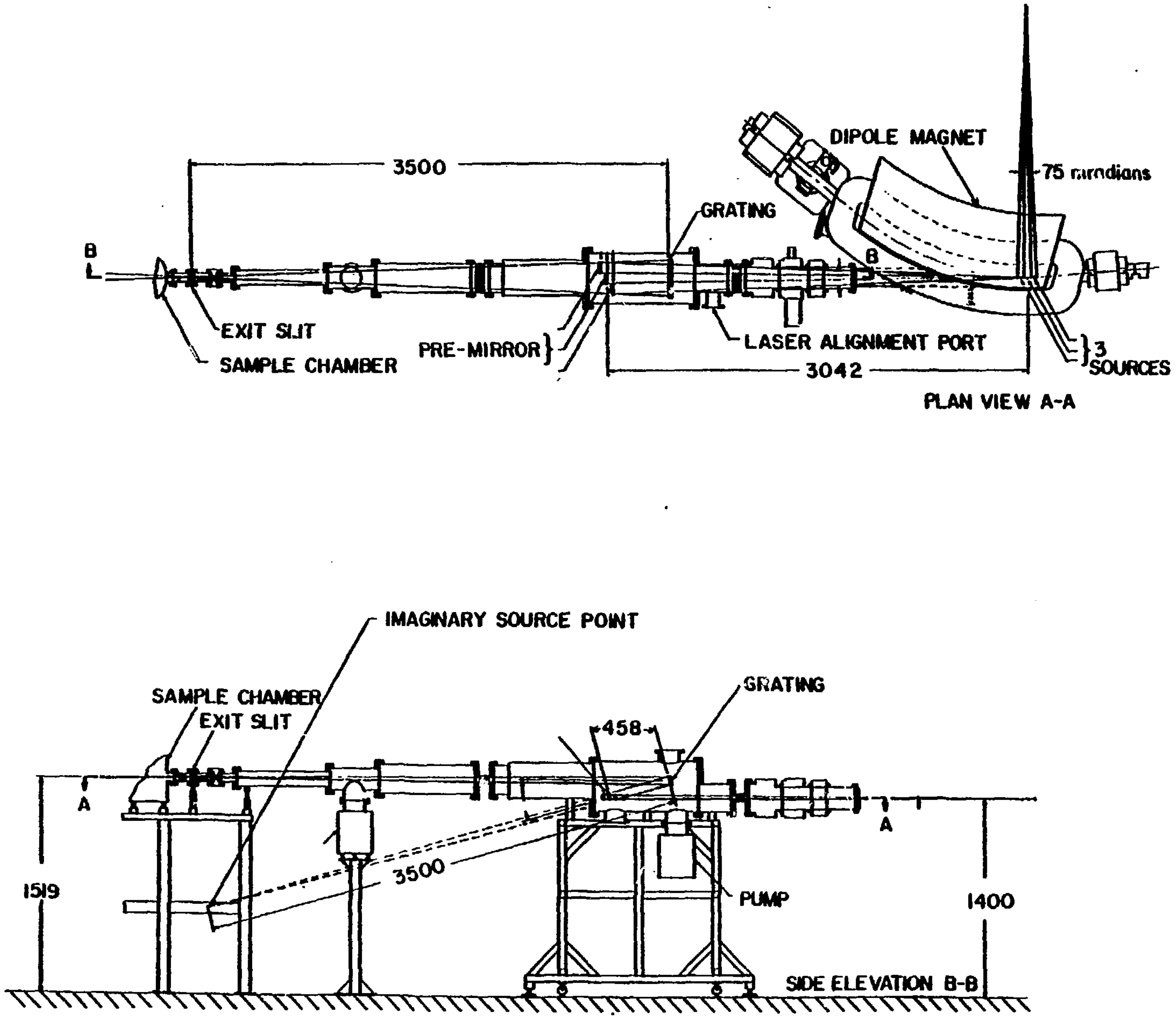

DIPOLE MAGNET
75 mradians
3500
GRATING
B
L
B
EXIT SLIT
PRE-MIRROR
SAMPLE CHAMBER
LASER ALIGNMENT PORT
3042
3 SOURCES
PLAN VIEW A-A
IMAGINARY SOURCE POINT
SAMPLE CHAMBER
EXIT SLIT
GRATING
458
A
A
3500
1519
PUMP
1400
SIDE ELEVATION B-B

Figure 2.

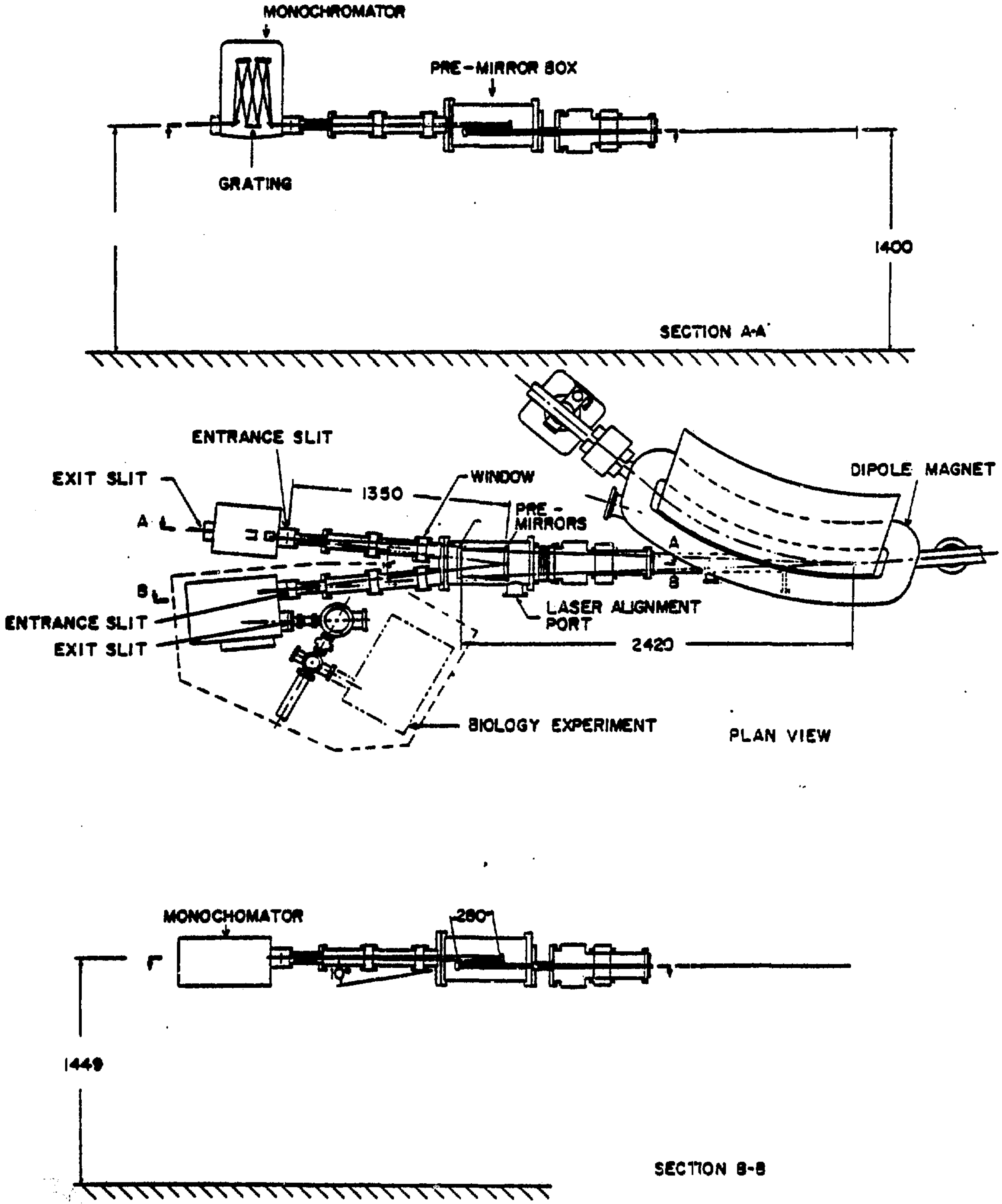
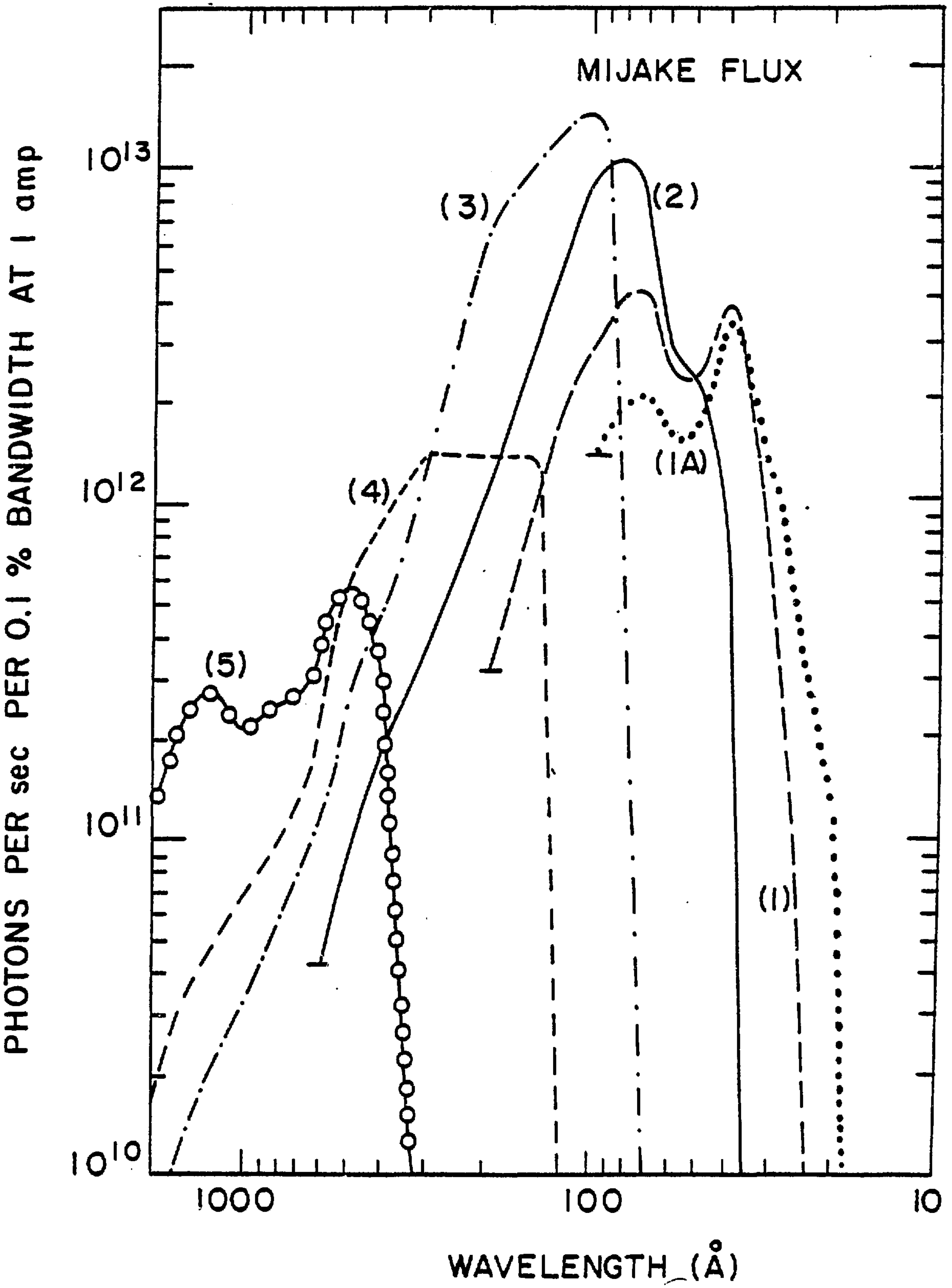
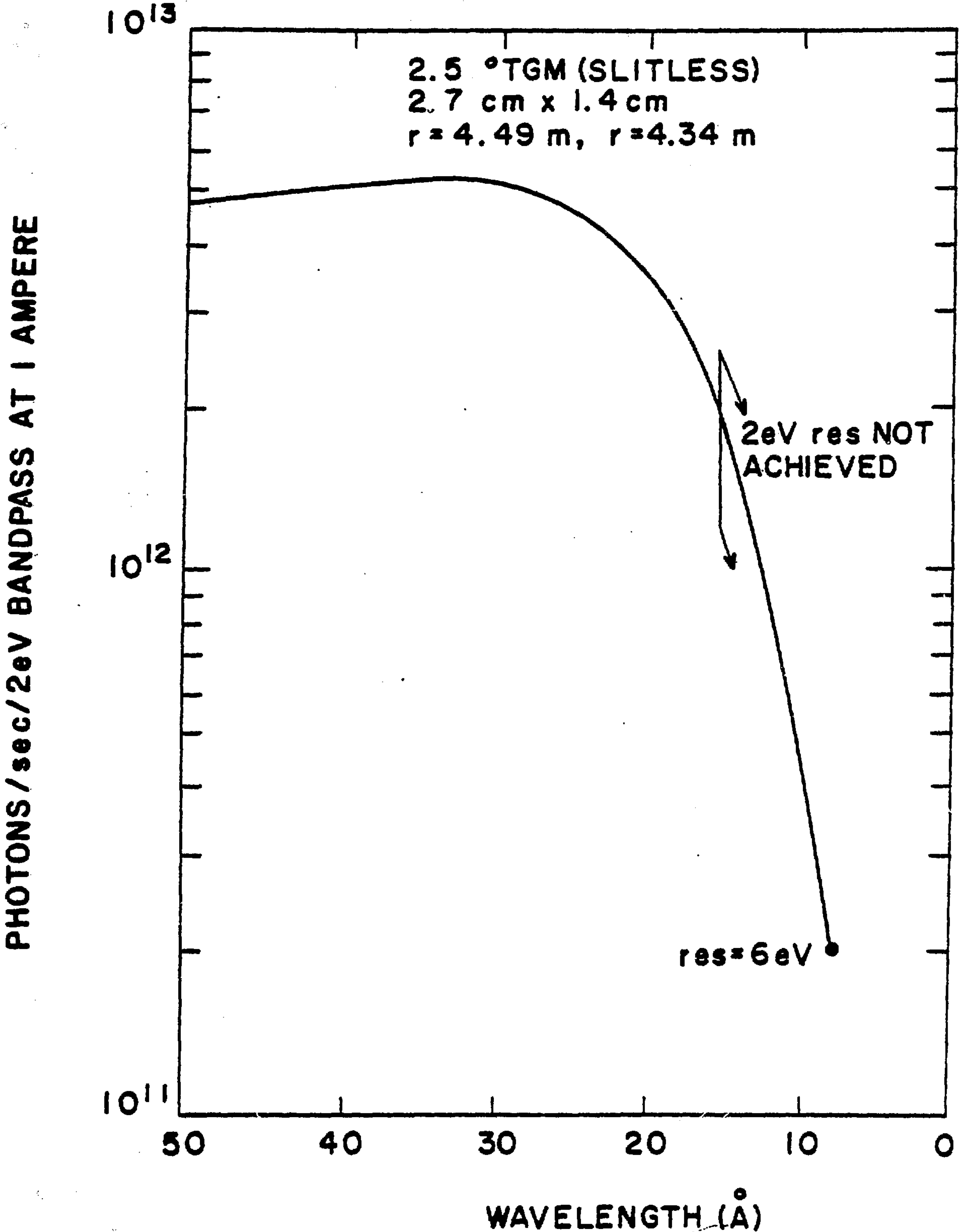

MONOCHROMATOR
PRE-MIRROR BOX
GRATING
1400
SECTION A-A
ENTRANCE SLIT
EXIT SLIT
1350
WINDOW
PRE-MIRRORS
DIPOLE MAGNET
A
B
LASER ALIGNMENT PORT
ENTRANCE SLIT
EXIT SLIT
2420
BIOLOGY EXPERIMENT
PLAN VIEW
MONOCHOMATOR
280
10°
1449
SECTION B-B

Figure 3.



MIJAKE FLUX
PHOTONS PER sec PER 0.1 % BANDWIDTH AT 1 amp
$10^{13}$
$10^{12}$
$10^{11}$
$10^{10}$
(1)
(1A)
(2)
(3)
(4)
(5)
1000
100
10
WAVELENGTH (Å)

Figure 4.



2.5 °TGM (SLITLESS)
2.7 cm x 1.4 cm
r = 4.49 m, r = 4.34 m
2eV res NOT ACHIEVED
res = 6 eV
PHOTONS/sec/2eV BANDPASS AT 1 AMPERE
$10^{13}$
$10^{12}$
$10^{11}$
50
40
30
20
10
0
WAVELENGTH (Å)

Figure 5.

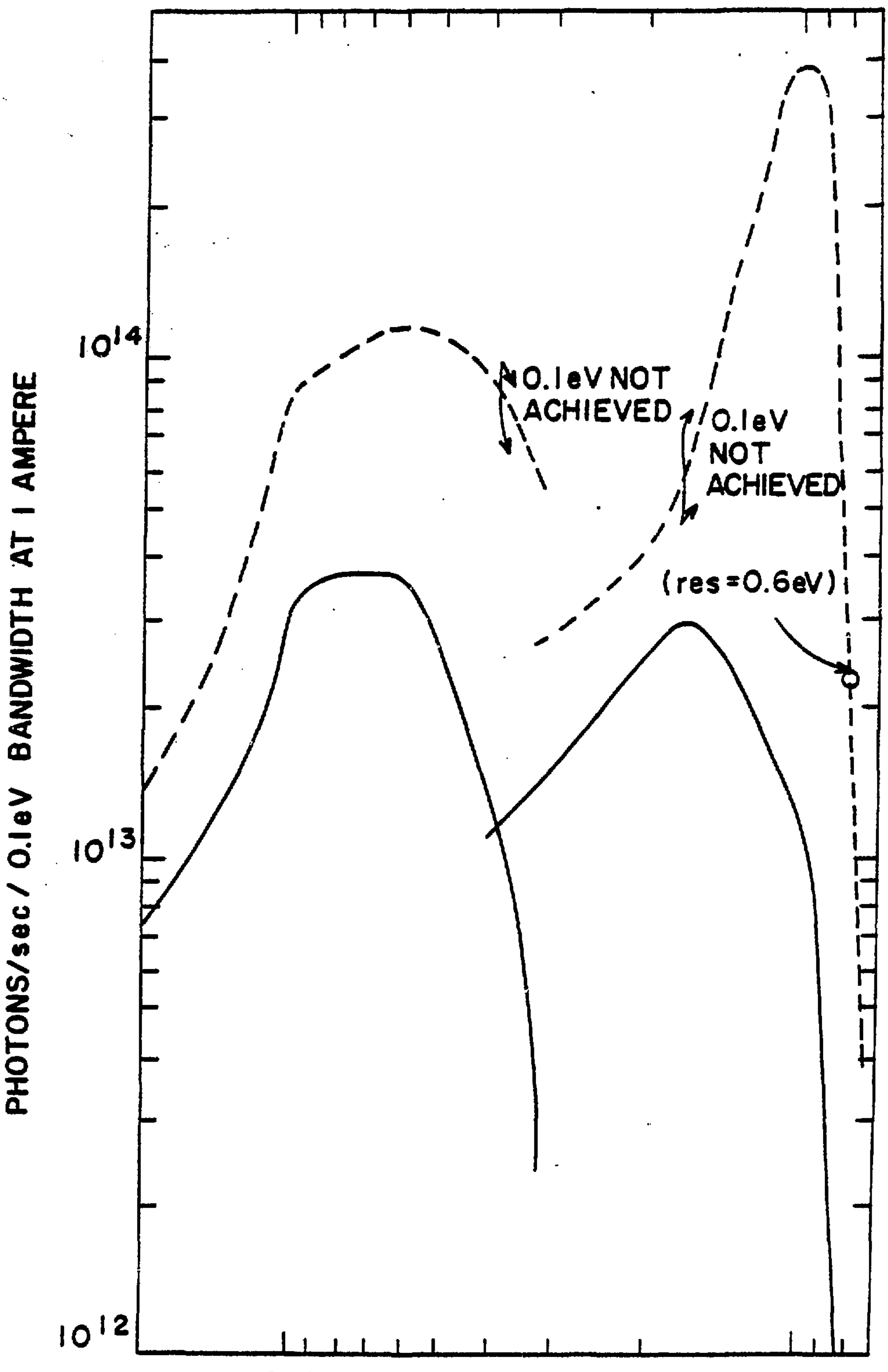

PHOTONS/sec / 0.1eV BANDWIDTH AT 1 AMPERE
10^14
10^13
10^12
0.1eV NOT ACHIEVED
0.1eV NOT ACHIEVED
(res=0.6eV)
1000
100
WAVELENGTH (Å)

Figure 6.

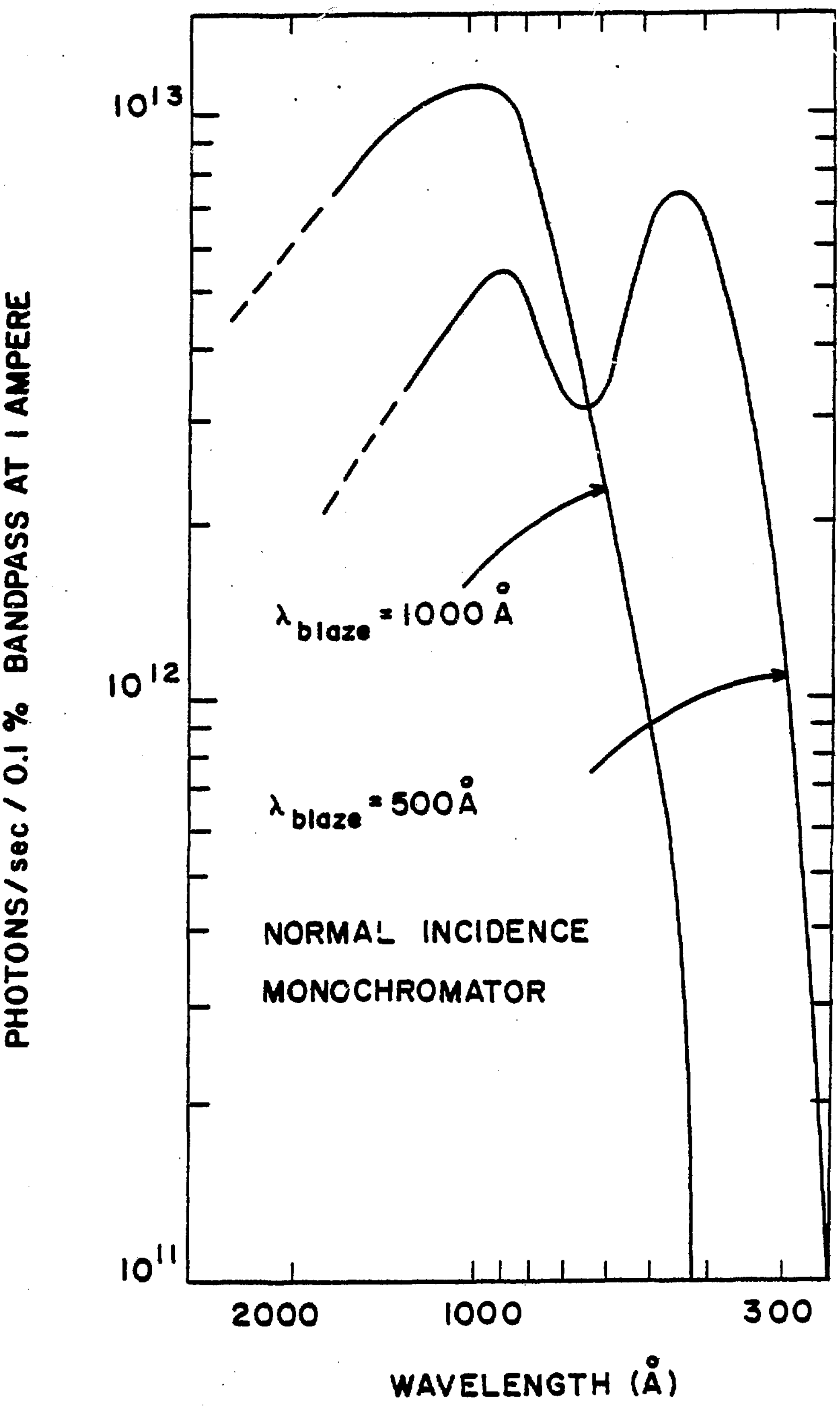

PHOTONS/sec / 0.1 % BANDPASS AT 1 AMPERE
$10^{13}$
$10^{12}$
$10^{11}$
$\lambda_{blaze} = 1000$ Å
$\lambda_{blaze} = 500$ Å
NORMAL INCIDENCE
MONOCHROMATOR
2000
1000
300
WAVELENGTH (Å)

Figure 7.

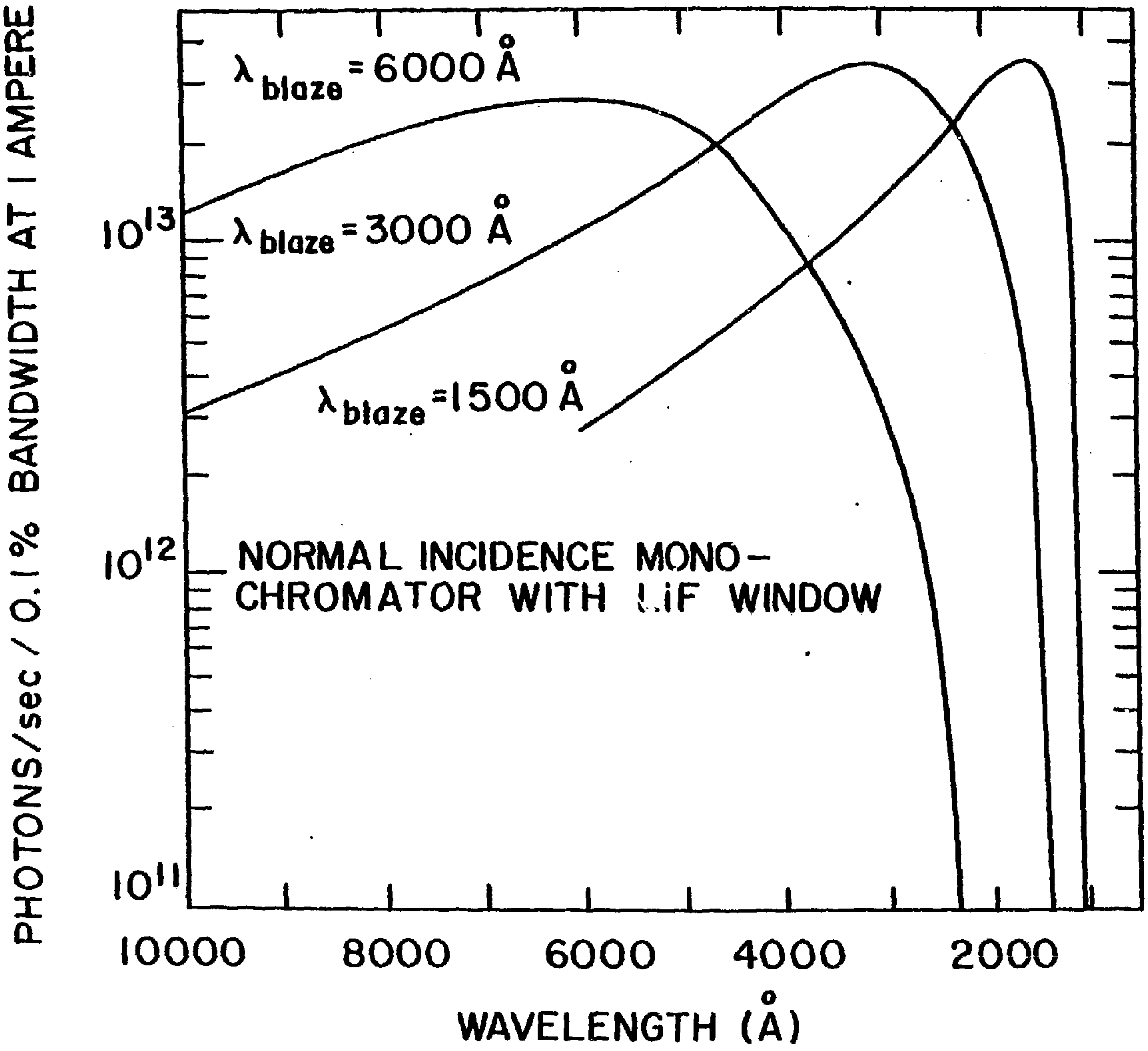

PHOTONS/sec / 0.1% BANDWIDTH AT 1 AMPERE
$10^{13}$
$10^{12}$
$10^{11}$
10000
8000
6000
4000
2000
WAVELENGTH (Å)
$\lambda_{blaze}$ = 6000 Å
$\lambda_{blaze}$ = 3000 Å
$\lambda_{blaze}$ = 1500 Å
NORMAL INCIDENCE MONO-
CHROMATOR WITH LiF WINDOW

Figure 8.