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The National Synchrotron Light Source VUV and Soft X-ray Beam Lines:
Performance Characteristics*

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ABSTRACT

A total of five beam lines are currently being constructed and commissioned at the NSLS. They involve a 2.75° toroidal grating monochromator, a plane grating grazing monochromator, a large aperture modified Wadsworth monochromator, a Seya-Namioka instrument and a Czerny-Turner instrument. We present details of these beam lines and their anticipated operational characteristics.

DISCLAIMER

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1. INTRODUCTION

At the present time there are five beam lines being installed by the NSLS on the 700MeV, 1A electron storage ring. Normal incidence Seya-Namioka, Czerny-Turner and modified Wadsworth monochromators will be utilized on beam lines U9a, U9B and U11 while grazing incidence plane grating and toroidal grating monochromators will be utilized on beam lines U14 and U15.

Some of the above beam lines will effectively use the small synchrotron radiation source size ($\text{FWHM} \approx 0.2\text{mm}$) as an entrance slit. Another feature that the beam lines have in common is that, wherever possible, synchrotron light is vertically reflected and dispersed to maintain a high degree of horizontal polarization. This procedure also results in an efficient use of floor space by extending beam lines away from the crowded region adjacent to the storage ring.

With experimental research expected to begin on the UV ring in September, 1981, the beam line design that we discuss below is at a more advanced stage than previously reported⁽¹⁾ and most of the optical components⁽²⁾ for these lines are in house. Below we will also provide revised photon flux estimates based on updated performance characteristics of each beam line's optical components.

2. Seya-Namioka Beam Line U9A

As shown schematically in Figs. 1 and 2, 37.5 horizontal mrad of synchrotron radiation are vertically deflected by a water-cooled plane mirror M1, and then focussed through a LiF window onto the entrance slit of the UHV Seya-Namioka monochromator by the spherical mirror M2 ($R=2000\text{mm}$). The plane mirror M1 is fabricated from copper and coated with $\text{MgF}_2/\text{Al}/\text{MgF}_2$. The spherical mirror M2 will be fabricated from fused silica and coated with Al/MgF_2 . The monochromator uses a concave

cylindrical mirror M3 ($R_1 = 221\text{mm}$) and a toroidal mirror M4 ($R_1 = 376\text{mm}$ concave; $R_2 = 112\text{mm}$ convex) to produce a stigmatic image of the source at a distance of 600mm from the exit slit. This distance was chosen in order to provide adequate space for the installation of an experimental chamber. Mirrors M3 and M4 will be fabricated from fused silica or Pyrex and coated with Al/MgF₂. The expected output flux is shown in Fig. 3 for two concave gratings with blazes of $1500\text{\AA}$ and $3500\text{\AA}$.

3. Czerny-Turner Beam Line U9B

As can be seen in Fig. 1, this beam line shares port (U9) with the Seya-Namioka beam line U9A. A water-cooled plane mirror deflects downward 37.5 horizontal mradians of synchrotron radiation incident at 45° , and an ellipsoidal mirror ($F_1 = 2580\text{mm}$, $F_2 = 1210\text{mm}$) then deflects the radiation horizontally while focussing it onto the vertical entrance slit of the Czerny-Turner monochromator with a magnification of approximately 0.5 . These two deflections rotate the source and polarization 90° to match the vertical entrance slits of the horizontally-dispersing Czerny-Turner monochromator. The plane mirror is made of copper with a MgF₂/Al/MgF₂ coating and the ellipsoidal mirror is made of fused silica with an Al/MgF₂ coating. It may be possible to choose an appropriate coating thickness for the ellipsoidal mirror so that the horizontally-deflected synchrotron radiation does not lose any of its polarization over specific wavelength ranges of experimental interest⁽³⁾. The output flux expected on this line is shown in Fig. 4.

4. Modified Wadsworth Beam Line U11

This beam line utilizes a Wadsworth monochromator to provide a maximum output flux while maintaining reasonable resolution. With the Wadsworth mounting it is possible to keep the primary aberrations of the concave grating (coma and astigmatism) small over a range of wavelengths close to the Wadsworth wavelength λ_w where they are zero⁽⁴⁾. For the NSLS design $\lambda_w = 866\text{\AA}$, giving a useful range of approximately 300 $\text{\AA}$ –3000 $\text{\AA}$.

The schematic layout for this line is shown in Fig. 5. A spherical mirror ($R=5754\text{mm}$) will collimate 55 horizontal mrad of synchrotron radiation which will then be vertically dispersed by a concave ($R=4000\text{mm}$) 1200g/mm ion-etched laminar grating and focussed onto a windowless interaction chamber for gas phase spectroscopy studies using a supersonic nozzle source. Both the mirror and the grating will be made from fused silica coated with osmium. Fig. 6 shows the estimated output flux for this beam line. The modified Wadsworth monochromator provides the highest flux available from any of the NSLS UV monochromators over the wavelength range of 300 $\text{\AA}$ –3000 $\text{\AA}$.

5. Plane Grating Monochromator Beam Line U14

The layout of the PGM beam line is shown in Fig. 7 where the positions of the mirror box, monochromator, preparation chamber and sample chamber are indicated. The extension of the slit into the experimental chamber prevents any further loss in flux that would occur if an additional mirror were located before the sample chamber.

A schematic of the PGM is shown in Fig. 8. The PGM uses a paraboloidal ($F=10\text{m}$) pre-mirror to collimate 4 horizontal mrad of synchrotron radiation incident at 88° . The light is then dispersed by a plane laminar grating and focussed by paraboloidal ($F=1\text{m}$) post-mirrors at incidence angles of 65° , 78° , 84° and 86° . The mirrors are diamond-turned Al/electrodeless Ni mirrors with gold coatings.

Total integrated scatter measurements performed on the mirrors after final polishing have yielded very low rms roughness values of $3.4 \pm 0.9 \text{ \AA}^{(5)}$.

A major reason for using the PGM design is to filter out diffracted orders higher than the first order by using mirrors after the grating^(6,7). Appropriate wave length scans were determined from plots of the first, second and third order thresholds for diffraction by a grating and reflection from the post-mirrors as a function of the angle of incidence α ⁽⁸⁾. By using negative order ($m=-1$), it is possible to suppress higher diffracted orders over a wider λ range than in positive order ($m=+1$). The λ ranges that are covered by the PGM in negative order are shown in Table I. The PGM uses two 600g/mm ion-etched laminar gratings: a 'high energy' grating (ranges 1 and 2) with a 110Å groove depth, and a 'low energy' grating (ranges 3 and 4) with a 200Å groove depth. The wavelength of maximum efficiency λ_m or the 'blaze' for each laminar grating was selected to give good grating efficiency over each wavelength range. The output fluxes for the four wavelength ranges are shown in Fig. 9 for negative order ($m=-1$). It is also possible to use positive order ($m=+1$) to achieve better resolution at the expense of higher order suppression and output flux.

A summary of the PGM performance is given in Table I where it is compared to the other NSLS UV monochromators. It should be emphasized that the PGM wavelength resolution is considerably smaller than the other monochromators at short λ .

6. 2.75° TGM beam line U15

The purpose of this line is to provide a high output flux at high energies with modest ($\sim 1\text{eV}$) resolution. As shown in Fig. 10, this is achieved by collecting 5 horizontal mrad of radiation using a toroidal grating ($R_1 = 100\text{m}$, $R_2 = 176\text{mm}$) as the only optical element, thereby

reducing reflection losses. The grating is an ion-etched 600g/mm laminar grating with an 83Å groove depth and is made from fused silica coated with gold.

The toroidal grating holder rotates the grating about a horizontal axis during wavelength scans and has a facility for carrying two interchangeable gratings. The output flux for the TGM is shown in Fig. 11 for an 87.25° angle of incidence.

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Figure Captions

- Fig. 1 - Schematic layout of NSLS Seya-Namioka beam line U9A and Czerny-Turner beam line U9B.
- Fig. 2 - Schematic of NSLS beam line U9A optical components.
- Fig. 3 - Estimated output flux on the U9A beam line for two gratings.
- Fig. 4 - Estimated output flux on beam line U9B.
- Fig. 5 - Schematic layout of NSLS modified Wadsworth beam line U11.
- Fig. 6 - Estimated output flux on beam line U11 for two gratings. The efficiency of the lamina grating oscillates below $400\text{\AA}$.
- Fig. 7a- Schematic layout of the front end and mirror box for beam line U14.
- Fig. 7b- Schematic layout of the plane grating monochromator, experimental chamber and preparation chamber for beam line U14.
- Fig. 8 - Schematic of the plane grating monochromator.
- Fig. 9 - Estimated output flux for the plane grating monochromator using a lamina grating with $100\text{\AA}$ groove depth for ranges 1 and 2 and a lamina grating with $200\text{\AA}$ groove depth for ranges 3 and 4.
- Fig. 10- Schematic layout of the 2.75° toroidal grating monochromator beam line U15.
- Fig. 11- Estimated output flux from the 2.75° toroidal grating monochromator.

NSLS VUV MONOCHROMATORS

	U9A	U9B	U11	U14A RANGE 1	U14A RANGE 2	U14A RANGE 3	U14A RANGE 4	U15
TYPE OF MONOCHROMATOR	0.5M SEYA	0.5M	4M WADSWORTH	PGM	PGM	PGM	PGM	2.75° TGM
WAVELENGTH RANGE (Å)	1200-12000	1200-12000	300-3000	20-40	30-150	75-315	200-1500	10-80
TYPICAL RESOLUTION (Å)	0.5	0.5	0.5	0.017	0.024	0.055	0.11	1eV
FLUX O/P (EST.) (PHOTONS/SEC/AMP/0.1eV)	1×10^{15}	2×10^{15}	8×10^{14}	2×10^{11}	2×10^{11}	3×10^{12}	1×10^{12}	2×10^{11}
WAVELENGTH (λ_0) OF FLUX ESTIMATE (Å)	2000	2000	1000	32	46	181	350	20
ORDER SORTING	POOR	POOR	GOOD	EXCELLENT	EXCELLENT	EXCELLENT	GOOD	POOR
POLARIZATION	GOOD	POOR	POOR	GOOD	GOOD	GOOD	GOOD	GOOD
DIVERGENCE OF O/P BEAM IN PLANE OF DISPERSION (MR)*	10	100	80	0.4	2.3	6.1	8.2	0.2
OUT OF PERP. PLANE (MR)*	38	25	11	50	46	45	41	2.5
HORIZONTAL ANGLE COLLECTED (MR)	38	38	55	4	4	4	4	5

*AT WAVELENGTH (λ_0)

FIG. 1

FIG. 3

FIG. 4

NSLS WINDOWLESS GAS PHASE BEAM LINE

FIG. 5

FIG. 6

MIRROR BOX

FIG. 7a

FIG. 7b

GRAZING INCIDENCE PLANE GRATING MONOCHROMATOR

FIG. 8

FIG. 10

FIG. 11