Submitted to Synchrotron Radiation Conference, Novosibirsk, USSR, July 4-6, 1984

BNL-35004
CONF-840780--1

BNL--35004
DE84 015291

PHASE II BEAM LINES AT THE NATIONAL SYNCHROTRON LIGHT SOURCE

W. Thomlinson
National Synchrotron Light Source
Brookhaven National Laboratory
Upton, New York 11973

JUNE 1984

PHASE II BEAM LINES AT THE NATIONAL SYNCHROTRON LIGHT SOURCE

W. Thomlinson
National Synchrotron Light Source
Brookhaven National Laboratory
Upton, New York 11973

June 1984

Research Supported by the
OFFICE OF BASIC ENERGY SCIENCES
U.S. DEPARTMENT OF ENERGY
WASHINGTON, D.C.

NATIONAL SYNCHROTRON LIGHT SOURCE
BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.

Under contract No. DE-AC02-76CH00016 with the
United States Department of Energy

I. Introduction

In July of 1982, Dr. A. van Steenbergen presented a paper at the Synchrotron Radiation Conference in Novosibirsk in which the commissioning of the National Synchrotron Light Source and the development of special radiation sources were discussed.[1] Since that time, the U.S. Department of Energy has funded the Phase II Project at the NSLS to provide laboratory and experimental support areas for approximately 80 beam lines, to provide integrated work and office space for the entire NSLS staff, and to design and construct six beam lines.[2] Five of the new beam lines will utilize the radiation from special insertion devices such as those discussed by van Steenbergen.[1] This paper will concentrate mainly on the four beam lines which are presently under development, presenting as much information on their photon spectra, hardware development, conceptual designs, and scientific program as possible at this time. In some cases, however, details of the experimental end stations, detectors, and even the photon optics have not been decided yet. No discussion will occur for the NSLS Phase I operations, other than the inclusion of the machine parameters listed in Table I for completeness. The non-Phase II programs such as the Free Electron Laser, the Compton Backscattering Experiment, the Transverse Optical Klystron, and the arc source lines included in Phase will not be discussed.

The Phase II beam lines, with the excep on of the infrared line on the VUV ring, will utilize insertion devices installed in the long straight sections of the storage rings. The six beam lines are listed, along with the type of insertion device, in Table II, and their locations are shown on Figure 1. This figure shows the proposed layout of the expanded experimental level of the NSLS. A second story expansion will contain offices and technical support work areas for the NSLS staff.

Table 1

NSLS, ACCELERATOR AND STORAGE RING PARAMETERS

	X-RAY STORAGE RING	VUV STORAGE RING	BOOSTER SYNCHROTRON
ENERGY RANGE (GeV)	0.7-2.5	0.7	0.1-0.7
DESIGN CURRENT (A.)	0.5 (1.9 10^{12} e^-)	1.0 (1.1 10^{12} e^-)	0.02 (=10^{10} e^-)
CIRCUMFERENCE (m.)	170.1	51.0	28.35
B(max.), (ρ) (T.), (m.)	1.22 (6.875,	1.22 (1.91)	1.22 (1.91)
τ_{ORB}, (h) (NSEC)	567.7 (30)	170.2 (9)	94.6 (5)
DAMPING TIMES (SEC.)	τ_x=τ_y=0.006; τ_ε=0.003*	τ_x=τ_y=0.021; τ_ε=0.011	τ_x=0.006; τ_y=0.012; τ_ε=0.013
$\tau_{TOUSCHEK}$ (HRS.)	≳8 (2.5 GeV)	≳3**	≳1.4 (0.7 GeV)
LATTICE STRUCTURE	SEP. FUNCT. TRIPLETS, 8f.	SEP. FUNCT. DOUBLETS, 4f.	HYBRID STRUCT., FODO, 4f.
MAGNET COMPLEMENT	16B (2.7 m.)	8B (1.5 m.)	8B (1.5 m.) (+defoc. comp.)
	40Q (0.45 m.) 16Q (0.8 m.)	24Q (0.3 m.)	8Q (0.3 m.) (foc. elem. only)
	32S (0.2 m.)	12S (0.2 m.)	4S (0.2 m.)
NOMINAL TUNES ν_x,ν_y	9.7, 5.7	3.3, 1.3	2.4, 1.4
MOMENTUM COMPACT., α_p	0.0065	0.023	0.106
RF, FREQUENCY (MHz)	52.880	52.880	52.880
RADIATED POWER (KW)	252+33 $W_{WIGGLER}$	11.3	0.22
RF, PEAK VOLTAGE (KV)	800	100	20
DESIGN RF POWER (KW)	500 (300 BEAM)	50	0.4
ν_s	0.0042	0.0022	0.0015
ENERGY SPREAD, (σ_ε/E)	8.2 10^{-4}	4.4 10^{-4}	6.4 10^{-4}
NAT. BUNCH, 2σ_L (cm)	10.5	7.6	16.0
EQUIL. ε_x (m.rad)	8.0 10^{-8}	8.8 10^{-8}	4.8 10^{-8}
(K=0.1): ε_y (m.rad)	8.0 10^{-10}	8.8 10^{-10}	4.8 10^{-10}

* τ_x=τ_y=0.26 sec; τ_ε=0.13 sec at 0.7 GeV with $\hat{V}_{rf}$=50 kV.

** For $\hat{V}$=100 kV at twice the natural bunch length.

Table 2. Experimental Beam Lines and Insertions

NSLS Phase II Construction

Beam Line	Port Number	Insertion Device
High Energy Material Science and Angiography	X17	Superconducting Wiggler
High Q Resolution X-ray Scattering	X25	Hybrid Wiggler
X-ray Microscopy and Holography	X1	Soft X-ray Undulator
Infrared	U3	None
Soft X-ray Spectroscopy	U13	Multipole Wiggler
High Energy Resolution Inelastic X-ray Scattering	X21	Hybrid Wiggler

II. X17 - Material Sciences and Coronary Angiography

Almost any field of synchrotron radiation experimentation has classes of experiments which need, or could benefit from, a high brightness source at energies between 20 and 100 keV. In order to provide such a source, the NSLS has designed, constructed, and tested the superconducting wiggler magnet discussed previously.[1] Its parameters and the principle uses of the beam line to be built on it are summarized in Table 3. The photon spectrum is presented in Figure 2 and compared with the flux from the NSLS arc sources and the hybrid wiggler to be constructed for the X25 and X21 beam lines (see below). A cross section of the superconducting wiggler is shown in Figure 3.

Table 3. X17 - Material Science and Coronary Angiography - High Energy Photons

High Field Superconducting Wiggler:	7 poles - 5 @ 5 Tesla 2 @ 2.5 Tesla 17.4 cm period Fixed Gap E_C = 25 keV
Horizontal mrad:	39.6 (15 usable)
Peak Power:	3.21 kW/mrad^2
Energy Range:	10-100 keV variable for material science 33 keV dual energy for angiography
Scientific Program:	Crystallography, EXAFS, topography, high pressure physics, human coronary angiography

Although this paper will be able to give only summaries of the uses, plans, engineering, and decisions related to the X17 beam line (and the others as well), a complete description with engineering details can be found in the conceptual design report (CDR) prepared for the U.S. Department of Energy.[3] Each of the Phase II beam lines has a conceptual design report available from the NSLS. As detailed in the CDR, the X17 program is multi-purpose and hence complex. For example, due to vacuum chamber and magnet constraints, only 15 mrad of the total 48 mrad of horizontal radiation is available. The central 5 mrad is to be instrumented for Phase II and must serve programs in EXAFS, crystallography, high pressure, topography, and human coronary angiography. The material research programs will share an experimental area inside the present building at about 30 m from the source. For 25% of the time, however, the 5 mrad beam will be brought through the hutch into a new angiography laboratory to be constructed in the new expanded area. The angiography program is under the direction of Dr. E.B. Hughes from Stanford University.[4] The beam line optics, i.e. focusing monochromator, for the materials research is now under development at the NSLS. It will be a two-crystal device, initially nonfocusing, but will advance to a focusing geometry as experience is gained. It will be tunable from 10 keV to as high as 100 keV, with scan ranges of 1 keV. The horizontal collection angle and focusing properties are unknown at the present time.

For the angiography program, the optics are being built now for use with the current experimental program at the Stanford Synchrotron Radiation Laboratory. The dual energy monochromator, focusing systems, timing slits, data acquisition systems, etc. will be upgraded continuously and eventually either brought to the NSLS or constructed for use specifically at the NSLS.

The front end hardware has been designed to not only allow the 5 mrad central beam out, but also a fan of radiation continuously variable from 0 to approximately 3 mrad on each side. Proposals for the use of these side beams are being solicited, but the rather difficult geometry involved limits the types of viable proposals. It is conceivable that on one side a white beam can be developed, and on the other side, a fixed single energy monochromatic line.

In the discussion to this point it has been assumed that the white beams come out safely from the storage ring through the front end exit chambers and beam defining hardware. Actually the overwhelming percentage of the design effort on X17 (and therefore for X1 and X25 as well) has been learning how to design hardware to handle the extremely intense radiation beams. A study of the power densities in the insertion device beams shows that even for the undulators, peak powers of 1-6 kW/cm^2 occur. Figure 4 shows the front end for X17 and illustrates the type of absorber, apertures, and diagnostics necessary. Wherever the beam can strike walls, beam splitters, chambers, photon shutters, variable apertures, or filter assemblies, a detailed thermal and stress analysis has been carried out using a finite element computer code.[3,5] For example, Figure 5 shows the power profile for the SUW beam incident at 6° on a water cooled Cu absorber at a distance of about 9 meters from the source. The 6° angle reduces the power density on the Cu to a level where the thermal cycling and fatigue lifetimes are acceptable. On some absorbers, such as the beam splitting stops, an angle of 2° was found to be necessary. Incorporating these results into the design, leads to a typical piece of hardware such as the X17 photon shutters shown in Figure 6. In this case, a 6° absorber for the central 5 mrad operates by moving vertically in and out of the beam, whereas the side beams are varied in width by horizontally moving absorbers. Each of the high intensity beam lines will use variations of these techniques.

In order to insure that the photon beam does not destroy the exit chamber, several techniques will be employed: first, vertical electron beam scrapers will be installed to limit the vertical angular deviations of the synchrotron beam to ± 3 mrad. Second, the exit chambers have been completely redesigned with properly water cooled surfaces and a larger vertical slot for the beam. Third, active feedback on the photon beam position will be obtained from beam position monitors. Initially, the concept for the monitors will be that currently used on beam line VI at SSRL.[6] They consist of vertical tungsten blades which emit a photoemission current when struck by the photon beam. A difference signal between the blades above and below the beam can be calibrated to give beam position.

It is desirable, and necessary on X17, to eventually bring the white beam through a Be window. In order to accomplish this, the staff at the Lawrence Berkeley Laboratory and SSRL designed a series of thin pyrolitic graphite foils which absorb sufficient low energy radiation from the synchrotron beam.[7] The graphite absorbs the radiation and then radiates the energy as heat. Following their example, the NSLS has designed a filter set for the X17 beam lines.[8] Figure 7 shows the effects on the photon spectrum of inserting a set of filters, followed by a Be window. All beams on X17 will go through the graphite and Be window. In addition, Suortti[8] has designed a Xe gas filter which will be used when the angiography experiments at 33 keV are being carried out. This combination reduces the power on the angiography monochromator by a factor of 5, with only a factor of 2 reduction in flux at the iodine K-edge. The graphite/Xe assembly is shown in Figure 8.

As stated earlier there is a very diverse community desiring instrumentation and beam time on the superconducting wiggler line. The necessary resources, both financial and manpower, must be a shared responsibility between the NSLS and users. The NSLS is in the process of establishing the agreements which will encourage participation by outside groups in return for appropriate priority usage of the beam lines. An Insertion Device Team is being established, headed by Dr. W. Thomlinson, to coordinate this instrumentation effort. Similar IDT's are being formed for the other Phase II beam lines. Thus, in the next few months decisions will be made by the X17 IDT regarding the optics, end stations, data acquisition and computer control systems. and beam line design.

III. X-25 High $\vec{Q}$ Resolution Scattering Beam Line

Extensive experience with high $\vec{Q}$ resolution x-ray scattering has provided many examples of the important scientific value of this type of experiment. The x-ray intensity levels associated with NSLS bending magnet beam lines will be inadequate for many frontier areas of structural physics research. Fortunately, intensity levels may be increased by factors of 10 to 100 using short-period, permanent-magnet wigglers which are uniquely suited to installation in NSLS straight sections. Examples of such programs that need a high intensity source are studies of incompletely ordered hydrocarbon monolayers reconstructed on modulated monolayers, atomic clusters, magnetic scattering, and Wigner lattice systems. The magnetic device, and associated beam line, being constructed during the Phase II program are described by J. Hastings in the Phase II Conceptual Design Report.[9] The beam line is to be installed on beam port X25 at the NSLS.

The hybrid wiggler for this beam line will be of the permanent magnet construction described by van Steenbergen[1], and whose parameters are summarized in Table 4.

Table 4. X25 - High Q Resolution Scattering - High Brightness Source

Hybrid Wiggler:	15 periods (12 cm)
	$SmCo_5$/Vanadium Permadur Variable Gap
	E_c(1 cm, 2T) = 8.3 keV
	E_c(2.2 cm, 1.1T) = 4.58 keV
Horizontal mrad:	3.0 at 1.1T
	5.4 at 2.0T
Peak Power:	3.53 kW/mrad^2 at 1.1T
	6.42 kW/mrad^2 at 2.0T
Energy Range:	1-16 keV
Resolution:	$\Delta E/E \sim 10^{-4}$
Scientific Program:	Surface structural probe, phase transitions, magnetic scattering

The 15 period magnet will have $SmCo_5$ magnets and Vanadium Permadur poles. Figure 9 shows a cross section of the magnet. One feature of this device will be the variable gap chamber which will have a gap continuously variable from 1 cm (on axis field 2T, E_c = 8.3 keV) to 2.2 cm (on axis field 1.1T, E_c = 4.58 keV). This places the peak energy of the photon beams in the energy range 1-16 keV. The photon spectrum is shown in Figure 2. Note the extremely high intensity of the beam relative to the arc source. Table 4 also illustrates the very high power densities that must be dealt with for this insertion device. Thus, the same exit chamber as for X17 will be used on X25, and similar solutions to apertures, filters, and shutters are being planned.

The design value for the resolution, $\Delta Q/Q \sim \Delta E/E \sim 10^{-4}$ will be achieved by a combination mirror/monochromator system. The monochromator will be the same basic design as the two-crystal system to be developed for the X17 line. The proposed focusing system is based on the ideas of the Kirkpatrick-Baez microscope[10] and multilayer reflectors to achieve a high throughput-small aberration optical system.[11] The first element will be a horizontal focusing reflector, coated with multilayers of tungsten and carbon to take the high heat load from the beam. The second element, the vertical focusing Pt coated mirror, the Be window, and the monochromator will thus see very low power levels. A research and development program is necessary to prove the technologies, although much progress has been made by Barbee.[12]

IV. X1 - Holography and Microscopy Beam Line

This beam line is designed primarily for soft x-ray imaging experiments. These include forms of microscopy, holography, diffraction, etc. The experiments are directed primarily, although not exclusively, toward developing and using tools for biological research.[13, 14]

Any experiments involving the elements C,O,N in an important way have a special interest in the energy region spanning the K edges of those elements. The overall science needs appear to be well served by a larger range, say: 0.25 - 3.5 keV.

For imaging experiments it is necessary to have beams of sufficient spatial and temporal coherence. In the absence of a naturally coherent source like a laser we must select the coherent part of the output of a non-coherent source. The spatially coherent part is selected by using a pinhole which subtends an angle at the source equal to the source's coherence angle. This accepts only a small fraction (<0.1%) of the total emission angle. The flux emitted into the coherence solid angle can be shown to be proportional to the brightness. Hence, the need for a high brightness source. Temporal coherence is achieved by the use of monochromators. The coherence length ($\lambda^2/\Delta\lambda$) of the radiation is determined by the monochromator resolution ($\Delta\lambda$). The required values of this differ for different experiments so a flexible monochromator is needed which optimizes flux for both modest resolution ($\lambda/\Delta\lambda \sim 200$-$400$ for microscopy) and high resolution ($\lambda/\Delta\lambda > 1000$ for some types of holography).

To get the highest brightness source with the required wavelength coverage we use an undulator, which can be tuned so that the region 0.25-0.65 keV is covered fully by the first harmonic for a 2.5 GeV storage ring energy. This device also covers a much wider range with high flux using higher harmonics: up to 3.5 keV at half maximum flux for 2.5 GeV. Detailed discussions of this device have been given by van Steenbergen[1] and Howells.[14] The important parameters for the beam line are given in Table 5.

Table 5. X1 - Holography/Microscopy - Bright, Coherent Source

Undulator:	37 periods (8 cm)
	$SmCo_5$/Iron Poles
	Variable Gap
Horizontal mrad:	0.43 at K=0.5 (B=0.067T)
	0.88 at K=2.6 (B=0.348T)
Peak Power:	2.98 kW/mrad^2 at K=2.6
Energy Range:	0.25 - 3.5 keV
First Harmonic:	19-72 Å
	(0.65 - 0.17 keV)
Scientific Program:	Imaging biological samples

The undulator spectrum produced by this permanent magnet, variable gap source is shown in Figure 10, for a specific value of the magnetic deflection parameter K=0.5 (B=0.067T). As indicated in Table 5, K can vary from 0.5 to 2.6, varying the first harmonic wavelength from 19-72 Å. It is interesting to note that although the total power produced by the magnet is small since the horizontal angle is only 0.43-0.88 mrad, the power density on axis is ~ 3 kW/mrad^2. Thus, many of the thermal designs for apertures, chambers, and optics are equivalent to those for the X17 high field wiggler. For example, the photon shutters are shown in Figure 11. Details of the magnetic structure for the undulator assembly, and the variable gap drive assembly are shown in Figures 12 and 13.

The proposed layout of the X1 line, and its placement in the NSLS facility are shown in Figure 14. Two beam lines are illustrated, one being the central high brightness coherent beam for the imaging line. Note the position of the separation mirror with a slit which passes the central beam to the 100 μ diameter pinhole. The pinhole follows the splitting mirror so it receives the full power density but only 20% of the total power. A great deal of effort in the proper thermal design has gone into the design of the mirror and pinhole.

The splitting mirror is a flat, horizontally deflecting mirror large enough to accept the whole beam. It allows the central beam through and deflects the remaining beam at 5°. This beam will be used for soft x-ray spectroscopy where the coherence of the radiation is not important. The mirror will be water cooled, electroless nickel plated copper. A detailed engineering study has been performed to develop this grazing incidence high power mirror which controls thermal distortions.[14]

V. IR4 - Infrared Beam Line

The only Phase II beam line not associated with an insertion device is the infrared beam line to be placed near beam port U4 on the NSLS VUV ring. The description of this beam line can be found in detail in the Conceptual Design Report by G. Williams.[15]

Table 6. IR4 - Infrared Spectroscopy - High Brightness, Large Aperture Source

VUV Bending Magnet:	E_C = 0.5 keV
Wavelength Range:	300 Å - 1 mm
Brightness:	1000 x black body @ 2000 K
Scientific Program:	Surface vibrational structure, relaxation effects in semi-conductors

The primary design goal is to extract 90 mrad horizontally by 90 mrad vertically of radiation and transport it to an accessible 1:1 focus. It is required that wavelengths up to 1 mm be brought to the experiments. The large acceptance angle is needed to preserve the source brightness at the long wavelengths where diffraction would be significant. The characteristics of the radiation expected to be available are given in Table 7, and listed on Figure 15.

Table 7. Characteristics of the NSLS Emission in the Infra-Red

λ(μm)	Flux Photons/Sec/0.1% $\Delta\lambda/\lambda$	Radiation Opening Angle (mrads) VxH
1	5.8×10^{14}	9 x 90
10	2.9×10^{14}	35 x 90
100	1.2×10^{14}	75 x 90
1000	5.6×10^{13}	90 x 90

A great deal of design effort has been expended on several unique problems: extraction of the large aperture beam from the storage ring, design of a beam line to bring the radiation up to a platform experimental area, and optical devices. The scheme for extracting a beam with a large opening angle is shown in Figure 15.

Shown are the existing 5° and 22° ports and the suggested infra-red port at 33.5°. It can be seen that the extracted beam is of radiation which would otherwise be wasted. The front end design allows the primary restriction in vertical aperture (the dipole coil separation) to be much closer to the source and hence subtend a much larger angle. Furthermore, a wide vertical slot of 40 mm would be cut in the ring vacuum chamber compared to the 6 mm at a standard port. The length of the slot would be 290 mm compared to 168 mm or 216 mm on a standard port. As far as the electron beam is concerned, thin film resistors are required on the side of the extraction line to compensate for the change in impedance which such an orifice represents. The design shown in Fig. 15 also calls for water cooling at the back of the new chamber in case the first mirror is removed as will be discussed later.

The optical design is controlled by (a) high power loadings on the first mirror (b) the need to transport the beam out of and away from the ring without interference with existing ports (c) diffraction and (d) the desire only to have pure horizontal or pure vertical deflections of the beam for polarization control. The conceptual design is shown in Figure 16.

The I-R beam is extracted by M1, which is a plane mirror 661 mm from the source and of dimensions 63 x 90 mm. M1 will have to be cooled and may be made of silicon carbide. M2 is also a plane mirror of size 115 x 163 mm, 550 mm above M1 and the M1,M2 combination is designed to be able to be inserted (or extracted) as a prealigned pair without breaking machine vacuum. The M1,M2 "periscope" sends the beam back along in the "upstream" direction of the electron beam to M3, which is an ellipsoidal mirror 145 mm x 205 mm situated 314 mm from M2. M3 deflects the beam horizontally by 90° (p-polarization) onto the experimental floor where it is intercepted by plane mirror M4 880 mm away and of dimension 72 x 102 mm. M4 deflects the beam vertically to M5 which is 820 mm away and is a focusing mirror identical to M3. Thus, an image of the source with a magnification of 0.9 is produced (primary focus) between M4 and M5 which is remagnified to give a 1:1 image (secondary focus) near the window, 1550 mm from M5.

For the secondary focus, a number of beam line options are possible, one of which is to refocus onto the entrance slit of a grating spectrometer. Another depicted schematically in Figure 16 is to collimate the beam into an interferometer.

As with the insertion device lines, thermal loading in the optics is a problem, especially the first mirror M1. The total power in the mirror is 224 W but the power density at the center is 481 W/cm^2. A careful thermal distribution analysis is being done to study the cooling techniques, and to understand the tolerance of the long wavelengths to thermally induced figure changes.

Finally, the problem of manufacturing the off-axis ellipsoids, M3 and M5, is being solved in cooperation with the Lawrence Livermore Laboratory. Figure 17 shows that a diamond turning machine must have a clear throat of about 2300 mm, if the mirrors are to be diamond turned metal. Such a machine may be available at LLL with some modifications to the mirror mounts.

VI. Future Beam Lines

There are two beam lines which have been approved for Phase II construction but which, for reasons of scheduling and technical development are not in a detailed design stage. Both the High Energy Resolution Line (X21) and the Soft X-Ray Spectroscopy Line (U13) have been deferred to the future, contingent upon the progress made on the four lines already discussed. That is not to say that the basic goals, both scientific and engineering, have not been established. As is clear from Table 8, some basic parameters have been established.

Table 8

X21 - High E Resolution Scattering

Hybrid Wiggler (same as X25)
$\Delta E/E \sim 10^{-5}\ 10^{-7}$
Scientific Program: Inelastic Scattering

U13 - High Resolution Soft X-Ray Spectroscopy (TOK)

Variable Gap Permanent Magnet
$E_c \sim 2.5$ keV

The High E Resolution Beam Line will be developed in order to establish a program for inelastic x-ray scattering, ultimately with energy resolution $\Delta E/E \sim 10^{-7}$ in the E = 10 keV range. The use of x-ray inelastic scattering, as a technique complementary to neutron inelastic scattering, will provide, for example a powerful tool for studying surface excitations. The magnetic insertion device for X21 will be essentially the same as the permanent-magnet, hybrid-wiggler with variable gap discussed earlier for the X25 program. It's high brightness in the 1-16 keV range will provide the necessary flux for the inelastic scattering experiments. Various optical schemes have been advanced, and new ones are always being considered, for this technically difficult program.

The soft x-ray spectroscopy beam line will be developed as a separate beam line on the VUV port used for the transverse optical Klystron experiment.[16] The magnetic device for this port will be designed and developed specifically for the TOK program. The scientific goal is to establish a beam line for high resolution spectroscopy in the 0.1-2 keV energy range.

With the development of these six beam ports, and potential side stations on the primary lines, the NSLS will be left with just one available straight section, X13, for development. At the present time there are no decisions made concerning its use. Proposals will be reviewed as time goes on for the appropriate development of this special source.

Acknowledgements

The entire NSLS scientific and engineering staff is responsible for the planning and development of the Phase II beam lines. Jules Godel is Phase II project manager and as such has overall responsibility for the program. The individual scientists involved are J.B. Hastings, M. Howells, R. Klaffky, D. Moncton, W. Thomlinson and G.P. Williams. Engineers with project responsibility are (X1) P. Mortazavi, (X17) H. Hsieh, (X25) M. Woodle, and (IR4) M. Shleifer.

References

1. A. van Steenbergen, Synchrotron Radiation Conference, Novosibirsk, USSR, 1982 (BNL 31571).
2. NSLS Phase II Conceptual Design Report (BNL 33189).
3. W. Thomlinson, NSLS Superconducting Wiggler Beam Line (X17) Conceptual Design Report.
4. E.B. Hughes, et al., Nucl. Instrum. and Methods 208 (1983) 665.
5. S. Sharma and S. Ulc, Vacuum Ring Exit Chamber Temperature Due to Wiggler Beam Heating, BNL 34314.
6. E. Hoyer, Lawrence Berkeley Laboratory, and R. Hettel, SSRL, private communication.
7. E. Hoyer, Lawrence Radiation Laboratory Engineering Notes, Nos. M6043 and M6104.
8. P. Suortti and W. Thomlinson, X-Ray Filters for Synchrotron Radiation, BNL 34934.
9. J.B. Hastings, NSLS High Q Resolution Beam Line (X25) Conceptual Design Report.
10. P. Kirkpatrick and A.V. Baez, JOSA 38, 9, 766 (1948).
11. J.B. Hastings and W. Thomlinson, Nucl. Instrum. and Methods 222 (1984).
12. T.W. Barbee, Conf. on Low Energy X-Ray Diagnostics, Monterey, California, AIP Conf. Proceedings #75, D. Attwood and B. Henke (Eds.) 1981.
13. J.M. Kenney, J. Kirz, H. Rarback, M.R. Howells, P. Chang, P.J. Coane, R. Feder, P.J. Houzego, D.P. Kern and D. Sayre, Nucl. Instrum. and Methods 222 (1984).
14. M. Howells, J. Kirz, and S. Krinsky, A Beam Line for Experiments with Coherent Soft X-Rays, BNL 32519 (1982). M. Howells, NSLS X-Ray Microscopy and Holography Beam Line (X1) Conceptual Design Report.
15. G.P. Williams, NSLS Infra-Red Beam Line Conceptual Design Report.
16. M.R. Howells, Some Ideas on the Design of Soft X-Ray Monochromators For Use with Wiggler/Undulator Radiation, BNL 31030.

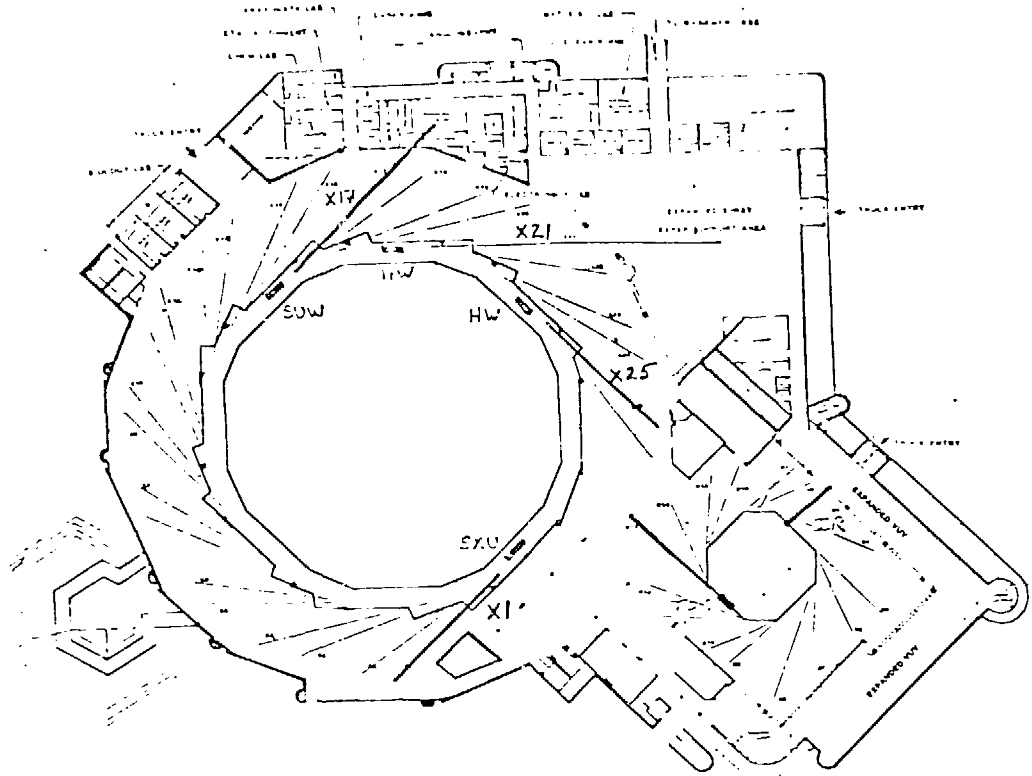

Fig. 1. NSLS Phase II Beam Lines

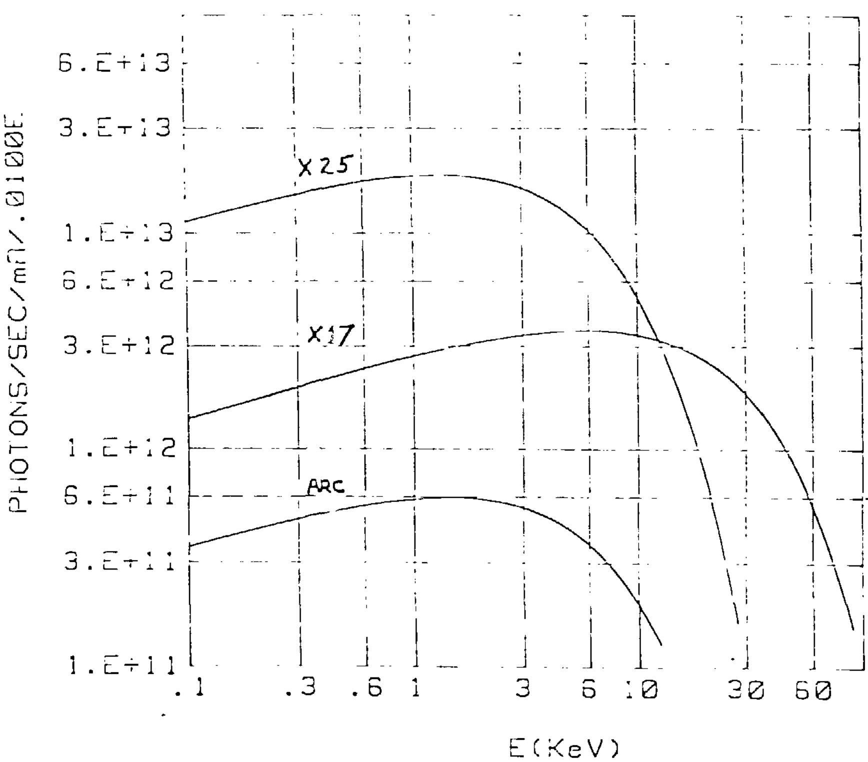

Fig. 2. Photon Spectra for Superconducting Wiggler, Hybrid Wiggler, and X-Ray Ring Arc Source at 2.5 GeV

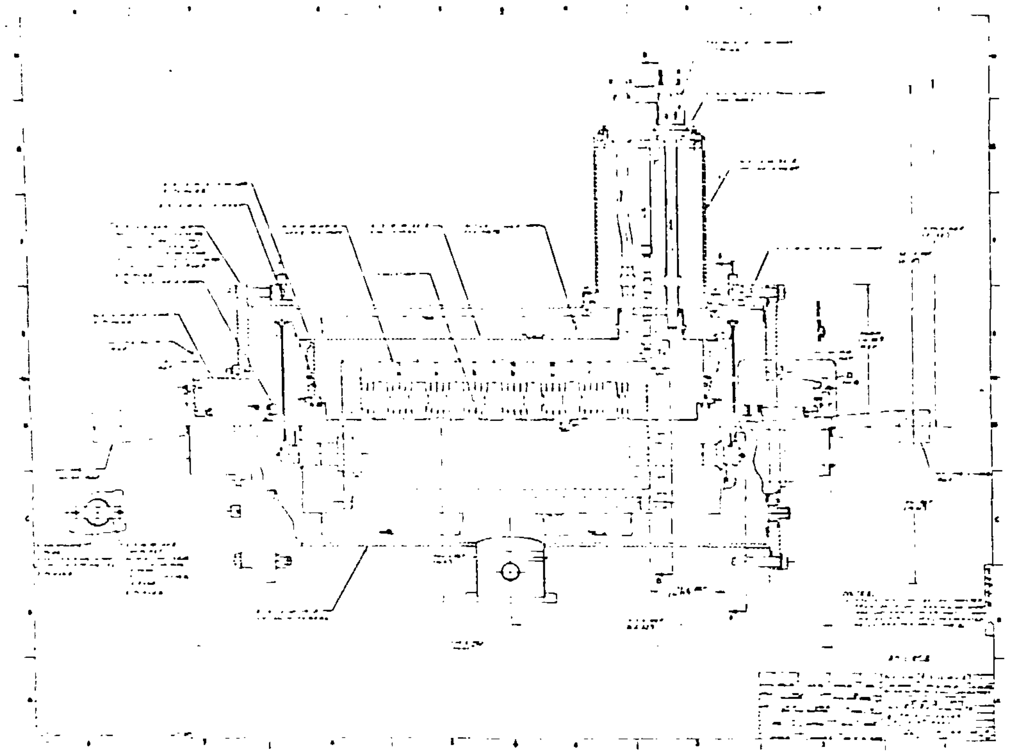

Fig. 3. Cross Section of Superconducting Wiggler Magnet

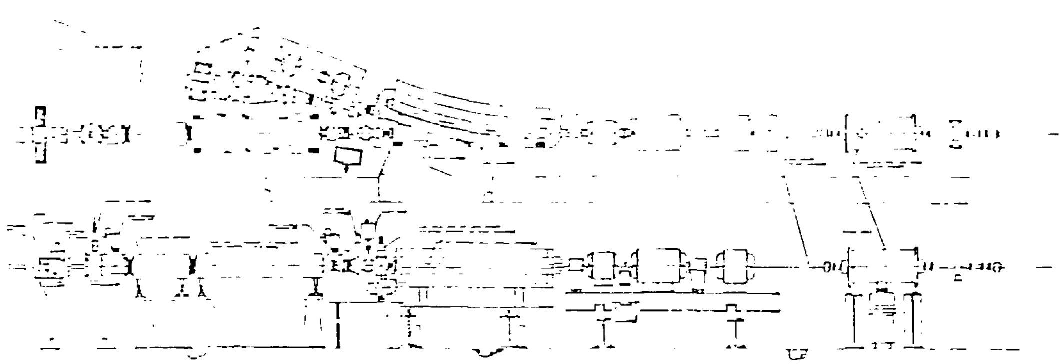

Fig. 4. X17 Front End

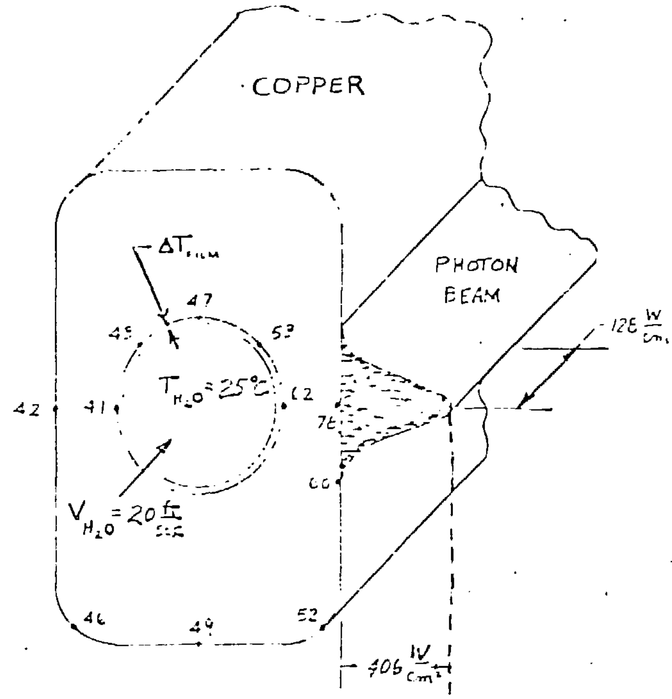

Fig. 5. Beam Power Profile and Thermal Profile for X17 Absorber

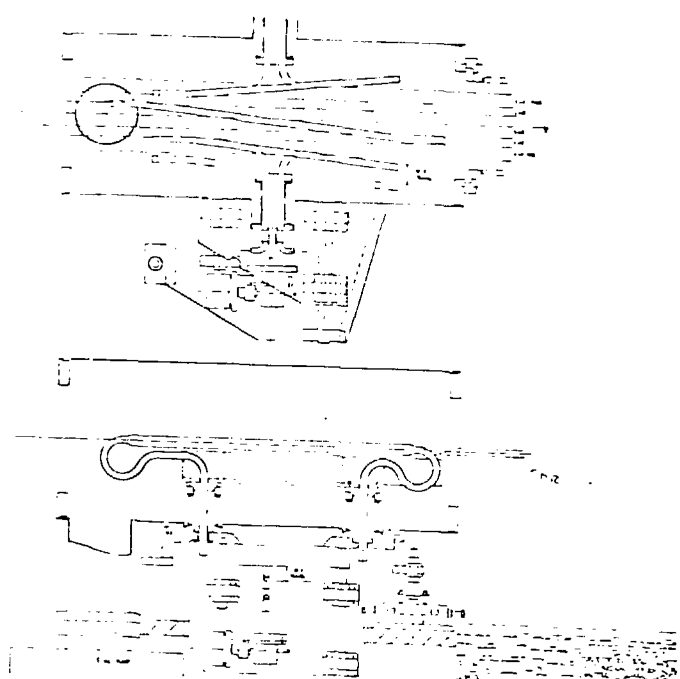

Fig. 6. X17 Photon Shutters

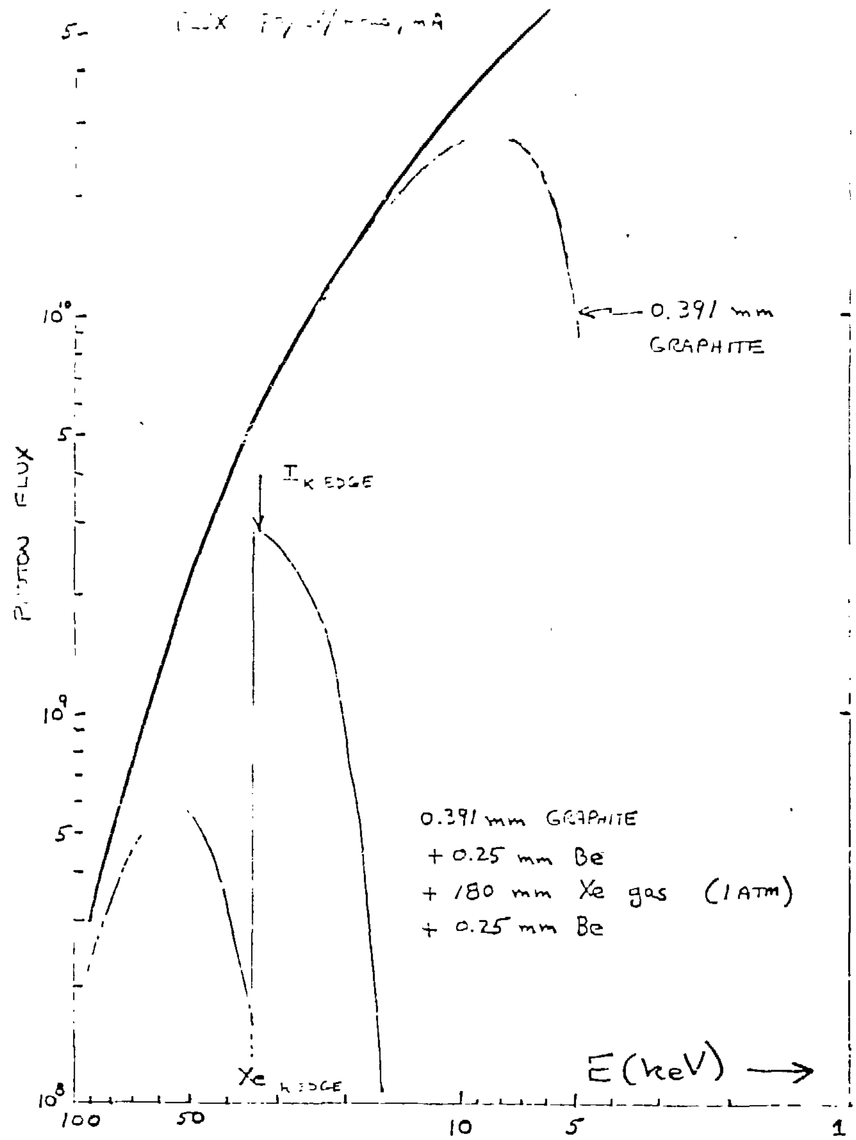

Fig. 7. X17 Flux with C, Be, and Xe Filters

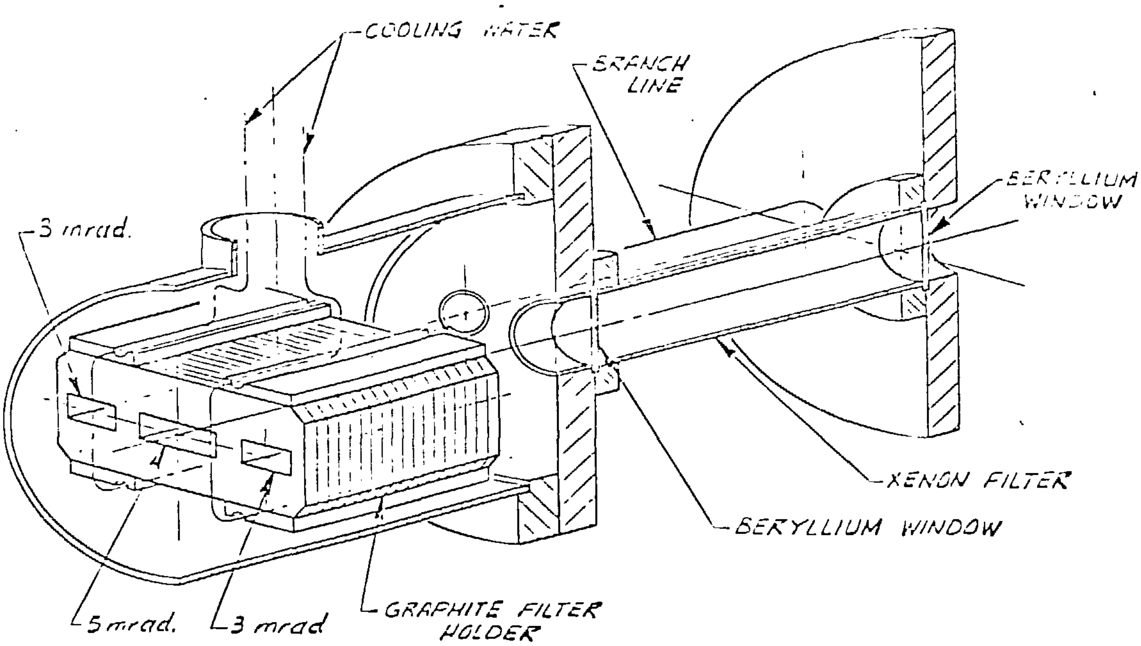

Fig. 8. C and Xe Photon Filter Assembly

Engineering Drawing Unavailable

Fig. 9

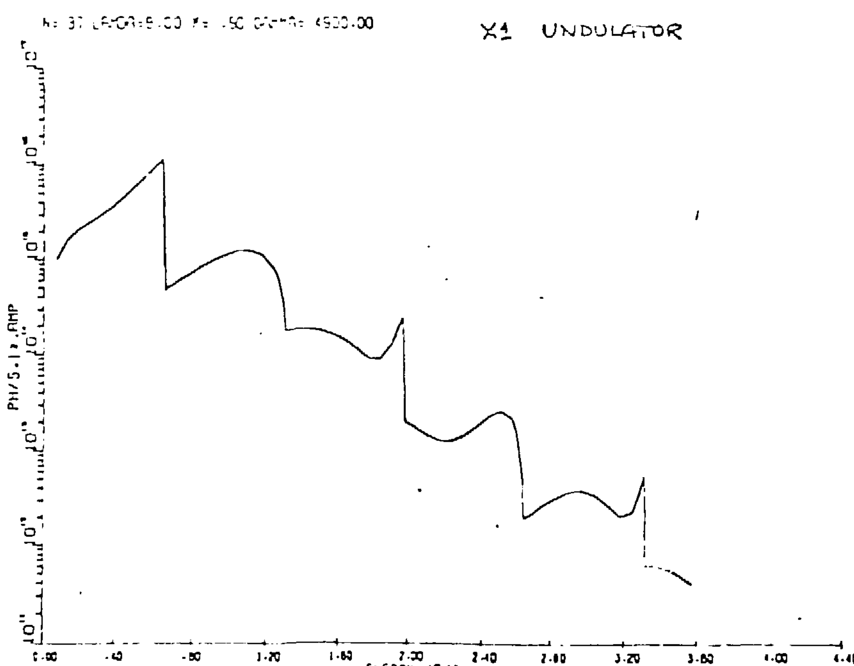

Fig. 10. Soft X-Ray Undulator Spectrum

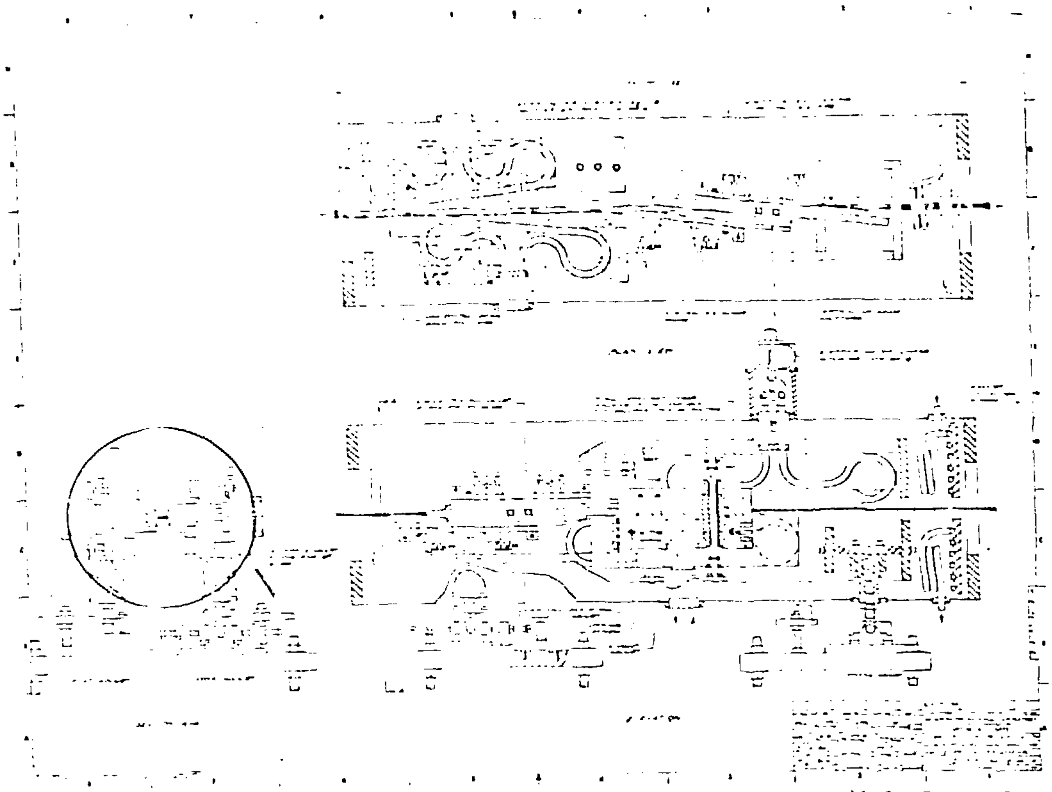

Fig. 11. X1 Photon Shutters

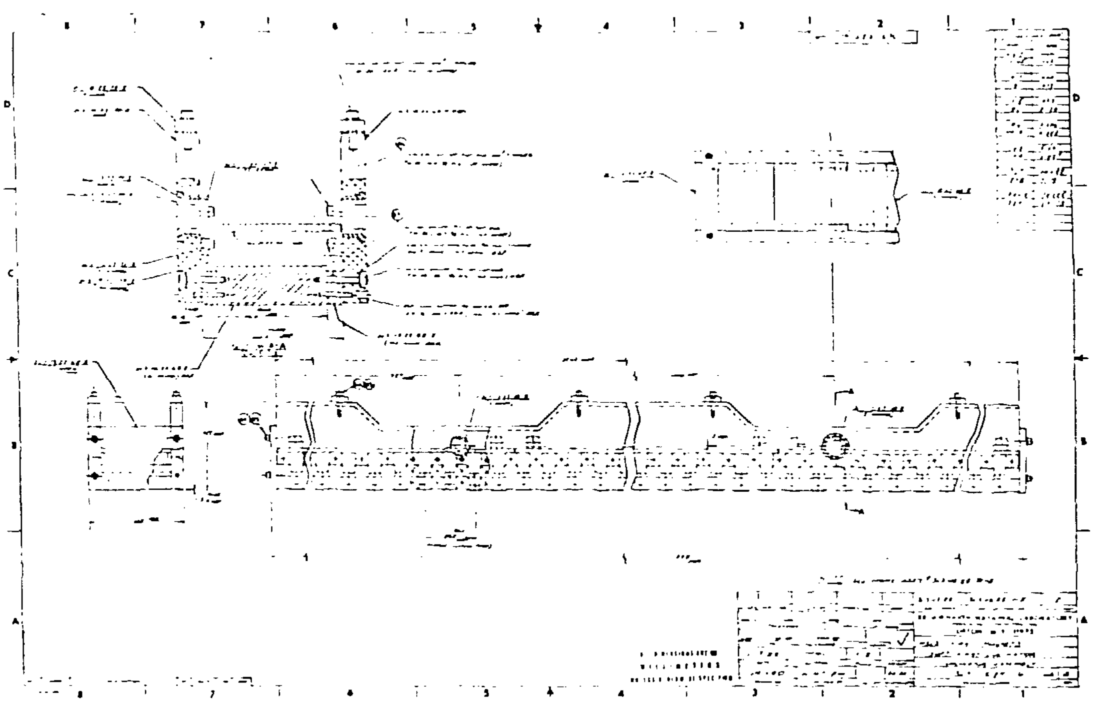

Fig. 12. Soft X-Ray Undulator Assembly

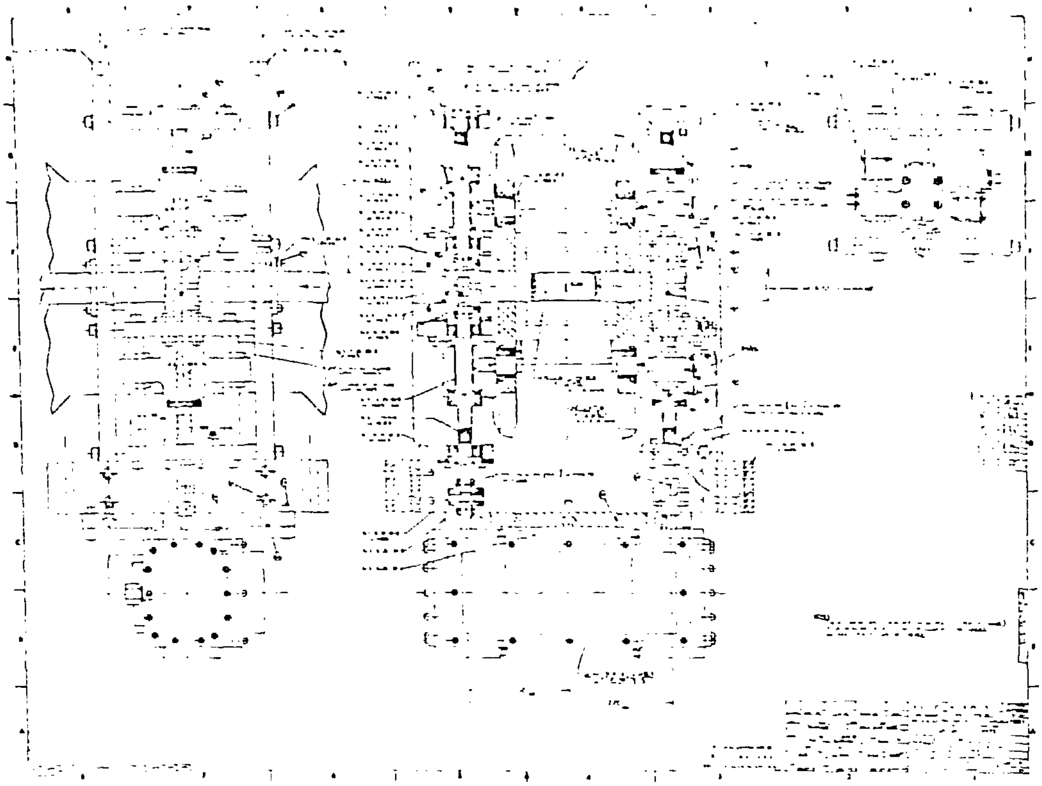

Fig. 13. Soft X-Ray Undulator Drive Assembly

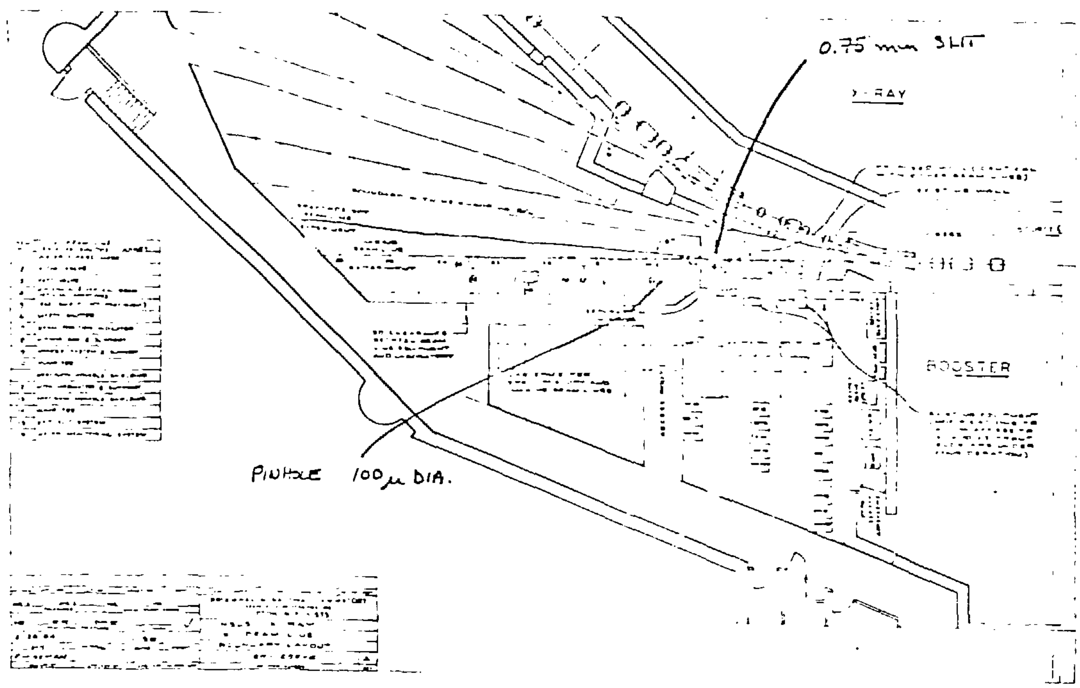

Fig. 14. X1 oor Plan

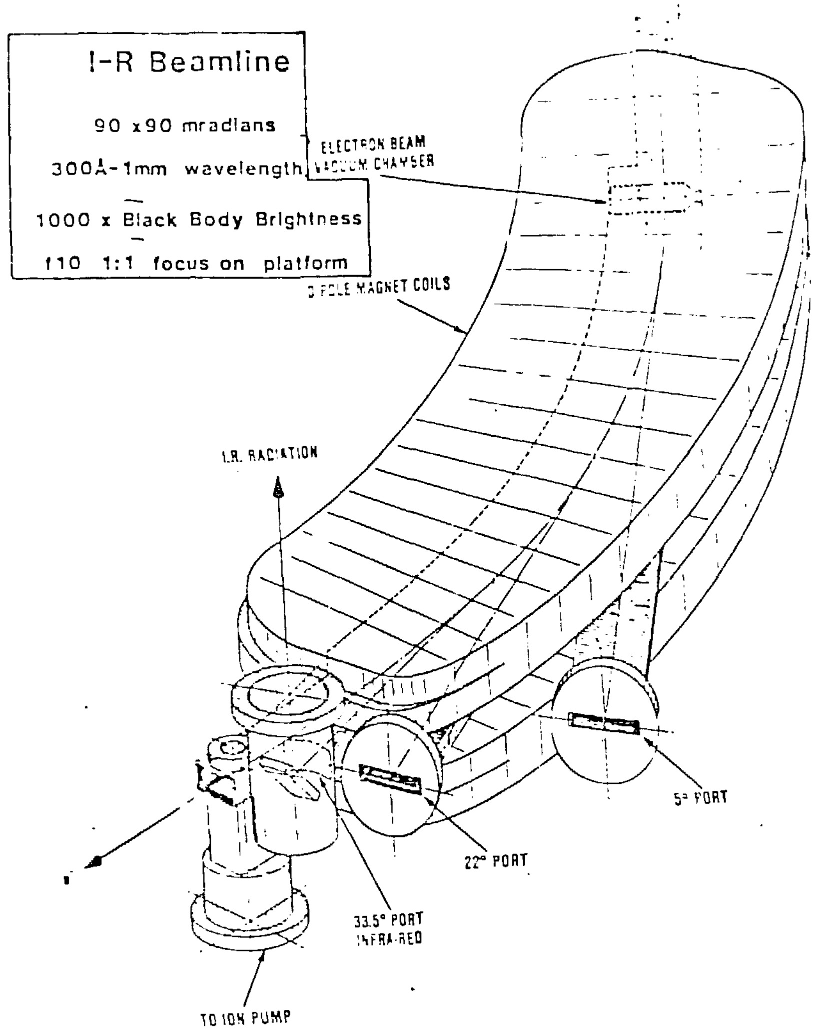

Fig. 15. NSLS Phase2 Infra-Red Beam Extraction

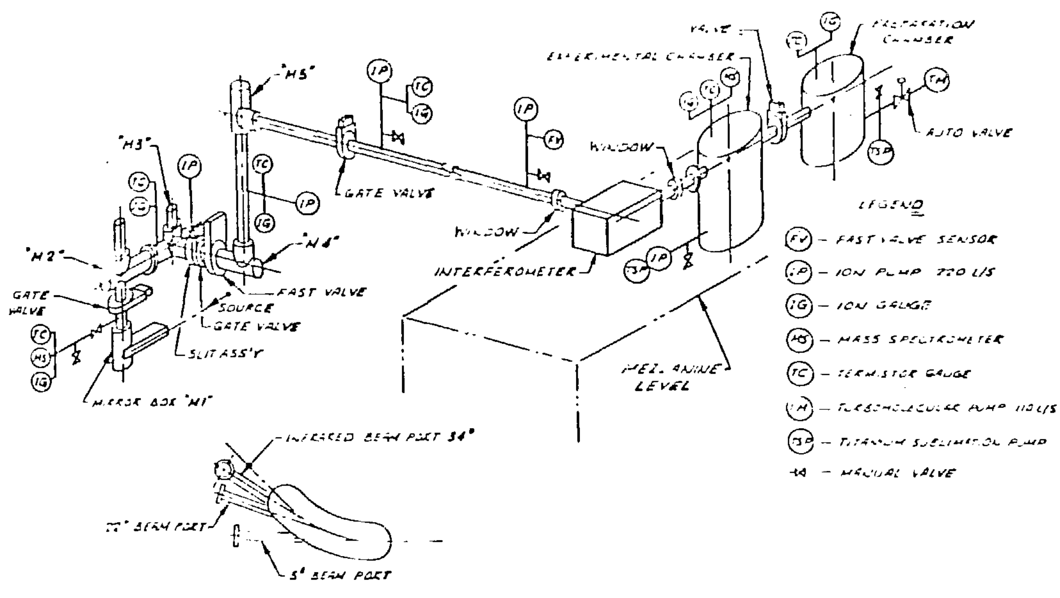

Fig. 16. I-R Beamline Schematic

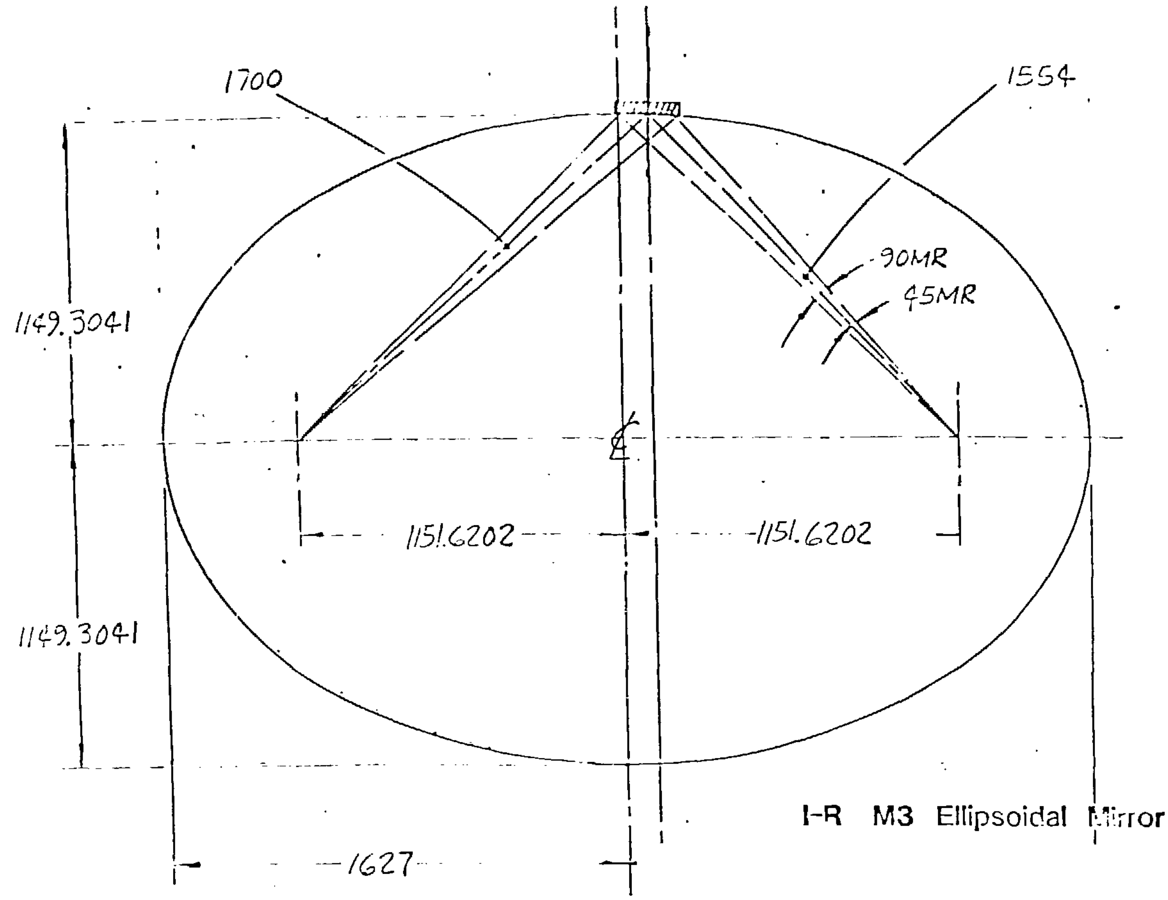
1700
1554
90MR
45MR
1149.3041
1149.3041
1151.6202
1151.6202
1627
I-R M3 Ellipsoidal Mirror

Fig. 17