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ALS Beamlines for Independent Investigators

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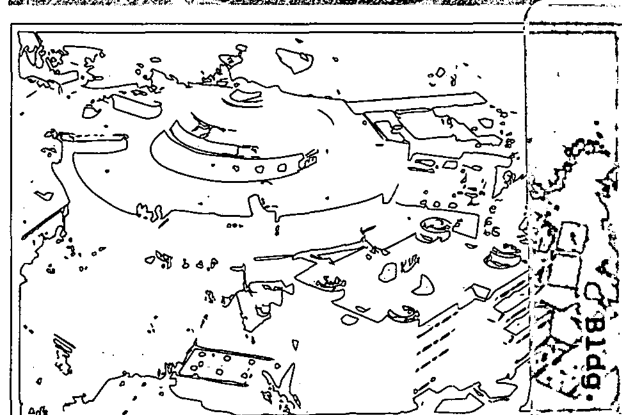
for Independent Investigators

A Summary of the Capabilities and Characteristics of Beamlines at the ALS

August 1992



Lawrence Berkeley Laboratory
University of California

ALS Beamlines for Independent Investigators

A Summary of the Capabilities and Characteristics of Beamlines at the ALS

August 1992

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1.
INTRODUCTION

Conducting Research at the Advanced Light Source

About the Advanced Light Source

The Advanced Light Source (ALS) is a national facility for scientific research and development located at the Lawrence Berkeley Laboratory (LBL) of the University of California. Its purpose is to generate beams of very bright light in the far ultraviolet and soft x-ray regions of the spectrum. Within these spectral regions, the ALS produces the world's brightest light available as an experimental tool. This $99.5 million facility, funded by the U.S. Department of Energy, is available to qualified researchers from industry, universities, and government laboratories.

Modes of conducting research

There are two modes of conducting research at the ALS:

- To work as a member of a participating research team (PRT).
- To work as an independent investigator.

PRTs are responsible for building beamlines, end stations, and, in some cases, insertion devices. Thus, PRT members have privileged access to the ALS. Independent investigators will use beamline facilities made available by PRTs. The purpose of this handbook is to describe these facilities.

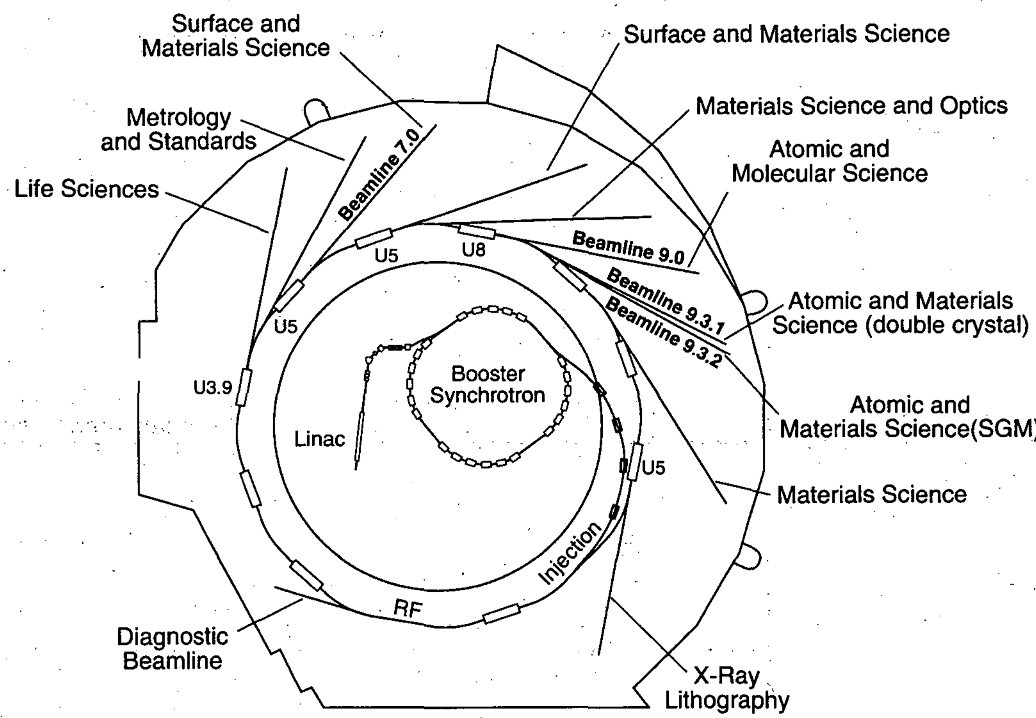
Available beamlines

As presently planned, four beamlines are available to independent investigators:

- Beamline 7.0, which delivers light from a 5-cm-period undulator and is equipped with a spherical grating monochromator (SGM).
- Beamline 9.0, which delivers light from an 8-cm-period undulator and is equipped with an SGM.
- Beamline 9.3.1, which delivers light from a bend magnet and is equipped with a double-crystal monochromator.
- Beamline 9.3.2, which also delivers light from a bend magnet and is equipped with an SGM.

Beamlines on the ALS floor

The following diagram of the ALS floor shows all the beamlines planned for construction through 1995. Those available to independent investigators are indicated by the labels *Beamline 7.0, Beamline 9.0, Beamline 9.3.1,* and *Beamline 9.3.2.*



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Obtaining More Information

In this handbook

Undulator beamlines	See Chapter 2
Bend-magnet beamlines	See Chapter 3

LBL and PRT sources of information

For additional technical information on these facilities, please contact the Lawrence Berkeley Laboratory (LBL) beamline representative listed in the following table. For information on the research planned for the beamlines or to discuss opportunities for collaboration with the PRT, please contact the PRT spokesperson.

Beam-line	LBL Contact	PRT Spokesperson
7.0	Dr. Tony Warwick MS 2-400 Lawrence Berkeley Laboratory Berkeley, CA 94720 Telephone: (510) 486-5819 Fax: (510) 486-7696 E-mail: warwick@lbl	Professor Brian Tonner University of Wisconsin Department of Physics 1900 E. Kenwood Blvd. Milwaukee, WI 53211 Telephone: (414) 229 4626 Fax: (414) 229 5589 E-mail: tonner@csd4.milw.wisc.edu
9.0	Dr. Philip A. Heimann MS 2-400 Lawrence Berkeley Laboratory Berkeley, CA 94720 Telephone: (510) 486-7628 Fax: (510) 486-7696 E-mail: phil@lbl	Professor Denise Caldwell University of Central Florida Department of Physics Orlando, FL 32816-0993 Telephone: (407) 823-5208 Fax: (407) 823-5112 E-mail: cdc@phys.physics.ucf.edu
9.3.1	Dr. Rupert C. Perera MS 2-400 Lawrence Berkeley Laboratory Berkeley, CA 94720 Telephone: (510) 486-5680 Fax: (510) 486-7696 E-mail: rupert@lbl	Professor Dennis W. Lindle University of Nevada, Las Vegas Department of Chemistry 4505 S. Maryland Parkway Las Vegas, NV 89154 Telephone: (702) 597-4426 Fax: (702) 597-4159 E-mail: lindle@uns-helios.nevada.edu
9.3.2	Dr. Zahid Hussain MS 2-300 Lawrence Berkeley Laboratory Berkeley, CA 94720 Telephone: (510) 486-7591 Fax: (510) 486-4299 E-mail: hussain@lbl	Professor Charles S. Fadley MS 2-400 Lawrence Berkeley Laboratory Materials Sciences Division Berkeley, CA 94720 Telephone: (510) 486-5774 Fax: (510) 486-5530 E-mail: fadley@lbl

For general information about working at the ALS, please contact

Dr. A.S. Schlachter
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Berkeley, CA 94720
Telephone: (510) 486-4892
Fax: (510) 486-4873
E-mail: fred@lbl.

2. UNDULATOR BEAMLINES

Introduction

Available beamlines

Two undulator beamlines are available to independent investigators.

Beamline Name	Undulator
7.0	5 cm period
9.0	8 cm period

More information

Sections 2.1 and 2.2 of this chapter describe the characteristics and components of these beamlines.

2.1 Beamline 7.0

Application

Spectro-microscopy

Beamline 7.0 is an undulator facility devoted to spectromicroscopy, a fast-growing technology that combines x-ray microscopy and spectroscopy.

Examples of topics for investigation

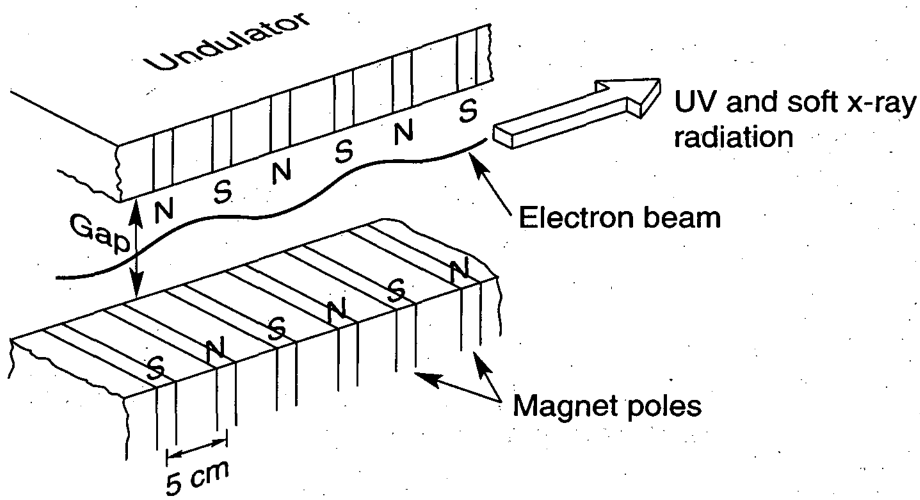
The following topics have been proposed for investigation with Beamline 7.0.

- Electronic properties of mesoscopic structures such as highly patterned epitaxial structures.
- Spatially resolved surface chemical reactions (e.g., catalysis, chemisorption, or corrosion).
- Film-growth kinetics in heteroepitaxy.
- Lateral electronic inhomogeneities in semiconductor interfaces.
- Correlated electron systems.
- Novel interface phenomena such as chemistry at grain boundaries.

5-cm-Period Undulator*

Description

The 5-cm-period undulator is a source of intense ultraviolet and soft x-ray radiation. The energies of its harmonics, which can range from 60 to 1500 eV, depend on the magnetic gap.



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During the initial operation of the ALS, the gap and the harmonic energies will be fixed for each fill of the storage ring, which can last up to 6 hours. Later, it will be possible to change the gap and the harmonic energies at will.

Parameters

The following table lists the major parameters for the 5-cm-period undulator. A detailed design document is available.[1]

Number of periods	89
Length	4.5 meters
Minimum field	0.16 tesla, K = 0.75, magnetic gap = 4.0 cm
Maximum field*	0.86 tesla, K = 4.0, magnetic gap = 1.6 cm
Maximum power (400 mA, 1.5 GeV)	1.9 kW
Useful harmonics	1, 3, and 5
Maximum rms beam divergence of the first harmonic	σ'_v = 75 µrad, σ'_h = 78 µrad
* During 1993, the gap can be no smaller than 2.2 cm, giving a minimum photon energy of approximately 100 eV.	

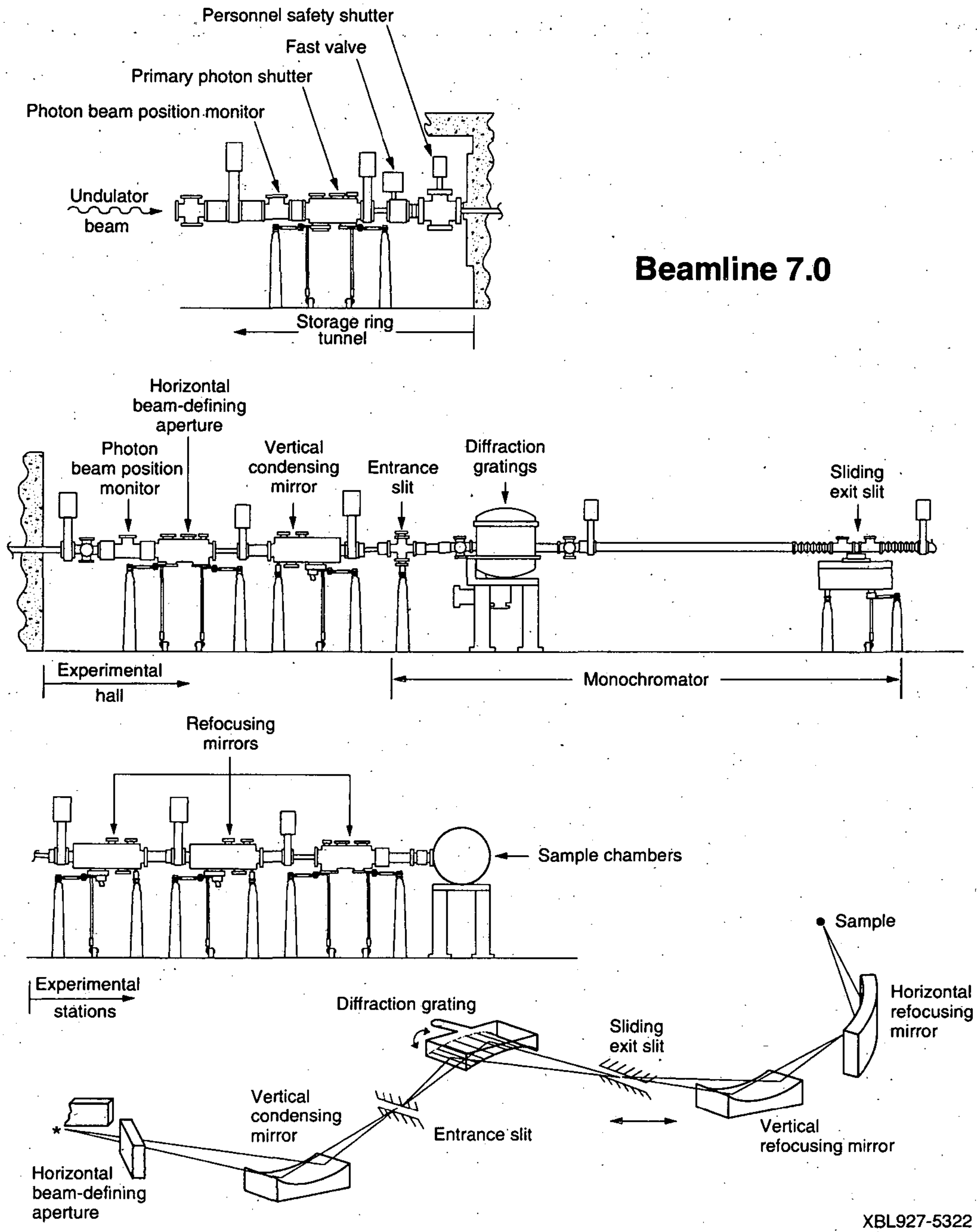
Beamline Characteristics

Monochromator	Beamline 7.0 has a spherical grating monochromator (SGM) with three interchangeable diffraction gratings for selecting photon energies.
Photon energy	The diffraction gratings cover the range of photon energies from 70 to 1200 eV.
Harmonics	The beamline delivers photons from the first, third, and fifth undulator harmonics with minimum losses and high resolution.
Spot Size	The minimum spot size at the experimental stations is 50×50 μm (FWHM).

Beamline Components

Layout

The figure below shows the layout for Beamline 7.0. The front-end components inside the shielding wall (top part of the figure) are identical on all ALS undulator beamlines.



Beamline Components (continued)

Component list

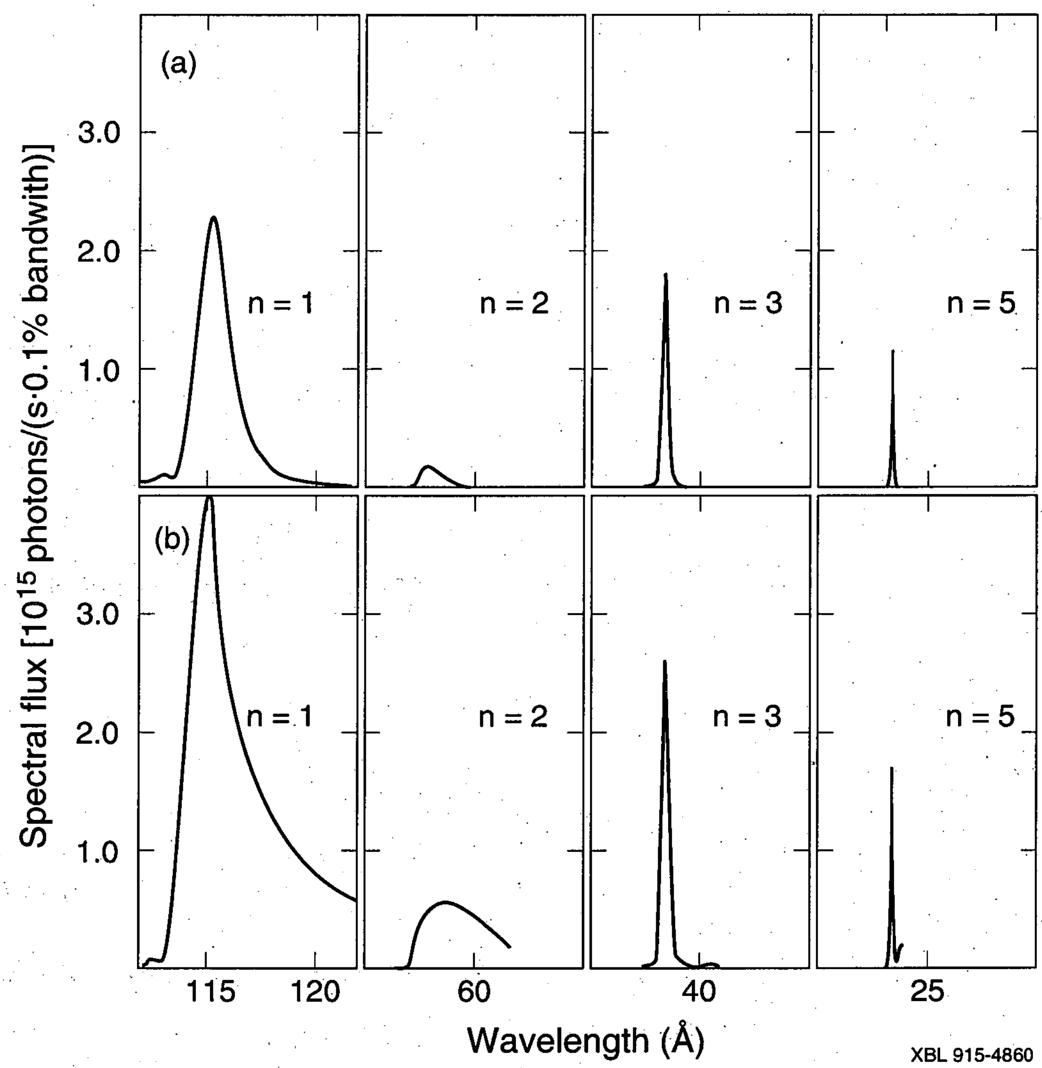
The following table lists and describes the components of Beamline 7.0.

Component	Description/Function
Photon beam position monitors (2)	• Provide information on the position and angle of the electron beam at the center of the undulator to within 10% of the beam rms size and divergence. • Provide error signals for electron-beam stabilization feedback loops. • One monitor inside and one outside the shielding wall.
Horizontal beam-defining aperture	• Adjustable. • Water-cooled. • Passes entire central cone of undulator radiation. • May be used to select radiation off axis (e.g., the second harmonic). • See plots of spectral flux through aperture on next page.
Vertical condensing mirror	• Generates vertical image of the source (a horizontal line) at the entrance slit of the monochromator. • Gold, 2° grazing, water-cooled, spherical. • Demagnification factor: 15.
Monochromator	
Entrance slit	• Stationary, water-cooled, typically 10 µm wide. • Blades open to various widths to admit photon beam. • Minimum width: 5 µm.
Interchangeable diffraction gratings (3)	1. 150 l/mm, laminar profile, gold coating (70–200 eV). 2. 375 l/mm, laminar profile, gold coating (180–500 eV). 3. 950 l/mm, laminar profile, platinum coating (450–1200 eV).
Exit slit	• Uncooled. • Moves up and down the beamline through a distance of 0.75 meter. • Blades open to various widths. • Minimum width: 5 µm.
Refocusing mirrors	• Provide focused beam to experimental stations. • Can serve several experimental stations by switching horizontal mirrors and by varying focal length of vertical (deformable) mirror.
Vertical	Variable radius, nickel coating, 3° grazing.
Horizontal	• Gold, 2° or 3° grazing, interchangeable. • Demagnification factor: 14.

Spectral Flux Through Horizontal Beam-Defining Aperture

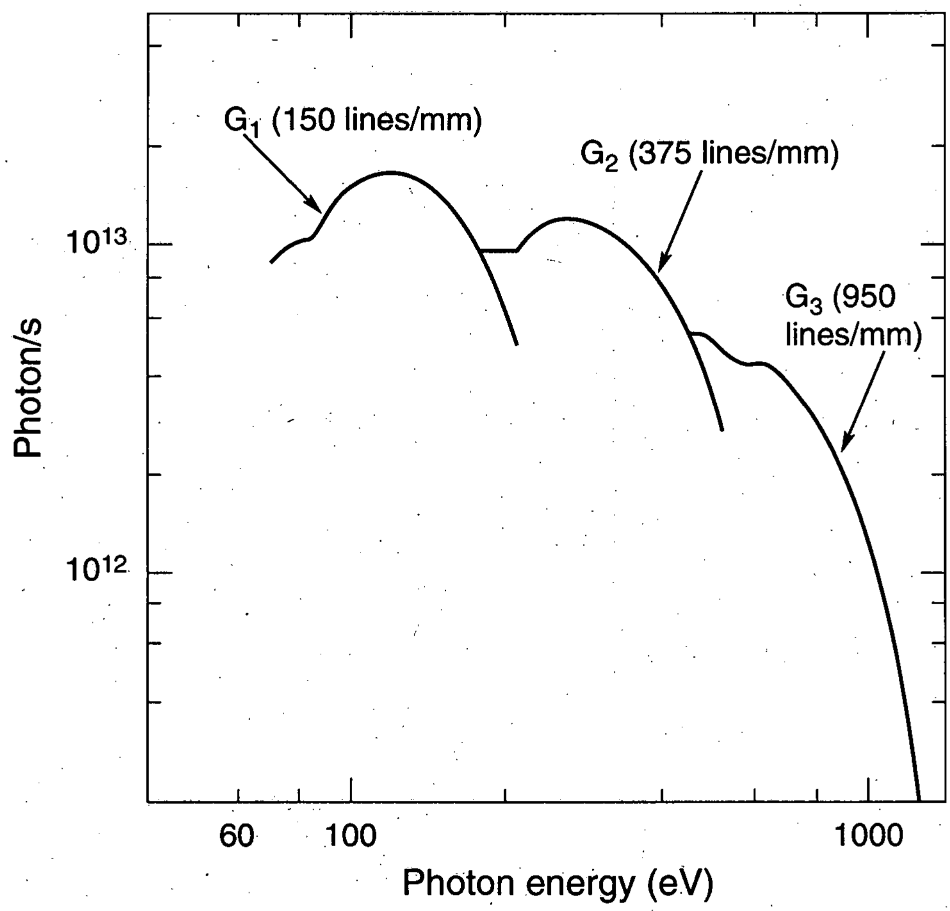
Flux transmitted into the beamline

The figure below shows the spectral flux passed by the horizontal beam-defining aperture on Beamline 7.0 for two aperture sizes: (a) $2\sigma \times 2\sigma$ and (b) $8\sigma \times 2\sigma$, where σ is the rms size of the central cone of the undulator fundamental. The K value is 2.5, and the first, second, third, and fifth harmonics are shown.



Resolved flux vs. photon energy

The figure below shows the calculated resolved flux after the exit slit for each diffraction grating. The resolved flux is computed as the width of the entrance slit is varied to fix the slit-width-limited resolving power at 10,000. The calculations are based on the predicted flux from the undulator, neglecting field errors and using the first, third, or fifth harmonics for the first, second, and third gratings, respectively. These calculations include mirror absorption, aberration losses at the entrance slit, and a diffraction efficiency for square-wave gratings, in first order, with shadowing.[2] In practice, grating aberrations and slope errors prevent this value from ever being achieved.



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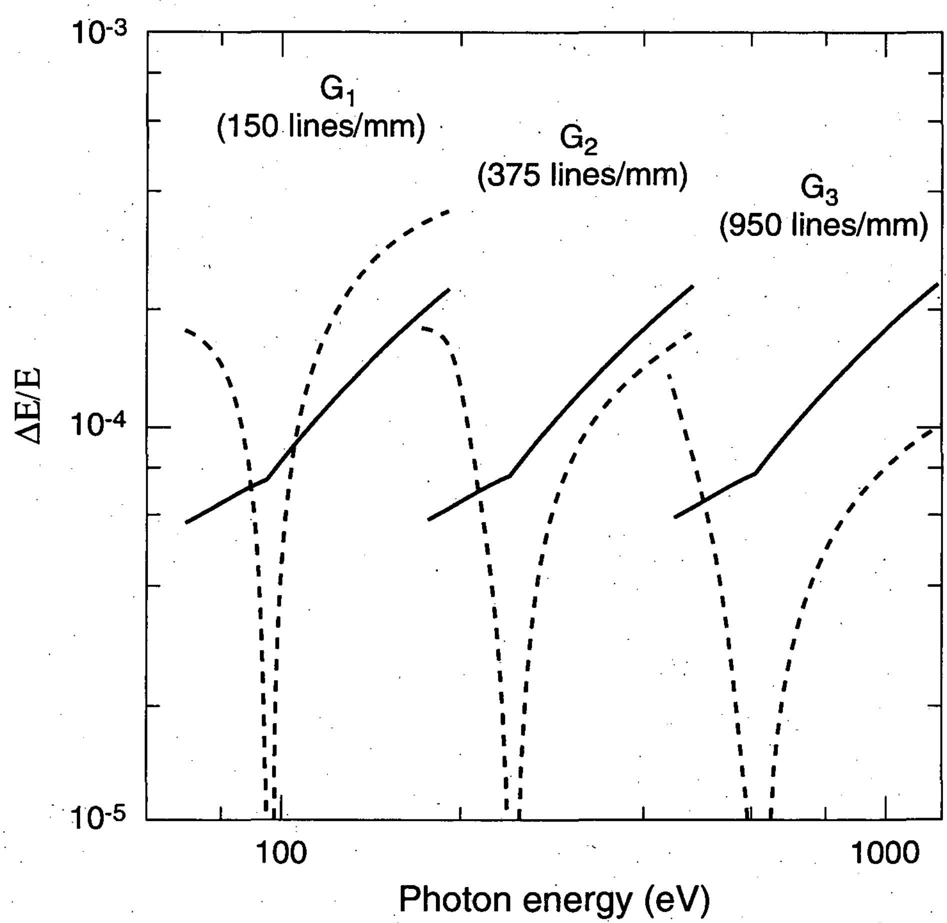
Note: During 1993, while the minimum undulator gap is 2.2 cm, the region of the spectrum below 100 eV will not be accessible.

Resolution vs. photon energy

The resolution of the monochromator was computed analytically as a function of photon energy, including the geometrical aberrations of the spherical grating and the effects of finite slits.[3] These analytical results have been confirmed by explicit ray-trace analyses. The solid lines in the figure below show the resolution contribution of 10-μm slits. The broken lines show the contribution of spherical aberration. Other aberrations are negligible.



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End Stations

Description

Beamline 7.0 has two end stations available to independent investigators, one at 30.0 meters and one at 31.1 meters from the source.

30.0-meter station

The end station at 30.0 meters is outfitted with a photoelectron spectrometer. Current plans call for the following features:

- 10 meV resolution at 100 eV; 40 meV resolution at 1500 eV.
- Multi-anode detector for simultaneous multiple-energy acquisition.
- Variable accepted solid-angle from 0.5-degree half-angle to 6-degree half-angle.
- Sample manipulator with high-precision, computer-controlled angular goniometer that has three-axis motion (angles), three linear axes, heating, and cooling.
- Fast sample introduction from ambient to UHV.

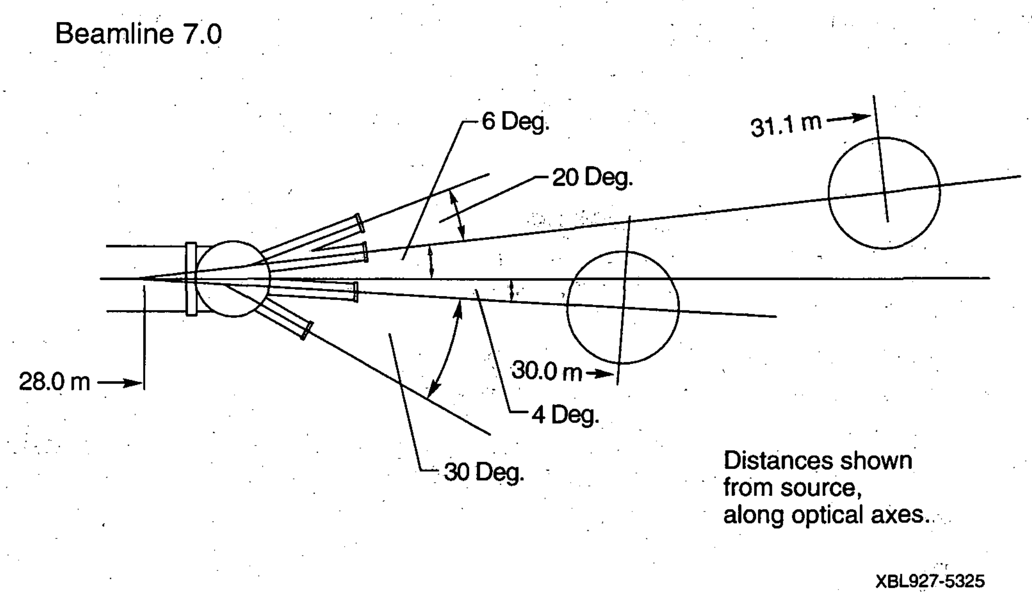
Independent investigators who are interested in using this end station should contact Professor Brian Tonner for additional details about the spectrometer. (See page 3 for contact information.)

31.1-meter station

The end station at 31.1 meters is yet to be equipped. Independent investigators must furnish their own experimental chambers to work at this end station.

Floor layout

Floor layout of the experimental space at the end of Beamline 7.0. Circles represent end stations.



2.2 Beamline 9.0

Application

Photoprocesses in atoms, molecules, ions

Beamline 9.0 is an undulator facility dedicated to the investigation of photoprocesses in atoms, molecules, and ions.

Examples of topics for investigation

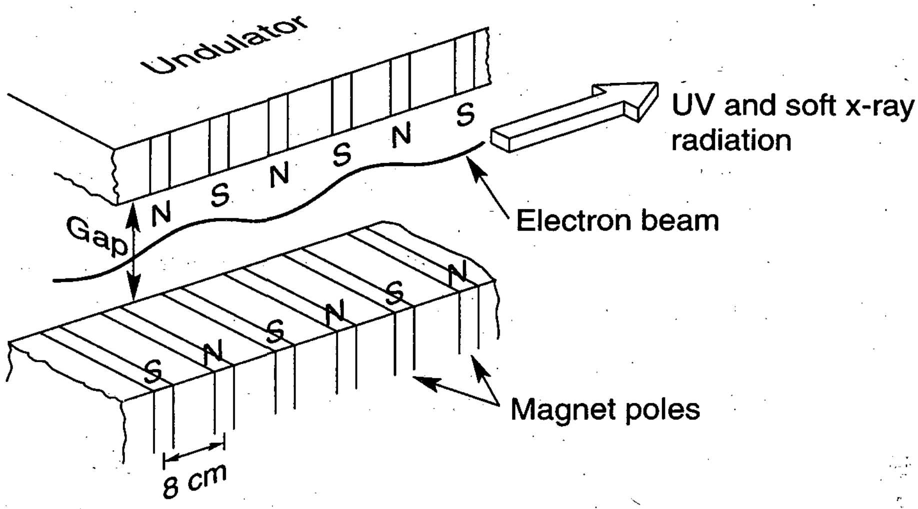
The following topics have been proposed for investigation with Beamline 9.0.

- High-resolution electron spectroscopy.
- Eectron-electron and electron-ion coincidence measurements.
- Fluorescence detection.
- Electron correlation at high excitation energies.
- Core excitation of specific carbon K-edge features in small molecules and the analysis of decay products by mass spectrometry.
- High-energy molecular spectroscopy.
- Photon-ion interactions.

8-cm-Period Undulator

Description

The 8-cm-period undulator is a source of intense ultraviolet and soft x-ray radiation. The energies of its harmonics, which can range from 14 to 1000 eV, depend on the magnetic gap.



During initial operation of the facility, the gap and the harmonic energies will be fixed for each fill of the ALS storage ring, which can last up to 6 hours. Later, it will be possible to change the gap and harmonic energies at will.

Parameters

The following table lists the major parameters for the 8-cm-period undulator. A detailed design document is available.[4]

Number of periods	55
Length	4.5 meters
Minimum field	0.40 tesla, K = 3.0, magnetic gap = 4.0 cm
Maximum field*	1.0 tesla, K = 7.5, magnetic gap = 1.9 cm
Maximum power (400 mA, 1.5 GeV)	2.6 kW
Useful harmonics	1, 3, and 5
Maximum rms beam divergence of the first harmonic	$\sigma'_v = 150\ \mu rad$, $\sigma'_h = 150\ \mu rad$

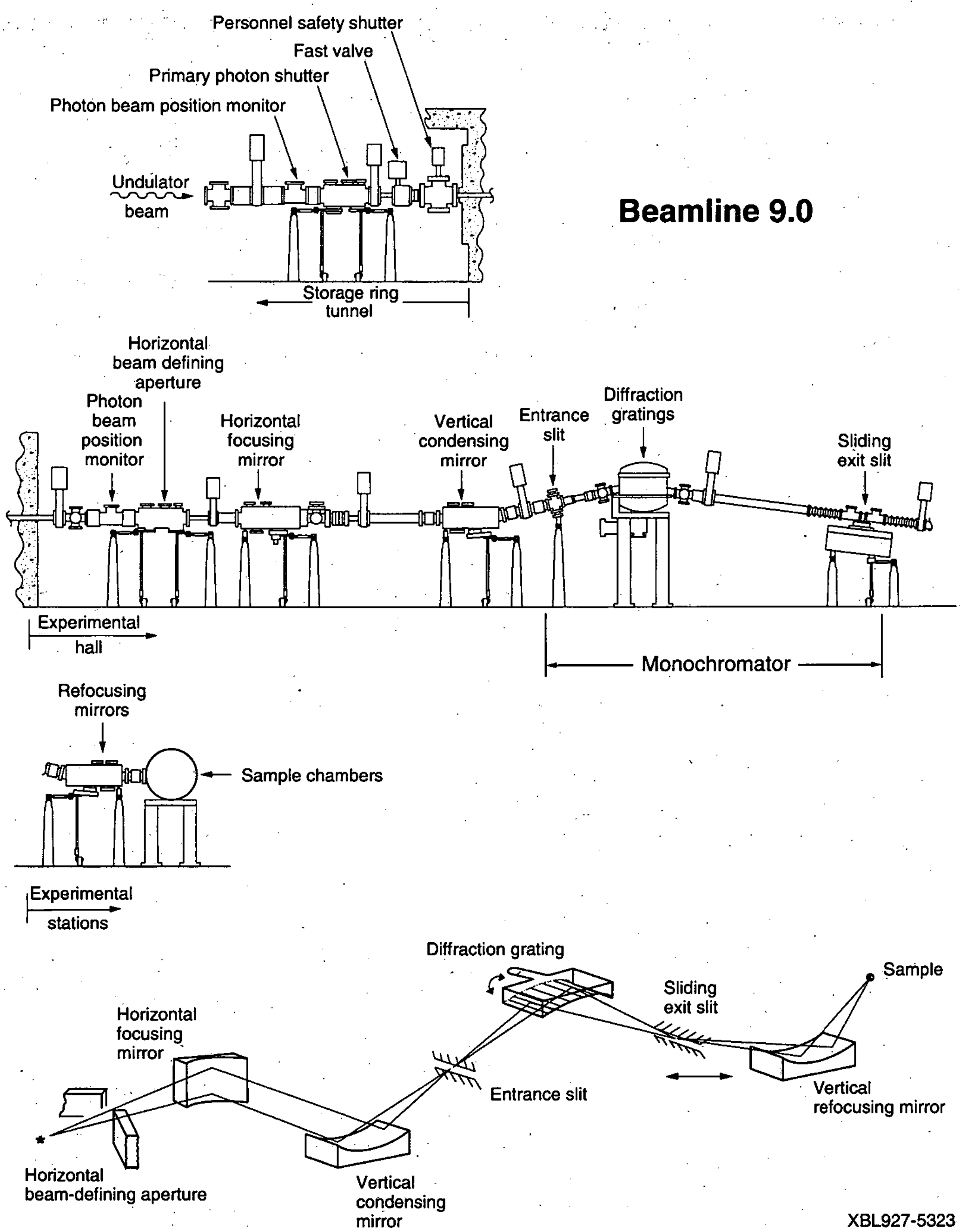
* During 1993, the gap can be no smaller than 2.5 cm, giving a minimum photon energy of approximately 18 eV.

Beamline Characteristics

Monochromator	Beamline 9.0 has a spherical grating monochromator (SGM) with three interchangeable diffraction gratings for selecting photon energies.
Photon energy	The diffraction gratings cover the range of photon energies from 20 to 300 eV.
Harmonics	The beamline delivers photons from the first, third, and fifth undulator harmonics with minimum losses and high resolution.
Spot size	The minimum spot size at the experimental stations is 50 × 800 μm (FWHM).

Layout

The figure below shows the layout for Beamline 9.0. The front-end components inside the shielding wall (top part of the figure) are identical on all ALS undulator beamlines.



Component list

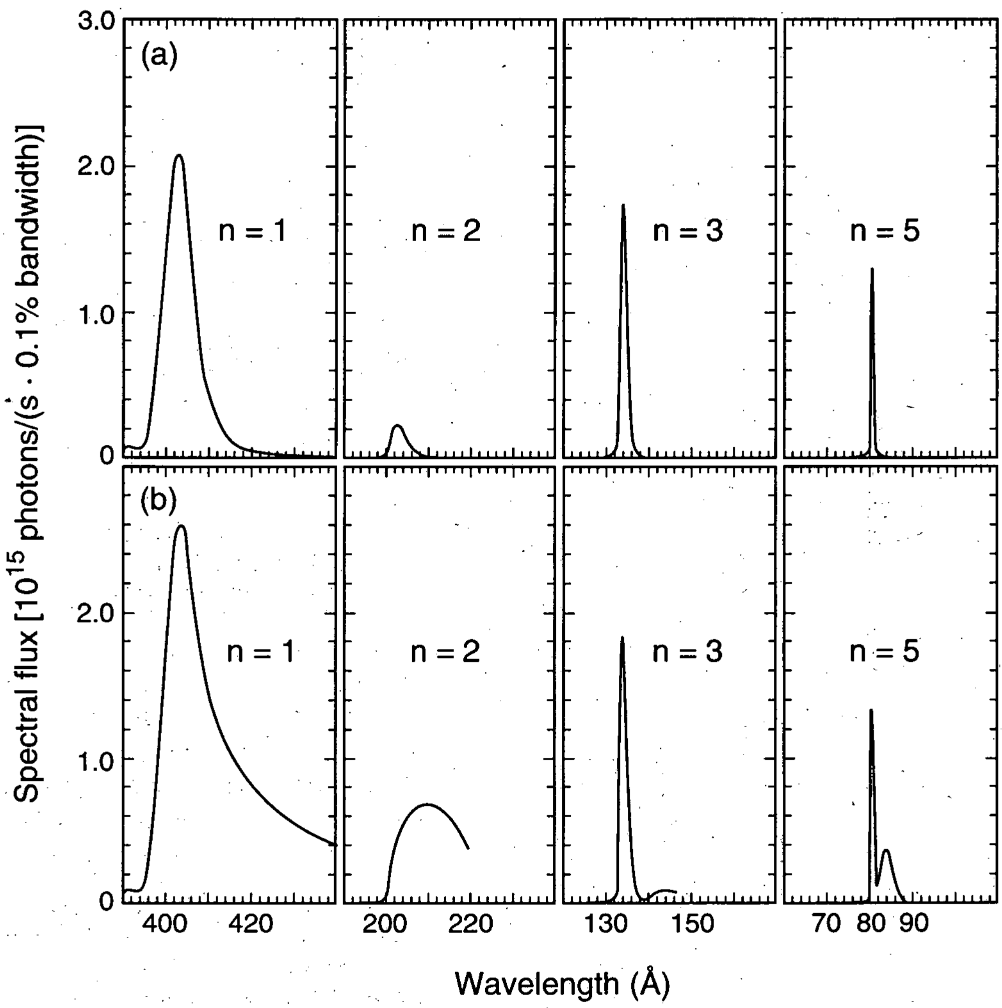
The following table lists and describes the components of Beamline 9.0.

Component	Description/Function
Photon beam position monitors (2)	• Provide information on the position and angle of the electron beam at the center of the undulator to within 10% of the beam rms size and divergence. • Provide error signals for electron-beam stabilization feedback loops. • One monitor inside and one outside the shielding wall.
Horizontal beam-defining aperture	• Adjustable. • Water-cooled. • Passes entire central cone of undulator radiation. • May be used to select radiation off axis (e.g., the second harmonic). • See plots of spectral flux through aperture on next page.
Horizontal focusing mirror	• Generates a horizontal focus at the sample. • Acts as a power filter, absorbing photons at energies above the operating range. • Has two coatings to absorb photons at different energies: Carbon: 20–260 eV. Nickel: Up to 300 eV. • Translates vertically to switch between the two coatings. • Water-cooled. • 3° grazing.
Vertical condensing mirror	• Generates vertical image of the source (a horizontal line) at the entrance slit of the monochromator. • Nickel, 4.5° grazing, water-cooled, spherical. • Demagnification factor: 8.
Monochromator	
Entrance slit	• Stationary, water-cooled. • Blades open to various widths to admit photon beam. • Minimum width: 5 μm.
Interchangeable diffraction gratings (3)	1. 385 l/mm, laminar profile, gold coating (20–60 eV). 2. 900 l/mm, laminar profile, gold coating (47–140 eV). 3. 2100 l/mm, laminar profile, nickel coating (109–300 eV).
Exit slit	• Uncooled. • Moves up and down the beamline through a distance of 0.75 meter. • Blades open to various widths. • Minimum width: 5 μm.
Vertical refocusing mirror	• Collects radiation diverging from monochromator exit slit and focuses it on the sample. • Variable radius. • Nickel coating. • 3° grazing.

Spectral Flux Through Horizontal Beam-Defining Aperture

Flux transmitted into the beamline

The figure below shows the spectral flux passed by the horizontal beam-defining aperture on Beamline 9.0 for two aperture sizes: (a) 2σ × 2σ and (b) 8σ × 2σ, where σ is the rms size of the central cone of the undulator fundamental. The K value is 4.0, and the first, second, third, and fifth harmonics are shown.



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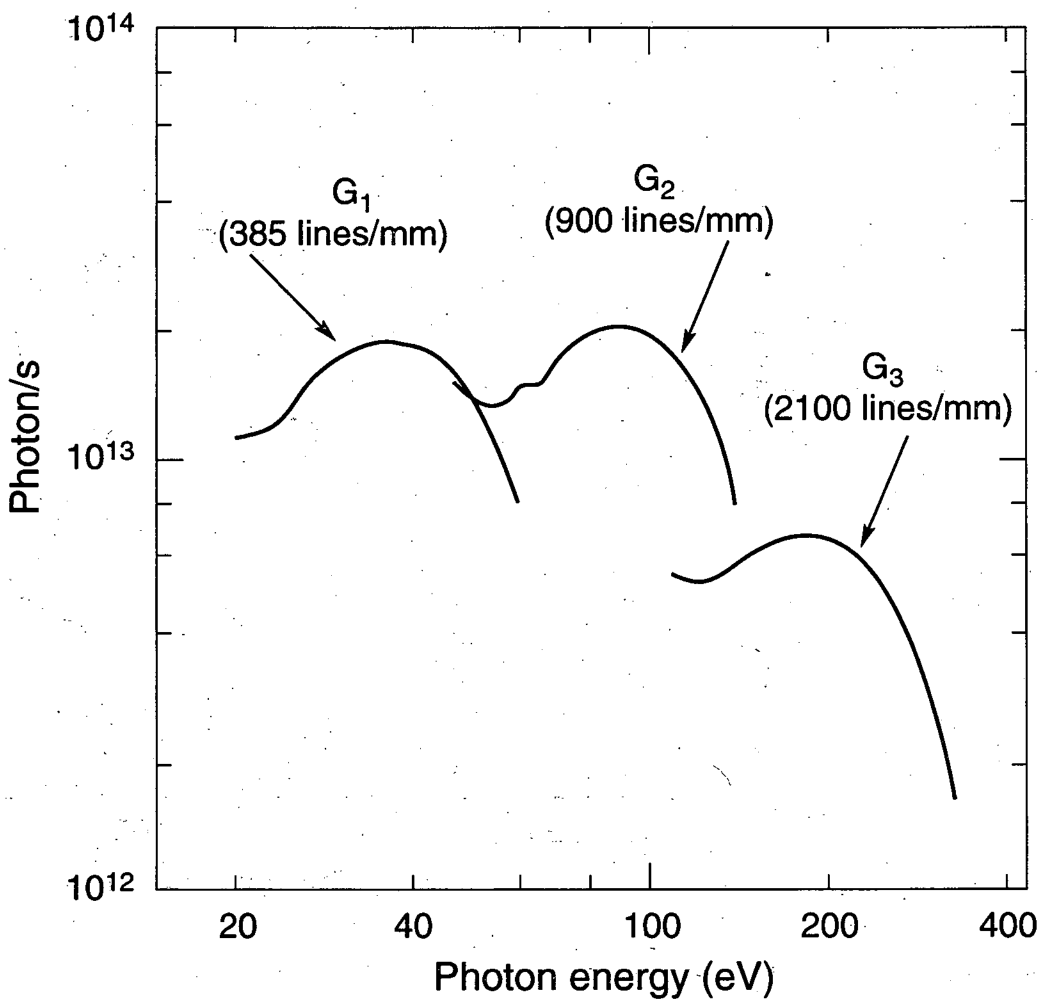
Resolved flux vs. photon energy

The figure below shows the calculated resolved flux after the exit slit for each diffraction grating.[5] The resolved flux is computed as the width of the entrance slit is varied to fix the slit-width-limited resolving power at 10,000. In practice, grating aberrations and slope errors prevent this value from ever being achieved. The calculations are based on the predicted flux from the undulator, neglecting field errors and using the first or third harmonic. The calculations include mirror absorption, aberration losses at the entrance slit, and a diffraction efficiency for square-wave gratings, in first order, with shadowing.[2]



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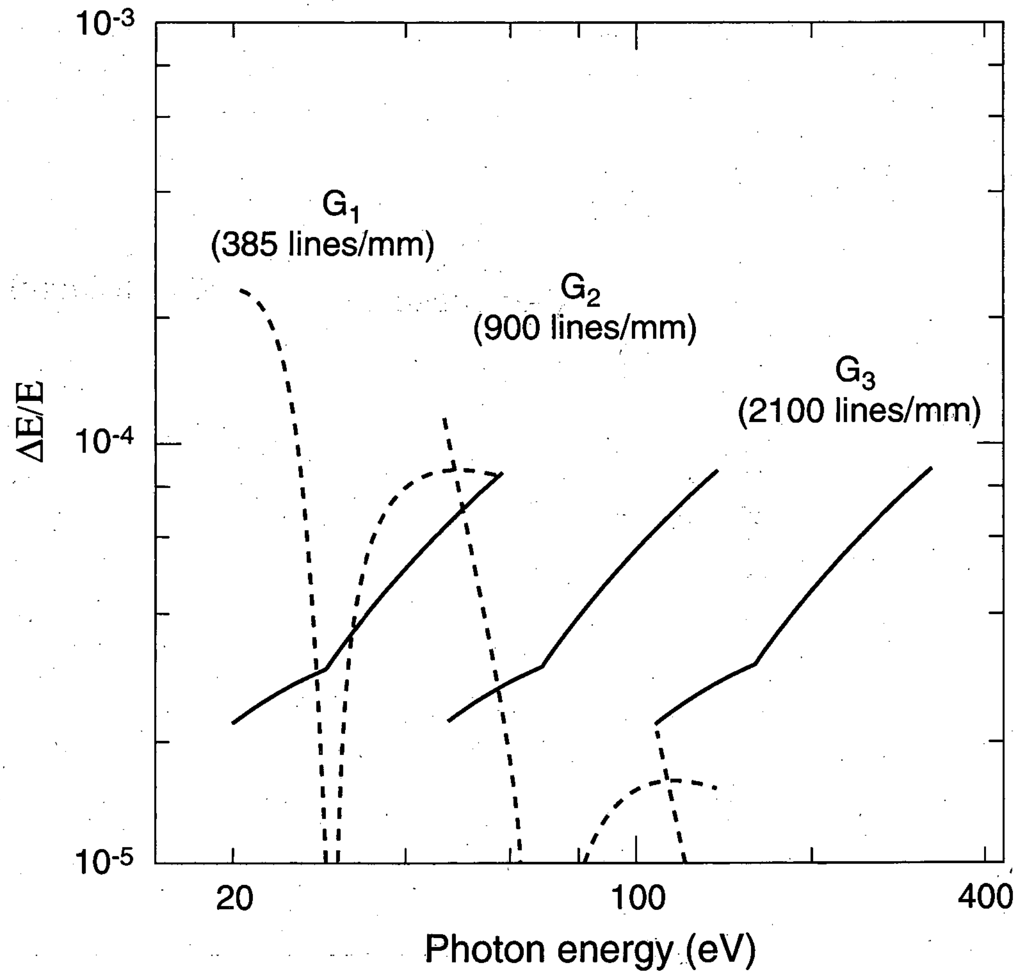
Resolution vs. photon energy

The resolution of the monochromator was computed analytically as a function of photon energy, including the geometrical aberrations of the spherical grating and the effects of finite slits.[3] These analytical results have been confirmed by explicit ray-trace analyses. The solid lines in the figure below show the resolution contribution of 10-μm slits. The broken lines show the contribution of spherical aberration. Other aberrations are negligible.



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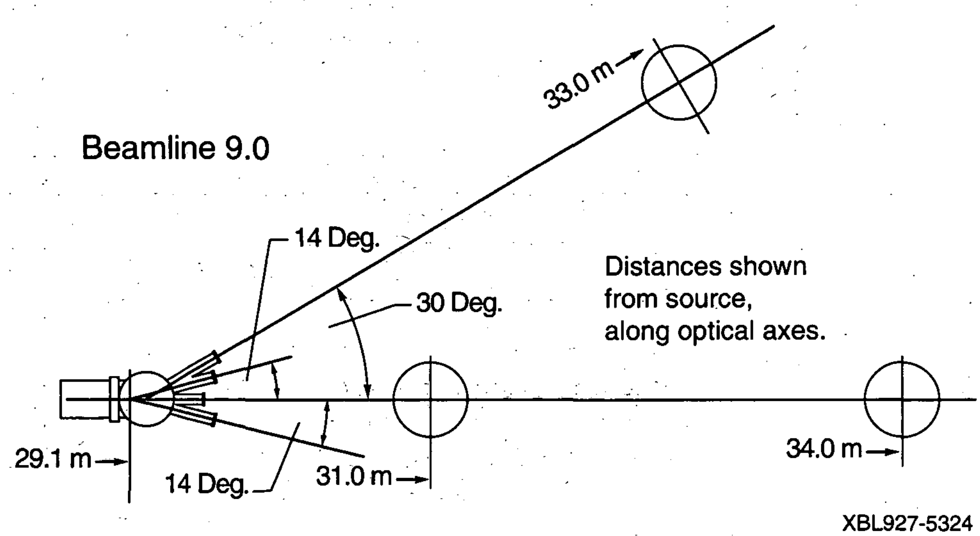
End Stations

Description

- Beamline 9.0 has two ports available to independent investigators: the straight-through port and one at 14 degrees.
- The straight-through port will have a permanent, aligned differential pumping section for gas-phase experiments.
- On either port, independent investigators can use an ALS gas-phase experimental chamber, including electron and mass spectrometers. Independent investigators who are interested in using this beamline should contact Dr. Philip A. Heimann for details about the gas phase experimental chamber. (See page 3 for contact information.)

Floor layout

Floor layout of the experimental space at the end of Beamline 9.0. The straight-through port and the port 14 degrees to its right (as one faces the beamline) are available to independent investigators.



3.
BEND-MAGNET BEAMLINES

Introduction

Available beamlines

Two bend-magnet beamlines are available to independent investigators:

- Beamline 9.3.1
- Beamline 9.3.2.

Each is an independent branchline from the same bend magnet.

More information

Section 3.1 of this Chapter contains information about ALS bend magnets. Sections 3.2 and 3.3 describe the characteristics and components of the bend-magnet beamlines.

3.1 ALS Bend Magnets

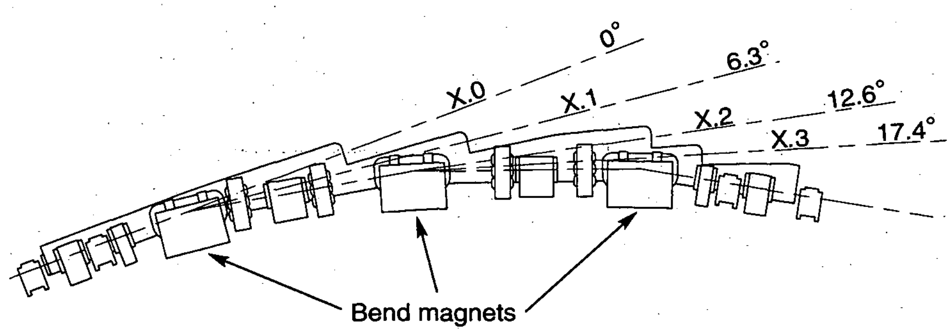
Bend-Magnet Ports

Number of ports

The ALS has a total of 36 ports for synchrotron radiation from bend magnets. Three are on each of the 12 arc sectors of the storage ring.

Port nomenclature

In a given arc sector, bend-magnet ports are named X.1, X.2, and X.3, where X is a sector number 1 through 12. (The name X.0 is assigned to the port delivering radiation from an insertion device located in the preceding straight section).



Angular separation of ports

The angular separation of the bend-magnet ports X.1 through X.3 are 6.3, 12.6, and 17.4 degrees, respectively, with respect to port X.0.

Premium ports

- Ports X.2 and X.3, from the center bend magnets in each arc sector are premium ports because they provide the smallest vertical source size.
- Ports X.1 will be developed as needed.

Source Size

The table below summarizes the size of the electron beam at the source points for radiation in the bend magnets.

Port	Source size, σ (μm)
X.1	
Horizontal	67
Vertical	142
X.2	
Horizontal	119
Vertical	38
X.3	
Horizontal	119
Vertical	38

Properties of ALS Bend-Magnet Radiation

Calculated spectral properties

The following table lists values for the spectral flux, the integrated angular flux density, the flux density in the horizontal plane, and the spectral brightness. These values were calculated using ALS storage-ring parameters and assuming standard operating conditions (i.e., a beam energy of 1.5 GeV and stored current of 400 mA).

Photon energy (keV)	Spectral Flux [photons/(s-0.1% bandwidth)]	Spectral flux per unit horizontal angle [photons/(s-mr-0.1% bandwidth)]	Spectral flux per unit solid angle [photons/(s-mr^2-0.1% bandwidth)]	Spectral brightness [photons/(s-mm^2-mr^2-0.1% bandwidth)]
5.000E–04	1.081E+13	2.161E+12	1.599E+11	3.509E+12
1.000E–03	1.359E+13	2.717E+12	2.585E+11	6.832E+12
5.000E–03	2.295E+13	4.590E+12	7.557E+11	2.326E+13
1.000E–02	2.860E+13	5.719E+12	1.199E+12	3.743E+13
5.000E–02	4.608E+13	9.217E+12	3.477E+12	1.095E+14
1.000E–01	5.492E+13	1.098E+13	5.445E+12	1.715E+14
5.000E–01	6.753E+13	1.351E+13	1.367E+13	4.301E+14
1.000E+00	5.995E+13	1.199E+13	1.717E+13	5.392E+14
1.556E+00*	4.802E+13	9.603E+12	1.735E+13	5.433E+14
5.000E+00	7.862E+12	1.572E+12	5.335E+12	1.642E+14
1.000E+01	4.177E+11	8.354E+10	4.114E+11	1.234E+13
2.000E+01	9.159E+08	1.832E+08	1.300E+09	3.716E+10
5.000E+01	6.870E+00	1.374E+00	1.390E+01	3.651E+02
1.000E+02	1.475E–13	2.949E–14	4.104E–13	9.556E–12

*Critical energy.

For additional information on the spectral properties of bend-magnet radiation, see *An ALS Handbook*.[6]

3.2 Beamline 9.3.1

Application

X-ray spectroscopy

Beamline 9.3.1 is the outside branch on bend-magnet port 9.3 (i.e., the further of two branches from the storage ring). It is dedicated to x-ray spectroscopy.

Examples of topics for investigation

The experimental program planned for this beamline includes the following topics:

- Atomic, molecular, and optical science (x-ray emission, electron, and ion-yield spectroscopy)
- Surface and interface science (photoelectron diffraction and holography)
- Biology (time-resolved absorption spectroscopy, x-ray fluorescence spectroscopy, and EXAFS)
- X-ray optical development (diffracting elements for the 700–2000 eV spectral region and for circularly polarized radiation).

Beamline Characteristics

Introduction

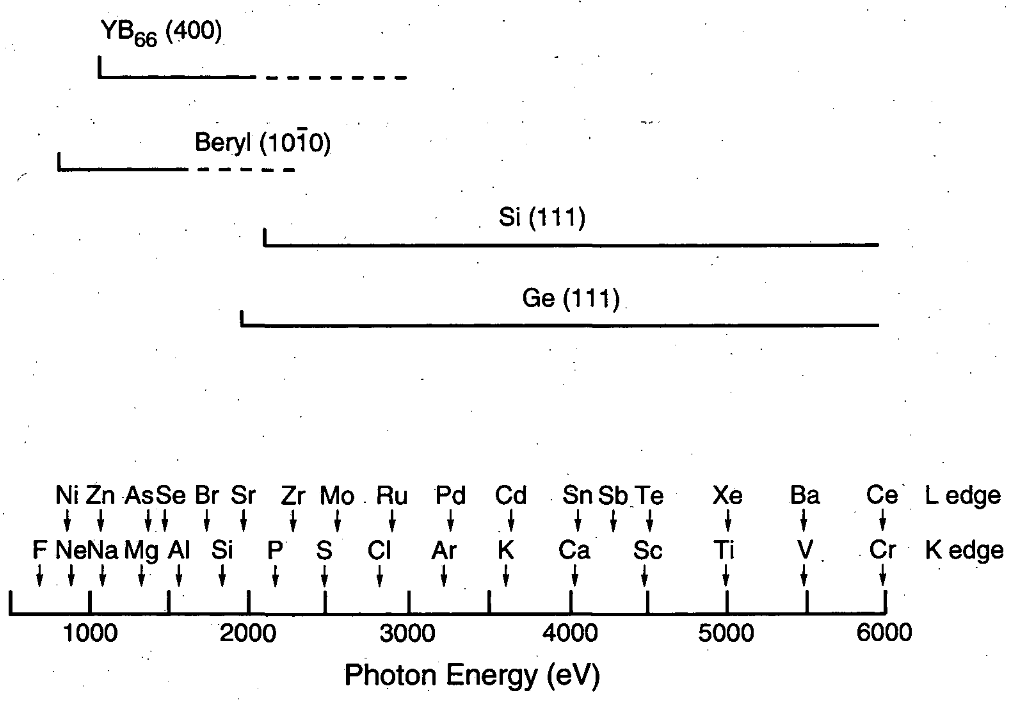
Beamline 9.3.1 is a windowless, ultra-high-vacuum beamline designed to achieve the goals of high resolution, high flux, and high intensity at the sample.

Monochromator

Beamline 9.3.1 has a double-crystal monochromator that will be equipped initially with germanium and silicon crystals. Other diffraction elements such as YB_{66}, beryl, and novel multilayers will be used as available.

Photon energy

The beamline delivers photons over the range from about 700 eV to 6 keV or higher. This energy range provides photons that reach deeper core levels than are accessible with other beamlines presently planned for the ALS. The figure below shows the energy ranges of the monochromator crystals in relation to the K and L edges of accessible elements. The solid lines indicate the most useful energy range of a crystal. The dashed lines indicate a possible, but less practical, energy range. Only silicon and germanium crystals will be available during initial operations.



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Photon flux	Beamline 9.3.1 provides a photon flux of at least 10^{11} photons/s in a $\leq$ 0.5-eV bandpass.
Spot size	The spot size at the sample position is variable in the range of 0.1 to 1 mm^2, depending on the horizontal acceptance.
Brightness	The spectral brightness of the beam is expected to exceed that from similarly designed beamlines by at least a factor of 10.

Beamline Components

Component list

The major components of Beamline 9.3.1 are a collimating mirror, a double-crystal monochromator, and a focusing mirror. These are described in the following table.

Component	Description	Function
Collimating mirror		• Collimates the beam. • Acts as a tunable low-pass filter.
Substrate	Metal	
Coating	Nickel	
Grazing-incidence angle (deg)	0–3	
Monochromator	Double crystal	• Selects desired photon energy by Bragg reflection and transmits a nearly monochromatic beam in a direction parallel to that of the incoming beam with a constant vertical displacement. • Different pairs of crystals are chosen to vary monochromator energy range and resolution.
Figure	Planar	
Bragg angle (deg)	14–70	
Silicon (111)		
Resolving power (E/ΔE)	7000–8000	
Germanium (111)		
Resolving power (E/ΔE)	3500–4000	
YB_{66} (400)		
Resolving power (E/ΔE)	2000	
Beryl ($10\bar{1}0$)		
Resolving power (E/ΔE)	2500–4000	
Maximum horizontal angular acceptance (mrad) for all crystals	8.0	
Focusing mirror		• Focuses beam horizontally and vertically to 0.1–1 mm^2 at sample, depending on the horizontal acceptance.
Substrate	Metal	
Coating	Nickel	
Grazing-incidence angle (mrad)	10–15	
Magnification	1:1	

Collimating Mirror

Varying angle of incidence

At a given incidence, a mirror will reflect photons efficiently only when the energy is below a critical value. Increasing the angle of incidence decreases the critical energy. The ability to vary the angle of incidence on the collimating mirror is therefore useful because it permits selection of the critical energy—the high-energy cut-off of the mirror. The incident flux can thus be reduced before reaching the monochromator crystals (the power load on the crystals is about one-half that on the first mirror), thereby reducing the heating of the monochromator crystals. In addition, unwanted higher orders transmitted by the monochromator are reduced.

Adjusting for changes in angle of incidence

Changing the angle of incidence on the collimating mirror affects the direction of the reflected beam. The entire beamline downstream from the first mirror must therefore pivot on the mirror's axis. This motion is accomplished by means of a stable pivoting platform for the most critical elements (monochromator and focusing mirror) and elevation positioners for the remainder of the vacuum system. The experimental apparatus moves vertically by a separate mechanism.

Double-Crystal Monochromator

Mechanical design

The mechanical design of the monochromator is of the "boomerang" type, in which a single rotary-motion vacuum feedthrough drives the rotation of both crystals as well as the translation of the second crystal.

Bragg angle

In double-crystal monochromators, the Bragg angle θ_B between the incident-beam direction and the planes of each crystal must be controlled to within the natural (Darwin) width of the diffracted radiation, which usually is a few seconds of arc (10 µrad). This stringent criterion is met by means of a piezoelectric driver that dithers the angle of the second crystal. The voltage applied to the piezoelectric device is derived from a closed-loop feedback circuit operating on a signal proportional to the flux emanating from the monochromator. With no human intervention, the circuit keeps the monochromator in tune, even while the boomerang is being scanned to vary the output photon energy.

Resolution

Resolution in many double-crystal monochromator designs is limited by the divergence of the x rays impinging upon the first crystal, giving rise to a range in θ_B. In Beamline 9.3.1, however, the first mirror collimates the beam in the vertical direction, which is the dispersion plane. The divergence of the incident x rays is thus reduced to below the Darwin width of the best crystals available for use in the energy range of interest. The x rays can thus be monochromatized to a bandwidth that is narrower than the width of atomic core levels in the 700-eV to 6-keV energy range.

End Station

Experimental chambers	At present, independent investigators who wish to work at Beamline 9.3.1 must furnish their own experimental chambers.
Gas-phase operations	For gas-phase operations, the beamline can be equipped with a diamond window that can withstand a differential pressure of 1 atmosphere.
Data acquisition	User-supplied data-acquisition systems must be compatible with the beamline control system to allow for operations such as step-scanning the monochromator with apparatus in the chamber.
For more information	For information about the end station, please contact Professor Dennis Lindle or Dr. Rupert C. Perera. (See page 3 for contact information.)
Future plans	Funding is being sought for an atomic, molecular, and optical spectroscopy end station for the beamline. This will include electron and ion spectrometers and an x-ray emission spectrometer.

3.3 Beamline 9.3.2

Application

High-resolution electron spectroscopy

Beamline 9.3.2 is the inside branch on bend-magnet port 9.3 (i.e., the closer of two branches to the storage ring). It is dedicated to the study of problems in materials and chemical sciences by high-resolution electron spectroscopy. Of special interest are the electronic, atomic, and magnetic structures of technologically important metal and semiconductor surfaces and interfaces, and microcluster growth on these surfaces.

Examples of topics for investigation

Examples of proposed research include:

- Structure determination by using angle-resolved core-level photoemission (photoelectron diffraction and photoelectron holography) for the study of site-specific and chemically specific adsorbates, interfaces, chemical kinetics and electrolysis.
- Spin-polarized photoelectron diffraction for the study of short-range magnetic order.
- Electron-electron correlation effects in free atoms and molecules.
- Angular distribution effects in threshold and near-edge photoexcitation phenomena, very fast processes, and processes requiring very high intensity and energy resolution.

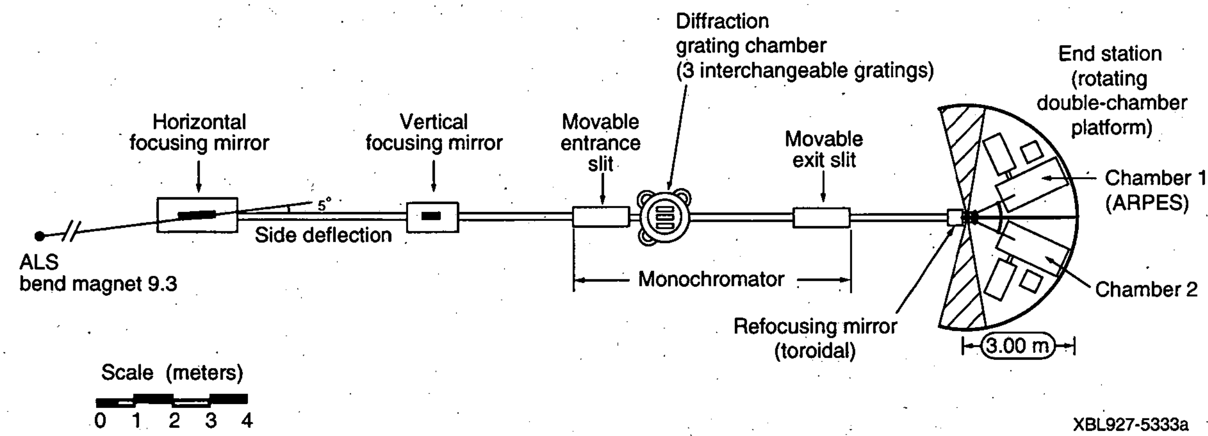
Beamline Characteristics

Introduction	Beamline 9.3.2 is a high-intensity, high-resolution beamline that operates in ultra-high vacuum. Its major components were moved to the ALS from Beamline 6-1 at Stanford Synchrotron Radiation Laboratory (SSRL) and modified to make best use of the high brightness of the ALS. A description of this beamline as it is operated at SSRL is given by Heimann.[7] A few important characteristics are given below.
Monochromator	Beamline 9.3.2 has a spherical grating monochromator (SGM) with three interchangeable gratings for selecting photon energies.
Photon energy	The diffraction gratings cover the range of photon energies from 30 eV to 1.5 keV.
Photon intensity at sample	The photon intensity is 5×10^{10} photons/s (0.01% bw) at 500 eV.
Resolution	$E/\Delta E$ is 10,000 with the monochromator entrance and exit slits set at 10 µm.
Spot size	The spot size is about 100 µm (vertical) × 500 µm (horizontal).

Beamline Components

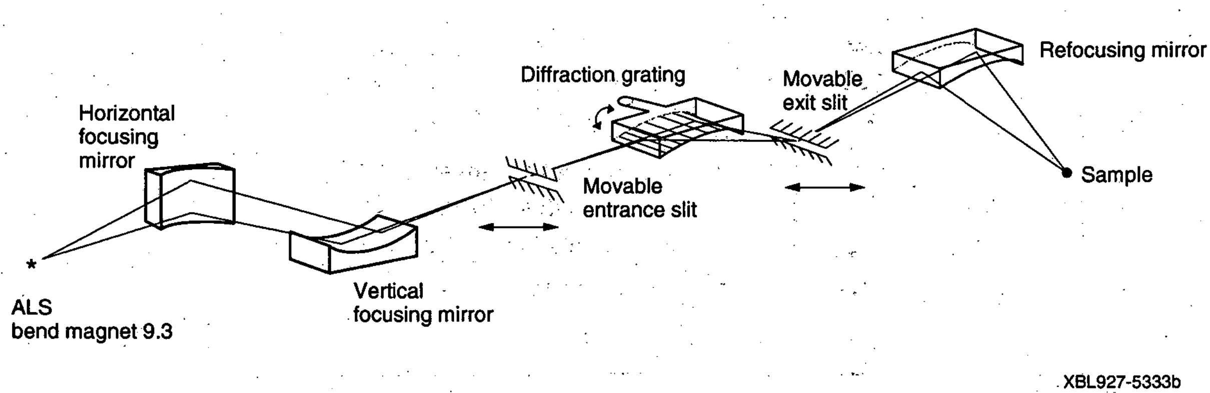
Layout

The figure below shows the layout for Beamline 9.3.2.



Optical components

The figure below is a schematic illustration of the photon beam path through the optical components.



Beamline Components (continued)

Component list

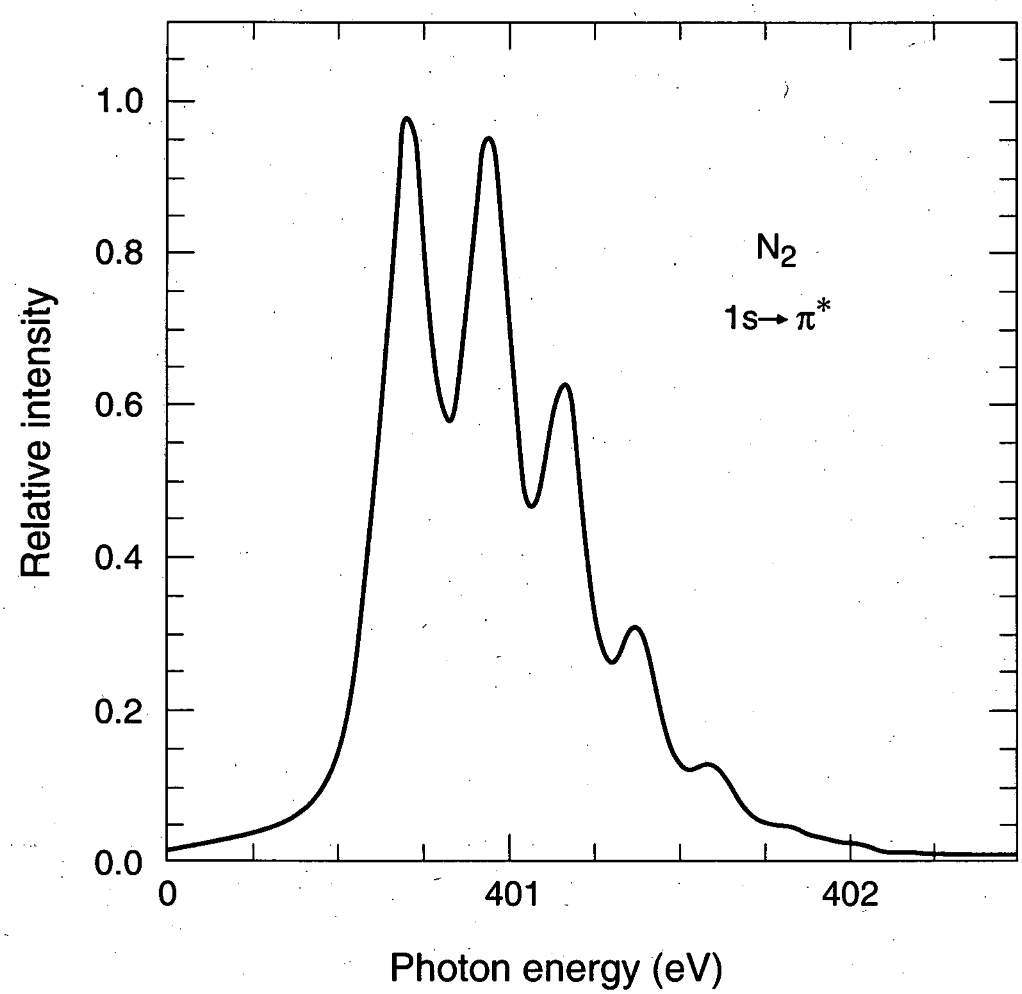
The following table lists and describes the components of Beamline 9.3.2. Except for the first horizontal focusing mirror, all of these components are outside the shielding wall in the experimental hall.

Component	Description	Function
Horizontal focusing mirror	Water-cooled	• Accepts 7.5 mrad of bend-magnet radiation. • Reflects the photon beam horizontally a distance of 5° toward the shielding wall. • Focuses the beam horizontally at mid-position on the movable monochromator exit slit.
Figure	Tangential cylinder	
Substrate	Glidcop™	
Coating	Gold	
Grazing incidence angle (deg)	2.5	
Vertical focusing mirror		• Deflects the photon beam vertically by 6°. • Focuses the beam vertically at mid-position on the movable monochromator entrance slit.
Figure	Spherical	
Substrate	Glidcop™	
Coating	Gold	
Grazing incidence angle (deg)	3.0	
Monochromator	SGM	Allows selection of photon energies.
Entrance slit		
Location	Movable	
Opening	Precision adjustable from 5 µm to 2 mm	
Diffraction gratings	Three interchangeable, gold-coated spherical gratings: 100 l/mm (30–200 eV, water-cooled) 600 l/mm (180–820 eV) 1200 l/mm (370–1500 eV, water-cooled)	
Resolving power ($E/\Delta E$)	10,000 (using 10-µm entrance and exit slits)	
Exit slit		
Location	Movable	
Opening	Precision adjustable from 5 µm to 2 mm	
Refocusing mirror		Provides focused synchrotron radiation to end station.
Figure	Toroidal	
Substrate	Quartz	
Coating	Gold	
Grazing incidence angle	2.0°	

Monochromator Resolution

Example

While in operation at SSRL, the monochromator achieved the slit-limited designed resolving power of up to 10,000. This is illustrated in the figure below, which shows the 1s --> π* photoabsorption resonance of nitrogen gas (with 10-μm slit openings).



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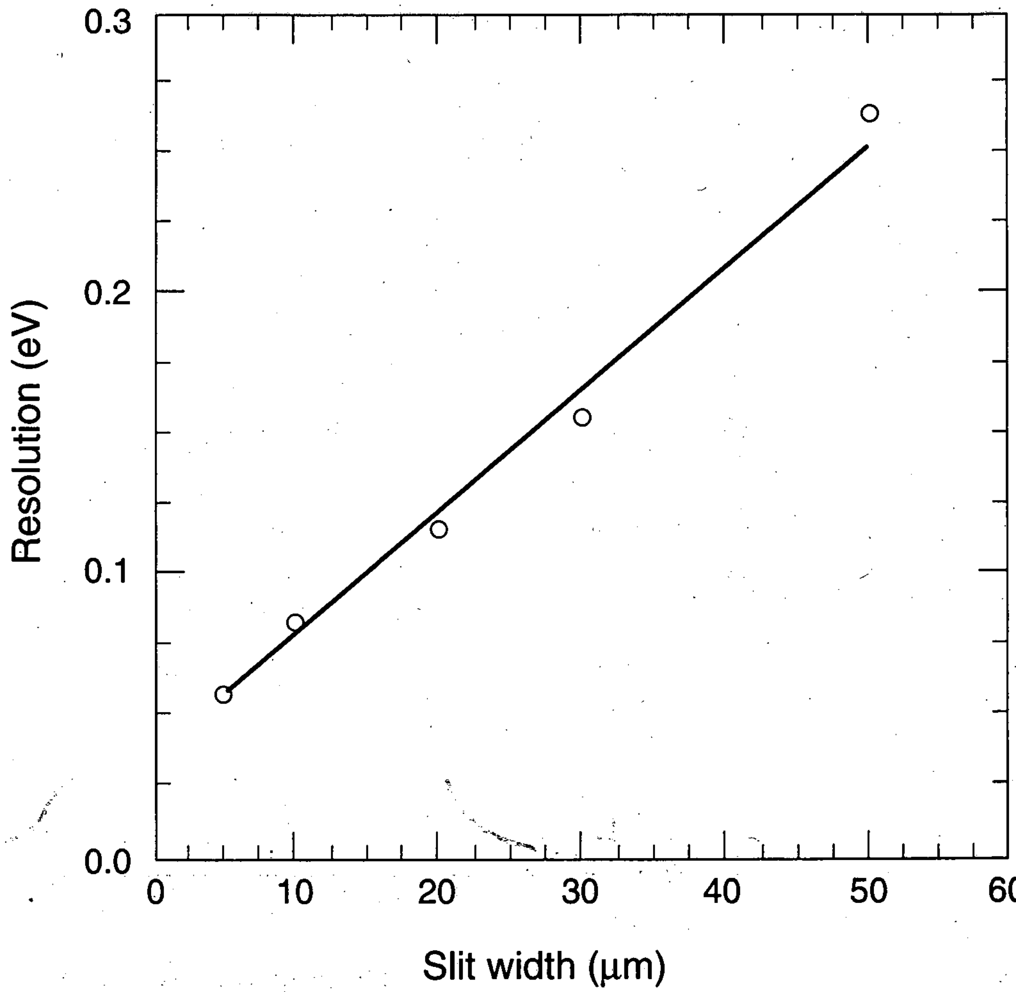
Resolution vs. slit width

The following figure shows the measured resolution of the monochromator as a function of slit width inferred from fitting experimental data such as that shown in the preceding figure.



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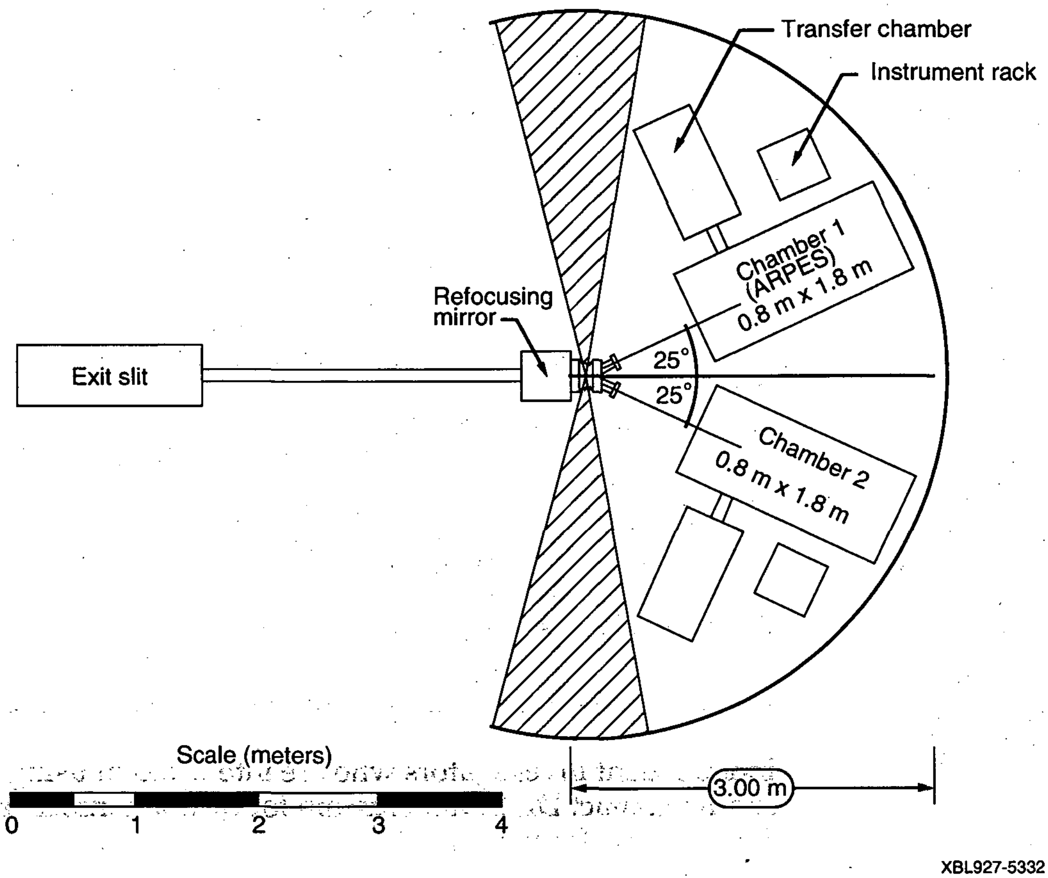
End Station

Layout

The beamline end station has a movable platform that accommodates two experimental chambers. It enables the photon beam to be directed to either experimental chamber without breaking the vacuum (see the drawing below).



ARPES system

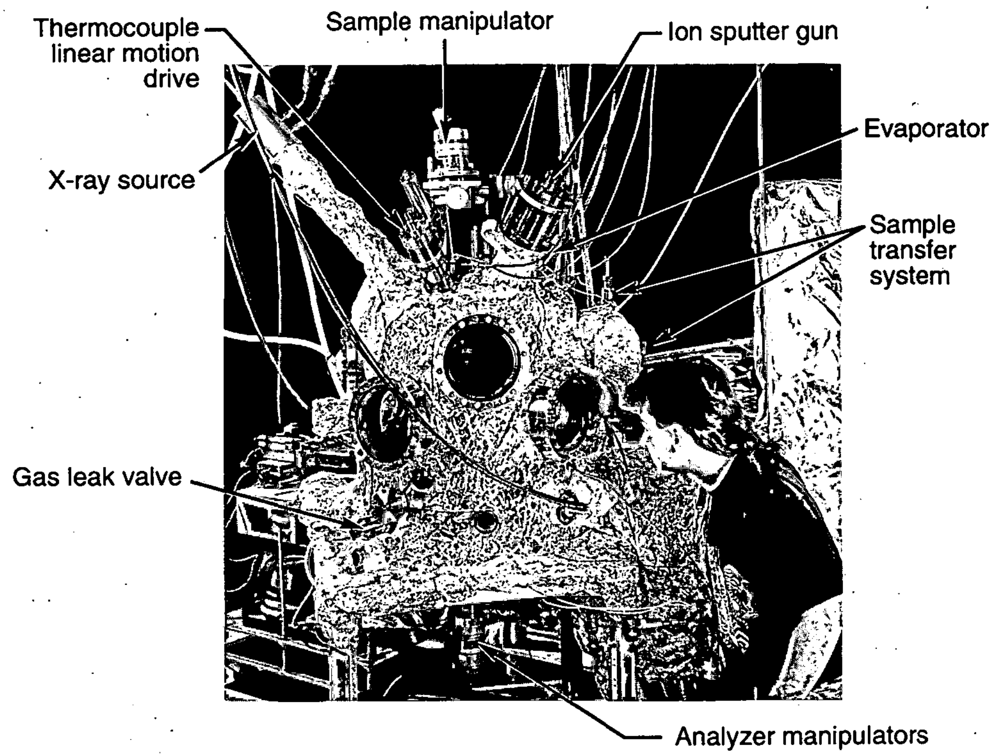
One of the chamber sites is outfitted with an angle-resolved photoemission spectrometer (ARPES) system dedicated to the beamline. The ARPES has the following components:

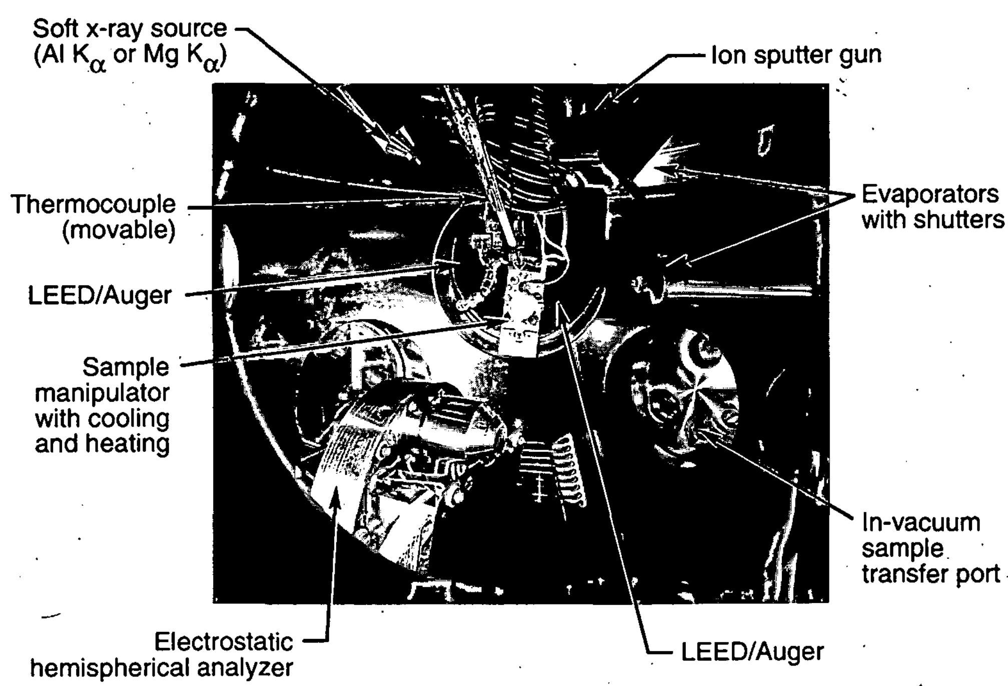
- Rotatable electrostatic hemispherical analyzer with multichannel detection
- Low-energy electron diffraction
- Partial yield electron detector
- Soft x-ray (Mg Kα) source
- Sample parking, preparation, and transfer system
- Sample manipulator with liquid nitrogen/liquid helium cooling, e-beam heating, and both polar and azimuthal rotation
- Residual gas analyzer (RGA)
- Ion sputter gun
- Gas doser with gas manifold
- Photoionization gas cell
- Complete data acquisition and data analysis system.

Independent investigators who are interested in using the ARPES system should contact Dr. Zahid Hussain for detailed information. (See page 3 for contact information.)

ARPES system

Top: an external view of the angle-resolved photoemission spectrometer (ARPES). Bottom: a view through a window of the ARPES.





Second chamber

At the second site, chambers may be interchanged. The site can accommodate chambers brought in by independent investigators. An advanced photoemission spectrometer with a large, high-efficiency, rotatable analyzer is under construction and is expected to be available by the end of 1993 for use at this site or on other beamlines.

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