

ADVANCED PHOTON SOURCE

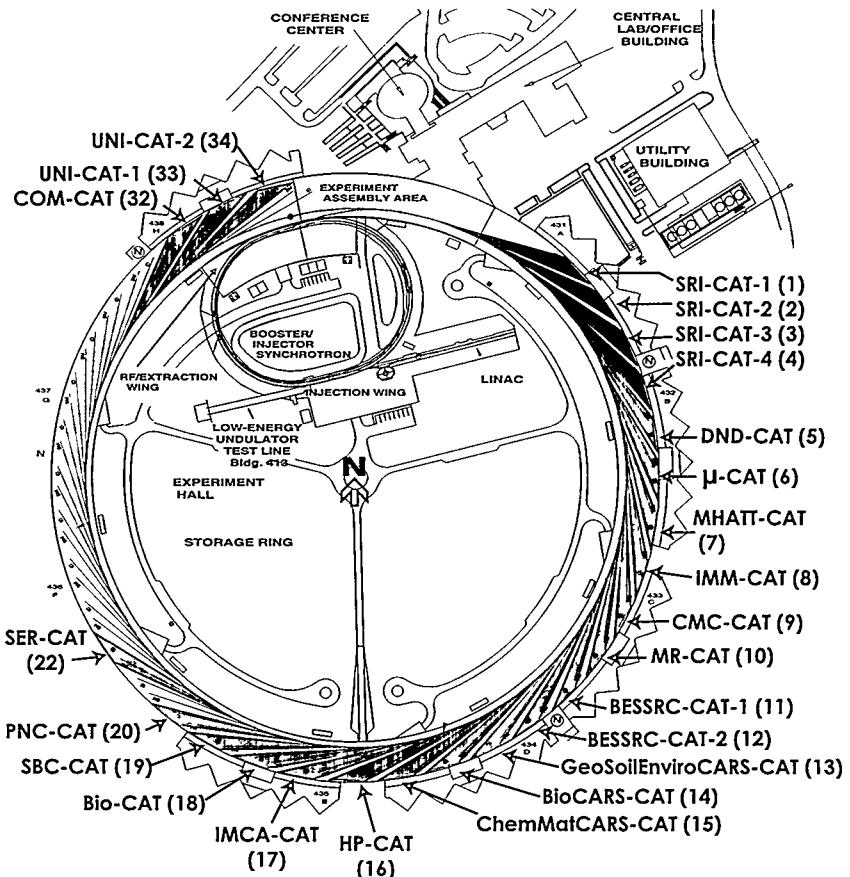
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# CAT Guide and Beamline Directory

A Key to APS Collaborative Access Teams

November 1999  
Argonne National Laboratory



## INSTRUMENTATION

MATERIALS SCIENCE,  
CHEMICAL SCIENCE,  
ATOMIC SCIENCE

GEO/SOIL/ENVIRONMENTAL  
SCIENCES

BIOLOGY

CAT ACRONYM	CAT NAME	SECTOR	BEAMLINE(S)
SRI-CAT	Synchrotron Radiation Instrumentation	1	1-BM, 1-ID
		2	2-BM, 2-ID
		3	3-ID
		4	4-ID
DND-CAT	DuPont–Northwestern–Dow	5	5-BM, 5-ID
mCAT	Midwest Universities	6	6-ID
MHATT-CAT	Center for Real-Time X-ray Studies	7	7-BM, 7-ID
IMM-CAT	IBM–MIT–McGill	8	8-BM, 8-ID
CMC-CAT	Complex Materials Consortium	9	9-BM, 9-ID
MR-CAT	Materials Research	10	10-ID
BESSRC-CAT	Basic Energy Sciences Synchrotron Radiation Center	11	11-ID
		12	12-BM, 12-ID
CARS-CAT	Consortium for Advanced RadiationSources GeoSoilEnviroCARS BioCARS ChemMatCARS	13	13-BM, 13-ID
		14	14-BM, 14-ID
		15	15-ID
HP-CAT	High-Pressure	16	under development
IMCA-CAT	Industrial Macromolecular Crystallography Association	17	17-BM, 17-ID
Bio-CAT	Biophysics	18	18-BM, 18-ID
SBC-CAT	Structural Biology Center	19	19-BM, 19-ID
SER-CAT	Southeast Regional	22	under development
PNC-CAT	Pacific Northwest Consortium	20	20-BM, 20-ID
COM-CAT	Commercial	32	32-ID
UNI-CAT	A University–National Laboratory–Industry	33	33-BM, 33-ID
		34	34-ID

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# CAT Guide and Beamline Directory

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# The Advanced Photon Source

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## Facility Overview

The Advanced Photon Source (APS), a national user facility for synchrotron radiation research, is located at Argonne National Laboratory, approximately 25 miles southwest of Chicago, Illinois. The APS is considered a third-generation synchrotron radiation facility (specifically designed to accommodate insertion devices to serve as radiation sources) and is one of three such facilities in the world. Currently, it is the most brilliant source in the United States for research in such diverse fields as biology, medicine, materials science, chemistry, geology, agriculture and soil science, physics, and manufacturing technology.

Researchers use the APS either as members of Collaborative Access Teams (CATs) or as Independent Investigators (IIs). CATs are responsible for designing, building, and operating beamlines in one or more sectors, each sector consisting of an insertion-device (ID) beamline and a bending-magnet (BM) beamline. Each beamline is designed to accommodate a specific type of research program(s) and is optimized accordingly.

## User Program

CAT members are entitled to use 75% of the available beam time to pursue CAT research goals. The remaining 25% of the available beam time must be made available to IIs, who are selected by the CAT through a proposal process determined by each CAT and approved by the APS. Prospective IIs submit proposals to the APS User Office, which screens each proposal for completeness, logs it in, arranges for review, then forwards it to the appropriate CAT(s). Proposal forms can be downloaded from the World Wide Web (WWW) at the following address: [http://www.aps.anl.gov/xfd/communicator/useroffice/llprop\\_form.html](http://www.aps.anl.gov/xfd/communicator/useroffice/llprop_form.html). This document, the *CAT Guide and Beamline Directory*, was written to help prospective IIs determine which beamlines are suitable for their specific experiments. Further information can be obtained from the APS User Office or the individual CATs (contact information is provided on the inside back cover of this document).

## Summary Beamline / Scientific Programs Table

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BEAMLINE	CAT	SCIENTIFIC FOCUS	PROGRAMS	SOURCE	STATUS *
1-BM	SRI	Synchrotron instrumentation and techniques, time-resolved studies	-Use and generation of polarized x-rays -Time-resolved studies, dispersive diffraction and spectroscopy	BM	O II
1-ID	SRI	Synchrotron instrumentation and techniques, high-energy x-rays, optics development	-High-energy x-ray scattering techniques -High-heat-load x-ray optics development	Und A (3.3 cm)	O II
2-BM	SRI	Synchrotron instrumentation and techniques, x-ray lithography, microtomography	-Deep x-ray lithography -X-ray microtomography -Development of x-ray optics -Beam diagnostics instrumentation -X-ray microprobe studies	BM	II
2-ID-B	SRI	Synchrotron instrumentation and techniques, imaging, coherence	-High-resolution imaging -Coherent scattering -Interferometry	5.5-cm Und	O II
2-ID-C	SRI	Synchrotron instrumentation and techniques, polarization spectroscopy	-High-resolution polarization-dependent x-ray spectroscopies	5.5-cm Und	O
2-ID-D/E	SRI	Synchrotron instrumentation and techniques, imaging, coherence	-High-resolution imaging -Coherence-based techniques	Und A (3.3 cm)	O II
3-ID	SRI	Synchrotron instrumentation and techniques, resonant and non-resonant inelastic scattering	-Nuclear resonant scattering -Inelastic x-ray scattering	2.7-cm Und	O II
4-ID	SRI	Synchrotron instrumentation and techniques, use of polarized x-rays	-Development of polarization optics and techniques for 0.5 - 100 keV -Development of high-heat-load front-end and optical components	Und A (3.3 cm) & Circularly Polarized Und	D
5-BM	DND	Crystallography, EXAFS, polymer scattering, tomography	-Materials science and engineering -Polymer science -Crystallography -Surface science -Catalysis -Imaging	BM	O C

5-ID	DND	Crystallography, EXAFS, polymer scattering, tomography	-Materials science and engineering -Polymer science -Crystallography -Surface science -Catalysis	Und A (3.3 cm)	O C
6-ID	$\mu$	Materials science	-Magnetic scattering and spectroscopy -Liquid-surface studies -Surface scattering	Und A (3.3 cm)	C
7-BM	MHATT	Real-time x-ray studies	-Real-time x-ray studies -X-ray microcharacterization -X-ray photon correlation spectroscopy	BM	D
7-ID	MHATT	Real-time x-ray studies	-Real-time x-ray studies -X-ray microcharacterization -X-ray photon correlation spectroscopy	Und A (3.3 cm)	O C
8-ID	IMM	Condensed matter physics, materials science	-Intensity fluctuation spectroscopy studies using coherent x-rays -Time-resolved x-ray scattering -X-ray scattering studies at very-low temperatures -X-ray magnetic scattering	Und A (3.3 cm)	O C
9-BM	CMC	Materials science	-EXAFS of complex materials -X-ray surface scattering -General diffraction	BM	C
9-ID	CMC	Materials science	-SAXS from complex materials -Liquid/solid surface scattering -EXAFS -General diffraction -Magnetic scattering	Und A (3.3 cm)	C
10-ID	MR	Materials science, environmental science	-Spectroscopy of dilute environmental systems -Combined techniques for <i>in situ</i> characterization of materials -Zone plate microfocusing spectroscopy and imaging	Und A (3.3 cm)	O C

\* O = operational (beamlines identified as operational may have facilities still being commissioned.)

C = commissioning

D = design / construction

II = accepting Independent Investigator proposals

BM = bending magnet

Und = undulator

BEAMLINE	CAT	SCIENTIFIC FOCUS	PROGRAMS	SOURCE	STATUS *
11-ID	BESSRC	Spectroscopy, scattering, high-energy diffraction, magnetic Compton scattering	<ul style="list-style-type: none"> <li>-Materials science: x-ray scattering, high-energy diffraction, dichroism, magnetism</li> <li>-Geoscience</li> <li>-Atomic physics</li> <li>-Chemistry: spectroscopy (EXAFS, XANES), time-dependent spectroscopy of excited states</li> </ul>	Elliptical Multipole Wiggler	D
12-BM	BESSRC	Spectroscopy, x-ray scattering, diffraction	<ul style="list-style-type: none"> <li>-Materials science: x-ray scattering, diffraction and spectroscopy</li> <li>-Geoscience: mineral-liquid interface characterization by x-ray scattering and spectroscopy</li> <li>-Chemistry: EXAFS and XANES spectroscopy of actinides and lanthanides</li> <li>-Atomic physics</li> </ul>	BM	O C
12-ID	BESSRC	Materials science, atomic physics, geoscience	<ul style="list-style-type: none"> <li>-Materials science: elastic and inelastic scattering, MOCVD, x-ray standing waves, electrochemistry</li> <li>-Geoscience: mineral-liquid interface characterization</li> <li>-Chemistry: small-angle scattering</li> <li>-Atomic physics, spectroscopy</li> </ul>	Und A (3.3 cm)	O C
13-BM	CARS GSECARS	Geosciences, environmental science, soil science	<ul style="list-style-type: none"> <li>-High-pressure diffraction in diamond-anvil cell</li> <li>-High-pressure diffraction in multi-anvil press</li> <li>-Microspectroscopy and XRF microprobe</li> <li>-Microtomography</li> </ul>	BM	O
13-ID	CARS GSECARS	Geosciences, environmental science, soil science	<ul style="list-style-type: none"> <li>-High-pressure diffraction in diamond-anvil cell</li> <li>-High-pressure diffraction in multi-anvil press</li> <li>-Microspectroscopy and XRF microprobe</li> <li>-Microcrystal diffraction</li> <li>-Surface diffraction</li> <li>-X-ray absorption fine structure spectroscopy</li> </ul>	Und A (3.3 cm)	O

14-BM	CARS BioCARS	Structural biology	<ul style="list-style-type: none"> <li>-Large unit cell (virus) crystallography</li> <li>-Small unit cell (protein) crystallography</li> <li>-MAD phasing</li> <li>-Time-resolved crystallography</li> <li>-Laue diffraction</li> <li>-Study of microcrystals</li> </ul>	BM	O
14-ID	CARS BioCARS	Structural biology	-See above	Wiggler A (8.5 cm)	O
15-ID	CARS ChemMat- CARS	Dynamic and structural condensed matter physics	<ul style="list-style-type: none"> <li>-Time-dependent chemical crystallography scattering</li> <li>-Static and time-dependent surface scattering studies of surface and interfacial properties</li> <li>-Small-angle and wide-angle x-ray scattering</li> <li>-Coherent x-ray scattering studies of dynamic properties</li> </ul>	Und A (3.3 cm)	C
16-BM	HP	High-pressure research	-Under development	BM	D
16-ID	HP	High-pressure research	-Under development	Und A (3.3 cm)	D
17-BM	IMCA	Pharmaceutical macromolecular crystallography	<ul style="list-style-type: none"> <li>-Structures of protein-ligand complexes</li> <li>-<i>De novo</i> protein structures</li> <li>-Drug design</li> <li>-Protein engineering</li> <li>-Crystallographic methods development</li> </ul>	BM	O
17-ID	IMCA	Pharmaceutical macromolecular crystallography	-See above	Und A (3.3 cm)	O
18-ID	Bio	Static and dynamic studies of partially ordered biological systems	<ul style="list-style-type: none"> <li>-Fiber diffraction</li> <li>-X-ray scattering</li> <li>-X-ray absorption/emission spectroscopy</li> <li>-X-ray imaging and tomography</li> </ul>	Und A (3.3 cm)	O

\* O = operational (beamlines identified as operational may have facilities still being commissioned.)

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BM = bending magnet

Und = undulator

BEAMLINE	CAT	SCIENTIFIC FOCUS	PROGRAMS	SOURCE	STATUS *
19-BM	SBC	Macromolecular crystallography	-Structural biology	BM	O
19-ID	SBC	Macromolecular crystallography	-Structural biology	Und A (3.3 cm)	O
20-BM	PNC	Materials science, environmental science	-Materials science -Environmental science -Surface science	BM	D
20-ID	PNC	Materials science, environmental science	-Materials science -Environmental science -UHV/surface science, MBE growth -X-ray microbeams	Und A (3.3 cm)	O
22-BM	SER	Macromolecular crystallography	-Structural biology	BM	D
22-ID	SER	Macromolecular crystallography	-Structural biology	Und A (3.3 cm)	D
32-ID	COM	Materials characterization	-Analytical materials characterization -Fee-for-service" analyses	Und A (3.3 cm)	D
33-BM	UNI	Materials science and condensed matter physics	-Materials science -Ceramic science -Phase transitions -Surface science -Thin-films structure and growth -Materials physics	BM	D
33-ID	UNI	Materials science and condensed matter physics	-Materials science -Ceramic science -Phase transitions -Surface science -Thin-films structure and growth -Materials physics	Und A (3.3 cm)	O
34-ID	UNI	Microfocusing and coherent x-ray scattering	-Coherent x-ray diffraction -Microbeam scattering	Und A (3.3 cm)	D

\* O = operational (beamlines identified as operational may have facilities still being commissioned.)

C = commissioning

D = design / construction

II = accepting Independent Investigator proposals

BM = bending magnet

Und = undulator



## Synchrotron Radiation Instrumentation CAT

### **Overview**

SRI-CAT is organized into instrumentation developers and scientific members, with the developers coming primarily from the Experimental Facilities Division of the APS, as well as from Purdue University, University of Houston, National Institute of Science and Technology, Lawrence Berkeley National Laboratory, Stanford Synchrotron Radiation Laboratory, Cornell High Energy Synchrotron Source, and many Australian institutions managed by the Australian Nuclear Science and Technology Organization.

### **Research Focus**

The principal mission of SRI-CAT is to develop new and unique forefront instruments and techniques to advance the use of synchrotron radiation. To that end, research programs involve the design, construction, and operation of standard and specialized insertion devices; diagnostics of radiation from these insertion devices; development of high-heat-load optics; the design, construction, and testing of various standard and modular beamline components; and the development of strategic instruments and techniques. Among those instruments/capabilities are the application of microbeam techniques, the development of scientific capabilities at high energies (>50 keV), the application of coherence-based techniques, the development of 0.5- to 4-keV scientific capabilities, the development of ultrahigh-resolution inelastic scattering techniques, and the application of nuclear coherent spectroscopy. The insertion-device beamline in sector 4 is currently being developed to provide variably polarized x-rays with energies from 0.5 keV to 100 keV and higher. In the low-energy range (0.5 keV to 3 keV), a helical undulator with grazing-angle reflective optics will be used; for energies above 3 keV, a standard APS undulator A with crystal optics will be used as the radiation source. These unique tunable polarization and energy capabilities on one beamline will provide scientists with the ability to cover all important absorption edges from M to K for magnetic spectroscopy experiments, spectro-microscopy, and resonant magnetic scattering.

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# Beamline 1-BM / SRI-CAT

**Scientific focus:** Synchrotron instrumentation and techniques, polarization, and time-resolved studies

**Scientific programs:** Use and generation of polarized x-rays, time-resolved studies, dispersive diffraction, and spectroscopy

## Bending magnet Source Characteristics (nominal)

source	APS bending magnet
critical energy	19.51 keV
energy range	1.0 - 100.0 keV
on-axis peak brilliance at 16.3 keV	$2.9 \times 10^{15}$ ph/sec/mrad <sup>2</sup> /mm <sup>2</sup> /0.1%bw
on-axis peak angular flux at 16.3 keV	$9.6 \times 10^{13}$ ph/sec/mrad <sup>2</sup> /0.1%bw
on-axis peak horizontal angular flux at 5.6 keV	$1.6 \times 10^{13}$ ph/sec/mradh/0.1%bw
source size at critical energy $\Sigma_x$	145 $\mu$ m
$\Sigma_y$	36 $\mu$ m
source divergence at critical energy $\Sigma_x'$	6 mrad
$\Sigma_y'$	47 $\mu$ rads
1-BM acceptance	3.7 mrad

## Optics & Optical Performance

- vertical collimating mirror  
25.5 m from source  
bent cylinder
- bent-crystal monochromator  
31.5 m from source  
horizontal focus
- vertical focusing mirror  
45.5 m from source  
cylindrical bend
- PSL double-crystal monochromator  
27.2 m from source  
sagittal focus  
Si(111) crystal  
 $10^{-4}$  energy resolution (dE/E)  
35 mm beam offset  
water cooling

## Experiment Stations

- 1-BM-A  
first optics enclosure  
collimating mirror  
PSL monochromator
- 1-BM-B  
white, pink, and monochromatic beam station  
dispersive modes
- 1-BM-C  
monochromatic beam station

## Detectors

- NaI scintillation counters
- ionization chambers
- Si(Li) energy dispersive detectors
- CCDs

## Beamline Controls and Data Acquisition

- Sun UNIX running EPICS with VME
- SPEC

## Beamline Support Equipment/Facilities

- 6-circle Huber diffractometer

**Beamline contacts:** Peter Lee  
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## Beamline 1-ID / SRI-CAT

**Scientific focus:** Synchrotron instrumentation and techniques, high-energy x-rays, and optics development

**Scientific programs:** High-energy x-ray scattering techniques and high-heat-load x-ray optics development

### Insertion-device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ mm $^2$ /0.1% bw
source size at 8.0 keV $\Sigma_x$ $\Sigma_y$	359 $\mu$ m 21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x'$ $\Sigma_y'$	24 $\mu$ rad 6.9 $\mu$ rad

## Optics & Optical Performance

- Kohzu double-crystal constant off-set monochromator
  - 30 m from source
  - 4–20 keV energy range Si(111)
  - $10^{-4}$  energy resolution ( $dE/E$ ) at 10 keV
  - 35 mm offset
  - liquid-nitrogen cooling
- high-energy monochromator
  - 35 m from source
  - 30–150 keV energy range

## Experiment Stations

- 1-ID-A
  - white beam first optics enclosure
  - Kohzu monochromator
- 1-ID-B
  - white beam station
  - high-energy studies
- 1-ID-C
  - monochromatic beam station

## Detectors

- NaI scintillation
- ionization chambers
- Princeton Instruments CCD
- Ge & Si(Li) solid state detectors
- image plate

## Beamline Controls and Data Acquisition

- Sun UNIX running EPICS with VME, SPEC
- SPEC

## Beamline Support Equipment/Facilities

#### • Beamline Support Equip.

**Beamline contacts:** Dean Haeffner  
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# Beamline 2-BM / SRI-CAT

**Scientific focus:** Synchrotron instrumentation and techniques, x-ray lithography, and microtomography

**Scientific programs:** Deep x-ray lithography, x-ray microtomography, development of x-ray optics, beam diagnostics instrumentation, and x-ray microprobe studies

## Bending Magnet Source Characteristics (nominal)

source	APS bending magnet
critical energy	19.51 keV
energy range	1.0 - 100.0 keV
on-axis peak brilliance at 16.3 keV	$2.9 \times 10^{15}$ ph/sec/mrad <sup>2</sup> /mm <sup>2</sup> /0.1%bw
on-axis peak angular flux at 16.3 keV	$9.6 \times 10^{13}$ ph/sec/mrad <sup>2</sup> /0.1%bw
on-axis peak horizontal angular flux at 5.6 keV	$1.6 \times 10^{13}$ ph/sec/mradh/0.1%bw
source size at critical energy $\Sigma_x$	145 $\mu$ m
$\Sigma_y$	36 $\mu$ m
source divergence at critical energy $\Sigma_x'$	6 mrad
$\Sigma_y'$	47 $\mu$ rad
2-BM acceptance	2.0 mrad

## Optics & Optical Performance

- vertical deflecting mirror  
24.9 m from source  
0.15° incident angle  
Cr, Pt coatings  
plane figure
- double multilayer monochromator  
27.4 m from source  
unfocussed
- Kohzu double-crystal monochromator  
28.8 m from source  
unfocussed
- vertical deflecting mirror  
49.4 m from source  
0°–2° incident angle, variable  
Pt coating  
plane figure

## Experiment Stations

- 2-BM-A  
white beam first optics enclosure
- 2-BM-B  
pink and monochromatic beam station

## Detectors

- energy dispersive detector
- scintillation detector
- ionization chambers
- peltier-cooled CCD camera

## Beamline Controls and Data Acquisition

- Sun UNIX running EPICS with VME; NT and MacOS workstations
- SPEC

## Beamline Support Equipment/Facilities

- precision scanning stage for x-ray lithography
- micropositioning system
- 6-circle diffractometer

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# Beamline 2-ID-B / SRI-CAT

**Scientific focus:** Synchrotron instrumentation and techniques, imaging, and coherence

**Scientific programs:** High-resolution imaging, coherent scattering, and interferometry

## Insertion Device Source Characteristics (nominal)

source	5.5 cm undulator
period	5.50 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	6.57
energy range 1st harmonic	0.4 - 7.0 keV
energy range 1st - 5th harmonics	0.4 - 25.0 keV
on-axis peak brilliance at 4.0 keV	$4.2 \times 10^{18}$ ph/sec/mrad $^2$ /mm $^2$ /0.1%bw
source size at 4.0 keV $\Sigma_x$ $\Sigma_y$	359 $\mu$ m 21 $\mu$ m
source divergence at 4.0 keV $\Sigma_x'$ $\Sigma_y'$	24 $\mu$ rad 9.0 $\mu$ rad

## Optics & Optical Performance

- high-heat-load mirror M1
  - 29.5 m from source
  - 0.15° incident angle
  - plane figure
  - Pt, Rh, and Si coatings
- horizontal focusing mirror M2B
  - 31.1 m from source
  - 1.25° incident angle
  - spherical figure
  - Pt, Rh, multilayer coatings
- vertical focusing mirror M3B
  - 31.6 m from source
  - 1.25° incident angle
  - cylindrical figure
  - Pt, Rh, multilayer coatings
- multilayer spherical grating monochromator
  - 46.8 m from source
  - 0.5–4.0 keV energy range
  - 600, 1200, and 1800 lines/mm gratings
  - 100–4000 resolution E/dE
  - 1.5 mm hor. x 0.5 mm vert. beam size FWHM

- microprobe zone plate
  - 60.3 m from source
  - 60 nm x 60 nm focus size
  - $10^7$ – $10^8$  ph/sec/0.1% bw microprobe flux

## Experiment Station

- 2-ID-B

## Detectors

- absolute-calibrated photodiodes
- avalanche photodiodes
- dispersive LIGe fluorescence detector
- thinned/backside-illuminated CCD camera

## Beamline Controls and Data Acquisition

- Sun UNIX running EPICS with VME
- Windows NT CCD camera controller

## Beamline Support Equipment/Facilities

- scanning/holographic microscope
- 2-circle goniometer
- image processing workstations
- fast scan stage (0.8 nm resolution)

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# Beamline 2-ID-C / SRI-CAT

**Scientific focus:** Synchrotron instrumentation and techniques and polarization spectroscopy

**Scientific programs:** High-resolution polarization dependent x-ray spectroscopies and spectro-microscopy

## Insertion Device Source Characteristics (nominal)

source	5.5 cm undulator
period	5.50 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	6.57
energy range 1st harmonic	0.4 - 7.0 keV
energy range 1st - 5th harmonics	0.4 - 25.0 keV
on-axis peak brilliance at 4.0 keV	$4.2 \times 10^{18}$ ph/sec/mrad $^2$ /mm $^2$ /0.1%bw
source size at 4.0 keV $\Sigma_x$ $\Sigma_y$	359 $\mu$ m 21 $\mu$ m
source divergence at 4.0 keV $\Sigma_x'$ $\Sigma_y'$	24 $\mu$ rad 9.0 $\mu$ rad

## Optics & Optical Performance

- high-heat-load mirror M1  
29.5 m from source  
0.15° incident angle  
plane figure  
Pt, Rh, and Si coatings
- horizontal focusing mirror M2C  
30.6 m from source  
1.25° incident angle  
spherical figure  
Pt, Rh, and Si multilayers coatings
- vertical focusing mirror M3C  
41.4 m from source  
1.00° incident angle  
spherical figure  
Rh and Si coatings

- multilayer spherical grating monochromator  
50 m from source  
0.5–3.0 keV energy range  
 $10^{-3}$ – $10^{-4}$  monochromaticity dE/E  
2.5 mm hor. x 0.25 mm vert. beam size  
 $10^{11}$ – $10^{13}$  ph/sec flux at sample

## Experiment Station

- 2-ID-C

## Detectors

- 16-channel hemispherical electron/ion analyzer
- total electron yield
- total fluorescence via photodiode

## Beamline Controls and Data Acquisition

- Sun UNIX running EPICS with VME

## Beamline Support Equipment/Facilities

- UHV x-ray photo-emission spectroscopy chamber
- UHV photo-emission microscope (PEEM)
- UHV reflectometer
- UHV scanning stage microscope

# Beamline 2-ID-D & 2-ID -E / SRI-CAT

**Scientific focus:** Synchrotron instrumentation and techniques, imaging, and coherence

**Scientific programs:** High-resolution imaging and coherence-based techniques

## Insertion-device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ /mm $^2$ /0.1% bw
source size at 8.0 keV $\Sigma_x$	359 $\mu$ m
	21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x'$	24 $\mu$ rad
	6.9 $\mu$ rad

## Optics & Optical Performance

- high-heat-load mirror M1  
29.5 m from source  
0.15° incident angle  
plane figure  
Pt, Rh, and Si coatings
- Kohzu monochromator  
62.0 m from source  
2-32 keV energy range Si(111)  
 $10^{-4}$  monochromaticity dE/E  
4.2 mm hor. x 1.6 mm vert. beam size FWHM  
 $10^{11}$ - $10^{13}$  ph/sec flux at sample
- zone plate microprobe  
71.0 m from source  
0.1  $\mu$ m hor. x 0.1  $\mu$ m vert. focus size  
 $10^{11}$  ph/sec/ $\mu$ m $^2$ /0.1% bw flux

## Experiment Stations

- 2-ID-D
- 2-ID-E

## Detectors

- ionization chambers
- NaI scintillation detector
- avalanche photodiodes
- CCD cameras

## Beamline Controls and Data Acquisition

- Sun UNIX running EPICS with VME

## Beamline Support Equipment/Facilities

- optical table with six degrees of freedom
- scanning microscope
- high-resolution x-ray spectrometer
- image processing workstation

## Beamline contacts:

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# Beamline 3-ID / SRI-CAT

**Scientific focus:** Synchrotron instrumentation and techniques, resonant and non-resonant inelastic scattering

**Scientific programs:** Nuclear resonant scattering (inelastic nuclear resonant scattering, lattice dynamics of thin films, amorphous materials, and vibrational properties of biomolecules), and inelastic x-ray scattering (momentum-resolved lattice dynamic)

## Insertion Device Source Characteristics (nominal)

source	2.7 cm undulator
period	2.70 cm
length	2.5 m
effective $K_{\max}$ (at minimum gap = 8.5 mm)	2.18
energy range 1st harmonic	5.1 - 16.0 keV
energy range 1st - 5th harmonics	5.1 - 60.0 keV
on-axis peak brilliance at 7.9 keV	$1.3 \times 10^{30}$ ph/sec/mrad <sup>2</sup> /mm <sup>2</sup> /0.1%bw
source size at 8.0 keV $\Sigma_x$ $\Sigma_y$	359 $\mu$ m 21 $\mu$ m
source divergence at 8.0 keV $\Sigma_{x'}$ $\Sigma_{y'}$	24 $\mu$ rad 6.9 $\mu$ rad

## Optics & Optical Performance

- Kohzu HLM-2 double-crystal monochromator
  - diamond (111) nondispersive crystals
  - water cooling
- high-resolution monochromator
 

energy	resolution
13.8 keV	6 meV
14.4 keV	5.5, 2, 0.85, and 0.66 meV
21.5 keV	1 meV
23.8 keV	3.5 and 1 meV
- Zeiss mirror
  - Zerodur substrate
  - Pd coating
  - two groove, collimating and horizontal focusing
  - bendable for vertical focusing
  - 0.8 m length

## Experiment Stations

- 3-ID-A
  - white beam first optics enclosure
- 3-ID-B
  - monochromatic beam station
  - x-ray optics development
  - nuclear resonant scattering
- 3-ID-C
  - monochromatic beam station
  - inelastic x-ray scattering
- 3-ID-D
  - monochromatic beam station
  - nuclear resonant scattering

## Detectors

- avalanche photodiodes
- PIN-diodes, Si, CdZnTe (Amptek)
- ionization chambers
- NaI
- Si(Li)

## Beamline Controls and Data Acquisition

- VME-based motion control, EPICS software
- Graphical user interface: MEDM implemented on Sun workstations, Solaris operating system

## Beamline Support Equipment/Facilities

- Kohzu high-angular resolution stages (12.5 nrad)
- 6-circle diffractometer
- optical tables
- Euler cradle
- misc. linear stages
- Oxford 7-T superconducting magnet/cryostat, Oxford microscope cryostat
- optical tables

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# Beamline 4-ID / SRI-CAT

**Scientific focus:** Synchrotron instrumentation and techniques and use of polarized x-rays

**Scientific programs:** Development of polarization optics/techniques for 0.5–3 keV (magnetic circular dichroism, resonant magnetic scattering, and fluorescence), development of polarization optics and techniques for 3–100 keV (magnetic scattering, magnetic circular dichroism, and magnetic Compton scattering), and development of high-heat-load front-end and optical components

## Circularly Polarized Undulator (nominal)\*

period	12.8 cm
length	2.3 m
effective $K_{\max}$ (for both horizontal and vertical fields)	2.65
peak field $B_{\max}$	0.28 Tesla
maximum currents at $B_{\max}$	1.4 kA horizontal 0.32 kA vertical
energy range 1st harmonic (helical mode)	0.44 - 3.0 keV
energy range 1st harmonic (linear mode)	0.8 - 3.0 keV
energy range 1st - 5th harmonics (linear mode)	0.8 - 10.0 keV
on-axis peak circular brilliance at 1.5 keV	$1.0 \times 10^{18}$ ph/sec/mrad $^2$ /mm $^2$ /0.1%bw
on-axis peak linear brilliance at 1.9 keV	$7.0 \times 10^{17}$ ph/sec/mrad $^2$ /mm $^2$ /0.1%bw
switching frequency	0 - 10 Hz
switching rise time	20 ms
source size at 1.5 keV $\Sigma_x$ $\Sigma_y$	359 $\mu$ rads 21 $\mu$ rads
source divergence at 1.5 keV $\Sigma_x'$ $\Sigma_y'$	27 $\mu$ rads 14.7 $\mu$ rads

\* Sector 4 will be equipped with two canted insertion devices, a standard Undulator A and an elliptically polarized undulator.

## Optics & Optical Performance

Hard x-ray branch optics and optics performance

- double-crystal monochromator

3.0–50.0 keV energy range Si(111)  
5 mm hor. x 2 mm vert. acceptance  
1°–60° Bragg angle rotation range  
10 arcsec Bragg accuracy  
0.5 arcsec resolution  
10–35 mm beam offset, variable  
liquid-nitrogen cooling

## Insertion Device Source Characteristics (nominal)\*

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ /mm $^2$ /0.1%bw
source size at 8.0 keV $\Sigma_x$ $\Sigma_y$	359 $\mu$ m 21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x'$ $\Sigma_y'$	24 $\mu$ rads 6.9 $\mu$ rads

- Mirror

two groove, toroidal figure  
80.5 mm sagittal radius, focusing  
345 mm sagittal radius, collimating  
18–7 km meridional radius, adjustable  
800 mm L x 30 mm W  
1.5–3.85 mrad angular range

Intermediate x-ray branch optics and optics performance

- horizontal focusing mirror M1C

28.6 m from source  
1.1° incident angle  
plane figure  
Pt, Rh, Si, and multilayer coatings

- horizontal focusing mirror M2C

31 m from source  
1.1° incident angle  
spherical figure (R=1610 m)  
Pt, Rh, Si, and multilayer coatings

continued on pg. 16

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# Beamline 4-ID / SRI-CAT

**Scientific focus:** Synchrotron instrumentation and techniques and use of polarized x-rays

**Scientific programs:** Development of polarization optics/techniques for 0.5–3 keV (magnetic circular dichroism, resonant magnetic scattering, and fluorescence), development of polarization optics and techniques for 3–100 keV (magnetic scattering, magnetic circular dichroism, and magnetic Compton scattering), and development of high-heat-load front-end and optical components

*continued from pg. 15*

- vertical focusing mirror M3C
  - 41.4 m from source
  - 1.00° incident angle
  - spherical figure
  - Rh coating
- multilayer spherical grating monochromator
  - 50 m from source
  - 0.5–3.0 keV energy range
  - $10^{-3}$ – $10^{-4}$  monochromaticity  $dE/E$
  - 2.5 mm hor. x 0.25 mm vert. beam size
  - $10^{11}$ – $10^{13}$  ph/sec flux at sample

## Experiment Stations

- 4-ID-A
  - white beam first optic enclosure
- 4-ID-B and -D
  - white and monochromatic “hard” x-ray stations
- 4-ID-C
  - soft x-ray station

## Beamline Controls and Data Acquisition

- Sun UNIX running Epics with VME, SPEC

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## **E.I. Du Pont de Nemours & Co-Northwestern University-The Dow Chemical Company CAT**

### **Overview**

The DND-CAT is a team of senior scientists and engineers formed jointly by the E.I. Du Pont de Nemours Co., Northwestern University, and the Dow Chemical Company to develop, build, and operate facilities dedicated to advancing x-ray research on new materials. The ability to characterize the increasing numbers of new and advanced materials with specifically engineered properties is closely coupled with the ability to analyze their molecular structure.

### **Research Focus**

The scientific thrust of DND-CAT is concentrated in three main areas: the study of the atomic structure of bulk materials, the study of two-dimensional atomic structures (e.g., surfaces, interfaces, and thin films), and polymer science and technology.

#### *Atomic Structure of Bulk Materials*

In addition to crystallographic determinations of unknown compounds, this aspect of DND-CAT's program concentrates on the determination of defects and local atomic arrangements in materials. For example, the arrangement of dopant atoms and other lattice defects in metals, catalysts, and semiconductors is under study. In addition, DND-CAT researchers are extensively studying catalysts under realistic conditions of high temperature and pressure. Catalysts of interest include supported metal and bimetallic catalysts (e.g., Pd, Pd-Re), zeolites, and catalysts for environmentally benign chlorofluorocarbons.

#### *Study of Two-Dimensional Structures*

The structure of surfaces at interfaces is a primary factor controlling the properties of materials in many technologically important applications. Some of these include catalysis, corrosion, tribology, crystal growth, and ion transport through biomembranes. DND-CAT researchers will use a custom-designed ultra-high-vacuum system to study buried interfaces, thin films, and surfaces to determine mechanisms of film growth, segregation at grain boundaries, surface melting, and other two-dimensional phenomena.

#### *Polymer Science and Engineering*

The third major area for DND-CAT is polymer physics, chemistry, and engineering. Areas of interest include solution characterization of polymers and their precursors, structure formation, polymer melt rheology, fiber formation, structure/property/processing relationships, and mechanical properties.

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# Beamline 5-BM / DND-CAT

**Scientific focus:** Crystallography, EXAFS, and polymer scattering tomography

**Scientific programs:** Material science and engineering, polymer science, crystallography, surface science, catalysis, and imaging

## Bending Magnet Source Characteristics (nominal)

source	APS bending magnet
critical energy	19.51 keV
energy range	1.0 - 100.0 keV
on-axis peak brilliance at 16.3 keV	$2.9 \times 10^{15}$ ph/sec/mrad <sup>2</sup> /mm <sup>2</sup> /0.1%bw
on-axis peak angular flux at 16.3 keV	$9.6 \times 10^{13}$ ph/sec/mrad <sup>2</sup> /0.1%bw
on-axis peak horizontal angular flux at 5.6 keV	$1.6 \times 10^{13}$ ph/sec/mradh/0.1%bw
source size at critical energy $\Sigma_x$	145 $\mu$ m
$\Sigma_y$	36 $\mu$ m
source divergence at critical energy $\Sigma_x'$	6 mrad
$\Sigma_y'$	47 $\mu$ rad

## Optics & Optical Performance

- 4.5–80 keV spectral range (white beam)

## Experiment Stations

- 5-BM-B monochromatic beam station
- 5-BM-C monochromatic and white beam beam station powder diffraction
- 5-BM-D monochromatic and white beam station general purpose station for EXAFS crystallography x-ray scattering

## Detectors

- spectroscopy-grade ionization chambers
- Lytle detector
- Fuji BAS 2000 image-plate system
- scintillation detectors
- avalanche photodiodes
- Mar 135 mm CCD detector
- Spectra Source CCD camera for imaging applications
- EG&G Ortec Iglet solid-state detector

## Beamline Controls and Data Acquisition

- Linux running custom control code for motors and actuators on all systems
- SPEC used to control diffractometers and surface-science instruments
- Vendor-supplied software used to control CCD detectors

## Beamline Support Equipment/Facilities

- 6-circle diffractometer
- 2-circle powder diffractometer
- Mar CCD detector system
- Fuji BAS 2000 image-plate system

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# Beamline 5-ID / DND-CAT

**Scientific focus:** Crystallography, EXAFS, polymer scattering, and tomography

**Scientific programs:** Material science and engineering, polymer science, crystallography, surface science, and catalysis

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ /mm $^2$ /0.1% bw
source size at 8.0 keV $\Sigma_x$	359 $\mu$ m
$\Sigma_y$	21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x'$	24 $\mu$ rad
$\Sigma_y'$	6.9 $\mu$ rad

## Optics & Optical Performance

- 7-18 keV spectral range
- cryogenic Si(111) crystals  
fixed-gap channel cut configuration
- energy range limited due to crystal size

## Experiment Stations

- 5-ID-B  
monochromatic general-purpose beam station  
4-circle Huber goniometer  
Mar CCD  
single-crystal diffraction  
EXAFS
- 5-ID-C  
monochromatic beam station  
surface science using custom UHV system  
surface scattering  
standing waves
- 5-ID-D  
small- and wide-angle scattering  
polymer scattering station

## Detectors

- spectroscopy-grade ionization chambers
- Lytle detector
- Fuji BAS 2000 image-plate system
- scintillation detectors
- avalanche photodiodes
- Mar 135 mm CCD detector
- Spectra Source CCD camera for imaging applications
- EG&G Ortec Iglet solid-state detector

## Beamline Controls and Data Acquisition

- Linux running custom control code for motors and actuators for all systems
- SPEC used to control diffractometers and surface-science instruments
- Vendor-supplied software used to control CCD detectors

## Beamline Support Equipment/Facilities

- 6-circle diffractometer
- 2-circle powder diffractometer
- custom UHV system
- Mar CCD detector system
- Fuji BAS 2000 image-plate system

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## **Midwest Universities CAT**

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### **Overview**

The Midwest Universities CAT was organized in 1990. At present, its member institutions include Ames Laboratory/Iowa State University, University of Missouri at Columbia, Georgia Institute of Technology, Washington University, University of Wisconsin at Madison, University of Nebraska at Lincoln, Kent State University, State University of New York at Stony Brook, Michigan State University, and the Institut für Festkörperforschung Forschungszentrum Jülich GmbH. The main undulator line of the sector features a four-circle diffractometer for single-crystal work, a liquid surface reflectometer, and a new surface science chamber. In addition, a high-energy side station (30-120 keV) is currently under construction and will run in parallel with the main undulator line [3-22 keV for Si (111) monochromating crystals].

### **Research Focus**

Research efforts are focused in the areas of magnetic scattering and spectroscopy, as well as in resonant and nonresonant-scattering studies of magnetic materials. The technique of circular magnetic x-ray dichroism (CMXD) offers tremendous potential as a tool for studies of the electronic states associated with magnetic order in ferromagnetic materials of fundamental and technological interest. Resonant and nonresonant magnetic x-ray scattering measurements offer important and complementary means of determining magnetic structures in materials that are ill-suited, by reasons of size or chemical composition, to traditional neutron measurements (e.g., for magnetic structure studies of metastable phases and surfaces).

Research efforts in the surface-scattering program are centered on the study of the kinetics and growth of two-dimensional systems, the role of defects in epitaxy, ordered non-epitaxial overlayers, phase transitions, and investigations of liquid surfaces. The surface chamber constructed for this sector will enable surface-scattering investigations to expand into new areas: real-time growth characterization in a variety of growth environments, low-Z adsorbate systems, and two-dimensional surface kinetics. A liquid surface diffractometer will be used to probe the chemistry and physics of monolayer films at liquid surfaces, as well as of realistic models of biological membranes.

General scattering programs include microdiffraction techniques, coherent scattering, high-temperature processing of materials, studies of liquid crystals and polymers, and strain in thin films and interfaces.

Work on the high-energy side station will include techniques such as nonresonant magnetic scattering, radial distribution function analysis of disordered and partially ordered materials, and *in situ* time-resolved measurements of high-temperature materials processing.

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# Beamline 6-ID / $\mu$ -CAT

**Scientific focus:** Materials science

**Scientific programs:** Magnetic scattering and spectroscopy, liquid surface studies, and surface scattering

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ mm $^2$ 0.1% bw
source size at 8.0 keV $\Sigma_x$	359 $\mu$ m
	21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x'$	24 $\mu$ rad
	6.9 $\mu$ rad

## Optics & Optical Performance

- Kohzu double-crystal constant-offset monochromator  
29.5 m from source  
3.2–20 keV energy range Si(111)  
 $10^{-4}$  energy resolution (dE/E) at 10 keV  
25 mm offset  
liquid-nitrogen cooling
- 3-stripe vertically focusing 70 cm mirror  
60 cm active length (clear aperture)  
Al, Rh, Pt coating stripes  
12, 23, 31 keV high-energy cutoffs at 0.15°  
1:1 vertical focusing (variable) at 6-ID-B  
< 0.5 arcsec meridional slope error  
< 5 arcsec sagittal slope error  
3 Å rms roughness

## Experiment Stations

- 6-ID-A  
white beam first optics enclosure  
Kohzu monochromator
- 6-ID-B  
monochromatic beam station  
4-circle diffractometer  
liquid surface reflectometer
- 6-ID-C  
monochromatic beam station  
UHV surface science chamber

## Detectors

- NaI detectors
- ionization chambers
- 3-element Si energy dispersive array detector

## Beamline Controls and Data Acquisition

- Sun UNIX running EPICS with VME
- SPEC control software

## Beamline Support Equipment/Facilities

- 6K Dispex
- 3.4 K° Heliplex
- polarization modifier
- polarization analyzer

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## **MHATT-CAT**

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### **Center for Real-Time X-ray Studies**

#### **Overview**

The Center for Real-Time X-ray Studies CAT (MHATT-CAT) was formed in 1989 as a university-industry partnership between the University of Michigan, Howard University, and Bell Laboratories (Lucent Technologies). MHATT-CAT's facilities include two fully instrumented beamlines (one based on an undulator and the other on a bend magnet) to exploit the unique characteristics of the APS. A high-speed communications network between the participating institutions and the APS is planned to facilitate the involvement of students in the MHATT-CAT collaboration and to maximize participation in research at national user facilities.

#### **Research Focus**

MHATT-CAT's research program is focused on time-dependent structural phenomena across a broad range of materials systems, including thin films, polymers, liquid crystals, and biomaterials. The undulator line serves as the host for microprobe studies of high-temperature superconductors, interconnects, and optical fibers; for the development of coherent x-ray scattering techniques; and for the application of ultrafast lasers. The sector is expected to develop into an international gathering point for scientists and engineers with strong interest in time-resolved structural studies.

# Beamline 7-ID / MHATT-CAT

**Scientific focus:** Real-time x-ray studies

**Scientific programs:** Real-time x-ray studies, x-ray microcharacterization, and x-ray photon correlation spectroscopy

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad <sup>2</sup> /mm <sup>2</sup> /0.1% bw
source size at 8.0 keV $\Sigma_x$ $\Sigma_y$	359 $\mu$ m 21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x'$ $\Sigma_y'$	24 $\mu$ rad 6.9 $\mu$ rad

## Optics & Optical Performance

- BESSRC-type double-crystal fixed-exit HHL monochromator
  - 30 m from source
  - 5–50 keV energy range
  - $10^{-4}$  energy resolution (dE/E) at 10 keV
  - 35 mm offset
  - liquid-nitrogen cooling
- pink-beam mirror filter
  - 30 m from source (centered on HHL mono)
  - 6–10 keV energy range
  - 0.03 energy resolution (dE/E)

## Experiment Stations

- 7-ID-A
  - white beam first optics enclosure
  - HHL monochromator
- 7-ID-B
  - white beam station
  - 5 m x 7 m
- 7-ID-C
  - monochromatic and pink beam station
  - 5 m x 7 m
  - diffraction
- 7-ID-D
  - monochromatic and pink beam station
  - 5 m x 6 m
  - diffraction

## Detectors

- NaI scintillation
- ionization chambers
- various CCD detectors
- Amptek Si detector

## Beamline Controls and Data Acquisition

- EPICS
- SPEC
- k-Space Associates real-time CCD data acquisition
- LabView VI environment

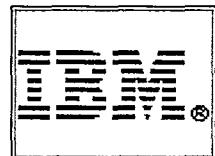
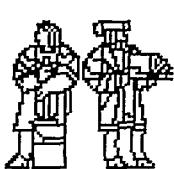
## Beamline Support Equipment

- Newport/Micro-Control 6-circle Kappa goniometer (7-ID-C)
- Huber 4-circle goniometer (7-ID-B)
- two xyz optical tables (4 ft x 6 ft)

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IBM-MIT-McGill CAT

## Overview

The IBM-MIT-McGill CAT (IMM-CAT) was organized by individual scientists from the three institutions to build and operate a sector at the APS optimized for research involving dynamic phenomena in materials science, physics, chemistry, and recently, structural biology.

## Research Focus

IMM-CAT's research involves a broad range of topics emphasizing processes and phenomena that take place over time, such as the growth of thin films. Experiments conducted by CAT member scientists fall primarily into the following four areas:

1. Time-resolved x-ray-scattering studies of bulk phase transition kinetics.
2. Grazing-incidence scattering studies of surface structure and kinetics.
3. Scattering studies of the structure and kinetics of buried interfaces.
4. Studies of dynamics by x-ray intensity fluctuation spectroscopy and related coherent x-ray methods.

A primary goal is to aid the development and understanding of new materials, which may lead to improved products such as magnetic disk drives, computer chips, and computer displays, as well as improvements in processing techniques.

For example, the study of interfaces where layers of magnetic materials meet helps in the engineering of materials with more desirable magnetic properties for use in magnetic disks (used for information storage). Research into thin polymer films can lead to improved coatings, such as those used for lubricants in magnetic disk drives and for orienting liquid-crystal films in flat panel displays.

The construction of a bending-magnet beamline devoted to structural biology is under consideration.

# Beamline 8-ID / IMM-CAT

**Scientific focus:** Condensed matter physics and materials science

**Scientific programs:** Intensity fluctuation spectroscopy studies using coherent x-rays, time-resolved x-ray scattering, x-ray scattering studies and very low temperatures, and x-ray magnetic scattering

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ mm $^2$ /0.1% bw
source size at 8.0 keV $\Sigma_x$	359 $\mu$ m
$\Sigma_y$	21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x'$	24 $\mu$ rad
$\Sigma_y'$	6.9 $\mu$ rad

## Optics & Optical Performance

- horizontally deflecting mirror  
29.2 m from source  
6–30 keV energy range  
water cooling
- transmission diamond monochromator  
51.6 m from source  
6–30 keV energy range  
 $\Delta\lambda/\lambda = 44 \times 10^{-6}$  energy resolution at 8 keV  
symmetric Bragg diamond (111)  
water cooling

## Experiment Stations

- 8-ID-A white beam first optics enclosure
- 8-ID-D pink beam monochromator enclosure
- 8-ID-E pink beam experimental station
- 8-ID-I pink beam experimental end station

## Detectors

- two PI direct detection CCD detectors
- PI optically coupled CCD detector
- photodiode array linear detector
- Amptek CZT and Si detectors

## Beamline Controls and Data Acquisition

- Linux-based control system
- SPEC x-ray control software

## Beamline Support Equipment/Facilities

- coherent small-angle scattering spectrometer
- time-resolved diffractometer
- He-3 cryostat on horizontally scattering spectrometer

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## CMC-CAT

### Complex Materials Consortium CAT

#### Overview

The Complex Materials Consortium CAT (CMC-CAT) was organized by individuals who share a common research interest in complex materials and a strong dedication to the use of the unique properties of synchrotron radiation to structurally and functionally characterize them. This organization was subsequently formalized into a consortium containing the following institutional members: Exxon Research and Engineering Company, University of Pennsylvania, Brookhaven National Laboratory, Princeton University, University of California at Santa Barbara, Los Alamos National Laboratory, Oak Ridge National Laboratory, and the University of Tennessee.

#### Research Focus

Complex materials, broadly defined, are materials that possess unique and novel properties by virtue of the complexity of their molecules and/or the complexity of interaction between their molecules. These materials include polymers, surfactants, liquid crystals, biomaterials, membranes, and thin molecular films of hydrocarbons on solid or liquid surfaces. They also include novel synthetic materials such as fullerenes, fibers, polymer composites, and zeolites. A basic understanding of the molecular structure, morphology, and molecular dynamics of such materials, particularly under non-equilibrium conditions or at interfaces, is essential for the development and optimization of novel materials and processes for industry. It is equally important for obtaining a complete theoretical description of the equilibrium and non-equilibrium behavior of complex, multicomponent systems.

At the APS, CMC-CAT uses several experimental techniques to study complex materials on a variety of length and time scales. The techniques include small-angle and wide-angle x-ray scattering, x-ray diffraction, x-ray surface scattering, x-ray spectroscopy, magnetic scattering, and x-ray microtomography and imaging. The studies depend on novel technical developments such as ultrafast-high-resolution two-dimensional imaging detectors, high-speed data inversion and image-processing algorithms, and novel x-ray microfocusing devices. Using such techniques, CMC-CAT researchers study phenomena such as the dynamic response of polymers, membranes, fibers, and fluids to applied stresses; the kinetics of phase separation in mixed systems; the formation of pitting, corrosion, and protective layers on metals in electrolytic solutions; the formation of novel surface structures on catalysts undergoing reactions; the formation of cracks and voids in composite materials; and the flow of fluids through microporous solids such as oil-bearing rocks or sand.

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# Beamline 9-BM / CMC-CAT

**Scientific focus:** Materials science

**Scientific programs:** EXAFS of complex materials, x-ray surface scattering, and general diffraction

## Bending Magnet Source Characteristics (nominal)

source	APS bending magnet
critical energy	19.51 keV
energy range	1.0 - 100.0 keV
on-axis peak brilliance at 16.3 keV	$2.9 \times 10^{15}$ ph/sec/mrad <sup>2</sup> /mm <sup>2</sup> /0.1%bw
on-axis peak angular flux at 16.3 keV	$9.6 \times 10^{13}$ ph/sec/mrad <sup>2</sup> /0.1%bw
on-axis peak horizontal angular flux at 5.6 keV	$1.6 \times 10^8$ ph/sec/mradh/0.1%bw
source size at critical energy $\Sigma_x$ $\Sigma_y$	145 $\mu$ m 36 $\mu$ m
source divergence at critical energy $\Sigma_x'$ $\Sigma_y'$	6 mrad 47 $\mu$ rad

## Optics & Optical Performance

- white beam slits (APS design L3-20)
- double-crystal, cryo-cooled Si monochromator
- toroidal mirror
- monochromatic slits (APS design L4)

## Experiment Stations

- 9-BM-A  
white beam first optics enclosure
- 9-BM-B  
monochromatic beam station  
EXAFS
- 9-BM-C  
monochromatic beam station  
surface diffraction  
general diffraction

## Detectors

- Smart 1500 CCD
- scintillation counters

## Beamline Controls and Data Acquisition

- Sun UNIX running EPICS with VME, SPEC

## Beamline Support Equipment/Facilities

- UHV surface apparatus
- EXAFS instrumentation

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# Beamline 9-ID / CMC-CAT

**Scientific focus:** Materials science

**Scientific programs:** SAXS from complex materials, liquid/solid surface scattering, EXAFS, general diffraction, and magnetic scattering

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ /mm $^2$ /0.1% bw
source size at 8.0 keV $\Sigma_x$ $\Sigma_y$	359 $\mu$ m 21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x'$ $\Sigma_y'$	24 $\mu$ rad 6.9 $\mu$ rad

## Optics & Optical Performance

Primary branch optics and optical performance

- white-beam slit
  - 4.5 mm x 4.5 mm input aperture
  - 2.1 mm x 2.1 mm max. output aperture
  - ctr. of output aperture adjustable w/ input aperture
- double-crystal Si(111) monochromator
  - 30.5 m from source
  - 3.1-22.5 keV energy range
  - 25.4 mm beam offset
  - $10^{-4}$  energy resolution (dE/E) at 10 keV
  - cryogenic cooling
- vertical-focusing mirror
  - 33 m from source
  - flat figure with bender
  - 600 mm x 120 mm
  - Au, Ni, Rh coatings
  - 0-4 mrad incident angle

- horizontal-focusing mirror
  - 34.5 m from source
  - flat figure with bender
  - 900 mm x 120 mm
  - Au, Ni, Rh coatings
  - 0-4 mrad incident angle

Secondary branch optics and optical performance

- side-station monochromator
  - 28 m from source
  - horizontal double crystal
  - 5-9.5 keV energy range
  - water-cooled diamond crystal
  - 1000 mm horizontal beam offset
  - $10^{-4}$  energy resolution
- vertical-focusing mirror
- horizontal-focusing mirror

## Experiment Stations

- 9-ID-A
  - white beam first optics enclosure
- 9-ID-B & -C
  - monochromatic beam station
  - general diffraction
  - SAXS
  - EXAFS
  - liquids

## Detectors

- Smart 1500 CCD
- BNL 2D WIRE
- BNL 1D WIRE

## Beamline Controls and Data Acquisition

- Sun UNIX running EPICS w/ VME, SPEC, etc.

## Beamline Support Equipment/Facilities

- 6-circle diffractometer
- SAXS set up
- Bonse-Hart camera
- liquid surface reflectometer
- UHV surface apparatus

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## Materials Research CAT

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### Overview

The Materials Research CAT (MR-CAT) is composed of groups from four universities (University of Florida, Illinois Institute of Technology, Northwestern University, and University of Notre Dame), a major corporation (BP-Amoco) and a federal research laboratory (Argonne National Laboratory/Chemical Technology and Environmental Research Divisions).

### Research Focus

The scientific program of MR-CAT focuses on the study of advanced materials *in situ* as a means of characterizing their structure and electronic properties, as well as understanding their preparation. The primary research techniques of wide- and small-angle scattering, diffraction (single-crystal and powder), absorption spectroscopy (XFS), reflectivity, standing waves, diffraction anomalous fine structure (DAFS), and time-dependent and microfocus techniques are being used to study the following *in situ*:

- structural phase changes, especially in non-equilibrium systems
- disordered systems (e.g., alloys and amorphous materials)
- growth, recrystallization, surfaces, and interfaces of electronic materials
- catalysts (*in situ* time-dependent studies)
- structure of static and dynamic confined liquids
- organic thin films and self-assembling systems
- polymers (e.g., dynamics of block copolymers, single-fiber studies)

# Beamline 10-ID / MR-CAT

**Scientific focus:** Materials science and environmental science

**Scientific programs:** Spectroscopy of dilute environmental systems, combined techniques for *in situ* characterization of materials, and zone plate micro-focusing spectroscopy and imaging

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ /mm $^2$ /0.1% bw
source size at 8.0 keV $\Sigma_x$	359 $\mu$ m
$\Sigma_y$	21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x'$	24 $\mu$ rad
$\Sigma_y'$	6.9 $\mu$ rad

## Optics & Optical Performance

- Daresbury/Fisons monochromator
  - 30 m from source
  - 4-30 keV energy range Si(111)
  - 1st crystal, IIT-design, cryo cooling w/  
pseudo-fixed offset crystal cage
  - 2nd crystal, 240 mm with Bragg normal  
motion
  - $10^{-4}$  energy resolution (dE/E) at 10 keV
  - 35 mm offset
  - liquid-nitrogen cooling

- harmonic rejection mirror
- zone plate focusing

## Experiment Stations

- 10-ID-A
  - white beam first optics enclosure
  - monochromator
- 10-ID-B
  - monochromatic beam station
  - all experiments 4 m x 12 m

## Detectors

- Bruker 1k x 1k CCD
- Canberra Si energy-dispersive detector
- Daresbury/Lesker spectroscopy ionization chambers
- Lytle detectors

## Beamline Controls and Data Acquisition

- Debien Linux running "MX"

## Beamline Support Equipment/Facilities

- large Huber 8-circle goniometer with positioning
- X95 rail system for experiment alignment

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## Basic Energy Sciences Synchrotron Radiation Center CAT

### Overview

The Basic Energy Sciences Synchrotron Radiation Center CAT (BESSRC-CAT) includes scientists from the Chemistry and Materials Science Divisions at Argonne National Laboratory (ANL), researchers from the ANL geophysics program, and scientists from the Department of Physics at Northern Illinois University. Its two sectors are developed and instrumented to serve the research needs of users with particular interests in materials science, chemical science, atomic physics, solid-state physics, and geosciences. The facility's two sectors are equipped with seven separate instrumental stations. One sector consists of an undulator and bending magnet with four experiment stations. The other sector has an elliptical multi-pole wiggler and is split into three beamlines with three experiment stations.

### Research Focus

Scientific areas of interest include time-resolved studies of photoexcited states in photosynthetic materials, real-time investigations of chemical reactions, and time-dependent studies of phase transformations in crystalline compounds. Structural studies of actinide materials, studies of ultra-small crystals, trace-element analysis, and surface and interface studies also form part of the research focus. Examples of studies conducted include radiation-induced surface modification, impurity clustering at grain boundaries, measurements of the electrical double layer at electrodes in electrochemical cells, concentration profiling at dissimilar interfaces, studies of the magnetic structure of ultra-thin films, and others.

BESSRC-CAT has an MOCVD system in the undulator beamline for *in situ* growth studies of oxides and GaN and also an MBE system on line for structural studies of surfaces and interfaces under UHV conditions. There is an extensive research program in the use of small-angle x-ray scattering and anomalous small-angle x-ray scattering with particular emphasis on time-resolved measurements. BESSRC-CAT has established a research program directed towards the use of high-energy diffraction techniques to study the structure of materials. Additionally, an extensive research program is directed towards the use of circularly polarized x-rays in the study of the magnetic properties of materials, i.e., using XMCD, magnetic Compton scattering, and magnetic scattering.

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# Beamline 11-ID / BESSRC-CAT

**Scientific focus:** Spectroscopy, scattering, high-energy diffraction, and magnetic Compton scattering

**Scientific programs:** Materials science (x-ray scattering, high-energy diffraction, dichroism, magnetism), geoscience, atomic physics, and chemistry (spectroscopy [EXAFS, XANES], time-dependent spectroscopy of excited states)

## Insertion Device Source Characteristics (nominal)

source	elliptical multipole wiggler
period	16.0 cm
length	2.8 m
number of poles	36, electromagnets 34, permanent magnets
effective $K_x$ max (at max. current = 1.15 kA, $B_{max}$ = 0.087 Tesla)	1.3
peak $K_y$ max (at minimum gap = 24.0 mm)	14.4
switching frequency	0 - 10 Hz
critical energy (at minimum gap = 24.0 mm)	59.1 keV
energy range	5.0 - 200.0 keV
source size at critical energy $\Sigma_x$ $\Sigma_y$	359 $\mu$ m 21 $\mu$ m
source divergence at critical energy $\Sigma_x'$ (FWHM 1.9 mrad, non-Gaussian) $\Sigma_y'$	820 $\mu$ rad 47 $\mu$ rad

## Optics & Optical Performance

- focusing Bragg or flat Laue monochromator
- 11-ID-D
  - modified standard BESSRC monochromator
  - 4.8–50 keV energy range Si(220)
  - 20 mm fixed offset
  - cryo-cooled 1st and 2nd crystals
  - mirrors
  - Pt and Pd coatings
  - 2.8 mrad incident angle/Pt mirror
  - 4.0 mrad incident angle/Pd mirror
- 11-ID-B & -C
  - Bragg or Laue horiz. deflecting monochromator
  - 40–200 keV energy range
  - Si(311) or Si(220) crystal
  - water/Ga cooling

## Experiment Stations

- 11-ID-A
  - white beam first optics enclosure
  - double-crystal monochromator (for 11-ID-D)
  - double (side-by-side) mirror system (for 11-ID-D)
  - side-deflecting monochromator (for B & C stations)
- 11-ID-B
  - magnetic Compton scattering
- 11-ID-C
  - high-energy diffractometer
- 11-ID-D
  - spectroscopy (EXAFS, XANES, dichroism)
  - x-ray scattering

## Detectors

- ionization chambers
- Bicron
- solid-state detectors (Si and Ge)
- Canberra 9-element Ge

## Beamline Controls and Data Acquisition

- 11-ID-B & -C
  - MacOS-EPICS
- 11-ID-B
  - Solaris-EPICS
  - SPEC
  - MacOS
  - Windows EPICS

## Beamline Support Equipment/Facilities

- 11-ID-C
  - high-energy diffractometer (vertical, post mono)
  - diffractometer
  - analyzer
  - detector
- 11-ID-D
  - spectroscopy table
  - 8-circle Huber  $\psi$  goniometer

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# Beamline 12-BM / BESSRC-CAT

**Scientific focus:** Spectroscopy, x-ray scattering, and diffraction

**Scientific programs:** Materials science (x-ray scattering, diffraction, spectroscopy), geoscience (mineral-liquid interface characterization by x-ray scattering and spectroscopy), chemistry (EXAFS and XANES spectroscopy of actinides and lanthanides), and atomic physics

## Bending Magnet Source Characteristics (nominal)

source	APS bending magnet
critical energy	19.51 keV
energy range	1.0 - 100.0 keV
on-axis peak brilliance at 16.3 keV	$2.9 \times 10^{15}$ ph/sec/mrad $^2$ mm $^2$ 0.1%bw
on-axis peak angular flux at 16.3 keV	$9.6 \times 10^{13}$ ph/sec/mrad $^2$ 0.1%bw
on-axis peak horizontal angular flux at 5.6 keV	$1.6 \times 10^{13}$ ph/sec/mradh/0.1%bw
source size at critical energy $\Sigma_x$	145 $\mu$ m
$\Sigma_y$	36 $\mu$ m
source divergence at critical energy $\Sigma_x'$	6 mrad
$\Sigma_y'$	47 $\mu$ rad

## Optics & Optical Performance

- BESSRC standard monochromator  
4-34 keV energy range Si(111)  
35 mm offset  
water cooling  
UHV vacuum compatibility
- Mirrors (removable double-mirror system)  
down deflection, flat figure, Pd coating  
up deflection, toroidal figure, Rh coating  
20 keV energy cutoff

## Experiment Stations

- 12-BM-A  
white beam first optics enclosure  
white beam slits  
monochromator and mirror system
- 12-BM-B  
monochromatic beam station  
x-ray scattering  
diffraction  
spectroscopy (EXAFS and XANES)

## Detectors

- ionization chambers
- Bicron
- Lytle detector
- solid-state detectors
- single-element Si and Ge
- Canberra 9-element Ge

## Beamline Controls and Data Acquisition

- SPARC station with Solaris operating system running EPICS with VME and SPEC software
- Windows NT running EPICS applications
- Macintosh with MacOS software running EPICS applications

## Beamline Support Equipment/Facilities

- 12-BM-B  
spectroscopy table  
6-circle Huber goniometer

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# Beamline 12-ID / BESSRC-CAT

**Scientific focus:** Materials science, atomic physics, and geoscience

**Scientific programs:** Materials science (elastic and inelastic scattering, MOCVD, x-ray standing waves, electrochemistry), geoscience (mineral-liquid interface characterization), chemistry (small-angle scattering), and atomic physics (spectroscopy)

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad <sup>2</sup> /mm <sup>2</sup> /0.1% bw
source size at 8.0 keV $\Sigma_x$ $\Sigma_y$	359 $\mu$ m 21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x'$ $\Sigma_y'$	24 $\mu$ rad 6.9 $\mu$ rad

## Optics & Optical Performance

- BESSRC standard monochromator
  - Si(111) crystal
  - 4–27 keV energy range
  - 35 mm offset
  - liquid-nitrogen cooling
  - 2nd crystal: Cu braid, liquid nitrogen cooling
  - UHV vacuum compatibility
- flat focusing monochromatic mirror
  - 40 m from source
  - Pt, Pd, and SiO<sub>2</sub> coatings
  - 2.5–4 mrad incident angle
  - ~100  $\mu$ m focus in 12-ID-B

## Experiment Stations

- 12-ID-A
  - white beam first optics enclosure
  - monochromator
  - quad photodiode
  - monochromator pinhole apertures

- 12-ID-B
  - spectroscopy
  - elastic and inelastic scattering
  - reflectivity
  - small-angle scattering
- 12-ID-C
  - atomic physics
  - small-angle scattering (low Q)
- 12-ID-D
  - MOCVD chamber
  - surface chamber
  - x-ray scattering

## Detectors

- ionization chambers
- Bicron
- solid-state detectors
- single-element Si and Ge
- Canberra 9-element Ge
- 2-D proportional wire detector
- gold CCD camera

## Beamline Controls and Data Acquisition

- 12-ID-B
  - Solaris running SPEC, Windows NT, and MacOS running EPICS applications
- 12-ID-C
  - Solaris running SPEC, Windows NT, and MacOS running EPICS applications
- 12-ID-D
  - Linux workstation running SPEC (non-EPICS version) and EPICS applications

## Beamline Support Equipment/Facilities

- 12-ID-B
  - Huber 8-circle goniometer
  - spectroscopy
  - optics table
  - small-angle scattering instrumentation
- 12-ID-D
  - 6-circle goniometer
  - surface chamber
  - MOCVD apparatus

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## Consortium for Advanced Radiation Sources CAT

### **Overview**

The Consortium for Advanced Radiation Sources (CARS) currently has four institutional members—The University of Chicago (the managing agent for CARS), Northern Illinois University, Southern Illinois University, and the Australian Nuclear Science and Technology Organization—and four national user groups—BioCARS for structural biology, GeoCARS for geophysical sciences, SoilEnviroCARS for soil/environmental sciences, and ChemMatCARS for chemistry and materials science. At present, CARS has developed or is developing five x-ray beamlines for use by the faculty and staff of its institutional members and national user groups for frontier research that exploits the unique characteristics of the APS as an x-ray source.

### **Research Focus**

The scientific program and experiments carried out on CARS beamlines exploit the unique features of the x-rays emitted by both wiggler and undulator sources. Two main themes are (1) the study of samples with which x-rays interact very weakly because of their small size (area or volume), low concentration, large crystallographic unit cell dimensions, or necessity for monochromatic radiation of unusually narrow bandpass and (2) time-dependent studies of samples with which x-rays interact more strongly.

For BioCARS, the main thrust is to understand basic biological processes in structural terms. Experiments involve crystallographic studies of viruses, ribosomes, and other complexes with very large unit cells; studies of microcrystals; time-resolved crystallography; and phase determination by MAD techniques.

In GeoSoilEnviroCARS, research is designed to further knowledge of the composition, structure, and properties of earth and planetary materials and the processes they control. High-pressure research in both a diamond-anvil cell and a large-volume press; x-ray diffraction, scattering, and absorption spectroscopies from earth and planetary materials; and x-ray fluorescence microprobe analysis and microtomography should make possible major advances in understanding such diverse processes as earthquake development and nitrogen fixation in roots.

In ChemMatCARS, research focuses on several aspects of dynamic and structural condensed matter and materials chemistry. Research areas include surface and interfacial properties in soft condensed matter; molecular liquids and liquid metals; chemical crystallography with emphasis on dynamics of energy transfer, fast photochemical processes, and valence and element specific crystallography; the structure and properties of molecular aggregates; and interfacial and bulk properties of novel polymers and composites including supramolecular, mesoscopic, and nanometer structures.

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# Beamline 13-BM / GSECARS-CAT

**Scientific focus:** Geosciences, environmental science, and soil science

**Scientific programs:** High-pressure diffraction in diamond-anvil cell, high-pressure diffraction in multi-anvil press, microspectroscopy and XRF microprobe, and microtomography

## Bending Magnet Source Characteristics (nominal)

source	APS bending magnet
critical energy	19.51 keV
energy range	1.0 - 100.0 keV
on-axis peak brilliance at 16.3 keV	$2.9 \times 10^{15}$ ph/sec/mrad <sup>2</sup> /mm <sup>2</sup> /0.1%bw
on-axis peak angular flux at 16.3 keV	$9.6 \times 10^{13}$ ph/sec/mrad <sup>2</sup> /0.1%bw
on-axis peak horizontal angular flux at 5.6 keV	$1.6 \times 10^{13}$ ph/sec/mradh/0.1%bw
source size at critical energy $\Sigma_x$ $\Sigma_y$	145 $\mu$ m 36 $\mu$ m
source divergence at critical energy $\Sigma_x'$ $\Sigma_y'$	6 mrad 47 prad

## Optics & Optical Performance

- VG double-crystal monochromator  
28 m from source  
Si(111) or Si(220) crystal  
water cooling  
+30 mm offset
- vertical focusing mirror  
45 m from source  
Si substrate  
Pt, Rh, Si coatings  
internal water cooling  
elliptically bent flat geometry  
0–5 mrad grazing angle  
6:1 to 3:1 demagnification
- small Kirkpatrick-Baez microfocusing mirrors

## Experiment Stations

- 13-BM-A  
white beam first optics enclosure
- 13-BM-B  
white beam second optics enclosure
- 13-BM-C  
monochromatic beam station  
diffraction  
tomography
- 13-BM-D  
white or monochromatic beam station  
multi-anvil press high-pressure diffraction  
tomography  
microprobe  
microspectroscopy

## Detectors

- Canberra 16-element Ge detectors (two)
- Bruker 2K CCD detector
- Canberra single-element Ge and Si(Li) detectors
- Princeton Instruments visible light CCD cameras (two)

## Beamline Controls and Data Acquisition

- Windows NT workstations running EPICS with VME
- SPEC, IDL, Bruker SMART and GADDS
- Princeton Instruments WinView and WinSpec

## Beamline Support Equipment/Facilities

- 250-ton multi-anvil press with DIA and T-cup tooling (13-BM-D)
- laser Raman system in support laboratory

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# Beamline 13-ID / GSECARS-CAT

**Scientific focus:** Geosciences, environmental science, and soil science

**Scientific programs:** High-pressure diffraction in diamond-anvil cell, high-pressure diffraction in multi-anvil press, microspectroscopy and XRF microprobe, microcrystal diffraction, surface diffraction, and x-ray absorption fine structure spectroscopy

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ /mm $^2$ /0.1% bw
source size at 8.0 keV $\Sigma_x$ $\Sigma_y$	359 $\mu$ m 21 $\mu$ m
source divergence at 8.0 keV $\Sigma_{x'}$ $\Sigma_{y'}$	24 $\mu$ rad 6.9 $\mu$ rad

## Optics & Optical Performance

- VG double-crystal monochromator
  - 29 m from source
  - Si(220) crystal
  - cryogenic cooling
  - +50 mm offset
- vertical focusing mirror
  - 45 m from source
  - Si substrate
  - Pt, Rh, Si coatings
  - internal water cooling
  - Kirkpatrick-Baez geometry
  - 0-5 mrad grazing angle
  - 6:1 to 3:1 demagnification
- horizontal focusing mirror
  - 47 m from source
  - Si substrate
  - Pt, Rh, Si coatings
  - internal water cooling
  - Kirkpatrick-Baez geometry
  - 0-5 mrad grazing angle
  - 7:1 to 3:1 demagnification
- small Kirkpatrick-Baez microfocusing mirrors

## Experiment Stations

- 13-ID-A
  - white beam first optics enclosure
- 13-ID-B
  - white beam second optics enclosure
- 13-ID-C
  - white or monochromatic beam station
  - x-ray absorption fine-structure spectroscopy
  - XRF microprobe
  - microspectroscopy
  - microcrystal diffraction
  - surface diffraction
- 13-ID-D
  - white or monochromatic beam station
  - multi-anvil press high-pressure diffraction
  - diamond anvil cell high-pressure diffraction

## Detectors

- Canberra 16-element Ge detectors (two)
- Bruker 2K CCD detector
- Canberra single-element Ge and Si(Li) detectors
- Princeton Instrument visible light CCD cameras (two)

## Beamline Controls and Data Acquisition

- Windows NT workstations running EPICS with VME
- SPEC, IDL, Bruker SMART and GADDS
- Princeton Instruments WinView and WinSpec

## Beamline Support Equipment/Facilities

- 13-ID-C
  - Newport general-purpose diffractometer
- 13-ID-D
  - diamond-anvil cell with laser heating
  - two-circle diffractometer
  - 1000-ton multi-anvil press w/ DIA and T-cup tooling
- laser Raman system in support laboratory

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# Beamline 14-BM / BioCARS-CAT

**Scientific focus:** Structural biology

**Scientific programs:** Large unit cell (virus) crystallography, small unit cell (protein) crystallography, MAD phasing, time-resolved crystallography, Laue diffraction, and study of microcrystals

## Bending Magnet Source Characteristics (nominal)

source	APS bending magnet
critical energy	19.51 keV
energy range	1.0 - 100.0 keV
on-axis peak brilliance at 16.3 keV	$2.9 \times 10^{15}$ ph/sec/mrad <sup>2</sup> /mm <sup>2</sup> /0.1%bw
on-axis peak angular flux at 16.3 keV	$9.6 \times 10^{13}$ ph/sec/mrad <sup>2</sup> /0.1%bw
on-axis peak horizontal angular flux at 5.6 keV	$1.6 \times 10^{13}$ ph/sec/mradh/0.1%bw
source size at critical energy $\Sigma_x$	145 $\mu$ m
$\Sigma_y$	36 $\mu$ m
source divergence at critical energy $\Sigma_x'$	6 mrad
$\Sigma_y'$	47 $\mu$ rad

## Optics & Optical Performance

### 14-BM-C optics and optical performance

- 7–17 keV energy range
- 0.21 mm hor. x 0.35 mm vert. focal spot size
- CARS-design conical focusing mirror
  - 25.731 m from source (on orbit along 3 mrad line)
  - Si substrate, Rh coating
  - water cooling at midplane
  - 4.1 mrad design angle
  - horizontal focus: focusing monochromator
  - vertical focus: bender
- CARS-design bent Ge(111) monochromator
  - 46.6 m from source (along 3 mrad centerline)
  - Ge(111) single crystal
  - water cooling
  - bent triangle horizontal focusing
- Misc. slits, collimators, filters, etc.

## 14-BM-D optics and optical performance

- 6.5–18.5 keV energy range
- 0.4 mm hor. x 0.6 mm vert. focal spot size
- CARS-design Si(111) double-bounce monochromator
  - 23.860 m from source (on orbit along 5 mrad line)
  - 6.5–18.5 energy range Si(111) crystal sets
  - $10^{-4}$  energy resolution (dE/E) at 10 keV
  - 1.5 in. nominal offset (fixed-exit, up bounce)
  - water cooling
- CARS-design cylindrical focusing mirror
  - Si substrate, Rh coating
  - water cooling at midplane
  - 25.731 m from source (variable height along 5 mrad line)
  - 4.1 mrad design angle
  - horizontal focus: sagittal cylindrical figure
  - vertical focus: bender mechanism
- misc. slits, collimators, filters, etc.

## Experiment Stations

- 14-BM-A
  - white beam first optics enclosure
  - 8.6 m x 1.8 m x 2.8 m (L x W x H)
- 14-BM-B
  - pink beam optics enclosure
  - 7.6 m x 1.2 m x 2.8 m (L x W x H)
- 14-BM-C
  - monochromatic beam station
  - 5.2 m x 3.7 m x 2.8 m (L x W x H)
  - virus crystallography
- 14-BM-D
  - pink or monochromatic beam station
  - 6.4 m x 2.2 m x 2.8 m (L x W x H)
  - MAD phasing
  - time-resolved Laue
  - protein crystallography

## Detectors

- 60° kappa diffractometer (14-BM-D)
- single-axis diffractometer (14-BM-C)
- ADSC Q1, ADSC Q4, MAR345 and off-line image plate detectors
- NaI scintillation detectors
- Ge detector

## Beamline contacts:

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# Beamline 14-BM / BioCARS-CAT

**Scientific focus:** Structural biology

**Scientific programs:** Large unit cell (virus) crystallography, small unit cell (protein) crystallography, MAD phasing, time-resolved crystallography, Laue diffraction, and study of microcrystals

## Beamline Controls and Data Acquisition

- beamline controls: HP9000/778 HPUX 10.2 running EPICS via VME
- experiment: SGI 02 IRIX 6.3 running ADSC or MAR control software via in-house (kbscan>) software
- analysis: fast SGI 02 IRIX 6.5 running DENZO, MOSFILM, DPS, etc.

## Beamline Support Equipment/Facilities

- cryo-coolers: Oxford CryoStream, Oxford CryoJet, MSC, and CARS LN<sub>2</sub>/LHe<sub>2</sub> Cooler
- collimators, filters, slits, beam stop, CCD alignment camera
- beam position monitors (1  $\mu\text{m}$  resolution)
- beam flux monitors
- BL3 facility, sample prep areas, cold room

<b>Beamline contacts:</b>	Keith Moffat Wilfried Schildkamp Gary Navrotski	tel 773.702.9950 tel 630.252.0445 tel 630.252.0444	moffat@cars.uchicago.edu schildkamp@cars.uchicago.edu navrotski@cars.uchicago.edu
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# Beamline 14-ID / BioCARS-CAT

**Scientific focus:** Structural biology

**Scientific programs:** Large unit cell (virus) crystallography, small unit cell (protein) crystallography, MAD phasing, time-resolved crystallography, Laue diffraction, and study of microcrystals

## Insertion Device Source Characteristics (nominal)

source	wiggler A
period	8.50 cm
length	2.4 m
peak $K_{\max}$ (at minimum gap = 18.1 mm)	8.74
critical energy (at minimum gap = 18.1 mm)	35.9 keV
energy range (wiggler mode)	5.0 - 200.0 keV
energy range 1st harmonic (undulator mode)	0.2 - 4.0 keV
energy range 1st - 5th harmonics (undulator mode)	0.2 - 15.0 keV
on-axis peak brilliance at 2.7 keV (undulator mode)	$2.0 \times 10^{18}$ ph/sec/mrad <sup>2</sup> /mm <sup>2</sup> /0.1%bw
on-axis peak brilliance at 29.9 keV (wiggler mode at minimum gap = 18.1 mm)	$1.1 \times 10^{17}$ ph/sec/mrad <sup>2</sup> /mm <sup>2</sup> /0.1%bw
on-axis peak angular flux at 29.9 keV (wiggler mode at minimum gap = 18.1 mm)	$5.4 \times 10^{15}$ ph/sec/mrad <sup>2</sup> /0.1%bw
source size at critical energy $\Sigma_x$	359 $\mu$ m
$\Sigma_y$	21 $\mu$ m
source divergence at critical energy $\Sigma_x'$ (FWHM 1.2 mrad, non-Gaussian)	510 $\mu$ rad
$\Sigma_y'$	47 $\mu$ rad

## Optics & Optical Performance

- slits
- power filters
- CARS-design Si(111) monochromator  
28.013 m from source (on orbit along  
0 mrad line)  
double bounce  
6.5–18.5 energy range w/ Si(111) crystal sets  
 $10^{-4}$  energy resolution (dE/E) at 10 keV  
1.5 in. offset (fixed-exit, down bounce)  
water or liquid-nitrogen cooling

- CARS design cylindrical focusing mirror  
29.870 m from source (on orbit along  
0 mrad line)  
Si substrate, Rh coating  
water cooling at midplane  
4.1 mrad design angle  
horizontal focus: sagittal cylindrical figure  
vertical focus: bender

## Experiment Stations

- 14-ID-A  
white beam first optics enclosure  
10.5 m x 1.7 m x 2.8 m (L x W x H)
- 14-ID-B  
pink or monochromatic beam station  
4.5 m x 2.6 m x 2.8 m (L x W x H)  
MAD phasing  
microcrystallography  
virus/protein  
Laue  
time-resolved crystallography

## Detectors

- ADSC Q4, MAR345 and off-line image plate detectors
- NaI scintillation detectors
- Ge fluorescence detector

## Beamline Controls and Data Acquisition

- beamline controls: HP9000/778 HPUX 10.2 running EPICS via VME
- experiment: SGI 02 IRIX 6.3 running ADSC or Mar control software via in-house (kbscan>) software
- analysis: Fast SGI 02 IRIX 6.5 running DENZO, MOSFILM, DPS, etc.

## Beamline Support Equipment/Facilities

- cryo-coolers: Oxford CryoJet and CARS liquid-nitrogen/liquid-helium cooler
- collimators, filters, slits, beam-stop, CCD alignment camera
- beam position monitors (1  $\mu$ m resolution)
- beam flux monitors
- BL3 facility, sample-prep areas, cold room

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# Beamline 15-ID / ChemMatCARS-CAT

**Scientific focus:** Dynamic and structural condensed matter physics

**Scientific programs:** Time-dependent chemical crystallography scattering, anomalous scattering, micro crystallography; static and time-dependent surface scattering, dynamic protein diffraction, and small beam probing of complex structural polymers; interfacial and bulk studies using small- and wide-angle x-ray scattering; and coherent x-ray scattering of polymer/metal nanocomposites, nano-colloidal, and opaque materials.

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad <sup>2</sup> /mm <sup>2</sup> /0.1% bw
source size at 8.0 keV $\Sigma_x$ $\Sigma_y$	359 $\mu$ m 21 $\mu$ m
source divergence at 8.0 keV $\Sigma_{x'}$ $\Sigma_{y'}$	24 $\mu$ rad 6.9 $\mu$ rad

## Optics & Optical Performance

- Kohzu Seiki monochromator HLD-3  
3.1–22.5 keV energy range (for Si(111)  
and 25-mm offset)  
5°–40° angular range  
25–35 mm offset  
cryo-cooled Si or water-cooled diamond modes
- Oxford/SESO vertically focusing mirror (A)  
water cooling  
white beam compatible
- Oxford/SESO water-cooled 2nd steering mirror (B)
- modes of operation:  
1) monochromator w/ or w/out mirror(s)  
2) white beam mirror operation
- high-energy-resolution monochromator  
 $dE/E \sim 10^{-5}$   
used with Kohzu monochromator
- in-station optics  
steering crystal or multilayer for surface science  
microfocusing optics

## Experiment Stations

- 15-ID-A  
white beam first optics enclosure
- 15-ID-B  
white beam station  
crystallography
- 15-ID-C  
pink beam station  
surface science
- 15-ID-D  
SAXS/WAXS  
10 m L x 5.8 m H

## Detectors

- Fuji image plates
- Bruker model 1500/1000 CCD
- Princeton Scientific model LN/CCD-1024SF CCD
- NaI
- ionization chambers
- avalanche photodiodes

## Beamline Controls and Data Acquisition

- EPICS and SPEC in addition to IDL, Windows NT and Sun Workstations running channel access with tools such as MEDM
- electronics VM- and NIM-based

## Beamline Support Equipment/Facilities

- Huber 6-circle (15-ID-B & -C)
- liquid surface spectrometer (15-ID-C)
- monochromatic beam chopper for time-resolved studies  
open time ~2.4  $\mu$ sec  
frequency ~ 1.3 kHz  
attenuation  $\sim 2 \times 10^{-7}$  at 33 keV
- Nd:YAG laser ( $\lambda=355$  nm, 400  $\mu$ J at 1000 Hz)

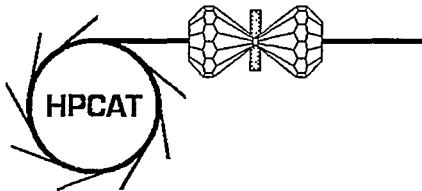
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## High-Pressure CAT

### Overview

The High-Pressure Collaborative Access Team (HP-CAT) currently has three institutional members: the Carnegie Institution of Washington (managing member), Lawrence Livermore National Laboratory, and the University of Nevada, Las Vegas. These members pool resources and share expertise for the development, construction, and operation of sector 16. The purpose of HP-CAT is to provide its members with facilities for state-of-the-art educational and research activities and to assist the members and general users in operating these facilities; the goal is to advance high-pressure research with synchrotron radiation. The ultimate aim of HP-CAT is to set up a world-leading high-pressure research center at the APS and to make it accessible to the scientific community.

### Research Focus

Extreme pressure conditions radically alter the properties of materials. With the recent advances and developments in the technology of pressure vessels, which can now reach several hundreds of gigapascal (1 GPa = 10 kbar), the pressure variable promises to add a whole new dimension in fundamental physics, chemistry, earth and planetary sciences, and material science and technology. HP-CAT is dedicated to the scientific exploration of these fields with a common focus on the high-pressure dimension.

In ultrahigh pressure research, the power of an integrated approach is far greater than the sum of individual techniques. Comprehensive understanding of high-pressure phenomena relies on the combination of complementary measurements. HP-CAT integrates x-ray diffraction and spectroscopy with samples at high pressures and variable temperatures (from cryogenic conditions to thousands of degrees). These techniques include single-crystal structure refinement using energy-dispersive x-ray diffraction, high-resolution angle-dispersive polycrystalline x-ray diffraction, high-resolution x-ray emission spectroscopy, x-ray absorption spectroscopy, nuclear resonance forward scattering, inelastic x-ray scattering, and Compton scattering. The structural, vibrational, electronic, and magnetic properties of materials can thus be measured *in situ* for identifying novel phenomena and transitions at high pressures.

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# Beamline 16-BM / HP-CAT

**Scientific focus:** Study of materials at high pressures in the fields of physics, chemistry, materials science, and planetary science

**Scientific programs:** Studies of materials under high pressure and variable temperature using diamond-anvil cells and other high-pressure devices by energy-dispersive diffraction from single crystals and powders and EXAFS

## Bending Magnet Source Characteristics (nominal)

source	APS bending magnet
critical energy	19.51 keV
energy range	1.0 - 100.0 keV
on-axis peak brilliance at 16.3 keV	$2.9 \times 10^{15}$ ph/sec/mrad <sup>2</sup> /mm <sup>2</sup> /0.1%bw
on-axis peak angular flux at 16.3 keV	$9.6 \times 10^{13}$ ph/sec/mrad <sup>2</sup> /0.1%bw
on-axis peak horizontal angular flux at 5.6 keV	$1.6 \times 10^{13}$ ph/sec/mradh/0.1%bw
source size at critical energy $\Sigma_x$	145 $\mu$ m
$\Sigma_y$	36 $\mu$ m
source divergence at critical energy $\Sigma_x'$	6 mrad
$\Sigma_y'$	47 $\mu$ rad

NOTE: The design parameters of beamline 16-BM are currently undergoing detailed reviews. Hence, the general characteristics given below will be refined and altered in the near future. Therefore, these parameters should be regarded as indicative only.

## Optics & Optical Performance

- water-cooled collimating mirror
- double-crystal monochromator
  - water-cooled 1st crystal
  - sagittally focusing 2nd crystal
- vertically focusing mirror
- small Kirkpatrick-Baez microfocusing mirrors

## Experiment Stations

- 16-BM-B
  - white beam diffraction techniques using microfocusing
- 16-BM-C
  - EXAFS experiments

## Detectors

- Ge and Si(Li) detectors
- other detectors to be defined

## Beamline Controls and Data Acquisition

- Windows NT-UNIX-Linux workstations running EPICS with VME
- SPEC, IDL, and other suitable control and data acquisition programs

## Beamline Support Equipment/Facilities

- custom-designed diffractometers and other sample handling stages
- diamond-anvil cells
- large-volume cell
- pressure measurement instrumentation
- cryostat
- optical spectrometers

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# Beamline 16-ID / HP-CAT

**Scientific focus:** Study of materials at high pressures in the fields of physics, chemistry, materials science, and planetary science

**Scientific programs:** Studies of materials under high pressure and variable temperature using diamond-anvil cells and other high-pressure devices by microfocus angle-dispersive diffraction from single crystals and powders, nuclear resonance forward scattering, inelastic scattering, Compton scattering, and emission and absorption spectroscopy

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ mm $^2$ /0.1% bw
source size at 8.0 keV $\Sigma_x$ $\Sigma_y$	359 $\mu$ m 21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x'$ $\Sigma_y'$	24 $\mu$ rad 6.9 $\mu$ rad

NOTE: The design parameters of beamline 16-ID are currently undergoing detailed reviews. Hence, the general characteristics given below will be refined and altered in the near future. Therefore, these parameters should be regarded as indicative only.

## Optics & Optical Performance

- fixed-exit double-crystal monochromator
  - diamond(111)
  - water-cooled
- two-crystal branching monochromator
  - diamond(111)
  - water-cooled
- small Kirkpatrick-Baez microfocusing mirrors
- four-reflections / high-resolution monochromator
- vertically and horizontally focusing long mirrors

## Experiment Stations

- 16-ID-B  
monochromatic side-branch station for microbeam diffraction
- 16-ID-D  
white and monochromatic station for diffraction, spectroscopy, new techniques, and developments
- 16-ID-E  
white and monochromatic station for spectroscopy with high-resolution inelastic x-ray scattering spectrometer

## Detectors

- avalanche photodiode system for nuclear scattering
- Si PIN diode system for inelastic scattering
- area detector for angle-dispersive diffraction (to be defined)
- other detectors to be defined

## Beamline Controls and Data Acquisition

- Windows NT-UNIX-Linux workstations running EPICS with VME
- SPEC, IDL, and other suitable control and data acquisition programs

## Beamline Support Equipment/Facilities

- custom-designed diffractometers and other sample handling stages
- diamond-anvil cells
- large-volume cell
- pressure measurement instrumentation
- cryostat
- laser-heating system
- optical spectrometers

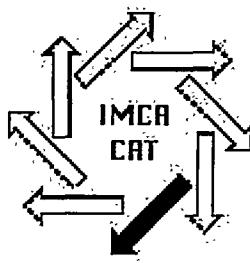
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## Industrial Macromolecular Crystallography Association CAT

### **Overview**

The Industrial Macromolecular Crystallography Association (IMCA) is a consortium of crystallographic groups from 12 companies with major pharmaceutical research laboratories in the United States. IMCA-CAT comprises both IMCA and the Center for Synchrotron Radiation Research (CSRRI) at the Illinois Institute of Technology. The 12 corporate members of IMCA are Abbott Laboratories; Bayer Corporation; Bristol-Myers Squibb Pharmaceutical Research Institute; Glaxo Wellcome Research Institute; Eli Lilly and Company; Merck and Company, Incorporated; Monsanto / Searle; Parke-Davis Pharmaceutical Research; Pharmacia and Upjohn, Incorporated; The Procter and Gamble Company; Schering-Plough Research Institute; and SmithKline Beecham Pharmaceuticals. IMCA-CAT is unusual in that a large fraction of research conducted by CAT members is expected to be proprietary. Member scientists function as competitors in the discovery research that arises from their data-collection efforts; however, they collaborate in methods development and collectively fund the operation of the beamlines.

### **Research Focus**

Macromolecular crystallography is the primary research focus for IMCA, with the ultimate objective of facilitating the process of rational drug design. Traditional drug design methods involve testing thousands of compounds to determine biological activity. Rational drug design research attempts to elucidate biological processes in detail, which depends heavily on detailed knowledge of the atomic structure of the molecules involved. IMCA-CAT's insertion-device beamline is designed primarily for monochromatic and multiwavelength anomalous diffraction (MAD) experiments on small (<80 micrometer) protein crystals over an energy range of 6 to 20 keV. The bending-magnet line is designed mostly for monochromatic and MAD experiments on somewhat larger protein crystals over a similar energy range.

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# Beamline 17-BM / IMCA-CAT

**Scientific focus:** Pharmaceutical macromolecular crystallography

**Scientific programs:** Structures of protein-ligand complexes, *de novo* protein structures, drug design, protein engineering, and crystallographic methods development

Bending Magnet Source Characteristics (nominal)	
source	APS bending magnet
critical energy	19.51 keV
energy range	1.0 - 100.0 keV
on-axis peak brilliance at 16.3 keV	$2.9 \times 10^{15}$ ph/sec/mrad <sup>2</sup> mm <sup>2</sup> 0.1%bw
on-axis peak angular flux at 16.3 keV	$9.6 \times 10^{13}$ ph/sec/mrad <sup>2</sup> 0.1%bw
on-axis peak horizontal angular flux at 5.6 keV	$1.6 \times 10^8$ ph/sec/mradh/0.1%bw
source size at critical energy $\Sigma_x$	145 $\mu$ m
$\Sigma_y$	36 $\mu$ m
source divergence at critical energy $\Sigma_x'$	6 mrad
$\Sigma_y'$	47 $\mu$ rad

## Optics & Optical Performance

- Daresbury double-crystal constant off-set monochromator
  - 28 m from source
  - 6–20 keV energy range Si(111)
  - $10^{-4}$  energy resolution (dE/E) at 10 keV
  - 35 mm offset below orbital plane
  - water cooling
- sagittally bent 2nd monochromator crystal
- Daresbury vertically focusing mirror

## Experiment Stations

- 17-BM-A
  - white beam first optics enclosure
- 17-BM-B
  - white/monochromatic beam station
  - monochromatic macromolecular crystallography

## Detectors

- Bruker 4-element CCD array for crystallography
- MAR345 image plate for crystallography
- fluorescence detector

## Beamline Controls and Data Acquisition

- controls: Sun and Linux systems running EPICS with VME "MX" software (locally developed), running on UNIX
- data acquisition: proprietary software from Bruker and Mar

## Beamline Support Equipment/Facilities

- 4° chill room in wet lab

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# Beamline 17-ID / IMCA-CAT

**Scientific focus:** Pharmaceutical macromolecular crystallography

**Scientific programs:** Structures of protein- ligand complexes, *de novo* protein structures, drug design, protein engineering, and crystallographic methods development

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ mm $^2$ 0.1% bw
source size at 8.0 keV $\Sigma_x$	359 $\mu$ m
$\Sigma_y$	21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x'$	24 $\mu$ rad
$\Sigma_y'$	6.9 $\mu$ rad

## Optics & Optical Performance

- Daresbury double-crystal constant off-set monochromator
  - 28 m from source
  - 6-20 keV energy range Si(111)
  - $10^{-4}$  energy resolution (dE/E) at 10 keV
  - 35 mm offset below orbital plane
  - liquid-nitrogen cooling

## Experiment Stations

- 17-ID-A
  - white beam first optics enclosure
- 17-ID-B
  - monochromatic beam station
  - macromolecular crystallography
  - 3.5 m x 7 m

## Detectors

- Mar 165-mm single-element CCD
- Bicron fluorescence detector

## Beamline Controls and Data Acquisition

- controls: Sun and Linux systems running EPICS with VME "MX" software (locally developed), running on UNIX
- data acquisition: proprietary software from Bruker and Mar

## Beamline Support Equipment/Facilities

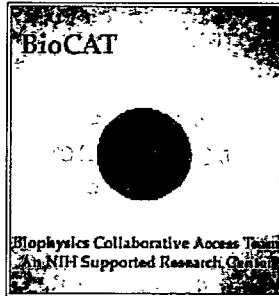
- 4° chill room in wet lab
- Oxford cryo-stream system

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## Biophysics CAT

### **Overview**

The Biophysics CAT (Bio-CAT) is organized as a national research resource to be used primarily to study the structure of partially ordered biological molecules, complexes of biomolecules, and cellular structures under conditions similar to those present in living cells. The goal of this research is to determine the detailed mechanism of action of biological systems at the molecular level. The techniques used are x-ray fiber diffraction, x-ray scattering, x-ray absorption/emission spectroscopy, and advanced imaging techniques such as diffraction enhanced imaging. The research conducted at Bio-CAT's beamlines complements that done by other APS CATs (specifically, those that emphasize protein crystallography: BioCARS, IMCA-CAT, and SBC-CAT).

### **Research Focus**

Many biological macromolecules (e.g., enzymes) and complexes (e.g., viruses) can be crystallized and subjected to classic crystallographic analysis. However, in living cells, most biological systems are noncrystalline, and many biological structures cannot be studied in this manner because they cannot be crystallized, are transiently formed, or have structures or dynamical behaviors that change upon crystallization. For example, comparison of x-ray absorption spectra from crystalline and solution enzyme samples has shown that the processes of crystallization can change the microstructures sufficiently that crystallographic structural analysis alone would lead to incorrect interpretations of the enzymes' mechanisms of action.

All biological systems have some degree of spatial or dynamic order; this order can be probed by noncrystallographic diffraction and x-ray absorption. Of key interest to Bio-CAT scientists are the structures of small ordered domains such as single muscle fibers and connective tissues and studies of the time dependence of structural changes that occur as biomolecular complexes carry out their functions. Key research areas involve biological processes and systems of direct biomedical importance such as enzymes (particularly metalloproteins), DNA-binding proteins, proteins involved in gene expression, cell membranes, nerve cells, immune system components, the processes of cell transport, and cell motility.

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# Beamline 18-ID / Bio-CAT

**Scientific focus:** Static and dynamic studies of partially ordered biological systems

**Scientific programs:** X-ray fiber diffraction, x-ray scattering, x-ray absorption/emission spectroscopy, and x-ray imaging and tomography

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ /mm $^2$ /0.1% bw
source size at 8.0 keV $\Sigma_x$	359 $\mu$ m
$\Sigma_y$	21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x'$	24 $\mu$ rad
$\Sigma_y'$	6.9 $\mu$ rad

## Optics & Optical Performance

- 3.5–35 keV energy range
- vertical beam size: 2 mm unfocused– 0.02 mm focused
- horizontal beam size: 5 mm unfocused– 0.01 mm focused
- Rosenbaum-Rock high-resolution monochromator #1  
6.5°–38° Bragg angle range  
1st crystal, Si(111), liquid-nitrogen cooling  
2nd crystal, Si(111), 10 mm wide (stabilized at 25°C, sagitally bent)  
7:1 demagnification  
35 mm beam offset (nominal)  
motorized tune, twist, & roll control  
(4 mm range, 50 nm resolution)

- Rosenbaum-Rock high-flux monochromator #2  
6.5°–38° Bragg angle range  
1st crystal, Si(400), liquid-nitrogen cooling  
2nd crystal, Si(400), 10 mm wide (stabilized at 25°C, sagitally bent)  
7:1 demagnification  
35 mm beam offset (nominal)  
motorized tune, twist, & roll control  
(4 mm range, 50 nm resolution)
- Rosenbaum-Rock vertical focusing mirror  
plane mirror substrate:  
Zerodur  
1020 mm x 95 mm x 38 mm  
2 Å rms roughness  
4  $\mu$ rad surface figure error, mounted  
Pt, none, and Pd coating stripes  
two motorized, encoded supports  
dynamic, independent bending mechanisms at both ends  
aberration correction via elliptical bending  
11:1 demagnification

## Experiment Station

- 18-ID-D  
monochromatic beam station  
12 m x 5 m x 3 m

## Detectors

- Fuji BAS 2500 image plate scanner
- 1024 x 1024 CCD detector with 60  $\mu$ m pixels
- fast-time-slicing plastic scintillator array
- Lytle fluorescence detector
- multilayer fluorescence analyzer

## Beamline Support Equipment/Facilities

- small-angle camera (up to 8 m camera length)
- Huber 4-circle (small), Huber 2-circle with quarter chi-segment
- Displex cryostat
- 3 ft x 5 ft optical table with five axes of motion

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## *Structural Biology Center*

### **Structural Biology Center CAT**

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#### **Overview**

The Structural Biology Center CAT has constructed a national user facility at the APS for studies in macromolecular crystallography. Funded by the Department of Energy's Office of Biological and Environmental Research, the Structural Biology Center provides users with a full complement of instrumentation, ancillary facilities, software, and support staff to enhance the productivity of their research. The majority of beamtime is allocated to Independent Investigators through a proposal process, with a small amount of time reserved for research and development activities by SBC-CAT staff members.

#### **Research Focus**

The principal focus of the SBC-CAT research program is macromolecular crystallography. Designed as a rapid-throughput facility, the Structural Biology Center provides researchers with the ability to use both standard crystallographic techniques and multiple energy anomalous dispersion (MAD) phasing methods.

One current major program focuses on the study of macromolecular assemblies, with an emphasis on molecular recognition and interaction between macromolecules. Specific projects include molecular chaperones (bacterial and archaeal chaperonins 60, human hsc70 chaperone), protein/nucleic acid complexes (trp repressor/operator systems), and multimeric enzymes.

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# Beamline 19-BM / SBC-CAT

**Scientific focus:** Macromolecular crystallography

**Scientific program:** Structural biology

## Bending Magnet Source Characteristics (nominal)

source	APS bending magnet
critical energy	19.51 keV
energy range	1.0 - 100.0 keV
on-axis peak brilliance at 16.3 keV	$2.9 \times 10^{15}$ ph/sec/mrad <sup>2</sup> /mm <sup>2</sup> /0.1%bw
on-axis peak angular flux at 16.3 keV	$9.6 \times 10^{13}$ ph/sec/mrad <sup>2</sup> /0.1%bw
on-axis peak horizontal angular flux at 5.6 keV	$1.6 \times 10^{13}$ ph/sec/mradh/0.1%bw
source size at critical energy $\Sigma_x$ $\Sigma_y$	145 $\mu$ m 36 $\mu$ m
source divergence at critical energy $\Sigma_x'$ $\Sigma_y'$	6 mrad 47 $\mu$ rad

## Optics & Optical Performance

- 6–20 keV standard spectral range
- 0.14 mm hor. x 0.06 mm vert. FWHM focused spot size
- Rosenbaum-Rock double-crystal monochromator
  - water cooled
  - sagittally focusing 2nd crystal
  - 6:1 demagnification
  - 6°–40° Bragg angle range
  - 1st crystals: Si(111), Si (220), Si(331)  
25 mm wide, common cooler carrier
  - 2nd crystals: Si(111), Si(220), Si(331)  
exchangeable, 25 mm x 125 mm  
35 mm beam offset (nominal)

- Rosenbaum-Rock vertical focusing mirror
  - 9:1 demagnification
  - Zerodur plane mirror substrate
  - 1020 mm x 100 mm x 38 mm
  - 2 Å rms roughness
  - 1  $\mu$ rad surface figure error
  - Pt, none, Pd coating stripes (35 mm wide ea.)
  - two motorized, encoded supports
  - dynamic, independent bending mechanism at both ends
  - aberration correction via elliptical bending

## Experiment Stations

- 19-BM-A
  - white beam first optics enclosure
- 19-BM-C
  - white beam optics enclosure
- 19-BM-D
  - monochromatic experiment station
  - kappa goniostat for macromolecular crystallography
  - guard slits
  - filter/shutter
  - detector support and positioner

## Detectors

- SBC1 3k x 3k CCD
  - built by ANL-ECT
  - 210 mm x 210 mm active area
  - 1.8 sec readout

## Beamline Controls and Data Acquisition

- Multiprocessor SG1 workstation, plus two UNIX work stations for data acquisition and data processing
- 3 HP workstations running EPICS, VME for beamline and detector control
- PMAC motor controller, software by ANL-ECT
- GUI for beamline control, data acquisition, and detector control by ANL-ECT

## Beamline Support Equipment/Facilities

- Rosenbaum-Rock miniaturized kappa goniostat
- high-magnification-alignment cameras (two)
- Rosenbaum-Rock high-precision detector support and positioner
- liquid-nitrogen cryosystem sample cooler

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# Beamline 19-ID / SBC-CAT

Scientific focus: Macromolecular crystallography

Scientific program: Structural biology

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{16}$ ph/sec/mrad <sup>2</sup> /mm <sup>2</sup> /0.1% bw
source size at 8.0 keV $\Sigma_x$	359 $\mu$ m
$\Sigma_y$	21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x'$	24 $\mu$ rad
$\Sigma_y'$	6.9 $\mu$ rad

## Optics & Optical Performance

- 6–20 keV standard spectral range
- 0.08 mm hor. x 0.04 mm vert. FWHM focused beam size
- Rosenbaum-Rock monochromator #1
  - high-resolution double-crystal sagittal focusing
  - 1st crystal, Si(220), liquid-nitrogen cooled
  - 2nd crystal, Si(220), 10 mm wide (stabilized at 25°C, sagitally bent)
  - 7:1 demagnification
  - 6.5°–38° Bragg angle range
  - 35 mm beam offset (nominal)
  - motorized tune, twist, & roll control (4 mm range, 50 nm resolution)
- Rosenbaum-Rock monochromator #2
  - 1st crystal, Si(111), liquid-nitrogen cooled
  - 2nd crystal, Si(111), 10 mm wide, (stabilized at 25°C, sagitally bent)
  - 7:1 demagnification
  - 6.5°–38° Bragg angle range
  - 35 mm beam offset (nominal)
  - motorized tune, twist, & roll control (4 mm range, 50 nm resolution)

- Rosenbaum-Rock vertical focusing mirror
  - 11:1 demagnification
  - Zerodur plane mirror substrate
  - 1020 mm x 100 mm x 38 mm
  - 2 Å rms roughness
  - 1  $\mu$ rad surface figure error
  - Pt, none, and Pd coating stripes (35 mm wide ea.)
  - two motorized angle and weight adjustments, encoded supports
  - dynamic, independent bending mechanism at both ends
  - aberration correction via elliptical bending

## Experiment Stations

- 19-ID-A
  - white beam first optics enclosure
- 19-ID-C
  - white beam optics enclosure
- 19-ID-D
  - monochromatic experiment station
  - kappa goniostat for macromolecular crystallography
  - guard slits
  - filter/shutter
  - detector support and positioner

## Detectors

- SBC2 3k x 3k CCD
  - built by ANL-ECT
  - 210 mm x 210 mm active area
  - 1.8 sec readout

## Beamline Controls and Data Acquisition

- Multiprocessor SG1 workstation, plus two UNIX workstations for data acquisition
- Three HP workstations running EPICS, VME for beamline and detector control
- PMAC motor controller, software by ANL-ECT
- GUI for beamline control & data acquisition, detector control by ANL-ECT

## Beamline Support Equipment/Facilities

- Rosenbaum-Rock miniaturized kappa goniostat
- high-magnification alignment cameras (two)
- Rosenbaum-Rock high-precision detector support and positioner
- liquid-nitrogen cryosystem sample cooler

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## **Pacific Northwest Consortium CAT**

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### **Overview**

The Pacific Northwestern Consortium CAT (PNC-CAT) includes a number of institutions in the Pacific Northwest regions of both the United States and Canada. Scientists from the lead institutions of the University of Washington, Pacific Northwest National Laboratories, and Simon Fraser University share several common research goals: specifically, a basic understanding of materials as related to their physical and chemical properties, the development of new strategies for environmental cleanup based on a fundamental understanding of the interaction of pollutants with the ambient environs, and structure-function properties of macromolecules.

### **Research Focus**

Several innovative instruments, including an analytical x-ray microscope with 0.1- $\mu$ m resolution and capability to measure diffraction, x-ray absorption fine structure (XAFS), and diffraction anomalous fine structure (DAFS), will enable investigators to characterize heterogeneous materials in new ways. These measurements can be combined with two- and three-dimensional imaging using absorption and phase contrast. UHV and MBE facilities are available for *in situ* investigations using surface diffraction and XAFS. Capabilities for time-resolved measurements in the nanosecond scale are planned. These techniques and instruments will be used to investigate materials science and environmental problems, on both a fundamental and applied level.

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# Beamline 20-BM / PNC-CAT

**Scientific focus:** Materials science and environmental science

**Scientific programs:** Material science, environmental science, and surface science

## Bending Magnet Source Characteristics (nominal)

source	APS bending magnet
critical energy	19.51 keV
energy range	1.0 - 100.0 keV
on-axis peak brilliance at 16.3 keV	$2.9 \times 10^{15}$ ph/sec/mrad $^2$ mm $^2$ /0.1%bw
on-axis peak angular flux at 16.3 keV	$9.6 \times 10^{13}$ ph/sec/mrad $^2$ /0.1%bw
on-axis peak horizontal angular flux at 5.6 keV	$1.6 \times 10^8$ ph/sec/mradh/0.1%bw
source size at critical energy $\Sigma_x$	145 $\mu$ m
$\Sigma_y$	36 $\mu$ m
source divergence at critical energy $\Sigma_x'$	6 mrad
$\Sigma_y'$	47 $\mu$ rad

## Optics & Optical Performance

- BESSRC-type monochromator
  - 29 m from source
  - 2–30 keV energy range
  - $1-2 \times 10^{-4}$  energy resolution (dE/E)
  - 35 mm offset
  - water cooling
  - 2nd crystal : 4 mrad acceptance for sagittal focusing
- bent mirror
  - 26 m from source
  - 2–30 keV energy range
  - 2.7 mrad glancing angle

## Experiment Stations

- 20-BM-A  
white beam first optics enclosure
- 20-BM-B  
monochromatic general purpose station

## Detectors

- ionization chambers
- 13-element Ge
- CCDs

## Beamline Controls and Data Acquisition

- Sun, UNIX with EPICS/VME
- Windows NT with LabView
- SPEC

## Beamline Support Equipment/Facilities

- MBE/UHV surface chamber

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# Beamline 20-ID / PNC-CAT

**Scientific focus:** Materials science and environmental science

**Scientific programs:** Material science, environmental science, UHV/surface science-MBE growth, and x-ray microbeams

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ /mm $^2$ /0.1% bw
source size at 8.0 keV $\Sigma_x$ $\Sigma_y$	359 $\mu$ m 21 $\mu$ m
source divergence at 8.0 keV $\Sigma_{x'}$ $\Sigma_{y'}$	24 $\mu$ rad 6.9 $\mu$ rad

## Optics & Optical Performance

- BESSRC high-heat-load monochromator
  - 31 m from source
  - 3–27 keV energy range, Si(111)
  - 6–50 keV energy range, Si(311)
  - $1-2 \times 10^{-4}$  energy resolution (dE/E), Si(111)
  - $0.5-1 \times 10^{-4}$  energy resolution (dE/E), Si(311)
  - 35 mm offset
  - liquid-nitrogen cooling
  - $\sim 10^{13}$  ph/sec flux at 10 keV, Si(111)
- toroidal focusing mirror
  - 34 m from source
  - 3–30 keV energy range
  - Al, Rh, Pt coatings (selectable)
  - 2.2–2.7 mrad glancing angle
  - $\sim 400 \times 200 \mu\text{m}$  (H,V) focal spot
- Kirkpatrick-Baez mirrors
  - 3–20 keV energy range
  - 1  $\mu\text{m}$  or 5  $\mu\text{m}$  focal spot (mirror dependent)
  - 4 mrad glancing angle
  - $\sim 10^{12}$  flux at 10 keV

- tapered capillaries
  - 3–30 keV energy range
  - $<0.5 \mu\text{m}$  focal spot
  - 150  $\mu\text{m}$  beam acceptance
  - $10^9-10^{10}$  ph/sec flux

## Experiment Stations

- 20-ID-A
  - white beam first optics enclosure
- 20-ID-B
  - monochromatic beam station
  - microbeams
  - XAFS
- 20-ID-C
  - monochromatic beam station
  - diffraction
  - surface science

## Detectors

- ionization chambers
- 13-element Ge detector
- NaI scintillation
- CCDs

## Beamline Controls and Data Acquisition

- Sun UNIX with EPICS/VME
- Windows NT with LabView
- SPEC

## Beamline Support Equipment/Facilities

- Huber surface diffractometer with UHV chamber (20-ID-C)
- MBE-capable surface XAFS, reflectivity and standing wave chamber (20-ID-B & C)
- diamond phase plate

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## Southeast Regional CAT

### **Overview**

SER-CAT, which represents institutions from the states of Alabama, Florida, Georgia, Kentucky, Missouri, North Carolina, South Carolina, Tennessee, and Virginia, as well as the Intramural Program of the National Institutes of Health, plans to build and operate a sector at the APS. The SER-CAT mission is to provide researchers from its member institutions with timely access to tunable, high-intensity x-rays for x-ray diffraction structural studies of biomolecules. SER-CAT plans to provide its users with a complete research facility, including a full complement of instrumentation, software, and support staff for high-throughput data collection and processing. SER-CAT also plans to provide 25% of its beam time to outside users through its Independent Investigator program via a proposal process.

### **Research Focus**

The principal focus of the SER-CAT research program is macromolecular crystallography. The SER-CAT beamline designs are based on those of SBC-CAT; researchers will be able to use both traditional and multiple wavelength anomalous dispersion (MAD) techniques for structure determination and investigation.

The research interests of SER-CAT researchers are varied, ranging from DNA, protein and virus structures, to catalysts and basic materials science.

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# Beamline 22-BM / SER-CAT

**Scientific focus:** Macromolecular crystallography

**Scientific program:** Structural biology

**Summary reflects projected performance parameters and planned equipment and hardware.**

## Bending Magnet Source Characteristics (nominal)

source	APS bending magnet
critical energy	19.51 keV
energy range	1.0 - 100.0 keV
on-axis peak brilliance at 16.3 keV	$2.9 \times 10^{15}$ ph/sec/mrad $^2$ mm $^2$ 0.1%bw
on-axis peak angular flux at 16.3 keV	$9.6 \times 10^{13}$ ph/sec/mrad $^2$ 0.1%bw
on-axis peak horizontal angular flux at 5.6 keV	$1.6 \times 10^{13}$ ph/sec/mradh/0.1%bw
source size at critical energy $\Sigma_x$	145 $\mu$ m
$\Sigma_y$	36 $\mu$ m
source divergence at critical energy $\Sigma_x'$	6 mrad
$\Sigma_y'$	47 $\mu$ rad

## Optics & Optical Performance

- 6–20 keV standard spectral range
- 0.14 mm hor. x 0.06 mm vert. FWHM focused spot size
- Rosenbaum-Rock double-crystal monochromator water cooling
  - 1st crystals: Si(111), Si (220), Si(331)  
25 mm wide, common cooler carrier
  - 2nd crystals: Si(111), Si(220), Si(331)  
sagittal focusing  
exchangeable  
125 mm L x 25 mm W
- 6:1 demagnification
- 6°–40° Bragg angle range
- 35 mm beam offset (nominal)

- Rosenbaum-Rock vertical focusing mirror  
9:1 demagnification  
ULE plane mirror substrate  
1020 mm x 100 mm x 38 mm  
2  $\text{\AA}$  rms roughness  
1  $\mu$ rad surface figure error  
Pt, none, Pd coating stripes (35 mm wide ea.)  
two motorized angle and weight adjustments, encoded supports  
dynamic, independent bending mechanism at both ends  
aberration correction via elliptical bending

## Experiment Stations

- 22-BM-A  
white beam enclosure
- 22-BM-C  
white beam optics enclosure
- 22-BM-D  
monochromatic experiment station  
kappa goniostat for macromolecular crystallography  
adjustable collimator slits  
filter/shutter  
detector support and positioner

## Detectors

- CCD area detector

## Beamline Controls and Data Acquisition

- detector control and interface hardware and software to be defined
- beamline control and data acquisition software to be defined
- computers to be defined
- DC-servomotor; PMAC motor controller
- electrometer amplifiers; VME-based, computer-controlled V/F converter and scaler (ANL-ECT design)

## Beamline Support Equipment/Facilities

- Rosenbaum-Rock miniaturized kappa goniostat
- high-magnification-alignment cameras (two)
- Rosenbaum-Rock high-precision detector support and positioner
- liquid-nitrogen cryosystem sample cooler

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# Beamline 22-ID / SER-CAT

Scientific focus: Macromolecular crystallography

Scientific program: Structural biology

Summary reflects projected performance parameters and planned equipment and hardware.

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ /mm $^2$ /0.1% bw
source size at 8.0 keV $\Sigma_x$	359 $\mu$ m
$\Sigma_y$	21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x$	24 $\mu$ rad
$\Sigma_y$	6.9 $\mu$ rad

## Optics & Optical Performance

- 6–20 keV standard spectral range
- 0.08 mm hor. x 0.04 mm vert. FWHM focused beam size
- Rosenbaum-Rock monochromator high-resolution double-crystal sagittal focusing  
1st crystal, Si(220), liquid-nitrogen cooling  
2nd crystal, Si(220), 10 mm wide (stabilized at 25°C, sagittally bent)  
7:1 demagnification  
6.5°–38° Bragg angle range  
35 mm beam offset (nominal)  
motorized tune, twist, & roll control  
(4 mm range, 50 nm resolution)

- Rosenbaum-Rock vertical focusing mirror  
11:1 demagnification  
ULE plane mirror substrate  
1020 mm x 100 mm x 38 mm  
2 Å rms roughness  
1  $\mu$ rad surface figure error  
Pt, none, and Pd coating stripes (35 mm wide ea.)  
two motorized, encoded supports  
dynamic, independent bending mechanism at both ends  
aberration correction via elliptical bending

## Experiment Stations

- 22-ID-A  
white beam enclosure
- 22-ID-C  
white beam optics enclosure
- 22-ID-D  
monochromatic experiment station  
kappa goniostat for macromolecular crystallography  
adjustable collimator slits  
filter/shutter  
detector support and positioner

## Detectors

- CCD area detector

## Beamline Controls and Data Acquisition (to be defined)

- detector control and interface hardware and software to be defined
- beamline control and data acquisition software to be defined
- computers to be defined
- DC-servomotor; PMAC motor controller
- electrometer amplifiers; VME-based, computer-controlled V/F converter and scaler (ANL-ECT design)

## Beamline Support Equipment/Facilities

- Rosenbaum-Rock miniaturized kappa goniostat
- high-magnification alignment cameras (two)
- Rosenbaum-Rock high-precision detector support and positioner
- liquid-nitrogen cryosystem sample cooler

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## COM-CAT

### Commercial CAT

#### Overview

The Commercial Beamline Collaborative Access Team (COM-CAT) will be specializing in the application of synchrotron radiation to industrial problems. COM-CAT plans to operate a general-purpose beamline as an analytical service laboratory, providing both materials analysis and data interpretation for problems that require synchrotron radiation techniques for their solution. Funds for beamline construction were provided by the State of Illinois. Beamline operations will ultimately be funded on a fee-for-service basis.

#### Research Focus

Analyses based on synchrotron radiation are generally applicable to problems in materials science. Industrial companies have used synchrotron facilities to examine a wide variety of materials, including polymers, catalysts, candidate drugs, and biomolecules. COM-CAT expects to provide a convenient means to use synchrotron analysis capabilities to industrial organizations who either do not have current access to a beamline or require rapid turnaround of samples.

COM-CAT will, in its initial stages, construct and operate a single undulator beamline. To provide as broad a range of analytical capabilities as possible, the experimental facilities will consist of three permanent stations devoted to spectroscopy, single-crystal diffraction, small-angle scattering, and x-ray fluorescence. Zone plates will be used when microfocusing is required. To maximize use of the available beam, each table will have a permanent basic configuration. To use a downstream station, the upstream tables will be lowered below the flight path of the x-ray beam.

COM-CAT is also involved in outreach to the general industrial community. It has organized a workshop on industrial applications of synchrotron radiation and will provide on-site introductions to synchrotron radiation for potential customers.

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# Beamline 32-ID / COM-CAT

**Scientific focus:** Materials characterization

**Scientific programs:** Analytical materials characterization and capability for commercial customers

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ mm $^2$ /0.1% bw
source size at 8.0 keV $\Sigma_x$ $\Sigma_y$	359 $\mu$ m 21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x'$ $\Sigma_y'$	24 $\mu$ rad 6.9 $\mu$ rad

## Optics & Optical Performance

- L5-90 standard component primary aperture
- Kohzu HLD-3 monochromator
- horizontally focusing mirror  
Pd, Pt coating stripes

## Experiment Stations

- 32-ID-A  
white beam first optics enclosure
- 32-ID-B  
white beam station  
monochromatic experiments  
spectroscopy  
scattering  
crystallography

## Detectors

- Lytle detector
- multi-element energy dispersive detector
- ionization chambers
- scintillation counters
- CCD area detector

## Beamline Controls and Data Acquisition

- Linux PC running SPEC

## Beamline Support Equipment/Facilities

- 6-circle diffractometer; spectroscopy instruments
- crystallography station

**Beamline contacts:** Kevin D'Amico  
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## A University-National Laboratory-Industry CAT

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### Overview

The UNI-CAT is a collaboration between scientists from the University of Illinois, the Oak Ridge National Laboratory, the National Institute of Standards and Technology, and UOP Research and Development. The UNI-CAT mission is to instrument and operate x-ray research facilities at the APS that provide advanced x-ray techniques to a diverse scientific community. This goal is achieved through the development of two sectors at the APS that are designed for cutting-edge x-ray studies in materials, physics, chemistry, biology, and geology. This is a multi-purpose scattering facility capable of high-resolution scattering with excellent energy resolution and beam-focusing optics. Special capabilities in the UNI-CAT sectors also include a dedicated surface/interface diffraction station equipped with a molecular-beam epitaxy and chemical-vapor deposition facility, an ultra-small-angle x-ray scattering apparatus, an x-ray microscope, a topography station, a dedicated insertion-device beamline for microfocus and coherent x-ray diffraction, instrumentation for time-resolved x-ray scattering experiments, and reactive environment x-ray absorption spectroscopy.

### Research Focus

The primary research areas of UNI-CAT members encompass materials sciences and condensed matter physics, and include techniques such as structural crystallography, diffuse x-ray scattering, magnetic x-ray scattering, ultra-small-angle x-ray scattering, x-ray microscopy, millivolt resolution spectroscopy, surface and interface scattering, absorption spectroscopy, x-ray topography, microbeam techniques, coherent x-ray diffraction, and time-resolved techniques. These research tools permit UNI-CAT scientists and collaborators to explore fundamental structure/property relationships in bulk solids, at surfaces, and at internal interface boundaries.

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**CAT contacts:**

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# Beamline 33-BM / UNI-CAT

**Scientific focus:** Materials science and condensed matter physics

**Scientific programs:** Materials Science, ceramic science, phase transitions, surface science, thin-film structure and growth, and materials physics

Bending Magnet Source Characteristics (nominal)	
source	APS bending magnet
critical energy	19.51 keV
energy range	1.0 - 100.0 keV
on-axis peak brilliance at 16.3 keV	$2.9 \times 10^{15}$ ph/sec/mrad $^2$ mm $^2$ 0.1%bw
on-axis peak angular flux at 16.3 keV	$9.6 \times 10^{13}$ ph/sec/mrad $^2$ 0.1%bw
on-axis peak horizontal angular flux at 5.6 keV	$1.6 \times 10^{13}$ ph/sec/mradh/0.1%bw
source size at critical energy $\Sigma_x$ $\Sigma_y$	145 $\mu$ m 36 $\mu$ m
source divergence at critical energy $\Sigma_x'$ $\Sigma_y'$	6 mrad 47 $\mu$ rad

## Optics & Optical Performance

- 4–40 keV energy range
- collimating mirror
- double-crystal monochromator
- focusing mirror

## Experiment Stations

- 33-BM-B  
EXAFS  
topography station
- 33-BM-C  
general purpose scattering station

## Detectors

- NaI scintillation counters
- gas-filled proportional counters (Xe, Ar)
- ionization chambers

## Beamline Controls and Data Acquisition

- Sun UNIX running EPICS with VME, SPEC

## Beamline Support Equipment/Facilities

- topography station (33-BM-B)
- EXAFS table (33-BM-B)
- Huber 4-circle diffractometer (33-BM-C)

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# Beamline 33-ID / UNI-CAT

**Scientific focus:** Material Science and condensed matter physics

**Scientific programs:** Material science, ceramic science, phase transitions, surface science, thin-films structure and growth, and materials physics

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ /mm $^2$ /0.1% bw
source size at 8.0 keV $\Sigma_x$	359 $\mu$ m
$\Sigma_y$	21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x$	24 $\mu$ rad
$\Sigma_y$	6.9 $\mu$ rad

## Optics & Optical Performance

- focused beam size 280  $\mu$ m hor. x 100  $\mu$ m vert.
- PSL double-crystal monochromator  
45 m from source  
4.0–40.0 keV energy range Si(111)  
 $10^{-4}$  energy resolution (dE/E)  
20–35 mm beam offset  
liquid-nitrogen cooling  
variable sagittal focus
- vertical focusing mirror  
2.0–4.0 mrad angle of incidence  
Pt, Si, Rh coating stripes  
variable vertical focus
- harmonic rejection mirror  
2.0–4.0 mrad angle of incidence  
Pt, Si, Rh coating stripes

## Experiment Stations

- 33-ID-D  
general purpose scattering  
USAXS station
- 33-ID-E  
surface and interface scattering station

## Detectors

- NaI scintillation counters
- ionization chambers
- gas-filled proportional counters (Xe, Ar)

## Beamline Controls and Data Acquisition

- Sun UNIX running EPICS with VME, SPEC

## Beamline Support Equipment/Facilities

- Huber 4-circle diffractometer (33-ID-D)
- Newport 6-circle goniometer w/ kappa geometry (33-ID-D)
- USAXS (33-ID-D)
- UHV surface/interface scattering chamber (33-ID-E)

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# Beamline 34-ID / UNI-CAT

**Scientific focus:** Microfocussing and coherent x-ray scattering

**Scientific programs:** Coherent x-ray diffraction, microbeam scattering, and x-ray microprobe

## Insertion Device Source Characteristics (nominal)

source	Undulator A
period	3.30 cm
length	2.47 m
effective $K_{\max}$ (at minimum gap = 10.5 mm)	2.78
energy range 1st harmonic	2.9 - 13.0 keV
energy range 1st - 5th harmonics	2.9 - 45.0 keV
on-axis peak brilliance at 6.5 keV	$9.6 \times 10^{18}$ ph/sec/mrad $^2$ mm $^2$ 0.1% bw
source size at 8.0 keV $\Sigma_x$ $\Sigma_y$	359 $\mu$ m 21 $\mu$ m
source divergence at 8.0 keV $\Sigma_x'$ $\Sigma_y'$	24 $\mu$ rad 6.9 $\mu$ rad

## Optics & Optical Performance

- beamline under design
- beam-splitting mirrors
- monochromators

## Experiment Stations

- 34-ID-C  
coherent beam diffraction station
- 34-ID-E  
microbeam scattering station

## Detectors

- various CCD cameras
- NaI scintillation counters

## Beamline Controls and Data Acquisition

- To be determined

## Beamline Support Equipment/Facilities

- Kappa diffractometer with surface science capability (34-ID-C)
- microbeam scattering table (34-ID-E)

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# Directory

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CARS-CAT	Consortium for Advanced Radiation Sources GeoSoilEnviroCARS BioCARS ChemMatCARS	434	13, 14, 15	630.252.0450	630.252.0443	franklin@cars.uchicago.edu
CMC-CAT	Complex Materials Consortium	433	9	630.252.0320	630.252.0339	gog@anl.gov
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SBC-CAT	Structural Biology Center	435	19	630.252.0560	630.252.0564	cmzimmer@anl.gov
SER-CAT	Southeast Regional	363A	22 (under devel.)	630.252.0640	630.252.0641	junik@anl.gov
SRI-CAT	Synchrotron Radiation Instrumentation	431	1, 2, 3, 4	630.252.0160	630.252.0161	ljs@aps.anl.gov
UNI-CAT	A University–National Laboratory–Industry	438	33, 34	630.252.0860	630.252.0862	zschack@anl.gov
To call an insertion-device beamline, dial 630.252.18XX		To call a bending-magnet beamline, dial 630.252-17XX			(where XX is the sector number)	