BASIC ENERGY SCIENCES –
Serving the Present, Shaping the Future

http://www.science.doe.gov/bes

Basic Energy Sciences

Beta Test of Alternative Metrics for Assessing the BES Light Sources

Patricia M. Dehmer
Director, Basic Energy Sciences

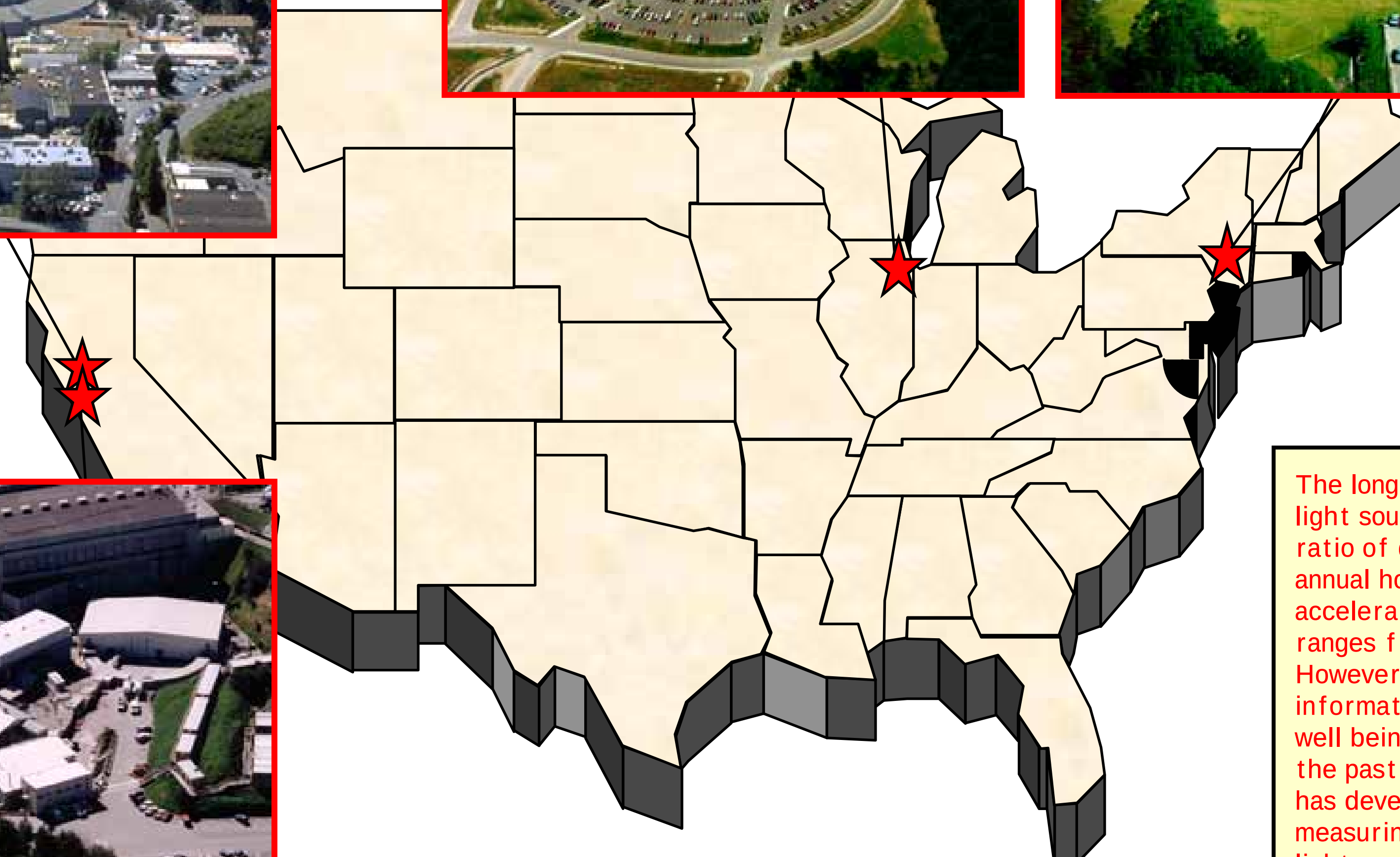
October 2005

BES Facilities for X-ray Scattering

Advanced Light Source

Advanced Photon Source

National Synchrotron Light Source

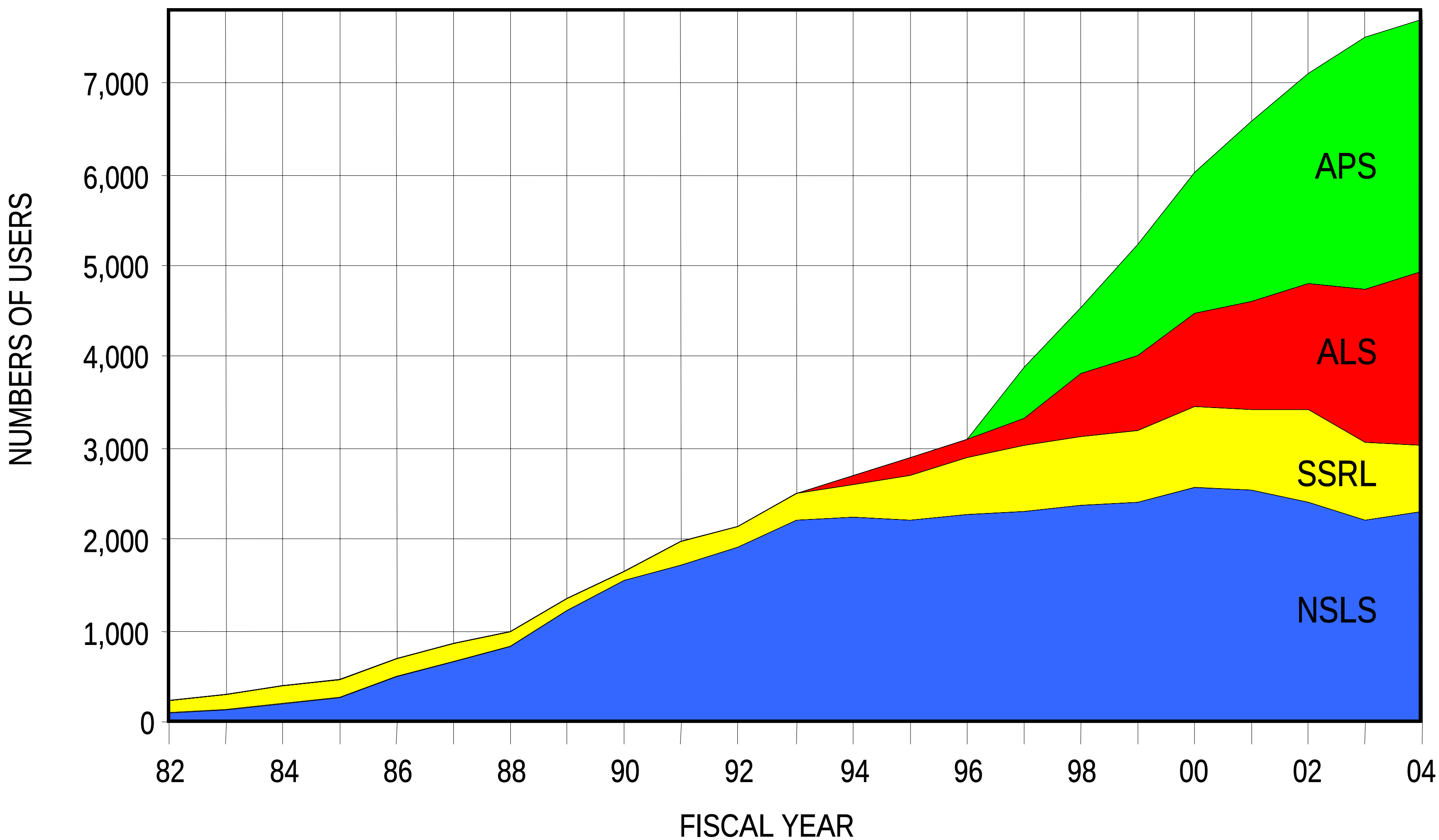


Stanford Synchrotron Radiation Laboratory

The long-established metric for light source operation – i.e., the ratio of delivered to scheduled annual hours of operation of the accelerator complex – generally ranges from 0.95 to 1.00. However, this ratio gives little information about the overall well being of the facility. Over the past year and a half, BES has developed alternate ways of measuring how effectively the light sources are utilized.

A New Methodology for Assessing Utilization of the Synchrotron Radiation Light Sources

(and, by extension, the other BES user facilities, too)



In FY 2006, the four BES light sources accounted for 44% of the BES facilities budget and 21% of the total BES budget excluding construction. They are visited by nearly 8,000 users per year.

Synchrotron radiation light sources command national-level attention, because they enable scientific investigations in areas closely aligned with national priorities including nanotechnology, energy security, defense technologies, and biomedical research. The scientific progress and hence the relative international competitive position of U.S. research efforts depend to an extent upon the overall capability and efficient utilization of U.S. synchrotron radiation light source facilities.

Effective utilization means maximizing science output. In turn, this means that we must measure more than the operation of the accelerator complex. We also must look to the “user experience” to determine the overall effectiveness of the facility.

Assessments of the BES Light Sources

http://www.sc.doe.gov/bes/synchrotron_techniques/

As a start to developing additional assessment tools for the light sources, the light sources were asked to group all of the beamlines into technique-oriented categories. Twelve categories emerged, and descriptions of each with examples of the science enabled are posted on the web.

SPECTROSCOPY techniques are used to study the energies of particles that are emitted or absorbed by samples that are exposed to the light-source beam and are commonly used to determine the characteristics of chemical bonding and electron motion.

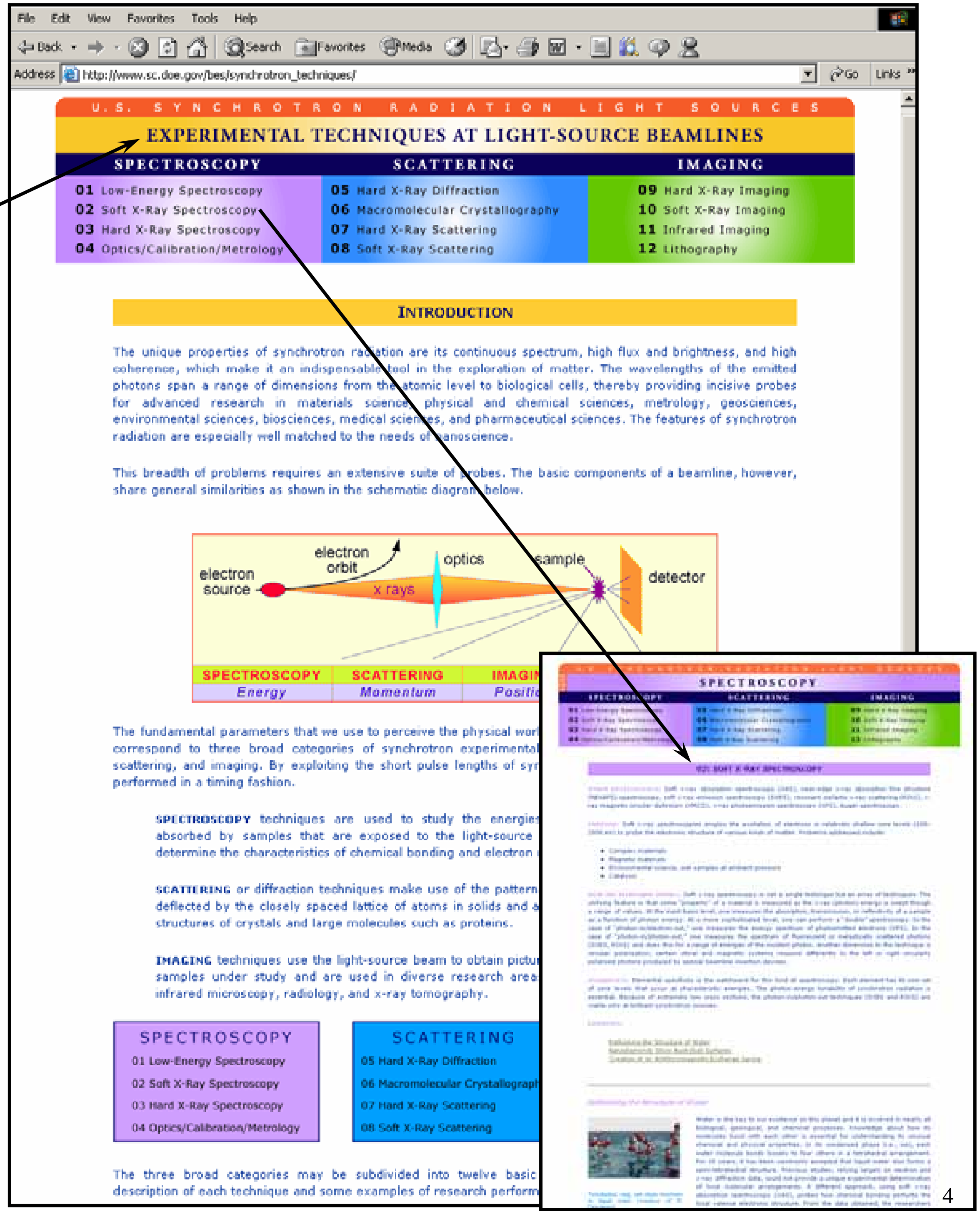
01 Low-Energy Spectroscopy
02 Soft X-Ray Spectroscopy
03 Hard X-Ray Spectroscopy
04 Optics/Calibration/Metrology

SCATTERING or diffraction techniques make use of the patterns of light produced when x-rays are deflected by the closely spaced lattice of atoms in solids and are commonly used to determine the structures of crystals and large molecules such as proteins.

05 Hard X-Ray Diffraction
06 Macromolecular Crystallography
07 Hard X-Ray Scattering
08 Soft X-Ray Scattering

IMAGING techniques use the light-source beam to obtain pictures with fine spatial resolution of the samples under study and are used in diverse research areas such as cell biology, lithography, infrared microscopy, radiology, and x-ray tomography.

09 Hard X-Ray Imaging
10 Soft X-Ray Imaging
11 Infrared Imaging
12 Lithography



Beamline Matrix – Advanced Photon Source (44)

Then each light source mapped every one of its operating beamlines onto a matrix of the 12 techniques.

Together, there are 179 operating beamlines at the four BES light sources. There are another ~100 beamlines that have never been instrumented or that have obsolete instrumentation.

Note, though, that not all 100 of these "open" spaces for beamlines could be developed into "best-in-class" beamlines. This is due primarily to space limitations on the light source experimental floors and to ultimate brightness of the beam from the beam port. For example, at the APS, only 20% of the uncommitted ports are high brightness insertion device lines.

Utilization Matrix for the Four DOE/BES Light Sources

DESCRIPTIONS of 12 TECHNIQUES: ...oe.gov/bes/synchrotron_techniques/index.htm

BEAMLINE TECHNIQUES — Percentage for each technique that is available on each beamline. The sum of percentages equals 100% for each beamline.

Spectroscopy (01–04) | Scattering (05–08) | Imaging (09–12)

FY 2004 — Operational Beamlines

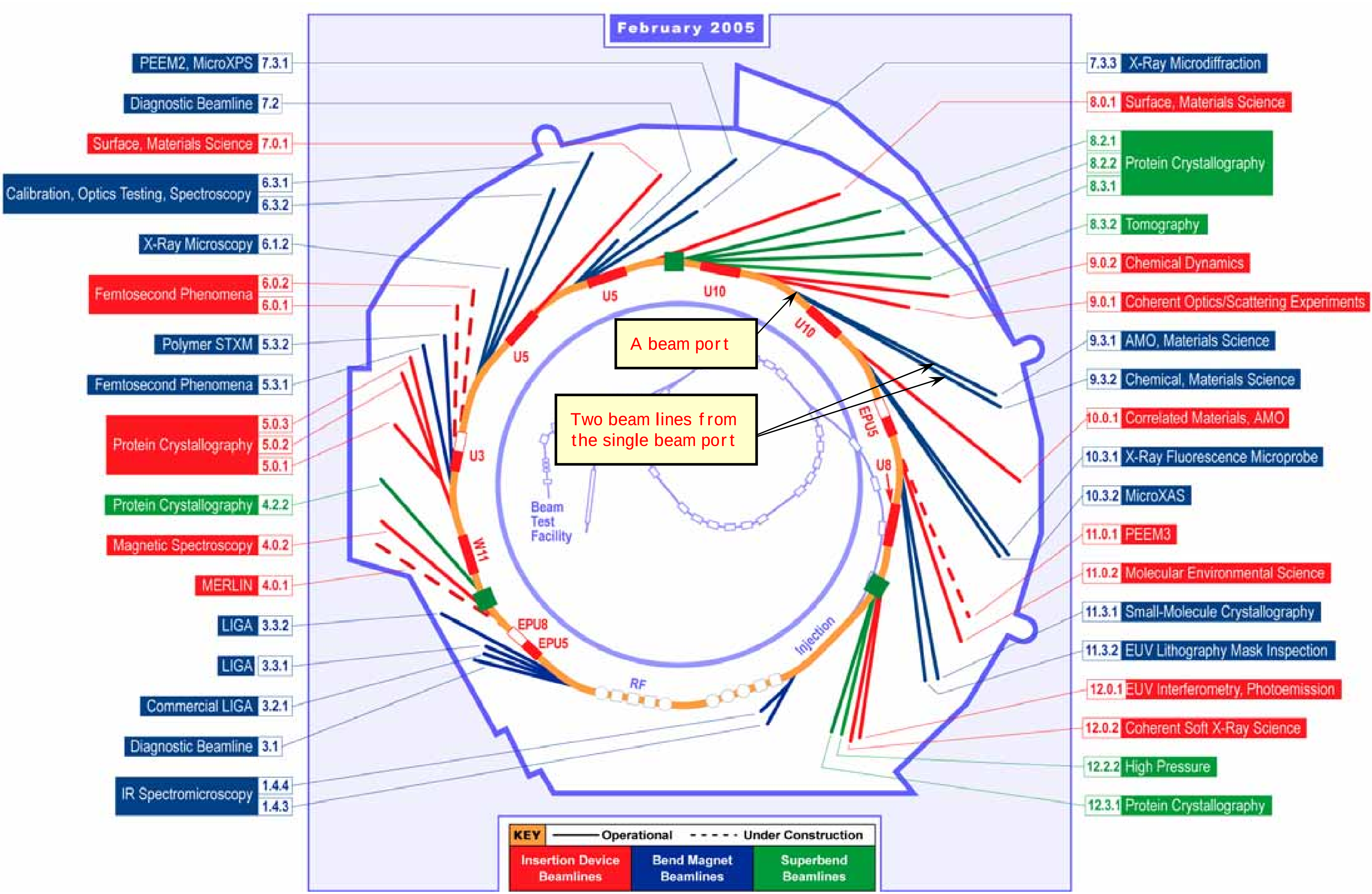
Beamline Type	Count	01 Low energy spectroscopy	02 Soft x-ray spectroscopy	03 Hard x-ray spectroscopy	04 Optics; calibration; metrology	05 Hard x-ray diffraction	06 Macromolecular crystallography	07 Hard x-ray scattering	08 Soft x-ray scattering	09 Hard x-ray imaging	10 Soft x-ray imaging	11 IR imaging	12 Lithography	#	Facility	Designation	Check (X) means that the beamline is "Best in Class" as bench-marked against similar capabilities worldwide
...raction, and imaging	1					30		40		30				1	APS	01-BM	
...raction, and imaging	2					35		35		30				1	APS	01-ID	
...iffraction	3					30				70				1	APS	02-BM	X
...attering	4								30		70			1	APS	02-ID-B	X
	5					10				90				1	APS	02-ID-D	X
	6									100				1	APS	02-ID-E	
	7				20			80						1	APS	03-ID	X
...cattering, and imaging	8		40						30		30			1	APS	04-ID-C	
	9			20		60				20				1	APS	04-ID-D	X
...nd diffraction	10			50		50								1	APS	05-BM-C	
... scattering	11					50		50						1	APS	05-BM-D	
...graphy and hard x-ray diffraction and scattering	12					25	50	25						1	APS	05-ID	
... scattering	13					50		50						1	APS	06-ID	
... scattering	14					50		50						1	APS	06-ID-D	
	15					100								1	APS	07-ID	
...graphy	16						100							1	APS	08-BM	
... scattering	17					50		50						1	APS	08-ID	
	18					5		95						1	APS	09-ID	
	19			70		30									APS	10-ID	
	20					100									APS	11-ID-B	
	21					100									APS	11-ID-C	
...nd diffraction	22			50		50									APS	11-ID-D	
Hard x-ray spectroscopy and diffraction	23			50		50									APS	12-BM	
Hard x-ray diffraction and scattering	24					50		50							APS	12-ID	X
Hard x-ray diffraction, spectroscopy, and imaging	25			25		50				25					APS	13-BM	X
Hard x-ray diffraction, spectroscopy, scattering, and imaging	26			35		35		15		15					APS	13-ID	X
Macromolecular crystallography	27						100								APS	14-BM-C	
Macromolecular crystallography	28						100								APS	14-BM-D	X
Macromolecular crystallography	29						100								APS	14-ID	
Hard x-ray diffraction	30					100									APS	15-ID	X
Hard x-ray diffraction and scattering	31					50		50							APS	16-ID-B	X
Macromolecular crystallography	32						100								APS	17-BM	
Macromolecular crystallography	33						100								APS	17-ID	
Hard x-ray scattering	34			20				80							APS	18-ID	
Macromolecular crystallography	35						100								APS	19-BM	X
Macromolecular crystallography	36						100							1	APS	19-ID	X
Hard x-ray spectroscopy	37			100										1	APS	20-BM	
Hard x-ray spectroscopy and diffraction	38			50		50								1	APS	20-ID	X
Macromolecular crystallography	39						100							1	APS	22-BM	
Macromolecular crystallography	40						100							1	APS	22-ID	X
Macromolecular crystallography	41						100							1	APS	31-ID	
Hard x-ray spectroscopy	42			100										1	APS	33-BM	
Hard x-ray diffraction, spectroscopy, scattering, and imaging	43					40		30		30				1	APS	33-ID	X
Hard x-ray imaging	44					20				80				1	APS	34-ID	

Note: Some "beam ports" – which are the primary openings for x-ray radiation from the electron storage ring – can support more than one "beamline." See example for the Advanced Light Source on the next chart.

Note: The check marks indicate beamlines that are "best in class."

The Difference Between Beam Ports and Beam Lines

Example from the Advanced Light Source



Beamline Matrix – Advanced Light Source (35)

DESCRIPTIONS of 12 TECHNIQUES:

http://www.sc.doe.gov/bes/synchrotron_techniques/index.htm

Utilization Matrix for the Four DOE/BES Light Sources

BEAMLINE TECHNIQUES
Percentage for each technique that is available on each beamline. The sum of percentages equals 100% for each beamline.

FY 2004

		Spectroscopy				Scattering				Imaging							
Beamline Type	Count	Low energy spectroscopy	Soft x-ray spectroscopy	Hard x-ray spectroscopy	Optics; calibration; metrology	Hard x-ray diffraction	Macromolecular crystallography	Hard x-ray scattering	Soft x-ray scattering	Hard x-ray imaging	Soft x-ray imaging	IR imaging	Lithography	#	Facility	Designation	Check (X) means that the beamline is "Best in Class" as bench-marked against similar capabilities worldwide
Low energy spectroscopy and IR Imaging	45	50										50		1	ALS	1.4.3	
IR imaging	46	25										75		1	ALS	1.4.4	
Lithography	47												100	1	ALS	3.2.1	X
Lithography	48												100	1	ALS	3.3.1	X
Lithography	49												100	1	ALS	3.3.2	X
Soft x-ray spectroscopy	50		95								5			1	ALS	4.0.2	X
Macromolecular crystallography	51						100							1	ALS	4.2.2	X
Macromolecular crystallography	52						100							1	ALS	5.0.1	
Macromolecular crystallography	53						100							1	ALS	5.0.2	X
Macromolecular crystallography	54						100							1	ALS	5.0.3	
Hard x-ray diffraction	55					100								1	ALS	5.3.1	
Soft x-ray spectroscopy and soft x-ray imaging	56		50								50			1	ALS	5.3.2	
Soft x-ray imaging	57										100			1	ALS	6.1.2	X
Soft x-ray spectroscopy	58		100											1	ALS	6.3.1	
Optics; calibration; metrology	59		20		80									1	ALS	6.3.2	X
Low energy spectroscopy	60	50	25						25							0.1	X
Soft x-ray imaging	61										100					3.1.1/2	X
Hard x-ray imaging	62									100						3.3	
Soft x-ray scattering and spectroscopy	63		50						50							0.1	
Macromolecular crystallography	64						100									2.1	X
Macromolecular crystallography	65						100									2.2	X
Macromolecular crystallography	66						100									3.1	X
Hard x-ray imaging	67									100				1	ALS	8.3.2	
Low energy spectroscopy	68	80									20			1	ALS	9.0.1/2	X
Soft x-ray spectroscopy	69		100											1	ALS	9.3.1	
Soft x-ray spectroscopy	70	20	80											1	ALS	9.3.2	
Low energy spectroscopy	71	100												1	ALS	10.0.1.1/2	X
Hard x-ray imaging	72									100				1	ALS	10.3.1	
Hard x-ray imaging, diffraction, and spectroscopy	73			25		25				50				1	ALS	10.3.2	X
Soft x-ray spectroscopy	74		50						20		30			1	ALS	11.0.2	X
Hard x-ray diffraction	75					100								1	ALS	11.3.1	
Optics; calibration; metrology	76				100									1	ALS	11.3.2	X
Lithography, low energy spectroscopy, and soft x-ray imaging	77	30									20		50	1	ALS	12.0.1.1/2	X
Hard x-ray diffraction	78					100								1	ALS	12.2.2	
Macromolecular crystallography	79						70	30						1	ALS	12.3.1	X

A large number of beamlines at the ALS are rated "best in class."

Beamline Matrix – National Synchrotron Light Source (77)

Beamline Type	Count	Low energy spectroscopy	Soft x-ray spectroscopy	Hard x-ray spectroscopy	Optics; calibration; metrology	Hard x-ray diffraction	Macromolecular crystallography	Hard x-ray scattering	Soft x-ray scattering	Hard x-ray imaging	Soft x-ray imaging	IR imaging	Lithography	#	Facility	Designation	Check (X) means that the beamline is "Best in Class" as bench-marked against similar capabilities worldwide
DESCRIPTIONS of 12 TECHNIQUES: http://www.sc.doe.gov/bes/synchrotron_techniques/index.htm		Utilization Matrix for the Four DOE/BES Light Sources — BEAMLINE TECHNIQUES: Percentage for each technique that is available on each beamline. The sum of percentages equals 100% for each beamline.												FY 2004			
		Spectroscopy				Scattering				Imaging							
Soft x-ray spectroscopy	80		100											1	NSLS	U1A	
Low energy spectroscopy	81	100												1	NSLS	U2A	
IR imaging	82	30										70		1	NSLS	U2B	
Optics; calibration; metrology	83				100									1	NSLS	U3C	
Low energy spectroscopy and IR Imaging	84	50										50		1	NSLS	U4IR	
Low energy spectroscopy	85	100												1	NSLS	U4A	
Soft x-ray spectroscopy	86		80						20					1	NSLS	U4B	
Low energy spectroscopy	87	100												1	NSLS	U5U	
Soft x-ray spectroscopy	88		100											1	NSLS	U7A	
Low energy spectroscopy	89	100												1	NSLS	U7B	
Soft x-ray spectroscopy	90		100											1	NSLS	U8B	
Optics; calibration; metrology	91				100									1	NSLS	U9A	
Low energy spectroscopy	92	100												1	NSLS	U9B	
Low energy spectroscopy	93	100												1	NSLS	U10A	
IR imaging	94											100		1	NSLS	U10B	
Low energy spectroscopy	95	100												1	NSLS	U11	
Low energy spectroscopy	96	100												1	NSLS	U12IR	X
Soft x-ray spectroscopy	97		100											1	NSLS	U12A	
Low energy spectroscopy	98	100												1	NSLS	U13U	X
Optics; calibration; metrology	99				100									1	NSLS	U15	
Soft x-ray spectroscopy	100		100											1	NSLS	U16B	
Soft x-ray imaging	101										100			1	NSLS	X1A1	
Soft x-ray imaging	102										100			1	NSLS	X1A2	
Soft x-ray scattering and spectroscopy	103		30						70							1B	X
Hard x-ray imaging	104									100						2B	
Hard x-ray diffraction	105					100										3B1	
Macromolecular crystallography	106						100									4A	
Macromolecular crystallography	107						100									4C	
Hard x-ray diffraction	108					100										5A	
Macromolecular crystallography	109						100							1	NSLS	X6A	
Hard x-ray diffraction	110					100								1	NSLS	X6B	
Hard x-ray diffraction	111					100								1	NSLS	X7A	
Hard x-ray diffraction	112					100								1	NSLS	X7B	
Optics; calibration; metrology	113				100									1	NSLS	X8A	
Macromolecular crystallography	114						100							1	NSLS	X8C	
Macromolecular crystallography	115						100							1	NSLS	X9A	
Hard x-ray spectroscopy	116			100										1	NSLS	X9B	
Hard x-ray scattering	117					30		70						1	NSLS	X10A	

Relatively few beamlines at the NSLS are rated "best in class."

— continued —

Beamline Matrix – National Synchrotron Light Source (77)

— continued —

Utilization Matrix for the Four DOE/BES Light Sources

DESCRIPTIONS of 12 TECHNIQUES:

http://www.sc.doe.gov/bes/synchrotron_techniques/index.htm

BEAMLINE TECHNIQUES

Percentage for each technique that is available on each beamline. The sum of percentages equals 100% for each beamline.

FY 2004

Beamline Type	Count	Spectroscopy				Scattering				Imaging				FY 2004			
		Low energy spectroscopy	Soft x-ray spectroscopy	Hard x-ray spectroscopy	Optics; calibration; metrology	Hard x-ray diffraction	Macromolecular crystallography	Hard x-ray scattering	Soft x-ray scattering	Hard x-ray imaging	Soft x-ray imaging	IR imaging	Lithography	#	Facility	Designation	Check (X) means that the beamline is "Best in Class" as bench-marked against similar capabilities worldwide
Hard x-ray diffraction	118					100								1	NSLS	X10B	
Hard x-ray spectroscopy	119			100										1	NSLS	X10C	
Hard x-ray spectroscopy	120			100										1	NSLS	X11A	
Hard x-ray spectroscopy	121			100										1	NSLS	X11B	
Optics; calibration; metrology	122				100									1	NSLS	X12A	
Macromolecular crystallography	123						80	20						1	NSLS	X12B	
Macromolecular crystallography	124						100							1	NSLS	X12C	
Hard x-ray imaging and soft x-ray spectroscopy and scattering	125		30						20	50				1	NSLS	X13	
Hard x-ray diffraction	126					70		30						1	NSLS	X14A	
Hard x-ray diffraction and imaging	127					50				50				1	NSLS	X15A	
Hard x-ray spectroscopy	128			100										1	NSLS	X15B	
Hard x-ray diffraction	129					100								1	NSLS	X16A	
Hard x-ray diffraction and scattering	130					50		50						1	NSLS	X16B	
Hard x-ray spectroscopy	131			100										1	NSLS	X16C	
Hard x-ray diffraction	132					100								1	NSLS	X17B	
Hard x-ray diffraction	133					100								1	NSLS	X17C	
Hard x-ray diffraction	134					70		30						1	NSLS	X18A	
Hard x-ray spectroscopy	135			100										1	NSLS	X18B	
Hard x-ray spectroscopy	136			80				20						1	NSLS	X19A	
Hard x-ray scattering and imaging	137							60		40				1	NSLS	X19C	
Hard x-ray scattering, diffraction, and imaging	138					20		40		40				1	NSLS	X20A	
Hard x-ray scattering	139							100						1	NSLS	X20B	
Hard x-ray diffraction	140					100								1	NSLS	X20C	
Hard x-ray scattering	141					20		80						1	NSLS	X21	
Hard x-ray scattering	142							100						1	NSLS	X22A	
Hard x-ray scattering	143							100						1	NSLS	X22B	
Hard x-ray scattering	144					20		80						1	NSLS	X22C	
Hard x-ray spectroscopy	145			100										1	NSLS	X23A	
Hard x-ray spectroscopy	146			80		20								1	NSLS	X23B	
Hard x-ray spectroscopy and diffraction	147			50		50								1	NSLS	X24A	
Optics; calibration; metrology	148				100									1	NSLS	X24C	
Macromolecular crystallography	149						100							1	NSLS	X25	
Hard x-ray imaging	150									100				1	NSLS	X26A	
Macromolecular crystallography	151						100							1	NSLS	X26C	
Hard x-ray imaging	152									100				1	NSLS	X27A	
Lithography	153												100	1	NSLS	X27B	
Hard x-ray scattering	154							100						1	NSLS	X27C	
Hard x-ray spectroscopy	155			100										1	NSLS	X28C	
Macromolecular crystallography	156						100							1	NSLS	X29	X

Beamline Matrix – Stanford Synchrotron Radiation Laboratory (23)

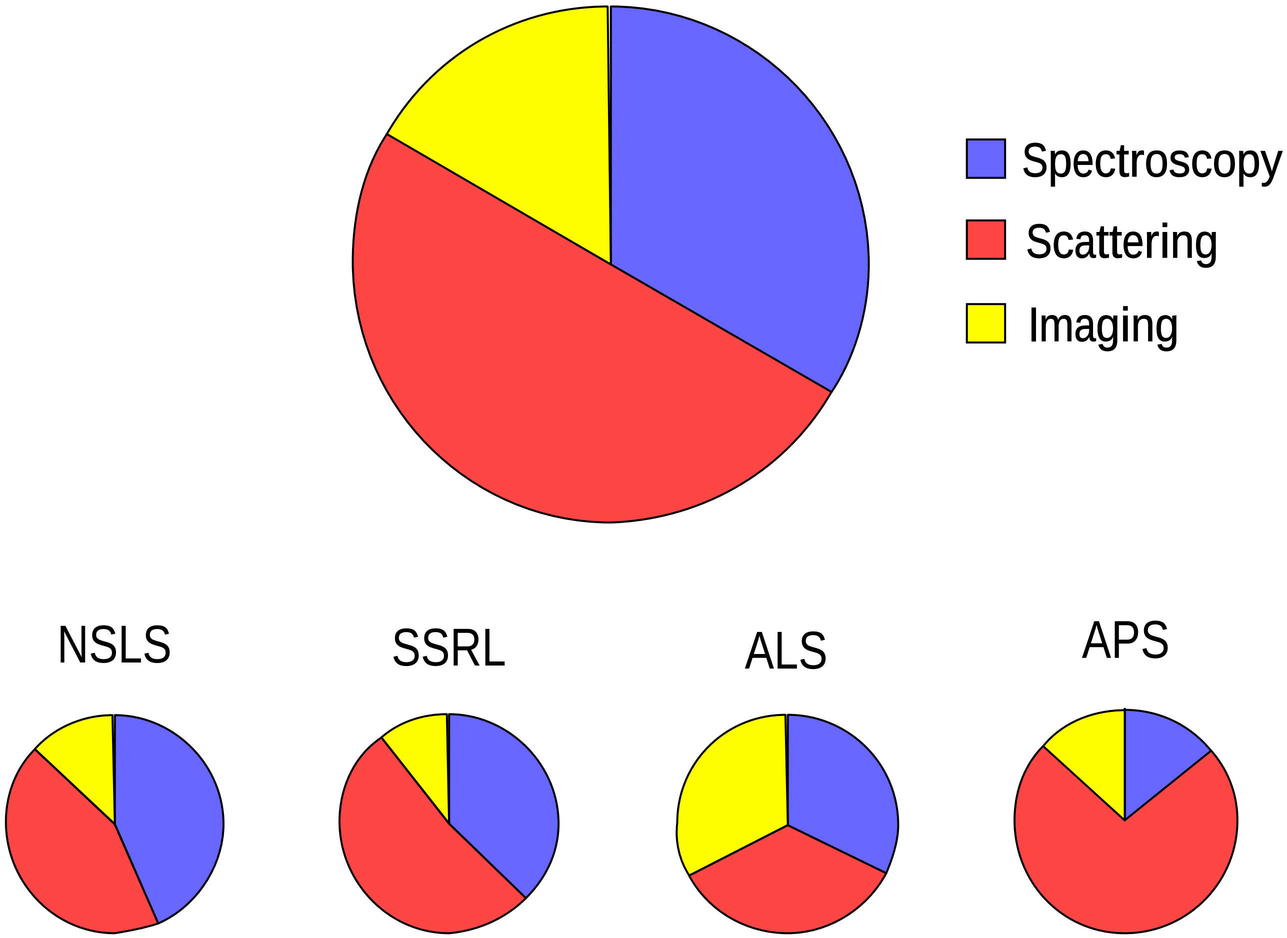
DESCRIPTIONS of 12 TECHNIQUES: http://www.sc.doe.gov/bes/synchrotron_techniques/index.htm		Utilization Matrix for the Four DOE/BES Light Sources — BEAMLINE TECHNIQUES: Percentage for each technique that is available on each beamline. The sum of percentages equals 100% for each beamline.												FY 2004			
		Spectroscopy				Scattering				Imaging							
Beamline Type	Count	Low energy spectroscopy	Soft x-ray spectroscopy	Hard x-ray spectroscopy	Optics; calibration; metrology	Hard x-ray diffraction	Macromolecular crystallography	Hard x-ray scattering	Soft x-ray scattering	Hard x-ray imaging	Soft x-ray imaging	IR imaging	Lithography	#	Facility	Designation	Check (X) means that the beamline is "Best in Class" as bench-marked against similar capabilities worldwide
Hard x-ray scattering	157							100						1	SSRL	1-4	
Macromolecular crystallography	158						100							1	SSRL	1-5	
Hard x-ray diffraction	159					100								1	SSRL	2-1	
Hard x-ray imaging and diffraction	160					40				60				1	SSRL	2-2	
Hard x-ray spectroscopy	161			80	20									1	SSRL	2-3	
Lithography	162												100	1	SSRL	3-1	
Hard x-ray scattering	163							100						1	SSRL	4-2	
Low energy spectroscopy	164	50	25								25			1	SSRL	5	X
Hard and soft x-ray spectroscopy and hard x-ray imaging	165		30	40						30				1	SSRL	6-2	
Macromolecular crystallography	166						100							1	SSRL	7-1	
Hard x-ray diffraction	167					100								1	SSRL	7-2	
Hard x-ray spectroscopy	168			100										1	SSRL	7-3	
Low energy spectroscopy and soft x-ray spectroscopy	169	50	50											1	SSRL	8-1	
Soft x-ray spectroscopy	170		100											1	SSRL	8-2	
Macromolecular crystallography	171						100							1	SSRL	9-1	
Macromolecular crystallography	172						100							1	SSRL	9-2	X
Hard x-ray spectroscopy	173			80						20				1	SSRL	9-3	X
Soft x-ray spectroscopy	174		100											1	SSRL	10-1	
Hard x-ray diffraction, spectroscopy, scattering, and imaging	175			30		40		20		10				1	SSRL	10-2	
Macromolecular crystallography	176						100							1	SSRL	11-1	
Hard x-ray spectroscopy	177			100										1	SSRL	11-2	X
Macromolecular crystallography and hard x-ray diffraction	178					50	50							1	SSRL	11-3	
Hard x-ray scattering	179							100						1	SSRL	SPPS	X
		01	02	03	04	05	06	07	08	09	10	11	12	# of Beamlines			
		0.00	0.40	5.70	0.20	12.70	11.50	7.00	0.60	4.90	1.00	0.00	0.00	44.00	APS		
		3.55	5.70	0.25	1.80	3.25	7.70	0.30	0.95	3.50	3.25	1.25	3.50	35.00	ALS		
		9.80	6.40	11.10	6.00	14.00	9.80	8.80	1.10	4.80	2.00	2.20	1.00	77.00	NSLS		
		1.00	3.05	4.30	0.20	3.30	5.50	3.20	0.00	1.20	0.25	0.00	1.00	23.00	SSRL		
		14.35	15.55	21.35	8.20	33.25	34.50	19.30	2.65	14.40	6.50	3.45	5.50	179.00	All 4		
		8%	9%	12%	5%	19%	19%	11%	1%	8%	4%	2%	3%	100%			

Here are some summary statistics for the 179 operating beamlines.

Distribution of Beamline Techniques

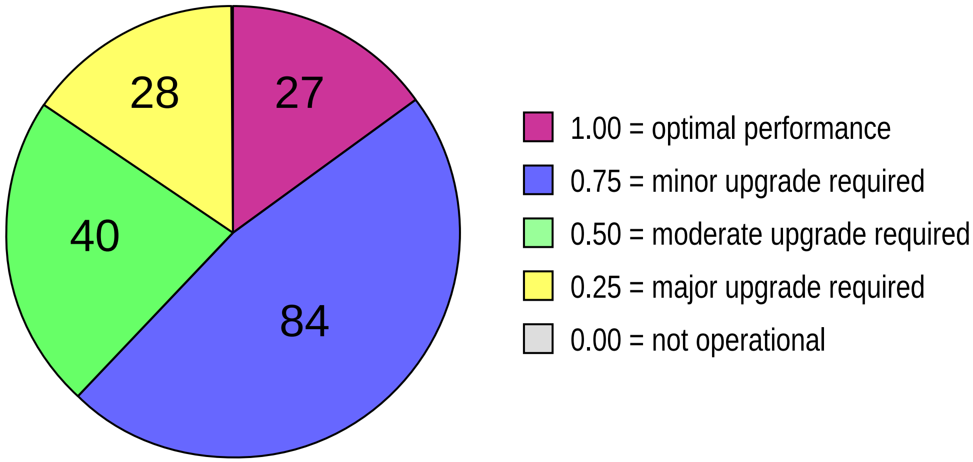
Here is a graphical display of the summary statistics for all 179 operating beam lines at the four DOE light sources.

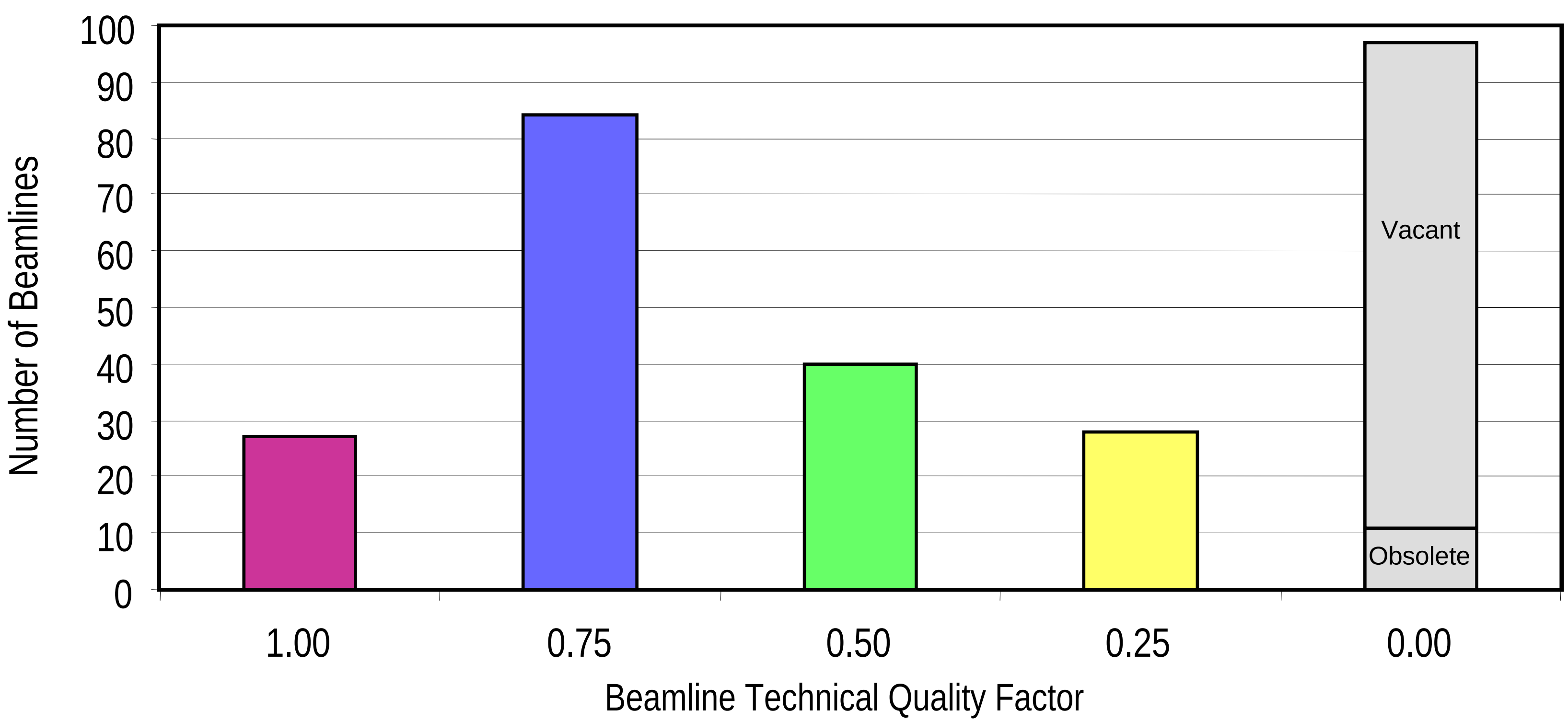
Note that the APS (a hard x-ray light source) emphasizes scattering while ALS (a soft x-ray light source) emphasizes spectroscopy and imaging.



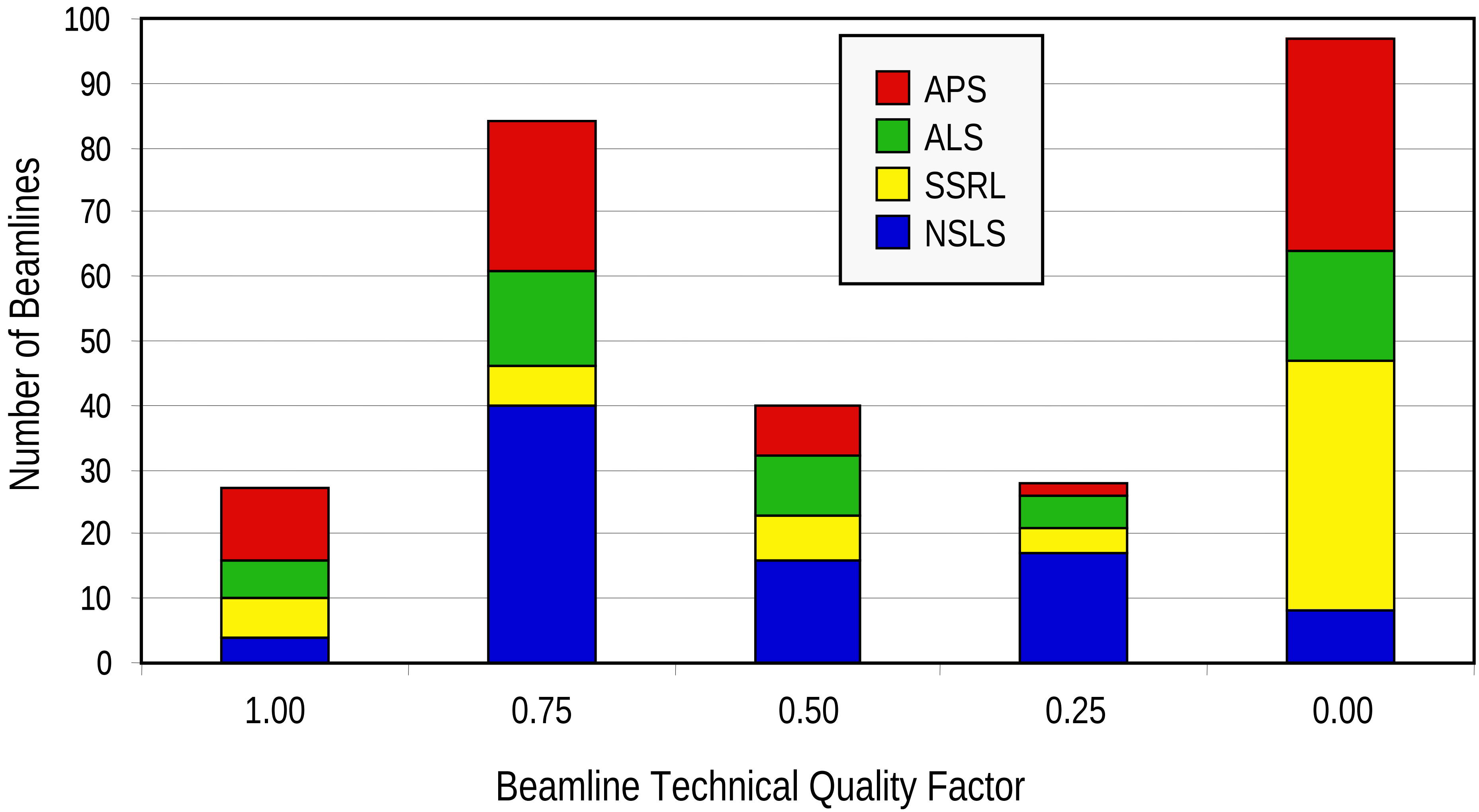
Quality Distribution of 179 Operating Beamlines

The light sources then rated each beamline according to a quality factor. A "normalization" team consisting of one senior technical staff member from each light source visited the four light sources and spot checked the ratings to ensure uniformity.





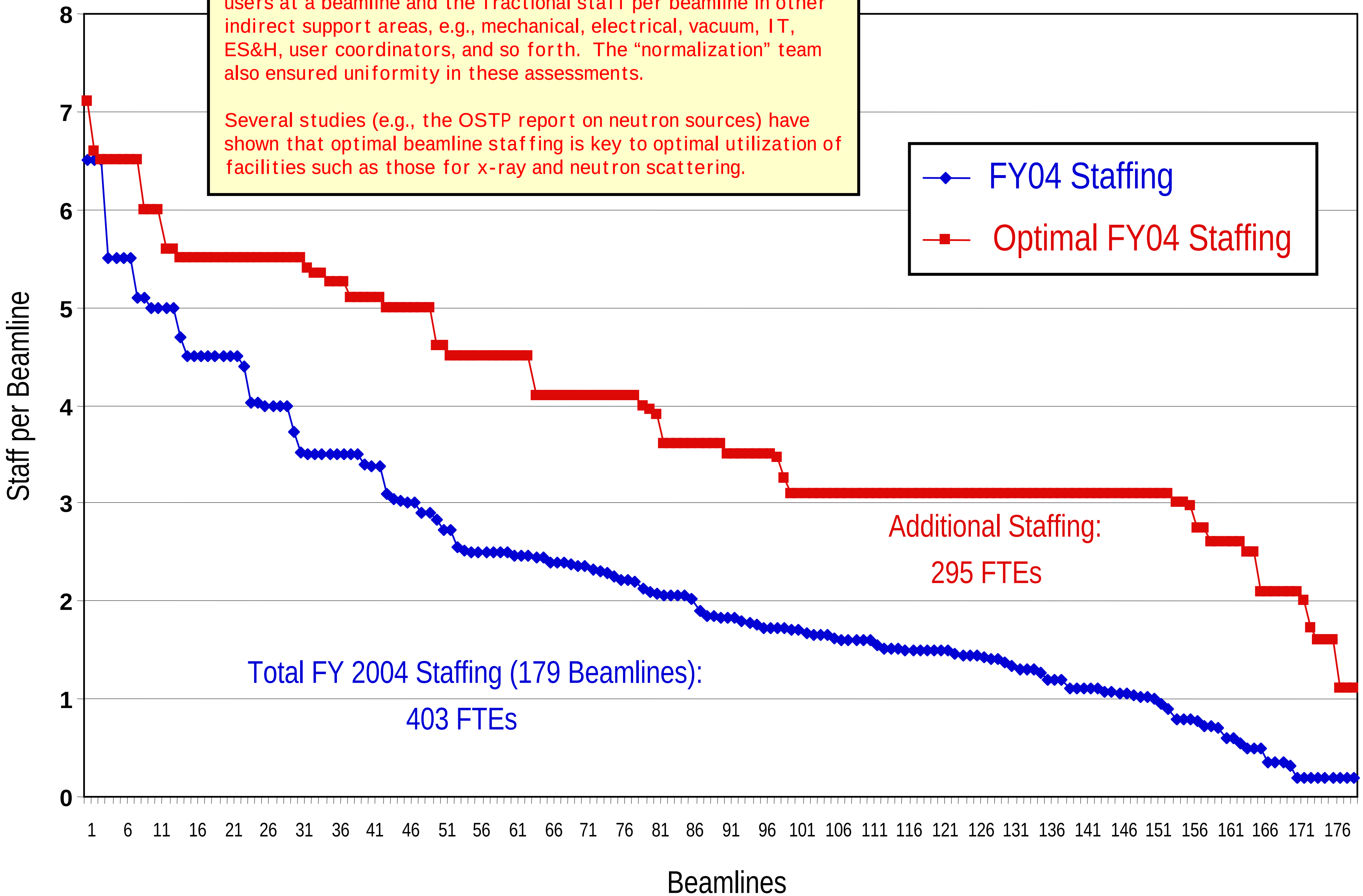
Beamline Quality Distribution by DOE Light Source Facility



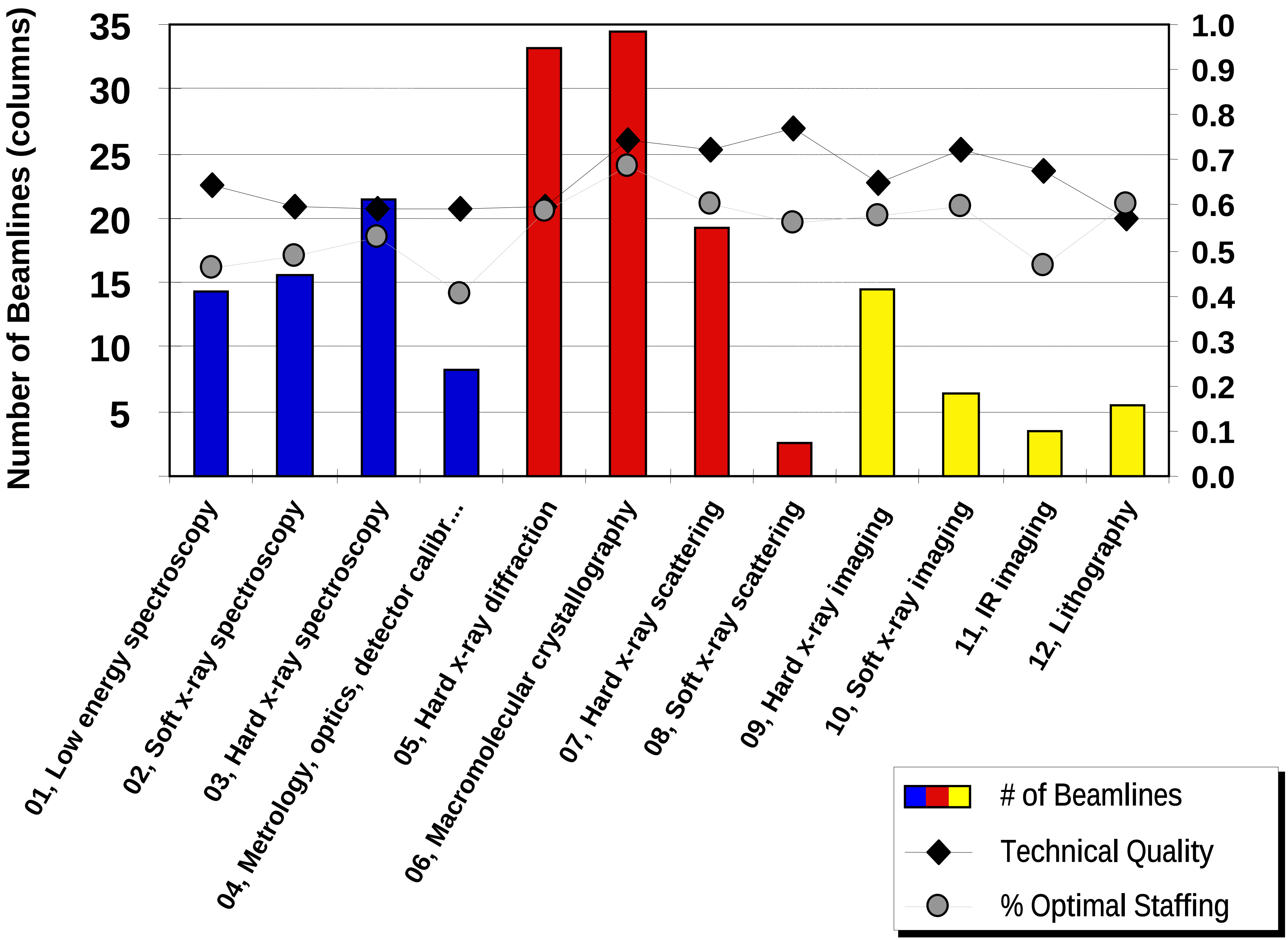
FY 2004 Beamline Staffing versus Optimal Staffing

Finally, the light sources determined the staffing levels at each beamline and estimated the "optimum" number for each beamline. Staffing levels include the number of staff who directly support users at a beamline and the fractional staff per beamline in other indirect support areas, e.g., mechanical, electrical, vacuum, IT, ES&H, user coordinators, and so forth. The "normalization" team also ensured uniformity in these assessments.

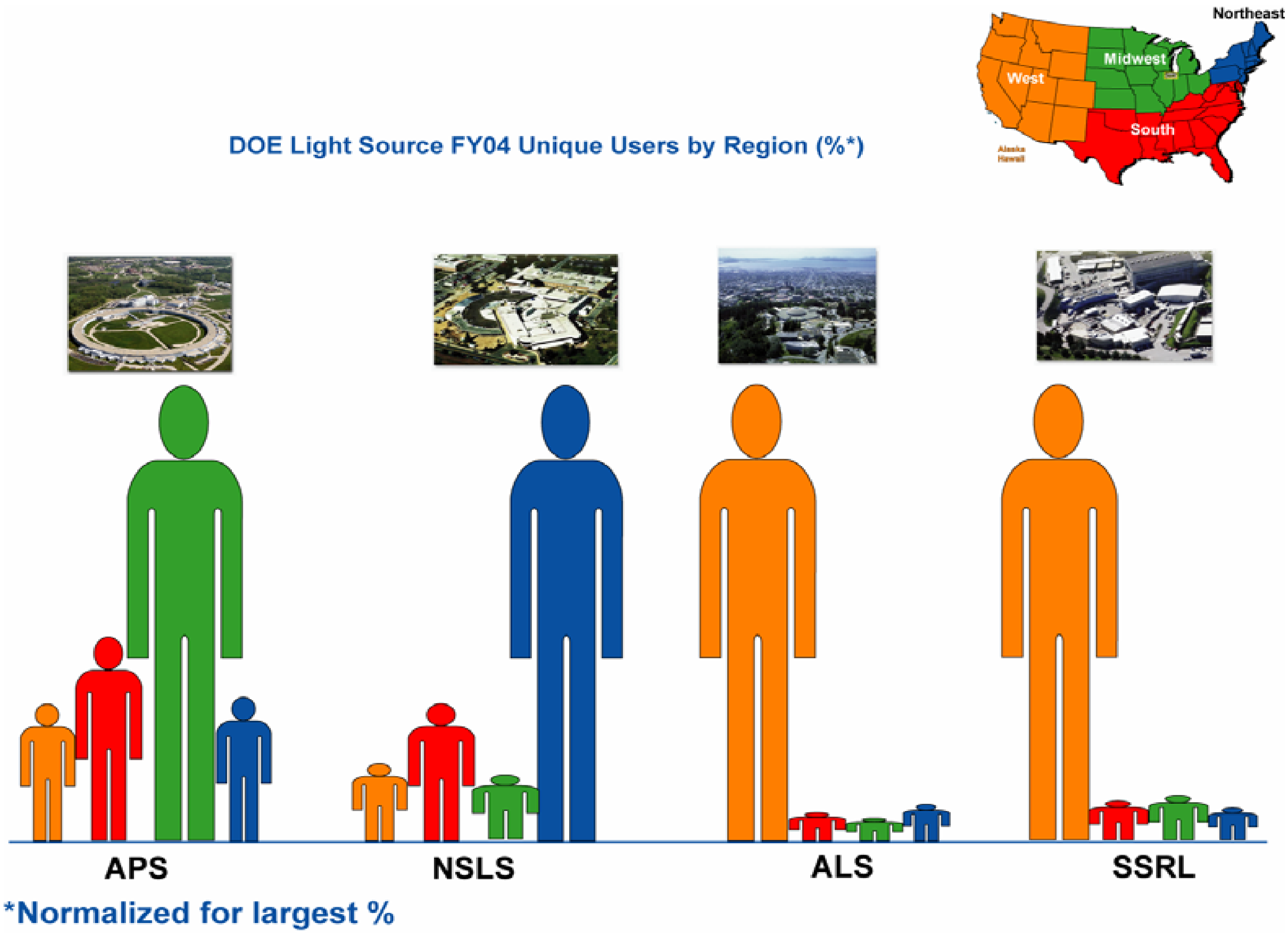
Several studies (e.g., the OSTP report on neutron sources) have shown that optimal beamline staffing is key to optimal utilization of facilities such as those for x-ray and neutron scattering.



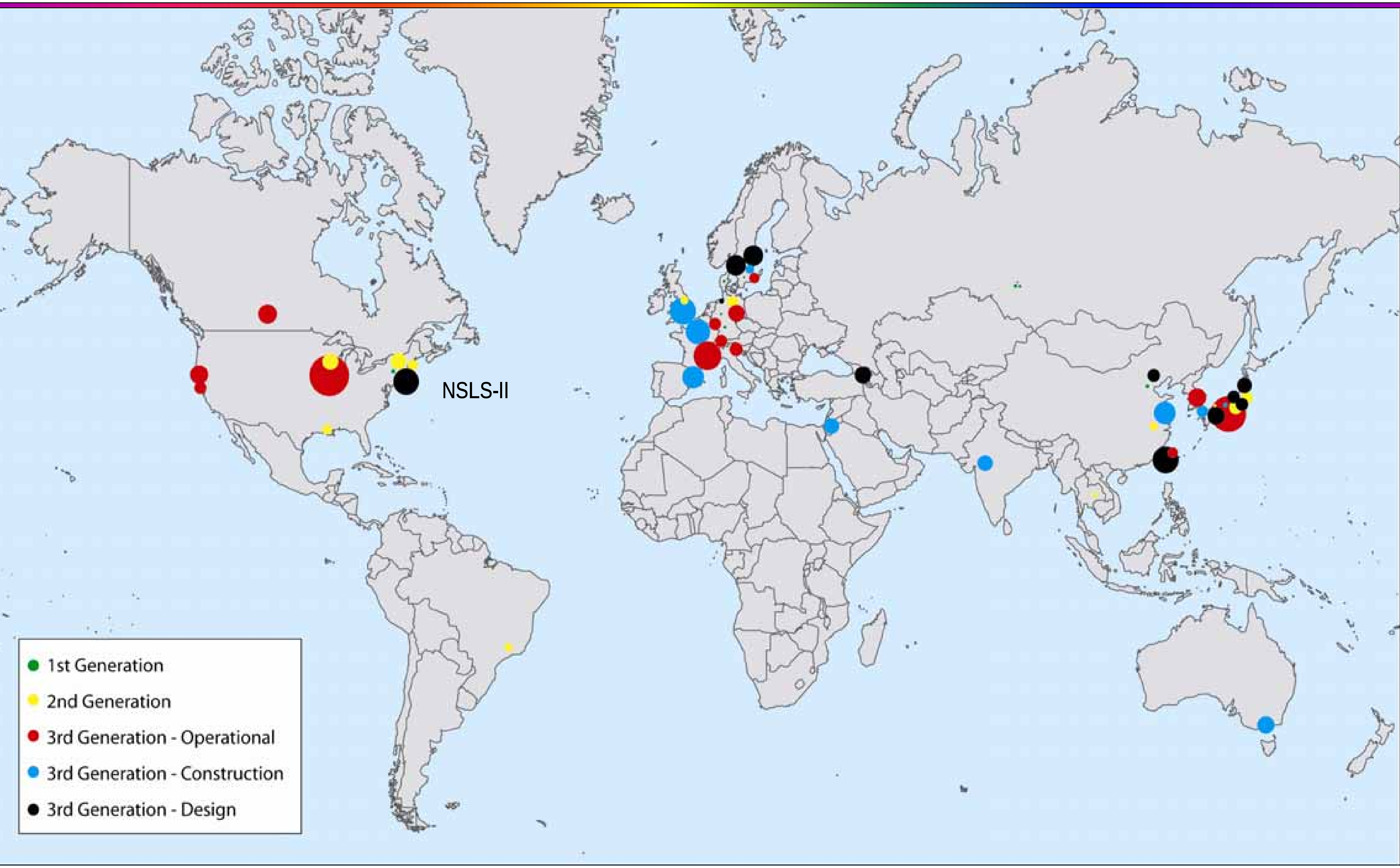
Beamline Quality Data by Beamline Technique



User Demographics



International Benchmarking: Synchrotrons Worldwide



The dots show all 1st, 2nd, and 3rd generation light sources worldwide that are operational, under construction, and in design. The dot diameter is proportional to the total number of beamlines at each facility. The number of users that a facility can host scales with the number of beamlines.

Red, blue, and black dots show 3rd generation machines. The numbers of beamlines for these machines are shown on the next chart.

Major Light Sources Worldwide

Country	City	Name	Generation[3]	E [GeV]	Circum [m]	Current [ma]	Horiz Emit [nm-rad]	Vert Emit [nm-rad]	Cells	Usable Insertion Device Straights	Usable Bending Magnet Ports	Total ID Straights & BM Ports	Bunch Length (σ_L) [psec]	Lattice[1]	Top-Off	Status[4]	Start Ops	Construction Funding Commitment
China	Beijing	BSRF	1	2.2	240.4	65	76	7.6	4	3	3	6	83	FODO	N	O	1989	N/A
Denmark	Aarhus	ASTRID	1	0.58	40	250	160	2.2	4	1	4	5	?	DBA	N	O	1990	N/A
Germany	Dortmund	DELTA	1	1.5	115.2	120	16	0.5	16	3	2	5	?	FODO	N	O	1995	N/A
Germany	Bonn	ELSA	1	1.6-3.0	164.4	25-250	760	76	12	0	4	4	?	FODO	N	O	1988	N/A
Russia	Novosibirsk	VEPP-4M	1	6	366	100	400	120	4	2	4	6	?	FODO	N	O	1998	N/A
Russia	Novosibirsk	VEPP-3	1	2	74	250	270	2.7	2	1	2	3	?	FODO	N	O	1973	N/A
Russia	Novisibirsk	VEPP-2M	1	0.7	18	300	460	4.6	3	2	3	5	?	FODO	N	O	1972	N/A
Sweden	Lund	MAX-I	1	0.55	90	300	40	1.2	4	1	3	4	80	DBA	N	O	1986	N/A
U.S.	Ithaca	CHESS	1	5.3	795	190	200	20	?	3	4	7	67	FODO	N	O	1980	N/A
Brazil	Campinas	LNLS	2	1.37	93.2	250	100	3	6	4	10	14	?	DBA	N	O	1997	N/A
China	Hefei	NSRL	2	0.8	66.1	180	134	4	4	2	12	14	?	TBA	N	O	1991	N/A
England	Warrington	Daresbury SRS	2	2	96	250	150	4.5	8	5	9	14	?	FODO	N	O	1981	N/A
Germany	Hamburg	DORIS-III	2	4.5	289	150	432	13	?	10	10	20	?	FODO	N	O	1974	N/A
Japan	Tsukuba	PF-AR	2	6.5	377	55	168	1.7	8	4	1	5	29	FODO	N	O	1984	N/A
Japan	Okazaki	UVSOR-II	2	0.75	53.2	300	27.4	2.7	8	7	16	23	170	DBA	N	O	1983	N/A
Japan	Tsukuba	Photon Factory	2	2.5	187	450	36	0.36	10	6	15	21	33	FODO	N	O	1982	N/A
Thailand	Nakhon Ratchasima	NSRC	2	1	81.3	150	226	2.3	4	4	4	8	135	DBA	N	O	2002	N/A
U.S.	Baton Rouge	CAMD	2	1.3	55	200	235	2.4	4	1	16	17	?	DBA	N	O	1992	N/A
U.S.	Madison, WI	ALADDIN-SRC	2	1	88.9	190	108	2.7	4	4	24	28	350	TBA	N	O	1985	N/A
U.S.	Upton, NY	NSLS X-ray	2	2.8	170	280	63	0.13	8	7	21	28	145	DBA	N	O	1982	N/A
U.S.	Upton, NY	NSLS IR/VUV	2	0.8	51	1000	160	4	4	2	16	18	162	DBA	N	O	1982	N/A
Canada	Saskatoon	CLS	3	2.9	171	200	18	0.36	12	9	24	33	42	DBA	N	O	2004	N/A
France	Grenoble	ESRF	3	6	844	200	3.8	0.023	32	27	22	49	20	DBA	N	O	1994	N/A
Germany	Karlsruhe	ANKA	3	2.5	240	110	80	0.24	8	5	16	21	?	DBA	N	O	2000	N/A
Germany	Berlin	BESSY-II	3	1.7	240	270	5.2	0.052	16	13	16	29	17	DBA	N	O	1998	N/A
Italy	Trieste	ELETTRA	3	2	260	320	7	0.07	12	11	12	23	18	DBA	N	O	1993	N/A
Japan	Nishi-Harima, Hyogo	SPRING-8	3	8	1436	100	3	0.06	48	38	24	62	15.5	DBA	N	O	1997	N/A
Korea	Pohang	PLS	3	2.5	281	180	13	0.13	12	10	22	32	21.2	TBA	N	O	1995	N/A
Sweden	Lund	MAX-II	3	1.5	90	250	8.8	0.088	10	8	10	18	20	DBA	N	O	1997	N/A
Switzerland	Villigen	SLS	3	2.4	288	400	5	0.05	12	9	12	21	12	TBA	Y	O	2001	N/A
Taiwan	Hsinchu	TLS (NSRRC)	3	1.5	120	200	25	2.5	6	6	12	18	25	TBA	N	O	1993	N/A

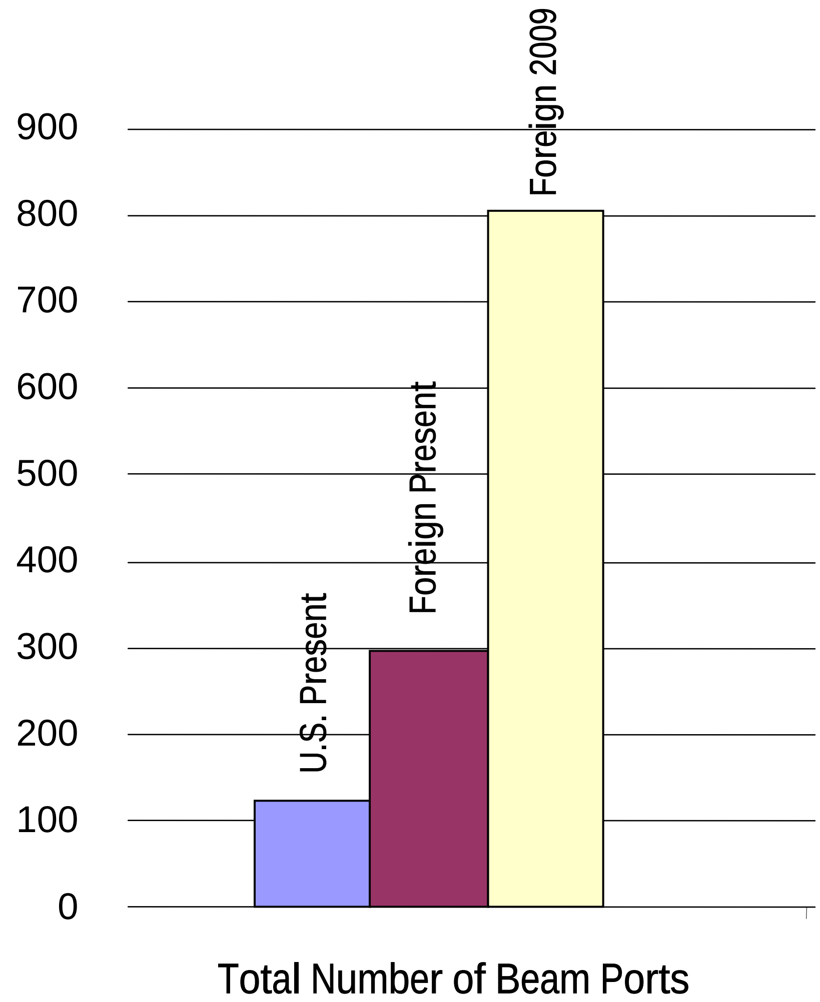
Major Light Sources Worldwide (con't)

Country	City	Name	Generation[3]	E [GeV]	Circum [m]	Current [ma]	Horiz Emit [nm-rad]	Vert Emit [nm-rad]	Cells	Usable Insertion Device Straights	Usable Bending Magnet Ports	Total ID Straights & BM Ports	Bunch Length (σ_L) [psec]	Lattice[1]	Top-Off	Status[4]	Start Ops	Construction Funding Commitment
U.S.	San Francisco, CA	SPEAR3	3	3	240	500	18	0.18	18	14	18	32	19	DBA	Y	O	2004	N/A
U.S.	Chicago	APS	3	7	1060	100	3.1	0.031	40	35	35	70	26	DBA	Y	O	1995	N/A
U.S.	San Francisco, CA	ALS	3	1.9	197	400	6.8	0.14	12	9	12	21	40	TBA	N	O	1993	N/A
Australia	Melbourne, Victoria	AUST. SYNCH.	3	3	216	200	7	0.07	14	12	18	30	?	DBA	N	C	2007	Yes
China	Shanghai	SSRF	3	3.5	432	300	3	0.03	20	18	20	38	14	DBA	Y	C	2009	Yes
England	Didcot, Oxfordshire	DIAMOND	3	3	561.6	300	2.7	0.027	24	22	24	46	26	DBA	N	C	2007	Yes
France	GIF-sur-YVETTE CEDEX	SOLEIL	3	2.75	354	500	3.74	0.037	24	21	22	43	13.8	DBA	Y	C	2006	Yes
India	Indore	INDUS-II	3	2.5	173	300	58	5.8	8	5	22	27	?	DBA	N	C	2005	Yes
Japan	Nishi-Harima, Hyogo	NEW SUBARU	3	1.5	119	500	67	6.7	6	4	4	8	26	DBA	N	C	2006	Yes
Japan	Tosu, Saga	Saga LS	3	1.4	75.6	300	15	0.15	8	6	14	20	29	DBA	N	C	2005	Yes
Jordan	Allan	SESAME	3	2.5	129	400	26	0.26	8	11	16	27	38	DBA	N	C	2009	Yes
Spain	Barcelona	ALBA	3	3	264	400	3.6	0.036	20	18	20	38	?	DBA	Y	D	2010	Yes
Sweden	Lund	MAX-III	3	0.7	36	300	14	1.4	8	7	8	15	75	DBA	N	C	2005	Yes
Armenia	Yerevan	CANDLE	3	3	216	350	8.4	0.084	16	13	16	29	22	DBA	N	C	2007	Partial[1]
China	Beijing	BLS	3	2.2	240.4	300	3.3	0.1	8	6	16	22	?	5BA	?	D	?	No
Germany	Hamburg	PETRA-III	3	6	2304	100	1	0.01	9[2]	9	0	9	40	DBA[2]	N	D	2009	Yes[2]
Japan	Sendai	TOHOKU LS	3	1.5	187	300	7.4	0.074	12	10	20	30	14.3	DBA	N	D	?	No
Japan	Kashiwa, Chiba	VSX	3	1	249	200	0.75	0.075	4	4	18	22	7.3	Racetrack	N	D	?	No
Japan	Okazaki, Aichi	SUPER SOR	3	1.8	280	500	8	0.08	14	12	14	26	13.3	DBA	Y	D	?	No
Japan	Ichihara, Chiba	NANOHANA	3	2	108	300	70	2.1	8	6	16	22	5000	DBA	N	D	?	No
Sweden	Lund	MAX-IV-3	3	3	287	500	0.9	0.009	12	11	24	35	?	7BA	Y	D	?	No
Sweden	Lund	MAX-IV-1.5	3	1.5	287	500	0.3	0.003	12	11	24	35	?	7BA	Y	D	?	No
Taiwan	Hsinchu	TLS-II	3	3	240	400	10	0.3	16	14	32	46	?	DBA	?	D	?	No
U.S.	Upton, NY	NSLS-II	3	3	630	500	0.5	0.005	24	21	24	45	12.8	TBA	Y	D	2013	No

1Armenian Government funded office building and land, U.S. funded design; still seeking full construction funding commitment. See http://www.cerncourier.com/main/article/44/5/15

[2]On May 23, 2005, the German Federal Government and the State of Hamburg signed a contrac[illegible] the construction of Petra-III. Construction to start in 2007.

International Benchmarking: 3rd Generation Synchrotrons Worldwide



Considering only beam ports on the 3rd generation sources, this shows that by 2009 the U.S. will be outnumbered by the rest of the world by 7:1 (123 beam ports in the U.S. versus 806 beam ports in the rest of the world).

Light Sources – Findings and Conclusions from Assessment Study

I. Light sources have proven to be indispensable for the study of materials structure and function. The number of users has increased by more than a factor of 30 since 1982 and by a factor of 2.5 since 1996, the year of the commissioning of the APS.

II. The light source accelerator complexes have high availability, dependability, and reliability, delivering more than 95% of scheduled beamtime to the beamports.

III. The 2005 study of utilization has shown:

a. There is unused capacity – about 179 beamlines are in service, but another 100 beamlines are not in service.

b. Beamline instrument technical quality varies considerably, but overall it is below par. Only 15% of in-service beamlines are at optimal quality; 47% need minor upgrades; 22% need moderate upgrade; and 16% need major upgrade.

c. Beamline staffing is less than 60% of optimal.

IV. Additional findings from the BES 2005 peer review of the light sources:

a. Accelerator staffing is thin at all of the light sources.

b. Accelerator and beamline components are starting to show the effects of age, even at the newer 3rd generation sources.

c. Maintenance and improvements (such as top-off mode) are critical to the future success.

d. Automation employed for macromolecular crystallography beamlines could help overall efficiency in other techniques.

e. Power cost increases could reduce significantly the number of operating hours at the light sources.

V. Additional findings from international benchmarking:

a. Considering only beam ports on the 3rd generation sources, by 2009 the U.S. will be outnumbered by the rest of the world by 7:1.

VI. Conclusions:

a. The U.S. light sources are at a critical point and will fall far below optimum capabilities without increased funding.

b. Emphasis should be given to upgrading infrastructure and instruments and to providing beamline staff to the world-class facilities.

c. Investments should be made for minor upgrades such as top-off mode at the world-class facilities.