1. Summary of Experimental Stations

1-1. Outline

There are 70 experimental stations on the PF storage ring and the PF-AR, as shown in Figs. 1 and 2. Two thirds of them are dedicated for research using hard X-rays, while the rest one third in the VUV and soft X-ray region. These experimental stations are summarized to designate research fields carried out on them in Tables 1 and 2, respectively, for the PF storage ring and PF-AR. Each experimental station has a different specification in optics and performance depending on the methodology performed. Tables 3 and 4 list the optics of hard X-ray and soft X-ray or VUV stations, respectively, together with the principal performances, such as energy range, spot size, photon flux and energy resolution.

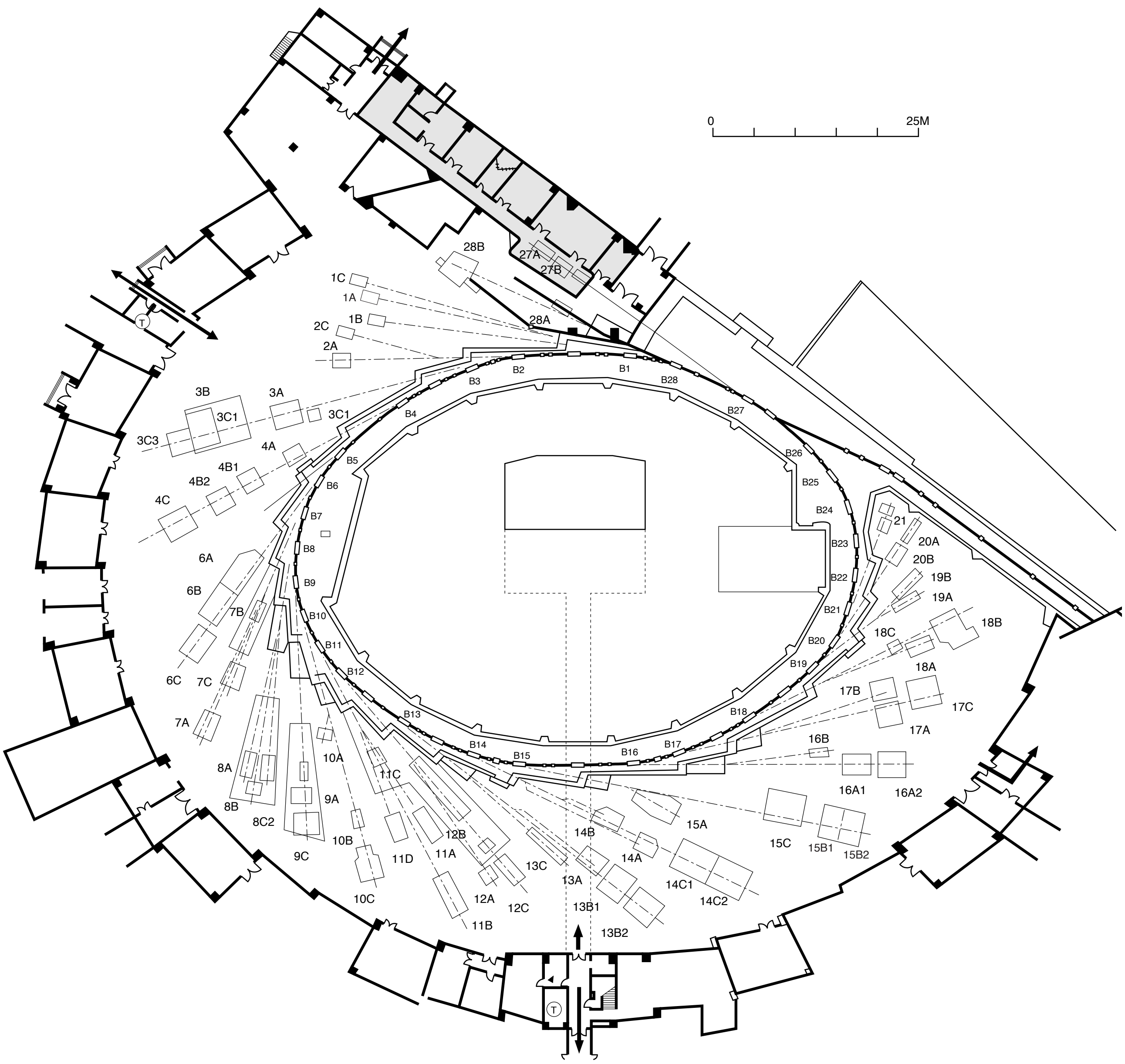

Figure 1.
Plan view of the PF experimental hall.

Table 1. List of Experimental Stations at the PF Storage Ring.

Experimental Station		Spokesperson
BL-1		
A	X-ray powder diffraction under extreme condition (under construction)	H.Nakao
B	X-ray powder diffraction under extreme condition	H.Nakao
C	VUV and soft X-ray photoelectron spectroscopy	T.Saitoh, M.Nakatake
BL-2	(Undulator)	
A	Soft X-ray spectroscopy	Y.Kitajima
C	Soft X-ray spectroscopy	A.Yagishita
BL-3		
A	X-ray diffraction and scattering	M.Tanaka
B	VUV and soft X-ray spectroscopy	Y.Azuma
C1	X-ray diffraction	H.Adachi, H.Kawata
C2	Characterization of X-ray optical elements	M.Ando
C3	X-ray magnetic Bragg scattering by means of white X-rays	H.Adachi, H.Kawata
BL-4		
A	Trace element analysis, X-ray microprobe	A.Iida
B1	Micro-crystal and -area structure analysis	K.Ohsumi
B2	Powder diffraction	M.Tanaka
C	X-ray diffraction and scattering	H.Nakao
BL-6		
A	Macromolecular crystallography	N.Igarashi
B	[SBSP]Macromolecular crystallography by Weissenberg camera	N.Sakabe[SBSP], M.Suzuki
C	[SBSP]Macromolecular crystallography by Weissenberg camera	N.Sakabe[SBSP], M.Suzuki
BL-7		
A	[RCS]Soft X-ray XAFS, XMCD, XPS	K.Amemiya[RCS], K.Ito
B	[RCS]Surface photochemical reaction and angle resolved photoelectron spectroscopy	K.Amemiya[RCS], K.Ito
C	X-ray spectroscopy and diffraction	T.Iwazumi
BL-8		
A	[Hitachi]Soft X-ray spectroscopy	K.Ogata[Hitachi], K.Mase
B	[Hitachi]EXAFS	K.Ogata[Hitachi], K.Mase
C	[Hitachi]X-ray tomography and X-ray microscopy	K.Ogata[Hitachi], K.Mase
BL-9		
A	XAFS	M.Nomura
C	X-ray versatile station	M.Nomura
BL-10		
A	X-ray diffraction/scattering	M.Tanaka
B	XAFS	N.Usami
C	Small-angle X-ray scattering of solution sample	K.Kobayashi
BL-11		
A	Soft X-ray spectroscopy	Y.Kitajima
B	Surface EXAFS, soft X-ray spectroscopy	Y.Kitajima
C	VUV spectroscopy (solid state)	M.Nakatake
D	VUV and soft X-ray photoelectron spectroscopy for solid	T.Saitoh
BL-12		
A	Characterization of VUV-SX optical elements, soft X-ray spectroscopy	A.Yagishita
B	VUV high-resolution spectroscopy	K.Ito
C	XAFS	M.Nomura

Experimental Station		Spokesperson
BL-13	(Multipole Wiggler/Undulator)	
A	Laser-heating high-pressure and high-temperature X-ray diffraction (DAC)	T.Kikegawa
B1	Surface-sensitive XAFS, X-ray diffraction	T.Kikegawa
B2	High-pressure and high-temperature X-ray diffraction	T.Kikegawa
C	Soft X-ray photoemission spectroscopy and XAFS	K.Mase
BL-14	(Vertical Wiggler)	
A	Crystal structure analysis, EXAFS	S.Kishimoto
B	High-precision X-ray optics	K.Hirano
C1	Medical applications and General purpose (X-ray)	K.Hyodo
C2	High-pressure and high-temperature X-ray diffraction (MAX-III)	T.Kikegawa
BL-15		
A	Small-angle X-ray scattering of muscle and alloys	M.Suzuki
B1	White X-ray topography and X-ray magnetic Bragg scattering	H.Kawata
B2	Surface and interface diffraction	H.Sugiyama, H.Kawata
C	High-resolution X-ray diffraction	K.Hirano
BL-16	(Multipole Wiggler/Undulator)	
A1	General purpose (X-ray)	H.Nakao
A2	X-ray diffraction and scattering	H.Nakao
B	Soft X-ray spectroscopy	J.Adachi
BL-17		
A	[Fujitsu]XAFS	N.Awaji[Fujitsu], A.Iida
B	[Fujitsu]Photochemical vapor deposition	N.Awaji[Fujitsu], A.Iida
C	[Fujitsu]Grazing incident X-ray diffraction, X-ray fluorescence analysis	N.Awaji[Fujitsu], A.Iida
BL-18		
A	[ISSP]Angle-resolved photoelectron spectroscopy of surfaces and interfaces	T.Kinoshita[ISSP], T.Saitoh
B	Macromolecular crystallography	M.Suzuki
C	High pressure X-ray powder diffraction (DAC)	T.Kikegawa
BL-19	(Revolver Undulator)	
A	[ISSP]Spin-resolved photoelectron spectroscopy (Mott detector)	T.Kinoshita[ISSP], T.Saitoh
B	[ISSP]Spin-resolved photoelectron spectroscopy (SPLEED)	S.Shin[ISSP], T.Saitoh
	[ISSP]Soft X-ray emission spectroscopy	
BL-20		
A	VUV spectroscopy	K.Ito
B	[ANBF]White and monochromatic beam general purpose X-ray station	G.Foran[ANBF], K.Ohsumi
BL-21	[Light Source Division]Beam position monitoring	M.Kobayashi[Light Source]
BL-27	(Beamline for experiments using radioisotopes)	
A	Radiation biology, soft X-ray photoelectron spectroscopy	K.Kobayashi
B	Radiation biology, XAFS, X-ray diffuse scattering	N.Usami
BL-28	(Elliptical Multipole Wiggler / Helical Undulator)	
A	VUV and soft X-ray spectroscopy with circularly polarized undulator radiation	T.Koide
B	Spectroscopy and scattering with circularly polarized X-rays	T.Iwazumi

SBSP Structural Biology Sakabe Project, Foundation for Advancement of International Science
RCS Research Center for Spectrochemistry, the University of Tokyo
ISSP Institute for Solid State Physics, the University of Tokyo
ANBF Australian National Beamline Facility

Table 2. List of Experimental Stations at the PF-AR.

Experimental Station		Spokesperson
AR-NE1	(Elliptical Multipole Wiggler / Helical Undulator)	
A1	High-resolution Compton and magnetic Compton scattering	H.Kawata
A2	Coronary Angiography	K.Hyodo
B	Spectroscopy with circularly polarized soft X-rays	T.Koide
AR-NE3	(Undulator)	
A	Nuclear resonant scattering	X.Zhang
AR-NE5		
A	Medical applications	K.Hyodo
B	Bunch-purity and beam-position monitoring	S.Kishimoto
C	High pressure and high temperature X-ray diffraction (MAX-80)	T.Kikegawa
AR-NE9		
B	[Accelerator Laboratory]Vacuum science and technology	K.Kanazawa[Acc.Lab.]
AR-NW2	(Undulator)	
A	XAFS/Dispersive XAFS (under construction)	M.Nomura
AR-NW12	(Undulator)	
A	Macromolecular crystallography (under construction)	N.Matsugaki

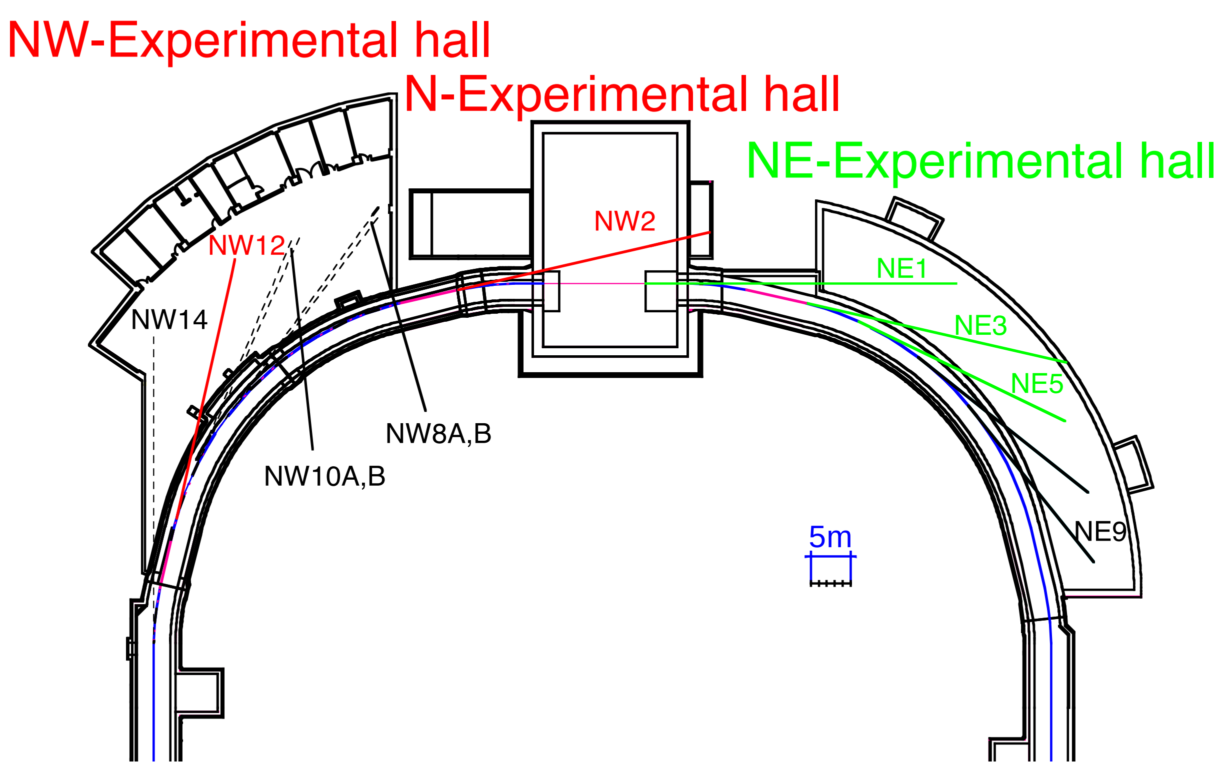

Figure 2.
Plan view of the beamlines in the PF-AR north-east, north, and north-west experimental halls.

Table 3. X-Ray Beamline Optics.

Branch Beamline	Horizontal Acceptance (mrad)	Type of Monochromator	Mirror	Photon Energy (keV)	Beam Size (H×V) (mm)	Photon Flux at Sample Position (/s)	Energy Resolution $(\Delta E/E)\times10^{-4}$	Reference
BL-1B	2	Flat Double Crystal Si(111)	Bent Cylinder	6 ~ 21	0.7×0.5	8×10^{10}/4mm^2 (8.3 keV, 300 mA)	~ 5	1
BL-3A	4	Double Crystal Si(111) Sagittal Focusing	Collimating Focusing Mirrors (Fused Quartz)	6 ~ 20	100×5 2×1		~ 2	2 - 4
BL-3C2	2	Double Crystal Si(111), Si(311)	None	4 ~ 20 6 ~ 34	5×2	1×10^{10} 2×10^{9}		
BL-3C3	2	Double Crystal Si(111)	None	5 ~ 30 or white	20×4 0.1×0.1			
BL-4A	6	Double Crystal Sagittal Focusing	None	4 ~ 20	50×4 4×1		~ 2	5
BL-4B1	4.5	Double Crystal Si(111)	None	4 ~ 35	50×5		~ 2	6
BL-4B2	4.5	Double Crystal Si(111)	Bent Cylinder	6 ~ 20	13×2		~2	7, 8
BL-4C	2	Flat Double Crystal Si (111)	Bent Cylinder	6 ~ 21	0.7×0.5		~5	9, 10
BL-6A	1.2	Bent Si(111) (α = 0°, 6.0°, 7.8°, 9.5°, 11.4°, 13.7°, 16.5°)	Bent Plane Fused Quartz	5 ~ 25	2.5×1			11
BL-6B	1	Bent Si(111)	Bent Plane Si Pt-coated		1.7×0.2			12
BL-6C	2	Bent Si (111)	Bent Plane Si Pt-coated					13
BL-7C	4	Double Crystal Si (111) Sagittal Focusing	Double Mirror Fused Quartz Focusing	4 ~ 20 (4 ~ 13)	5×1	1×10^{10}/6mm^2 (8 keV, 300 mA) (1×10^{11} when focused)	~ 2	14 - 16
BL-8C	5	Channel-Cut Si(220), Si(111), Si(400)	None	5 ~ 40	50×5	6×10^{8}/mm^2 (10 keV, 300 mA)	~2	
BL-9A	3	Double Crystal Si (111)	Collimating and Focusing Bent Conical Mirrors (Rh Coated) Double Flat Mirror (Rh/Ni Coated)	2.2 ~ 15	1×0.3	4×10^{11}(9 keV, 300 mA)	2	17, 18
BL-9C	3.5	Double Crystal Si(111)	Bent Cylinder Rh-coated Si	4 ~ 23 or white	1×1	5×10^{10}(9 keV, 300 mA)	~ 2	

Branch Beamline	Horizontal Acceptance (mrad)	Type of Monochromator	Mirror	Photon Energy (keV)	Beam Size (H×V) (mm)	Photon Flux at Sample Position (/s)	Energy Resolution $(\Delta E/E)\times10^{-4}$	Reference
BL-10A	1	Si(111), Si(311) Quartz(100), PG(002) Curved Si(111) (α~ 4°, 8°)	Plane Pt coated Fuzed Quartz	5 ~ 25	10×3		10 ~ 5	19
BL-10B	2	Channel-Cut Si(311)	None	6 ~ 30	5×1	1×10^{9}/7mm^2	1	
BL-10C	4	Double Crystal Si(111)	Bent Cylinder	4 ~ 10	1.2×0.2	~10^{11}/1.5mm^2 (8 keV, 400 mA)	2	
BL-12C	2	Double Crystal Si(111) Si(311)	Bent Cylinder	6 ~ 23	0.65×0.4	5×10^{10}/1mm^2 (8 keV, 300mA) w.Si(111)	~ 2	20
BL-13A	1	Double Crystal Si(111), Ge(111)	Cylinder Pt-coat Fused Quartz	30	0.045×0.032	5×10^{10}/1mm^2	~ 2	21
BL-13B1 B2	4	Double Crystal Si(111), Si(220) Sagittal Focusing	Bent Plane Fused Quartz	4 ~ 30	4×1		~ 2	22
BL-14A	1.28 (Vertical)	Double Crystal Si (111) Si (311) Si (553)	Bent Cylinder Pt-coated Fused Quartz	5.1 ~ 19.1 9.9 ~ 35.6 22.7 ~ 84.5	2×1 at focus 5×38		2	23
BL-14B	2.2 (Vertical)	Double Crystal Si(111),	None	10 ~ 57	5×14		2	
BL-14C1 C2	1.3 (Vertical)	Double Crystal Si(111), Si(220)	None	5 ~ 100 or white	6×35		2	24, 25
BL-15A	2	Bent Crystal Ge(111) (α = 8.0°)	Bent Plane, Fused Quartz Pt-coated	8.0 (fixed)	0.5×0.25	9×10^{10}/mm^2 (8.0 keV, 350 mA)	~ 10	26
BL-15B1 B2	2	Double Crystal Si (111)	Bent Cylinder	5 ~ 20 or white	0.6×0.4	10^{11}/1mm^2 (8.0keV, 350mA)	~ 2	
BL-15C	2	Double Crystal Si (111)	None	4 ~ 30	60×6			
BL-16A1 A2	1	Double Crystal Si(111) Sagittal Focusing	Bent Plane (Ph on Si) and Bent Plane (Rh on SiC)	4 ~ 25	1.2×0.5	~1×10^{13} (8.3 keV, 300 mA)	~ 1	27
BL-17A	4	Double Crystal Si(111)	None	5 ~ 13	100×10		~ 2	28
BL-17C	1	Double Crystal Si(111)	None	5 ~ 13	20×5		~ 2	29

Branch Beamline	Horizontal Acceptance (mrad)	Type of Monochromator	Mirror	Photon Energy (keV)	Beam Size (H×V) (mm)	Photon Flux at Sample Position (/s)	Energy Resolution $(\Delta E/E)\times10^{-4}$	Reference
BL-18B	2	Double Crystal Si(111) Si(220) Ge(111) Ge(220)	Bent Cylinder Fused Quartz, Pt-coated	6 ~ 30	0.6×0.4	1.1×10^{10} (12.4 keV, 300 mA) Si(111)	~ 2	30
BL-18C	1	Double Crystal Si(111)	Cylinder Fused Quartz, Pt-coated	6~25	0.07×0.04		~2	
BL-20B	2	Channel Cut Si(111) Double Crystal Sagittal focusing Si(111)	None	4 ~ 25	26×3		~ 2	31
BL-27B	4	Double Crystal Si(111)	None	4 ~ 20	100×6		~ 2	32
BL-28B	H: 4 V:0.2	Double Crystal Si(111) Si (220) InSb(111)	Pre-mirror Bent Cylinder Si Pt- & Ni-coated Post-mirror Bent Plane Fused Quartz Pt- & Ni-coated	2 ~ 10	2.0×0.2	3×10^{10} (9 keV, 300mA Si(220) Pc ~ 0.5)	~ 2 (Si(111))	33
AR-NE1A1	2	Double Bent Crystal Si(111) Si(400)		40 ~ 70 80 ~ 160	2×0.5	2×10^{13} (60 keV, 35mA)	8	34-36
AR-NE1A2	2	Asym. cut Single Crystal Si(311)		33 ~ 38	75×120 ~140	10^{10}(33 keV)	60	
AR-NE3	H:0.3 V:0.03	Double Crystal Si(111) High-resolution Monochromator Nuclear Monochro- mator of Single Crys- tal $^{57}Fe_2O_3$(777)		5 ~ 25 8 ~ 26 14.4	15×2	 1×10^{3} (14.4 keV)	1 5×10^{-3} 1×10^{-7}	37
AR-NE5A	10	Asym.Cut Single Crystal Si(311), Si(511) (α= 4° ~ 6°) Double Crystal Si (311), Si(111), Si(220)		20 ~ 60 20 ~ 100	150×80 100×3	5×10^{8} (33.2 keV)	60 2	38, 39
AR-NE5C	3	Double Crystal Si (111)	None	30 ~ 100 or white	60×5		5	40

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Table 4. VUV and Soft X-ray Beamline Optics.

Branch Beamline	Acceptance Hor. & Ver. (mrad)	Type of Monochromator	Grating Groove Density (l/mm)	Photon Energy (eV)	Beam Size (mm)	Typical Resolving Power (E/ΔE) and Photon Flux (/s)	Reference
BL-1C	5 3	Varied-Space Plane Grating	300 600 1200	20 ~ 60 40 ~ 120 80 ~ 240	1 × 1	1000 ~ 10000 10^{11} ~ 10^{9}	1
BL-2A Undulator	K = 0.5 ~ 2.2 λ_u = 6 cm	Double Crystal InSb (111), Si (111)	——	1740 ~ 5000	< 1ϕ	2000, 8000 10^{11}	2 - 5
BL-2C Undulator	K = 0.55 ~ 2.2 λ_u = 6 cm	Varied-Space Plane Grating	1000 2200	250 ~ 1400	0.9 × 0.1	5000 ~ 10000 10^{11} ~ 10^{10}	6-8
BL-3B	10 2	Grazing Incidence R = 24 m $\alpha+\beta$ = 165°	200 600 1800	10 ~ 280	< 2ϕ	200 ~ 3000 10^{12} ~ 10^{9}	9, 10
BL-7A (RCS)	6 1	Varied-Line-Space Plane Grating	150 300 650	50 ~ 1500	2.5 × 0.5	1000 ~ 9000 10^{12} ~ 10^{9}	
BL-7B (RCS)	6 4	1m Seya-Namioka	1200 2400	5 ~ 50	1 × 1	1000	11
BL-8A (Hitachi)	0.5 1	SX700 Plane Grating	1221	38 ~ 2300	5 × 1	2000 10^{10}	
BL-8B (Hitachi)	3 0.5	Double Crystal InSb (111), Si (311)	——	1700 ~ 14000	1.9 × 0.5	5000	12
BL-11A	5 1	Varied-Line-Space Plane Grating	300 800 1200	70 ~ 1900	2 × 1	500 ~ 5000 10^{12} ~ 10^{9}	13 - 16
BL-11B	4 0.6	Double Crystal InSb (111), Ge (111)	——	1760 ~ 3910	5 × 2	2000 10^{10}	4, 17, 18
BL-11C	4.8 3	1m Seya-Namioka	1200	4 ~ 35	~1ϕ	1000	19
BL-11D	4 2	Varied-deviation angle-type Grazing Incidence On-blaze Mount R_1 = 52.5 m R_3 = 22.5 m	2400	G_3 60~245 G_1 200~900	1 × 0.1	2000 10^{11}	20
BL-12A	2.2 0.34	Grazing Incidence R = 2 m α = 88°	1200	30 ~ 1000	2 × 3	1000 10^{9}	21
BL-12B	5 3.6	6.65 m Off-Plane Eagle	1200 4800	5 ~ 30	——	2.5 × 10^{5} 10^{4}	22 - 24
BL-13C Undulator	K = 0.3 ~ 4.2 λ_u = 18 cm	Grazing Incidence R = 50 m $\alpha+\beta$ = 173.2°	350 750	70 ~ 500 150 ~ 1000	5 × 1	1000 ~ 6000 10^{12} ~ 10^{10}	25, 26

Branch Beamline	Acceptance Hor. & Ver. (mrad)	Type of Monochromator	Grating Groove Density (l/mm)	Photon Energy (eV)	Beam Size (mm)	Typical Resolving Power (E/ΔE) and Photon Flux (/s)	Reference
BL-16B Undulator	K = 0.5 ~ 5.75 λ_u = 12 cm	Grazing Incidence R = 24 m $\alpha+\beta$ = 168.6°	400 900 2000	40 ~ 550	< 1φ	1000 ~ 10000 10^{12} ~ 10^{10}	27 - 29
BL-17B (Fujitsu)	8 1	Toroidal Mirror	____	____	10 × 1	____	____
BL-18A (ISSP)	2 2	Grazing Incidence R = 3 m $\alpha+\beta$ = 160° R = 6.65 m $\alpha+\beta$ = 167.5°	300 600 1200 500	15 ~ 150	< 1 φ	1000~2000 10^{11}~10^{9}	30
BL-19A Revolver Undulator (ISSP)	K = 1.0 ~ 9.0 λ_u = 16.4 cm K = 0.5 ~ 1.25 λ_u = 5 cm	Grazing Incidence R = 2 m $\alpha+\beta$ = 160° R = 4 m $\alpha+\beta$ = 170°	600 1200 600 1200	12 ~ 250	< 0.7φ	1000 10^{12}	31, 32
BL-19B Revolver Undulator (ISSP)	K = 0.5 ~ 2.5 λ_u = 7.2 cm K = 1.0 ~ 5.0 λ_u = 10 cm	Varied-space Plane Grating	800 2400	10 ~ 1200	< 0.5φ	400~4000 10^{12} ~10^{11}	32-34
BL-20A	28 5	3m Normal Incidence	1200 2400	5 ~ 40	2 × 1	300 ~ 30000 10^{12} ~ 10^{8}	35
BL-27A	5 0.5	Double Crystal InSb (111)	____	1800 ~ 4000		2000	36
BL-28A Helical Undulator	K_x = 0.23 ~ 3 K_y = 0.23 ~ 6 λ_u = 16 cm	Grazing Incidence R = 2 m $\alpha+\beta$ = 160° R = 4 m $\alpha+\beta$ = 170°	600 1200 600 1200	30 ~ 250	< 0.5 φ	1000 10^{10}	37
AR-NE1B Helical Undulator	Kx = 0.2 ~ 3 Ky = 0.2 ~ 6 λ_u = 16 cm	Grazing Incidence R = 10m β = 89°	1200 2400	250 ~ 1800	~ 0.8 × 0.2	1000~5000 10^{11} ~10^{9}	38, 39

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