6 Summary of Experimental Stations

About 54 experimental stations are operated at the PF storage ring, the PF-AR and the slow positron facility (SPF), as shown in Figs. 1, 2 and 3. 35 stations are dedicated to research using hard X-rays, 16 stations for studies in the VUV and soft X-ray energy regions, and 3 stations for studies using slow positrons. Tables 1, 2 and 3 summarize the areas of research carried out at the experimental stations at the PF storage ring, PF-AR and SPF. The specifications in terms of the optics and performance of each experimental station differ according to experimental requirements and methodology. Tables 4, 5 and 6 list the details of the optics of the hard X-ray stations, the soft X-ray / VUV stations and slow positron stations. The principal performance parameters, including energy range, energy resolution, beam-spot size, and photon flux at the sample position for PF and PF-AR, and energy range, pulse width, frequency, and positron flux for SPF are shown.

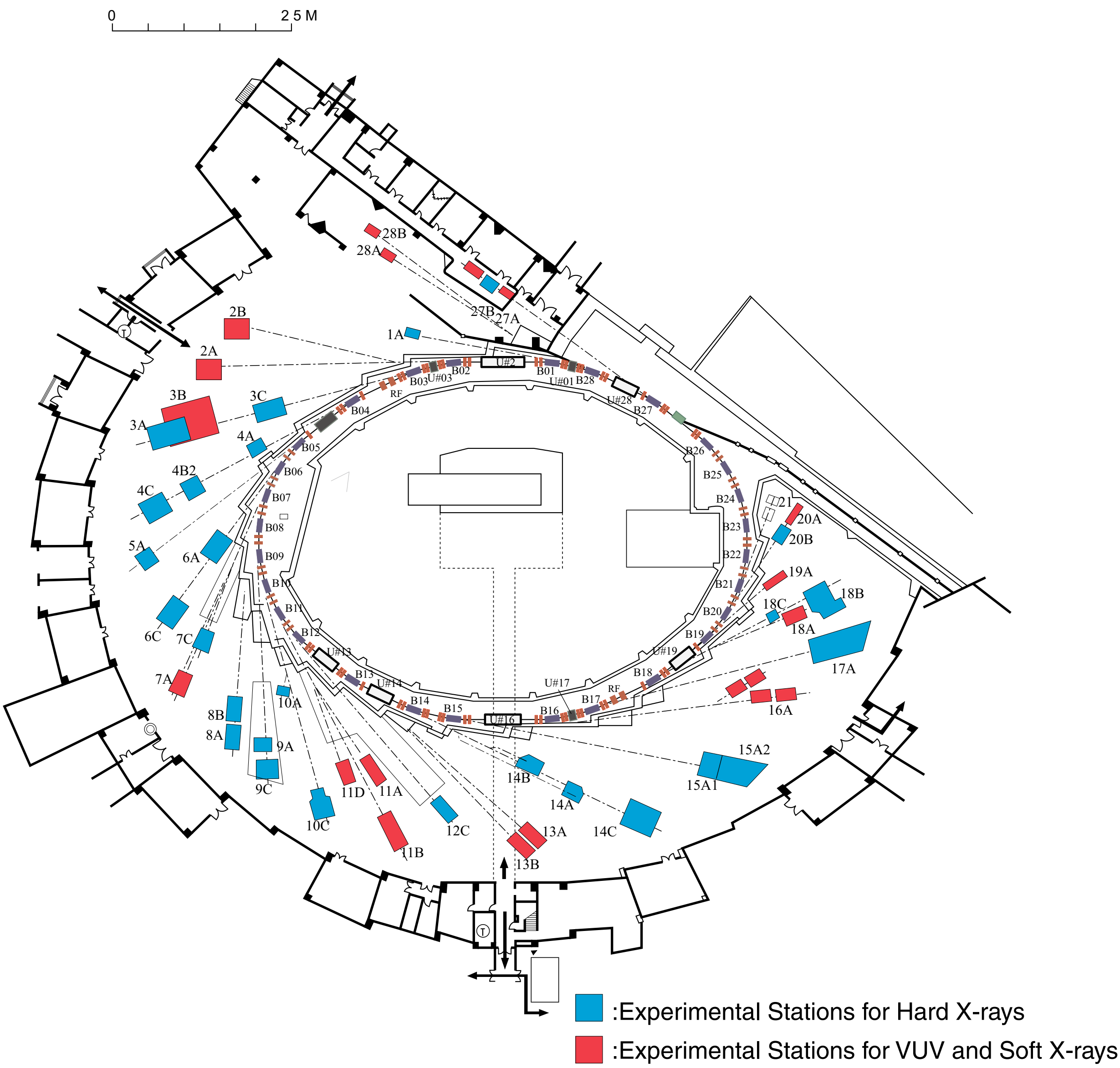

Figure 1: Plan view of the PF experimental hall, showing hard X-ray experimental stations (blue), and VUV and soft X-ray experimental stations (red).

Table 1: List of experimental stations at the PF storage ring.

Experimental Station		Person in Charge
BL-1	(Short Gap Undulator)	
A	Macromolecular crystallography	N. Matsugaki
BL-2	(Undulator)	
A*	Soft X-ray spectroscopy	K. Amemiya
B*	Soft X-ray spectroscopy	K. Amemiya
BL-3	(A: Short Gap Undulator)	
A	X-ray diffraction and scattering station for materials science	H. Nakao
B	VUV and soft X-ray spectroscopy(◊)	H. Kato [Hirosaki Univ.], A. Yagishita
C	Characterization of X-ray optical elements/White X-ray magnetic diffraction	K. Hirano
BL-4		
A	Trace element analysis, X-ray microprobe	A. Iida
B2	High resolution powder diffraction(♠)	T. Ida [Nagoya Inst. Tech.], H. Nakao
C	X-ray diffraction and scattering	Y. Yamasaki
BL-5	(Multipole Wiggler)	
A	Macromolecular crystallography	N. Matsugaki
BL-6		N. Igarashi
A	Small-angle X-ray scattering	S. Sasaki [Tokyo Inst. Tech.],
C	X-ray diffraction and scattering(♠)	H. Kawata
BL-7		
A	Soft X-ray spectroscopy(♦)	J. Okabayashi [RCS], K. Amemiya
C	X-ray spectroscopy and diffraction	H. Sugiyama
BL-8		
A	Weissenberg camera for powder/Single-crystal measurements under extreme conditions	R. Kumai
B	Weissenberg camera for powder/Single-crystal measurements under extreme conditions	R. Kumai
BL-9		
A	XAFS	H. Abe
C	XAFS	H. Abe
BL-10		
A	X-ray diffraction and scattering(♠)	A. Yoshiasa [Kumamoto Univ.], Y. Yamasaki
C	Small-angle X-ray scattering	N. Shimizu
BL-11		
A	Soft X-ray spectroscopy	Y. Kitajima
B	Surface EXAFS, soft X-ray spectroscopy	Y. Kitajima
D	Characterization of optical elements used in the VSX region	K. Mase
BL-12		
C	XAFS	H. Nitani

Experimental Station		Person in Charge
BL-13 A/B	(Undulator) Scanning transmission soft X-ray microscopy and microspectroscopy	 K. Mase
BL-14 A B C	(Vertical Wiggler) Crystal structure analysis and detector development High-precision X-ray optics Medical applications and general purpose (X-ray)	 S. Kishimoto K. Hirano K. Hyodo
BL-15 A1* A2*	 Semi-microbeam XAFS High brilliance small-angle X-ray scattering	 H. Nitani N. Shimizu
BL-16 A	(Variable Polarization Undulator) Soft X-ray spectroscopies with circular and linear polarization	 K. Amemiya
BL-17 A	(Short Gap Undulator) Macromolecular crystallography	 Y. Yamada
BL-18 A B* C	 Angle-resolved photoelectron spectroscopy of surfaces and interfaces(♦) Multipurpose monochromatic hard X-ray station(♦) High pressure X-ray powder diffraction (DAC)(♠)	 K. Yaji [ISSP], A. Yagishita S. Velaga [India, Saha Institute], R. Kumai S. Nakano [NIMS], T. Kikegawa
BL-19 A	(Revolver Undulator) Spin-resolved photoelectron spectroscopy (Mott detector)(♦)	 K. Yaji [ISSP], A. Yagishita
BL-20 A B	 VUV spectroscopy(◊) White & monochromatic X-ray topography and X-ray diffraction experiment	 N. Kouchi [Tokyo Inst. Tech], J. Adachi H. Sugiyama
BL-27 A B	(Beamline for experiments using radioisotopes) Radiation biology, soft X-ray photoelectron spectroscopy Radiation biology, XAFS, X-ray diffuse scattering	 N. Usami N. Usami
BL-28 A/B	(Elliptical / Helical Undulator) High-resolution VUV-SX beamline for angle-resolved photoemission High-resolution VUV-SX spectroscopy	 K. Ono

♠ User group operated beamline
♦ External beamline
◊ Operated by University
* Under reconstruction
RCS: Research Center for Spectrochemistry, the University of Tokyo
ISSP: Institute for Solid State Physics, the University of Tokyo

Table 2: List of experimental stations at the PF-AR.

Experimental Station		Person in Charge
AR-NE1 A	(Multipole Wiggler) Laser-heating high pressure X-ray diffraction and nuclear resonant scattering (DAC)	T. Kikegawa
AR-NE3 A	(Undulator) Macromolecular crystallography	Y. Yamada
AR-NE5 C	High pressure and high temperature X-ray diffraction (MAX-80)	T. Kikegawa
AR-NE7 A	High pressure and high temperature X-ray diffraction (MAX-III), X-ray imaging	K. Hyodo
AR-NW2 A	(Undulator) XAFS/Dispersive XAFS/Time-resolved-X-ray diffraction	H. Abe
AR-NW10 A	XAFS	H. Nitani
AR-NW12 A	(Undulator) Macromolecular crystallography	Y. Yamada
AR-NW14 A	(Undulator) Time-resolved X-ray diffraction, scattering and absorption	S. Nozawa

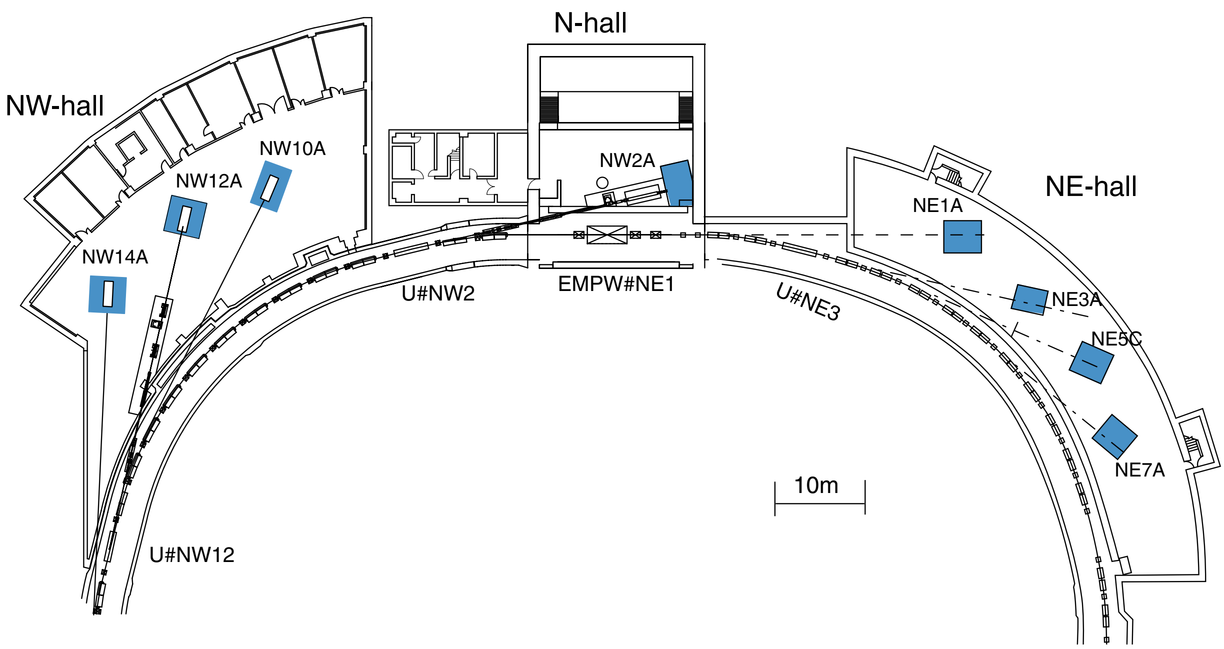

Figure 2: Plan view of beamlines in the PF-AR north-east, north, and north-west experimental halls.

Table 3: List of experimental stations at the Slow Positron Facility.

Experimental Station		Person in Charge
SPF-A3*	Total-reflection high-energy positron diffraction	T. Hyodo
SPF-B1	General purpose (Positronium negative ion)	T. Hyodo
SPF-B2	Positronium time-of-flight	T. Hyodo

* Under reconstruction

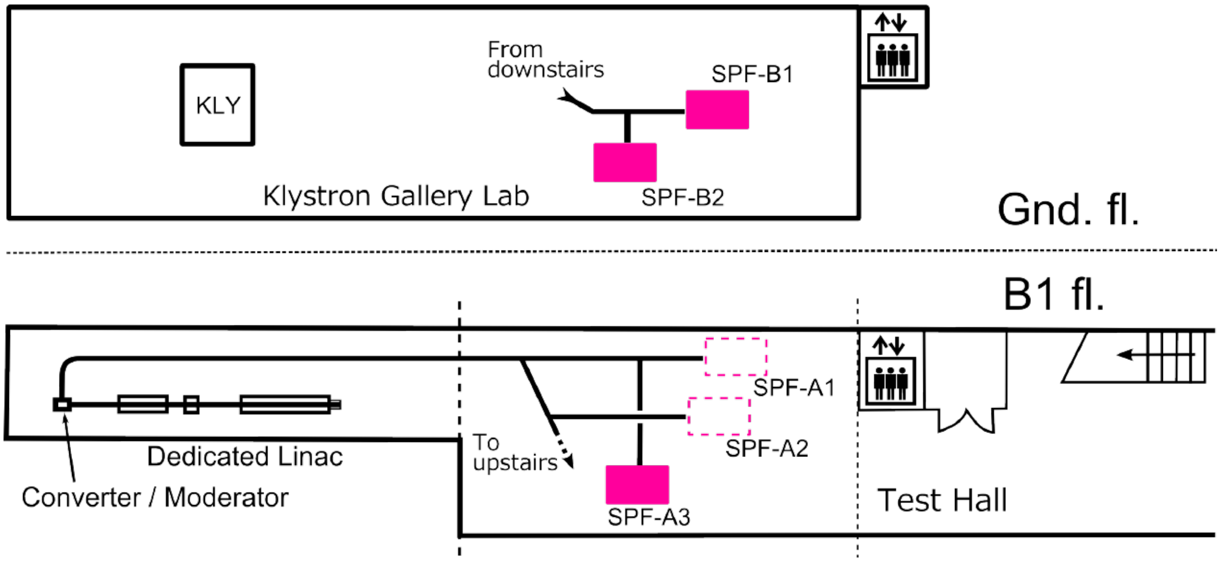

Figure 3: View of beamlines in the Slow Positron Facility.

Table 4: Specifications of 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 ($\Delta E/E$)×10⁻⁴	Reference
BL-1A	0.15	Channel-Cut Si(111) Liquid N_2 Cooling	Bimorph Si Rh-Coated Si Rh-Coated	3.7 ~ 4.5 11.2 ~ 12.9	0.05×0.01	4×10^{11}@11.2 keV (0.025×0.01mm²)	~2	
BL-3A	1	Flat Double Crystal Si(111)	Bent Cylinder	4 ~ 14	0.7×0.2	6×10^{12}	~5	1, 2
BL-3C	1.75	Double Crystal Si(111)	None	4 ~ 20 or white	20×6(mono) 0.1x0.1(white)		~2	
BL-4A	6	Double Crystal Si(111)	Vertical Focusing Mirror	4 ~ 20	50×4		~2	3
BL-4B2	4.5	Flat Double Crystal Si(111)	Bent Cylinder	6 ~ 20	13×2		~2	4, 5
BL-4C	2	Flat Double Crystal Si(111)	Bent Cylinder	5 ~ 19	0.7×0.5		~5	6, 7
BL-5A	0.5	Micro-Channel Double Crystal Si(111)	Bent Plane Si Rh-Coated Bent Cylinder Si Rh-Coated	6.5 ~ 17	1.2×0.4	3×10^{11} (0.2×0.2 mm²)	~2	
BL-6A	2	Bent Crystal Ge(111) (α = 8.0°)	Bent Plane ULE	8.3 (fixed)	0.5×0.2	1.0×10^{12}/mm² (Slit full-open)	~10	8
BL-6C	2	Flat Double Crystal Si(111)	Bent Cylinder	5 ~ 20 (~25 non-Focus)	0.5×0.3			
BL-7C	4	Double Crystal Si(111) Sagittal Focusing	Double Mirror Fused Quartz Focusing	4 ~ 20 (4 ~ 13)	5×1	1×10^{10}/6mm² (8 keV, 300 mA) (1×10^{11} when focused)	~2	9 - 11
BL-8A	2.22	Flat Double Crystal Si(111)	Bent Cylinder	5 ~ 19	0.82×0.52	3.2×10^{11} (12.4keV, 400mA)	~5	12
BL-8B	2.21	Flat Double Crystal Si(111)	Bent Cylinder	5 ~ 19	0.75×0.45	2.2×10^{11} (12.4keV, 400mA)	~5	12
BL-9A	3	Double Crystal Si (111)	Collimating and Focusing Bent Conical Mirrors Rh-Coated Double Flat Mirror Ni-Coated	2.1 ~ 15	0.5×0.3	6×10^{11}(7keV, 450 mA)	2	13, 14
BL-9C	3.5	Double Crystal Si(111)	Bent Cylinder Rh-Coated Si	4 ~ 23	0.8×0.6	1×10^{11}(8keV, 450 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 (ΔE/E)×10⁻⁴	Reference
BL-10A	1	Si(111), Si(311) Quartz(100) PG(002) Curved Si(111) (α~ 4°, 8°)	Plane Pt Coated Fused Quartz	5 ~ 25	10×3		10 ~5	15
BL-10C	2.1	Fix-Exit Double Crystal Si(111)	Bent Cylinder Rh-Coated	6 ~ 14	0.63×0.18	1.5 x 10^{11} (8 keV)	2	
BL-12C	2	Double Crystal Si(111)	Bent Cylinder Double Flat Mirror Ni-Coated	4 ~ 23	0.6×0.6	9×10^{10} (8 keV, 450mA)	~2	16
BL-14A	1.28 (Vertical)	Double Crystal Si (111) Si (311) Si (553)	Bent Cylinder Rh-Coated Fused Quartz	5.1 ~ 19.1 9.9 ~ 35.6 22.7 ~ 84.5	2×1 at focus 5×38		2	17
BL-14B	2.2 (Vertical)	Flat Double Crystal Si(111)	None	10 ~ 57	5×14		2	18
BL-14C	1.96 (Vertical)	Double Crystal Si(111), Si(220)	None	5 ~ 100 or white	6×70		2	19, 20
BL-15A1* BL-15A2*	0.2	Double Crystal Si(111) Liquid N_2 Cooling	Horizontal: Bent Plane Si Rh-Coated Bimorph Silica Rh-Coated Vertical: Benet Plane Si Rh-Coated Double Flat Si Ni-Coated	2.1 ~ 15	0.02×0.02 0.6×0.04	3.5×10^{11} (7.5 keV, 450mA)	~2	21
BL-17A	0.1 ~ 0.2	Double Crystal Si(111) Liquid N_2 Cooling	Bent Plane Si Rh-Coated Bent Plane Si Rh-Coated	6 ~ 13	0.25×0.04	10^{10} (12.4 keV, 450mA, 0.02×0.02mm^2)	~2	22 - 24
BL-18B [India, DST]	2	Double Crystal Si(111)	Plane and Bent Cylinder	6 ~ 20			~2	
BL-18C	1	Double Crystal Si(111)	Cylinder Fused Quartz Pt-Coated	6 ~ 25	0.07×0.04		~2	
BL-20B	1.6	Double Crystal Si(111)	None	5 ~ 25 or white	20×5	1×10^{11} (12 keV, 450mA)	~2	
BL-27B	4	Double Crystal Si(111)	None	4 ~ 20	100×6		~2	25

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 (∆E/E)×10⁻⁴	Reference
AR-NE1A	0.28	Micro-Channel Double Crystal Si(111), High-Resolution Channel Cut Si(4,2,2)&(12,2,2)	Bent Plane W/C Multilayer Coated Si	6 ~ 50	0.8×0.2	8×10^{11} ($0.2\times0.2mm^2$)	~2	
AR-NE3A	H:0.2 V:0.1	Double Crystal Si(111) Liquid N_2 Cooling	Pre-Mirror Bent Flat Si Rh-Coated Post-Mirror Bent Cylinder Fused Quartz Rh-Coated	6.5 ~ 17	0.8×0.2	8×10^{11} ($0.2\times0.2mm^2$)	~2	26, 27
AR-NE5C	3	Double Crystal Si(111)	None	30 ~ 100 or white	60×5		5	28
AR-NE7A	4	Double Crystal Si(111)		25 ~ 50 or white	80×3		5	
AR-NW2A	H:1.0 V:0.2	Double Crystal Si(111) Liquid N_2 Cooling	Bent Cylinder Si Rh-Coated Bent Flat Si Rh-Coated	5 ~ 25	0.6×0.2 ~10×0.06	6×10^{12} (12keV, 60mA)	~2	29 - 31
AR-NW10A	1.2	Si(311)	Pt-Coated Bent Cylinder Double Flat Mirror Rh-Coated	8 ~ 42	2.2×0.5	1×10^{10}(22 keV, 60mA)	~1	32
AR-NW12A	H:0.3 V:0.1	Double Crystal Si(111) Liquid N_2 Cooling	Pre-Mirror Bent Flat Si Rh-Coated Post-Mirror Bent Cylinder Si Rh-Coated	6.5 ~ 17	1.3×0.3	2×10^{11} ($0.2\times0.2\ mm^2$)	~2	33 - 35
AR-NW14A	H:0.3 V:0.1	Double Crystal Si(111) Liquid N_2 Cooling	Bent Cylinder Rh-Coated Bent Flat Rh-Coated	4.9 ~ 25	0.45×0.25	5×10^{12}	~2	36

* Under reconstruction
India DST: Department of Science & Technology

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Table 5: Specifications of VUV and soft X-ray beamline optics.

Beamline	Acceptance H × V (mrad) or Undulator Parameters	Type of Monochromator	Groove Density (ℓ/mm)	Energy Range (eV)	Beam Size H × V (mm)	Resolving Power (E/ΔE) Photon Flux (photons/s)	Reference
BL-2A* Undulator	ID02: K_{max} = 2.3, λ_u = 6 cm ID022: K_{max} = 5.0, λ_u = 16 cm	Variable-Included-Angle Varied-Line-Spacing Plane Grating	400 600 1000	30 ~ 2000	~0.5 × 0.1	2000 ~ 20000 10^{13} ~ 10^{11}	1
BL-2B* Undulator	ID02: K_{max} = 2.3, λ_u = 6 cm ID022: K_{max} = 5.0, λ_u = 16 cm	Variable-Included-Angle Varied-Line-Spacing Plane Grating Double Crystal InSb(111), Ge(111), Si(111)	400 600 1000	30 ~ 4000	~0.5 × 0.1	2000 ~ 20000 10^{13} ~ 10^{11}	1
BL-3B	10 × 2	Grazing Incidence R = 24 m $\alpha+\beta$ = 165° 1800	200 600	10 ~ 280	< 2ϕ	200 ~ 3000 10^{12} ~ 10^{9}	2, 3
BL-7A [RCS]	6 × 1	Varied-Line-Space Plane Grating	300 650	50 ~ 1300	2.5 × 0.5	1000 ~ 9000 10^{12} ~ 10^{9}	4
BL-11A	5 × 1	Varied-Line-Space Plane Grating	300 800 1200	70 ~ 1900	2 × 1	500 ~ 5000 10^{12} ~ 10^{9}	5 - 8
BL-11B	4 × 0.6	Double Crystal InSb (111), Si (111)		1724 ~ 5000	5 × 2	2000 10^{10}	9 - 11
BL-11D	4 × 2	Grazing Incidence Varied Deviation-Angle On-Blaze Mount R_1 = 52.5 m R_3 = 22.5 m	2400	60 ~ 245 200 ~ 900	1 × 0.1	2000 10^{11}	12, 13
BL-13A/B Undulator	K_{max} = 8 λ_u = 18 cm	Variable-Included-Angle Varied-Line-Spacing Plane Grating	300 1000	30 ~ 330 100 ~ 1600	~0.2 × 0.04	4000 ~ 10000 10^{12} ~ 10^{9}	14 - 16
BL-16A Undulator	K_{max} = 2.37 (Circular Polarization) K_{max} = 3.12 (Horizontal Linear Polarization) K_{max} = 1.98 (Vertical Linear Polarization) K_{max} = 1.73 (45-deg Linear Polarization) λ_u = 5.6 cm	Variable-Included-Angle Varied-Line-Spacing Plane Grating	500 1000	250 ~ 1500	~0.2 × 0.1	4000 ~ 8000 10^{12} ~ 10^{11}	17, 18
BL-18A [ISSP]	2 × 2	Grazing Incidence R = 3 m $\alpha+\beta$ = 160° R = 6.65 m $\alpha+\beta$ = 167.5°	300 600 1000	15 ~ 150	< 1ϕ	1000~2000 10^{11} ~10^{9}	19
BL-19A Revolver Undulator [ISSP]	[K = 1.0 ~ 9.0 λ_u = 16.4 cm K = 0.5 ~ 1.25 λ_u = 5 cm K = 0.5 ~ 2.5 λ_u = 7.2 cm K = 1.0 ~ 5.0 λ_u = 10 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}	20, 21

Beamline	Acceptance H × V (mrad) or Undulator Parameters	Type of Monochromator	Groove Density (ℓ/mm)	Energy Range (eV)	Beam Size H × V (mm)	Resolving Power (E/ΔE) Photon Flux (photons/s)	Reference
BL-20A	28 × 5	3m Normal Incidence	1200 2400	5 ~ 40	2 × 1	300 ~ 30000 10^{12} ~ 10^{8}	22
BL-27A	5 × 0.5	Double Crystal InSb (111)		1800 ~ 4000		2000	23
BL-28A/B Helical Undulator	K_x = 0.23 ~ 3 K_y = 0.23 ~ 6 K_y = 0.23 ~ 6	Varied-Line-Space Plane Grating	400	30 ~ 300	0.15 × 0.05	30000 10^{12}	1

* Under reconstruction
RCS: Research Center for Spectrochemistry, the University of Tokyo
ISSP: Institute for Solid State Physics, the University of Tokyo

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Table 6: Specifications of the beamlines at Slow Positron Facility.

Beamline	Beam Energy	Pulse Width	Frequency	Intensity	Reference
SPF-A3*	100eV - 35keV	1µs	≤ 50Hz	5x10^{7} e+/s (5x10^{6} e+/s after brightness enhancement)	3,4
SPF-B1	100eV - 35keV	1-10ns	≤ 50Hz	5x10^{6} e+/s	1,2,3,4
SPF-B2	100eV - 35keV	1-10ns	≤ 50Hz	5x10^{6} e+/s	5,6

* Under reconstruction

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