1 Outline of the Accelerators

The Photon Factory manages two storage rings as light sources: the 2.5-GeV PF and the 6.5-GeV PF-AR. The 2.5-GeV ring belongs to the Photon Factory, and continues to be operated by the Light Source Division of the PF. In contrast, the PF-AR is operated by the KEK Accelerator Laboratory for the historical reason that it was constructed as a booster synchrotron for the TRISTAN collider for particle physics, and was only used as an X-ray source parasitically. The two rings are provided with electron beams by the KEK linear accelerator. The 2.5-GeV injection energy of the PF ring is equal to its operation energy (full-energy injection), whereas it is necessary to ramp the energy of the PF-AR from its injection energy of 3 GeV to its operation energy of 6.5 GeV. Table 1 shows the machine parameters of the two rings. Figure 1 displays the spectral distribution of synchrotron radiation emitted from bending sections and from insertion devices. The calculated spectral characteristics are listed in Table 2. The PF ring underwent heavy modifications for the purpose of producing several new straight sections for insertion devices during the Straight-Section Upgrade Project that was carried out from March to September 2005. However, to preserve the optical parameters, specifications and arrangements of the existing beamlines, the machine parameters are almost unchanged.

Throughout FY2005 the PF ring was predominantly operated in multi-bunch mode at 2.5 GeV, with some operation time dedicated to single-bunch mode at 2.5 GeV and multi-bunch mode at 3 GeV. On the other hand, PF-AR was mostly operated in single-bunch mode at 6.5 GeV, with a special operation mode at 5 GeV exclusively for medical applications being used nine times in FY2005.

Table 1 Principal beam parameters of the PF Ring and PF-AR.

	PF	PF-AR
Energy	2.5 GeV (3 GeV)	6.5 GeV (5 GeV)
Natural emittance	34.6 nm·rad	293 nm·rad
Circumference	187 m	377 m
RF frequency	500.1 MHz	508.6 MHz
Bending radius	8.66 m	23.2 m
Energy loss per turn	0.4 MeV	6.66 MeV
Damping time		
Vertical	7.8 ms	2.5 ms
Longitudinal	3.9 ms	1.2 ms
Natural bunch length	10 mm	18.6 mm
Momentum compaction factor	0.00644	0.0129
Natural chromaticity		
Horizontal	–12.9	−14.3
Vertical	−17.3	−13.1
Stored current (initial values)	450 mA	55 mA (70 mA*)
Number of bunches	280	1
Beam lifetime	30-40** hr (at 450 mA)	15 hr (at 60 mA)

* Two-bunch operation at 5 GeV for medical applications.
**The lifetime has not recoverd after the renewal of the vacuum components.

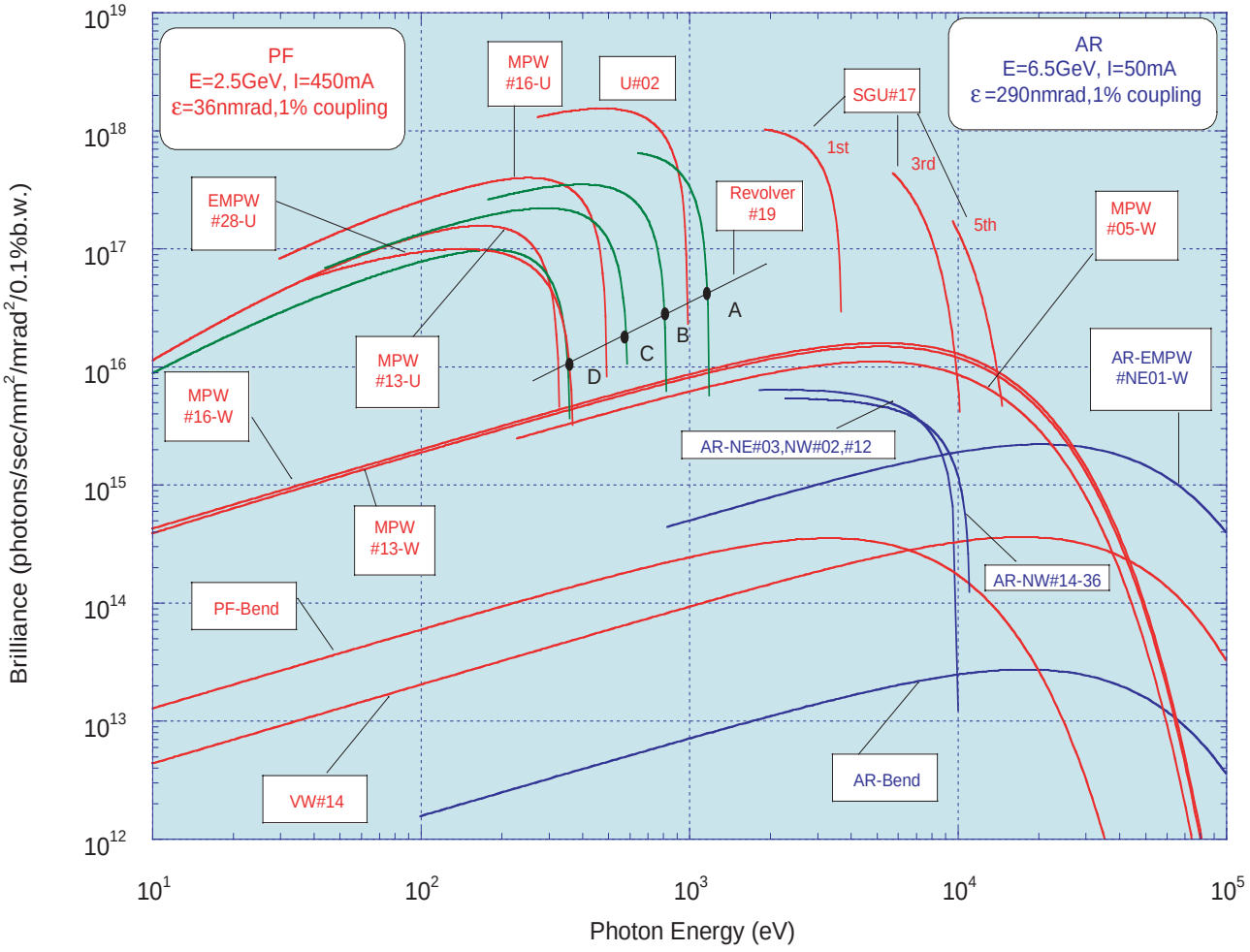

Figure 1
Synchrotron radiation spectra available at the PF Storage Ring (2.5 GeV) and the PF-AR (6.5 GeV). Brilliance of radiation vs. photon energy for the insertion devices (U#02, MPW#05, MPW#13, VW#14, MPW#16, SGU#17, Revolver#19 and EMPW#28) and bending magnets (PF-Bend) of the PF Storage Ring, and for the insertion devices (EMPW#NE1, U#NE03, U#NW02, U#NW12 and U#NW14-36) and the bending magnets (AR-Bend) of the PF-AR. The name of each source is assigned in Table 2. Several insertion devices have both undulator and wiggler modes, which are denoted by U and W, respectively (the undulator mode of MPW#05 and AR-EMPW#NE01 are not shown). The spectral curve of each undulator (or undulator mode of multipole wiggler) is a locus of the peak of the first harmonic within the allowance range of *K* parameter. Spectra of Revolver#19 are shown for four kinds of period. Note that not the first harmonic but the third or fifth harmonic is used for X-ray experiments at AR-NE3, AR-NW2 and AR-NW12 beamlines.

Table 2 Insertion devices.

Name	*E*/*I*	λ_u	*N*	*L*	$G_y(G_x)$	$B_y(B_x)$	Type of magnet	σ_x	σ_y	$\sigma_{x'}$	$\sigma_{y'}$	$K_y(K_x)$	$\varepsilon_1/\varepsilon_c$	*D*	*B*	*P*
	GeV/mA	cm		m	cm	T		mm	mm	mrad	mrad		keV			kW
PF Storage Ring	2.5/450															
Bend								0.41	0.059	0.178	0.012		4	5.38×10^{13}	3.48×10^{14}	
U#02		6	60	3.6	2.8	0.4	H(NdFeB)	0.65	0.042	0.054	0.008	2.3		2.73×10^{17}	1.55×10^{18}	1.07
MPW#05-W		12	21	2.5	2.64	1.4	H(NdFeB)	0.71	0.045	0.078	0.009	16	5.9	2.22×10^{15}	1.10×10^{16}	8.83
MPW#13-W		18	13	2.5	2.71	1.5	H(NdFeB)	0.74	0.02	0.094	0.019	25	6.2	1.45×10^{13}	1.47×10^{16}	9.73
MPW#13-U												2		1.70×10^{16}	1.57×10^{17}	0.06
VW#14					5	5	S.C.	0.53	0.045	0.128	0.008		20.8	5.42×10^{13}	3.59×10^{14}	
MPW#16-W		12	26	3.12			H(NdFeB)	0.654	0.042	0.055	0.008	16.8	6.2	2.76×10^{15}	1.58×10^{16}	12.2
MPW#16-U												2		7.13×10^{16}	4.00×10^{17}	0.17
SGU#17		1.6	29	3.6	2.8	0.92	P(NdFeB)	0.6	0.012	0.088	0.029	1.37		7.88×10^{15}	1.71×10^{17}	0.69
Revolver#19		5	46	2.3	3.0	0.28	H(NdFeB)	0.7	0.045	0.078	0.009	1.3		1.31×10^{17}	6.48×10^{17}	0.31
		7.2	32			0.4	H(NdFeB)					2.7		7.17×10^{16}	3.52×10^{17}	0.63
		10	23			0.54	H(NdFeB)					5		4.53×10^{16}	2.22×10^{17}	1.15
		16.4	14			0.62	P(NdFeB)					9.5		2.02×10^{16}	9.81×10^{16}	1.52
EMPW#28-U		16	12	1.92	3(11)		P(NdFeB)	0.53	0.045	0.127	0.008	3(3)		1.55×10^{16}	1.00×10^{16}	0.26
PF-AR	6.5/50															
Bend								1	0.2	0.593	0.036		26	3.25×10^{13}	2.59×10^{13}	
EMPW#NE1W		16	21	3.36	3(11)	1(0.2)	P(NdFeB)	1.07	1.07	0.268	0.032	15(3)	28(90%)	1.53×10^{15}	2.12×10^{15}	4.6
EMPW#NE1U												3(3)		3.41×10^{15}	4.70×10^{15}	0.35
U#NE3		4	90	3.6	1	0.8	P(NdFeB)	1.57	0.17	0.312	0.029	3		1.08×10^{16}	6.39×10^{15}	3.09
U#NW2		4	90	3.6	1	0.8	P(NdFeB)	1.57	0.17	0.312	0.029	3		1.08×10^{16}	6.39×10^{15}	3.09
U#NW12		4	95	3.8	1	0.8	P(NdFeB)	1.57	0.17	0.312	0.029	3		1.08×10^{16}	6.39×10^{15}	3.26
U#NW14-36		3.6	79	2.8	1	0.8	P(NdFeB)	1.35	0.14	0.338	0.036	2.8		6.41×10^{15}	5.41×10^{15}	2.6

Calculated spectral performance of the bend source and all the insertion devices at the PF Storage Ring (2.5 GeV, 450 mA) and the PF-AR (6.5 GeV, 50 mA). λ_u: period length, *N*: number of the periods, *L*: length of undulator or wiggler, $G_y(G_x)$: minimum vertical (horizontal) gap height, $B_y(B_x)$: maximum vertical (horizontal) magnetic field, Type of magnet, H: hybrid configuration, S.C.: superconducting magnet, σ_x,σ_y: horizontal or vertical beam size, $\sigma_{x'}$,$\sigma_{y'}$: horizontal or vertical beam divergence, $K_y(K_x)$: vertical (horizontal) deflection parameter, *D*: photon flux density (photons/sec/mrad^2/0.1%b.w.), *B*: brilliance (photons/sec/mm^2/mrad^2/0.1%b.w.), P_T: total radiated power. Different operating modes of undulator and wiggler are denoted by -U and -W, respectively.