2 3-GeV ERL Design

The ERL-based light source consists of a 3-GeV ERL and a 6-7 GeV XFEL-O. The 3-GeV ERL provides super-bright and/or ultra-short synchrotron radiation (SR) in the vacuum ultra-violet (VUV) to hard X-ray range, and the 6-7 GeV XFEL-O provides fully coherent radiation. In the XFEL-O operation, an electron beam is accelerated twice by the superconducting main linac of the ERL without energy recovery and fed to the XFEL-O after acceleration up to 6 GeV (or 7 GeV with an upgrade in the main linac). Typical operational modes and their parameters of the ERL-based light source are given in Table 1.

The lattice and optics design of the 3-GeV ERL was started [1, 2]. In the design, the injection energy is assumed to be 10 MeV. The main linac consists of more than 200 superconducting (SC) 9-cell cavities to accelerate the electron beam up to 3 GeV with a moderate accelerating gradient of 15 MV/m or less, which can suppress harmful field emission from the cavities. Quadrupole triplets are placed at every eight SC cavities for focusing. The optics of the main linac is mirror-symmetric for acceleration and deceleration and designed so that the betatron function is well suppressed for achieving a high BBU threshold current. The return loop of the 3-GeV ERL has 28 TBA (Triple Bend Achromat) cells with 22 × 6-m and 6 × 30-m long straight sections for insertion devices. The lattice and optics of these TBA cells are shown in Figs. 1 and 2. The bending radius of the bending magnet is sufficiently long to suppress the incoherent SR effects. Figure 3 shows the preliminary result of the optical functions for the main linac and the return loop of the 3-GeV ERL. In this optics, the emittance growth and energy spread increase due to incoherent and coherent SR are negligibly small for both Ultimate and XFEL-O modes. Figure 4 shows the tentative layout of the ERL light source in the KEK Tsukuba campus.

Figure 5 shows examples of the calculated spectral brightness for VUV-SX (soft X-ray) and X-ray undulators [3]. As shown in this figure, the 3-GeV ERL can provide undulator radiation with the maximum spectral brightness of 10^{22} – 10^{23} phs/s/mm^2/mrad^2/0.1%b.w. The 6-7 GeV XFEL-O generates spatially and temporally coherent X-rays with the brightness of about 10^{26} phs/s/mm^2/mrad^2/0.1%b.w. [4]. For future development, a 300-m long straight section is reserved in the middle of the return loop. This section has major potential for (1) EEHG (Echo-Enabled Harmonic Generation) including attosecond pulse generation [5, 6], (2) 3-GeV XFEL-O using the higher harmonics [7], (3) a very long undulator with spectral brightness of up to 10^{23} – 10^{24} phs/s/mm^2/mrad^2/0.1%b.w. and so on.

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Table 1 Typical operational modes and their parameters for the ERL-based light source.

	HC[†1]	HF[†2]	UL[†3]	US[†4]	XFEL-O
Beam energy	3 GeV				6-7 GeV
Beam current	10 mA	100 mA	100 mA	77 μA	20 μA
Bunch charge	7.7 pC	77 pC	77 pC	77 pC	20 pC
Repetition rate	1.3 GHz	1.3 GHz	1.3 GHz	1 MHz	1 MHz
Norm. emittance	0.1 mm· mrad	1.0 mm· mrad	0.1 mm· mrad	-	0.2 mm· mrad
Emittance	17 pm· rad	170 pm· rad	17 pm· rad		15 pm· rad
Energy spread	2×10^{-4}	2×10^{-4}	2×10^{-4}	-	5×10^{-5}
Bunch length	2 ps	2 ps	2 ps	< 100 fs	1 ps

[†1] HC: High Coherence mode, [†2] HF: High Flux mode, [†3] UL: Ultimate mode, [†4] US: Ultra-Short Pulse mode

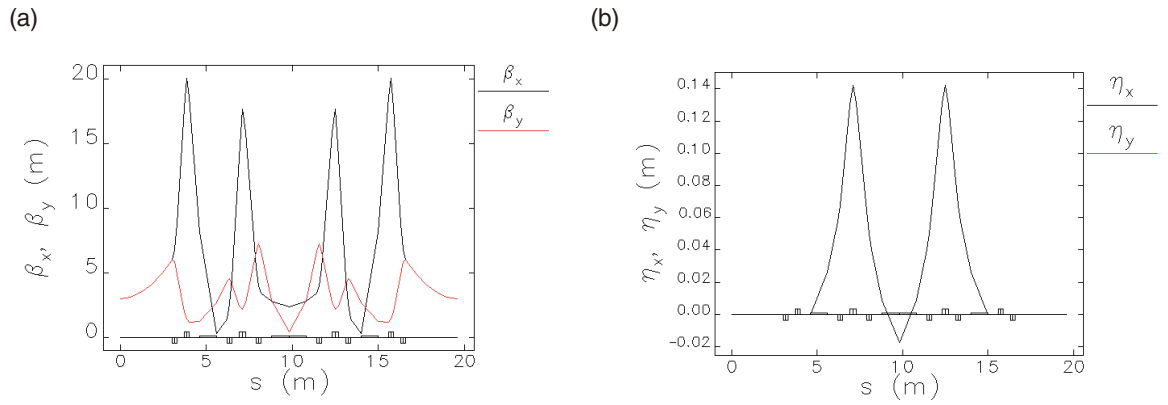

Figure 1
Betatron (a) and dispersion (b) functions of the TBA cell with a 6-m straight section in the return loop for the 3-GeV ERL.

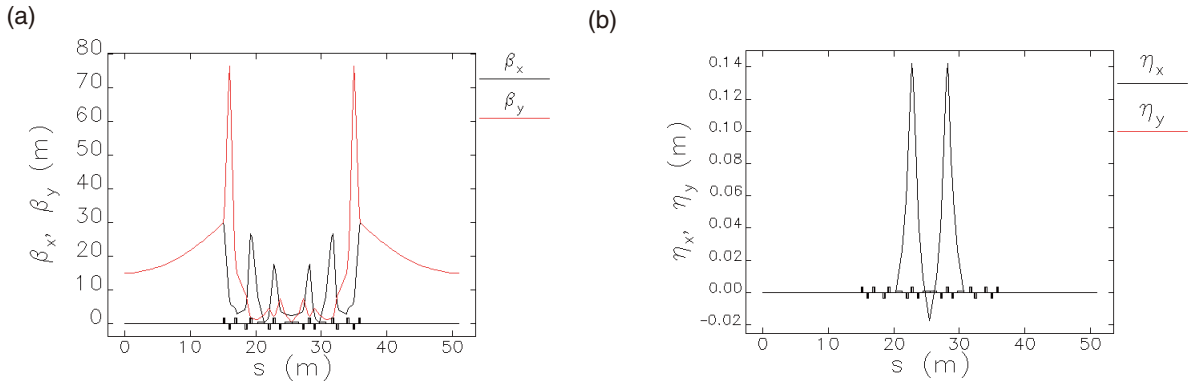

Figure 2
Betatron (a) and dispersion (b) functions of the TBA cell with a 30-m straight section in the return loop for the 3-GeV ERL.

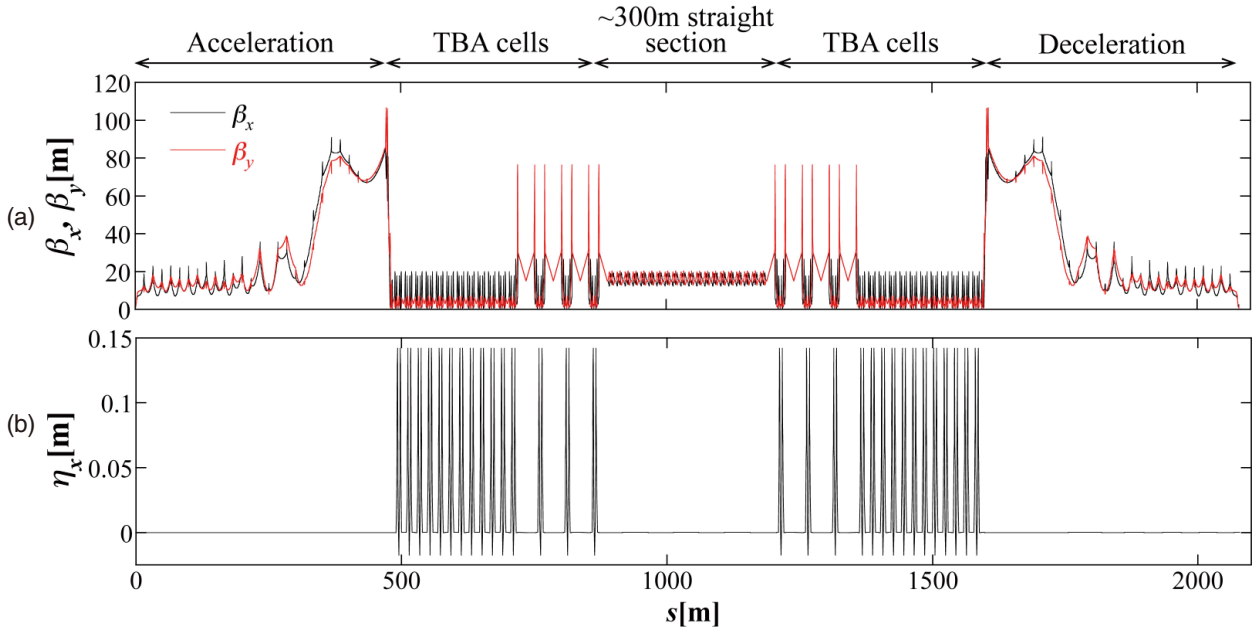

Figure 3
Betatron (a) and dispersion (b) functions of the main linac and the return loop for the 3-GeV ERL.

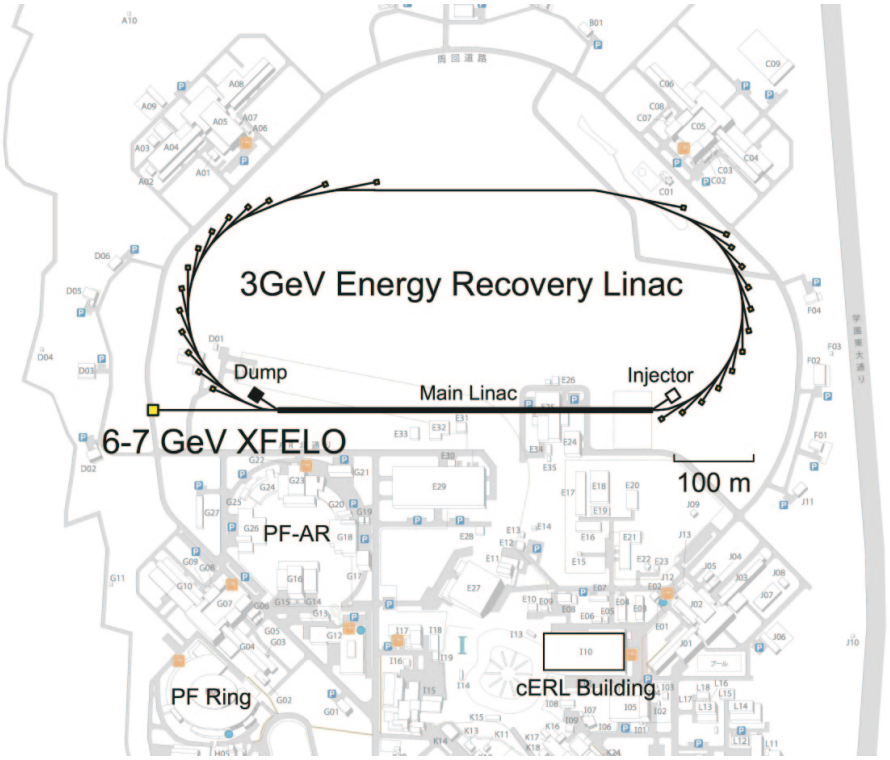

Figure 4
Tentative layout of the ERL-based light source at KEK Tsukuba campus

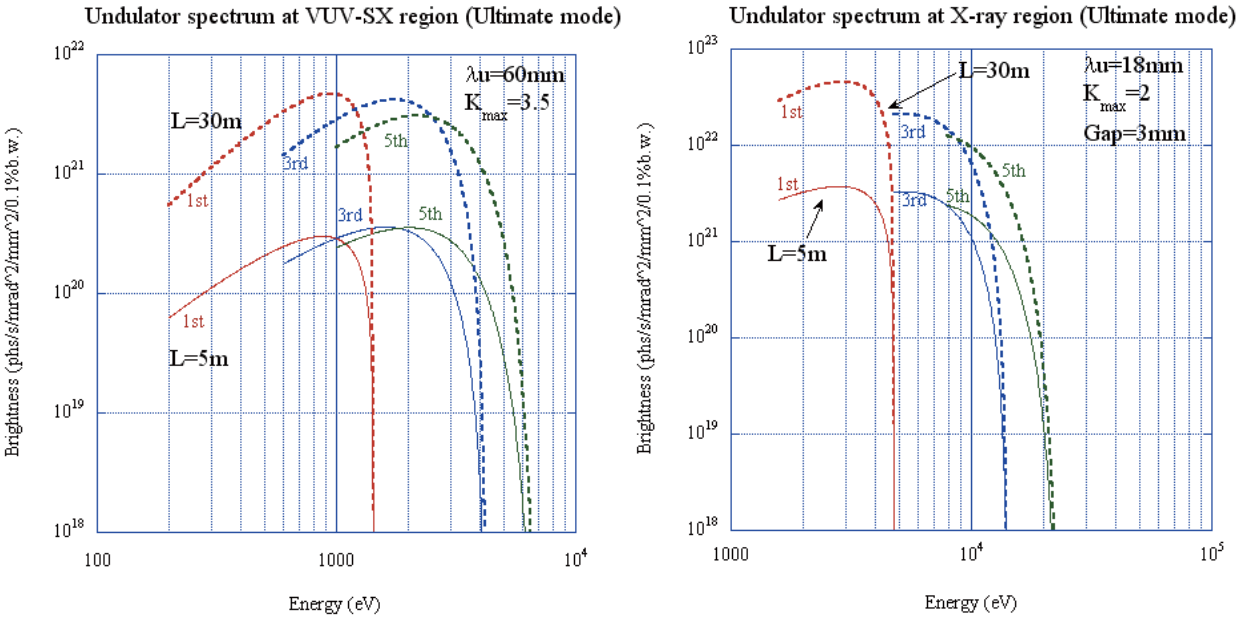

Figure 5
Examples of calculated spectral brightness for VUV-SX and X-ray undulators.