PRELIMINARY FEL SIMULATION STUDY FOR PAL XFEL

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Abstract

Pohang Accelerator Laboratory X-ray Free Electron Laser (PAL XFEL) will provide X-ray FEL radiation in a range of 0.1 and 10nm with five undulator beamlines. A undulator section for hard X-ray is designed for 0.1nm SASE FEL. We present FEL simulation study by using GENESIS.

INTRODUCTION

Pohang Accelerator Laboratory X-ray Free Electron Laser (PAL XFEL) will generate X-ray FEL radiation in a range of 0.1 and 10nm in five undulator beamlines [1]. It consists of a photocathode RF gun, a 10-GeV linac with S-band and undulators. A major goal is a hard X-ray with wavelength of 0.1nm by Self-Amplified Stimulated Emission (SASE). The lasing performance in the steady-state and the time-dependent model is investigated by tracking simulation, GENESIS [2]. Tapering is considered. The main parameters for a hard X-ray generation are listed in Table 1.

Table 1: PAL XFEL parameter for 0.1nm X-ray

Electron energy	10 GeV
Charge	200 pC
Peak current	3 kA
Emittance	0.5 umrad
Energy spread	10^{-4}
Undulator period	24.4 mm
Undulator parameter K	2.0683
Beta function	18 m

UNDULATOR LATTICE

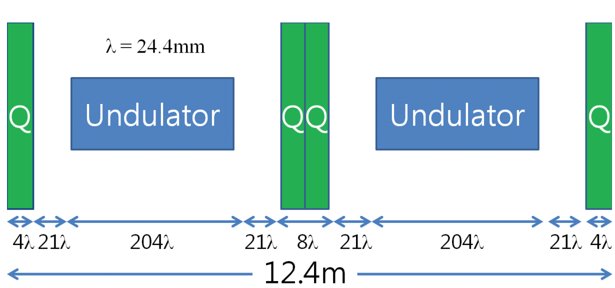

Figure 1: Schematic layout of undulator and FODO cell for simulation.

The saturation power and length are affected by the averaged beta-function. A symmetric FODO configuration can be adopted in the undulator section. The length of half-cell is 6.2 m and the phase advance is 45 degrees. The beta functions at quadrupoles are 24.1m and 10.9m.

SASE SIMULATION

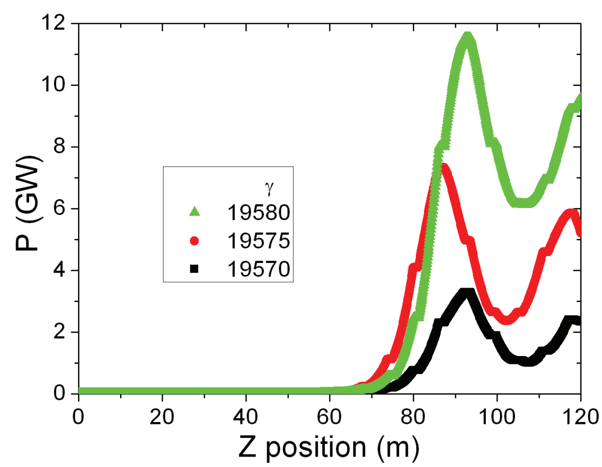

Figure 2: SASE lasing in steady-state with various energy.

The lasing performances are studied by code GENESIS. At first, the steady-state simulation was performed at 0.1 nm wavelength with the input condition of electron beam 10 GeV, charge 200 pC, normalized emittance 0.5 umrad and 3 kA beam current. The saturation power of 13.9 GW and length 53.7 m are expected by Ming Xie's formula.

Figure 2 shows the saturation power and length along the longitudinal coordinate. SASE radiation at 0.1 nm can be saturated at 75 m with 7.5 GW while12 GW power is obtained at 92 m with higher beam energy. These are longer length and weaker power due to space for quadrupoles and diagnositics.

Figure 3 shows slice properties of a beam profile for time dependent simulation. This beam profile satisfies the requirements except the beam current. Some required values are marked as red line. While the beam current is smaller than the target value 3kA in most parts, the normalized transverse emittances are slightly lower than the requirements and the energy spread is acceptable. The beam energy was selected by scan-test and one of the best cases is shown in Fig. 3. The energy of the center slice is higher than the theoretical value by 8 in gamma unit.

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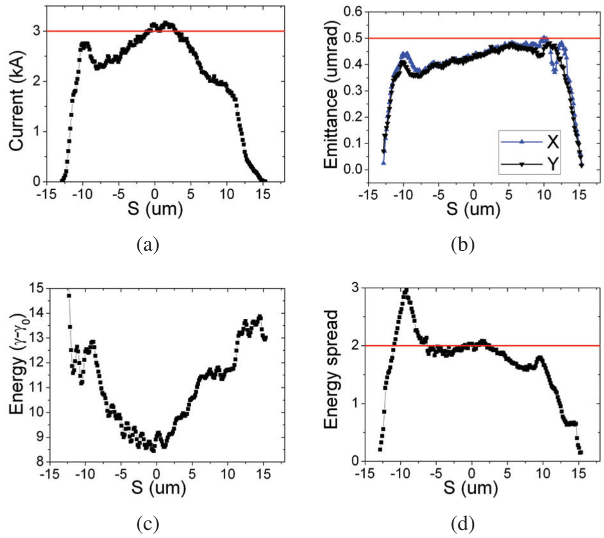

Figure 3: Slice properties of input beamfile for time-dependent simulation. (a) Beam current is smaller than target value, (b) normalized transverse emittances are slightly lower than requirements, (c) energy is selected by scan-test and (d) energy spread is acceptable.

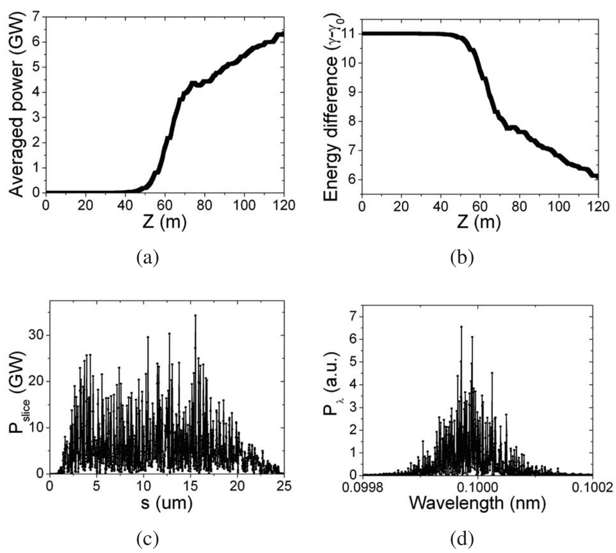

Figure 4: An example of time-dependent simulation. (a) radiation power is saturated at 75m and slowly growing, (b) averaged energy is reduced with lasing, (c) peak power reaches 30GW while averaged power is 4.5GW at 75m and (d) radiation wavelength is centered at 0.1nm with 3×10^{-4} width.

In a time-dependent simulation, SASE lasing is weaker than the steady-state calculation by various effects as shown in Fig. 4. The averaged radiation power over whole range is saturated as 4.5 GW at 75 m in Fig. 4(a), and the electron energy is dropped as the opposite direction in Fig. 4(b). The radiation wavelength is 0.1 nm with 3×10^{-4} width.

TAPERING

As the radiation increases, the beam energy decreases and the required undulator strength to generate X-ray at the same wavelength. Therefore undulator gap is opened to extend the resonance region for higher power. Figure 5 is steady-state simulation that the tapering starts from 60 m and quadratically reduced 0-0.6% at 120 m. In time-dependent simulation, the optimal condition is 0.3% tapering from 40 m to 120 m as shown in Fig. 6.

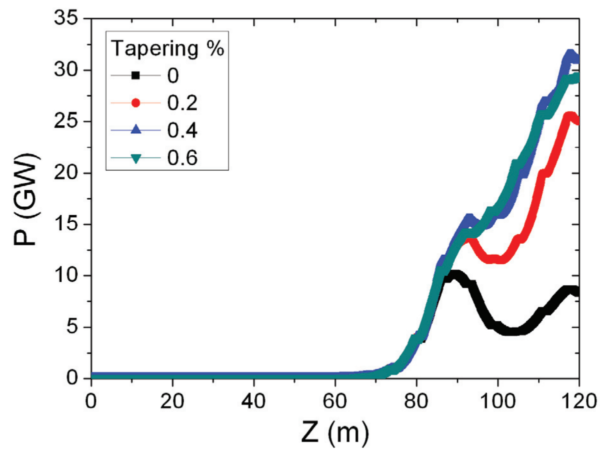

Figure 5: Tapering in steady-state simulation.

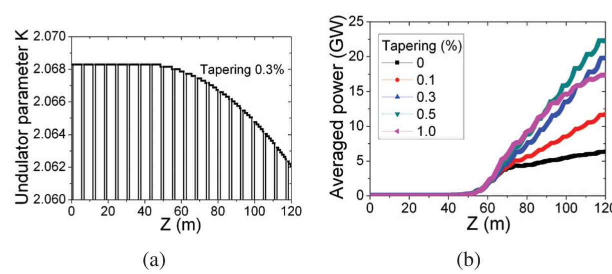

Figure 6: Tapering in time-dependent simulation. (a) 0.3-0.5% quadratic tapering is effective. (b) Variation of undulator parameter in case of 0.3% tapering.

CONCLUSION

The basic properties of SASE 0.1 nm for PAL XFEL was studied by using GENESIS. Further study about wakefields, errors and other beamlines is on going.

REFERENCES

[1] J.-H. Han, H.-S. Kang and I. S. Ko, "STATUS OF THE PAL-XFEL PROJECT", Proc. IPAC2012, p. 1735 (2012).

[2] S. Reiche, "GENESIS 1.3: a fully 3D time-dependent FEL simulation code", Nucl. Inst. Meth. A, 429, p. 243-248 (1999).