DESIGN OF THE PAL TEST FEL MACHINE

Mungyung Kim*, Jinhyuk Choi, Jung Yun Huang, Heung-Sik Kang, In Soo Ko, Tae-Yeon Lee, Jong-Seok Oh, Sung Ju Park, PAL, Pohang, South Korea

Chang-Mook Yim, POSTECH, Pohang, South Korea

Abstract

In order to the PAL-XFEL, the 1st stage will be to build a test machine, whose design parameters are presented here. It will be a 200 MeV machine that has the target wavelength of visible range. The design details and simulation results are shown in this paper.

INTRODUCTION

The Pohang Accelerator Laboratory (PAL) is going to build a new X-ray free electron laser (XFEL) machine based on the self-amplified spontaneous emission (SASE) scheme [1]. For the first step of the project, a test machine is considered to build. But it means extra time and budget is required. Fortunately, we have found sufficient area in the linac building. Usually PAL linac is operated as an injector for the 2.5 GeV storage ring. So another linac, test linac, beside of the preinjector area in the linac building, is operated for low energy experiments with 60 ~ 100 MeV. Furthermore RF cathode gun system is installed to test as an injector of the PAL FEL in the assembly room of the building. The injector consists of two accelerator columns with about 80 MeV. If we combine with two machines, the test linac and the injector, we need only one acceleration column and one chicane to have a 200 MeV linac for the test machine of PAL FEL project. It means we can save time and budget to construct a building of the test machine. So the test machine is designed to install in the area. Fig 1 shows the structure of the PAL preinjector area and schematic layout of the test machine. In this paper, the simulation results and detail designs of the machine will be reported.

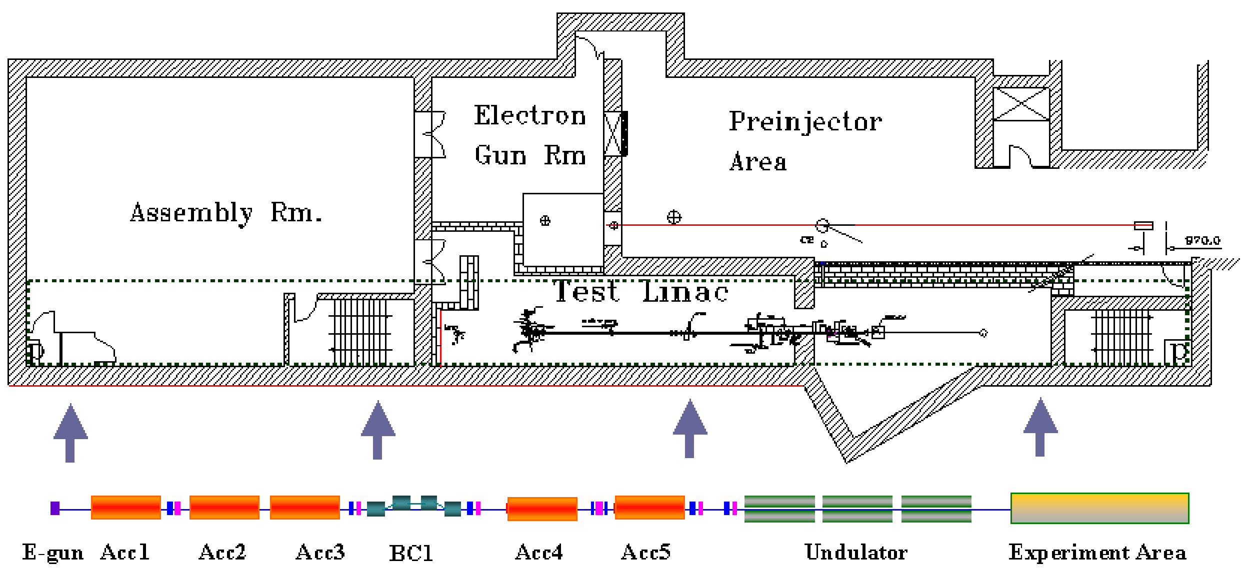

Figure 1: Drawing with preinjector area in the linac building and schematic layout of the test machine. The test machine is designed to install in the dashed block.

BEAM DYNAMICS DESIGN

The test machine consists of a 78 MeV injection part, linear accelerator with a chicane, beam transport line, SASE radiation area with three undulators and experiment area as shown in Fig. 1.

The injection part consists of a photo-cathode RF gun and two accelerating columns. The beam charge from the RF gun is 0.5 nC with 10 ps pulse length 60 Hz repetition rate in maximum, and the final energy of the injector is 78 MeV. After the injector, the beam pulse length is 777 µm, peak current is 60 A, energy spead is 0.3 % and rms normalized eimttances are 0.9 µmrad both direction with horizontal and vertical. PARMELA is used to simulate the injection part.

The linear accelerator is composed of two parts, bunch compressing and accelerating. The bunch compressing part consists of one accelerating column, L1, and one chicane bunch compressor BC1. At the exit of the injection part the electrons enter the L1 where they are

*mungyung@postech.ac.kr

accelerated to ~ 120 MeV. Acceleration occurs off-set crest to provide correlated energy spread along the bunch that will compress it in the compressor BC1 shown in Fig.1. The momentum spread for bunch compressing depends on RF phase (off-set crest) and power. The accelerating column is limited to accelerate up to ~ 50 MeV. And there is only one accelerating column in the L1. Because it limits the RF power, we have small variation about RF phase. The other component for bunch compressing is momentum compaction factor (R56) of BC1.

BC1 is located at that point of 110 MeV, and compresses the beam pulse length from 773 μm to around 228 μm to have peak current above 300 A. Because of the RF power limitation, momentum compaction factor (R56) of BC1 is also limited. RF phase affects on energy spread of the beam, and R56 affects significantly on emittance of the electron beam. We choose lower emittance, we get higher energy spread, and vice versa. For example, figure 2 shows the slice beam pulse shapes with the same peak current 390 A in the case R56 is varying. When R56 is -31.8 mm, the RF power of L1 is 16.7 MV/m and RF phase of L1 is –49.8°. When R56 is -63.1 mm, the RF power of L1 is 15.0 MV/m and the RF phase of L1 is –28.8°.

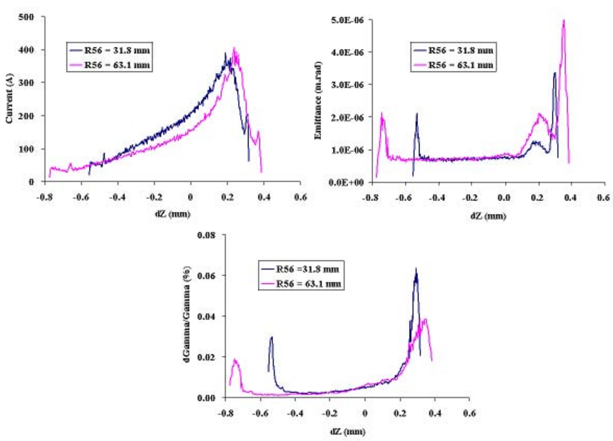

Figure 2: Slice beam pulse shapes at the entrance of the undulator. In the simulation particle number is 200,000 and slice number is 300. It shows current profiles (left), x-axis emittance profiles (Right) and energy spread (down).

From the tedious calculations with elegant code, we choose R56 is -31.8 mm. In the case, beam energy is 110 MeV, projected RMS energy spread is about 1.25 % at BC1. The bending angle of the BC1 is 7.2°, drift length between two dipole magnets is 1.2 m, and the length of each of four dipole magnets is 0.3 m.

2nd accelerating part (L2) consists of two accelerating columns with 15.4 MV/m RF power. Because L2 is also used in low energy experiment like as test machine in the same time, the structure is almost fixed. For the low energy experiments, another thermionic electron gun will be connected to the branch of the L2 at entrance.

The beam transport line from L2 to undulator is very short because of the space problem. So we have no dog-leg structure [2]. It consists of two quadrupole doublets to adjust beta function of the beam at the entrance undulator. At this point the beta-x is 6.22 m, alpha-x is –1.48, beta-y is 6.67 m and alpha-y is 1.44.

At the entrance of undulator, in this test machine, above 300-A peak current, below 1.5 μmrad emittance and below 0.2% energy spread are required for visible wavelength FEL. In this design, the simulation results using ELEGANT code satisfies the demands. At the entrance of undulator, the peak current is about 390 A, normalized slice emittance is 1.2 μmrad and energy spread is about 0.012 %.

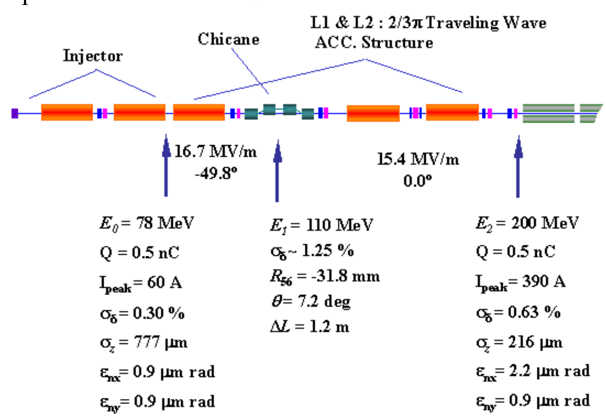

Figure 3: Layout of test machine for PAL XFEL

The figure 3 shows layout of the test machine and various beam dynamic simulation results. The figure 4 shows beta functions and eta functions along beamline, and figure 5 shows beam profiles in dE/E-dz plane. Table 1 summarize parameters of the test machine.

Table 1: Parameters of the Test Machine

Parameter	Value	Unit
Nominal electron energy	200	MeV
Peak current	390	A
Final bunch length	228	μm
RMS slice energy spread	0.012	%
Normalized slice emittance	1.2	μmrad
Radiation wavelength	visible	
Full undulator Length	10	m
Saturation undulator length	6 ~ 7	m

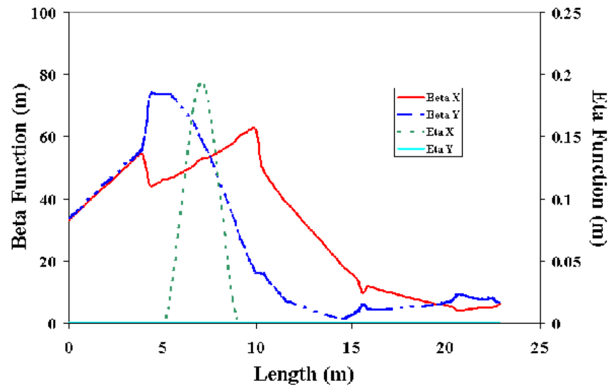

Figure 4: Beta and Eta functions along beamline of the test machine.

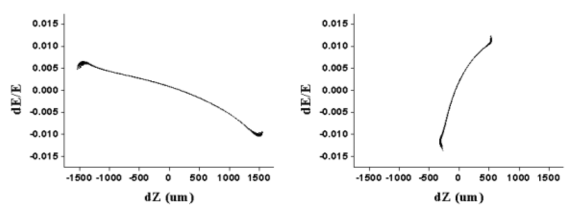

Figure 5: 200,000 particle profiles in dE/E-dZ plane at injector (left) and at entrance of the undulator (Right).

SUMMARY

The test machine with visible FEL using SASE for completion of 3.7 GeV PAL X-FEL is designed to satisfy demands of time and budget to construct. The simulation results are acceptable. We need more study about beam diagnosis system in the machine.

REFERENCES

[1] T. Y. Lee, Y. S. Bae, J. Choi, J. Y. Hunag, H. S. Kang, M. G. Kim, D. H. Kuk, J. S. Oh, Y. W. Parc, J. H. Park, S. J. Park and I. S. Ko, "Design and Physical Issues of the PAL-XFEL" Journal of the Korean Physical Society, Vol. 48, No. 4, April 2006, pp. 791 ~ 795.

[2] Linac Coherent Light Source (LCLS) Conceptual Design Report, SLAC-R_593, April 2002, UC-414.