PHYSICAL DESING OF VUV-FEL TEST MACHINE FOR 3.7 GEV XFEL LINAC

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Abstract

The PAL XFEL, an X-ray Free Electron Laser (XFEL) project based on the Self-Amplified Spontaneous Emission (SASE), is under progress at the Pohang Accelerator Laboratory (PAL). For successful completion of the project, a test machine is expected to construction. This test machine is designed to be 385 MeV VUV-FEL. It consists of a 135 MeV injection part, 6 accelerating columns, two bunch compressors, three matching sections and two undulartors. In this article we represent the physical simulation results of the test machine using ELEGANT Code.

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. But the SASE FEL is quite a scientific challenges, as is well known; the generation of an extremely low emittance beam through a photo-cathode RF gun, bunch compressing to an extremely short length, maintaining the low emittance to the end of the linac, and keeping the beam orbit as straight as possible in the undulator. The PAL XFEL adds a few more scientific difficulties [1]. This is easily understood by comparing the PAL-XFEL with another machine under construction, the Linac Coherent Light Source (LCLS) [2], which uses a 14.45-GeV electron beam, four times bigger in energy, to obtain 0.15-nm radiation that of the PAL-XFEL radiation. In other words, the PAL-XFEL is going to achieve hard X-ray laser with a relatively low energy electron beam.

The VUV-FEL test machine is designed to overcome these difficulties. We are going to constructing and testing with simpler SASE-FEL machine than 3.7 GeV XFEL SASE machine. This machine has no user's demands. This report presents the physical design of the test machine.

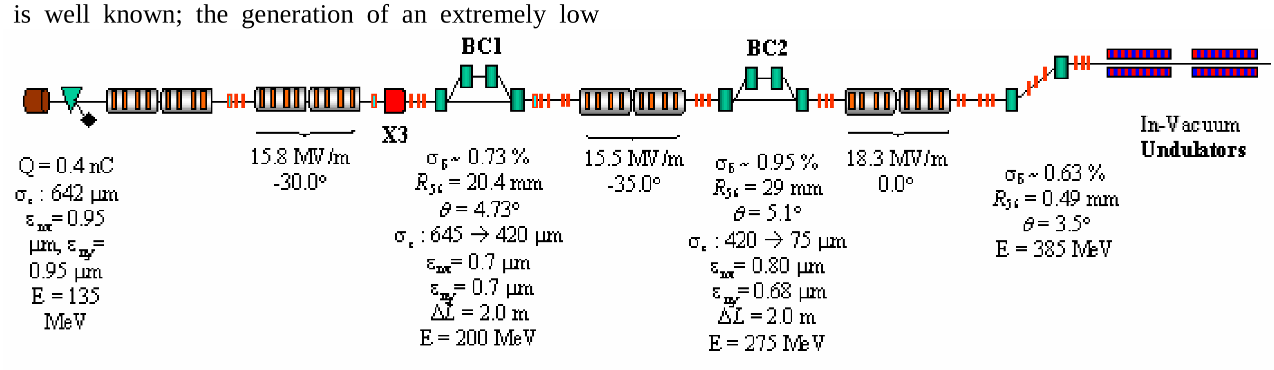

Figure 1. Layout of VUV-FEL Test Machine.

BEAM DYNAMICS DESIGN

The VUV-FEL test machine is consists an injection part, linear accelerator with two bunch compressors, beam transport line with dogleg and two undulators as shown in Fig. 1.

The injection part consists a photo-cathode RF gun and two accelerating columns. The beam charge from the RF gun is 0.4 nC with 10 pulse length, and the final energy of the injector is 135 MeV. After the injector, the beam pulse length is 642 um, and beam eimttance is 0.95 umrad both direction with horizontal and vertical.

The linear accelerator is composed of two sets of bunch compressors, one X-band accelerating, and conventional S-band accelerating columns. The first acceleration part initiates the compression process by accelerating from 135 MeV to 214 MeV off crest thereby generating the necessary linear energy-z correlation so that the first chicane, BC1, will compress the bunch. The first acceleration part is composed of two S-band rf accelerating columns. Because of the large off-crest phase angle (30 degree) and the relatively long bunch, the rms energy spread rapidly increases from 0.1 % to 0.71 %. A short X-band rf section is located just before BC1. The 0.6-m long X-band section is run at the decelerating crest phase (180 degree) so that second order energy-time correlation in the beam, which is included in the S-band section, can be removed. The net beam energy reduced 14 MeV. The rms energy spread increases from 0.71 % to 0.73 %. The second acceleration part is composed two S-band rf accelerating columns. It is also off-crest (35 degree) acceleration for compression in BC2. Beam energy increases in the section from 200 MeV to 275

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MeV. The rms energy spread increases from 0.73 % to 0.95 %. The third acceleration part is composed two S-band rf accelerating columns. It is on-crest acceleration. Beam energy increases in the section from 273 MeV to 385 MeV. The rms energy spread decreases from 0.95 % to 0.65 %.

BC1 is located at that point of 200 MeV, and the second one (BC2) is located at 275 MeV. BC1 compresses the 642 um injector output to around 420 um, and BC2 compresses it further to 75 um. The BC1 and BC2 parameters are summarized in Table 1 and Table 2.

After the acceleration section 9-m long beam transport line follows. It includes a dog-leg composed of 2 bending magnets, each of which bends a slight angle of 3.5 degree. The purpose of this dog-leg is to escape from the dark current coming from the gun. The dog-leg lattice has been carefully designed to cause insignificant emittance dilution due to the CSR effect [3]. Figure 2 shows beta function and dispersion functions in the test machine including beam transport line.

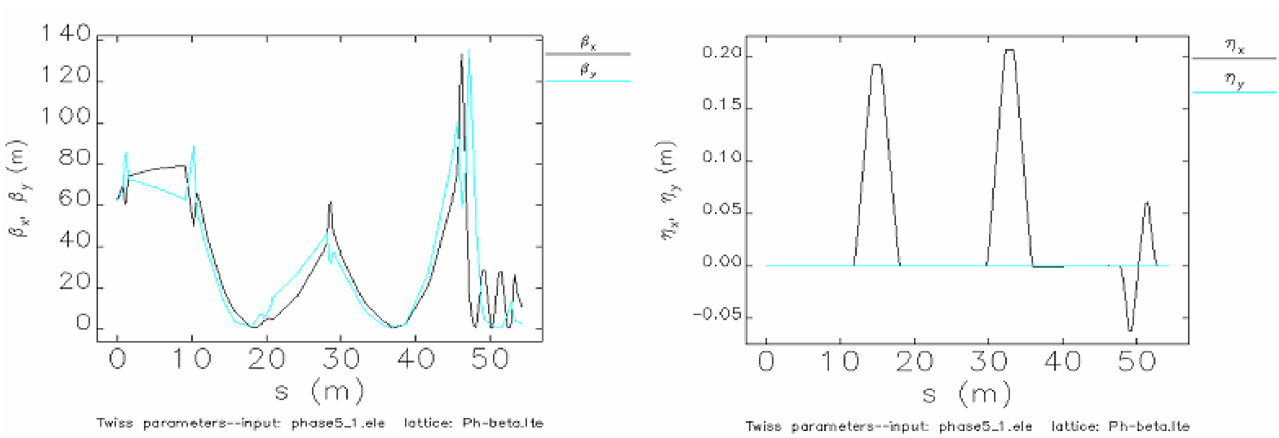

Figure 2. beta and dispersion functions through beamline up to undulator entrance.

Table 1. BC1 parameters.

Parameter	**Value**	**Unit**
Nominal electron energy	200	MeV
Initial bunch length	645	□m
Final bunch length	420	□m
RMS relative energy spread	0.73	%
Momentum compaction	20.4	mm
Length of each of the four dipole magnets	0.3	m
Bending angle of each four magnets	4.73	deg
Maximum dispersion	0.19	m
Drift length between first two dipole	2.0	m

The beam transport line has tow matching section. One is for beta function in the dog-leg. The other is for beta function at the entrance of undulator.

At the entrance of undulator, the more significant required beam parameters are average slice peak current, normalized slice emittance and slice energy spread. In this test machine, above 400-A peak current, below 0.8 umrad emittance and below 0.45 dgamma for energy spread are required. In this design, the simulation results using ELEGANT code satisfies the demands. At the entrance of undulator, the peak current is above 500 A, normalized slice emittance is 0.78 umrad and dgamma is average 0.4.

The Figure 3 shows transverse beam profiles, the Figure 4 shows energy spred-z correlation and the Figure 5 shows longitudinal slice status like as current, emittance, dgamma via z-direction at the end of injector and entrance of the undulator.

Table 2. BC2 parameter.

Parameter	**Value**	**Unit**
Nominal electron energy	275	MeV
Initial bunch length	420	□m
Final bunch length	75	□m
RMS relative energy spread	0.95	%
Momentum compaction	29	mm
Length of each of the four dipole magnets	0.3	m
Bending angle of each four magnets	5.1	deg
Maximum dispersion	0.20	m
Drift length between first two dipole	2.0	m

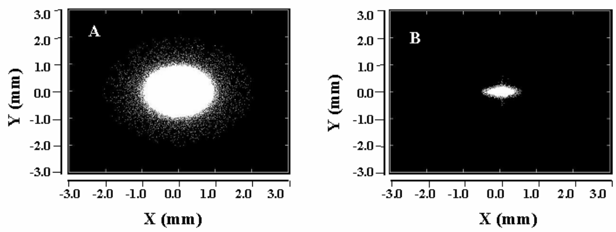

Figure 3. Phase space x-y plane at the end of injector (A) and at the undulator entrance.

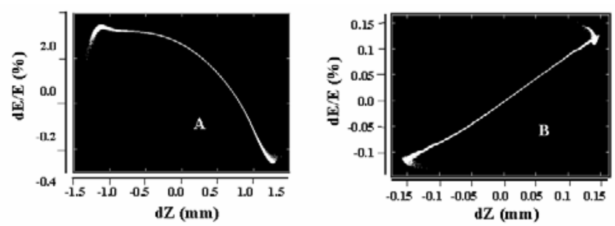

Figure 4. Energy-z at the end of injector (A) and at the undulator entrance.

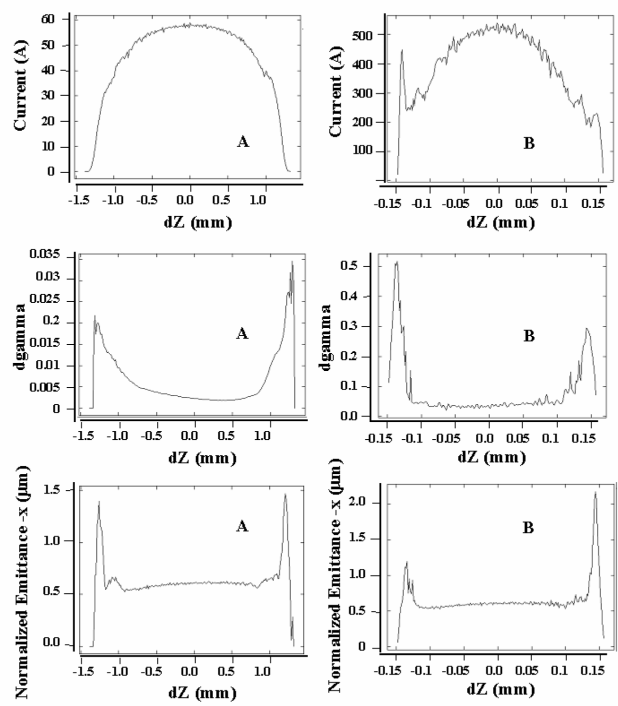

Figure 5. Slice peak current, dgamma and horizontal emittance at the end of injector (A) and at the undulator entrance (B). The simulation was carried out with 200,000 particles and 200 slices.

SUMMARY

The VUV-FEL test machine for completion of 3.7 GeV X-FEL of PLA is physically designed to satisfy demands of VUV-FEL using SASE. The simulation results are acceptable. We need more study about beam diagnosis system in the machine.

REFERENCES

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