STATUS OF fs-THz BEAM LINE PROJECT OF THE PAL*

H. S. Kang†, C. M. Lim, W. W. Lee, S. J. Kwon, B. R. Park, S. C. Kim, Y. G. Jung, I. H. Yu, Y. G. Son, C. B. Kim, S. J. Park, M. S. Lee, Y. J. Park, and J. H. Park
Pohang Accelerator Laboratory, POSTECH, Pohang 790-784, KOREA

Abstract

A femto-second THz radiation (fs-THz) facility is under construction at the Pohang Accelerator Laboratory (PAL), which is one of the beamline projects of Pohang Light Source (PLS). The facility will use a 60-MeV electron linac, which consists of an S-band photocathode RF gun with 1.6 cell cavity, two S-band accelerating columns, and two chicane-type bunch compressors. To generate intense femto-second THz radiation up to 3 THz, the electron beam with charge of 0.5 nC should be compressed down to below 100 fs. Two kinds of radiator will be prepared for pump-probe experiments for beamline: transition radiation for THz radiation (probe) and Cherenkov radiation for visible radiation (pump). The installation of the accelerator components was completed in June 2008, the rf conditioning ended in August 2008, and the electron beam test will start in September 2008. In this paper, we will present the construction status as well as the beam dynamics design results.

INTRODUCTION

Pohang Accelerator Laboratory (PAL) is constructing a 60-MeV electron linac for intense femto-second THz radiation source, which is a beamline construction project to be completed by 2009 [1]. The radiation wavenumber to provide is designed to be 10-100 cm^{-1} (0.3 - 3 THz), the radiation pulse duration should be shorter than 150 fs, and the energy per pulse is expected to be higher than 10 μJ.

Figure 1 depicts the layout of the electron linac. The linac will use an S-band photocathode RF-gun as an electron beam source, two S-band accelerating column (AC1 and AC2) to accelerate the beam to 60 MeV, two chicane-type bunch compressors to get femto-second electron bunch, and a coherent transition radiation (CTR) target as a radiator.

The relation of bunch charge and bunch length is shown in Table 1. The bunch length is designed to be 50 fs with 0.2 nC beam and 100 fs with 0.5 nC. To get short bunch length after bunch compression, the bunch length at the gun is 0.5 ps for 0.2 nC beam, 2 ps for 0.5 nC beam.

Generation of a few tens of femto-second bunch with a 60 MeV beam requires a minimization of non-linearity in bunch compression. When 0.5 nC beam is compressed from 2 ps to 100 fs, the compression ratio is 20. The limiting factors in the bunch compression with large compression ratio are space-charge force and non-linearity in energy-chirp. To minimize non-linearity resulting from RF wave curvature that the electron beam sees in RF-gun and accelerating column, a short bunch length of electron beam is used at the gun and high energy chirp at the first accelerating column (AC1). However, space charge force in a short bunch increases the bunch length during the transport from gun cathode to AC1 entrance. Thus, the accelerating field of the RF-gun should be high enough to minimize the space-charge effect at the gun. The higher the gun energy, the shorter is the bunch length after bunch compression. Emittance increase is expected in a short bunch operation at the gun due to strong space charge force. However, the emittance increase of 5 μm, even 10 μm, does not degrade the quality of THz radiation too much. Thus we can allow an increase of emittance within certain level in reducing the bunch length. The beam dynamics design is concentrated on reducing the bunch length at the expense of the emittance increase.

Table 1: Relation of bunch charge and bunch length

Beam charge	Bunch length after RF-Gun	Bunch length after chicane
0.2 nC	0.5 ps	50 fs
0.5 nC	2 ps	100 fs

Installation of all linac components was completed in June 2008 and RF-conditioning was completed in August 2008. Beam acceleration test will start in September 2008 and THz Radiation generation experiment will start in 2009.

SIMULATION OF SHORT BUNCH COMPRESSION

The beam dynamics design was carried out by using the PARMELA code. The parameters of Chicane-2 used in the simulation are: the beam energy is 55 MeV, the bending angle is 10 degrees, and R_{56} is -2.07 cm.

Figure 2 shows the bunch shapes after Chicane-2 in case RF-gun energy is 3 MeV (a) and 5 MeV (b). For 3-MeV case, the bunch length increases to 5 times that of 5 MeV. Thus, the beam energy of RF-gun needs to be higher than 5 MeV, which is available with the current gun technology.

However, the beam energy of the existing RF-gun is limited to 3.5 MeV and dark current is too high. So, A new RF-Gun is under preparation to generate higher beam energy above 5 MeV and lower dark current.

The laser beam profile plays an important role in reducing the bunch length. We simulated three different profiles:

* Work supported by Korean Ministry of Science and Technology
† hskang@postech.ac.kr

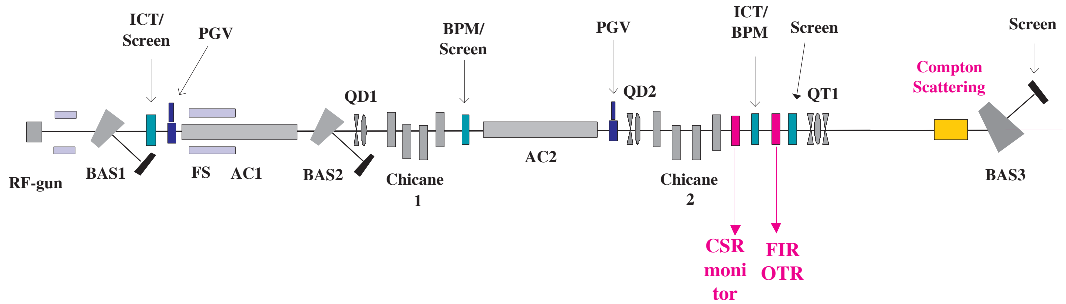

Figure 1: Layout of Linac. (QD: quadrupole doublet, ICT: integrated current transformer, FS: focusing solenoid, AC: accelerating column, QT: quadrupole triplet, OTR: optical transition radiation, BAS: beam energy analyzer, and YAG: YAG screen).

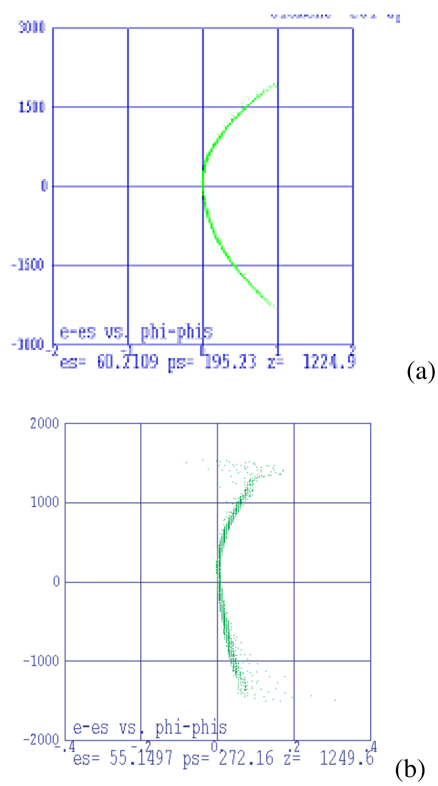

Figure 2: Bunch shape after Chicane-2 in case of RF-gun energy of 3 MeV (a) and 5 MeV (b). *es* represents the synchronous particle energy, *phis* the synchronous particle phase. The vertical axis is *e* - *es* in MeV and the horizontal axis is *phi* - *phis* in degrees. One degree corresponds to about 1 ps.

1) uniform in transverse and Gaussian in longitudinal, 2) Gaussian in transverse and Gaussian in longitudinal, 3) uniform in transverse and uniform in longitudinal. The best profile is the case 1) uniform in transverse and Gaussian in longitudinal. Uniform transverse profile helps reduce the space charge force in bunching process and Gaussian longitudinal profile helps reduce the number of particles in non-linear region of energy-chirp.

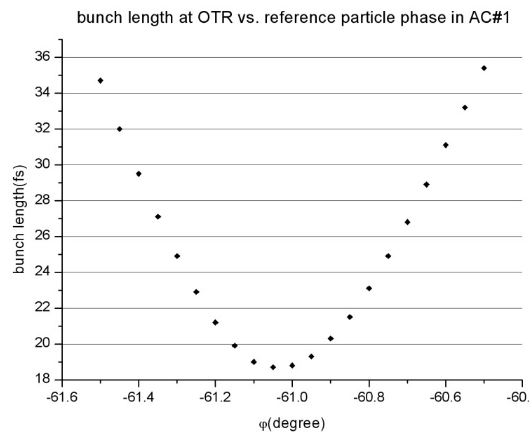

Figure 3: Bunch length's dependence on AC1 RF phase

PHASE JITTER REQUIREMENTS FOR SHORT BUNCH COMPRESSION

In the bunch compression, the most sensitive parameter affecting the bunch length is RF-phase which can change the beam energy and therefore change the energy chirping parameters. To estimate the RF-phase jitter requirements for short bunch compression, we performed a simulation of the bunch length's dependence on AC1 RF-phase (see Fig. 3).

From Figure 3, we can find that 1-deg RF-phase change results in 3 times increase of bunch length after the bunch compressor (Chicane-2). To stably generate THz radiation, the bunch length increase due to RF-phase jitter should be less than 20 %, which gives RF phase stability requirement w.r.t reference RF (shot to shot) is less than 0.1 deg (=100 fs). The largest contribution of RF phase jitter comes from klystron modulator. Finally, we calculated the modulator voltage stability requirement of 0.01 % (100 ppm pkpk).

We made a great effort to develop a ultra high stable klystron modulator which uses a high precision inverter power supply. Figure 4 shows the klystron voltage stability of the inverter type modulator developed for this project.

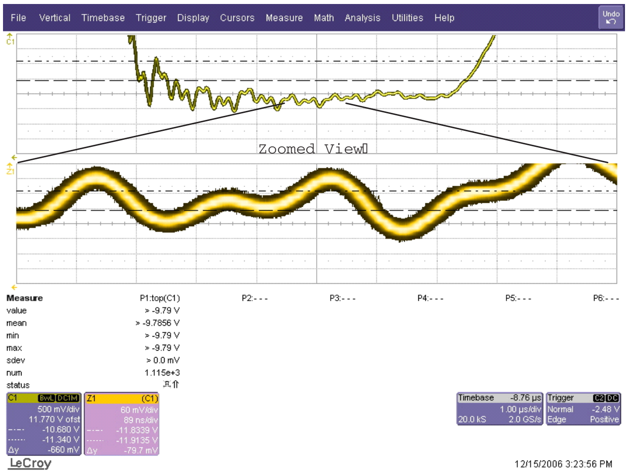

Figure 4: Klystron voltage stability of the inverter type modulator. The upper figure: klystron beam voltage, lower figure: zoomed view.

Shot to shot stability of the high voltage pulse is 133 ppm (pKpK), slightly higher than the requirement of 100 ppm (pKpK), which is acceptable.

SUMMARY

To achieve a very short bunch compression, a very strict phase jitter requirement should be satisfied. Klystron modulator with high precision inverter power supply was successfully developed. All systems including laser are ready for test. Beam acceleration test will start in September 2008 and THz Radiation generation experiment will start in 2009.

REFERENCES

[1] H. S. Kang, et al., in Proceedings of FEL 2007, Novosibirsk, Russia, p. 421.