ELECTRON-LINAC BASED FEMTOSECOND TERAHERTZ PROGRAM AT POHANG ACCELERATOR LABORATORY*

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Abstract

A 60 MeV electron linac for the source of coherent fs-THz pulses is under construction at PAL, Korea. The 266 nm pulses provided by the 3rd harmonic conversion of 800nm Ti:Sapphire amplifier system are to be delivered to the photocathode rf-gun. The electron bunches produced from the photocathode rf gun are accelerated and compressed down to several tens of femtosecond in the linac. Then the relativistic electron bunches are used to generate intense fs-THz pulses by coherent transition radiation (CTR). The radiated THz pulses are extracted from the linac vacuum pipe through a CVD diamond window. The beam, which is took up part of the 800nm beam out of the fs-regenerative amplifier, is sent to the THz laboratory to do THz pump-Optical/IR probe experiment.

INTRODUCTION

The Terahertz (THz, 1THz≈33cm^{-1} or 4meV) region of the electromagnetic spectrum lies in the far-infrared spectral range, and has not been studied much due to the lack of conventional generation and detection methods, but the THz sources have a great potential to be applied in many fields from biology to physics, chemistry and material science. Over the past decade a significant advance in THz sources has been made with the advent of coherent THz radiation from photoconductive antennas and optical rectification. Recently it has been reported that the dramatically enhanced energy, peak power, and peak electric field of the coherent THz radiation has been generated from the coherent superposition of the radiated fields emitted by ultrafast electron bunches.[1-3] This intense THz source has a great possibility in a variety of science matters including nonlinear optical phenomena.

The fs-THz beamline program at PAL (Pohang Accelerator Laboratory) is underway to generate intense fs-THz radiation from 60 MeV linac (linear accelerator). The radiation is expected to cover up to 3 THz(~100 cm^{-1}) and the pulse duration to be less than 200 fs. Spectroscopic methods are planned to study chemical and biological reaction dynamics. The construction of beamline is scheduled to be completed by the end of 2009.

RESULTS

The bunch length of the relativistic electron beam should be shorter than 100 fs to fulfill the goal. Although the relativistic electrons emit radiation at all wavelengths, only wavelengths with the same order of the bunch length or longer are to be coherent.

The power of the coherent part is much greater than that of the incoherent part when the bunch form factor ($f(\lambda)$) is close to 1. As shown in figure 1, the calculated result of the coherent enhancement of synchrotron radiation from a bending magnet is greatly affected by bunch lengths in rms. The photon flux of coherent radiation is N_e(number of electrons) times higher than that of incoherent radiation.

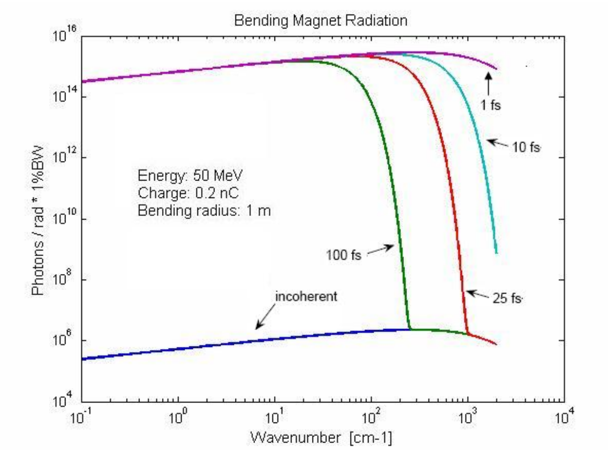

Figure 1: Synchrotron radiation from a bending magnet at different bunch lengths.

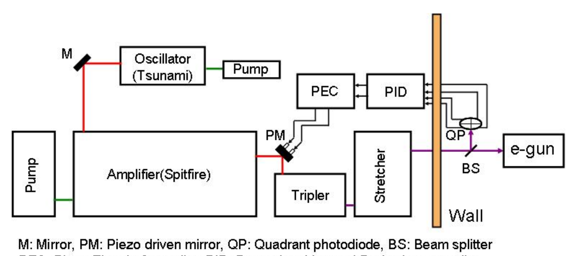

Figure 2: Beam pointing stabilization unit.

The layout of the fs-THz beamline is described below. First, the 266 nm UV pulses provided by the 3rd harmonic conversion of 800nm Ti:Sapphire amplifier system are to be delivered to a photocathode rf-gun at close to the normal incidence angle. Although the pulse width out of the 3rd harmonic conversion is less than 200 fs, the variation of this pulse width is available in a pulse stretcher up to 10 ps. Spatially stable 266 nm UV beam to the rf-gun in the linac will be provided by the beam pointing stabilization unit (figure 2), which consists of the fast opto-electronic feedback device, based on quadrant photodiode detectors and piezo-driven mirrors.

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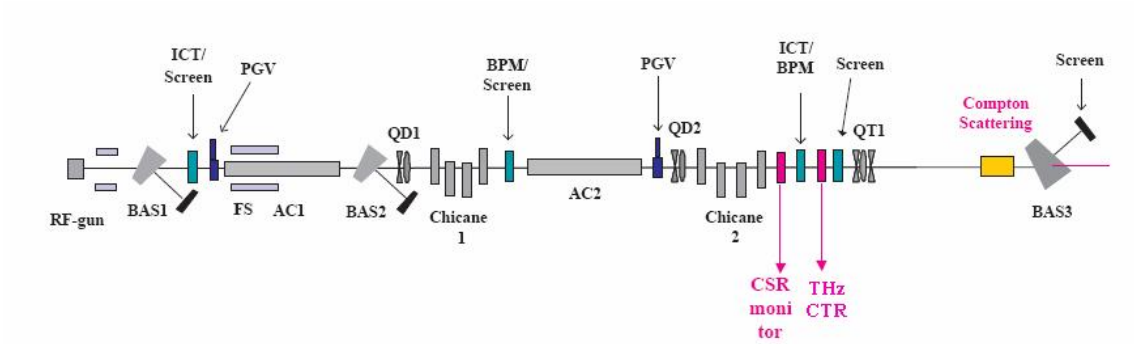

Figure 3: Layout of fs-THz Linac. (QD: quadrupole doublet, ICT: integrated current transformer, FS: focusing solenoid, AC: accelerating column, QT: quadrupole triplet, CTR: coherent transition radiation, BAS: beam energy analyzer)

Figure 3 depicts the layout of the electron linac. The electron bunches generated from the photocathode of the rf-gun have about 0.5 nC charge and up to 60 Hz repetition rate. The electron bunches are to be accelerated to 60 MeV in the two S-band accelerating structures (AC1 and AC2), and compressed down to 50 fs with 0.2 nC and 150 fs with 0.5 nC charged electron bunches in a chicane type bunch compressor. Parameters of the linac are listed in Table 1 and the relation between bunch charge and bunch length is listed in Table 2. Since the electron bunch length out of the RF-gun should be about 0.5 ps with 0.2 nC beam charge to get short bunch length after the bunch compression as described above, the electron beam has the relatively high emittance, 5 mm-mrad. The compressed electron bunches are incident on 1 inch diameter aluminum foil or copper mirror and generate fs-THz pulses by coherent transition radiation (CTR). The radiated THz pulses are extracted from the linac vacuum pipe through a 24 mm diameter CVD diamond window and delivered to the beamline laboratory.

Table 1: Parameters of the Linac

Parameters	**Value**
Beam Energy	60 MeV
Beam Charge	0.2-0.5 nC
Beam Emittance	5 mm-mrad
Beam Pulse Repetition Rate	60 Hz max.

Table 2: 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	150 fs

About 30% of the 3 W, 1 kHz Ti:Sapphire regenerative amplifier output is sent to the THz laboratory through the 4 mm Dia. 10 m delivery pipe to carry out further experiment. This 800 nm beam is delivered to Optical Parametric Amplifier (OPA) and generate beams from UV (200 nm) to IR (10 μm), which are to be used as a pump or probe source. THz pump-UV/Vis/IR probe experiments as well as UV/Vis/IR pump-THz probe experiments will be performed.

Single cycle coherent fs-THz pulses will be available in the middle of 2009 from a linear accelerator by coherent transition radiation (CTR). The relatively weaker fs-THz pulses are also generated by the optical rectification method using the output of the regenerative amplifier system. Therefore, the characterization of the emitted THz pulses is a big part of the work in 2008-2009. Pyroelectric detector and Golay cell with lock-in amplifier are used to measure the power of the THz beam.

Electro-optic sampling in ⟨1 1 0⟩ ZnTe crystal is used for the coherent detection of freely propagating THz radiation. A single shot electro-optic measurement as well as conventional time-domain electro-optic sampling will be applied for the measurement of the THz pulses. When a linearly chirped optical probe pulse and a THz pulse co-propagate in the electro-optic (EO) crystal (ZnTe), different portions of the THz pulse modulate different wavelength components of the linearly chirped pulse through the Pockels effect. The spectral distribution is measured with a spectrometer and an array detector combination. The temporal THz signal will be extracted from the difference between the spectral distributions of the chirped optical probe pulse with the THz pulse on and off. This single shot method provides greatly improved data acquisition rate.

REFERENCES

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