IMPROVEMENT OF ELECTRON INTENSITY REDUCTION SYSTEM AT SLRI BEAM TEST FACILITY*

K. Kittimanapun†, N. Chanlek, P. Klysubun, S. Krainara, and S. Supajeerapan,
Synchrotron Light Research Institute (SLRI), Nakhon Ratchasima, 30000 Thailand

Abstract

Synchrotron Light Research Institute (SLRI) has been commissioning an additional experimental station, a Beam Test Facility (BTF), to the SLRI accelerator complex. SLRI BTF was constructed to provide electron test beams with energy ranging from 40 MeV up to 1.2 GeV and with tunable electron intensity from a few to millions of electrons per burst. In order to obtain low intensity of test beams, an approach using a metal target together with an energy selector has been employed. A combination of a target chamber installed at the high-energy beam transport line and the existing 4-degree bending magnet that is used as an energy selector first produced low intensity test beams. However, the test beam profile was not well determined due to the insufficient bending angle of the energy selector and high primary beam energy. Another approach mounting a target chamber at the low-energy beam transport line and using the synchrotron booster as an energy selector was implemented to avoid such problems. Moreover, the shielding concrete wall was constructed to minimize secondary particles surviving to the experimental hall. Once in operation, the facility will have the potential to service calibration and testing of high-energy detectors as well as beam diagnostic instrumentations.

INTRODUCTION

Synchrotron Light Research Institute (SLRI) has initiated a new Beam Test Facility (BTF) directly utilizing an electron beam for research in addition to generation of synchrotron light [1]. As requested by users developing the high-energy particle detectors and diagnostic instrumentations, SLRI-BTF has capability to provide plenty of beam time that benefits from the current injection scheme. The facility able to operate during the normal service of synchrotron light is extended from the high-energy beam transport beamline (HBT) and locates underground together with other injector components.

The important parameters of the electron test beam, depending on types of measurement, are electron beam energy and intensity. Since electrons are accelerated by the synchrotron booster, the electron beam energy could be tunable from 40 MeV - 1.2 GeV upon the number of turns electrons travel. While high-intensity electron test beam can provide large output signal, low-intensity electron beam is useful for investigation of particle tracking devices, such as monolithic active pixel devices. In order to lessen an amount of time in data analysis, a clean beam with well determined profile is necessary.

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† kritsadak@slri.or.th

OVERVIEW OF SLRI-BTF

Figure 1 illustrates the concept of SLRI-BTF where electrons are produced from the electron gun, accelerated by a coupled linac and the synchrotron booster, and transported to the SLRI-BTF experimental station via HBT. Table 1 lists the electron and machine parameters at HBT beamline. Two target chambers have been mounted at the low-energy beam transport beamline (LBT) and the HBT beamline in order to reduce electron intensity from approximately 10 mA to less than 10 electrons per burst. Inside the HBT target chamber, a tungsten target with three different thickness; $1.7X_0$, $2.0X_0$, and $2.3X_0$ whereX_0 is radiation length, is used to attenuate electron intensity and allows flexibility to select electron output. Traversing electrons with large transverse momentum are first absorbed at the upstream slit. While electrons with desired energy travel through the magnetic energy selector (BH), those with large energy dispersion are lost to the beam pipe inside the magnetic field region and to the downstream slit. Two sets of focusing-defocusing quadrupoles (QF-QD) used to tune the beam are normally adjusted to transport the electron beam to the electron storage ring (SR). When SLRI-BTF is in operation, the vertical bending magnet (BV) that deflects electrons to the storage ring (SR) is turned off to allow electrons to transfer to the detector.

Table 1: Electron Beam Parameters at High-Energy Beam Transport Line (HBT)

Particle	electron
Energy	up to 1.2 GeV
Energy spread	-0.05%
Current	10 mA
Pulse duration	8.5 ns
Bunch length	0.5 ns
Repetition rate	0.5 Hz
# of electrons per burst	10^8

IMPROVEMENT OF INTENSITY REDUCTION SYSTEM

Construction of HBT Shielding Wall

The Monte-Carlo N-Particle (MCNP) [2] code was employed to investigate distribution of secondary particles that are produced after the high-energy electron beam impinges on the target. Illustrated in Fig. 2 (top and middle), the distributed flux of electrons generated from the electron-target

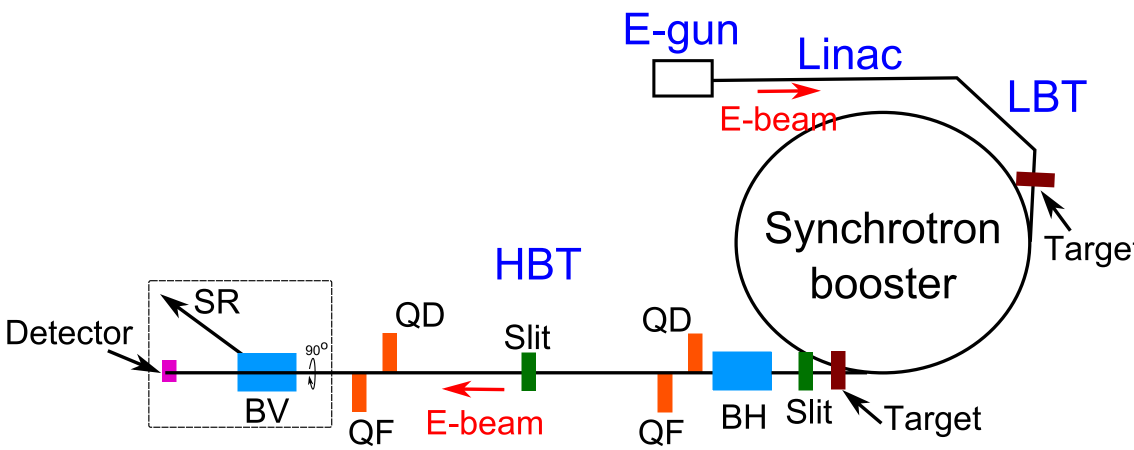

Figure 1: Conceptual diagram of SLRI-BTF.

collision for different thickness. The target is 4-degree tilted from the transverse plan to match the real design while the beampipe and the chamber are neglected. The number of secondary particles and their distributions vary depending on the thickness of the target. The thin target creates more secondary particles than the thick one. Secondary particles with low transverse momentum are likely to travel to the experimental station; on the contrary, those with large transverse momentum are lost to the tunnel wall.

In order to minimize the number of the secondary particles detected on the studied device, the shielding concrete wall was constructed to prevent the secondary particles travelling to the end station. The location of the shielding concrete wall that was chosen based on the availability of the existing space is downstream of the 2nd slit and between two pair of quadrupoles. Its dimension of 50 cm thick, 150 cm wide, and 2 m high was determined to allow enough room for other activities such as regular preventive maintenance,

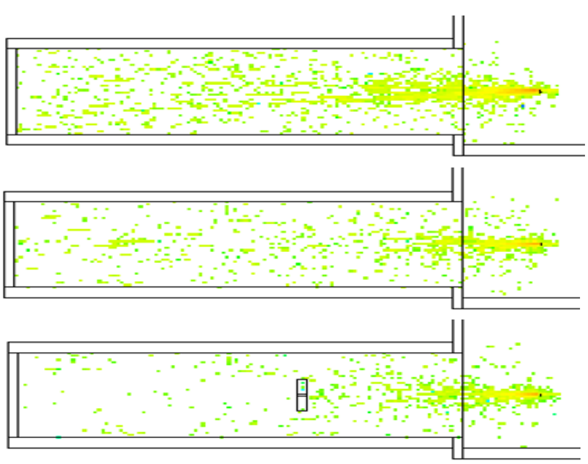

Figure 2: MCNP calculation of secondary particles in the tunnel and at the SLRI-BTF experimental area when the thin target ($1.7X_0$) (top) and the thick target ($2.3X_0$) (middle) are used and when the shielding concrete is included together with the thick target (bottom).

beam alignment, etc. Figure 2 (bottom) shows results using the shielding concrete wall to block undesired particles created from the electron-target collision. Most of the particles having small transverse velocity are blocked by the shielding wall. Although some particles may travel further toward the experimental area, they eventually hit the surrounding concrete wall. The tertiary particles produced could have small energy insufficient to penetrate the shielding box that contains the diagnostic devices.

Installation of LBT Target

Besides construction of the shielding concrete wall, the location of the target chamber was considered as well. By replacing the single to the dual-axis diagnostic box that supports both the screen monitor and the target manipulator, an additional target was installed at the end of LBT to reduce the intensity of the low-energy electrons before transferred to the synchrotron booster, see Fig. 1. With this scheme, the secondary particles produced when the primary electron beam impinges on the target is significantly smaller than those generated by the HBT target.

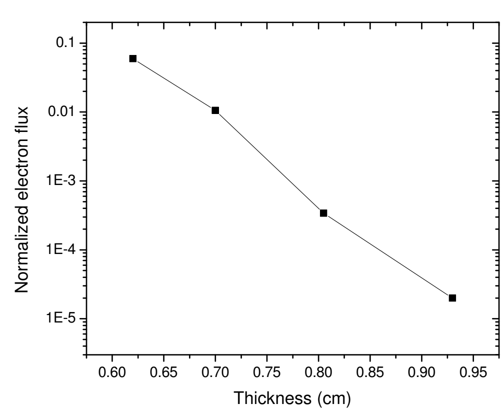

Figure 3: MCNP calculation showing flux of electrons traversing a tungsten target at different thickness.

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The wedge-shape tungsten target was employed in order to provide flexibility in tuning the electron beam due to the instability of the linac and the klystron. The 40-mm wide and 60-mm long target is mounted with the flat side facing the electron beam. Its dimension was designed to sufficiently be larger than the electron beam size, while the thickness was from calculation using MCNP. Figure 3 shows the plot of the electron flux traversing the 40-MeV target as a function of the target thickness. Assuming the intensity of the primary beam 1×10^6 electrons per burst, the electrons that survive from the collision on the target is 200 electrons using a target of 9.3 mm thick. Since the injection septum of the booster synchrotron is also deoptimized in order to decrease transportation efficiency of 40-MeV electron beam to the booster, the 6-mm target is thick enough to completely stop the beam. The target thickness at the center of the beamline can be adjusted up to 6 mm with resolution of 10 μm. If less than 10 electrons per burst is required, the target thickness can be 2.9±1 mm. Figure 4 shows the location of the LBT target chamber completely installed next to the synchrotron booster.

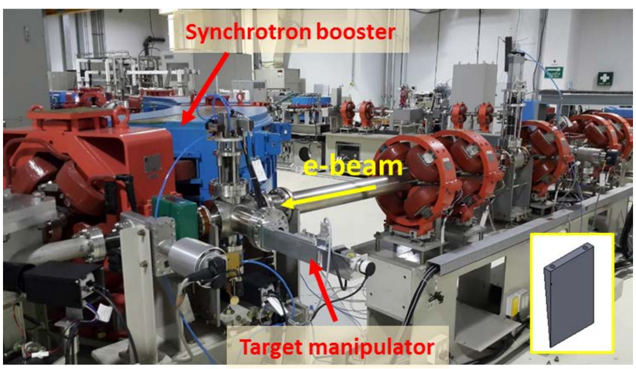

Figure 4: The LBT target chamber to reduce electron intensity before entering the synchrotron booster. An inset is the wedge-shape tungsten target.

SETUP AND PRELIMINARY RESULT

In the commissioning of the LBT target, the injector was operated with similar parameters used during the regular injection except that all beam transport elements starting from the first vertical bending magnet to the last element of HBT were not in operation. The electron beam was produced and accelerated to 1 GeV every 2 s. The electron intensity was first reduced by deoptimizing the injection septum to the minimum allowed value. The target was then inserted and adjusted around its thickness of 2.9 mm in order to obtained less than 10 electron per burst at the BTF experiment. The Timepix detector [3] with the external trigger of 100 ns was generated from the central timing unit to measure low-intensity electron beam.

Figure 5 depicts the comparison of electron distribution on the Timepix sensors when the HBT and the LBT targets were inserted to reduce electron intensity. It is obvious that, in case of using HBT target, the distribution of the electrons detected on the sensor is not well defined and its shape reflects the size of the exit window. Although we could possibly adjust the focusing elements of BTF to provide a good electron profile, there is still background on the sensor that is irremovable. On the other hand, the distribution of the high-energy electrons observed when the LBT target was inserted is clean and the electron beam profile is well determined. The electron intensity was measured to be 6 electrons per burst.

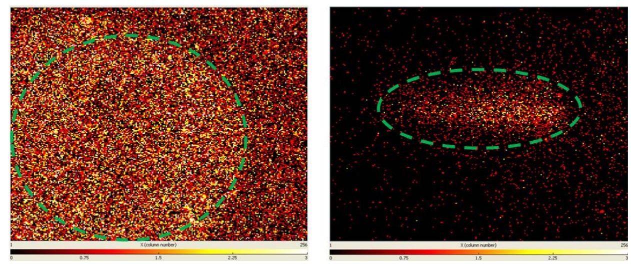

Figure 5: Distribution of high-energy electrons detected by the Timepix detector when the primary electron beam is attenuated by the HBT target (left) and the LBT target (right).

CONCLUSION

The quality of the high-energy electron beam detected at the SLRI-BTF experimental station has been improved by constructing the shielding concrete wall to prevent secondary particles and by adding another target at LBT. Not only does the reduction of the electron intensity at LBT produces low amount of secondary particles, it is also hard for such particles to travel to the detector due to the large angle and the long distance between the target and the detector. Simulations were performed to show the decrease of the secondary particles while the measurement confirmed to obtain clean electron distribution and well determined electron beam profile.

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