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ENERGY SELECTION OF SYNCHROTRON BOOSTER FOR SLRI BEAM TEST FACILITY*

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Abstract

The SLRI Beam Test Facility (SLRI-BTF) is able to produce electron test beam with maximum energy of 1.2 GeV and various intensities from a few to millions of electrons per repetition. The main components of the SLRI-BTF are the Siam Photon Source (SPS) injector consisting of a 40-MeV linear accelerator, a low-energy transport beamline, a synchrotron booster increasing electron energy to 1.2 GeV, and a high-energy transport beamline. As the SLRI-BTF has successfully utilized the electron test beam to characterize pixel sensors for high-energy particle detectors and to perform high-energy electron irradiation, the test beam with lower energy ranges has also been requested by users. In this work, the test beam with lower energy can be obtained by changing the acceleration pattern of the SPS booster and adjusting high-energy transport beamline to match the extracted beam energy. Production of test beam with lower energy can be confirmed by test beam measurement at the SLRI-BTF experimental station.

INTRODUCTION

The Beam Test Facility (BTF) at the Synchrotron Light Research Institute (SLRI) has been constructed to utilize the electron beam produced from the Siam Photon Source (SPS) injector [1]. As the SPS injector operates in full-energy mode, the SLRI-BTF is capable of providing an electron test beam with a maximum energy of 1.2 GeV. Additionally, a metal target has been implemented to adjust the intensity of an electron beam from a few to millions of electrons per repetition rate. The facility is situated in the accelerator hall, adjacent to the vertical bending magnet that deflects a high-energy electron beam to the SPS storage ring, where the electron beam is stored to generate synchrotron light. Figure 1 displays the layout of the SPS injector and the BTF location. The electron beam is first produced from an electron gun, then accelerated to 40 MeV by a coupled linac, and transferred to a Low energy Beam Transport beamline (LBT) before entering a synchrotron booster. Once reaching the desired energy, the electron beam is extracted to a High energy Beam Transport beamline (HBT) toward the SLRI-BTF. The electron beam parameters at the HBT during regular operation are detailed in Table 1.

Since the achievement of test beam production, the beam time has primarily been allocated to the research and development of pixel sensor detectors, for which the lower intensity test beam is required. However, there have been requests from users of different communities interested in test beams with a lower energy range. To accommodate test beams for various kinds of research, the study of energy selection by the SPS synchrotron booster has been initiated.

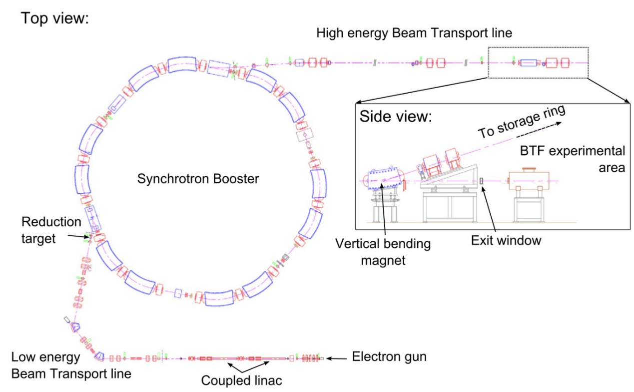

Figure 1: Siam Photon Source (SPS) layout and location of the SLRI beam test facility.

Table 1: Electron Beam Parameters at High-energy Beam Transport Beamline (HBT)

Particle	electron
Energy	1.2 GeV
Energy spread	0.05%
Current	10 mA
Pulse duration	8.5 ns
Bunch length	0.5 ns
Repetition rate	0.33 Hz
# of electrons per repetition	10^8

EXPERIMENTAL SETUP

To prepare for the extraction of the electron beam before reaching full energy, it is necessary to investigate the current ramping pattern of the synchrotron bending magnet. Moreover, the correct timing of an extraction kicker and an extraction septum corresponding to the desired energy of the electron beam must be chosen.

From the study of Ref. [2], the relation between the magnetic field (B) and the supply current (I) of the synchrotron dipole magnet, as obtained from measurement, is given by:

$$B(\mathrm{T}) = -1.2121 \times 10^{-10} I^3 + 2.0711 \times 10^{-7} I^2 + 8.5596 \times 10^{-4} I + 3.645 \times 10^{-3}$$

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and with

$$E(\text{GeV}) = 0.299792 \times \rho(\text{m}) \times B(\text{T}),$$

where E and ρ are an electron beam energy and a bending radius of a dipole magnet, respectively, one can determine the appropriate current to supply the magnetic dipole for various electron beam energies. As the supply current increases during the acceleration period, the timing to extract the electron beam from the synchrotron booster at the correct magnetic field can be precisely selected from the current ramping pattern.

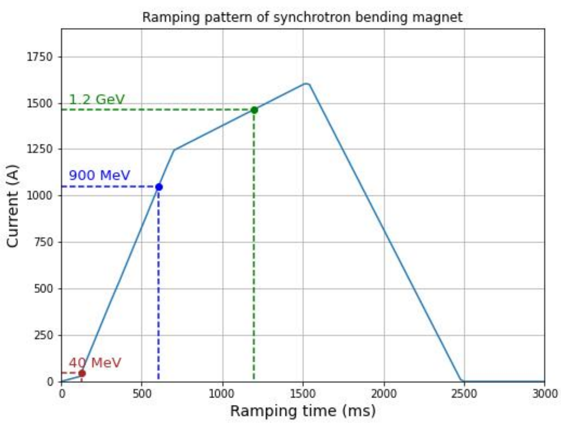

Figure 2: Ramping pattern of magnet current of the synchrotron booster for the full energy injection.

Figure 2 illustrates the ramping pattern of the synchrotron booster magnet. The repetition rate of the booster magnet is 3 s. The ramping of the magnet supply current, synchronized with the main clock, starts when the grid voltage is switched on to allow the extraction of the electron beam from the electron gun. Subsequently, the electron beam is bunched by a pre-buncher and a buncher, accelerated to 40 MeV by the linac, and transported to the synchrotron booster within 126 ms. Meanwhile, the magnet field is slowly ramped to 37 A to match the 40-MeV electron beam from the linac. Once the electron beam enters the synchrotron booster, the ramping rate is changed from 232 A/s to 2.1 kA/s as the electron beam energy continues to reach 1 GeV. After that, the ramping rate is reduced to 442 A/s in order to avoid damaging the magnet by supplying a high current to the coil in a short time. During this phase, the electron beam is accelerated from 1 to 1.2 GeV for the full energy injection to the SPS storage ring. Afterward, the supply current is decreased to zero within 1 s and stands by for 0.5 s before the new ramping cycle starts.

From the ramping pattern, it is obvious that to extract a 900-MeV electron beam, the signal to pulse both the kicker and the septum needs to be decreased by approximately 600 ms. However, it is slightly tricky to tune the extracted electron beam correctly since the magnetic field of the septum must be adjusted to match its energy. Therefore, instead of shortening the ramping time by 600 ms and adjusting the magnetic field of the septum, it is gradually reduced by 50 ms while maintaining the electron beam spot at the center of a monitoring screen by changing the magnetic field of the septum and a horizontal steerer.

After detecting the electron beam at the monitoring screen, the downstream transport elements, including two pairs of quadrupoles, 3 vertical and 1 horizontal steerers, and a 4-degree horizontal bending magnet, are adjusted to transfer the electron beam to the BTF. The test beams with different energies can be confirmed by a pixel sensor telescope. Figure 3 shows the pixel sensor telescope used to measure the electron test beam profile. It consists of 6 planes of the pixel sensors capable of measuring electron beam intensity down to a few electrons per repetition rate.

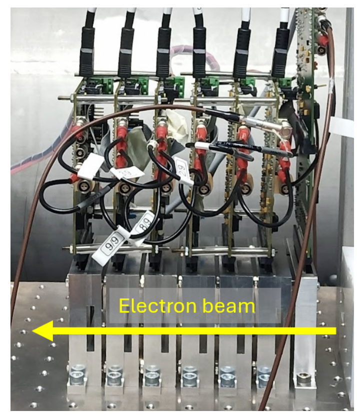

Figure 3: A pixel sensor telescope used to measure an electron test beam profile.

RESULTS AND DISCUSSIONS

The acceleration period of the electron beam can be obtained from the signal measured by a current monitor, as illustrated in Fig. 4. These signals indicate the electron beam currents in the synchrotron booster, and the signal widths relate to the acceleration period of the extracted electron beams at different energies. The longer the width, the higher the electron beam energy. The signals with the longest and the shortest widths correspond to the electron beam of 1.2 GeV or full energy and 0.35 GeV, respectively. Considering the signal amplitudes, it shows that the electron beam current gradually decreases while being accelerated. Table 2 presents the ramping times to pulse the kicker and the septum to extract the electron beams, magnet currents of the synchrotron booster, energies of the extracted electron beams, and signal widths of the electron beam during the acceleration.

The electron beam extracted to the HBT can be detected by a screen monitor located next to the first HBT vertical steerer. Figure 5 depicts the electron beam spot of 1.05 GeV captured on the screen monitor. The detection of the electron beam confirms that the electron beam of the selected energy is deflected by the kicker and the septum and transported from

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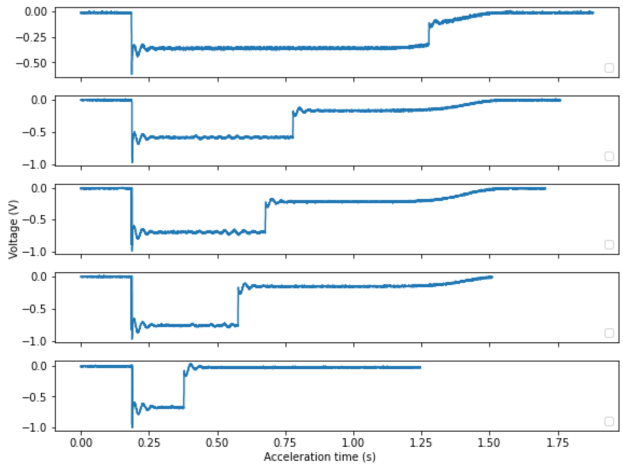

Figure 4: Signals of electron beam currents in the synchrotron booster for different acceleration periods.

Table 2: Parameters to Extract Electron Beams at Different Energies

Ramping time (ms)	Magnet current (A)	Electron beam energy (GeV)	Signal width (ms)
1199	1464	1.20	1090
699	1249	1.05	591
599	1030	0.89	491
499	837	0.72	391
299	174	0.35	191

the synchrotron booster to the HBT. Once the electron beam is obtained, beam tuning by the following optical elements mentioned previously can be performed.

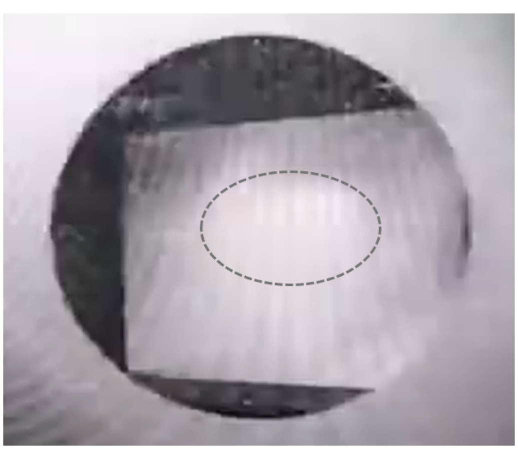

Figure 5: Electron beam spotted on the screen monition at the beginning of HBT.

After being successfully delivered to the BTF station, the electron beam is detected by the pixel sensor telescope to confirm the production of the electron test beam of the desired energy. Figure 6 depicts the electron beam profile detected by the 1st-plane sensor of the pixel sensor telescope.

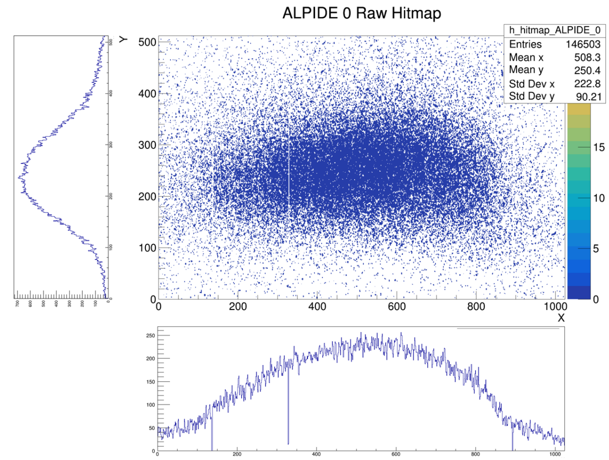

Figure 6: Electron beam profile captured at the SLRI beam test facility by the 1st-plane sensor of the pixel sensor telescope.

The electron beam sizes are 6.53 mm and 2.64 mm in the horizontal and vertical directions, respectively.

Since beam tuning typically consumes a significant amount of time and the time allocated to this activity is limited, the exploration of the electron beam at other energy ranges has not been undertaken. Since this activity was conducted during the machine study before the regular beam service, the next measurement will continue subsequently.

CONCLUSION

The SLRI-BTF has received requests to provide electron test beams at energy ranges lower than the full energy of the synchrotron booster. A systematic investigation into the production of low-energy electron beams was conducted, and the results reveal that by adjusting the timing of the kicker and the extraction septum, it is possible to obtain electron beams with varying energies. The electron beam within one of the lower energy ranges was confirmed at the SLRI-BTF station using the pixel sensor telescope, and its profile was measured.

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