DIAGNOSTIC SUPPORTS FOR TOP-UP OPERATION AT TLS

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Abstract

The routine top-up operation of Taiwan Light Source (TLS) began in October 2005. The beam stability and integrated flux were drastically improved. Various diagnostics are needed to support the top-up operation. These tools include diagnostics for measuring beam charge and current and injection efficiency, as well as a filling pattern monitor, a tune monitor, and an instability and loss pattern monitor. This study summarizes design considerations, details and future plans.

INTRODUCTION

The accelerator system at the Taiwan Light Source (TLS) consists of a 140 keV thermionic gun, a 50 MeV linear accelerator (LINAC), a linac-to-booster (LTB) transport line, a 1.5 GeV booster synchrotron, a 70 m long booster-to-storage ring (BTS) transport line and a 1.5 GeV storage ring. The goals of the top-up mode operation are to provide high stability and a highly integrated flux photon beam and to keep the heat load of the optical components constant. A complete diagnostic of the accelerator system is required for routine monitoring and machine debugging, to support the requirements of top-up mode operation. Major diagnostics that support top-up operation include charge, transmission of transport line, current, injection efficiency, orbit stability, electron loss, profiles, tune and instability and others. Table 1 summarizes these diagnostics.

MAJOR DIAGNOSTICS SUPPORT FOR TOPUP OPERATION

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LINAC and LTB Diagnostics

Diagnostic devices of the LINAC include several toroids, two fast gap monitors, and a screen monitor near the exit of LTB. These diagnostic devices can measure beam current, beam profile, energy and energy spread. A 60° bending magnet is adopted to bend the output of LINAC. An energy defining slit is located just before the last toroid to define the energy. Integrating the current waveform of this toroid monitor obtain the beam charge of the LINAC output. The energy and energy spectrum can be measured by scanning the bending angle of the bending magnet. A screen monitor is added behind the bending magnet, to measure the emittance of the LINAC by the quad-scan method when this bending magnet is turned off.

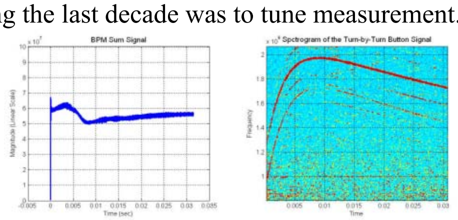
Table 1: Main diagnostics to support top-up operation

Accelerator system	Parameters should be monitor	Descriptions
Linac	Transmission	Toroid, gap monitor, oscilloscope
	Charge	Toroid and charge integrator
Booster synchrotron	Averaged beam current	MPCT
	Filling pattern	FCT, stripline with oscilloscope
BTS	Transmission	ICT and charge integrator
	Beam position	BPM
	Position, transverse profile	Screen monitor
Storage Ring	Averaged beam current	MPCT with 1 μA resolution
	Injection efficiency	$\Delta I_{avr,SR} * t_{rev,SR} / C_{ICT,BTS}$ per injection shot
	Filling pattern	Button pickups with oscilloscope
	Isolated bunch purity	Photon counting system – in planning

Note: $\Delta I_{avr,sr}$ is increment of beam current per injection shot, $t_{rev,SR}$ is the revolution period of the storage ring, $C_{ICT,\ BTS}$ is the beam charge pass the BTS per injection shot.

Booster Synchrotron Diagnostics

The booster synchrotron diagnostic consists of seven sets of screen monitors, MPCT, FCT, BPMs, and a synchrotron radiation monitor. The measured parameters include beam current, closed orbit, tune and beam profile. The averaged beam current is measured by the MPCT. The filling pattern is measured by the FCT. The synchrotron radiation monitor is upgraded using an IEEE-1394 camera with an external trigger and exposure time control functions. Several approaches have been applied during the last decade was to tune measurement. Figure 1



(a) (b)

Figure 1: (a) Beam intensity of the booster synchrotron; (b) tune variation during energy ramping.

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displays the Fourier analysis of the turn-by-turn beam position data captured by a Libera Electron.

BTS Diagnostics

Beam intensity, charge, trajectory and beam profile should be monitored routinely during top-up operation. The diagnostic devices of BTS consist of the FCT, ICT, BPMs and screen monitor. Bergoz's FCT and ICT is used to measure intensity and charge. Trajectory is measured using Bergoz's LR-BPM. Figure 2 plots the signal output of the charge amplifier to the timing waveform of Bergoz's charge integrator. In Fig. 3, the ICT signal suffers kicks the disturbance during injection. The solution to this problem warrants further study. The fired noise from injection kickers interferes with the baseline of the last ICT (ICT3) as shown in Fig.2. The ICT2 is located in the middle of BTS and located in the vertical bend. The charge measured by this ICT is accompanied with a charge increment per injection, enabling the injection efficiency of the storage ring to be computed.

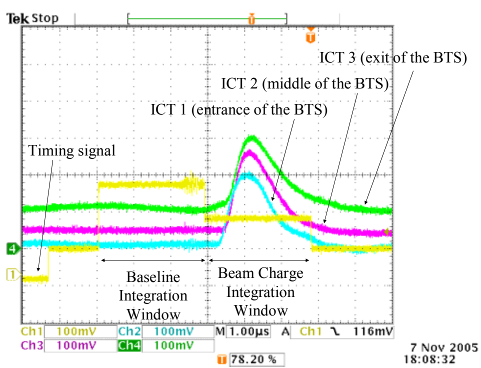

Figure 2: Signal output of the charge amplifier respectively to the timing signal of charge integrator.

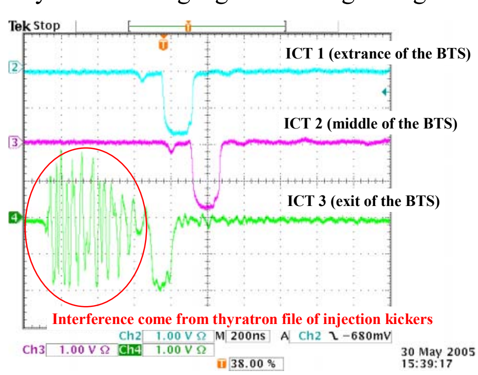

Figure 3: The ICT3 signal suffers the interference during injection kickers fired.

Storage Ring Diagnostics

The storage ring is equipped with the same standard diagnostics. The performance and functionality of the diagnostic system have been improved during the last decade. The new generation of BPM electronics are in their final integration phase. The synchrotron radiation monitor has been upgraded to include an IEEE-1396 digital camera, with drastic improvement in the dynamic range and linearity. The measurement parameter of the diagnostic system include closed orbit, beam current, tune, filling pattern, bunch current, beam loss, beam profile, emittance and beam energy. Several diagnostics are particular to the top-up operation and are addressed below.

The injection efficiency equals the increase in beam charge, measured by the DCCT of the storage ring, divided by the charge measured by the ICT2 of the BTS at the same injection cycle. Figure 4 plots the typical injection efficiency during top-up injection. An injection efficiency of over 70% is routinely achieved.

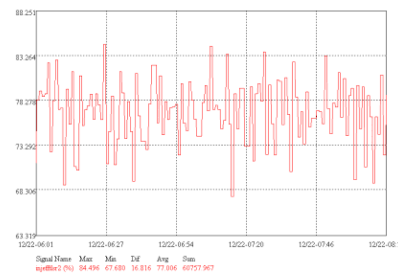

Figure 4: Typical injection efficiency of top-up mode operation.

The filling pattern of the storage ring drastically affects the operation performance. Control of the filling pattern is desirable. A dedicated filling pattern measurement system was set up as shown in Fig. 5, to satisfy the bunch current measurement requirements and possible filling pattern control in the near future. The sum of signal of BPM buttons is digitized by an Agilent 54832D oscilloscope with a bandwidth of 1 GHz, operated in equivalent sampling mode. The filling pattern server computer is connected to this oscilloscope via an Ethernet to the IEEE-488 adaptor. The ring clock triggers the oscilloscope. Performed analysis of the captured waveform can extract the relative bunch intensities of all bunches. The raw bunch intensity data normalized by the precision averaged beam current reading from DCCT is then obtain using a bunch-by-bunch current.

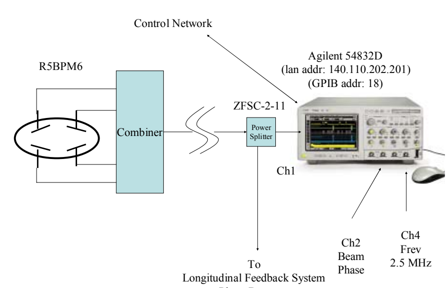

Figure 5: Setup for filling pattern measurement.

Figure 6 show the measured filling pattern with a stored beam current of 302 mA in a snapshot taken during top-up operation. This bunch current measurement has an accuracy of over 1%. The 16 nsec structure and bunch current variation are associated with the current injection scheme. A short bunch train of about 30 bunches is used to fill the storage ring at this moment, and the bucket is jump 8 bunched for each injection. This process is repeated during the top-up operation scenario, which is the reason with this 16 nesc bunch current variation. Despite this fact, the filling pattern can be maintained within 5% during several days of continued top-up operation.

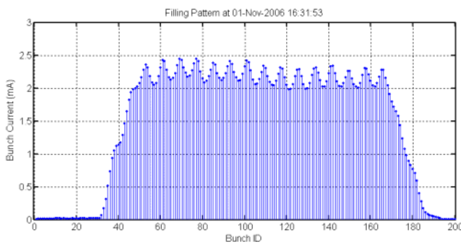

Figure 6: Measured bunch current of a snapshot during top-up operation. Total beam current is 302 mA.

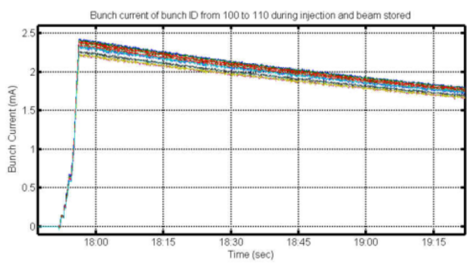

Figure 7: Bunch current of the decay mode operation.

The beam is perturbed in a fixed interval for top-up injection. This beam position oscillation caused by injection perturbation, can be captured by the new BPM electronics (Libera Electron). The Fourier analysis of the turn-by-turn data can extract the tune at every instance of injection. A Bergoz's type PIN diode beam loss monitor can acquire the radiation distribution. Several high counting rate scintillator type beam loss monitors are also installed to support various studies. A tune monitor and a beam loss monitor can support various studies and the monitoring of routine operation. Figure 8 plots the tune and beam loss as functions of the magnetic gap of a U9 undulator as an example.

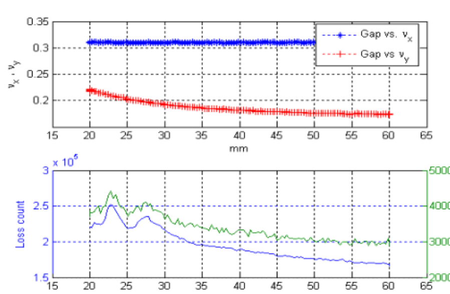

Figure 8: Bunch current of the decay mode operation. (tune vs. beam loss.)

An injection synchronization signal is available in all experimental stations, to deal with the beam perturbation caused by non-ideal injection local bump. This signal can help a user to gate out the signal when the beam is unstable upon injection, guaranteeing the quality of experimental data.

The stability of the beam position is important to the user. Figure 9 plots beam stability, measured by a tested Libera Electron at R4BPM5 during a top-up run. It is confirmed that 8 hours stability is around μm level.

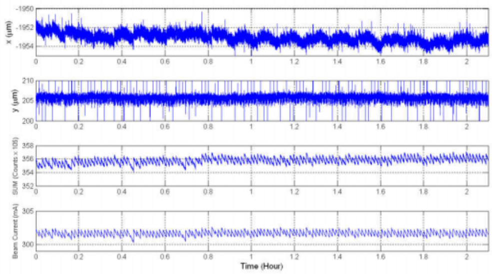

Figure 9: Eight hour position stability at R4BPM5 during top-up operation. The spike is due to the beam perturbation by the injection kick.

DISCUSSION

Diagnostics to support top-up operations of the TLS have been gradually improved over the last two years. Experience accumulated during the first year of top-up operation will support the next step improvement in coming year. Users require the injection of an isolated bunch in the multi-bunch filled-gap. The storage ring will be operated with a camshaft filling pattern is possible in the near future. Bunch purity diagnostics for this isolated bunch with photon counting technique is in planning. Study of the feasibility of purifying the single bunch at the booster synchrotron is under way.

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