DIAGNOSTICS FOR THE 150 MeV LINAC AND TEST TRANSPORT LINE OF TAIWAN PHOTON SOURCE

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Abstract

The TPS 150 MeV linac is in installation and commissioning phase at the test site for acceptance test. The linac will move to the final installation site after the building complete which is expected in 2012. The linac and a short transport line for main parameters measurement equips with several types of diagnostic devices, which include screen monitors, fast current transformers, integrated current transformer, wall current monitors, beam position monitors and Faraday cups. These devices are arranged to measure the specification parameters such as charge in bunch train, pulse purity, energy, energy spread, and emittance. Implementation details and preliminary test results will be summarized in this report.

INTRODUCTION

The TPS project will be a state-of-the-art synchrotron radiation facility featuring ultra-high photon brightness with extremely low emittance. It consists of a 150 MeV S-band linac, linac to booster transfer line (LTB), 0.15–3 GeV booster synchrotron, booster to storage ring transfer line (BTS), and 3 GeV storage ring. The TPS 150 MeV linac system as shown in Fig. 1 was contracted to the RI Research Instruments GmbH [1]. Major parameters of the linac are summarized in Table 1. The linac is being installed and commissioning at accelerator test site for acceptance during February ~ June, 2011. A test transport line is also installed to confirm the specifications of the linac. Various diagnostics for the linac and the test transport line are available and described in this report.

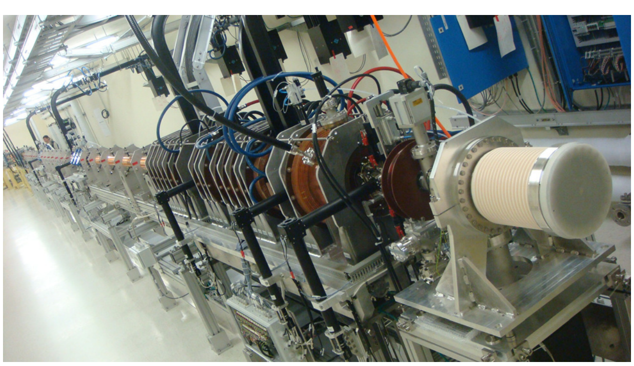

Figure 1: TPS 150 MeV linac being installed and commissioning at accelerator test site.

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Table 1: Major Parameters of the Linac

Parameter	Specifications
Bunch train length (μs)	LPM: 0.2 to 1; SPM: ≤ 0.001 (FWHM)
Charge in bunch train (nC)	LPM : ≥ 5; SPM: ≥ 1.5
Energy (MeV)	≥ 150
Pulse to pulse energy variation (%)	≤ 0.25 (rms)
Relative energy spread (%)	≤ 0.5 (rms), ±1.5 (full width)
Normalised emittance (1δ) (πmm mrad)	≤ 50 (both planes)
Repetition rate (Hz)	1 to 5 (adjustable)
Pulse to pulse time jitter (ps)	≤ 100
Pulse purity[1]	< 1% of main pulse charge

LPM: Long pulse mode; SPM: Short pulse mode

[1]with subharmonic pre-bunching system in 500 MHz buckets

LINAC DIAGNOSTICS

The linac is being installed and commissioning at the test site for acceptance. There are varying beam instrumentations, that comprise of five YAG:Ce screen monitors (SM) for beam position and profile observation by using a CCD camera which comply with GigE Vision standard, two Faraday cups at front of the subharmonic pre-buncher and 1st section of bunching section for monitoring intensity distribution and one integrating current transformer (ICT) for monitoring total bunch train charge. Wall current monitors (WCM) formed by equally spaced broadband ceramic resistors mounted on a flexible circuit board, wrapped around a short ceramic break, will also give information on beam charge as well as longitudinal profiles of electron bunches. Linac diagnostics are summarized in Fig. 2 and Table 2. All of these mentioned diagnostics will be provided by the vendor. Acceptance test of the linac system will be performed at a temporary site near the TPS main building and moved to the TPS building later after its completion. It is also planned that beam position monitors (BPMs) might be added between accelerator sections. These BPMs will be useful for RF phasing monitoring, feedback control and on-line beam position jitter observation.

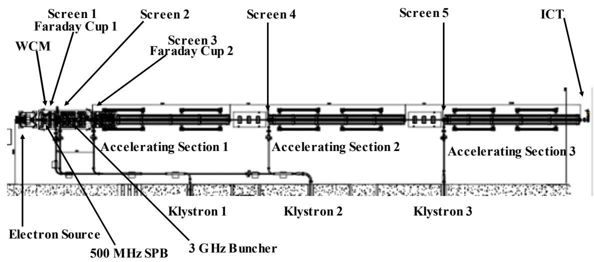


Figure 2: Diagnostic devices layout for the TPS linac.

Table 2: Linac Diagnostic Devices and its Functionality

Device	Quantity	Beam parameters
YAG:Ce screen	5	Position, profile
WCM	1	Intensity distribution at exit of electron source
Faraday Cup	2	Intensity distribution
ICT	1	Charge at exit of the linac

TRANSFER LINE FOR ACCEPTANCE TEST

Since the linac is being installed and commissioning is starting, a test transport line was installed ready for acceptance test. Diagnostic devices of this test transport line include beam charge, position stability, bunch pattern, energy and energy spread, and emittance. To fulfill these goals, various diagnostic devices were installed as shown in Fig. 3. Functionality of these devices is summarized in Table 3.

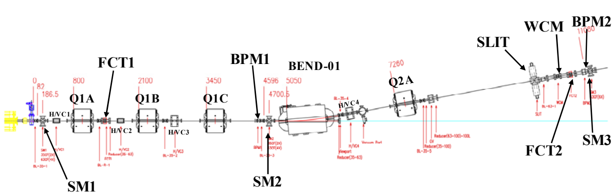


Figure 3: Functional block diagram of the temporary transport line for acceptance test.

Table 3: Test Transport Line Diagnostic Devices

Device	Quantity	Beam parameters
YAG:Ce/OTR screen	3	Position, profile
FCT	2	Beam intensity
BPM and single pass electronics	2	Beam position
WCM	1	Intensity distribution
Energy define slit	1	1 pair of horizontal jar

The YAG:Ce fluorescence screens will provide information on beam position and profile. The OTR screens are also considered to be used for high precision of beam emittance and energy spread measurement at the diagnostic branch of the LTB and to avoid saturation of YAG:Ce screens. The beam trajectory will be monitored with beam position monitors (BPMs) equipped with Libera Brilliance Single-Pass [2]. The fast current transformer (FCT) and wall current monitor (WCM) will provide information of beam intensity and beam intensity distribution, respectively.

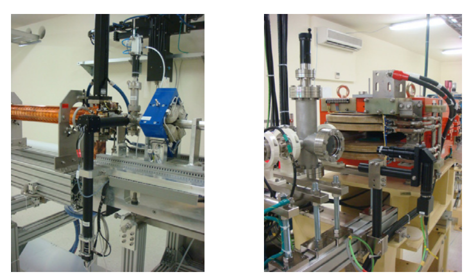
HIGHLIGHT OF SOME DIAGNOSTIC DEVICES

Diagnostic devices of the linac are provided by the RI Research Instruments GmbH as turn key solution. Goal of the diagnostic for the test transport line is to measure beam parameters at the linac output beam for acceptance test. Some diagnostic devices are highlight in here.

Screen Monitor

Beam profile in the linac is measured by five YAG:Ce screens. The screen is mounted at 45° against beam direction and driven by a pneumatic driver. The fluorescence light goes out in horizontal direction. The optics consist a refraction mirror bend the light 90° to the 75 mm lens and GigE Vision camera. The typical layout of the screen monitor is shown in Fig. 4(a).

Screen monitor of the test transport line at early commissioning stage is 25 mm diameter YAG:Ce screen with 0.5 mm thickness. This screen is mounted at a manual driven mechanism. This provision solution will be used at early stage of the beam test due to tightly schedule. The typical layout of the screen monitor is shown in Fig. 4(b).



(a) (b)

Figure 4: (a) Linac screen monitor and (b) test transport line screen monitor.

Screen monitor with YAG:Ce and OTR dual-position screen will replace the current simple screen later due to delivery delayed. The dual-position screen is commercial product made by RadiaBeam [3], and will be mounted on and driven by a motorized stage. The beam is normally incident to the YAG:Ce screen, a 45° mounted mirror will reflect the fluorescence light to the optics and camera. The OTR is mounted 45° against the beam. It is expected that this design will provide a better resolution. The OTR will delivery a much higher threshold of saturation level. The layout of the dual-position screen is shown in Fig. 5.

GigE Vision cameras are used to capture images. A dedicated EPICS IOC is used to acquire images and delivery waveform process variables (PVs) which represent the images. The image analysis IOC embedded Matlab environment to perform image processing and analysis. The screen monitor analysis GUI as shown in Fig. 6, has been developing and has various features including specify region-of-interest (ROI), optional background subtraction, 3D image viewing, and software multiple exposure. It also can create a simulated beam image for the purpose of evaluating the fitting correctness. All fitted parameters will be stored as EPICS PVs such that clients can easily access it for further usage.

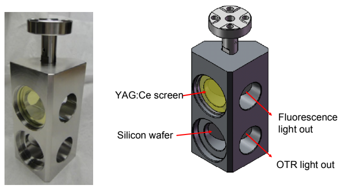
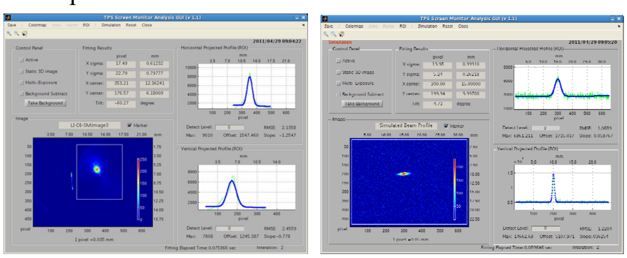


Figure 5: Dual-position screen assembly. The upper part is YAG:Ce working in normal incident, fluorescence is reflected to camera horizontally by a mirror installed the 45^o position. The silicon wafer coated with aluminium layer install at 45^o position used as OTR radiator is in the lower part.

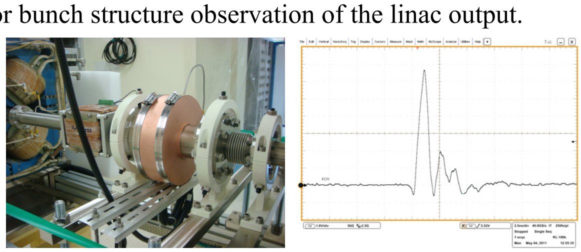


(a) Real beam (b) Simulated beam

Figure 6: Screen monitor analysis user interface.

Intensity Monitor

One WCM and two Faraday cups are located at the downstream of electron gun to monitor the bunch structure of 90 keV electron bunches. A Bergoz's ICT [4] is mounted at exit of the linac as a total beam charge monitor. Two Bergoz's FCTs are installed at the test transport line for transmission measurement as shown in Fig. 7. A WCM is installed near the end of transport line for bunch structure observation of the linac output.

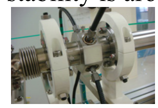


(a) Installed FCT1 (b) Observed single bunch signal

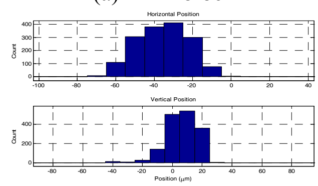
Figure 7: FCT and its signal at the test transport line.

Beam Position Monitor

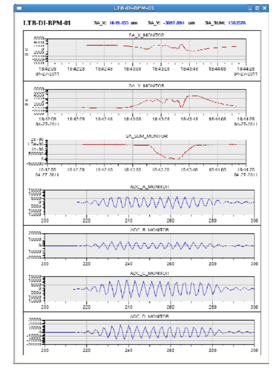
Button type BPMs were implemented by using ESRF 10 mm button. The Libera Brilliance Single-Pass is used to process the picked up signals. The beam position will be used for beam position and beam position stability measurements. The BPM located at the dispersion region can be use to monitor energy stability of the beam. The BPM assembly and data reading are shown in Fig. 8. The position stability is around 50 μm.



(a) BPM block



(b) Histogram of the position reading for 1500 shots at 5 Hz rate



(c) BPM data reading

Figure 8: BPM block and data at the test transport line.

Energy and Energy Spread Measurement

Current transport line configuration supports several possibilities for energy and energy spread measurements. Beam deflect by the bending magnet, with known integral field of the bending magnet, it can decide the energy on the position of the beam centroid by the profile of the YAG:Ce screen before the beam dump. De-convolute the beam profile with the beam size, it can determine the energy spectrum. The energy spectrum can be also measured by scan the bending magnet setting, the integrated signals of the FCT or beam profile monitor with the help of slits which also can measure the energy spread. It is also measured by fixing the setting value of the bending magnet and scanned the slit center with fixed slit width.

Other Diagnostics

Beam emittance of the linac outlet will be measured by the quadrupole scan method. The screen monitor before the bending magnet will be used for precisely transverse profile measurement. It is also planning to measure the bunch length by streak camera.

SUMMARY

Summary of diagnostics for the TPS linac and the test transport line are presented in this report. Commissioning of the system is underway. After the beam test started in April, various shortages were observed include diffraction due to edge of the YAG:Ce crystal disk, response of the homemade WCM, etc. These observed defects will be done later.

REFERENCES

[1] Document 2008–BP-8067, "TPS Linac Technical Design Report", ACCEL Instruments GmbH.

[2] A. Kosicek, et al., "Libera Brilliance Single Pass Position Measurements", Proceedings of the PAC09, Vancouver, May 2009, TH5RFP055.

[3] Radiabeam: http://www.radiabeam.com.

[4] Bergoz: http://www.bergoz.com.