RF RESCUE OPTION FOR TPS LINAC

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Abstract

The 150 MeV linac of Taiwan Photon Source was commissioned in June 2011. It consists of 90 keV electron source, bunching system and three S-band accelerating sections driven by three high-power klystrons. The rf system is equipped with rescue option such that the rf power from second klystron can be split and fed into both accelerating section-1 and -2. The rescue operation will be needed in the event of a failure occurred at the first klystron. In this report, the rescue capability will be illustrated and the test results will also be discussed.

INTRODUCTION

The commissioning of the TPS (Taiwan Photon Source) 150 MeV linac was completed in June 2011 [1]. The performance of the linac fulfilled the beam parameters specifications. Furthermore, its operation capability has been explored in the past few months in terms of operation availability and the test-run result has been satisfactory. The linac consists of electron source, bunching system and three S-band accelerating sections driven by three rf stations. For routine operation, each of the rf stations-1, -2, -3 provide rf power for bunching section and first accelerating section, second accelerating section, third accelerating section, respectively. The rf system is equipped with rescue option, in case rf station-1 malfunctioned, such that the rf power from rf station-2 can be split and fed into both accelerating section 1 and 2. It is expected that the rescue mode operation can sustain the 150 MeV electron beam injection into the booster. The switchover time needed for the rf power redistribution arrangement should be efficient to minimize its influence to routine operation.

Recently, rescue mode operation of 100 MeV linacs at Diamond Light Source and Australian Synchrotron Light Source were reported while operating at lower beam energy 45 MeV and 74 MeV with satisfactory results [2, 3].

In this report, the system rescue capability will be illustrated and the test-run results will also be discussed.

RESCUE MODE OPERATION

The test-run procedure for rescue mode operation is briefly described in this section. As follow:

1) Shut off rf station-1, and then transfer the rf power from station-2 to bunching section and accelerating section-1 through waveguide switches.
2) Provide proper rf power and identify that the accelerating section-1 electron beam is energized to 50 MeV.
3) Provide available rf power from station-2 to accelerating section-2 for further increasing of electron energy. (35 MeV in this case)
4) Increase rf power from station-3 to accelerating section-3 such that the linac delivers 150 MeV electrons. (65 MeV in this case)
5) Examine major beam parameters for quality assurance.
6) Test for switchover and system restoring reproducibility.

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Figure 1: Photo of the TPS linac waveguides.

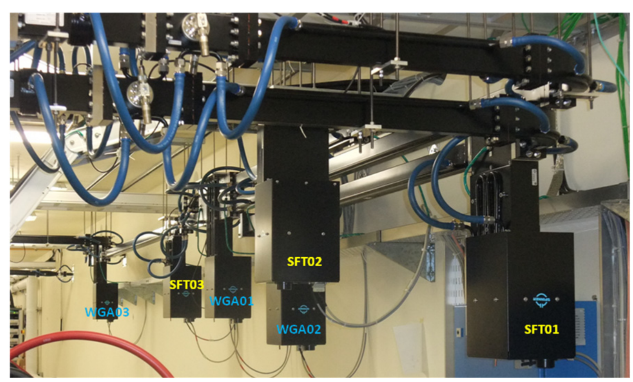

Figure 2: Photo of the waveguide configuration. WGA and SFT represent power splitters and phase-shifters, respectively.

RF Power Distribution

Photos of the rf waveguide configuration are shown in figure-1 and figure-2 where the power splitters and the phase-shifters involved in this study are indicated. The corresponding sketch of rf power distribution is illustrated in figure-3.

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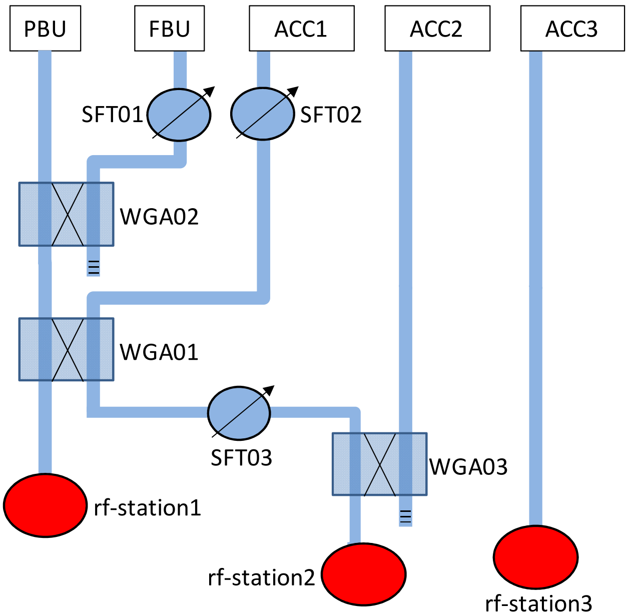

Figure 3: The sketch of rf power distribution.

50 MeV Electron Beam Identification

The diagnostics beamline [1,4] shown in figure-4 was setup for 50 MeV electron beam verification purpose at this stage. This 50 MeV electron was energized only by bunching section and accelerating section-1. The identification processes were carried out sequentially before and after the rf power was switchover from station-1 to station-2.

Verify Achievable Electron Beam Energy with only RF Station-2 Powering Accelerating Section-1 and Section-2

The rf power provided by the station-2 was increased and adequately distributed to both accelerating section-1 and section-2 for acquiring higher beam energy purpose. During this process, the beam energy was increased to available extended level and yet still comfortable with the rf station-2 operation while keeping the accelerating section-1 delivering 50 MeV electrons. Total beam energy of 85 MeV was achieved.

Supplement Beam Energy with RF Station-3

The rf power of station-3, feeding into accelerating section-3, was increased to obtain 150 MeV electron beam. The supplement of the needed rf power was befittingly achieved. As a result, the accelerating section-3 adds energy of 65 MeV to the electron beam.

BEAM PROPERTY MEASUREMENT

Measurements of typical beam parameters were carried out for both MB (multi-bunch) and SB (single-bunch) rescue mode operation. Quantitative analysis of the beam properties rely on the tools installed in the diagnostic beam line, as illustrated in figure-4. The measurement results are presented in this section.

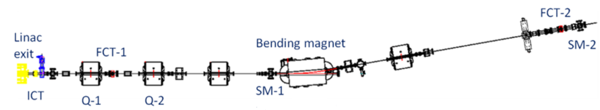

Figure 4: Layout of the diagnostics beamline.

Beam Energy, Energy Spread and Pulse to Pulse Energy Variation

The bending magnet acts as the analyzing magnet for beam energy determination and the associated beam energy spread is deduced from the beam size information observed at SM-2. The pulse-to-pulse energy variation is deduced from the beam position variation at SM-2. Typical examples of the beam size and beam center position readouts at SM-2 for MBM operation are illustrated in figure-5 and its 100 pulses histogram is given in figure-6.

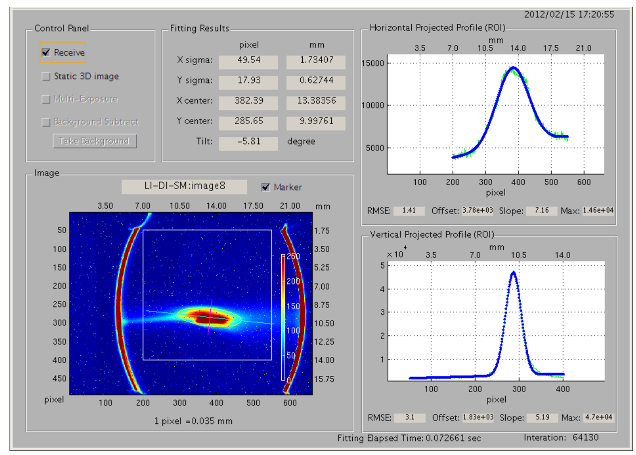

Figure 5: Beam shape observed at SM-2 for energy spread and energy stability measurements.

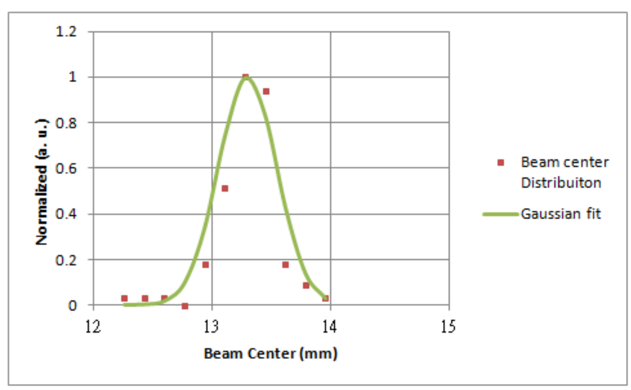

Figure 6: Histogram of beam center at SM-2 for energy stability analysis.

Normalized Emittance

The normalized emittance of the electron beam is determined from the beam size variation data in association with the quadrupole scans of Q-1 and Q-2 [5]. Typical example of the measurement is shown in figure-7 for MBM horizontal beam profile fitting.

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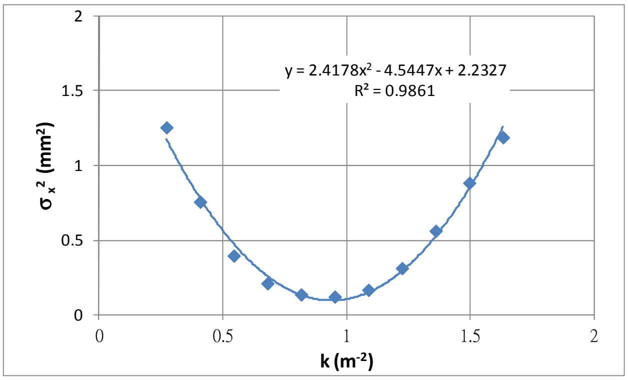

Figure 7: Beam size at SM-1 as a function of quadrupole strength for emittance measurements.

Measurement results for both routine and rescue modes operation are summarized in table-1. The performances in both cases are similar. The switchover time needed from routine to rescue mode operation would be within hour.

Table 1: Measured Linac Parameters

Parameter	Specification	Routine mode	Rescue mode
Bunch train length (μs)	0.2 to 1 FWHM ≤ 1 ns*	0.2 to 1 FWHM < 0.7 ns*	0.2 to 1 FWHM < 0.7 ns*
Charge in bunch train (nC)	≥ 5 ≥ 1.5*	>5 2*	>5 1.5*
Energy (MeV)	≥ 150	153	150
Pulse to pulse energy variation (%)	≤ 0.25 (rms)	0.07 0.08*	0.03 0.03*
Relative energy spread (%)	≤ 0.5 (rms)	0.3 0.2*	0.17 0.24*
Normalized emittance (1σ) (πmm · mrad)	≤ 50 (both plane)	(x, y)=(36, 47) (x, y)=(41, 36)*	(x, y)=(32, 56) (x, y)=(50, 45)*
Repetition rate (Hz)	1 to 5, adjustable	1 to 5, adjustable	measured at 3 Hz
*: SBM			

BOOSTER INJECTION AT 115 MEV

Other possible operation requests were considered if either rf station-2 or station-3 would fail. Test runs for individually adding 65 MeV electrons by either accelerating section-2 or section-3 were obtained while keeping 50 MeV electrons at the accelerating section-1. Total beam energy of 115 MeV was obtained in both cases. Since the rf power distribution of station-1 feeding into bunching section and accelerating section-1 requires further study, 115 MeV would be the beam energy available in this particular consideration. In this case, the booster injection energy would be changed from 150 MeV to 115 MeV instead. Further investigation on this scenario is required. The achievable electron energy of the possible cases is listed in table-2, where M1, M2 and M3 represent rf station-1, -2 and -3, respectively.

Table 2: The Achievable Electron Energy

Rescue Mode	Energy
M1 off, M2, M3 on	150 MeV
M1, M2 on, M3 off	115 MeV
M1, M3 on, M2 off	115 MeV

SUMMARY

The rescue mode operation of the TPS linac was successfully tested in providing 150 MeV electrons for downstream booster injection. Measurement results indicated that the corresponding beam quality sustains satisfaction as requested in the specifications. Other operation options were considered if rf station-2 or station-3 malfunctioned. In that case, the possibility of operating booster injection at 115 MeV requires further study.

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