# THE IMPROVEMENT OF NSRRC LINAC FOR TOP-UP MODE OPERATION

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*Abstract*

The performance of the 50 MeV linac at the National Synchrotron Radiation Research Center (NSRRC, Hsinchu) was examined and has been improved recently. The major improved items were 1) adopting a command-charging scheme to replace the resonance charging for the linac modulator; and 2) gun electronics. As a result, the beam quality was improved in terms of its energy spectrum and stability. The correlation between the improvement of beam quality and component upgrading is analyzed. The influence of the beam quality improvement to the recently proposed top-up mode operation in 2005 will also be discussed in this report.

## INTRODUCTION

The top-up mode operation is planned to be implemented at the National Synchrotron Radiation Research Center (NSRRC, Hsinchu) storage ring for users in 2005. The top-up operation is expected to reduce the influence of heat load variation at beamline components in comparison with the present refilling operation of storage ring beam current between 200 mA ←→100 mA. At present refilling operation, it takes about an hour before thermal effect on the beamline components become negligible to user experiments. After this 1 hour period, the storage ring beam current has already decreased to less than 180 mA. Also, during the following hours before next refilling, the beamline components suffer heat load variation. A typical example of this heat load effect at LSGM beamline is shown in Fig. 1 for illustration purpose. A photon beam vertical position monitor updates its reading every 5 minutes. Right after the refilling of beam current from 100 mA → 200 mA, the larger heat load at the beamline mirror moves the deflected photon beam to "higher" positions. After about 3 hours heat-accumulating duration, the mirror reaches thermal equilibrium state and the photon beam position becomes stable. As the beam current decreases, the heat load reduces accordingly and the deflected photon beam moves back to the "lower" positions.

Test runs of this mode of operation have been carried out in order to develop an optimal procedure for future implementation [1,2]. During the test runs, the storage ring beam current was maintained between 199.5 to 200 mA for over 24 hours. The beam current refilling process took place at every 2 minutes and the user interruption was about 1 seconds. It occurred that this continuous process was interrupted few times due to the desynchronizing of pulsed elements, such as injection and extraction magnets at storage ring and upstream booster as well as beam pulse from linac. Consequently, the reliability and stability of the pulsed elements at long period, continuous operation are essential to the success of top-up mode operation.

The NSRRC injector consists of 140 keV electron gun, 50 MeV linac, and1.5 GeV booster. The accelerated electron beam was guided through a 70 m transfer line and injected into the storage ring. Performance of elements involving in the injection process will directly contribute to the optimization of future top-up mode operation. Among which, reducing beam energy spread of the 50 MeV electron beam pulse from the linac to improve the injection efficiency into booster is emphasized in this report. The major improvement was to replace the original resonant charging power supply of the linac modulator by a command charging HV power supply. It is expected to improve the beam energy spread, system reliability, and reduce downstream radiation production in the future continuous top-up mode operation.

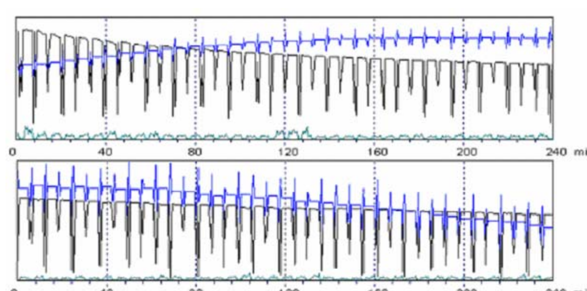

Figure 1: The largest signal on the upper left of the figure represents the measured photon current at the LSGM beamline. It decreases monotonically as the storage ring beam current decreases from 200 mA to 100 mA over the user shift of 8 hours. The mirror-deflected photon beam vertical position goes to "high" position right after the refilling to 200 mA and reaches steady a couple of hours later. It moves to "low" positions at the later half of the user shift as the storage ring beam current decreases.

## SYSTEM IMPROVEMENT

### *DC-charging power supply*

A functional block diagram of the 50 MeV linac and the associated components are shown in Fig. 2. The 140 keV electrons are accelerated by the linac to 50 MeV, guided with a 60 degree bend, and injected into the

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booster ring through a pulsed injection septum. Before entering the injection septum, the electrons pass through an adjustable slit which acts as a beam energy filter. The properly adjusted width of the slit defines a corresponding energy spread of the passing electron beam. The beam transfer efficiency can be optimized when the energy spread matches the acceptance of the downstream booster.

Presently, the routine user operation requires only beam injection at every 6 ~ 8 hours. User interruption of refilling storage ring beam current from 100 mA → 200 mA takes less than 5 minutes. However, for future top-up mode operation, both linac and booster are almost operating continuously. The interruption due to components failure could be fatal to the operation. Therefore, the optimal beam energy spread and its stability can greatly enhance the availability while operating at top-up mode.

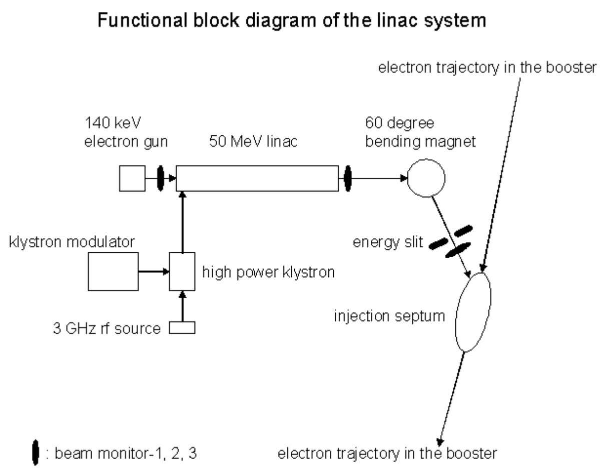


Figure 2: A functional block diagram of the linac and the associated components related to the stability discussion and verification.

As illustrated in the figure, the TH2100A klystron is capable of powering the 3 GHz rf signal up to 35 MW for electron acceleration in the linac and the associated modulator provides high tension for klystron operation. The high voltage stability applying to the klystron will directly influence the beam energy reproducibility of the linac. Consequently, reducing the voltage variation of the modulator will contribute to the improvement of energy spectrum of the accelerated electron beam.

The measurement result showed that the original modulator resonant charging circuit gave 1% voltage variation on both delivered PFN pulse (30 kV) as well as high voltage applied to the klystron (300 kV) [3]. Considering the fulfilling of the expected system reliability and the recent development of power electronic technique available in this field for linac operation, an EMI-303L [4] charging power supply was installed to replace the said resonant charging circuit mentioned previously. The EMI-303L gave < 0.1% stability at its output and the downstream klystron monitor indicated about 0.1% voltage stability over 4 hours operation duration.

### *Gun electronics*

The electron gun pulse has been operating steadily since 1992. It appeared sign of degrading of electron beam pulse generation in 2003 despite the fact that the electron gun cathode was replaced every year. The generated beam pulse intensity was not steady and causing difficulty in performing a stable operation. This phenomenon did not go away after installing a new cathode during winter shutdown in 2004. After careful examination, some degraded electronic parts for tuning of trigger circuit were identified and replaced. The electron beam pulse generation was performing well after this check out and was more stable than what it was in last year. The optimization of accelerator operation was then become possible.

## MEASUREMENTS AND RESULTS

### *Beam energy spectrum*

As indicated in Fig.1, the 60 degree bending magnet disperses electrons which has different energy around 50 MeV. The spread of electron beam trajectory is proportional to the energy difference of its normal value. By scanning the field strength of 60 degree bending magnet while monitoring beam signal variation at downstream monitor-3, the electron beam energy spectrum can be obtained. The measured result is shown in Fig. 3. It gives beam energy at 50 MeV with about 1% energy spread. This 1% energy spread is defined by setting width of the slit to be +/- 5 mm. Similar result appeared while performing the measurement at various width of the slit of +/- 7 mm and +/- 10 mm. It was surprising to note that no significant difference of the measured beam energy spectrum was observed with respect to the change of the width of slit. The above mentioned width of the slit +/- 5, 7, 10 mm corresponds to an effective energy filter of having beam energy spread of +/- 0.5, 0.7, 1%, respectively.

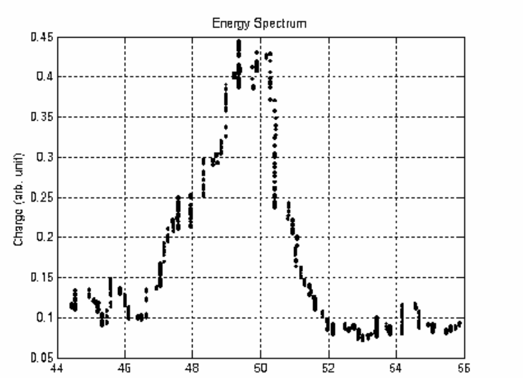


Figure 3: A typical measured energy spectrum of 50 MeV electrons with energy spread of 1%.

Calculation of the horizontal beam envelope from linac exit to the energy slit with various beam energy spread is given in Fig. 4. Considering the difference between the calculated beam envelope as a function of the width of the slit and the measured beam energy spectrum which is insensitive to the change of the width of the slit larger than +/- 5 mm, it is very likely that a large portion of the 50 MeV electrons sit within energy spread of +/- 0.5% (1%, peak to peak). Further verification will be done by going to smaller widths of the slit with slight modification of the control system.

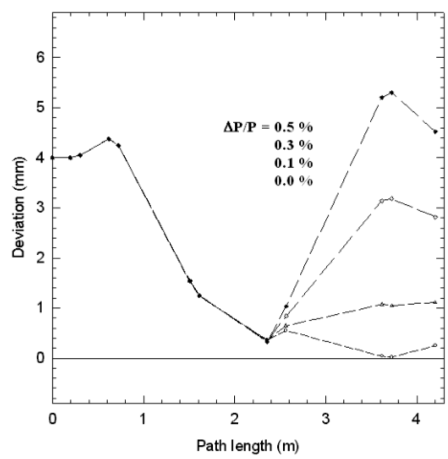


Figure 4: The calculated electron beam envelope with various energy spread consideration.

### *Electron pulse stability*

Fig. 5 shows the data recorded after the gun pulse electronic circuit check out. The measured beam signals at linac entrance, exit, and after energy slit indicating an optimal and steady electron beam generation along its acceleration trajectory. As indicated in Fig. 5, the 60 degree bending magnet disperses electrons which has different energy around 50 MeV. The spread of electron beam trajectory is proportional to the energy difference of it normal value. By scanning the field strength of 60 degree bending magnet while monitoring beam signal variation, a measured beam energy spectrum can be readily obtained.

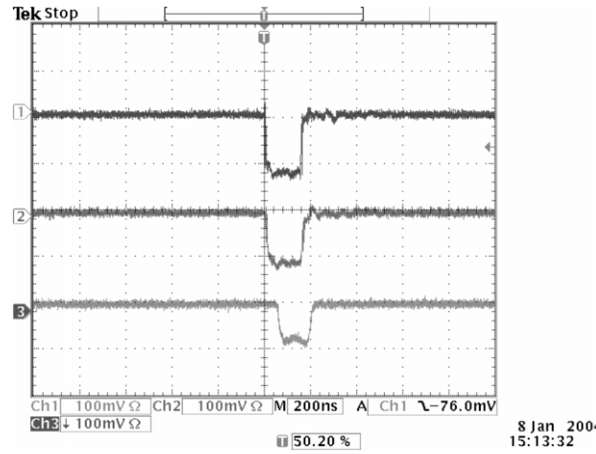


Figure 5: Pulsed electron beam signal recorded by beam monitors located at 1) linac entrance; 2) linac exit; 3) behind energy slit.

## DISCUSSION

The linac modulator resonant charging power supply has been replaced by a command charging power supply. It provides better stability of the delivered high voltage pulse. It is easy to control and convenient to maintain from operational view point. The measured result showed that the high voltage pulse stability was improved from 1% to 0.1%. Comparison between the measured beam energy spectrum and the calculated beam envelope implies that the beam energy spread is about 1% after the power supply upgrading. Further verification will be carried out as the equipment is available. The check out of the gun electronic circuit has restored its performance and is crucial to system optimization for preparing top-up mode operation.

## REFERENCES

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