PREINJECTOR PERFORMANCE IMPROVEMENT IN NSRRC

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Abstract

The 50 MeV preinjector of the National Synchrotron Radiation Center was operated since 1991. To satisfy the stringent requirements for top-up operation and to provide better filling pattern control of the storage ring, upgrade the performance of the preinjector system was performed recently. Command charging scheme was adopted to replace resonance charging for the klystron modulator. In order to achieve better beam quality, improving the microwave system is underway. A beam charge integrator has been installed to monitor routine operating performance. These efforts and status of the NSRRC preinjector are presented in this report.

INTRODUCTION

The top-up mode operation of the storage ring at the National Synchrotron Radiation Research Center (NSRRC) will be implemented in 2005. In order to fulfill the stringent requirement of top-up operation, a stable refilling beam current provided by booster on cycle-to-cycle basis and the control of filling pattern in the storage ring are essential for this type of operation. A stable electron beam provided by the preinjector will directly contribute to the operation requirements.

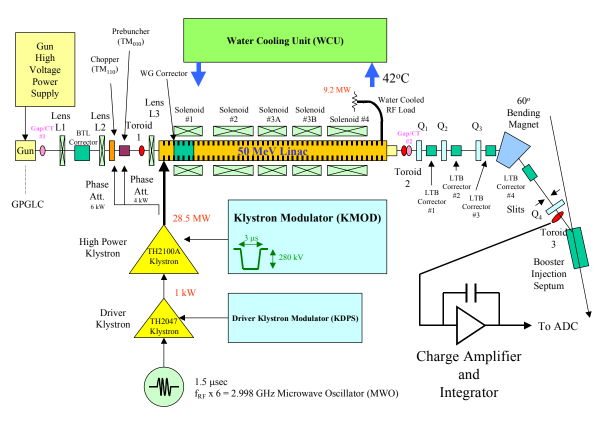

Figure 1: Synopsis of the preinjector, plus its diagnostics.

The NSRRC preinjector consists of a 140 kV thermionic electron gun, a microwave system, a klystron modulator, and accelerating tube. Figure 1 shows the layout of the perinjector including diagnostic elements. The accelerated beam energy exit from the preinjector is 50 MeV. Table 1 gives the main specifications of the preinjector.

The preinjector upgrade purpose is to improve its performance so as to satisfy the requirements of top-up mode operation.

Table 1: Main specifications of the preinjector

GENERAL SPECIFICATIONS	
Linac operation frequency	2997.9 MHz
Klystron peak rf output power	30 MW
Nominal pulse repetition rate	10 Hz
Loaded beam energy	50 MeV
Accelerator waveguide rf filling time	780 ns
Accelerator waveguide stored energy	13 joules
Normalized geometric beam emittance	100 π mm-mrad

IMPROVING THE PERFORMANCE OF THE PREINJECTOR SUBSYSTEMS

Linac Cooling Water System

The resonance frequency of the copper accelerator tube is sensitive to the temperature change. Therefore the rms temperature variation of the accelerator tube should be maintained within 0.1°C. The accelerator tube is equipped with a dedicated closed loop cooling system, which keeps temperature at 43°C. A PID regulator is userd to control the cooling water flow rate. Excess heat is removed by the primary chilled water of the heat exchanger. Figure 2 shows archive temperature readings of 0.25°C variation (peak-to-peak). It will be further reduced by optimizing the parameters of PID regulator.

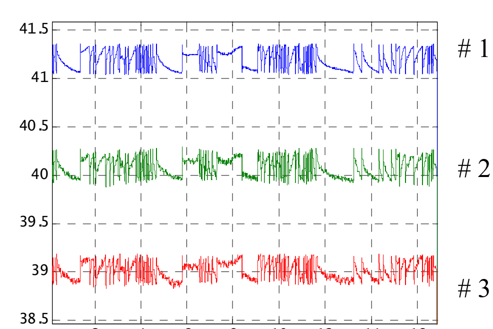

Figure 2: Temperature variations of accelerator tube at three locations, entrance, center and exit. Temperature readings at #2 and #3 are offset by –1°C and –2°C respectively for clarifying purpose.

Klystron Modulator Upgrade

The high voltage power supply of klystron modulator consists of variac transformer, high voltage transformer, rectifier, and de'Qing circuit. The variac transformer was controlled via variac motor with tuning range of 0 ~ 380V. The variac transformer output was connected to the primary side of high-voltage (HV) transformer. The transformer secondary output was 20kV 1.2A. The AC voltage of transformer output was rectified to DC voltage 30kV. In order to keep the PFN output stabilize, the de'Qing circuit is needed.

Most of the power electronic circuits were degrading since their operation ten years ago. It is important to improve the situation and upgrade the system for better performance. Consequently, the EMI-303L power supply was installed to replace variac transformer, HV transformer, rectifier and de'Qing circuits in July 2003. Figure 3 shows the typical pulsed high voltage signal at the klystron output. The PFN-HV reading using resonant charging shown in figure 4 indicates that the variation was quite large. After replacing it with the command charging EMI-PS, the variation was significantly reduced.

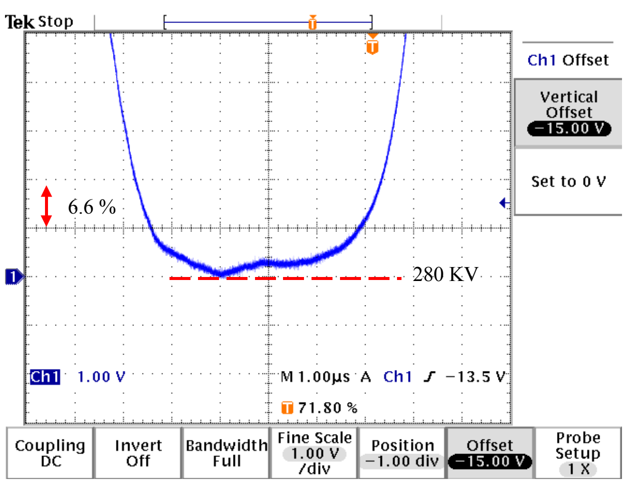

Figure 3: Typical HV pulse shape at the klystron output (offset –15V).

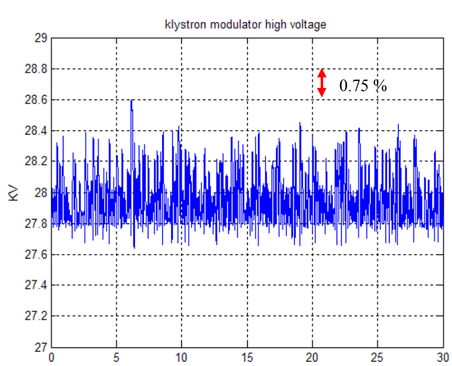

Figure 4: The variations of klystron HV modulator using resonance charging scheme.

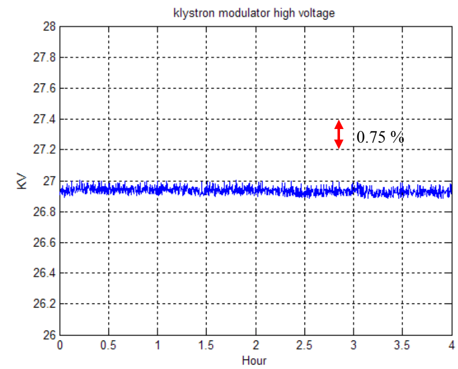

Figure 5: Long-term test of the klystron modulator high voltage after installing EMI-303L.

Figure 5 shows a long-term test result of the klystron modulator HV stability by using an EMI-303L power supply. The high voltage fluctuation is less than 0.1 KV. Figure 6 shows the histogram. Maintaining a quality HV of the klystron modulator will help to improve the performance of the preinjector.

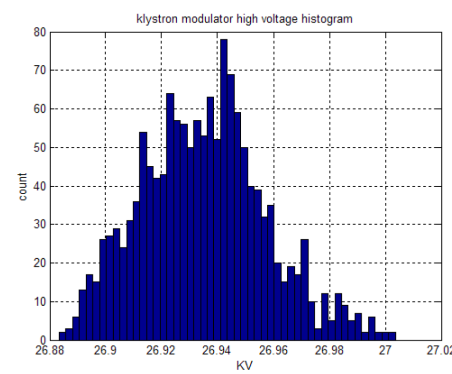

Figure 6: Long-term test of the klystron modulator high voltage histogram by EMI-303L.

Linac Microwave System

The microwave system is designed to produce the rf power for accelerating electron beam in the linac.

A Thales TH-2100A klystron was used to provide the required rf power of 35MW for linac. The linac operation frequency was 3GHz. The driving rf signal is shown in Fig7. The measured electron beam signals at the gun exit, entrance and exit of linac are given in Fig8. The transmission efficiency of linac was estimated to be about 80% before installing EMI-303L. It was greatly improved after using EMI-PS and the result is shown in Fig6. The linac beam transmission efficiency was over 90%.

The system consists of the klystron, the subsystems for the klystron, a frequency multiplier from 500 MHz to 3 GHz for the klystron drive system, a high-tension modulator and a transmission line to the accelerator.

Figure 7 shows the measured power waveform of the microwave power at the inlet of the linac. The unknown ringing may reduce the quality of the beam. The system is being monitored to observe the microwave power and phase. The peak-to-peak fluctuation is about 40 mV. It will potentially influence the fluctuation of the booster beam current intensity. The stability of the microwave system is currently being improved.

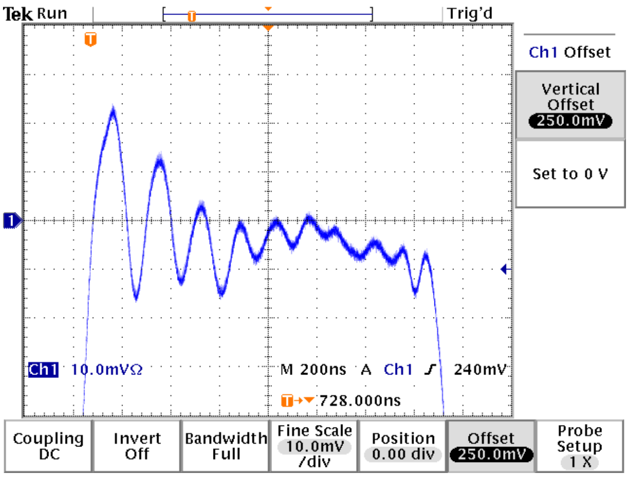

Figure 7: Linac microwave input (offset: 250mV).

MEASURING THE PERFORMANCE OF THE PERINJECTOR

Three current transformers were installed at both entrance and exit of the linac, and after the energy slit to monitor the beam transmission efficiency of the preinjector system. Figure 8 shows a typical example of the measurement result of these monitors. Usually the transmission of the linac exceeds 90%. However, the transmission from the exit of the lianc to the exit of energy slit was about 60%, as shown in figure 8. The energy slit was set to permit electrons to pass through with energy spread of less than 0.5%. A simple energy spread measurement system was setup to investigate the energy spectrum of the preinjector system. The output of the current transformer is connected to a charge integrator to monitor beam intensity. The measurement was carried out by scanning the magnetic filed strength at upstream of energy slit. Figure 9 shows the measured result of beam energy spectrum.

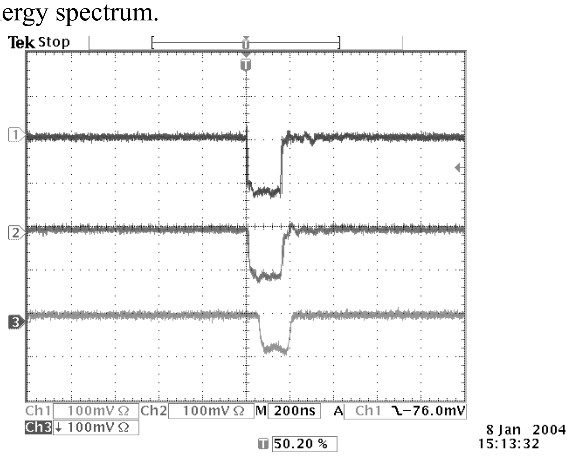

Figure 8: The signals of beam intensity monitor at linac entrance (Ch1), linac exit (Ch2), and energy slit exit (Ch3).

Considering the measured beam energy spectrum of figure 9 and the operation energy slit setting at 0.5%, the measured beam transmission efficiency of about 60% at the energy slit is well understood. The origin of the relatively wide energy spectrum, after installing the EMI-303L charging power supply, needs further study.

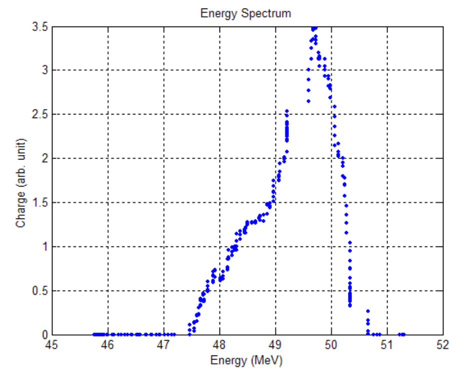

Figure 9: The energy spectrum of beam monitor 3.

SUMMARY

The performance of the preinjector has been improved by replacing the resonance charging circuit in the klystron modulator with a command charring EMI-303L power supply. The monitored HV readings show a factor of 10 improvement on its stability. This improvement will benefit to the beam quality improvement of the preinjector. The transfer efficiency of the accelerated electron in the linac exceeds 90% and the beam energy spectrum was measured and presented in this report. Only 60% of the accelerated electrons are within the energy spread of 0.5%. One of the possible causes, which affect the quality of beam spectrum, was allocated to be the cleanness of rf signal. Further study and necessary improvement on the preinjector rf system will be carried out in order to fulfill the stringent requirements of top-up mode operation in 2005.

REFERENCES

[1] T. Asaka, et. al., “Stabilization of the rf system at the Spring-8 linac”, Nuclear Instruments and Methods in Physics Research . Sec. A, No. 488, pp. 26 – 41, 2002.