PLSII LINAC RF CONDITIONING STATUS*

Heung-Soo Lee, Woon Ha Hwang, Jung Yun Hwang, Seunghan Shin, Sang Hee Kim, Hyung-Gyun Kim, Seung Hwan Kim, Sung-Ju Park, Young Jung Park, Kyungryul Kim, Sang Hoon Nam, Won Namkung, Soung Soo Park
Pohang Accelerator Laboratory, Pohang, Kyungbuk 790-784, Korea

Abstract

PLS linac has been upgraded in energy from 2.5 to 3.0 GeV. A klystron supplies RF power of 80 MW to four acceleration structures through a SLED. But our machine is not enough RF power to get 3 GeV beam energy. So we have changed the RF scheme in four modules as a klystron supplies RF power of 80 MW two accelerating structures through a SLED. There were several problems during the RF conditioning and beam operation. So we will describe the conditioning results and the current status in this paper.

INTRODUCTION

The PLS project was begun on April 1, 1988 and completed in 1994. After commissioning for about a year, we started user service on September 1, 1995. During the user service for five years, the user's demands for high flux x-ray have increased. Therefore, we ramped up the energy of the storage ring from 2.0 to 2.5 GeV. And finally, we began to inject 2.5 GeV electron beam in the storage ring directly after a couple of years by installing a modulator and a klystron feeding RF in two accelerating structures.

Table 1: PLS Chronology

Event	Date
Project started	Apr. 1 1988
Ground-breaking	Apr. 1 1991
2 GeV Linac commissioning	June 30 1994
Storage ring commissioning	Dec. 24 1994
User service started	Sept. 1 1995
Energy ramping to 2.5 GeV	Sept. 1 2000
2.5 GeV injection	Nov. 1 2002
3 GeV Linac rf conditioning	May 1 2011
3 GeV Linac commissioning	June 1 2011
3 Storage ring commissioning	July 1 2011

After 7 years operation for users, we decided to upgrade the PLS for 3 years. So, we planned two year preparation and a year shutdown of the PLS. And we changed the lattice of the storage ring and the number of the insertion devices from 10 to 20. Also the beam energy of the new machine was increased from 2.5 to 3.0 GeV. Consequently, this storage ring requires 3.0 GeV Linac as an injector [1].

*Work supported by MEST (Ministry of Education, Science and Technology) and POSCO.

LINAC UPGRADE FOR PLS-II

The Linac building has a limited length because the original Linac was a 2.0 GeV machine with 11 klystron feeding RF to 42 accelerating structures as like as Fig. 1. The average accelerating gradient is about 16 MV/m in the accelerating structure. We increase the Linac energy from 2.0 to 2.5 GeV by adding two accelerating structures and elevating the operating voltages of the klystrons. The average accelerating gradient became to 19 MV/m.

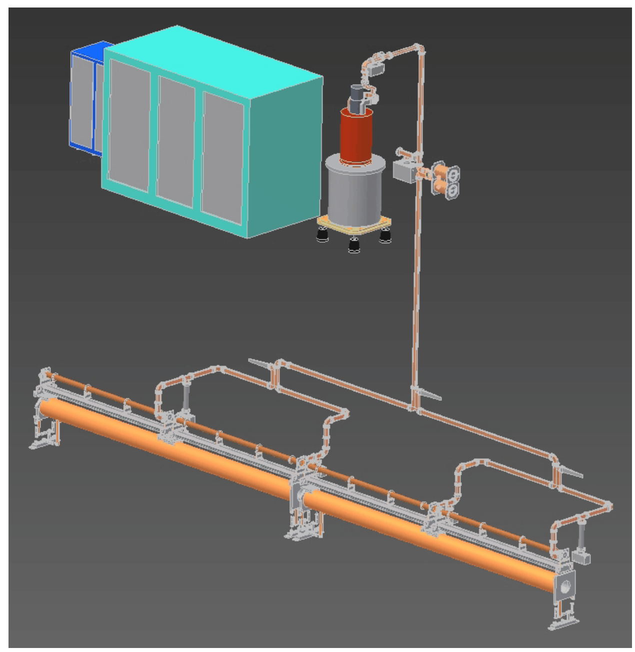

Figure 1: Layout of the RF system of the PLS Linac.

We installed two more accelerating structures for the PLSII Linac. There is no any more space in the length after this. So, we can get 46 accelerating structures for the PLS II Linac. In this case, the required averaged accelerating gradient is about 22 MV/m. If the maximum output power of an 80 MW klystron is fed in 4 accelerating structures through a SLED which has the beam energy gain of 1.5, the available maximum accelerating gradient is about 22 MV/m. In such case, it is impossible to operate all klystrons at the rage of the maximum out-put power. Hence, we added four klystrons by separating the accelerating structures as shown in Fig. 2 to get the electron beam with the energy of 3.0 GeV safely.

Finally, the PLSII Linac is composed of sixteen klystrons, fifteen SLEDs and forty six accelerating structures. Ten klystrons feed RF to two accelerating structures through SLEDs and the others except the

ISBN 978-3-95450-115-1

injector klystron supply RF to four accelerating structures. And the eight existing modulators so called "'Line Type Modulator" [2] supply electric power to the klystrons which supply RF to four accelerating structures. The other eight modulators called "Invert Type Modulator" were installed which is more compact in size than the line-type due to the limited space problem in the Linac gallery.

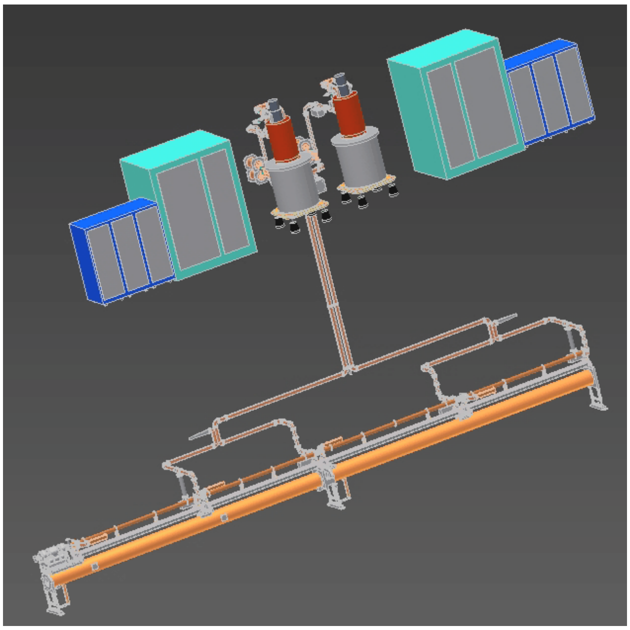

Figure 2: Layout of a modified RF system for the PLSII Linac.

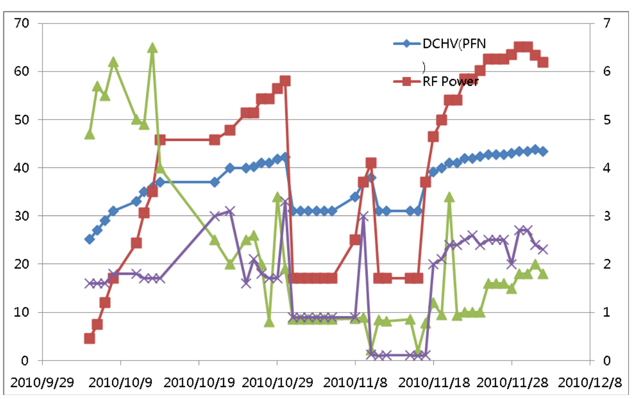

Figure 3: RF conditioning data of 11A module (◊:DC high voltage, □:RF output power, Δ:gallery vacuum, ×:tunnel vacuum).

LINAC RF CONDITIONING

There was a structural alteration in the 11th modulator system of the PLS Linac during the summer maintenance period in 2010 before doing the shutdown of the main machine for upgrading the PLS machine. Figures 3 and 4 are showing the process of increasing RF power after the structural alteration of the RF waveguide network system. There are several deep drops in input RF power due to the arcing coming from RF components such as RF windows and a SLED which were installed newly. The time required to get to about 60 MW of RF input power was about a month in the 11A.

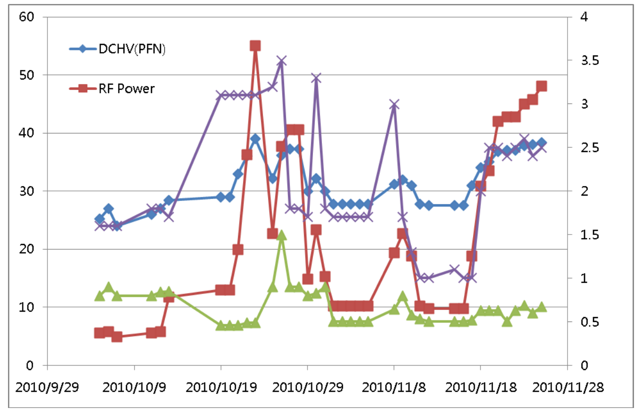

Figure 1: RF conditioning data of 11B module (◊:DC high voltage, □:RF output power, Δ:gallery vacuum, ×:tunnel vacuum).

In 11B case, it took three weeks to reach the about RF input power of 55 MW. But unfortunately, there was a big arcing, so we reduced the RF input power as shown in Fig. 4. After finishing the structural alteration and commissioning of the 11th module of the RF system, the machine was made shutdown after three months operation for upgrading it for six months on December, 2010. We did structural changes for 9th, 10th modules and added a module where a klystron feeds RF power to two accelerating structures. Figure 5 is showing the conditioning results for the 9B. We had arcing troubles during commissioning and operating it as shown in Fig. 5.

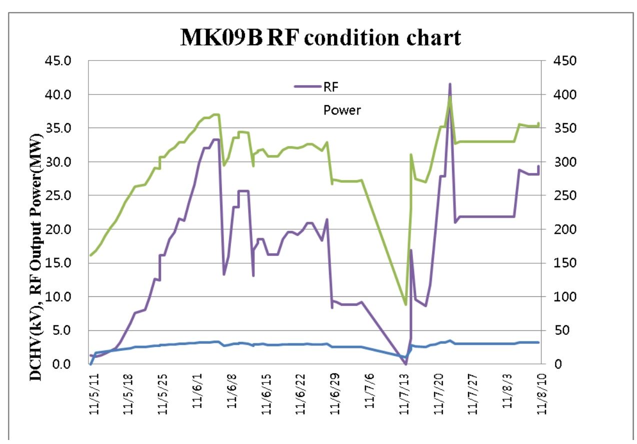

Figure 5: RF conditioning data of 9B (green: modulator current, violet: klystron RF output, blue: modulator DC high voltage).

Also, recent data of operating conditions were displayed in Fig. 6 on February 29th, 2012. The input RF power of the 10A is lower than other modules. The reason of voltage steps of the modulators between the 8th to 9th modules are due to the different modulator types as explained above. Therefore, there is two times difference in the DC voltage of the electric power source between types.

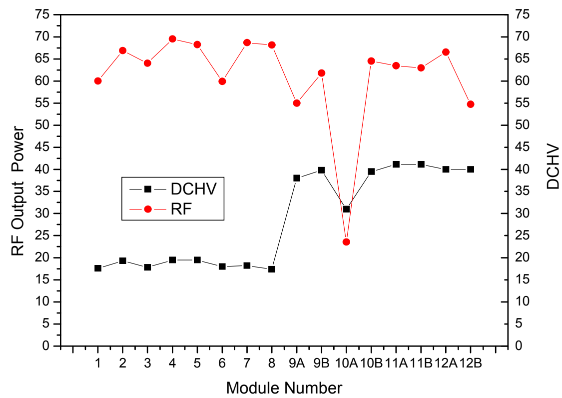

Figure 6: RF input power and DC high voltage of the modulator (February 29th, 2012).

RF CHARACTERISTICS OF PLSII LINAC

Recently on May 7th, 2012, we measured the RF characteristics of the PLSII Linac with a phase and amplitude detector developed at home. The measured data were displayed in Figs. 7, 8. The RF amplitude and phase stabilities of all klystrons were measured through the directional couplers located between a klystron and a SLED at each module. And we did the same process through the directional coupler of the SLED output port. Each measurement was done for two minutes. All data are rms values. Also, those data were measured for 0.5 micro-second after reversing RF phase through a PSK which can reverse 180 degree in RF phase. The results are displayed in Fig. 7.

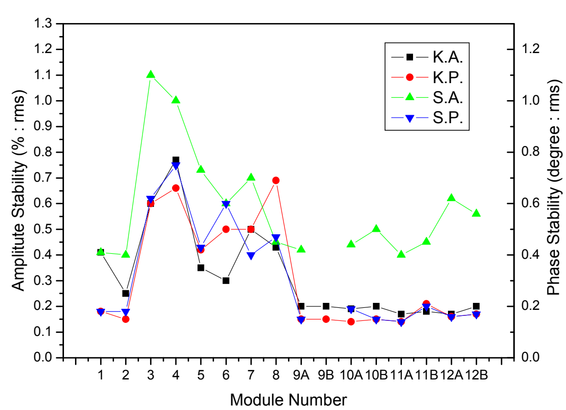

Figure 7: RF amplitude and phase stabilities before and after the SLEDs of the PLSII Linac (K.A.; RF amplitude stability before the SLEDs, K.P.; RF phase stabilities before the SLEDs, S.A.; RF amplitude stabilities after the SLEDs, RF phase stabilities after the SLEDs).

The amplitude and phase stabilities of RF from the 3rd to 8th module are two more times worse than the others because those are not working a deQing function. But the 1st and 2nd have the deQing function and the modulators from the 9th to 12th are the invert type modulators.

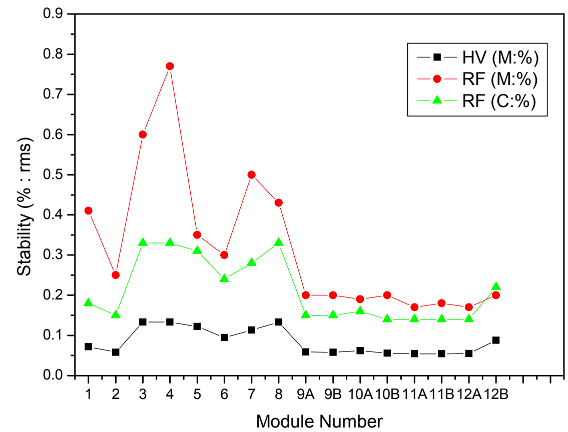

Figure 8: RF stabilities of the PLSII Linac (HV (M): measured modulator high voltage stabilities (rms), RF (M): RF amplitude stabilities of the klystron out-put (rms), RF (C): RF amplitude stabilities calculated from the high voltage of the modulators ($p_k = \mu\kappa V_m^{2.5}$, p_k: klystron output, V_m: modulator voltage)).

We compared the RF amplitude stabilities and the high voltage stabilities of the modulators in Fig. 8. The calculated amplitude stabilities of the klystron from the modulator voltage stabilities are about two times smaller than the measured RF amplitude stabilities. We can guess that the half of the errors come from the RF driving power and other environment conditions.

SUMMARY

We upgraded the PLSII Linac from 2.5 to 3.0 GeV and commissioned it according to plan successfully. Now it is working as a 3.0 GeV injector for the PLSII storage ring. We measured RF parameters such as the RF amplitudes and phases of klystrons and estimated stabilities of them. The average variations of the measured RF amplitudes of the klystrons were about 0.32%. The average of the calculated variations caused by the modulators is about 0.21%. And the average phase variation of the klystrons is about 0.31 degrees.

REFERENCE

[1] K.R. Kim, "Current Status of PLS-II Upgrade Project: Accelerating System", the 14th ICABU, October 7-8 (2010).

[2] R. B. Neal, ed., "The Stanford Two-Mile Accelerator," Q. A. Benjamin, New York (1968).

ISBN 978-3-95450-115-1