Stability of the RF System at SPring-8 Linac

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1. Introduction

The stability of the beam energy and energy spread at both the 1GeV S-band linac and the 8GeV synchrotron ring are crucial factors for determining the injection time for the storage ring. Since the linac has a lot of high-power RF equipment, any drift of the output power and phase from the various RF equipment will affect the beam energy in usual beam operation.

We measured the output power and phase stability of the following RF equipment, i.e., the 7MW booster klystron drive system, the other high-power klystron drive system, and the 80MW klystron. In order to investigate the drift of the RF parameters in klystron, which can be influence by outside factors, the cooling water temperature and environmental temperature were also measured. In this paper, the composition of the RF equipments and the measurement result are described.

2. Beam stability

In order to investigate the stability of the beam current and energy at the 1GeV LSBT, the beam current was measured by using a wall current monitor placed at the 1GeV straight line and after the 1GeV bending magnet and using a beam slit to permit an energy spread of 1% [1]. The beam conditions for this measurement were pulse width of 1 μsec and a beam current of 20mA, at an energy of 1GeV within the 1% energy spread. The result of this measurement is shown in Fig. 2-1 .

Though there was no change in the operating conditions under the measurement, the beam trigger was stopped six times because of vacuum deterioration at the RF power line and over currents of the klystron modulator, etc. The drift of the beam current after the 1GeV bending magnet was observed to have a period of 25 minutes. In addition, beam drift for 10 hours was also observed. In the usual beam operation, this long time drift is readjusted by the power and phase of the last 80MW klystron (M18), which feeds into two 3m long accelerating structures. The following factors are considered as these drift factors; change of the vacuum pressure, drive line which depends on the environmental temperature, and the resonant frequency of the klystron cavities which depend on the cooling water temperature, etc .

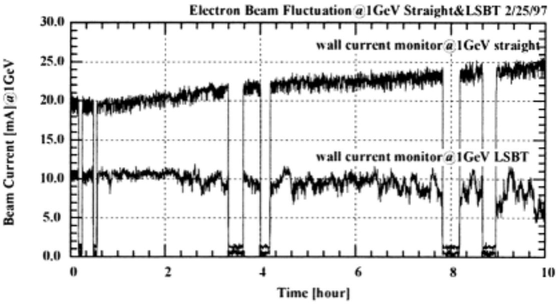

Fig. 2-1 Drift of a beam current at the 1GeV straight line and after the I GeV bending magnet, using a beam slit to permit on energy spread of I %.

3. Measurement system

The RF system of the linac consists of a 7MW booster klystron (MELCO PV2012) drive system, the other high-power klystron drive system, and a 13-set total 80MW klystron (TOSHIBA E3712). One klystron feeds into two 3m long accelerating structures with the exception being the HO klystron which feeds into a 3m long accelerating structure at the 60MeV pre-injector. In addition, the reference line is provided for the phase measurement and feedback system which are now under regulation [2].

The 2856MHz CW output of a master oscillator is divided into two signal lines. One of these lines is modulated by a 1~4μsec pulse width and 60Hz repetition rate by a PIN-diode pulse modulator, and the optimum input power of the booster klystron is adjusted by a 300W TWT amplifier. Another line provides for the reference line through a few watt CW amplifier.

The output power of the booster klystron is fed into two 2856MHz pre-buncher cavities and the 2856MHz standing wave 13-cell side couple-type buncher. In addition, this power is divided into the high-power klystron drive system from the wave guide with a 6dB directional coupler. The klystron drive system has a 70m wave guide (drive system) with directional couplers and feeds into the power attenuation/phase regulator IϕA) placed at each 80MW klystron. In order to reduce the influence of power fluctuations at the booster klystron, the input power of the 80MW klystron is set at the saturation point by IϕA. The 13-set klystron is operated in the region from 40MW to 60MW in usual operation [3].

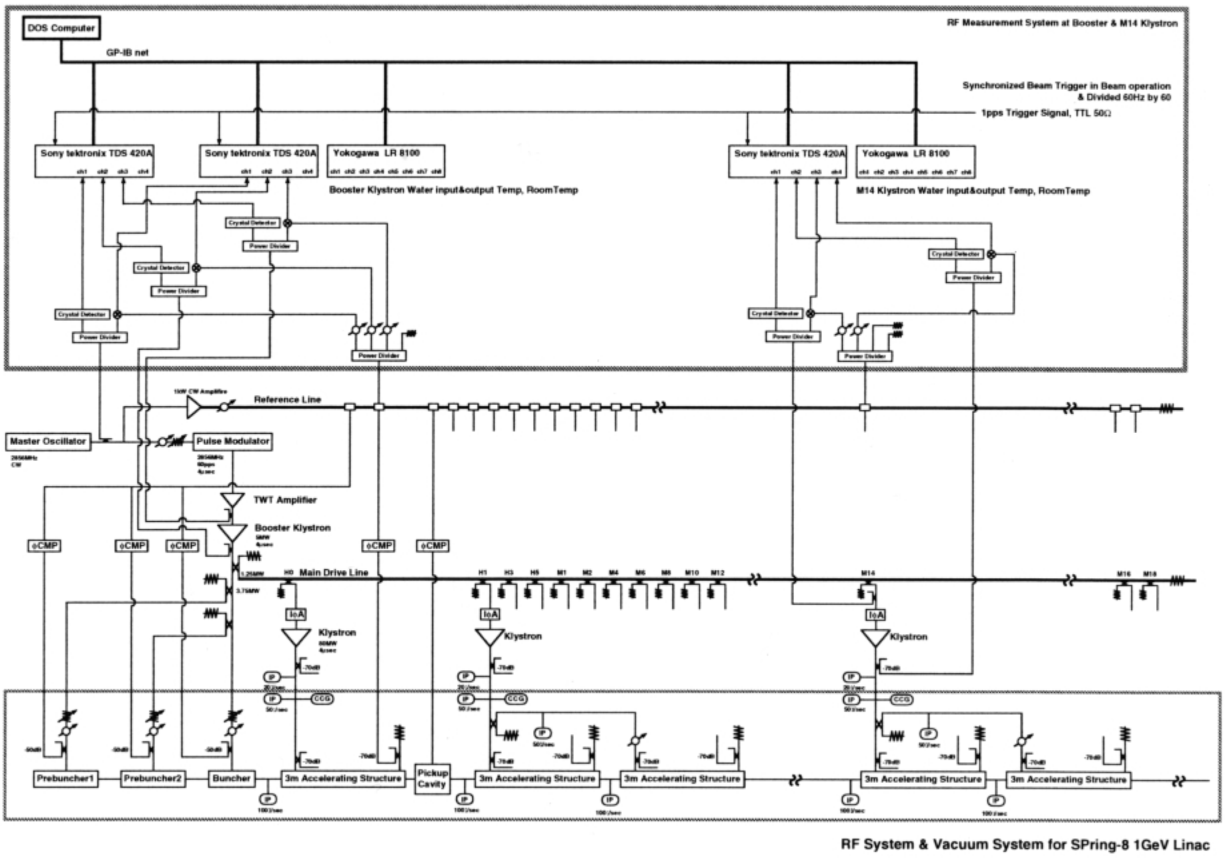

Fig.3-1 Schematic of RF composition and measurement system.

A schematic drawing of the RF composition and measurement system is shown in Fig. 3- -1. The RF power and phase were measured by using a calibrated crystal detector and a double balanced mixer. In particular, it was necessary to guarantee the phase drift of the reference line (design value was 0.25 degree/deg.c at 70m) with regard to the phase measurement. In order to confirm the high stability at the reference line, the phase was measured by a comparison between the input wave and reflected wave from the termination of the reference line was throughout one day. This measurement result was 0.8 degree/3.0 deg.c which was agreement with the design value. The following devices were chosen as the RF equipment for the measurement; master oscillator, TWT amplifier, booster klystron, drive line at the M14 klystron (about 60m from the booster klystron) and 80MW klystron (M14 klystron). In this measurement, the RF pulse width was set at 2.2μsec. The 2.2μsec pulsed signal from the crystal detectors and mixers was measured with 200MHZ oscilloscopes whose triggers were synchronized with the beam trigger. All of the oscilloscopes and the data-taking recorders for the temperature measurement are controlled by a sub-control computer (PC) through the GPIB. This data acquisition program was done for all of the oscilloscopes in the stop condition, in order to obtain the simultaneity of each RF equipment conditions, and the data acquisition was completed after compensation of the calibration value and attenuation level for the pulse signal from each piece of equipment. This series of measurements was operated routinely every 15 sec.

4. RF measurement results

This RF measurement was carried out during the period of one month. The power stability of the master oscillator and the TWT amplifier was less than 0.5 percent, equal to the accuracy of the measurement, and the phase stability was less than 0.2 degree equal to the accuracy of the measurement. Figure 4-1 shows example data of a phase drift of the drive line affected by the local environmental temperature.

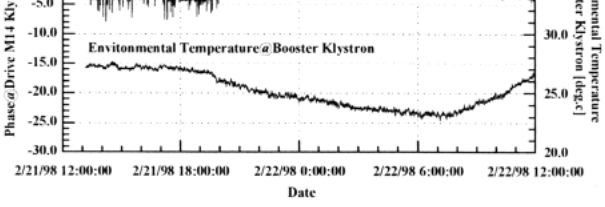

Fig.4-1 Phase of drive system for 80MW klystron dependence on the environmental temperature.

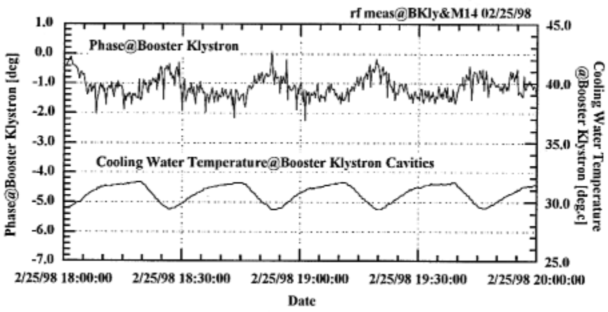

Fig.4-2 Phase of the M14 klystron dependence on the cooling water temperature.

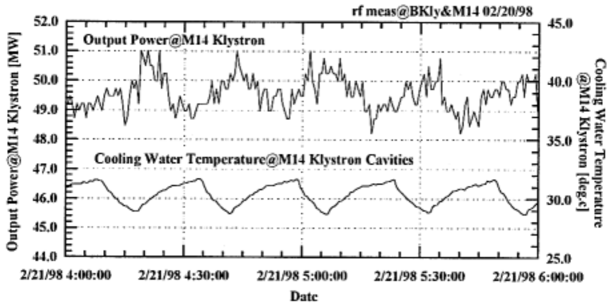

Fig.4-3 Output power of the M14 klystron dependence on the cooling water temperature.

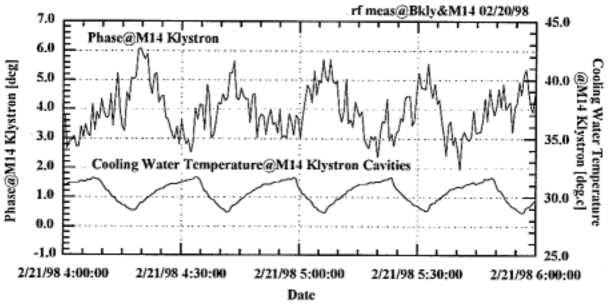

Fig.4-4 Phase of the M14 klystron dependence on the cooling water temperature.

The power stability for the booster klystron was also retained under 0.5 percent. However, the phase drift which depends on the cooling water temperature was 0.8 deg/deg.c with a period of 25 minutes as shown in Fig. 4-2.

In the M14 klystron, both the power and phase drift were not only affected from the cooling water temperature which had a period of 25 minutes, but an accidental shift also happened as shown in Fig.4-3, Fig. 4-4, and Fig. 4-5. This accidental shift was affected by fluctuations of the high voltage at the pulse modulator for the 80MW klystron as shown in Fig.4-6.

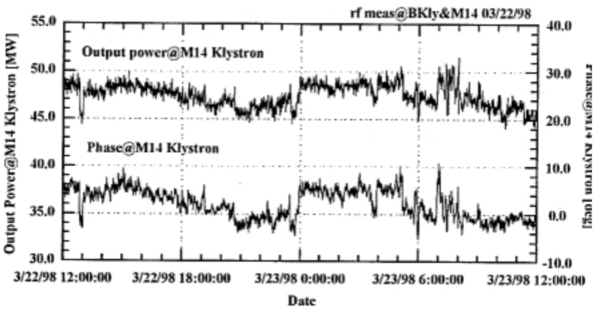

Fig.4-5 Output power and phase drift of the M14 klystron.

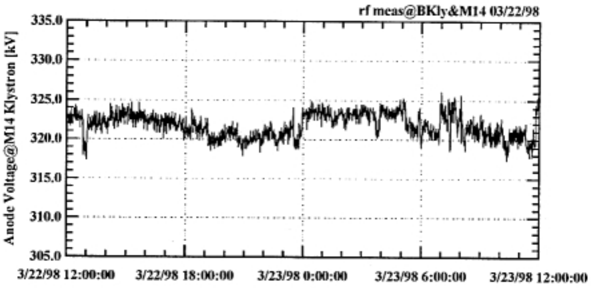

Fig.4-6 Drift of the pulse voltage at the M14 modulator

5. Summary

To investigate beam current and energy fluctuation values, the output power and phase for RF equipment were measured during the period of one month. The following factors were shown as three kinds of drift factors. The phase drift of the drive system for the 80MW klystron, which depends on the environmental temperature was I 0.0 deg/4.0 deg.c through one day. The phase drift of the booster klystron, which depends on the cooling water temperature was 0.8 deg/2.0 deg.c with a period of 25 minutes. The power and phase drift of the 80MW klystron (M14 klystron), which depends on the cooling water temperature were less than 1.0 MW/3.0 deg.c under 50MW operation and 2.0 deg/3.0 deg.c a period of 25 minutes. The power and phase were affected by fluctuations of the pulse modulator, which was 2% at 320kV.

Further improvements will reduce the drift of the cooling water temperature at the klystron cavities and the environmental temperature. In addition, the phase measurement system and the feedback system will be used in usual operations.

6. References

[1] K. Yanagida, “Wall Current Monitor for SPring-8 Linac”, JAERI-M 94-078.
[2] S. Suzuki et al., “Construction of SPring-8 Linac”, Proceedings of the 4th European Particle Accelerator Conference, London, July 1994.
[3] H. Yokomizo, in this annual report.