Construction of SPring-8 Linac

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Abstract

The construction of the SPring-8 linac (2856 MHz, 60 pps) was started in 1991 March. In 1993, we modified the design of Linac RF system. We choose new 80 MW klystrons, instead of 35 MW klystrons. With this situation, RF power from one klystron is led to two accelerating structures, instead of one accelerating structure. This linac is composed of 13 high power klystrons and 2 medium power klystrons with 26 accelerating structures.

1 INTRODUCTION

SPring-8 is constructed in Harima Science Garden City. It is composed of three accelerators, linac, synchrotron and storage ring. Electron or positron is accelerated up to 1.15 GeV or 0.9 GeV by the linac, and injected into the synchrotron. Electron (or positron) energy is increased to 8 GeV in the synchrotron before injection into the storage ring at final energy.

The preinjector of linac was already installed by MELCO in Tokai Establishment of JAERI on 1992 summer, and its commissioning is under way. The preinjector portion of SPring-8 linac consists of a thermonic gun (EIMAC Y796 cathode assembly), two single gap prebunchers and a standing wave 13 cell buncher. The prebunchers and buncher are powered by one 7 MW booster klystron (MELCO PV2012). And moreover, this klystron power will be used for drive power of other klystrons . Result of preinjector's commissioning is shown in the Table 1, and reported previous paper [1] in full.

Table 1: Preinjector Beam Status

Gun Voltage	200 kV
Gun Emission	
1~4 μs	6 A
10~40 ns	15 A
1 ns	20 A
Emission Stability	±1.5 %
Bunching Efficiency	64~65 %
Energy	9.1 MeV
Energy Spread	±2 %
Emittance	~8 πmm•mrad

This linac will be operated on four modes as shown in the Table 2. Mode 1 is long pulse mode. This mode will be operated for electron multi-bunch mode and beam phase pickup. Mode 2 and 4 are single bunch modes for electron and positron, which means the single bunch in synchrotron and storage ring. The beam of a few bunches (about 1 ns width) is extracted from the linac (2856 MHz) with high purity, and injected to one bucket of synchrotron (508 MHz). Mode 3 are short pulse mode. This mode will be operated for positron multi-bunch mode.

Table 2: Linac control modes

Beam mode	1	2	3	4
particle	e^-	e^-	e^+	e^+
Beam width (ns)	1000	1	10-40	1
Exit of Linac (mA)	100	300	10	10
Final Energy (GeV)	1.15	1.15	0.9	0.9

Positron will be generated at an area, where electron energy is 250 MeV, having a movable target for e^+/e^- conversion. When they request the positron beam for this linac, we will insert the target into the beam line. Generated positrons will be gathered by pulse and DC solenoid coils. We assume the conversion efficiency to be 0.1 %. But Mizuno et al. calculate that the conversion efficiency will be larger than 0.1 % [2] in this system. We expect this linac will be extracted about 20~30 mA positron beam.

2 RF SYSTEM

The 2856 MHz RF system is shown in Figure 1. This system is composed of booster klystron drive system, other klystron drive system, phase measurement system with reference line and high power RF system.

2.1 Booster Klystron and Drive Line

The 2856 MHz low level CW output of a highly stable master oscillator is divided into two signal lines. One of these signals is provided for booster klystron through PIN-diode pulse modulator and 300 W TWT amplifier. The other provides for the reference line through few watts CW amplifier to the phase measurement system.

Output of booster klystron is fed into injector line (two prebuncher and buncher). Drive line is divided by 6 dB directional coupler from injector line. The injector line is filled by 2 kg/cm^2 SF6 gas. In drive line, about 1 MW RF power that controlled by DRϕA in SF6 gas is provided in air. Each klystron is driven by RF (about 1 kW), branched by directional coupler, from drive line with IϕA (Isolator, Phase shifter, Attenuator).

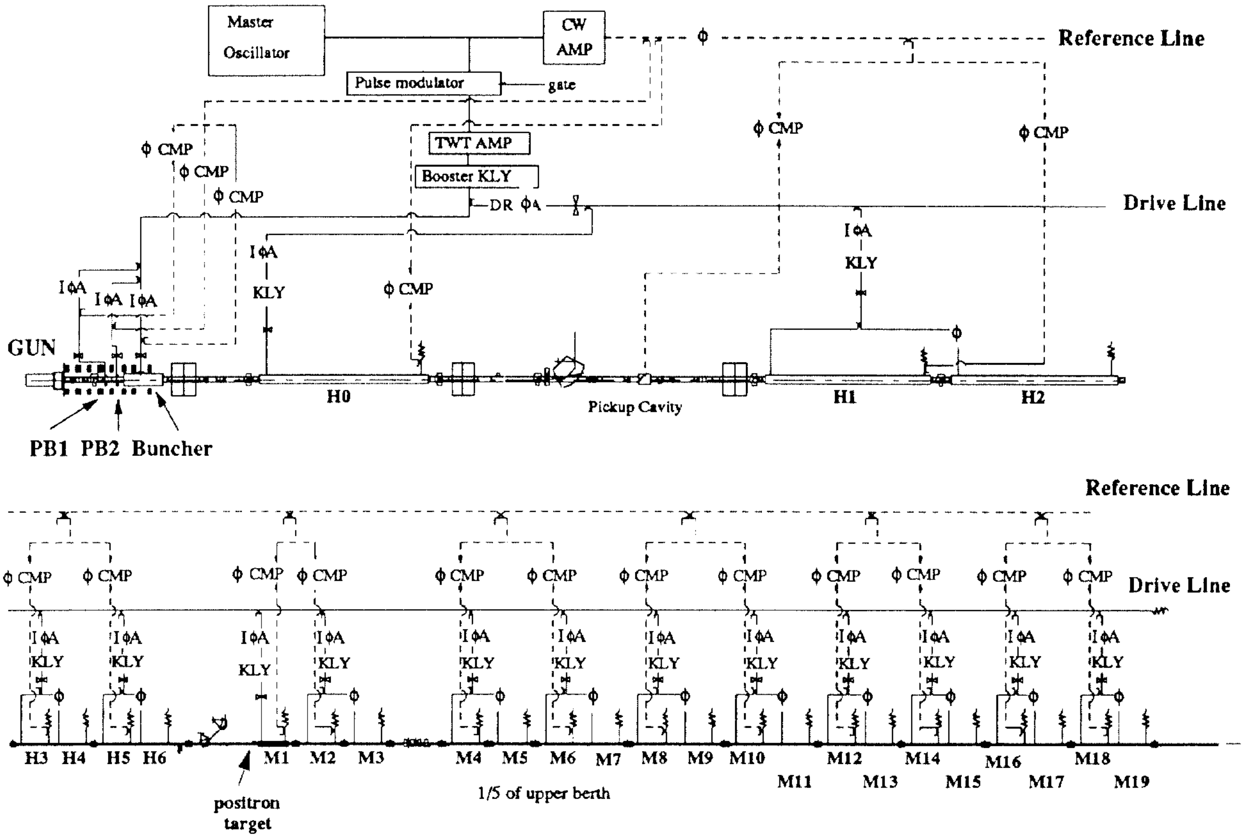

Figure 1: **RF system of SPring-8 Linac**

Solid line is high power line. Dashed line is monitor line.
H0~M19 : number of accelerating structure, KLY : klystron, ⋈ : RF window
ϕ : phase shifter, DRϕA : phase shifter and Attenuator for drive line
IϕA : isolator, phase shifter and Attenuator, ϕCMP : phase drift detector

2.2 *Phase Measurement System*

For high stability beam control, RF system needs phase measurement and feedback system. Drive line consists of 120 m length copper wave guide. Phase of drive line for last klystron drifts 11.2 degree/°C. For correction of the phase drift, ϕCMP detects phase drift by comparing with standard phase of reference line.

The reference line is the phase stabilized coaxial cable (Mitsubishi Cable). Electrical length of this cable is stabilized 2 PPM/°C (0.5 degree/°C at 140 m). Standard phase of reference line is picked up from the long pulse beam (or monitor directional coupler of buncher). Beam phase after H0 accelerating structure is detected by wave guide type pickup cavity (only long pulse mode). It is duplicated reference line by phase shifter after CW amplifier. Phase drift that detected by ϕCMP is corrected by VME controlled IϕA before each klystron. This system will be available for 2 degree phase drift.

2.3 *High Power RF System*

First accelerating structure is powered by one 80 MW klystron (Toshiba E3712). After second accelerating structure, the RF power from one 80 MW klystron is divided by 3 dB directional coupler, and fed to two accelerating structures exclude e^+/e^- converter section. It's important to control optimizing phase and power for positron converter section. The accelerator structure of converter section (M1 section in Figure 1) is driven by 35 MW klystron (MELCO PV3035) for 1:1 drive.

For 1.15 GeV electron beam, RF power of 26 MW is fed into all accelerating structures that produce an electric field gradient of about 16 MeV/m. As we have some margin, when one or two klystrons faults, we obtain the linac energy for injection by the rest klystron. Performance of high-power klystron E3712 and our typical operation parameters are shown in Table 3.

Each klystron is driven by traditional 190 MW pulse

Table 3: E3712 klystron tube parameters

	typical	max.	
Frequency	2856		MHz
Heater Voltage	100		V
Peak Beam Voltage	391		kV
Peak Beam Current	474		A
Peak Output Power		80	MW
Efficiency	44		%
Drive Power	255	500	W
Gain	55		dB
Pulse Width (Beam)	5	6.2	μ s
Pulse Width (RF)	2	4	μ s
Pulse Repetition	60		pps

modulator with 2 μs flat top within voltage fluctuation of ±0.5 % at 60 pps. This modulator output will be lead to klystron with the 1:16 pulse transformer. PFN charging voltage stability is achieved using the De-Q'ing method.

Wave guide circuit is composed of RF window, 3 dB directional coupler, vacuum pump and phase shifter. As wave guide is fevered about 50 °C increment at 80 MW without cooling, it is cooled by cooling water of normal system. En one side route to behind 3 dB directional coupler, high power phase shifter is prepared. By this, each phase of accelerating structure can be controlled.

3 ACCELERATING STRUCTURE

All accelerating structure construction has been already completed in Spring 1994 by MHI. The accelerating structures are 3 meter-long constant gradient traveling wave acceleration structures. They are traditional disk-loaded traveling wave type. Typical phase deviation of accelerating structure is shown in Figure 2.

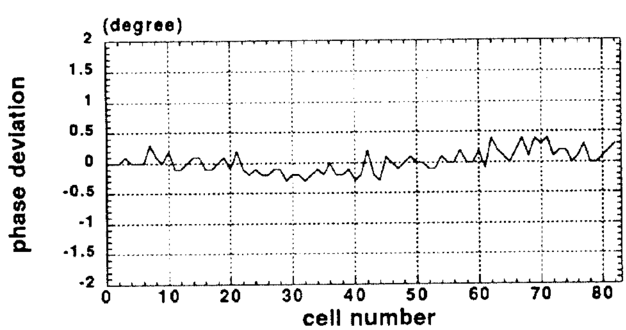

Figure 2: **Phase Deviation by Nodal Shift method**

4 CONTROL SYSTEM

This linac is controlled by distributed VME computers and a process server work-station at the remote control room. Software is designed by object oriented programming methodology, and a part of VME processes is already tested. Each control process on VMEs acts on devices when it receives standardized several commands SCC (SPring-8 Control Commands). Operation processes (including MMIF) issue SCCs to the control process as the message between control processes and operation processes. There are ready-made useful tools on the workstations (CASE and GUI), but class libraries of VME process must be built by in-house staff. Simplified modeling on OOPS (Machine Model) has contributed those huge jobs.

5 UTILITIES

5.1 *Linac Building*

The linac building is two-storied building. Machine tunnel is 170 m length including two switch yards and a beam dump. Klystrons and modulators are set in second floor. The height of second floor is 6.6 m for tall (1903 mm) klystron. Linac control room is near the end of linac.

5.2 *Cooling System*

The linac cooling system includes precision and normal system. The precision system for accelerating structures controlled on 30.0 ± 0.1°C. And water temperature is stabilized in negative feedback by the heater in nine subsections of two or four accelerating structures (one or two klystrons). Both systems are supplied on 8 kg/cm^2. Now, this system is designed details.

6 CONCLUSION

The construction of the SPring-8 linac was started in 1991 March, and preinjector, accelerating structure and some magnets were completed in March of 1994 on schedule. Construction of SPring-8 main linac began in March of 1994. We choose 80 MW high power klystrons for two accelerating structures and precision phase control system. The linac building will be completed in September this year. Cooling system will be completed in summer 1995. Preinjector system will be transferred from Tokai to Harima in summer 1995. Linac will be accomplished in 1996.

7 REFERENCES

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