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LOW-POWER RF SYSTEMS FOR THE KEKB INJECTOR LINAC

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Abstract

The low-power rf systems of the KEK electron linac have been upgraded for the KEKB. The main drive system is equipped with a new frequency multiplier/divider which generates five reference signals for the linac and the KEKB ring. The multiplier/divider was manufactured so as to have a very low noise performance in order to minimize any rf phase jitter. Eight sub-boosters, which drive four or eight high-power klystrons, respectively, were reinforced to generate 60-kW rf pulses. A solid-state 10-kW amplifier was newly installed for the 571-MHz sub-harmonic buncher. New RF sources are equipped with new PLC-based controllers which having panel displays.

1 INTRODUCTION

The KEK electron linac, which will be an injector for the KEKB collider rings, will have its energy upgraded from 2.5 to 8 GeV by increasing both the RF power and the total accelerator length[1].

The reinforcement of the RF sources is summarized in the following table. Increasing the acceleration RF power is mainly performed by replacing klystrons and adopting a SLED. The klystron modulators had been upgraded[2] in order to increase the output power and to extend the high-voltage pulse width up to 4 μ s on its flat top. The 30-MW Klystrons had been replaced by a new 50-MW type[3]. A SLED, which is an RF-pulse compressor, had been installed in every high-power RF source[4], as shown in Figure 1, except for two, which require severe phase and amplitude control. Sub-boosters, which drive high-power klystrons, were reinforced so as to

generate 60-kW RF pulses and to modulate their amplitude and phase for operating a SLED. Two new ones were installed for the extended part of the linac.

Reinforcement of the RF Sources of the Electron Linac

	2.5-GeV Linac	8-GeV Linac
<i>High Power RF Sources</i>		
Klystron	30-MW type (48 units)	40/50-MW type (58 units)
Modulator		
pulse output	80 MW	108 MW
SLED	0	56
Energy gain	65 MeV/unit	160 MeV/unit
<i>Low Power RF Sources</i>		
Sub-boosters	6 units	8 units
Klystron	10-kW type \times 2	60-kW type
Modulator	vacuum-tube type	solid-state type
SHB amplifier	vacuum-tube type	solid-state type
	119 MHz 5 kW	114 MHz 20 kW
	476 MHz 5 kW	571 MHz 10 kW

2 MAIN DRIVE SYSTEM

In the case of the previous TRISTAN main ring, the RF frequency for acceleration was not completely synchronized with beam injection from the linac. However, the KEKB project requires their synchronization within 30 ps. Therefore, the frequency for the KEKB ring RF system had to be shifted in range from 508.3 MHz to 508.9 MHz in order to have complete synchronization with the linac RF for acceleration. Finally, we fixed the following RF frequencies:

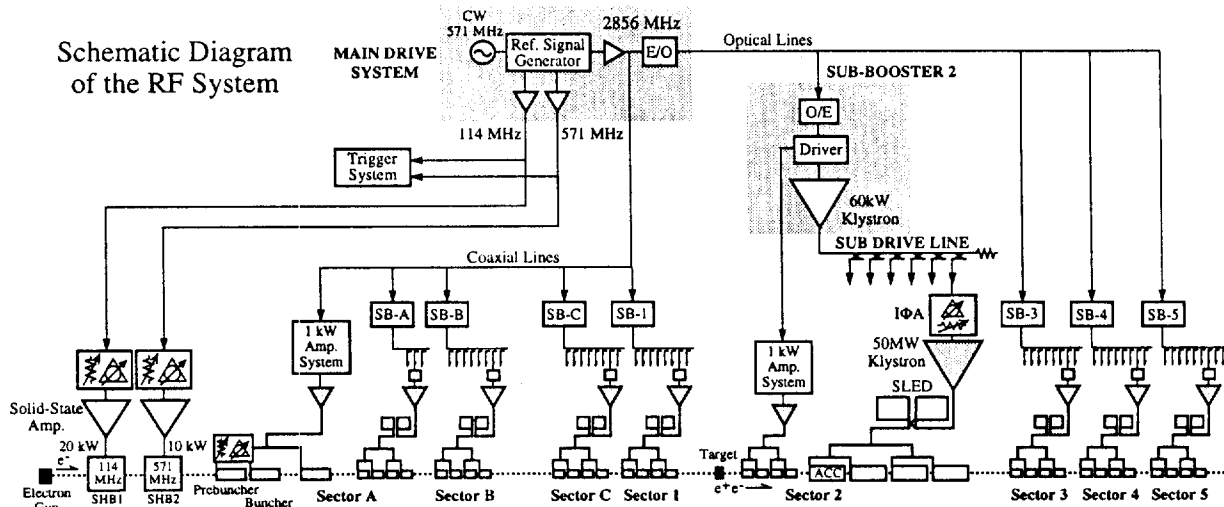


Figure 1 Diagram of the upgraded RF system

The RF frequencies for the KEKB

Fundamental	10.38546 MHz
KEKB ring RF'	508.88754 MHz
Linac SHB1	114.24006 MHz
Linac SHB2	571.2003 MHz
Linac acceleration	2856.0015 MHz

The specification of the injection-beam-energy distribution requires low phase jitter of less than 1 degree (or 1 ps). The master frequency of the linac RF system must be chosen so as to minimize the phase noise of reference signals. Consequently, the frequency for sub-harmonic buncher (SHB) 2 was determined to be the master frequency, and the synthesizer HP 8662A was employed for the master oscillator.

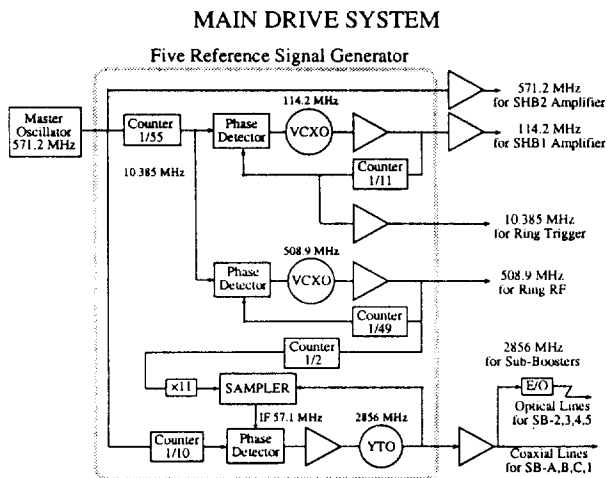


Figure 2 Block diagram of the main drive system

A reference signal source divides and multiplies the master frequency to generate the above-mentioned five frequencies. The signal generator, which was designed and manufactured by Sony/Tektronix, satisfies the specifications by means of precision PLL circuits represented in Figure 2.

The reference 2856 MHz has been fed to sectors 2,3,4 and 5 by optical cables so as to minimize any phase shift in the long transmission line caused by room-temperature variations. For the extended part of the linac, coaxial cables transmit reference signals to sectors A,B,C and 1, because we gave priority to eliminating phase drifts with E/O or O/E converters.

This main drive system, except for the master oscillator, is mounted in a thermostatic chamber, which regulates the inside temperature at 28 ± 0.2 °C. Thus, any slow phase drift is minimized.

3 SHB AMPLIFIER SYSTEM

The primary electron beam for positron production is specified to be a single bunch of 10 nC at the target. That is, the sub-harmonic bunchers must strongly compress the high-current electron beam in order to prevent the production of satellite bunches. The required

RF powers are 20 kW for 114 MHz and 10 kW for 571 MHz.

The previous 119-MHz SHB amplifier (5 kW) had been reinforced before making a new amplifier. Two vacuum-tube type amplifier units (for final stage) were tuned and cascaded so as to generate 15-kW RF pulses at maximum. A new 20-kW solid-state type will replace the present one in 2000.

A 571-MHz solid-state amplifier was newly manufactured and installed last spring. This amplifier system, as illustrated in Figure 3, comprises ten amplifier modules, a preamplifier, an amplitude & phase controller and a phase stabilizer.

The sources of phase variations of the microwaves stored in the SHB cavity are the amplifier, the transmission line, or the cavity, itself. The phase stabilizer compensates for these phase variations.

Specification of the 571-MHz amplifier

Type	solid-state, AB class
Frequency	571.2 \pm 5 MHz
Output power	10 kW
Input power	1 mW
Pulse width	10 - 50 μ s
Pulse repetition	50 pps
Long-term variation	
Amplitude	\pm 1.5 % (AGC off)
Phase	\pm 1.5 deg.

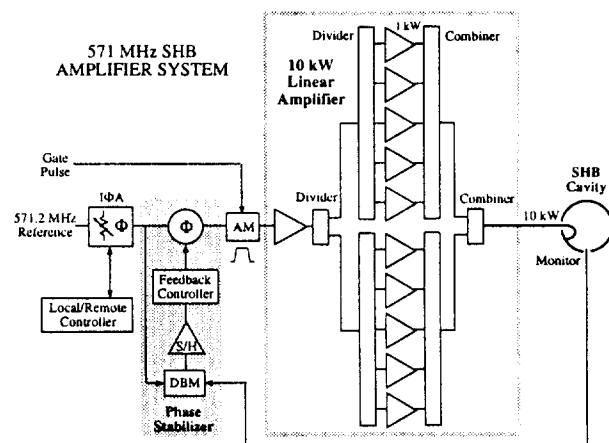


Figure 3 571-MHz solid-state amplifier system

4 SUB-BOOSTER SYSTEM

In order to operate the SLED's we upgraded the sub-booster system as follows (Figure 4): (1) Amplitude modulators and $0-\pi$ phase modulators were installed in every sub-booster. Thus, the sub-booster can generate rectangular RF pulses with a 4- μ s width and can reverse their phases of the last 1 μ s for SLED operation. (2) The phase modulator has a voltage-controlled fast phase shifter in it; the rise time of its control voltage is variable from 67 to 400 ns. A slow phase-reverse time, such as 300 ns,

reduces the power level of RF pulses reflected by the accelerator guide. (3) Every sub-booster station was relocated from the center of the sector to its head. Thus, since the timing of the accelerating RF pulses can be optimized, the beam energy can subsequently be maximized. (4) A 60-kW klystron, which can drive eight 50-MW klystrons, was newly developed. New pulse power supplies were also manufactured for the klystron. It is equipped with a solid-state switch (36 kV, 16A) instead of a vacuum tube for higher reliability.

A feedback controller was installed in every klystron-drive circuit in order to stabilize the phase and amplitude of the cw-RF signal amplified by a 3-W amplifier. This stabilized signal is transmitted to every RF monitor station[5] as a phase reference. The drive circuits are mounted in thermostatic chambers as well as the main drive system.

An RF-phase drift of the sub-booster strongly depends on the temperature of the cooling water for the klystron. The observed phase-temperature coefficient is about 1 deg/C.

Specification of the sub-booster

Klystron	
Frequency	2856 MHz
Output power	60 kW
Cathode voltage	-25 kV
Pulse width	4 μ s
Pulse repetition	50 pps
Long-term variation	
Amplitude	± 0.3 %
Phase	± 1 deg.

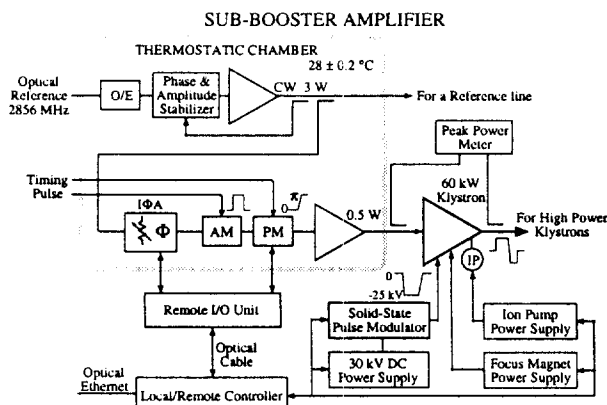


Figure 4 Sub-booster amplifier system

5 RF-DEVICE CONTROLLER

The RF-device controllers for the klystron modulator have worked for over 15 years. However, some of them are starting to show a remarkable failure rate of communication. It is easily expected that most of the failure will be caused by severe electromagnetic noise emitted by the reinforced modulators. In addition, it will be difficult to maintain the network for the controller over the next ten years, because it is not commercially

supported. We thus had to prepare a new device controller with high reliability and with good maintainability.

The design policy of the new controller is as follows: (1) high reliability of the hardware and network communication against severe EMI, (2) easy maintenance of the hard/software, (3) direct replacement with an old-type controller. Consequently, we developed a PLC-based controller. It has a TFT display with a touch panel for a user interface and optical Ethernet ports for communication.

The following fundamental functions of the new controller are the same as that of the old one:

- remote ON/OFF operation
- finding an interlock signal changed first
- remote operation of an RF devices, such as a phase shifter
- communication with a device manager

The controller also supports the following new functions:

- GUI for easy understanding and for easy local operation
- local trend displays of monitored signals, such as the RF powers or the pressures in the wave guides
- statistical processes of analog data
- automatic conditioning of an RF unit

The new controllers were introduced in the extended part of the linac and have worked without any problem for the last half year.

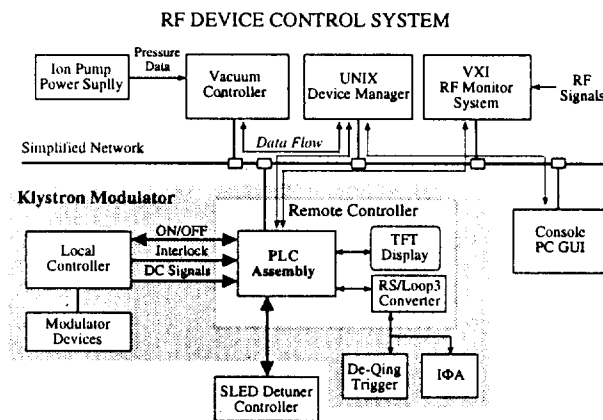


Figure 5 Block diagram of RF-device control

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