THE PLS 2 GEV ELECTRON LINEAR ACCELERATOR

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Summary

A third generation 2 GeV storage ring light source is currently being developed in Pohang, Korea. The injection system of this storage ring includes a 160-m long, full energy electron linac. This linac employs 12 klystrons and ten Energy Doublers. The accelerating section is 3.05 m long, constant gradient structure operated with $2\pi/3$ mode. Along the linac, there are a total of 44 accelerating sections, 16 quadrupole triplets, and various auxiliary components for monitoring the accelerated beam. Initially, this linac will inject electrons to the storage ring. With some modification, the linac will also have a capability of injecting positrons. Design features of the PLS 2 GeV injector linac are presented here.

Introduction

The PLS 2 GeV electron linac is a full energy injector for the synchrotron radiation source 2 GeV storage ring. As an injector for the storage ring, the linac should be able to fill the storage ring in any bunch pattern and with reasonable filling time. For both single bunch and multi-bunch modes of operation for the storage ring, the PLS linac will inject a 2-ns long, 400 mA single bunch electron beam pulse at the gun with a repetition rate of 10 Hz (120 Hz maximum). After some loss during the beam transport and injection, it is expected that about 100 mA beam current will be injected into the storage ring. The 100 mA electron beam current is high enough to fill all the 468 RF buckets of the storage ring with a filling time of less than one minute. The normalized emittance of the electron beam at the end of the linac is about 0.015 π MeV/c cm rad and the energy spread is $\pm 0.6\%$ at FWHM. For positron injection, which is planned in our future upgrade program, the electron beam current at the gun will be increased to 8 A to increase the yield of positrons. At the same time, the pulse repetition rate can also be increased to 20 Hz. Even in this case, the filling time for the multi-bunch mode is reasonably short, in fact less than five minutes.

The design study for the linac was started in March, 1989. The installation of the linac will begin in July, 1992. The commissioning will start from January, 1994.

General Description

Table I lists the main parameters of the PLS 2 GeV linac. The 160-m long beamline of the linac includes 44 accelerating sections and various auxiliary components for focusing and monitoring the beam. The accelerating section is equivalent to the SLAC model; a 3.05-m long, constant gradient structure operated with $2\pi/3$ mode. The accelerating sections are installed in the accelerator housing under the ground. At ground level, there is a klystron gallery which is 7.5 meters wide and 3 meters high. A total of 12 klystron and modulator sets are located in the gallery. Except for K1 and K3, each klystron feeds four accelerating sections and employs an energy doubler (ED).

Table I
Summary of the PLS 2 GeV Linac Parameters

• Beam parameters	
Beam species	Electron (Positron in the future)
Beam energy (GeV)	2
Beam current at the end of the linac (mA)	200 (operating)
Beam pulse length (ns)	2
Repetition rate (Hz)	
10 (operating)	
Energy spread (%)	0.6
Normalized emittance ($\pi MeV/c\ cm$)	0.015
• Electron gun parameters	
Voltage (kV)	80
Beam current (A)	> 2
Pulse length (ns)	2
Repetition rate (Hz)	
10 (operating)	
• Accelerating section parameters	
Accelerating section structure	constant gradient
Length of each section (m)	3.048
Number of sections	44
Operating mode	$2\pi/3$
Number of cavities in a section	86
Maximum phase excursion (°)	2
Shunt impedance ($M\Omega/m$)	53-60
Attenuation parameter (NP)	0.57
Group velocity, v_g/c	0.0204-0.0065
Filling time (μs)	0.83
• RF parameters	
Operating frequency (MHz)	2856
Pulse length (μs)	3.5 (maximum)
Repetition rate (Hz)	
10 (operating)	
Klystron output power (MW)	
Operating	50
Maximum	65
Maximum average power (kW)	27
Number of klystrons	12
Number of Energy Doublers	10
Energy Doubler gain factor	
Operating	1.3
Maximum	1.62
• Other parameters	
Total length of the linac (m)	160
Vacuum ($torr$)	1×10^{-7}
Accelerating section wall temperature (°C)	45±0.3
Number of quadrupole triplets	16
Number of steering magnet sets	16
Number of bending magnets	3
AC power capacity (KVA)	4500

The K1 and K3 klystrons respectively feed two accelerating sections. Therefore, this linac can deliver a 2.0 GeV electron beam with klystron power P=50 MW and ED gain factor S=1.3. The klystrons chosen are basically the same as the SLAC-5045 models (maximum power 65 MW) and will be purchased from the USA. In the future, if the klystrons and the EDs operate at the SLAC performance level, P=65 MW and S=1.62, this linac can deliver a positron beam up to 2.45 GeV. Three beam analyzing stations are provided at 60 MeV, 350 MeV, and 2 GeV. These places can also be used to extract the beam for physics experiments or other purposes that may be decided in the future. For the transportation of a beam, a total of 16 quadrupole triplets are placed along the linac. The arrangement of these triplets is mainly for positron beam transportation. In this way, the future modification to positron option can be made with minimal effort. Description of the focusing and beam transport system is presented in another paper for this conference [1].

Drive and Phasing System

The schematic diagram of the drive system is shown in Fig. 1. The drive system consists of three parts; signal source, booster station and main drive line. The signal source consists of a master oscillator and low-level signal conditioning circuits. The operating frequency of 2856 MHz is generated by the master oscillator, which is a high-precision synthesized signal generator. The output power of the master oscillator is 10 mW minimum. This power will be sufficient to drive the subsequent pre-amplifier. The low-level signal conditioning circuits consist of pre-amplifier, isolator, PIN diode pulse modulator and PS unit. The output power of the pre-amplifier is 2 W for distribution to the booster station drive line and the phase reference line. The RF CW signal out of the pre-amplifier is modulated by a PIN diode. The PSK shown in Fig.1 is used to shift the phase of 180° for the energy doubler. The two booster stations, each consisting of a high-power solid-state amplifier and IϕA unit, serve to provide the drive power for the first two high-power klystrons (K1 and K2). Maximum drive level of 830 W is available at the klystron station. The 140-m long main drive line is coupled out from K2. The drive line is a 1&5/8″ rigid coaxial line filled with dry nitrogen gas. The cooling water system is able to regulate the temperature variation of the drive line within 45±0.3°C.

The requirement of the phasing system is such that the phase drift between the beam bunches and the accelerating wave should be less than ±5°. Among various phase control schemes, the beam energy maximization method [2] has been chosen for the phasing control of the PLS 2 GeV linac. The phasing components consist of a PAD unit, IϕA unit, phase reference line, drop-out cable, etc. Based on these phasing components, the phase control unit is operated by a manual system and a computer system. In the early stage of operation of the linac, most of the phase controls will be carried out manually by operators. When the linac system is stabilized, the control will be transferred to the computer.

Vacuum System

The vacuum system consists of an accelerating column of 44 sections and of a waveguide system. The design goals are: the pressure in the center of the accelerating column is to be

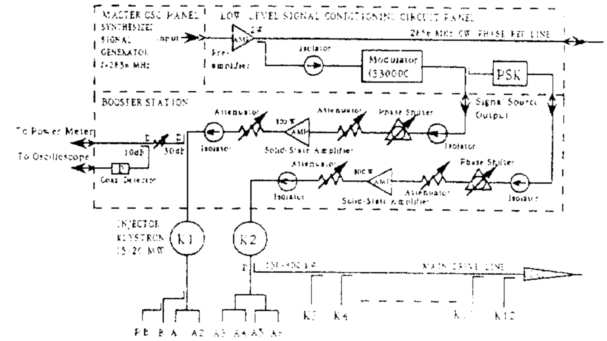

Fig.1 Block diagram of RF drive system of the PLS 2 GeV linac

5×10^{-7} torr, the pressure in the waveguide is to be 5×10^{-7} torr, the pressure in the waveguide at the klystron window is to be 5×10^{-8} torr. Because the linac vacuum is inherently conductance limited, we adopt the distributed pumping method in order to improve the vacuum near the accelerating column. Each 30 l/s sputter ion pump is connected to every accelerating column, and all the ion pumps in each sector are connected by one manifold. An approximate calculation indicates that the usage of the stainless steel manifold pipe with 63 mm diameter is desirable.

The whole 160-meter long linac is divided into five sectors by five all-metal pneumatic gate valves (inner diameter 25 mm - flange CF40). The longest sector is about 46 meters including 12 sections of accelerator column and three klystrons. The electron gun is evacuated by 60 l/s and 30 l/s sputter ion pumps to ensure the pressure is less than 1×10^{-8} torr. These two ion pumps serve as a cascade pumping system. Fig.2 shows a schematic diagram for a typical vacuum sector.

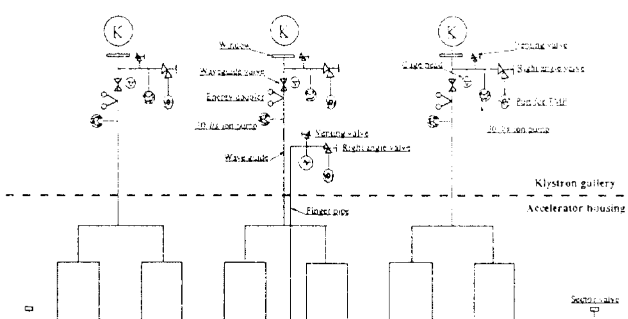

Fig.2 Schematic diagram for typical vacuum sector

Cooling Water System

The overall cooling water system of the PLS 2 GeV linac consists of two parts; a primary loop system and secondary loop system. The primary loop system includes the disk-loaded waveguide (DLWG) cooling system and the klystron cooling system. The DLWG cooling system includes the cooling of the rectangular waveguide, ED, drive and reference line. The DLWG cooling system is associated with a precision temperature control system which regulates the water temperature 45±0.3°C for the cooling of the accelerating section. The klystron cooling system includes the cooling of the magnet and focusing coil, which provides water temperature of 35°C. The future positron target and solenoid cooling system will also be included in the primary loop system. The secondary loop system includes the cooling tower water, and low-conductivity make-up water system.

A schematic flow diagram of the DLWG cooling system is shown in Fig.3. The temperature controlled water cools four units of DLWG. The water leaving the accelerating section cools the output loads. The flow rate of the cooling water is 13 gal/min for each DLWG cooling water jacket, 10 gal/min for the ED, and 5 gal/min for the drive line. The klystron cooling system is similar to that of the DLWG.

One cooling water pump station is installed along the linac. This station is placed in the middle of the klystron gallery in order to provide a reasonable response time for the water temperature control.

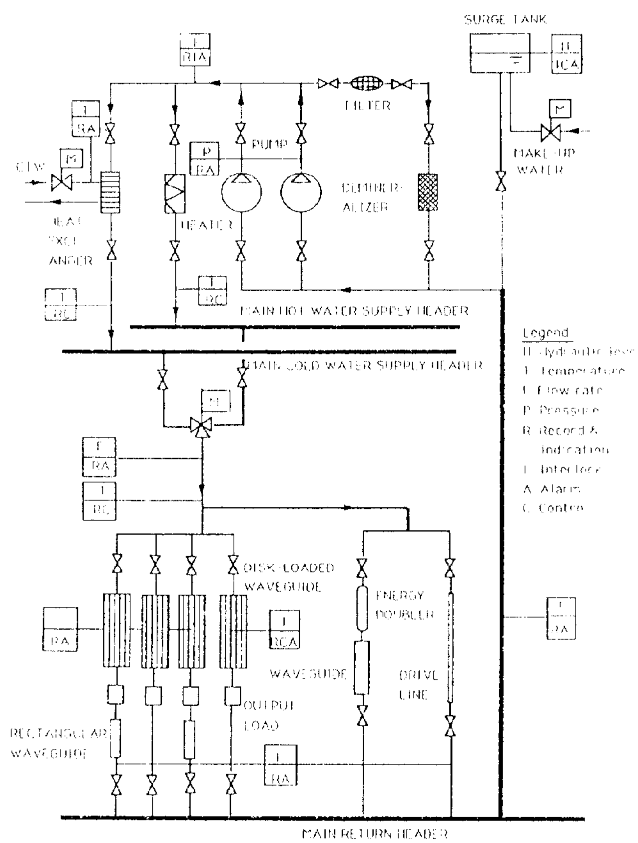

Fig.3 Schematic flow diagram of disk-loaded waveguide cooling water system

Instrumentation and Control

Along the linac, various instruments are installed for the purpose of beam diagnostics. These instruments include beam intensity monitors, beam profile monitors, beam position monitors, and beam loss monitors, etc. Beam bunch is measured using a bunch monitor. There are in total 8 sets of the beam intensity monitors and 10 profile monitors along the linac. The beam loss monitor is a coaxial cable with a length of 6 to 8 meters. Strip-line type monitors will be employed for measuring the accurate beam position in both x and y directions. The bunch monitor consists of two RF cavities, one resonant at 2856 MHz and the other at 14280 MHz. It is mounted on the beam line downstream of the injector.

In the PLS linac control system, a combination of front end intelligence controllers based on VME single board computers, microcomputers, and minicomputers is planned. A minicomputer (MICRO-VAX) will be used as a data acquisition computer and a host computer. Based on the VME system, the architecture of the 2 GeV linac control system is configured as shown in Fig. 4. The control system of the PLS linac and storage ring will be located in the same room. This control system is expected not to be ready until the storage ring major facility is built. Thus, initially some of the linac control will be done manually.

A basic requirement of the timing system is that the linac beam should fill up a single RF bucket of the storage ring in any bunch pattern. The linac beam pulse needs to be synchronized with the storage ring's 500 MHz RF. Thus timing signals are taken from the storage ring's RF master oscillator. For the triggering of klystrons, timing signals are generated by time delay modules. These triggers are sent to the MK and delayed by a programmable counter. Delay durations of 0-7.5 μs in the MK are enough to allow compensation for klystron triggering and cable length effects.

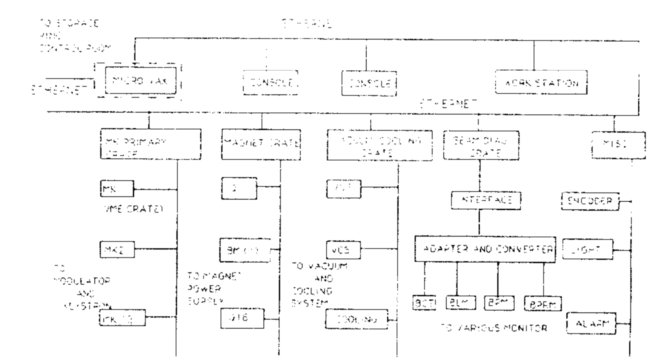

Fig.4 Control architecture for PLS 2 GeV linac

Upgrade Plan

In the future upgrade program, we plan to develop a new injection system which provides a shorter beam pulse. The shorter beam pulse of the injector linac should be able to provide a clean injection so that the linac beam pulse is well fitted into the storage ring RF bucket. For this purpose, we will employ two sub-harmonic bunchers, with frequencies of 119 MHz and 476 MHz, respectively. With these bunching systems, the 2.5 ns electron beam would be compressed to 0.2 ns. This is a single linac bunch with an extremely high charge density that can be used not only for injecting into the storage ring but also for carrying out physics experiments.

References

[1] M. Yoon, in these conference proceedings

[2] THE STANFORD TWO-MILE ACCELERATOR, R.B. Neal, ed, 1968 W.A.Benjamin, INC.