THE 200 MEV LINAC AT HESYRL

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Abstract

A 200 MeV LINAC is being built at HESYRL (Hefei National Synchrotron Radiation Laboratory, China). The LINAC is mainly as an injector for the 800 MeV electron storage ring, which is to be a facility dedicated to synchrotron radiation use.[1,2,3] To make full use of the LINAC, it can also provide beam for other research and application use. The beam current at the exit of the LINAC is supposed to be 50-100 mA in 2-4 ns or 0.2-1 μs pulses variable according to what is needed. It is expected to put the LINAC in service in 1987.

General Description

The LINAC is a traveling-wave type, operating at 2856 MHz and utilizes 5 klystron amplifiers, each delivering 15 MW of power in 2 μs pulses. It consists of 9 three-meter long constant impedance accelerating sections and 4 drift sections. The total length of the LINAC is about 35 meters at the first stage. Spare room is kept for future expansion when necessary.

Fig. 1 shows the layout of the LINAC and the building cross section. The accelerator tunnel and the klystron gallery are horizontally arranged and the tunnel is semi-underground with filled-earth as shielding. The consideration led to take this way of arrangement is dominantly due to the groundwater. Because of this problem, it is quite difficult to locate the tunnel deeper at that area.

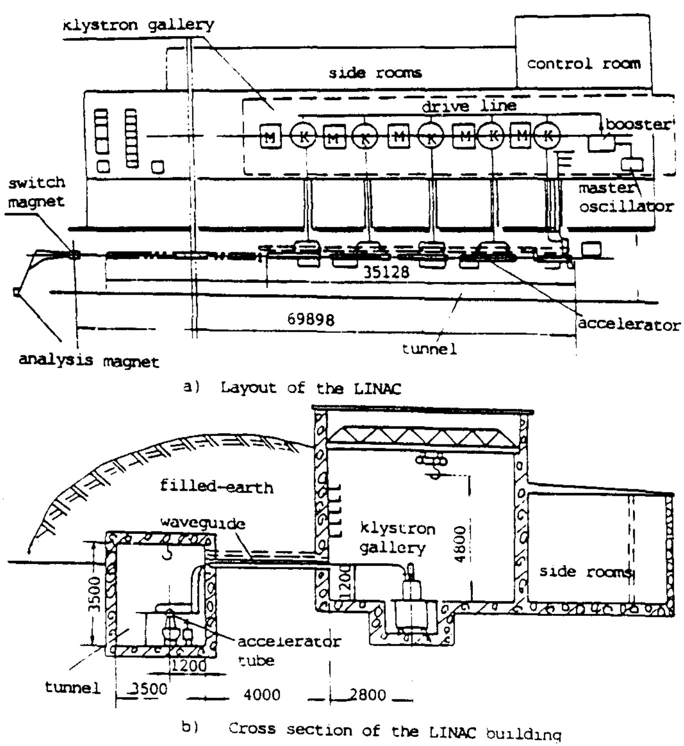

Fig. 1 a) Layout of the LINAC
b) Cross Section of the Building

The electron gun is grid-cathode type, which can produce up to 500 mA with 80kV injection energy in 2-4 ns or 0.2-1 μs pulse beams by means of altering the grid pulsers. The beam current at the end of the LINAC is supposed to be 50-100 mA. And there is a switch magnet at the end of the LINAC, by which the electron beams can be switched to the storage ring, the nuclear experiment hall, the energy analysis magnet or the beam dump according to what is needed. Table 1 lists the main parameters of the LINAC.

Table 1 The Main Parameters of the LINAC

Electron Energy	240 MeV (at 50 mA)
Beam Pulse Current	50 mA
Beam Pulse Width	2-4 ns or 0.2-1 μs
Energy Spread	1%
Beam Loading	0.4 MeV/mA
Repetition Rate	50 pps
RF Frequency	2856 MHz
RF Power per Klystron	15 MW
Number of Klystrons	5
Electron Gun Voltage	-80 kV
Gun Current (max.)	500 mA
Temperature of Cooling Water	45 ^{o}C
Vacuum	$1\text{x}10^{-6}$ Torr (with beam)

Accelerating Structure

The accelerating structure is the flat-disk loaded circular waveguide, and of the traveling-wave constant impedance type. The phase shift per cavity is $2\pi/3$ radians. Each three-meter accelerating section is composed of 86 cavities plus input and output couplers. Two such sections are assembled together to form a six-meter long accelerating unit.

A summary of the basic design features of the accelerating structure is given below:

f (frequency)	2856 MHz
φ (phase shift per cavity)	$2\pi/3$ radians
v_p (phase velocity)	c
v_g (group velocity)	0.012c
R (shunt impedance)	62.3 MΩ/m
I (voltage attenuation constant)	0.178 Np/m
Q	14000
T (filling time)	0.83 μs
L (effective length of an accelerating section)	3.04 m
2a(disk hole diameter)	21.984 mm
2b(waveguide inside diameter)	82.174 mm
D (periodic length)	34.989 mm
t (disk thickness)	5.000 mm
P_0(RF power into each accelerating section)	6.75 MW
E_0(field at the input end of accelerating section)	12.2 MV/m

The accelerating structures are fabricated at the campus. The results of tuning and measuring show that the accelerating tubes fabricated meet the requirement of the design parameters. The tolerance of total phase shift over a whole accelerating tube is within 3°, and the VSWR of the input and output couplers is less than 1.04.

RF System

The RF system for the LINAC consists of a master signal generator, a booster (medial-power amplifier), which delivers the drive power to the high-power klystron amplifiers, the drive system and 5 high-power klystron amplifiers. Every two accelerating sections except the first one, which shares a klystron with the buncher section and the prebuncher cavity, are fed by a klystron. Fig. 2 shows schematically the RF system of the LINAC.

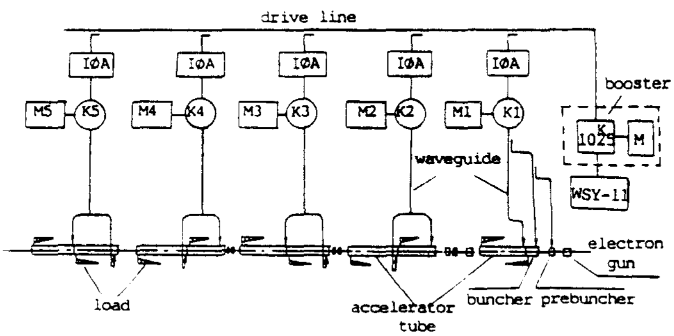

Fig. 2 The RF System of the LINAC

The master signal generator is a high stability phase-locked solid-state microwave source with 1 W of output power. Its central frequency is 2856 MHz with adjustable range ±50 kHz. The frequency stability is better than 10^{-6}/day. The drive power for the high-power klystron amplifiers is supplied by a medial-power klystron, type 1025, which input power comes from the master signal generator and output pulse power is 20 kW (at 25 kV voltage) delivering to the drive line. Then about 2 kW of pulse power is coupled out from the drive line at each station for driving the high-power klystron, type 406A. Though the klystrons can supply 20 MW of pulse power, it is to be operated at level of 15 MW to prolong its lifetime and to increase stability and reliability of operation. An IφA unit is used at the input front of each high-power klystron for adjusting of the phase and attenuation of the driving power to that klystron. The output power of each klystron is then divided into two way and fed into two accelerating sections. In order to compensate partially for the asymmetry of the field in couplers, the way of feeding of RF is alternative in orientation
The main features of the RF system are summarized in table 2.

Table 2 The Main Features of the RF System

Master Oscillator:	
Operating frequency	2856 MHz
Adjustable frequency range	±50 kHz
Frequency stability	10^{-6}/day
Output power	1 W
Booster:	
Peak pulse voltage	-25 kV
Pulse rise time	0.2 μs
Pulse fall time	0.4 μs
Pulse width (flat top)	2 μs
Pulse voltage amplitude droop and ripple (max.)	0.2%
RF pulse power output	20 kW
Repetition rate	50 pps
Phase modulation (for 0.1% beam voltage)	1.8°
Klystron Amplifiers:	
Peak pulse voltage	-250 kV
Pulse rise time (max.)	1 μs
Pulse fall time (max.)	1.4 μs
Pulse width (flat top)	2 μs
Pulse voltage amplitude droop and ripple	0.5%
RF pulse power output	15 MW
Repetition rate	50 pps
Phase modulation (for 1% beam voltage)	9°

Beam Dynamics

Bunching

The bunching of electrons is performed by the prebuncher, the buncher and the first accelerating section. Buncher of constant phase velocity is adopted . It is a 10 cm long section of uniform disk-loaded circular waveguide with 0.75c phase velocity in it. The prebuncher is a velocity modulation cavity, essentially a reentrant cavity. The Q value of the cavity is made intentionally low (Q_L is about 500) in order to reduce phase shift as a function of temperature and beam current. The effect of the standing wave field in the couplers and the space harmonics in the buncher and the first accelerating section on the eletron motion is considered in beam dynamics calculation.[4]

The first accelerating section, the buncher and the prebuncher share a klystron, feeding 7 MW to the first accelerating section, 0.4 MW to the buncher and 1 kW to the prebuncher.

On the basis of the design described above, electrons bursting from the gun within a phase interval of 260° can be bunched into a interval of 5° at the exit of the first accelerating section. That is, the capture efficiency is about 72%.

Focussing and Steering

Focussing system for the LINAC consists of 2 magnetic lenses, 5 groups of solenoid coils and 3 quadrupole magnet doublets. And nicalloy sheets of 0.2 mm thick are prepared for shielding of the accelerating tubes in order to reduce the effect of earth magnetic field on the beam motion. With these components, it is expected that the maximum envelope of beam will be kept less than 5 mm.

Along the whole LINAC, there are installed 7 sets of steering coils (vertical and horizontal). Every beam deviation due to earth magnetic field, other residual magnetic field, misalignment of the accelerator, etc. are all corrected by means of steering coils. Each steering coil has a steering ability of 2 mrad.

Other Systems

Beam Diagnostic

To monitor the position, intensity and profile of beams, 2 gap-stripline combined monitors, 5 current transformers and 3 flags are placed along the LINAC respectively. And there are 2 analysis magnets for analyzing of beam energy spectrum, one in the first drift section and the other at the end of the LINAC.

Vacuum

During operation of the accelerator, a pressure of 1×10^{-6} Torr is required to be maintained. 7 ion pumps (evacuating speed of 200 l/s) are distributed along the accelerator, all connected to a manifold of ϕ150 mm. One of them is placed very close to the gun in order to keep the pressure near the gun as low as possible (less than 1×10^{-8}). There are another 6 ion pumps (rated at 50 l/s) dedicated to evacuating of the waveguide system. They are placed near the klystrons to protect the klystron windows against breakdown.

Cooling Water

The temperature of cooling water is to be controlled at 45±0.5 ^{o}C and the pure water is to be used to keep clean in the cooling pipe, to protect against stopping-up, to increase heat transfer efficiency and insulating ability, and to decrease the activation by radiation.

Interlock and Control

Various interlocks are provided, either to protect personnel or to prevent equipment from damage. At the first stage, control is mainly in manual manner.

Alignment

A laser alignment system, which alignment accuracy is of ±0.1 mm, is to be used. The alignment accuracy over the whole LINAC is required to be of ±1 mm.

References

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