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THE 1.1/1.4 GEV ELECTRON POSITRON LINAC

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Abstract The 1.1/1.4 Gev eletron positron LINAC is a half energy injector of Beijing Electron Positron Collider (BEPC). It consists of a 150MEV high current eletron LINAC for positron production; 100MeV section for capturing positron beam; and the 1.1/1.4 GeV main section to accelerate either positron or electron to an energy of 1.1/1.4 GeV to meet the need of the BEPC storage ring. During past 5 years, this LINAC was designed, constructed and was put into operation for 7000 hours. Up to now, the LINAC energy and beam current arrived 1.55 GEV, 1000 mA for electron and 1.3 GeV, 7 mA for positron, both with energy spread: $\leq 1\%$, pulse width: 2.5ns.

INTRODUCTION

This LINAC, has to provide an energy of 1.1 GeV in first step and about two years later, its energy should be upgraded to 1.4 GeV. 12 klystron amplifiers, each with an energy doublor (The SLAC type RF power compressor, we call it ED), and 48 accelerating tubes, each is 3.05m long, are used to form the 1.1/1.4 GeV main section, to which, every one klystron amplifier and 4 accelerating tubes form a station providing an energy of 100/130 MeV, for an input RF power of 16/22 MW. For positron producing, the main section is preceded by a 150 MeV high current electron LINAC. Which consists of: a 30 MeV preinjector with buncher,prebuncher,feeded by one klystron amplifier with out ED, and a 4 A gun; a 120 MeV section formed with 4 accelerating tubes and one klystron amplifier with ED. At the output of the 120 MeV section, sets up a positron converter, including a movable tungsten target, 7mm think, a 2T. tapered field coil. When the positron is needed, the target is moved in across the electron beam line, The positron produced are captured by a 100 MeV section just down stream of target. After that,it pass through the main section to the end, where they reach an energy of 1.1/1.4 GeV. When the electron beam is needed, the target is moved up, the electron beam coming from the 150 Mev LINAC continue its way direct to the end, and can achieve an energy of 1.1/1.4 Gev too.

The SLAC type C.G. disk-loaded waveguide [1] was selected as BEPC injector's accelerating tube, but among the total number of 56 such tubes, 30 ones had a little improvement, that is, in the first 4 cavities of them, 4 small apertures were added on the disk.According to different apertures the accelerating tubes are classfied into two categories so as to make the LINAC possesses a series accelerating tubes of three kind, henc a higher limit of B.B.U threshold would be expected in it.

Each two accelerating tubes were installed and prealigned on one girder in factory, then together with girder, transported to the tunnel, assemblied along a straight line and aligned with a laser beam. The alignment accuracy arrived along the length of LINAC is ± 0.4mm.

The layout of the 1.1/1.4 electron positron LINAC is shown in FIGURE 1, and the main design parameters are listed in TABLE I column second.

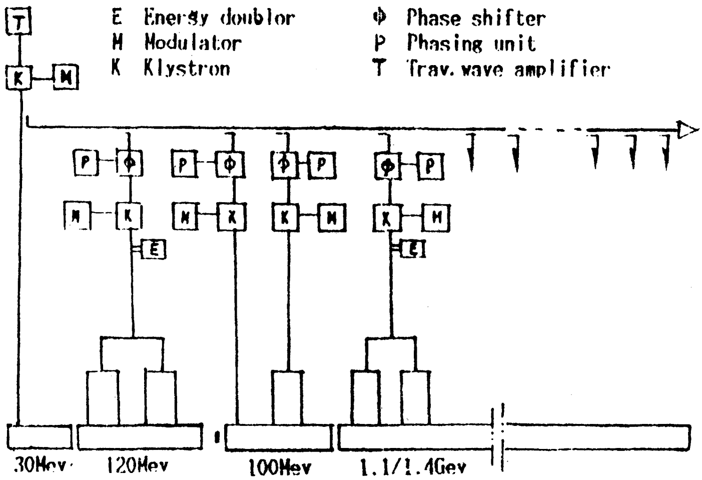

FIGURE 1 The layout of 1.1/1.4 GeV electron posieron LINAC.

TABLE I Parameters of the 1.1/1.4 e$^{\pm}$ LINAC

parameters	designed	operated
Output Energy [GeV]	1.1/1.4	1.1/1.5 ($e^{\pm}$), 1.1/1.3 (e^{+})
Output Current [mA]	200(e^{-}), 4-6(e^{+})	1000(e^{-}), 5–7(e^{+})
e^{-} current for e^{+} Yield [A]	1/2.5	2–2.5
e^{-} energy for e^{+} Yield [MeV]	150	150
Positron Yield $[\frac{e^{+}}{e^{-}} \frac{1}{GeV}]$	0.02	0.022
Energy Spread [%]	±0.6(e^{-}), ±1(e^{+})	±0.6(e^{-}), ±1(e^{+})
Admittances [π $MeV/C \cdot cm$]	0.22(e^{+})	0.16(e^{+}), 0.015(e^{-}) (0.015)
No. of acc. Tube	56	56
No. of Klystron	16	16
RF Power pulsed per Kly. [MW]	16/22	17
No. of ED	13	13
Mult. factory of ED	1.4	≥1.4
Operating Frequecy [MHZ]	2856	2856
Beam pulse Width [ns]	2.5	2.5
Repet. Rate [pps]	7/14	12.5
Total LINAC Length [M]	202	202

OPERATION

Early in 1985, We operated a 90 MeV prototype[2], and by the end of spring, 1987, The first trial operation of the first 250 MeV soction of the 1.1/1.4 GeV LINAC was carried out[3], and a positron beam of 2.5 mA and 99 MeV was observed. On Nov 19, 1987, the first operation for the whole LINAC started. On Dec. 5, 1987, the first electron beam of 1.17 GeV and 240 mA was obtained.Two weeks later,the electron beam injection test in BEPC project was succeeded.On Jun 26, 1988, the first positron beam about 1 mA was observed, ten days later, a positron beam of 6.4 mA, 1.2 Gev was arrived. (See FIG.2). On July 3, 1988, the positron beam injection test succeeded also. Since then, the LINAC have been brought into routine operation. The parameters operated are also listed in TABLE I, column third.

PERFORMANCE

The LINAC's operation shows, its performance is well, but some trouble also appeared during the operation period. The general status are presented as follows:

Accelerating system

All accelerating tubes worked well, no arcing occured in them, except the 150 MeV section in its very beginning time, but 3 months later,when the vacuum inner it become better, the arcing disappeared. The performance of the 30 MeV preinjector is satisfactory, the beam capture efficiency of which is 70 per cent and the energy spread is ±1%. No failure took place in positron source equipments, and the positron yield is about 0.022, which is coincident with the calculation result[4]. The beam transmission along the LINAC is shown in FIG. 3. The energy spread of the 1.4 Gev electron beam is ±0.6% (See FIG. 4). The energy stability is acceptable, but it is not good enough for a long time,for the phase of each klystron has a little shift. So, the phasing system needs to be run once a day. The commutation from e^- to e^+ or reversal now can be easily

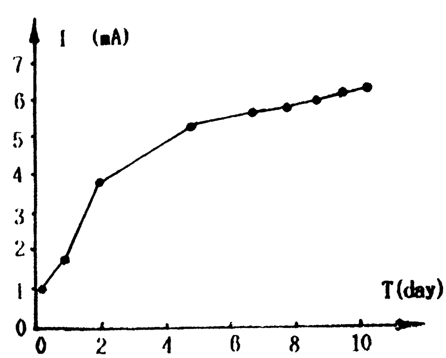

FIGURE 2. Positron intensity VS time of adjustment first

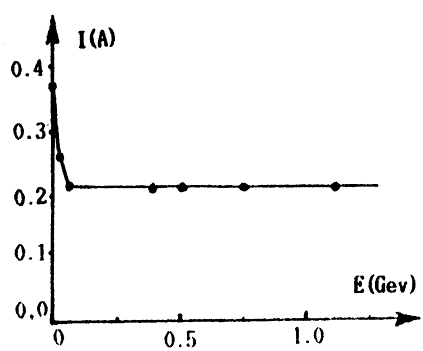

FIGURE 3. The beam transimission along the LINAC

carried out in 1~3 minutes, but early to do this, one or several hours was needed, because the optical path suitable both for e^+ or e^- beam was difficult to set up. Now, one or two klystron amplifiers often work on"standby" mode, so, any one klystron amplifier (except the No.1 to 4)operating on "acceleration" mode can be replaced by one of working on "standby" mode, if it has something wrong. As a result, the 1.1/1.4 Gev LINAC can be run 24 hours a day, for months.

The RF Power System

First, the high RF power system, it consists of the klystron and its modulater, the energy doublor (ED), transmission line–the standard rectangular waveguide including microwave valves, RF power splitters,dummy loads and etc. The parameters of this system are listed in TABLE II. Many parameters operated are coincident with that of designed, but the RF power and the high voltage of modulators operated are now lower than that of designed. It will be soon operated on a higher levev.

TABLE II parameters of high RF power system

parameters		designed	operated
A. Modulator			
High voltage pulsed	[KV]	270	230–250
current pulsed	[A]	295	240–250
pulse top flatness	[%]	±1	±0.8
puls width	[μs]	3	4
B. Klystron			
Frequency	[MHz]	2856	2856
Output power	[MW]	30	15–24
Pulse width	[μs]	3	3
Repet. rate	[pps]	50–300	12.5–25
C. Energy doublor			
Q factor (no load)		10^5	$0.95 - -1 \times 10^5$
Frequency	[MHz]	2856	2856
Multplication factor		1.4	1.4–1.44

No failure has been occured in klystron, ED and in transmission line, but occasionally, some trouble took place in modulators, the worst one is the arcing on the connector of high voltage cable at PFN end.

Second, the low Rf power system, by which we mean the travelling wave tube amplifier, the rigid coaxal cable and the phasing equipment. The first klystron, drived by the travelling wave tube amplifier, feeds 15 MW Rf power to the 30 MeV preinjector, and feeds another 300 KW to the rigid coaxal cable for driving all other klystrons. The phase of each klyatron can be adjusted by phase shifter to an accuracy of ±5°, and the phases of klystrons from number 3 to 16, can be adjusted togethher by a common phase shifter.

No serious trouble in operation was met in this low RF power system, but the rigid coaxal cable needs to be filled with nitrogen gas to improve its phase stability.

Control and beam monitor system

Up to now, the LINAC still operated with a manual control system. But it will be turned to a computor control system in the end of this year. Both systems are something similar, as far as the basic function in front end is concerned. For instance, all power supplies along the klystron gallery can be remote switched on/off, adjusted, and displayed in control room, and the timing system, is completely the same.

Three kinds of beam monitors had adopted: 12 beam current tranformers (BCT) used to measure the beam intensity, 9 fluorescent screens used to determine the beam size and position, with bending magnet or magnetic lens, it can be also used to mearsure beam energy spread or beam admittance (See FIG 5).

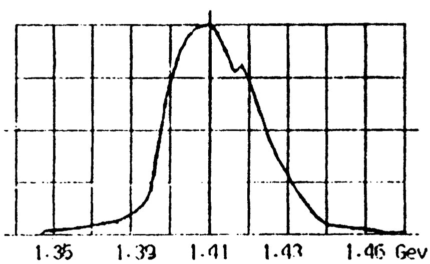

FIGURE 4. The LINAC energy spread

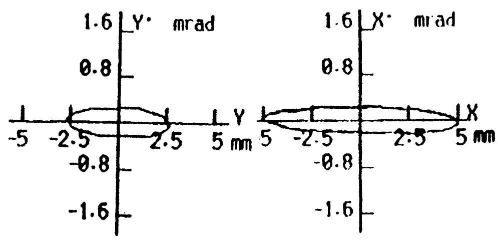

FIGURE 5. e^+ beam admittance

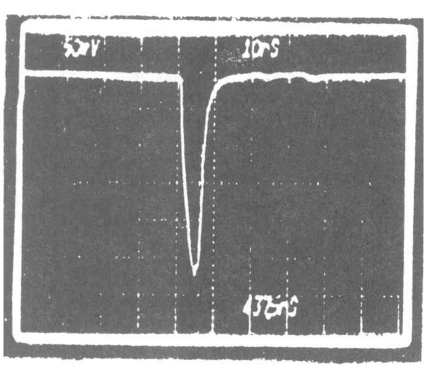

FIGURE 6. The positron beamm pulse measured with BCT.

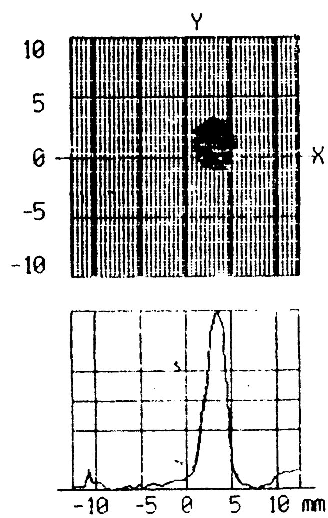

FIGURE 7. The Electron beam size detected with fluorescent screen

The third one is ionization cable, which is used to monitor beam loss. The positron beam pulse measured with BCT, and the electron beam size detected with fluorescent screen are shown in FIGURE 6. and FIGURE 7. The control and beam monitor system worked well. The only one disadvantage is the bad sensitivity to the week positron beam. For improving it, some preamplifier should be added in future.

The vacuum and water cooling systems

The vacuum is about $5 \times 10^{-8}\tau$ and $5 \times 10^{-9}\tau$ in the accelerating tubes and at the output of the window of the klystrons, this is about one order magnitude higher than that of it was designed.

The water cooling system can maintain the wall temperature of accelerating tubes, ED and ect.in a range of $45° \pm 0.3°C$. This two systems are good enough for LINAC operation.

CONCLUSION

As the operating performance shows, the 1.1/1.4 Gev electron positron LINAC is successfully brought into being,it has been operating 7000 hours without serious trouble up to now. As a half energy injector in first step, it has met the need of the BEPC storage ring. We shall make effort to do some improvements about the phasing system and about the positron source, in order to have a more stable phase and get more positrons in future.

ACKNOLEDGEMENT

In the construction period of this 1.1/1.4 GeV electron positron LINAC, there have been some cooperations between our labortory and SLAC. We wish to acknowledge to SLAC Lab.as their experiences are helpful for us.

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