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The 250 MeV Section of BEPC 1.1/1.4 GeV $e^{\pm}$ Linac

Electron Linac Laboratory

(Institute of High Energy Physics, Academia Sinica, Beijing)

The beam test of the 250 MeV section of the BEPC 1.1/1.4 GeV $e^{\pm}$ linac was performed four times during its installation phase. In May 1987, an electron beam of 760 mA and 250 MeV was obtained and a positron beam of 2.5 mA and 99 MeV was observed when an electron beam of 785 mA and 150 MeV bombarded a tungsten target. The main parameters of the linac have met the designed goal and reached the same technical level of similar accelerators in other countries.

The 1.1/1.4 GeV electron linac of the Beijing Electron Positron Collider (BEPC) [2] is the injector of the collider. It produces and accelerates electron and positron beams which are to be injected into the storage ring in order to realize the collision. Pairs of electrons and positrons are produced by hitting the converting target with a 150 MeV electron beam, and the captured positrons are then accelerated to 100 MeV in the initial 250 MeV section. A 250 MeV electron beam with an energy spread of about 1% can be obtained for the case of electron acceleration. The 250 MeV section is followed by twelve accelerating units with the same structure, each of them is composed of four constant gradient accelerating tubes, the RF power is fed by a klystron with an energy doubler (ED). The energy gain of each unit is 120 MeV.

There are three different accelerating systems in the 250 MeV section[1]:

The first part contains a prebuncher, a $\beta = 0.75$ buncher and a 3.05 m long constant gradient accelerating tube[1]. The field strength is as follows: the prebuncher 17.48 kV/cm, the buncher 35 kV/cm, $\beta = 1$ constant gradient acc. tube 120 kV/cm. The energy gain of this accelerating system is 30 MeV. The capture efficiency of electron is 81%. The RF power is fed to the prebuncher, buncher and accelerating tube respectively by a high power

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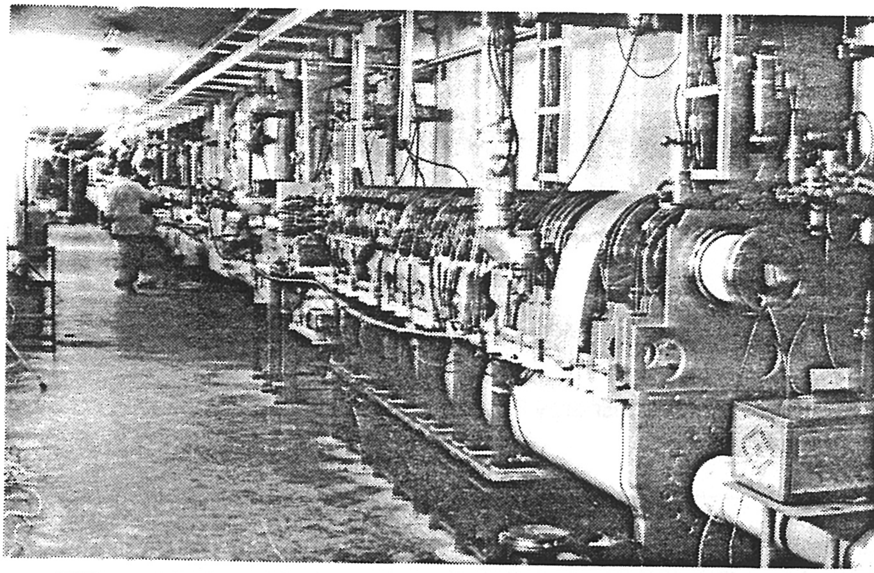

FIG. 1 The accelerating structure of BEPC 1.1/1.4 GeV e± linac.

klystron, and the driving power of the fifteen high power klystrons behind is also supplied by the first klystron through a 20 db coupler.

In the second part of the 250 MeV section, a klystron with ED feeds RF power to the four constant gradient accelerating tubes. The designed energy gain of this accelerating unit is 120 MeV. There are twelve such accelerating units behind the 250 MeV section. The energy gain can be expressed as follows:

$$E = 1.51 \times 20.83\sqrt{P(\mathrm{MW})},$$

here p is the pulse power of the klystron, about 10% of the power is dissipated in the waveguide transmission system. Up to now, we have got 120 MeV accelerating energy, so the output power of the klystron is

$$P = \left(\frac{E}{1.51 \times 20.83}\right)^2 \frac{1}{0.9} = 16.17\mathrm{MW}.$$

It is still below the designed output power level of the klystron, therefore the total energy of 1.4 GeV of this machine can be obtained.

The third part of the 250 MeV section is the positron source system (Fig 3). It consists of a positron converter, a positron capture system, a focusing and an accelerating system. Positron accelerating system includes three constant gradient accelerating tubes. The RF power of the first one A_5 is supplied by one klystron. The other two tubes (A_6, A_{55}) are supplied by another klystron. The converter system is composed of a target (a tungsten block of 10 mm diameter and 6 mm thickness), and a 6 kA pulsed focusing coil. The positron beam with a broad energy spread from the target is captured by the pulsed focus-

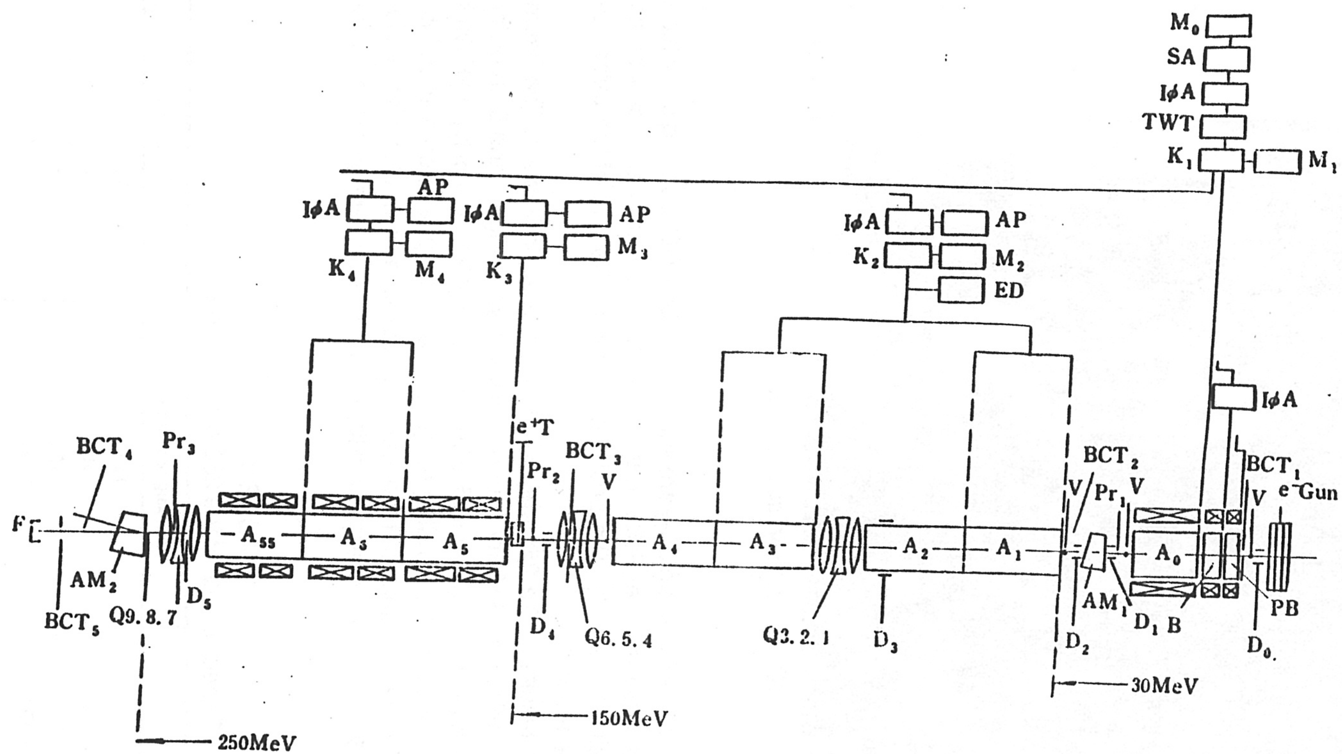

FIG. 2 Layout of the 250 MeV section. A_i) accelerating tube; e^- Gun) electron gun; F) Faraday cup; Am_i) analysis magnet; BCT_i) beam current transformer; ED) energy doubler; AP) phasing system; IϕA) isolator, phase shifter, attenuator; K_i) klystron; PB) prebuncher; V) vacuum valve; M_0) master oscillator; B) buncher; D_i) steering coil; M_i) modulator; Pr_i) beam profile monitor; SA) solid state amplifier; Q_i) quadrupole; TWT) travelling wave tube; e^+T) converter.

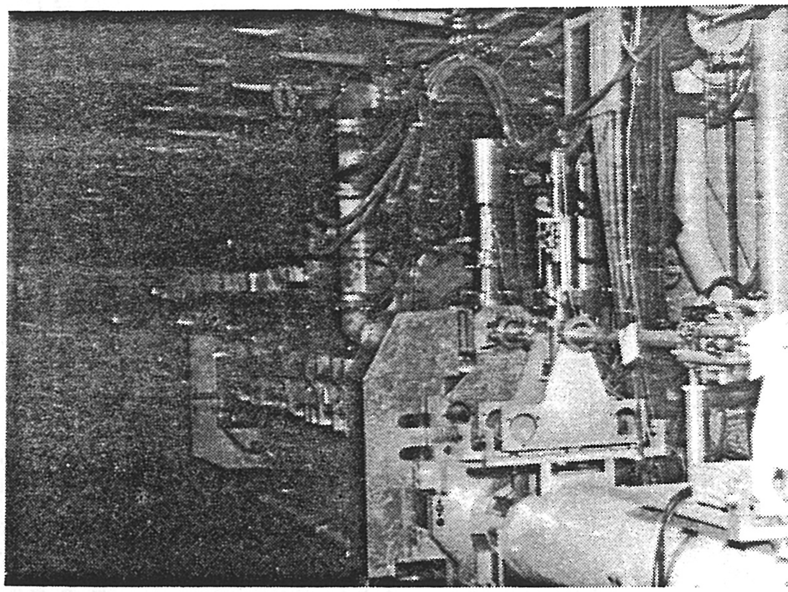

FIG. 3 Positron source system.

ing coil. The accelerating tubes A_5, A_6 and A_{55} are surrounded by a DC focusing coil which produces 0.3 kGs longitudinal magnet field. In this case the positron beam can be ac celerated and focused simultaneously. The positron energy at the end of the three accelerating tubes is about 100 MeV.

The main measured results of the 250 MeV section are listed in Table 1. The beam energy spread of the 30 MeV and 150 MeV sections are shown in Figs 4 and 5. In order to measure the beam energy and energy spread, a fluorescent Al_2O_3 target of type AF995R is placed on the focusing plane of the bending magnet. The light signal is converted into an electrical signal by a T.V. system and then processed by a on-line computer. The resolution of this system is 0.1%. The beam energy stability of the 30 MeV section plays an im-

TABLE 1

Tested results of the 250 MeV section

	Designed value	Tested results
Gun current I_{Gun} (mA)	1000	920
Bombarding current I_{e^-}(mA)	500	785
Bombarding energy E_{e^-} (MeV)	150	148
Diameter of e- beam at target ϕ (mm)	2—3	<2.5
e^+ beam energy E_{e^+} (MeV)	80—100	99
e^+ beam intensity I_{e^+} (mA)	1.5	2.5
Capture efficiency e^+/e^-.(GeV)	0.020	0.0215
Electron beam energy E_{e^-} (MeV)	250	250
Electron beam intensity I_{e^-} (mA)	500	760

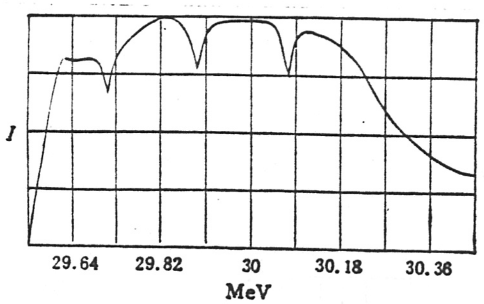

FIG. 4 Beam energy spread at 30 MeV section. Half width in X-direction: 19.7 mm, Energy spread 1.2%, measured by AM_1.

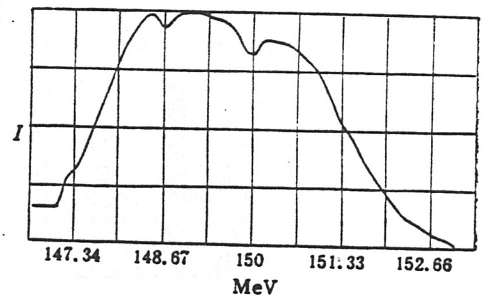

FIG. 5 Beam energy spread at 150 MeV section. Half width in X-direction: 13.9 mm, Energy spread is 1.2%, measured by AM_2.

portant role in the final beam quality. The microwave phase modulation caused by the instability of the pulse voltage of TWT and klystron is one of the factors which affects the beam energy spread. When the pulse width of the RF power is 3 μs, the filling time of the accelerator tube is 0.84 μs and the electron beam width is 2.5 ns, the phase modulation caused by the voltage regulation only affects the beam energy spread within (0.84 + 0.0025) μs. The measured pulse voltage wave shape of klystron K_1 is shown in Fig 6. The phase modulation of K_1 is about 5°. The electron beam pulse is so short that energy jitter caused by the phase modulation is insignificant.

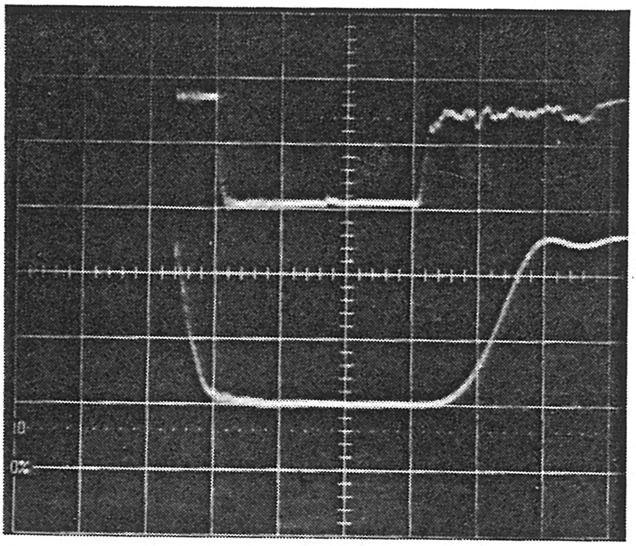

FIG. 6 Pulse voltage wave-form of K_1. Upper: envelope of TWT, bottom: pulse voltage of klystron.

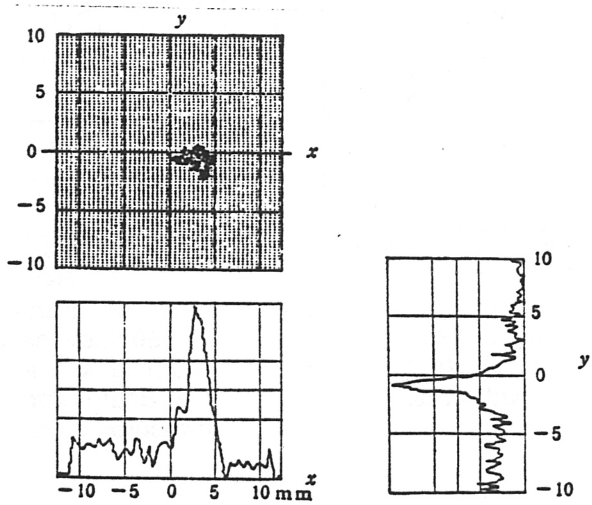

FIG. 7 Cross section of electron beam hitting the converter. Half width in X-direction: 2.5 mm, half width in Y-direction: 1.5 mm.

The size of the cross section of electron beam hitting the converter will affect the positron yield obviously. The measured cross section of the electron beam before the converter is shown in Fig.7.

The beam energy gain from each accelerating structure of the 250 MeV section is listed in Table 2.

The beam intensity is measured by the beam current transformer. The measurement range is 0.2 mA–2A. The rising time is less than 1 ns. The relative measurement error is about 5%. The capture efficiency defined as the ratio of the beam current at the exit of the 150 MeV section to the beam current injected from the electron gun is

$$785 \text{ mA}/920 \text{ mA} = 0.85.$$

And the transmission efficiency (beam current from the 250 MeV section vs. that from the 150 MeV section) is

TABLE 2
The energy gain from each acc. structure

Klystron	Acc. Tube	Beam Energy (MeV)
K_1	A_0	30
K_2	$A_1 - A_4$	120
K_3, K_4	A_5, A_6, A_{55}	99

$$760\ mA/785\ mA = 0.96$$

It means that the alignment of the accelerator is fine and the compensating and steering coils are effective.

DISCUSSIONS

1. According to the results of the test, it can be seen that the main designed technical goal of the 250 MeV section has been achieved, all parts of the machine are in good conditions and the general design is feasible, thereby a solid foundation has been built for later commissioning and operation of the 1.1/1.4 GeV electron linac.

2. In the second part of 250 MeV, four accelerating tubes are supplied with RF power by klystron K_2 through an energy doubler, the energy gain from this unit is 120 MeV. It means that if the efficiency of phasing is 0.95, the contribution of the twelve similar accelerating units behind the 250 MeV section will be

$$120 \times 0.95 \times 12 = 1368\ MeV,$$

In this case, the beam energy for electron acceleration will be:

$$1.368 + 0.25 = 1.618\ GeV.$$

We need to make great efforts to keep all the sixteen klystrons operating stably at the required power level simultaneously. The accelerating energy will get higher if we raise the klystron output power gradually. At the moment, we need to remain the output power of the klystron at 20 MW ,however,the possibility of raising the beam energy is limited.

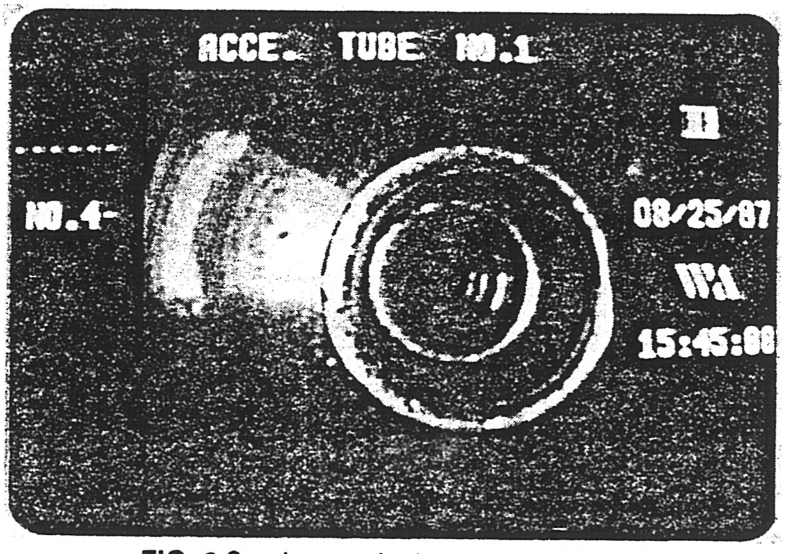

FIG. 8 Spark spots in the accelerator tube.

3. We found some sparking spots in the terminal accelerating structure of the 30 MeV section and the other higher field regions, as well as in the system of the positron target (see Fig 8). Therefore we must improve the vacuum condition in these areas. The protective devices should also be improved and strictly controlled in training the accelerating tubes.

REFERENCES

[1] R. B. Neal, et. The stanford Two Mile Accelerator (1968).
[2] Summary of the preliminary Design of Beijing 2.2/2.8 GeV Electron Positron Collider IHEP (1982, 9).