A 90 Mev ELECTRON LINAC OF IHEP

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Abstract

A 90 Mev electron linac has been built in IHEP (Institute of High Energy Physics), Academia Sinica as a prototype of the injector of BEPC(Beijing Electron Positron Collider).This accelerator consists of high current electron gun,prebuncher,buncher,one 3 meter accelerating section as pre-injecter and two sections more for further acceleration.

First beam was obtained in early 1985,and after tune-up,its performance has met the design specifications: energy,90 Mev ; pulse current,500 mA ; energy spread, 1% ; RF pulse width, 3μs ;beam pulse width, 2.5/20 ns ; energy multiplication factor of the SLED type pulse compression scheme,1.4.

Introduction

Two purposses for building such a prototype were expected: first this endeavour would be leading to a faster pace in construction of the 1.4 Gev injector because the 90 Mev linac was decided to be assemblied and adjusted two years early than that of 1.4 Gev injector. Before that,of course,most of the components and the necessary accessories for this prototype must be completed,that would be implied that the time used for prelimilary research of the 1.4 Gev injector has been shortened, second,the designed performance for BEPC injector,especially for the pre-injector, could be investigated through the adjustment of the 90 Mev prototype to see any of its parameters needs or not to be improved before the whole machine would be sent to fabrication.

General design

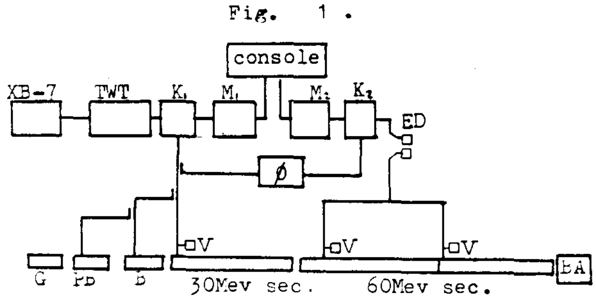
The designed parameters of the 90 Mev prototype just like that of the beginning part of the BEPC injector and some main ones of which are shown in the second column of the table 1.

Table 1.

parameters		designed	measured
Electon energy	Mev	80-90	90
Beam current	mA	200	500
Beam current duration	ns	2.5	2.5-20
Pulse repetition rate	pps	50	50
Energy spread		<1%	< 1%
Operating frequency	MHz	2856	2856
Num. of acc. section		3	3
Num. of energy doublor		1	1
Num. of klystron		2	2
RF power per klystron	MW	16	15

The layout of this prototype is illustrated as Fig. 1,and a few pictures are attached behind this paper.

Fig. 1 .



XB 7	RF generator	K K	Klystron
M M	Modulator	ϕ	Phase shifter
TWT	Driveamplifier	G	Electron gun
PB	Prebuncher	B	Buncher
BA	Beam analyser	ED	Energy doublor
V	Vacuum pump		

It consists of a ns electron gun,prebuncher,buncher, a 3 meter accelerating section around with long solenoid as a 30 Mev pre-injector and two sections more for further acceleration.Two klystron amplifiers each provides about 16 MW RF power,one for pre-injector,another for the next two sections via a SLAC type energy doublor.The first klystron is driven by a TWT amplifier, the second klystron is driven by the RFpower splited from the out put of the first one . The phase shift between the two klystrons could be regulated by a phasing system.Two turbine molecular pumps and seven sputter ion pumps are used to maintain the vacuum at 5x10^{7}torr to 5x10^{8}torr inner the accelerating sections and near the window of klystron respectively,and a water cooling system is equiped to control the temperature within 45±0.1℃ both on the accelerating sections and on the energy doublor.A manual console is furnished,on which besides some adjusting switches and display panels,the main system installed is a synchronous trigger accompanied with a few protecting circuits.

Describtion of processing

Electron gun

A 2.5 ns,500mA pulsed electron gun has been installed early 1983, but its two original parts ,the grid cathode assembly Y646B supplied by Varian Co . and the fast pulse amplifier like that used in PEP , SLAC,could not satisfy the demand of a newly increased intensity towards the gun for higher efficiency of positron production in the improvement design of BEPC project,so, half a year later, these two parts had been replaced with a new grid cathode assembly and a new type of transistor avalanche pulser both developed in our laboratory.After that,a pulsed electron beam was obtained,its intensity is 1 A,and pulse duration is 2.5-20 ns variable.

Accelerating section

We got the first section in the middle of 1983,it is a constant impedance one.We orderd it from the industry.The next two constant gradient sections were manufactured and brazed with a flame furnace at workshop of IHEP in July 1984. This three sections were all matched and tuned in our laboratory, The main parameters we measured are shown in table 2.

Table 2.

parameters		section 1	section 2	section 3
VSWR		1.04	1.1	1.03
Frequency	MHz	2856	2856	2856
Phase shift/cell		2.5	2.5	2.5
Band width	MHz	8	4	4

Modulator

The number one modulator as a first sample was finished in March 1983, and matched with a klystron, it was successfully used for adjustment of the 30 Mev pre-injector. But the pulsed voltage was not high enough for a further improving klystron,to which,the output RF power as high as 30 MW was expected.In order to meet the need of this new klystron,the pulsed voltage was inccreased to 270 Kv.Based on this new demand, the number two modulator was completed in June 1984. With some improvment this modulator was used to the 90 Mev prototype satisfactorily.Its specification is shown in table 3.

Table 3.

Pulse voltage	250-270	KV
Pulse current	250	A
Pulse length,flat top	3	μs
Rise time	0.7	μs
Fall time	1.3	μs
Pulse repetition rates	50	pps
Pulse height deviation from flatneess(max.)	1.2%	

Energy doubler

Because there were a series of technical problems blocked us in manufacturing the SLAC type energy doubler,so, only after two and a half years' effort,it was able to be fabricated and brazed together in the workshop of our institute,then it was tested at low level RF power,installed on the 90 Mev prototype and worked pretty good.Its specifications we measured are shown in table 4. The multification factor M=1.4 is obtained as a ratio of the energies with and without energy doublor from the 60 Mev section.

Table 4.

Unloaded quality factor	$Q=0.95\times10^5$
Coupling coefficient	$\beta=5.4$
Peak power gain	G=7.1 db
Energy multification factor	M=1.4
Operating frequency	F=2856 MHz

Synchronous trigger

The synchronous trigger was built in 1983,It can send a series of triggering pulses to the thyratrons in modulator,the TWT amplifier,the phase reversal of the energy doubler and the electron gun. The jitter time of these pulses was not more than 2 ns,and the spaces of time between them could be adjusted.The pps is variable up to 50 pulses/second.

Driving power

The microwave signal,generated by a commercial generator XB-7,is amplified through two TWT amplifiers connected in series to give out 1 KW RF power which is transmited with a RF cable to drive the first klystron (as meantioned above,the second klystron is driven by the first one). The phase stability of microwave for this TWT amplifiers is seriously influenced by the pulse voltage regulation across the TWT tubes. In early 1983,when the TWT amplifiers was just installed,the phase shift was as high as 20°,later on, as the pulse voltage regulation was surppressed the phase shift is no longer more than 4.5°.

Vacuum

The vacuum system is an oilless and metal sealed system with a TM pump as a rough evacuation pump,and one more TM pump prepared for electron gun if it is insulated from the whole system by closing the pneumatic valve downstream of it. Instead of using a big sputter ion pump for the whole machine, we prefered to adopt a design of distributing 7 small sputter ion pumps,each with an evacuating rate of 70 liter/second along the accelerator and in between of the RF power transmission line. By such an arrangement, through 24 hours' evacuation,the operational pressure of 5×10^{-8} torr in the electron gun and near the window of klystron,and of 5×10^{-7} torr inner the accelerating sections could be obtained.Through more than one year's continuous operation,even once a failure we never had in the vacuum system,so,the quality of it is rather reliable.

Beam monitors

At the time so far the 90 Mev prototype began to adjust ,we only fabricated a few beam monitors such as two of gap monitors ,a 90 Mev electron beam Farad cup, a beam profile detector with TV camra.With which and a double focusing 90 degree bending magnet, the beam performance was measured during the adjustment.

Cooling water system

In order to guarantee the RF phase stability,the temperature on the wall of the accelerating sections to be held at 45°±0. 4°C.We have achieved this demand by means of a cooling water system, in which a three-way blending valve controled the water flow and the temperature of it within ±0.1°C at the inlet of the pipe around on the accelerating sections. For resistance against the corrosion caused by the distiled water selected as coolant,the stainless steel components including the circulating pumps,the valves and the pipes,except some smaller branches like those copper pipes brazed around the accelerating sections, were selected to constitute the cooling water system.

Adjustment and conclusions

The adjustment of this prototype was completed by two stages:first, in Sep. 1983, we got the 200mA electron beam current with energy of 29.8 Mev from the 30 Mev pre-injector;second, in Nov.1984, when the 90 Mev prototype as a whole machine was assemblied, its adjustment soon be started, and in March 1985, this work brought to an end tentatively. The parameters we was able to measure during those adjustment are presented in the third column of table 1. Comparing these parameters with those of designed in the second column of the same table,it seems to be good in coincidence with each others,and some conclusions have been made after adjustment and present them as follow:

1. The physical design of our pre-injector,which is very important for constructing a good injector with a well bunched beam, is reasonable and feasible.
2. Most fabrications of components and equipments of the 1.4 Gev $e^{\pm}$ injector can be started immediately , but there were still some equipments,for which something have to be improved before put them into batch production.For instance, the klystrons being used are not stable,when the RF out put arrived at 16 MW(max. rated).So, it is reasonable to develop a higher power (34 MW)klystron for BEPC project.For another example ,the capacitors of PFN for klystron modulator could not withstand the high voltage,so,we decided to replace these capacitors with those supplied from SLAC.
3. Through the adjustment of 90 Mev prototype , we found that, some operation conditions must be modified or improved as described in follows:

a) owing to the arc taken place frequently in the RF power transmission line(the air in it was not evacuated) of the bunching system,so that, we decided to fill nitrogen in it or connect it through with the vacuum system,in order to suppress the arc when the RF power is at high level.

The water cooling system could stabilize the distiled water temperature within ±0.1°C, but when the pressure of the supply tap water in the heat exchanger or the pressure of the compressed air to motivate the three-way blending valve lost its own stabilization, it would be no longer available to maintain the tolerance of the temperature mentioned above. We must take care to this problem in constructing the cooling water system for the 1.4 Gev injector in future.

b) The interference from the modulator had seriously influenced the operation of the trigger system, so,we made effort to overcome this problem by means of improving the modulator's shielding,grounding and separated the high current wires from the weak signal cables.We thought,all of this efforts will be helpful for us in solving the same quastion anticipated in future.

Before we end this paper,we must point out that, during the adjustment the measurement for a important parameter,the emittance of the electron beam never achieved,because the instrument and the beam monitor needed for this measurement was not completed.

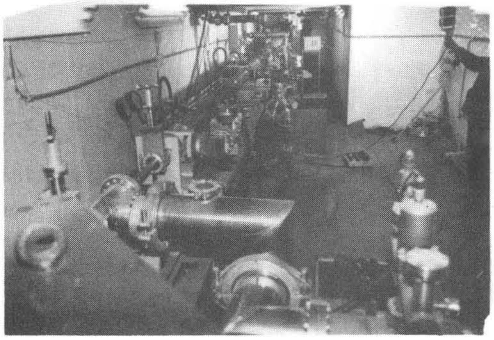
Acknowledgment

We wish to acknowledge to Dr.R.H.Miller and R.F. Koontz for joining us about a week in adjustment of the 30 Mev pre-injector in Dec.1983.Their experiences in adjusting the beam energy and measuring the energy spread are helpful for us. We also appreciate Dr.R. Ecken for his excellent work at our laboratory in improving the performance of our klystron modulator for 90 Mev prototype during his half month's visit to our laboratory in 1984.

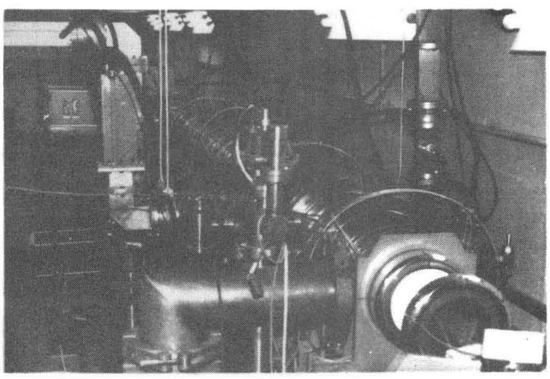
References

1. Summary of the preliminary design of Beijing 2.2/ 2.8 Gev electron positron collider(1982).
2. Gu Meng-ping,Zhu Guo-Hui,Qian Zhu-Ming,Mi Jian-Lin "A nanosecond Pulsed Electron gun System for BEPC." IEEE Transactions on Nuclear Science, Vol.NS-0, No.4,pp.2962-2964,August 1983.

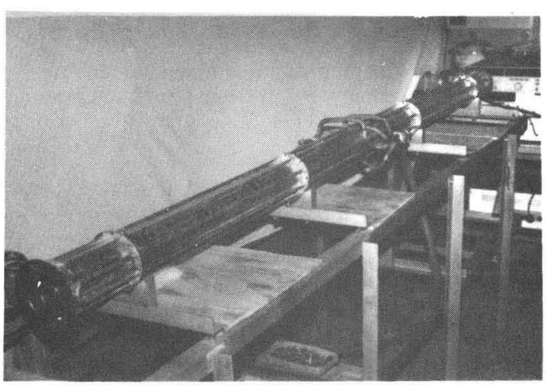
A few pictures of the 90 Mev electron linac of IHEP



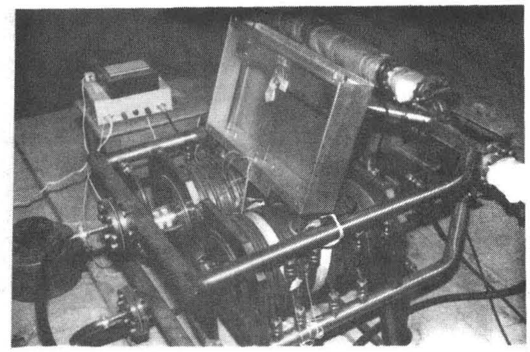
Pic.1. The 90 Mev electron linac



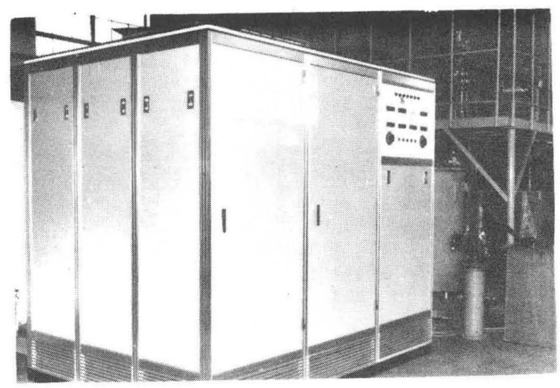
Pic.2. The 30 Mev section



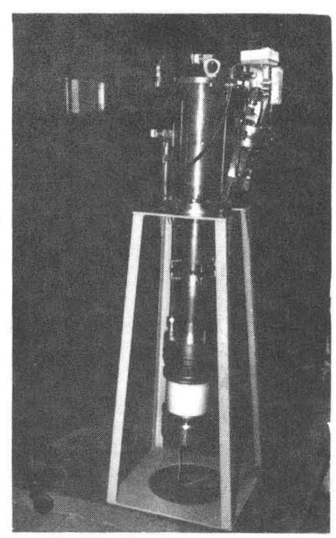
Pic.3. A 3 meter accelerating section



Pic.4. The SLAC type energy doublor



Pic.5. Klystron modulator



Pic.6. Klystron