THE STATUS OF BEPC 1.3-GEV LINAC

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ABSTRACT

As the injector of BEPC, the electron / positron linac has been put into operation for more than 5 years since March 1989. During past 5 years the performance of the linac was gradually improved. The routine injection energy was increased from 1.1 GeV to 1.3 GeV and the operation efficiency was enhanced to 98%. In order to achieve a higher injection efficiency and more stable beam in storage ring, a plan upgrading linac energy to 1.7 GeV is being carried forward. New 65MW klystrons equipped with 150MW modulators will replace some old ones. In the paper, the status of linac operation and RF power system upgrading are given.

INTRODUCTION

The BEPC injector is a traveling wave structure linac. The routine injection energy of electron and positron beam is 1.3 GeV. The preinjector is composed of thermocathode electron gun (4A, 80KV), prebuncher (β=0.5), buncher (β=0.75) and an accelerating column (30 MeV) with solenoid. There are 16 klystron amplifiers, 56 accelerating tubes, 13 SLED cavities (the SLAC type of RF power compressor) in the linac. Each klystron amplifier with a SLED and 4 accelerating tubes forms a standard accelerating unit which can provides an energy of 100 ~130 MeV with an input RF power of 16 ~22 MW. For e+ production the main section is preceded by a 150 MeV high current electron section. The positron converter contains a moveable tungsten target of 7 mm thick (2 radiation lengths), a 1.8T tapered field coil. The produced positron is captured by a 100MeV section with solenoid and then goes into the main section of the linac that consists of 12 standard accelerating units. Table 1 is a list of parameters of the BEPC injector.

Table 1. Parameters of the BEPC Injector.

parameters	routine value
output energy	1.3 GeV
e^- current	0.6 A
e^+ current ($\Delta\varepsilon/\varepsilon \le \pm 0.8\%$)	4 mA
RF frequency	2856 MHz
beam pulse width	2.5 ns
RF pulse width	3.0 μs
e gun current	3.2 A
emittance π(MeV/c)·cm	0.015 (e^-) 0.16 (e+)
energy spread	± 0.6 % (e^-) ± 1% (e+)
bombarding energy	140 MeV
positron yield	0.025 ($e+/e^-$·GeV)
repetition rate	12.5 pps
multiplication factor of SLED	1.4 (average)
No. of klystrons	16
No. of acc. columns	56
No. of SLED cavities	13
pulse power of klystron	19 MW (average)
total length of linac	202 m

PERFORMANCE

During the past 5 years the performance of the machine has been improved gradually. The output energy, positron intensity and the stability of the machine were emphasized.

__Stability and Reliability.__ Figure 1. shows the operation efficiency of the machine (providing beam time / running machine time) has risen to 97.8% in 1993 and 99% in first half year of 1994. The machine running time is about 256 days per year in average in the past 5 years. the ratio of machine running days to calendar days is about 70%. Observably, so high operation efficiency is a contribution to BEPC integral luminosity.

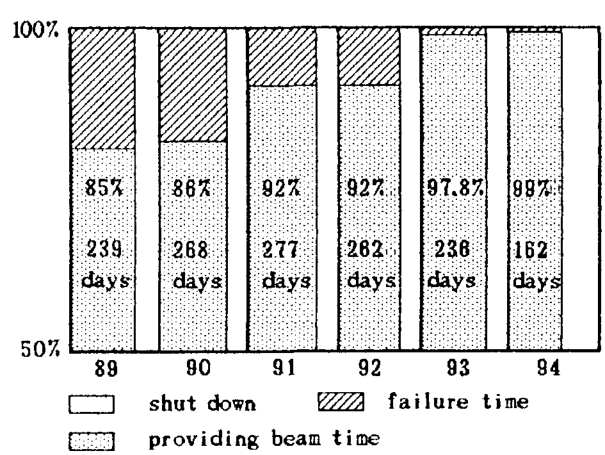

Figure 1. BEPC linac operation efficiency

Output Energy. The output energy was enhanced from 1.1 GeV to 1.3 GeV owing to the RF source improvement. The DC voltage of modulator was increased and the impedance match between klystron and modulator was optimized. Some old type components were replace by new ones and some parameters which are RF drive level, klystron solenoid current, heater power and impedance of modulator PFN etc. were optimized. The maximum electron energy is 1.8 GeV and maximum positron energy is 1.6GeV.

e+ Beam Intensity. The e+ beam intensity is more than 10 mA at the end of e+ capture section. After optimized beam optic path and using large aperture Q magnets, the maximum e+ beam intensity is 6.3 mA in e+ transport line ($\Delta\varepsilon/\varepsilon < 0.8\%$). The best positron yield is more than 0.03 $e^+/e^-\cdot$GeV.

ENERGY UPGRADE

An upgrading BEPC luminosity project is under going. Energy upgrade of the injector is a part of the project. The purpose is to improve the stability of injecting beam so that the beam intensity in storage ring can be enhanced. Two ways are considered to increase the output energy. One is to increase RF power of klystron. Some 30 MW klystron amplifiers will be replaced by 65 MW ones. Another way is to widen RF pulse from 3.0 μs to 3.5 μs or more wilder width so that higher energy multiplication factor can be achieved.

• 65 MW Klystron

A 65MW S band klystron is being manufactured. The main design parameters are following:

Table 2. 65 MW klystron Parameters

Pulse Output Power	65 MW
Operation Frequency	2856 MHz
Beam Voltage	350 kV
Beam Current	415 A
Perveance	$2.0\pm0.1 \cdot (10^{-6})$
Pulse Width	3.5 μs
Gain	51 dB
Repetition Rate	50 pps
Efficiency	45 %
Cathode	dispenser
Life Time	20,000 hours

The design of the electron gun for the klystron was carried out using SLAC Electron Trajectory program. The current density of dispenser cathode is about 8A/cm^2. The maximum voltage gradient is about 200kV/cm. The electron gun has been tested and the test result of short tube is good. When the heater power is 600W and the DC anode voltage is 860 V, the DC emission of the dispenser is 100 mA. Also the pulse emission of dispenser is good, the micro-perveance is 1.93.

The klystron has six cavities. The parameters of the RF interaction region, such as cavity frequencies, drift lengths and output gap impedance were optimized with an one-dimension , time-stepping disk model computer program. The klystron has two output windows paralleled of the pill-box type. The windows is coated with titanium nitride and tested in a resonant ring before assembling the klystron.

A new testing station for 65 MW klystron has been set up in IHEP. The station includes a RF drive system, a focusing system, a water load with ultra-high vacuum system and a modulator. The whole tube of the new klystron will be tested next month.

• 150 MW Modulator

The new klystron modulator equipped with 65MW klystron for BEPC linac has been designed and constructed. With careful consideration to reliability and EM compatibility , 3.7 μs wide pulse with 354 kV voltage and 430 A peak current were successfully generated under water dummy load. The results of the performance test are shown in table 3.

Table 3. The Result of Modulator Test

Peak power output	152 MW
Average Power output	25 kW
Output Pulse Voltage	354 kV
Output pulse Current	430 A
Load impedance	3.66 Ω
Output impedance	3.44 Ω
Pulse flat top length (<1.5 % deviation)	3.7 μs
Rise time (10~90%)	800 ns
Pulse amplitude drift	
short term	< 0.1 %
long term	< 0.3 % / 4 hrs
Repetition rate	25 pps

Some special considerations in design philosophy are introduced as follows :

The charging transformer primary inductance was chosen as large as possible. Because the repetition is so low as to chose the inductance of 80H. So that the thyratron CX1536A operated at comfortable condition with long charging voltage rise time and short full voltage hold-off duration on thyratron.

End of line clipper circuit was not only used, but also the whole function that had been proved at SLAC has been realized completely . Such as monitoring end of line clipper current each time a load fault occurs and protecting modulator in this event to be turned off for approximately 2 Sec. and then turned on again.

The choice of the main high voltage in the modulator was mainly governed by the ratings of CX1536A thyratron (ration 50 kV). Since the klystran requires a maximum of 350 kV on its cathode. the pulse transformer with a turns ratio of 1:15 was tested. At full rating the maximum voltage on PFN was about 47 kV, which gives slightly stringent margin to 50kV thyratron. A new pulse transformer with a turns ratio of 1:16 made in China will be tested in the near future.

SCR power controller was used instead of IVR. In the one hand DC high voltage regulation has been improved by using the phase control feed back system and the burden of the resistive D-Qing action has been reduced, on the other hand SCR power controller provided protection system with four different DCHV level on which the modulator operated when faults occurs. The first 150 MW modulator is being moved to the klystron gallery and installed on the linac.

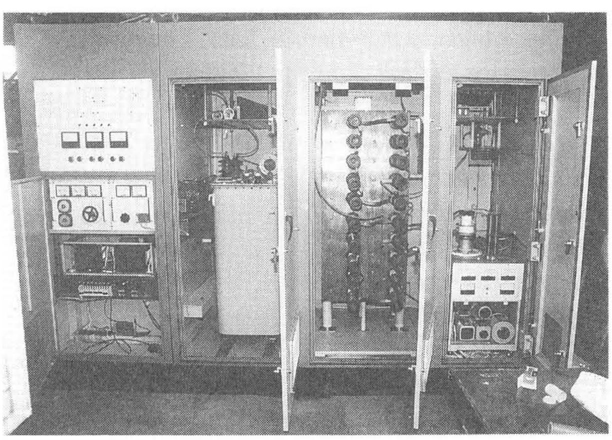

Figure 2. Picture of modulator

• Widening RF Pulse Width

The current energy multiplication factor (M) is 1.51 according to calculation under 0.83μs filling time of the structure and 3μs RF pulse width. In fact, the factor is about 1.4 by measurement. The table 2 gives the relation of RF width and the M factor. More than 3.5 μs RF pulse width and 1.5 of energy multiplication factor are expected. The RF pulse width limit depends on the bearing ability of klystron window.

Table 4. Relationship of RF Width and M Factor

RF pulse width	M in theory	expected M
3.0 μs	1.51	1.4(measurement)
3.5 μs	1.60	1.48
3.8 μs	1.65	1.5

• Energy Gain

By the Sept. 1995, 4 sets of 65MW RF power sources will be install in the linac. Those new power source will give a 80MeV energy gain contribution for each standard accelerating unit. 1.7 GeV is expected due to the 300MeV energy gain by new RF power source and 107% energy multiplication factor gain. The first set of RF source which included a klystron bought from SLAC and a modulator manufactured by IHEP has begun to install in the linac. By the energy upgrade schedule, 1.55 GeV energy will be achieved in the end of 1995 and that is 1.65 GeV in 1996 and 1.7 GeV in 1997.

ATTACHED IMPROVEMENTS

• RF transfer system. A 15dB directional coupler will replace 20 dB one in RF drive line so that the RF power can be double to fit to need of 65MW klystron input.

• A new W/G vacuum valve has been designed and manufactured in IHEP. The test result of low level RF specifications and vacuum are good. It will be installed in the waveguide system to replace old one which can just bear 35MW RF peak power at most.

• A new monitoring and interlock system is setting up. It includes 4 subsystems which are: MK subsystem which includes PLC local station, communication interface and a industrial personal computer as central control unit; a vacuum monitoring system with automatic emergent protection; a computer controlled e^+/e^- conversion device and a focusing and steering magnets control system. The industrial person computer will be used in every subsystem. Instead of old Manual operation the operators can run the machine by new system with PC touch panel.

REFERENCE

[1] W. Ren et al, "Physics Design of BEPC Injector", IHEP Internal Report, 1989 (Chinese)

[2] G. Li et al, " The Energy Doubler of Electron Linac", AEST 1985.6. (Chinese)