LINAC DESIGN FOR NUCLEAR DATA MEASUREMENT FACILITY*

M. Zhang #, X. Li, W. C. Fang, Q. Gu, SINAP, Shanghai 201800, China

Abstract

Pulsed neutrons based on an electron linear accelerator (linac) are effective for measuring energy dependent cross-sections with high resolution by using the time-of-flight (TOF) technique. In this paper, we describe a 15-MeV linac design for the nuclear data project in Shanghai Institute of Applied Physics (SINAP).The linac has three operating modes and the maximum average power is 7.5kW. The characteristics of the linac and the studies of the beam dynamics are also presented.

INTRODUCTION

Precise measurements of neutron cross section are of great importance for the safety design, the evaluation of neutron flux density and energy spectrum around a reactor. It is effective for measuring energy dependent cross section with time-of-flight (TOF) techniques [1].Photo-neutron source is a powerful tool to produce intense pulsed neutrons. For the first photo neutron source in China which located at SINAP JiaDing campus, one 15MeV electron LINAC is adopted to produce neutron by choosing the W as the target of photo–neutron source. For the next step, one 100 MeV electron LINAC will be built in the near future. At present, we have finished the technical design for the 15MeV linac and most of the hardware fabrication is finished as well. Installation will be started soon in an existed experimental hall and the commissioning of the machine will be in this summer. The operating modes and the beam specification are listed in table 1.

Table 1: Beam Specification for 15MeV Linac

Mode	Pulse Width [ns]	Pulse Frequency [Hz]	Beam energy [MeV]	Average Current [μA]
Short Pulse	~3	266	>15	0.5
Medium Pulse	15-30	266	>15	2.5-5
Long Pulse	500-3000	10-200	>15	18-100

LINAC DESIGN AND PARAMETER OPTIMIZATION

The facility consists of the linac section and the transport line， the overall layout is shown in Fig. 1.The 15MeV linac consists of an e-gun, a standing wave pre-buncher, a travelling wave buncher and one accelerating structure. After the beam cross through the linac, the high efficient transportation and collimation can be achieved in the transport line, as well as the beam size matching of the bunch.

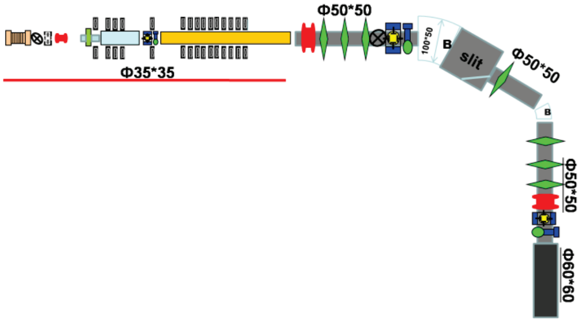


Figure 1: Layout of DCLS linac.

The electron beam is generated from a thermionic gun and the beam energy is chosen to 60keV.In order to get a high efficiency of capture and acceleration, a bunching system is used which consists of a pre-buncher and a buncher. The pre-buncher is one re-entrant type standing wave cavity made of stainless steel; the travelling wave buncher consists of 16 cavities including the input and the output coupler cavities. To improve the capture efficiency, before constant beta cavities, the parameters of the first six cavities are changed slightly and the cavity geometry parameters are shown in table 2.A prototype to test the performance of the TWB was done based on one project for industrial application and 1kW (2MeV) average beam power has been reached successfully.

Table 2: Cavity Parameters for Travelling Wave Buncher

No.	βp	βg/%	tf/ns	α	a/mm	b/mm	Q	Rm	f/MHz
1	0.63	0.7167	1.02594E-08	0.4507	10	41.502	9266	25.757	2856.035
2	0.6	0.7068	1.04031E-08	0.4801	10	41.575	8820	22.834	2856.005
3	0.6	0.7068	1.04031E-08	0.4801	10	41.575	8820	22.834	2856.005
4	0.87	0.7455	9.8631E-09	0.3258	10	41.102	12321.3	49.307	2856.006
5	0.93	0.7458	9.85913E-09	0.3094	10	41.035	12968.3	54.926	2856.013
6	0.96	0.7456	9.86178E-09	0.3023	10	41.005	13277.2	57.67	2856.002
7-16	0.98	0.7452	9.86707E-09	0.298	10	40.986	13478	59.474	2856.001

#zhangmeng@sinap.ac.cn

Two kinds of normally used accelerating structures are investigated for maximizing the accelerating efficiency. For the Constant Impedance (CI) structure [2], optimized beam current, maximum beam power and corresponding efficiency can be evaluated by the following formula.

$$\mathrm{I}_{opt} = \frac{\sqrt{2 \cdot \mathrm{P}_0 \cdot R_m \cdot \alpha} \cdot \left(1 - e^{-\alpha \cdot L}\right)}{2 \cdot R_m \cdot \left(\alpha \cdot L - \left(1 - e^{-\alpha \cdot L}\right)\right)},$$

$$P_{b\max} = \mathrm{I}_{opt} \cdot U_{bopt} = \frac{P_0 \cdot \left(1 - e^{-\alpha \cdot L}\right)^2}{2 \cdot \left(\alpha \cdot L - \left(1 - e^{-\alpha \cdot L}\right)\right)},$$

$$\eta = \frac{P_{b\max}}{P_0} = \frac{\left(1 - e^{-\alpha \cdot L}\right)^2}{2 \cdot \left(\alpha \cdot L - \left(1 - e^{-\alpha \cdot L}\right)\right)} = \frac{\left(1 - e^{-\tau}\right)^2}{2 \cdot \left(\tau - \left(1 - e^{-\tau}\right)\right)}$$

As for Constant Gradient (CG) structure, cavity parameter differs from cell to cell and a code is written based on the analytical method. The simulated results for CG structure are shown in Fig. 2 and the beam current is assumed constant during the acceleration. For meeting the 15MeV beam energy requirement, the input RF power should be more than 14MW and the accelerating efficiency is not distinct advantage over CI structure.

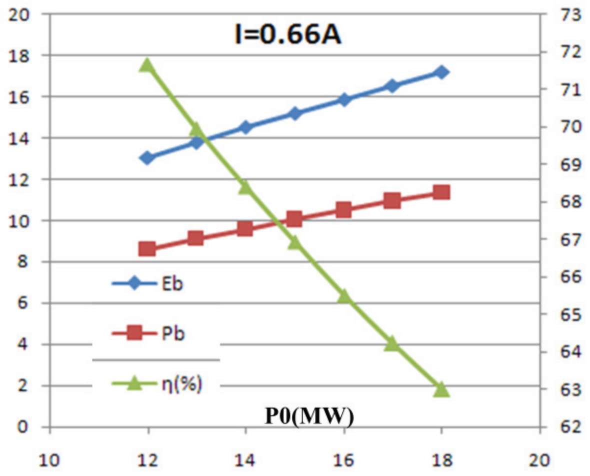


Figure 2: The beam energy, beam power and the accelerating efficiency depending on the different input RF power.

CI structure are finally adopted for our case, after balancing between accelerting effiency and the challenge for the fine machining requirement. The CI acclearing structrue consists of 40 cavities，operating at 2π/3 mode and the total length is about 1.5m.

The total power source for the travelling wave buncher and the accelerating structure is about 18MWand we choose TOSIBA E37308 as the pulsed power ampifier.

BEAM DYNAMICS SIMULATION

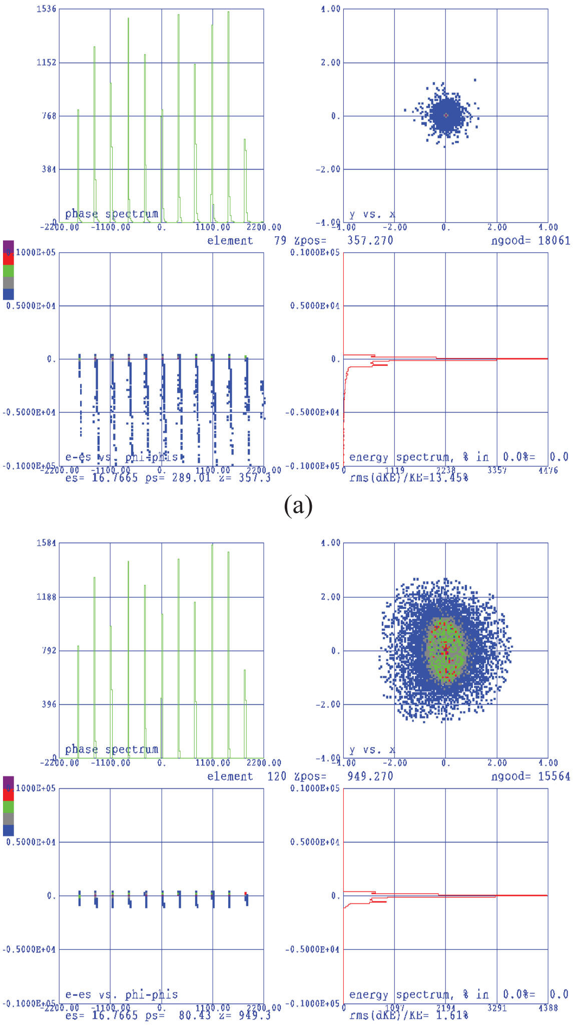
Parmela [3] is used for the tracking simulation. Before simulating the beam dynamics for the transport line, the beam optics optimization should be done according to the beam parameters coming from the accelerating structure.

Two sets of three quadrupoles are arranged before and after the two dipoles, each one bends the beam by 45º. For achromatic design of the bending section, another 10cm quadrupole is adopted in the center of the bending section and the magnetic field gradient is about 200G/cm.

Table 3: beam Parameters at Different Positions Along the Beam Line

	E-gun	Prebuncher	TWB	ACC	Transport
Input parameter	Φ8mm D27mm	6KV	2.4MW	14.4MW	---
Energy	60KV	58KV	2.13MV	16.8MV	16.8MV
Energy spread	<2%	7%	20%	13%	1.8%
Beam current	0.66A	0.66A	0.63A	0.6A	0.54A

The simulation results are summarized in table 3 in which the accelerating process is clearly shown. By modulating the beam using the prebuncher, 60KeV electron beam is bunched and captured in the following TWB and accelerated to the desired beam energy by the last ACC. The transportation efficiency for the linac is more than 90% and the energy spread is relatively large because of the long tail structure, as shown in Fig. 3(a), following the beam bunch.



(a)

(b)

Figure 3: The beam longitudinal, transverse profiles at the end of linac (a) and at the position for mounting the target (b).

After the last transport line section, beam energy spread is reduced and the long tail structure beam is collimated through the stair-like block, as shown in Fig. 3(b). 10% beam current is cut off and the average beam current is about 0.5mA for the target of photo–neutron experiment.

CONCLUTIONS

The first photo-neutron source for nuclear data measurement facility in China is designed. Optimizations for the injector section of the linac, both the RF optimization of the buncher and the strength optimization of the magnetic field are done for capturing and accelerating the beam effectively. Beam transportation and beam tail scraping occur simultaneously in a limited space. Installation will be started soon in an existed experimental hall and the commissioning of the machine will be in this summer.

REFERENCES

[1] G. N. Kim et al., “Pulsed neutron source using 100-MeV electron linac at Pohang accelerator laboratory”,PAC1999.
[2] Electron linear accelerator, C.G. Yao,1986 (in Chinese).
[3] L. M. Young, “ PARMELA ” Los Alamos National Laboratory report LA-UR-96-1835 (Revised April 22, 2003).