100-MEV ELECTRON LINAC FOR NEUTRON BEAM FACILITY AT PAL

J.-Y. Choi, H. S. Kang, G. N. Kim, M. H. Cho, I. S. Ko, and W. Namkung
Pohang Accelerator Laboratory, Pohang University of Science and Technology
Pohang, Kyungbuk, 790-784, Korea.

Abstract

We are constructing a neutron-beam facility at PAL with KAERI in order to establish a nuclear data center in Korea. The facility will consist of a 100-MeV electron linac, a neutron target room, and at least three time-of-flight beam lines. The linac will have two operating modes of beam pulse: short beam pulse modes of several nanosec and long pulse modes to the maximum of 4 μs. The major electron beam parameters are as follows: the maximum beam power of 10 kW, the beam current from 300 mA and 5 A, corresponding to long and short pulse modes, respectively. In the acceleration of long pulse beams, multi-bunch beam loading effects are expected to be so severe that a magnetic chicane system will be used to compensate the beam loading. We report the design results of the bunching system, the chicane system and the beam transport line to the neutron target.

1 INTRODUCTION

Accelerator-based pulsed white neutron sources are the most efficient neutron sources for neutron data production, especially high-resolution measurements of differential neutron cross sections. These sources are the only ones which can continuously cover the whole range from thermal energies up to several tens of MeV[1].

We are constructing a neutron-beam facility at PAL with KAERI in order to establish a nuclear data center in Korea[2,3]. The facility will consist of a 100-MeV electron linac, a neutron target, and at least three different time-of-flight (TOF) beam lines.

The electron linac is being constructed in the existing tunnel in parallel with the main 2.0-GeV linac of PLS. The present building arrangement at PAL makes it difficult to place the target in rectilinear downstream of the linac. The neutron target room will be newly constructed off the electron linac. At the linac end the electron beam must be bent in the direction of 45° to be transported to the neutron target. In this paper the design results of the electron linac are discussed, and the construction and acceleration tests are described elsewhere[4].

2 ELECTRON LINAC

2.1 Beam Modes and Parameters

The energy gains attainable with one SLAC5045 klystronfor various beam modes are shown in Table 1. It is assumed that the klystron is operated at 50 MW and 10% of the power is dissipated in the waveguide system.

Table 1. Electron beam modes and parameters.

Mode	Pulse Length, ns	Beam Current, A	Beam Energy, MeV	Beam Power, kW (RF pulse rep. rate)	
				(180pps)	(300pps)
Short Pulse	2	5	97	0.17	0.3
	10	5	88	0.8	1.3
	100	1	79	1.4	2.4
Long Pulse	1000	0.3	77	4.1	6.9

∗ The case where SLAC5045 is operated at the pulse repetition rate of 300 pps and the RF pulse length of 2 μs.

With a negligible beam loading as in the 2-ns beam, one klystron is capable of accelerating the beams to 100 MeV. In the acceleration of high-power electron beams the energy gain is reduced by a large amount due to the multi-bunch beam loading.

It is known that the neutron yield is not very sensitive to the incident electron energy if it is above 30 MeV, but very nearly proportional to the electron beam power[1]. Therefore, the energy spread of the electron beams at the target is not very important as far as neutron production is concerned. In our case, however, it is very important to reduce the energy spread due to the beam loading for transporting them to the target with a minimum beam loss at the bent transport line. The correction of beam loading will be performed by a magnetic chicane system. Table 1 shows that we can obtain a maximum beam power of 6.9 kW by operating the klystron at the pulse repetition rate of 300 pps and pulse length of 2 μs.

2.2 General Layout of Linac

Figure 1 shows the overall layout of the linac. The electron beam is produced by two options of an RF gun or a triode thermionic cathode gun, for which a Cockcroft-Walton type DC voltage generator supplies the accelerating voltage of 120 kV.

Electron beam will be accelerated through two 3-m accelerating sections of SLAC type fed by one SLAC5045 klystron. To compensate the beam loading in accelerating sections, a magnetic chicane system will be installed between the two accelerating sections. An achromatic bending system is located at the end of linac in order to bend the electron beam to the neutron target

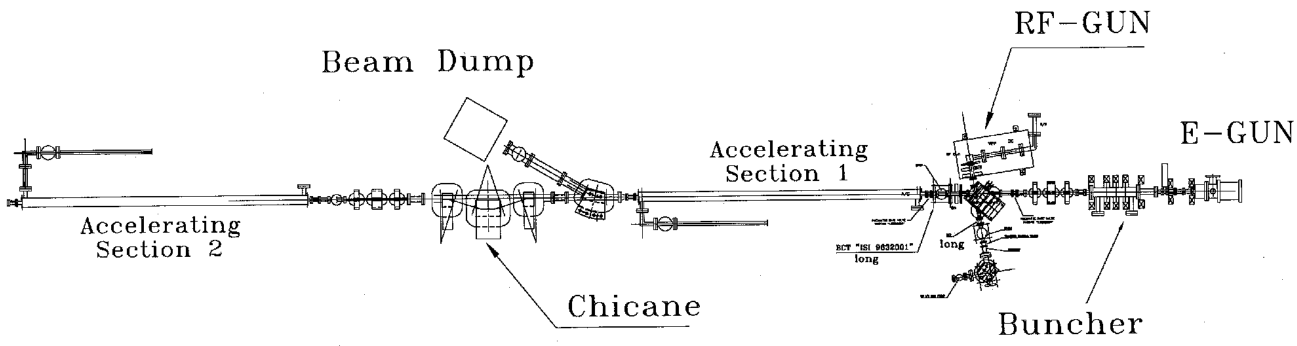

Figure 1: Schematic layout of the electron linac

2.3 Bunching System and Beam Dynamics

The bunching of the electron beam is carried out by a prebuncher and a buncher. The prebuncher is a standing-wave cavity with the resonant frequency of 2856 MHz.

For the bunching system we are considering two schemes. In the first scheme, an RF-gun is considered to be used in addition to the triode thermionic gun. Since the beam emerging from the RF-gun is already bunched, the RF-gun is jointed to the accelerator at the downstream of the buncher by an alpha magnet as shown in Figure 1. While this scheme enables alternative use of two electron sources, it is necessary to accelerate the bunched beam to a higher energy to minimize the debunching in the drift space around the junction point. It entails, therefore, a long buncher and a high RF power input to the buncher. The other scheme, which is considered here, is to use a triode thermionic gun as an electron source without a RF gun. In this case the bunching system will have the same configuration as the present PLS linac[5]. This scheme allows the flexibility in beam bunching.

Figure 2 shows an example of the simulations using the beam dynamics code, PARMELA. This example is for the long pulse and low peak current mode. We could obtain bunches with a bunch length of about 5 ps in the simulation. The particle transmission is about 88%, and the energy spread in the bunch is about 1%. By optimizing the focusing magnetic field along the linac, the beam radius can be maintained below 5 mm except for the bunching section and the drift space before the buncher. In the high current modes, we could obtain similar results.

2.4 Magnetic Chicane System

The energy spread of electron beams at the linac end must be low enough to control the beam size at the bending section. Among other methods, we adopted a chicane system consisting of three magnets, which is an economical and convenient method suitable for a relatively small-scale linac. Since the filling time of a

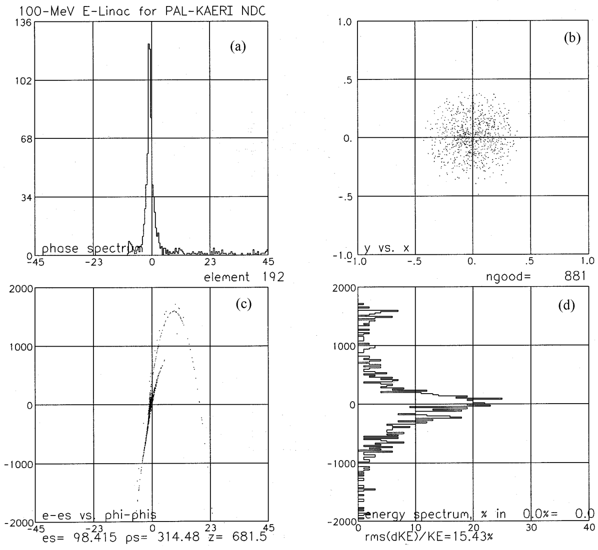

Figure 2: Example of the simulation results with PARMELA. (a) Number of particles vs. phase, (b) particle distribution in transverse real space (unit ; cm), (c) energy (MeV) vs. phase, (d) energy vs. number of particles. The energy and phase denote deviations from the values of the reference particle.

SLAC 3-m accelerating section is 0.83 μs, transient beam loading occurs in the short-pulsed beams and the energies of bunches decrease with beam pulse length. In the long-pulsed beam of 1 μs and 300 mA, the steady-state beam loading reduces the energy gains of the bunches after filling time by about 20% per accelerating section.

To reduce the multi-bunch beam loading, the chicane system will be located between the two accelerating sections. In the first accelerating section, the posterior bunches in a beam pulse receive gradually decreasing energies than its preceding bunches by multi-bunch beam loading. While the beam traverses the chicane, the bunch with lower energy makes a longer detour than one with higher energy. After traversing the chicane, the bunch spacings change and the bunch with a higher energy can be made to be accelerated on a less accelerating phase in the second accelerator. Therefore, the beam energies are averaged out to the steady state beam loading energy value.

Figure 3 shows a correction effect of the multi-bunch beam loading by the chicane system for the case of long pulse mode in Table 1. The multi-bunch beam loading can be lowered to ±1.3%. However, in the compensation using a chicane system we pay in return a generation of an additional energy spread within one bunch due to the acceleration on the off-crest phases in the second accelerating section. To minimize this adverse effect, it is important to produce short bunch lengths in the bunching system. With these two effects considered together, the total energy spread at the end of the linac is about ±2% for the beam of bunch length of 4 ps and about ±4% for 8 ps. We anticipate total beam energy spread lower than ±5% using this energy compensation system.

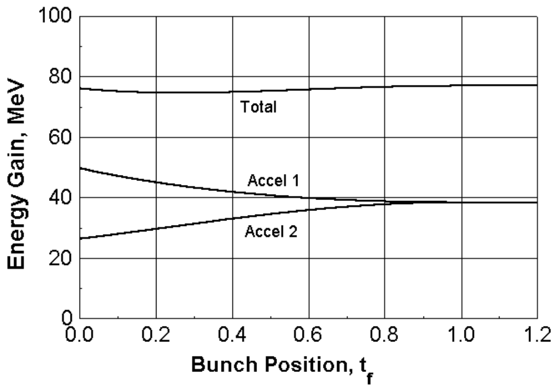

Figure 3: Energy gains of bunches in a long pulsed beam in using a chicane system; Accel 1, Accel 2 mean the energy gains in the first and second accelerating sections, respectively, and Total is their sum. The horizontal axis indicates the positions of bunches from the leading bunch in unit of the filling time of the accelerating section.

2.5 Bending Section and Transport Line

The electron beam accelerated in the linac must be bent toward the neutron target and transported along the beam transport line. We designed an achromatic bending system consisting of two bending magnets and quadrupole magnets using the code TRANSPORT. Figure 4 shows a result for the beam of the energy of 77 MeV and beam spread of ±5%. The figure shows the variations of the beam sizes in horizontal (x-size) and vertical (y-size) plane, and the dispersion function. It can be shown that the double bend achromatic system with a quadrupole singlet with a bore radius above 15 mm can transport the beam with energy spread of ±5% to the neutron target. Other calculation results showed that the beam radius in the horizontal plane is 16 mm for the energy spread of ±7%, and 23 mm for ±10%.

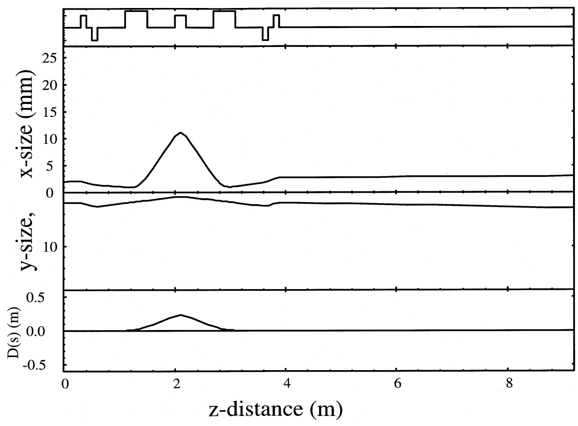

Figure 4: Result of the calculation of the bending system with TRANSPORT. The arrangement of the components is shown at the top of the figure; a quadrupole doublet, the first bending magnet, a quadrupole singlet, and the second bending magnet, a quadrupole doublet.

3 SUMMARY

We discussed the design of the 100-MeV electron linac for neutron beam production. According to the results, we expect to get electron beams of the maximum power of about 7 kW to produce neutron in our accelerator scheme. In order to obtain a beam power more than 10 kW in the 1 μs mode as our final target, we should add a set of one more klystron and accelerator sections to the present layout in the future. We are performing acceleration tests now[4].

4 ACKNOWLEDGMENTS

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