PULSED NEUTRON SOURCE USING 100-MEV ELECTRON LINAC AT POHANG ACCELERATOR LABORATORY*

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Abstract

The Pohang Accelerator Laboratory uses a 100-MeV electron linac for the pulsed neutron source as one of the long-term nuclear R&D programs at the Korea Atomic Energy Research Institute. The linac has two operating modes; one for short pulse mode with the various repetitions between 2 ns and 100 ns and the other for long pulse mode with 1 μs. The major beam parameters are as follows; the nominal beam energy is 100 MeV, the maximum beam power is 10 kW, and the beam current is varied from 300 mA to 5A depends on the pulse repetition. We constructed and tested a test-linac based on the existing equipment such as a SLAC-5045 klystron, two constant gradient accelerating sections, and a thermionic RF-gun. We describe the characteristics of the test-linac and report the status of the pulsed neutron source facilities including a target system and time-of-flight paths.

1 INTRODUCTION

The nuclear data project as one of the nation-wide nuclear R&D programs was launched by the KAERI in 1996 [1]. Its main goals are to establish a nuclear data system, to construct infrastructures for the nuclear data production and evaluation, and to develop a highly reliable nuclear data system. In order to build the infrastructures for the nuclear data production, KAERI is to build an intense pulsed neutron source by utilizing accelerator facilities, technologies, and manpower at the Pohang Accelerator Laboratory (PAL). The PAL proposed the Pohang Neutron Facility (PNF), which consists of a 100-MeV electron linac, a water-cooled Ta-target, and at least three different time-of-flight (TOF) paths [2]. We designed a 100-MeV electron linac [3] and constructed a test-linac based on experiences obtained from construction and operation of the 2-GeV linac at PAL.

In this paper, we describe the design of a 100-MeV electron linac and then present the status of neutron facility PFN compared with other pulsed neutron facilities in the world.

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2 DESIGN OF 100-MEV E-LINAC

We assumed that the klystron is operated at 85% of its maximum capacity and 10% of the power is dissipated in the wave-guide system. The energy gains attainable with one SLAC-5045 klystron for various beam modes are listed in Table 1.

Table 1. Electron beam modes and parameters.

Mode	Pulse Width [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 klystron is operated with the pulse repetition rate of 300 pps and with the RF pulse width of 2-μs.

Assuming a negligible beam loading, we can obtain 100-MeV with one SLAC-5045 klystron in the 2-ns operation mode. Table 1 shows that we can obtain a maximum beam power of 6.9-kW by operating the klystron in the pulse repetition rate of 300 pps. In the case of the high-power operation the energy gain is reduced by a large amount due to the multi-bunch beam loading.

The 100-MeV electron linac consists of an e-gun, an S-band prebuncher and buncher, two accelerating sections, and various components, as shown in Figure 1. The electron beam is generated either by an RF-gun or by a triode thermionic gun for which a Cockcroft-Walton-type DC voltage generator supplies the accelerating voltage of 120 kV. Electron beams from the e-gun then enter to the bunching system, which consists of a prebuncher and a buncher. The prebuncher is a re-entrant type standing-wave cavity made of stainless steel with a resonant frequency of 2,856 MHz. The buncher is a traveling-wave structure with 14 cavities including the input and the output coupler cavities. The bunched beams are then accelerated to 100 MeV by passing them through two SLAC-type accelerating sections fed by one SLAC 5045 klystron.

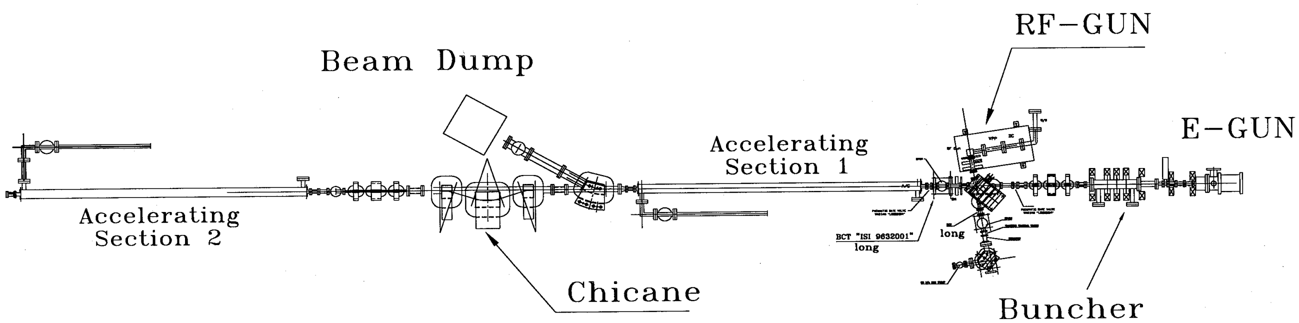

Figure 1. Configuration of 100-MeV electron linac

3 STATUS OF NEUTRON FACILITY

Pohang neutron facility (PNF) consists of a 100-MeV electron linac, a photoneutron target, and at least three different time-of-flight (TOF) paths.

3.1 Photoneutron Target

High-energy electrons injected in the target produce gamma rays via bremsstrahlung, these gamma rays then generate neutrons via photonuclear reactions. For a photoneutron target, it is necessary to use a heavy-mass material because the emission of gamma rays is almost proportional to the atomic number Z of the target material and to the energy of the incident electrons. We are considering tantalum rather than fissile materials because the technology for handling and characteristics of the targets are well known [4]. The neutron yield depends sensitively on the material and the geometry of the target. The design of the target system is done using the MC simulation codes, EGS4 and MCNP4. The target system, 4.9-cm in diameter and 7.4-cm in length, is composed of ten sheets of Ta plate, and there is 0.15-cm water gap between them, in order to cool the target effectively [5]. The estimated flow rate of the cooling water is about 5 liters per minute in order to maintain below 45 ^{o}C. The housing of the target is made of titanium. The conversion ratio obtained from MCNP4 code from a 100-MeV electron to neutrons is 0.032. The neutron yield per kW beam power at the target is 2.0×10^{12} n/sec, which is about 2.5% lower than the calculated value based on the Swanson's formula [6]. Based on this study, we have constructed a water-cooled Ta-target system.

3.2 Time of Flight Path

The pulsed neutron facility based on the electron linac is a useful tool for high-resolution measurements of microscopic neutron cross sections with the TOF method. In the TOF method, the energy resolution of neutrons depends on the TOF path length. Since we have to utilize the space and the infrastructures in the laboratory, TOF paths and experimental halls are placed in the same level as the main electron linac. Two or three different TOF paths range between 10-m and 100-m are arranged for experiments with various energy ranges.

3.3 TOF Test Facility

We have constructed a test-linac for the various R&D activities of the neutron facility by utilizing the existing components and infrastructures at PAL [7]. The test-linac consists of a thermionic RF-gun, an alpha magnet, four quadrupole magnets, two SLAC-type accelerating sections, a quadrupole triplet, and a beam-analyzing magnet. The test-linac is located in the tunnel beside the PLS 2-GeV linac.

After the RF-conditioning of the accelerating structures and the wave-guide network, we performed the beam acceleration test. The maximum RF power from a SLAC 5045 klystron was reached to 45 MW. The RF power fed to the RF-gun was 3 MW. The maximum energy is 75 MeV and the measured beam currents at the entrance of the first accelerating structure and at the end of linac are 100 mA and 40 mA, respectively. The length of electron beam pulse is 1.8 μs and the pulse repetition rate is 12 Hz. The measured energy spread is ±1% at minimum. The energy spread was reduced when optimizing the RF phase of the RF-gun and the magnetic field strength of the alpha magnet.

In order to get experiences for the TOF method, we constructed a TOF test facility using the test-linac. The electron beam is directed to a photoneutron target, which is located about 3 m below the ground level. The stainless tube of diameter 200 mm is used for TOF tubes. The detector station will be placed the second floor of the linac building, which will give the flight path lengths about 15 m. With this, the test of the Ta-target system and a data acquisition system will be performed.

4 COMPARISION OF NEUTRON FACILITIES

Neutron facilities based on the electron linac were used to support primarily the extensive nuclear energy programs during the last few decades. Thus, these facilities were mainly used to measure the high resolution microscopic neutron cross sections, such as neutron total cross sections, scattering cross sections, capture cross sections, fission cross sections, and others.

The design parameters for the PNF are compared with other pulsed neutron facilities in the world based on electron accelerators in Table 2. The table shows information on targets, beam energies, beam pulse currents, pulse length and pulse repetition rates, average beam power, average neutron yield, and lengths of flight paths. The average neutron yield is calculated by the Swanson's formula [6].

According to this table, the PNF is not a best facility in the world. However, this facility will be widely used for basic and applied problems of neutron interaction with matters and nuclei as well as for the nuclear data production in Korea.

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Table 2. Comparison of neutron facilities

Source/Location	GELINA Geel, Belgium	ORELA Knoxville, USA		Gaerttner- Linac Troy, USA	IREN Dubna, USSR	KURRI Linac Osaka, Japan		PNF Pohang, Korea
Target	U	Ta		Ta	U	Ta		Ta
Energy [MeV]	110	180	140	25 – 60	200	35	35	70 – 100
Pulse Current [A]	100	20	0.5	0.4 – 3	1.5	2.5-6	0.5	0.3-5
Pulse Width [ns]	<1	3	1,000	15 - 5,000	250	10-100	4,000	2-1,000
Pulse Repetition [Hz]	800	1,000	1,000	300 – 500	150	480	240	30-300
Beam Power [kW]	7.5	10.8	70	>10	10	10	16.8	0.2 ~ 7
Average Neutron Yield [10^{13} n/s]	3.4	2.2	14	4.0	2.1	2.0	3.4	~2.0
Flight Path [m]	8 - 400	9 – 200		10 – 250	10 - 1,000	10 – 50		10 – 100
Status	Operating	Operating		Operating	Considering	Operating		Planed
References	[8]	[9]		[10]	[11]	[12]		