I－4 LINAC PROJECT AT NUCLEAR ENGINEERING RESEARCH LABORATORY, UNIVERSITY OF TOKYO

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Abstract

A 35 MeV electron linear accelerator project at Nuclear Engineering Research Laboratory, Faculty of Engineering is reported. The machine has been working since the beginning, 1977.

Two important aims of the facility are following. The first is to combine the accelerator with a fast neutron source reactor "Yayoi", and to produce multiplied fast neutrons in order to perform researches on reactor physics and technology including safety and design of nuclear reactors.

The second is to get an intense and very narrow electron pulse for pulse radiolysis work. A single pulse with width less than 18ps and high electron density is now available. The pico-second pulse radiolysis is being proceeded.

Research projects in near future by using the facility are mentioned.

I. Introduction

An electron linear accelerator facility has been constructed during last 3 years starting the fiscal year of 1974. The machine components had been fabricated and the machine was installed by Mitsubishi Electric Co. The machine has been working since the beginning of the 1977 fiscal year.

The main purposes of our LINAC project at Nuclear Engineering Research Laboratory are following.

The first one is to combine the LINAC with a fast neutron source reactor called "YAYOI" which has been operated since May, 1971 and to get intense fast neutron pulses. This combined system is used for studies on reactor physics and engineering including the design and safety as particular subjects through the pulsing operation of the nuclear reactor.

The second one is to get very narrow and intense electron pulses for studies on transient phenomena including pico-second pulse radiolysis.

The machine has been operating since the beginning of April, 1977. The pico-second operation has started from the middle of June, 1977. The width of pico-second pulse has been confirmed less than 18ps by using a streak camera.

In this paper, the outline of the LINAC structure, performance of the machine and some of the experimental results obtained by using the facility are reported.

II. Research Project at Nuclear Engineering Research Laboratory

Details of research projects are following. Some of the projects have already started and others are now being prepared.

1. Pulse operation of the nuclear reactor
2. Time of flight experiments of pulsed neutron
3. Nano-and Pico-second pulse radiolysis
4. Fission neutron pulse radiolysis
5. Time resolved electron spin resonance experiment
6. Thermal shock experiments of heavy metal targets
7. Positron annihilation experiments by slow positrons from electron bombarded targets
8. Study on the measurement of short electron pulses

III. Outline of the Facility

Although there are many electron linear accelerators which are now being operated in the world, only few machines are available for experiments using controlled pico-second pulses including single pulse operation.

There now exist 4 machines in the world which can provide controlled pico-second pulses including a single shot operation of pico-second pulse.

They are listed in Table 1.

Table 1. Accelerators for pico-second experiments

	Energy (Mev)	Pulsed (ps)		
Argonne	22	35(250A)	L-band	Nuclear Physics, Pulse Radiolysis
S. Barbara EG&G	30	50	L-band	Radiation Physics
SLAC	22,800	Picosecond pulses	S-band	Particle Physics
Tokyo, NERL	35	18(∿100A)	S-band	Pulse Radiolysis, Neutron Physics

Train pulses; Toronto, Hahn Meitner, Notre Dame

IV. Constraction of the LINAC and Performance

The specifications of the 35 MeV LINAC-NERL are described in Table 2.

Table 2. Main specifications of Todai 35 MeV LINAC

(I) Steady mode

Duration of pulse: 0.1, 0.5, 1.0, 4.0 μs

Repetition: 10 ∿ 200 pps

Single shot operation and external triggering are possible.

	Energy	Current
	35 MeV	0
	25 MeV	200 mA

(II) Transient mode

Beam current: 2 A

Duration of Pulse: 2 ns, 10 ns

Bunching width: 20 ps

Beam diameter: 4 mmϕ

Current fluctuation: ±3%/5 min

1/6RF mode: 1 nC/fine pulse

Single pulse: >300 pC (1 nC)

The arrangement of the machine components and the layout of the facilities is shown in Fig. 1.

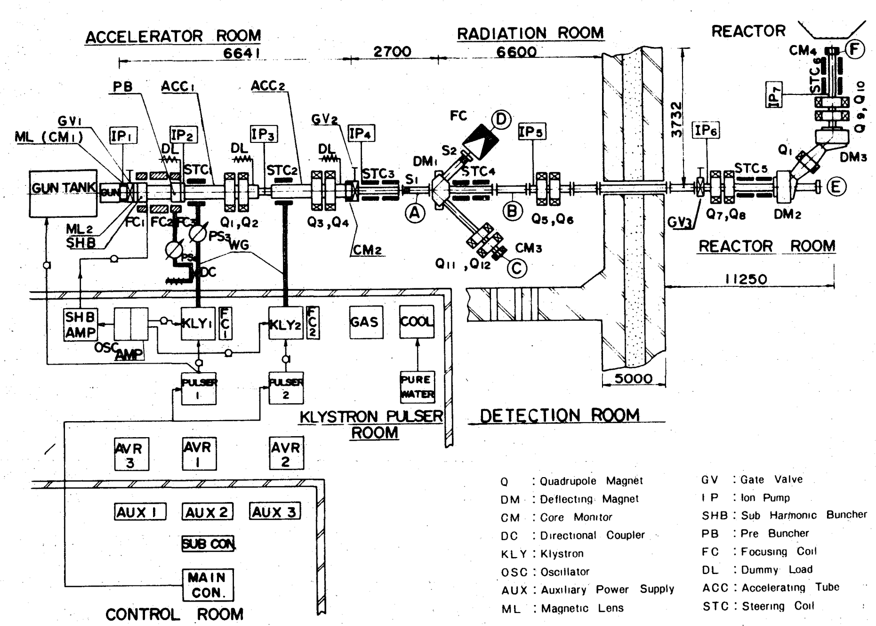

Fig. 1. Layout of the facility

The beam loading curves are given in Fig. 2. The results are indicating that all specifications are fully satisfied.

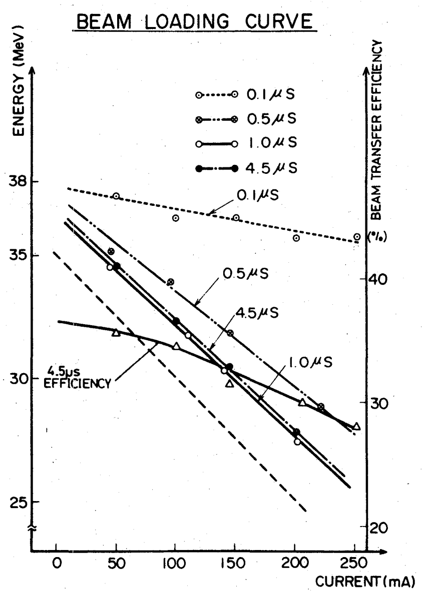

Fig. 2 Beam loading curves for different pulse durations. Beam transfer efficiency as a function of beam current is also shown.
------- indicates the designed values.

Those performance data are summarized in Table 3. together with the specifications.

In order to get a very narrow single pulse (less than 20 pico-second) with a high current (more than 1 nC), a subharmonic (1/6RF of 2856 MHz;S-band) buncher has been added to the LINAC system as one of the acceleration steps of electron beam. It has been tried to minimize the satellite pulses and those have been eliminated successfully. A very nice single pulse has been obtained, as will be mentioned later. It is necessary to have an intense electron emission pulse from the electron gun in order to get single pulse with a high electric charge. The electron gun has been specially designed for the specific purpose.

Table. 3 Performance data of the LINAC

Steady mode operation

	Performance	Specifications
Energy	38 MeV (∿0 mA) 26.8 MeV (200 mA)	35 MeV (∿0 mA) 25 MeV (200 mA)
Current	230 mA (25 MeV)	200 mA (25 MeV)
Pulse width	0.1, 0.6, 1.1, 4.5 μs	0.1, 0.5, 1.0, 4.5 μs

Pulse operation, single shot—200 pulse/second. Both internal and external triggering are available.

Transient mode operation

		Performance	Specifications
10 ns Beam	Energy	∿ 37 MeV	
	Current	2 A	2 A
	Pulse width	11 ns	10 ns
	Size of beam spot	3 ∿ 4 mmϕ	4 mmϕ
	Width of fine structure pulse	< 18 ps	20 ps
	Current stability	± 1.5%/5 min ± 3%/60 min	± 3%/5 min ± 6%/60 min
1/6 RF Beam	Charge per fine structure	1 nC	1 nC$\lesssim$
Single fine pulse	Charge	1 nC	300 pC<

V. Function of Each Component

1. Injection System

Injection system is most important in order to get an excellent performance of accelerators. The construction of our LINAC is shown in Fig. 3.

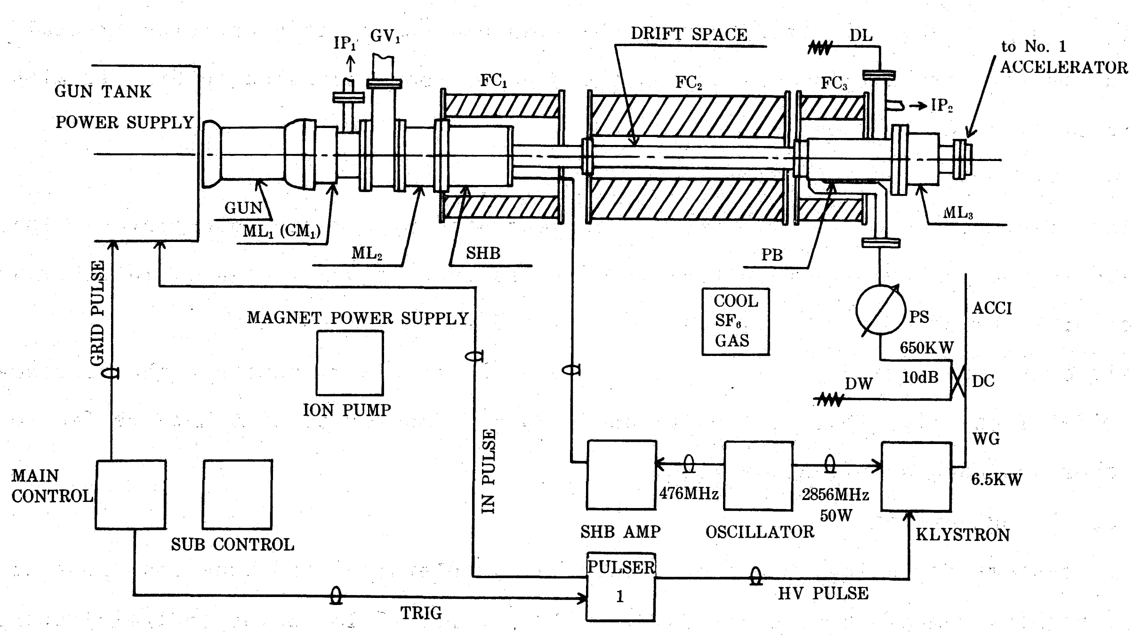

Fig. 3 Injection and bunching parts of the LINAC.

To pick up a series of intense pico-second pulses or an intense pico second single pulse from a train of fine pulses contained in the ns "macro" pulses, the subharmonic (SH) buncher is essential and plays most important role.

Two different kind of guns are used. One is for long pulses ranging 0.1 ∿ 4.5 μs, another is for short pulse ranging 2 ∿ 10 ns.

2. Accelerating System

Electrons are accelerated by microwave power of s-band.

The accelerating parts are composed of 2 wave guides (acceleration tube). Pulsed electrons are accelerated in a 2π/3 travelling wave mode with a constant impedance. The acceleration tube, I, is composed of 6 bunching cavities and 43 reqular cavities, and the length is 1.7 m. The second one, II, has 58 reqular cavities, and is 2 m in the length.

The temperature of the acceleration tube is maintained at 35°C ± 1°C and the resonant freaquency of micro-wave is controlled within certain limit.

Microwave power is fed to each acceleration tube from the klystron (I and II), with an output of 6.5M Watt each. The filling time of the RF power is 0.6 μs. The phasing among acceleration units is controlled through a phase shifter by a remote operation.

Qurdrapole magnets and steering coil units are used to guide and focus the accelerated electrons.

3. Beam Focusing System

Beam ducts with a diameter of 88 mmϕ are being used for transportation of electron beam. Q magnets, steering coil units, bending magnets and switching magnets are also used for the purpose. Electron beam can be transported to different experimental stations in the irradiation room and in the reactor room indicated in Fig. 1. with symbols of A, B, C, D, E and F.

4. Microwave Power Supplies

The original microwave with 119 MHz is generated by a master oscillator. This is supplied to the SH buncher by multiplying 4 times the frequency higher, in other words, a power of 15 kW of microwave with 476 MHz is fed to the SH buncher.

Microwave multiplied 6 times again is supplied to the prebuncher, the accelerating wave guides I and II. That is ; 60 kW and 6 MW of RF power of 2856 MHz are fed to the prebuncher and each acceleration tube.

5, Vacuum System

All systems including injection, bunching, acceleration and beam transport are under a high vacuum of an order of $3\times10^{-7} \sim 10^{-8}$ torr. 7 Ion-pumps (601/min) being used. 3 Gate valves are equipped to protect against damage by accidents such as window faifure.

6. Cooling and Insulation System

Temperature of every parts where input energies are consumed in the LINAC system is kept constant by circulating cooling water. The cooling water is mainained at 35°C ± 1°C. The capability of the cooling unit is 200 l/min in the volume flow rate and 5.5 kg/cm^2 in the head.

In order to protect the wave guide connected to the klystron from discharge, SF_6 gas is filled in it under a pressure of 1.4 ∿ 1.5 kg/cm^2.

7. Control System

The control system is composed of a control console and a graphic panel. Buttons for the operation are arranged on the control console. All orders can be given by pushing the buttons.

All status of the machine under operation can be clearly demonstrated by small lamp signals on the graphic panel.

The triggering system is included in the control console. The pulse timing scheme is represented in Fig. 4.

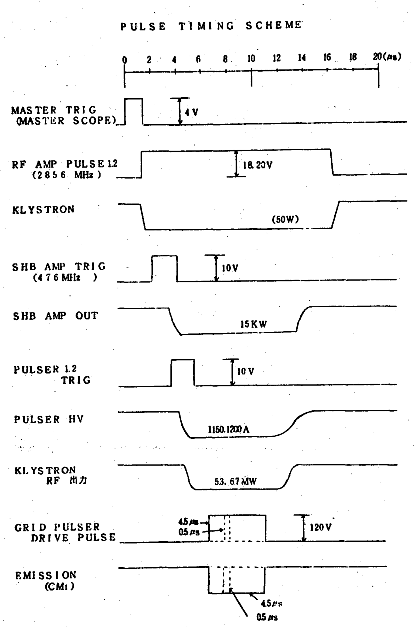

Fig. 4 Timing chart of the triggering system.