LINEAR ACCELERATOR FOR RADIATION CHEMISTRY RESEARCH AT NOTRE DAME

K. Whitham, S. Lyons, R. Miller, D. Nett, P. Treas, A. Zante
Titan Beta, Dublin, CA 94568
R. W. Fessenden, M. D. Thomas, Y. Wang
Radiation Laboratory, University of Notre Dame, Notre Dame, IN 46556

ABSTRACT:

An 8 MeV, S-Band linear accelerator has been delivered to Notre Dame by Titan Beta Corporation. This accelerator utilizes a variety of techniques to provide uniform dose repeatability, very low dark current, and high beam current over a range of pulse widths from 2 ns to 1.5 s. This paper describes the design and results of tests.

APPLICATION

The specifications for this LINAC were developed to meet the needs of basic research in Radiation Chemistry. Various types of samples will be irradiated, but the main application will involve production of short-lived chemical species in liquid samples (contained in a 1 cm silica cell) and their detection by optical absorption methods at visible and ultraviolet wavelengths (pulse radiolysis). Typically, the sample is irradiated by pulses every several seconds and the changes in photodetector output digitally recorded and averaged for improved signal-to-noise ratio. The special requirements include: a short pulse for study of very fast processes; enough charge accelerated to produce a sufficient chemical change; low pulse jitter relative to a trigger pulse; no current outside of the main pulse to avoid a complicated analysis of data; and a very low dark current so that, if the observation is carried out for a number of seconds, no additional irradiation will be occurring. The energy is selected to be high enough to penetrate several centimeters of material of moderate density without causing serious nuclear activation of the samples. Because the optical absorption at a number of wavelengths will be combined to form a spectrum, it is vital that the accelerated charge (dose) be accurately repeatable.

GENERAL DESCRIPTION OF THE LINAC SYSTEM:

The system is designed to have very repeatable shot to shot dose along with low pre and post pulse radiation.

The centerline shown in Figure 1 begins with a 130-140 kV gridded electron gun similar to the Stanford Linear Accelerator Center (SLAC) Injector gun. It includes a ceramic envelope capable of withstanding 150 kV DC in air, stainless steel electrodes and vacuum parts, and a replaceable 2 square cm dispenser grid cathode assembly.

Figure 1

The gun is followed by a high vacuum tee with ion pump, an isolation vacuum valve and a fast beam current monitor.

A water cooled, temperature stabilized prebuncher cavity is next, followed by a drift space designed to compress 60% of the charge emitted from the electron gun into a longitudinal phase space of 60 degrees at injection into the accelerator guide.

The accelerator is a 2 pi/3 mode, temperature stabilized guide with a tapered velocity buncher designed to satisfy the performance as stated below.

A thin lens is placed after the gun as part of the beam transport system. A bucking coil is placed over the cathode region of the gun to cancel out any fringe fields from the coil system.

A series of accurately aligned Helmholtz coils are provided along the beamline to transport the beam and to provide a beam diameter of approximately 5 mm at the output of the accelerator.

An ion pump is placed after the gun in the injection system and at the beginning of the accelerator to keep the operating vacuum in the proper range.

Evacuated RF waveguide is used in this system. This has many advantages for reliable and maintenance free operation.

The RF transmitter for the linac is comprised of a line- type modulator with all the necessary power supplies, controls, and monitors for operation of a SLAC model XK5 20 MW, 2856 Mhz klystron. Because of the requirement for a highly reproducible pulse to pulse dose rate, a very accurate switching power supply is used to charge the PFN.

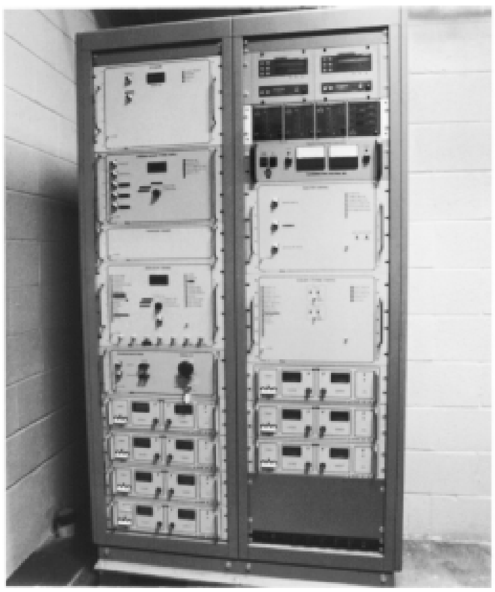

Figure 2

In addition, in order to be able to maintain dose repeatability within ± 1% between single pulses taken up to 30 minutes apart, the electron gun HV and control voltages and the PFN firing level are stabilized prior to triggering the pulse.

The need to minimize dark current required the use of a low dark current electron gun and the use of a pin diode switch to control the RF drive pulse with respect to the beam pulse.

A water cooling system is provided for maintaining the beam centerline components at 40 degrees C ± .4 degrees C and for removal of heat from the klystron, modulator, and magnetics.

Controls and monitors for system operation are mounted in a multiple bay vertical rack assembly in the control area. Some local control capability is provided for local service operations of the modulator. Figure 2 shows the control rack.

SPECIFICATION:

Frequency	2856 mHz
Input Power	18 mw (max)

STEADY STATE OPERATION:

Beam pulse width	1.5 s
Peak beam current	2 A
Energy	6 MeV

STORED ENERGY OPERATION:

Beam pulse width	2 ns to 10 ns
Beam current	4 A
Energy	8 MeV
Dark current	<10 pC
Pulse Jitter	± 100 pS
Dose Stability (pulse to pulse)	± 1%

PERFORMANCE:

The pulse current and time profile was determined using a terminated 50 ohm faraday target, a Heliax cable, and a Tektronix 644 digital oscilloscope. The integration feature was used to determine the charge in the pulse. The beam size was determined by coloration of glass plates and was checked by bleaching of blue cellophane. The beam characteristics at several pulse widths are

pulse width	peak current	beam size
2.8 ns	4.4 A	5 mm
10 ns	5 A	5 mm
100 ns	3.3 A	7 mm
1.7 s	2.2 A	10 mm

The time jitter of the beam pulse was determined by using the "infinite persistence" mode of the oscilloscope and measuring the width of the trace after recording a large number of pulses. The jitter was ± 125 ps.

The beam energy was measured with the 2.8 ns pulse by exposing a stack of glass plates and measuring the darkening with a spectrophotometer. A plot of absorbance against plate number gave the dose profile which could be extrapolated to the electron range.

Two measurements gave similar ranges of 5.15 g/cm2 for an energy of 8.9 MeV with the 4A 2.8 ns pulse. the microwave power setting was 18.6 MW.

The extraneous dose after the main pulse was determined from a recording on the digital oscilloscope which was checked by a photograph of the trace on a Tektronix 7104 with 7A29 plugin. It consisted of a slight tailing after the main pulse over about 20 ns with a total charge of 1% that of the main pulse. No echo pulses from reflections in the electron gun pulser were seen. The dark current was determined by use of an unterminated target and a Keithly electrometer. The current measured with high voltage on the electron gun but no rf for acceleration was 0.5 pA.

Dose repeatability was determined by integration of the current waveform on the 644 digital oscilloscope. Two different series were run using the 2.8 ns pulse. In the first, the pulse rate was set at 4 Hz and individual traces taken by manually arming the oscilloscope. the results are given below with an rms deviation of 0.45%. Then the accelerator was used single shot (with a single rf pulse) and pulses were recorded at about a 20 minute separation with the machine put at standby in between. The three pulses taken single shot are quite the same. This excellent behavior validates the care taken to stabilize the injector and modulator charging voltages.

1. Ten pulses taken with the repetition rate set at 4 Hz. The scope was triggered single shot and manually for each pulse and the area read. The average dose of 49.627 equals 10.9 nanocoulombs of charge.

49.435 ....49.410
49.859 ....49.820
49.930 ....49.510
49.255 ....49.530
49.905 ....49.620
average = 49.627
rms = 0.225 or 0.45%

2. Three single pulses taken with the machine turned off between pulses.

Time	Dose
9:24	49.345
9:47	49.574
10:02	49.570

CONCLUSIONS:

The system was installed, meets the specifications, and is in use at Notre Dame.