CRANE RF ACCELERATOR FOR HIGH CURRENT RADIATION DAMAGE STUDIES

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Introduction

An electron accelerator was designed and built for the Naval Weapons Support Center (NWSC) in Crane, Indiana for conducting Transient Radiation Effects on electronics (tree) experiments and test.

The Crane L Band RF Electron Linac was designed to provide high currents over a wide range of pulse widths and energies to perform damage studies on a variety of electronics. The energy extends to 60 Mev and pulse widths vary from a few ns to 10 μsec. Beam currents range from 20 amps in the short pulse case to 1.5 amps in the long pulse case.

Table 1 indicates the system requirements.

TABLE 1

Naval Weapons Supply Center
Crane, Indiana
L-Band Traveling Wave
Accelerator System

Requirements:

Output Beam Performance

Beam Diameter ------- 0.25cm
Beam Energy --------- 60 MeV
Beam Current -------- 15 A-18A
Pulse Width --------- 5 ns-10μs
PRF ----------------- 1-50 pps

Transient Mode Performance

Pulse Width --------- 3 ns-100 ns
T_{rise} --------------- </= 1 ns
T_{fall} --------------- </= 1.5 ns
Energy Spectrum
Spread -------------- <80% @ 150A
(40 MeV @ 50 ns PW) 25% @ 5A
Beam Current (Max) -- 20 A
Beam Energy (Max) --- 60 MeV

Steady State Performance

Pulse Width --------- 50 ns-
10 u-s Continuously Variable
T_{rise} --------------- </= 10 ns
T_{fall} --------------- </= 10 ns
Energy Spectrum Spread<+/- 100%
Beam Current Max. --- 1.5 A
Operating Energy ---- 40 MeV @ 0.5A

Description:

The Titan Beta Linac system, consists of a two stage, L band, traveling wave accelerator capable of accelerating electrons to energies from 20 MeV to 60 MeV together and 10 MeV to 30 MeV separately. Output currents are up to 20 amperes in the transient mode and 1.5 amperes in the steady state mode.

The system is capable of being pulsed from 1 to 50 pps with pulse widths from 3 ns to 100 ns in the transient mode and is continually variable from 50 ns to 10 us in the steady state mode. Figure 1 shows the beamline.

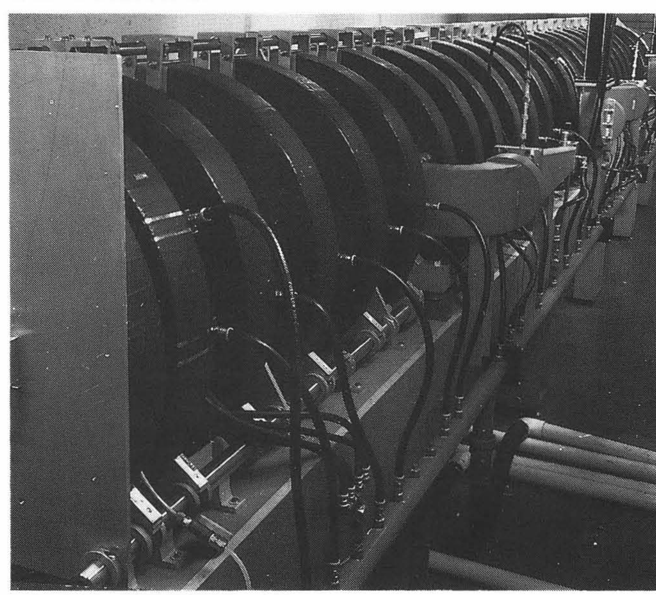

Figure 1

Architecture

The Crane linac system utilizes a 150 kV triode electron gun with a 5 cm diameter cathode operated at 120 kV nominally to obtain up to 40 amps of gun current.

The system directly injects the high current beam from the electron gun into the first L Band accelerator guide. The 3 m guide has a short buncher at the front end and is powered by a TH2022D Thompson klystron at up to 18 MW. The second accelerator waveguide is powered by a second Th2022D klystron. The power for the two klystrons is provided by a single modulator and then the klystrons are individually phased from the rf driver. Because of the range of operating energies and the allowable energy spread within the pulse, the beamline is surrounded by a series of water cooled coils which provide approximately a 1 Kg axial field continuously along the structure. This approximately solenoidal field allows the energy spread of the high current beam to be confined.

The beam exits into a target room with a translation table to position the targets precisely in front of the beam.

An air cooled spectrum analyzer magnet at the exit of the beam line provides spectrum measurements when needed.

The system is computer controlled using an IBM AT as the control computer.

Discussion of the various subsystems is provided below.

E-Gun and Pulser

Because of the combination of relatively high current and short pulse capability needed, a new electron gun structure designed and developed for this system. The requirements for a combination of high current short pulse and lower current long pulse necessitated development of a special pulser that is described below.

The E-gun pulser was required to provide two separate modes, a short pulse mode of 3 to 100 nanoseconds width, and a long pulse mode of 100 nanoseconds to 10 microseconds width. Two separate planar triode based pulse amplifiers were employed to generate these two modes of operation in the gun pulser.

The short pulse mode required a three stage planar triode amplifier chain to generate the higher current drive required for the short pulse mode. Microwave stripline techniques were used to minimize risetime and for impedance matching.

The long pulse mode used a single planar triode amplifier to supply the lower current long pulse.

The entire E-gun pulser and control circuitry floating deck assembly was housed in an SF6 insulated enclosure which provided the insulation and isolation for the 130kV accelerating potential applied to the E-gun cathode structure.

Crane Accelerator Waveguides

The accelerator sections are comprised of two L Band, velocity-of-light, disc-loaded accelerator sections operated in the $2\pi/3$ mode at 1300 MHz. The structures employ 37 cavities plus input and output couplers and are designed to have an approximately constant gradient of 10 MeV per meter at zero beam current.

The design no-load energy at 18 Mw per guide input is 64 MeV for both guides. At 500 ma beam current, the steady state design energy is 46 MeV for both guides. The stored energy is approximately 40 joules.

The velocity of light buncher captures approximately 50% of the injected beam. Stored energy current of up to 20A is achieved with 40A injected at 130 kV in the 10 ns time frame.

The accelerator structures were designed and manufactured by Haimson Research. They have been operated without problems from initial installation.

Klystrons and Modulator

A single line-type modulator drives the two TH2022D L-Band klystrons to peak powers of 20 Mw each. The modulator utilizes command change for control and was designed to operate up to 120 pps although the system is used to 50 pps only. The command charge tetrode is the Eimac 2CX35000C. The main thyratron is the ITT3C45.

Mechanical Assemblies

RF Transmission Waveguide System

Gas was used to insulate the transmission waveguide that connected the klystron RF input. The transmission waveguide components were manufactured from aluminum alloy L-Band (WR-650) rectangular tubing and CPR-650F flanges. Each component was pressure checked to 30 PSIG. RF contact and gas sealing was accomplished using composite aluminum alloy/elastomer gaskets. After the system was assembled, it was evacuated and backfilled with insulating gas. A halogen leak detector was used to verify that the system was leak tight.

Waveguide Temperature Control System

Water temperature is controlled by mixing hot and cold water with a 3-way mixing valve. The valve in turn is controlled by sensing the waveguide the input water to the waveguide. This temperature is sensed using an R.T.D. probe. The probe output is input to a P.I.D. (Proportional-Integral-Derivative) temperature controller. 4 to 20 mA is the output from the controller. A current to pneumatic transducer converts the 4 to 20 mA output to 3 to 15 psi. This variable pressure controls the position of the valve actuator and the output temperature of the water from the 3-way mixing valve.

Vacuum System

Ion pumps are used to keep the linac beamline components under high vacuum. The system is constructed of low outgassing, non-contaminating materials that can be temperature processed for long term high vacuum operation. Beamline components are connected using bolted joints with knife-edge OFHC copper seals.

Transport

After the electron gun, the beam passes through a short drift section which has a fast valve and a thin lens. Surrounding the drift and over the full lengths of both accelerator sections is a set of Helmholtz coils which provide an approximate 1 Kg field over the length of the system. The field taper over the first few coils was calculated using the Parmela code for numerous operating conditions and confirmed in operation. The Parmela calculations and tuning points were close together.

Steering coils were placed over the front end of each accelerator section to correct for earth's field and the effects of building steel. Care was taken to keep the coil lengths at less than 45 degrees phase advance. Near zero coil currents are required by the system.

The beam is brought out into the test cell where the test objects are placed on a transitionary table to allow for remote positioning.

Controls

Operational control of the system is performed through computer control using an IBM AT clone computer . The control program use for operation was a commercially purchased program called "the Fix". This program is process control oriented and imposed some limitations on the control and monitoring of the linac. A feature of this program that was used was real time PID loop control of the Waveguide and accelerator sections water temperature control. System adjustment parameters were also saved by the program to generate various operating configurations that can be quickly recalled as required.

Communication between the computer and linac controls was through OPTO-22 Optimux modules which transmit data via RS-422 fiber-optic links.

All critical safety and operational interlocks were hardwired directly into the control system, and various fault level detection circuits directly interacted with the control system when a fault occurred. In such a fault occurrence, the computer simply monitored the fault and provided an indication at the computer.

Performance

The system has met it pertinent specifications and has been in operation for two years.