HIGH POWER 2 MEV LINEAR ACCELERATOR DESIGN CHARACTERISTICS

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1. INTRODUCTION

This paper presents the design and performance characteristics of an S-band (2998 Mhz) electron linear accelerator MINILAC™ with average beam power of 10 kW. Electron beam energy is 2.0 MeV at 1.0 Amp. 3 MW of RF power input is available from the klystron.

Studies were performed to determine whether a traveling wave or standing wave structure would produce the highest RF to beam efficiency. After careful study it was decided that both structure types were capable of nearly the same efficiency. The customer chose traveling wave, because of prior favorable experience with the traveling wave structure.The system is comprised of a low voltage triode electron gun, a prebuncher and the accelerator structure with a tapered β section integral with a β=1 set of cavities The accelerator design uses $2\pi/3$ cavity geometry with constant potential gradient over all 13 cavities.

2. INJECTOR

The electron gun is a triode structure operating at voltages between 10 and 20 kV. The grid drive controls the beam with cutoff at -150 volts and maximum current with a drive of + 200 volts. The injector furnished uses an isolation pulse transformer to turn the grid on and off. The peak current is measured using a toroid monitor, and the information is fed back to a sample and hold comparator circuit to regulate the injected electron beam. The injected current is adjustable from the front panel. A DC power supply which is regulated to 1% furnishes the injection voltage. This voltage is adjustable from the front panel to enable matching the electron velocity to the optimum prebuncher drive.

3. PREBUNCHER

The prebuncher is a TM_{01} re-entrant cavity structure. The cavity is a copper structure with a Q_L of $\approx$ 1800. The RF power is coupled through a vacuum sealed coaxial connector to a loop coupler. There are two coax feed-through connectors: one for the power input and the second connector for a terminating load. The maximum power available at the prebuncher is $\approx$ 1500 watts peak. The power is provided by means of a 27 dB coupler from the main RF power feed from the klystron. The prebuncher power is connected via coaxial cable through a variable attenuator and phase shifter to enable manual adjustment for optimizing electron capture.

4. ACCELERATOR

The total length of the accelerator centerline is 82 cm measured from the e-gun housing to the output flange. The 37 cm long traveling wave structure has a buncher section with a tapered β starting at β=0.5 and increasing to β = 1.0 at the fifth cavity.

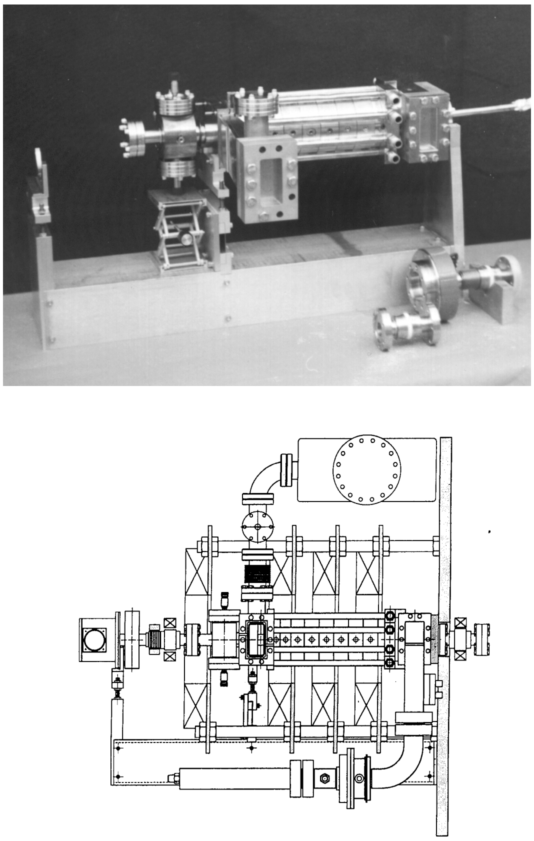

Fig.1 MINILAC™ beam centerline designed for the possibility of both vertical and horizontal operation.

The resultant electron beam capture exceeds 50% of high energy electrons out the exit window. The peak RF power at the input RF coupler of the accelerator is 2.7 MW. The power was determined by means of a calorimetric measurement into a dummy load. This confirmed the directional coupler monitor levels and enabled a suitable set of calibration points to be established.

The accelerator output coupler feeds RF through a vacuum isolation window to a water cooled RF load. The load is capable of dissipating the entire 3 MW peak and 15 kW average RF power output from the klystron.

Figure 1 shows the equipment arrangement for the accelerator system. The beam current is monitored by beam current monitor below the injector and at the output from the accelerator.

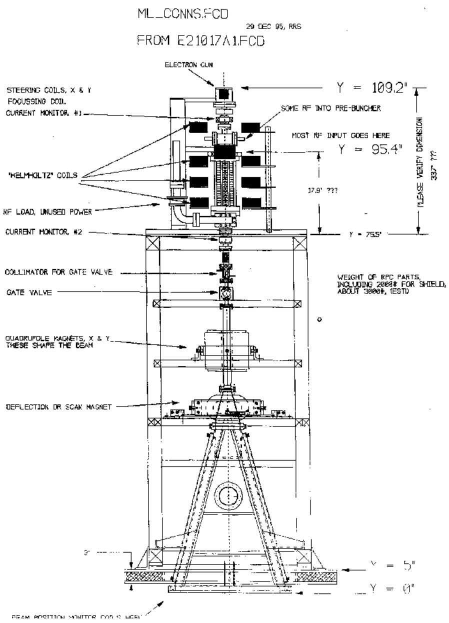

Fig. 2 View of complete system with scanner.

The magnetic fields used to confine the beam are comprised of a lens just beyond the injector anode followed by four (4) Helmholz coils to provide axial magnetic fields over the length of the accelerator. The Helmholz coils can provide field strength up to ≈1100 gauss.

A mechanical strongback is provided to support the accelerator structure and maintain accurate alignment of the accelerator to the transport and scan system. The strongback support is rigidly fastened to a mounting plate. The alignment supports are at the input and output coupler and are flexible in the axial direction. A fast acting valve is mounted between the electron gun and prebuncher. The valve actuator assembly is mechanically supported from the strongback.

The water cooling system is temperature regulated to operate at 40° C. The accelerator cooling is provided by cooling tubes brazed to the input and output manifolds. The prebuncher, RF dummy load and accelerator each have a separate water flow interlock.

Figure 2 shows the overall accelerator system centerline.

5. SYSTEM CHARACTERISTICS

The following is a table of beam design characteristics.

Beam Energy	2.0 MeV
Beam Current Peak	1.0 Amps
Beam Current Average	5 mA
Energy Spread	± 10%
Spot Size	10 mm at the end of accelerator
Frequency	2998 MHz
RF Peak Power	2.7 MW at accelerator
RF Average	15 kW at accelerator
Pulse Rep. Frequency	500 PPS
RF Pulse Length	10 µsec.

The specifications were met for all requirements.

Figure 3 shows the pass band. Figure 4 presents the measured results for energy and spectrum.

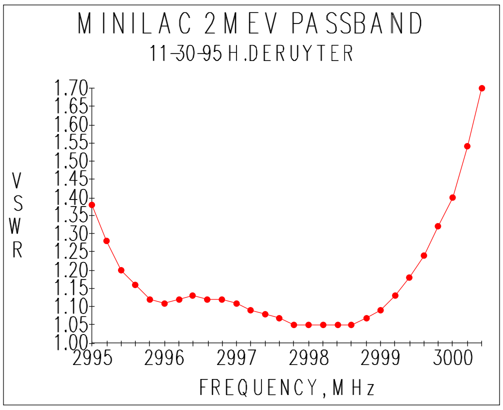

Fig.3 Passband of accelerator section after completing tuning procedure.

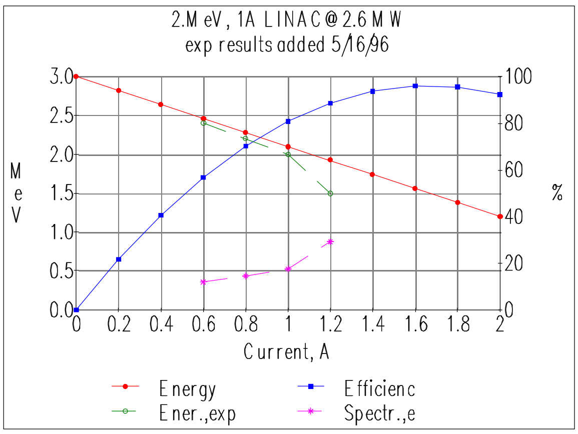

Fig.4 Calculated load line and efficiency in comparison with experimentally measured data.

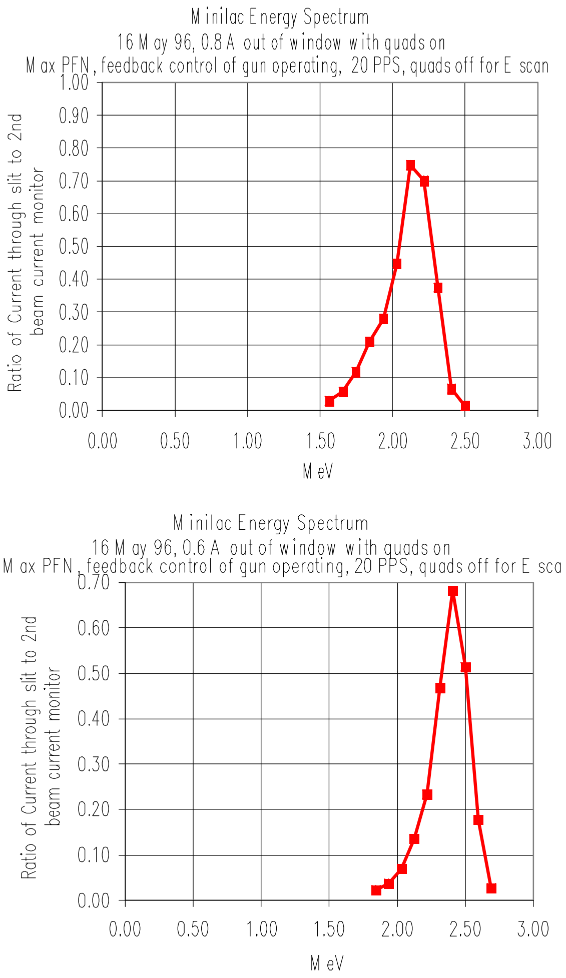

Fig.5 Beam energy spectrum at two energy values measured using deflection system.

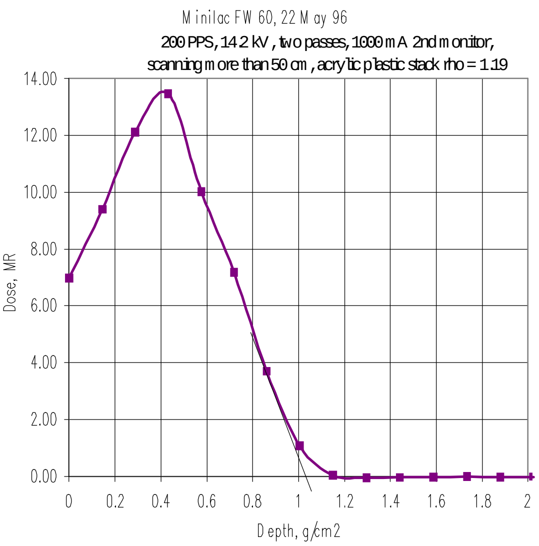

Fig.6

Figure 6 shows the depth dose in an acrylic stack. Figure 7 shows the dose uniformity passing through the beam at 1 meter/min measured at 40% average beam dose rate (200pps).

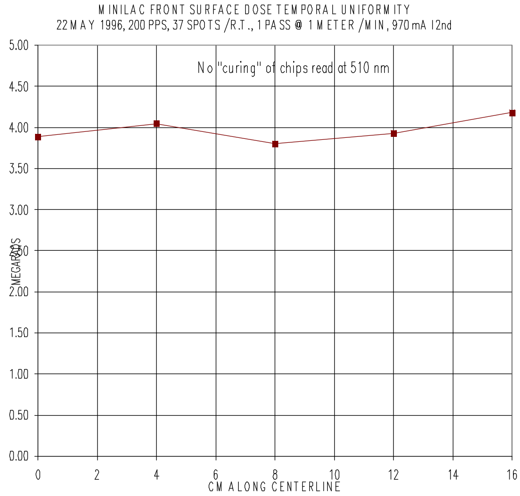

Fig.7

6. CONCLUSION

The system operates at very nearly the design level with a 71% RF to beam conversion. The operation was commenced within a year and final testing completed within a one month period. All aspects of the system from the modulator, water cooling, controls, monitor point, scanner, vacuum, etc. function in a suitable manner with few changes needed to obtain stable, full performance ratings.