THE ELECTRON GUN FOR THE DARESBURY SRS LINAC

D.M.Dykes
CLRC Daresbury Laboratory,
Warrington WA4 4AD, UK

Abstract

The electron gun for the Daresbury SRS linac injector has been modified to use the cathode-grid assembly from the Eimac planar triode 8755. The gun now has improved beam characteristics, is more reliable and the cathode assembly is quicker and easier to change. This paper describes the assembly of the electron gun, and then the re-conditioning of the cathode highlighting the vacuum environment. The action of the grid modulation system on the electron beam, which pre-bunches the electron beam, is described, and typical gun characteristics are shown.

Proposed developments to the gun system are discussed.

Introduction

Daresbury Laboratory operates the UK’s national synchrotron light source, the SRS. It is operational for approximately 7000 hours a year, providing synchrotron radiation used by many varied scientific disciplines. The electron storage ring energy is 2 GeV and the beam lifetime is in excess of 30 hours at 200 mA. The storage ring is filled to 250 mA once every 24 hours.

The injection system consists of a 80 kV electron gun feeding a 10 MeV S-band electron linac, the electron beam is accelerated to 600 MeV in a 500 MHz booster synchrotron. The beam is injected into the storage ring at 600 MeV and the energy ramped to 2 GeV. The injection process takes approximately 20 minutes. Consequently the gun injection equipment is operational for less than 1 hour per day.

The electron gun has been modified to use the cathode-grid assembly from the Eimac planar triode 8755 [1]. This gives improved beam characteristics over the previous system, it is more reliable and the cathode assembly is quicker and easier to change. The paper describes the assembly of the electron gun, and the re-conditioning of the cathode, highlighting the vacuum environment. The action of the grid modulation system, which pre-bunches the electron beam, is described, and typical gun characteristics are shown. Proposed developments to the gun system are also discussed.

The Electron Gun - Mechanical Layout

The original electron gun was similar to the design by Willard [2] for the Manchester Christie Hospital Linac. It contained a 1 inch (25.4 mm) spherical oxide cathode with a separate de-mountable grid, which was modulated at 500 MHz. When the cathode failed the cathode - grid assembly was de-mounted, and the cathode sprayed with the usual carbonate mix (barium, calcium and strontium). The carbonates were converted to oxides, and when this was completed activation of the cathode took place. This process took several hours, and satisfactory conversion and activation could never be guaranteed. As this process took place while the gun was attached to the linac, the decomposition products of the carbonates could have harmful effects on the vacuum surfaces of the linac.

The gun has now been modified. Figure 1 shows the mechanical arrangement of the present gun. A miniature ceramic - metal planar triode, Eimac type 8755, has been modified to be used as the cathode grid assembly of the gun. The triode can be used up to frequencies of 3 GHz. The cathode is a conventional oxide coated cathode, but the heater power is only 10 watts, a factor of ten lower than the original.

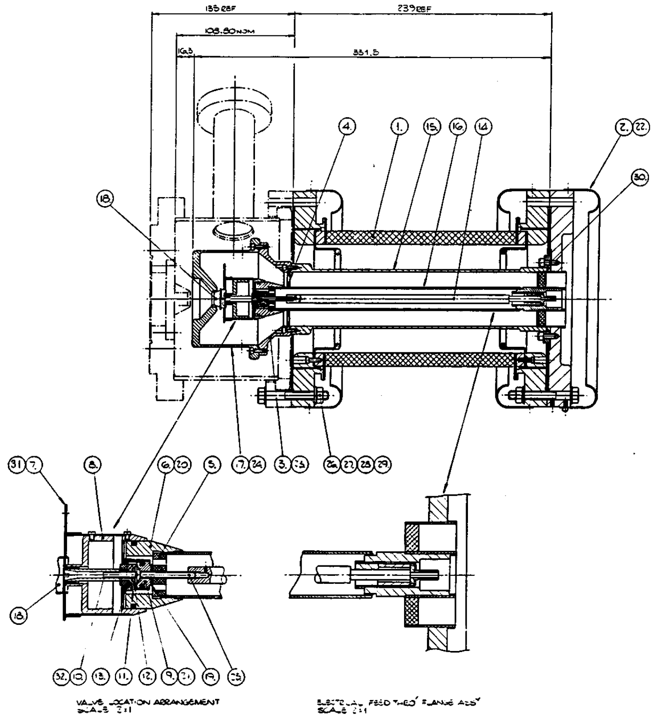

Figure 1: Mechanical Layout of the Gun

The triode is inserted in the gun assembly which is connected to a temporary heater supply, with the heater voltage set to about 2 V to keep the activated cathode temperature above 150 °C. The triode anode and body ceramic are broken off, and the beam forming electrode attached. The gun assembly is bolted to the linac and the gun evacuated, whilst maintaining the cathode temperature. Haas and Jensen [3] found that by keeping the temperature to 150 °C cathodes are not poisoned when exposed to air as the oxides are converted to hydroxides and the hydrate is prevented. The emission capabilities are preserved.

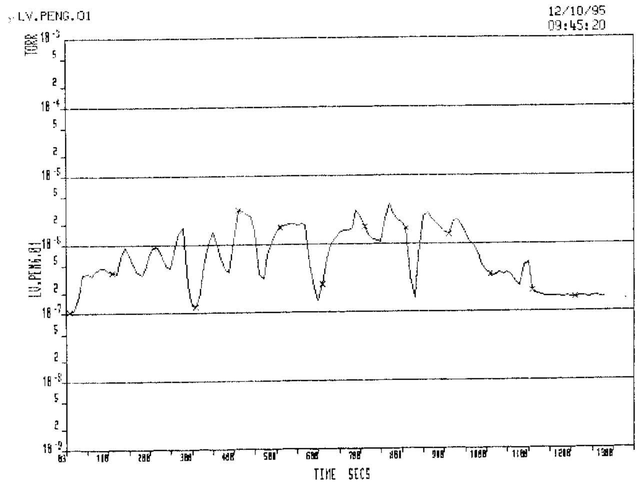

Figure 2: Plot of Gun Vacuum during Cathode Activation

When the vacuum pressure is better than 10^{-7} torr, the heater voltage is gradually increased, keeping the vacuum pressure below 10^{-5} torr. Figure 2 shows the typical vacuum pressure variation during this re-activation process, and Figure 3 the residual gas analysis at the same time. Note that the water peak increases initially, but that it is the methane peak that determines the overall pressure.

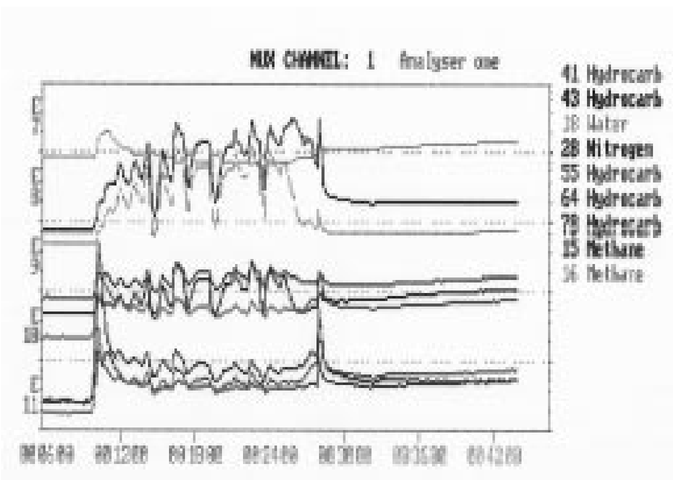

Figure 3: RGA during Cathode Activation

The installation and re-activation process is simple and quick, taking only 4 or so hours. The cathode life is typically two years, but recently improved vacuum conditions have extended that time.

The Electron Gun - Electrical Layout

Figure 4 shows the electrical layout of the gun system. The gun has to produce a 400 nS 80 keV bunch of electrons 10 times a second. The action of the triode is used to pre-bunch the beam before injection into the linac.

A three quarter wavelength coaxial cavity is connected to the gun, and sits at the gun HT, which is provided by a half sine wave pulse modulator, giving a -80 kV pulse. The heater power supply is at HT potential. There is a 0 to -200 V grid bias supply, and the 500 MHz grid modulation is fed via an 80 kV waveguide isolator.

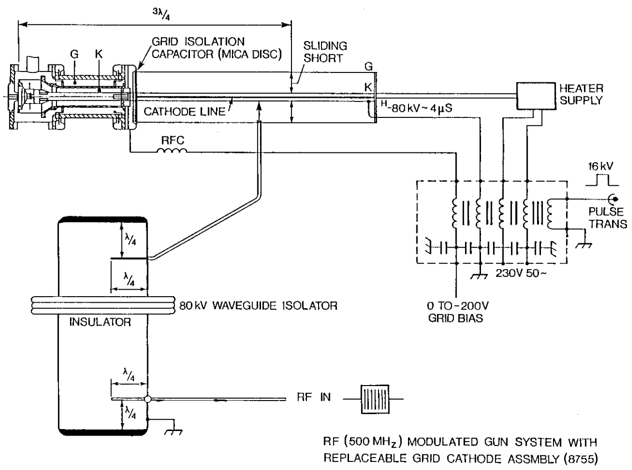

Figure 4: Electrical Layout of the Gun

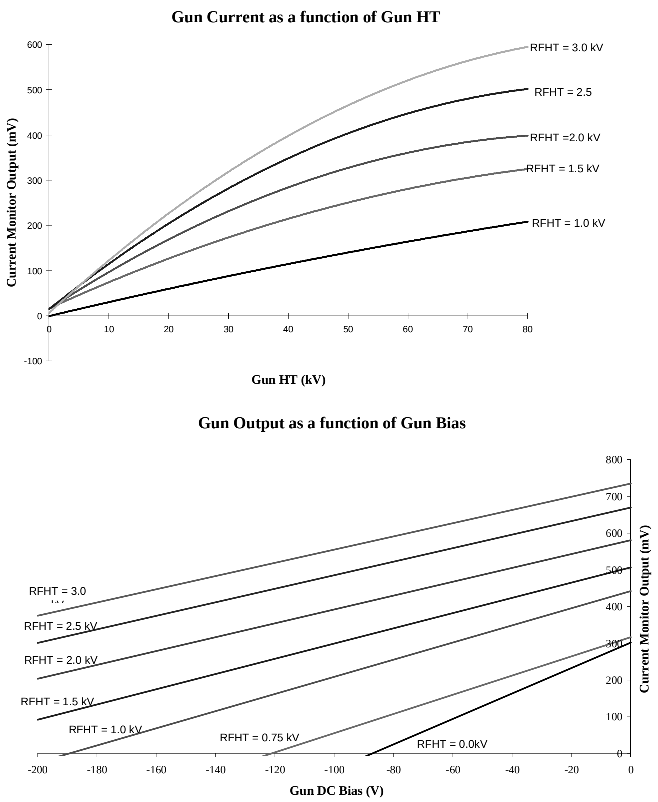

Figure 5: Gun Characteristics

Gun Characteristics

A current transformer type monitor with a bandwidth of 500 MHz, but followed by a 10 MHz filter monitors the gun current, Io. Typical gun characteristics are shown in figures 5a, the gun current as a function of gun HT for various values of grid RF modulation -dc grid bias set to -100 V, and 5b, gun current at a fixed HT at -80 kV as a function of DC grid bias for various values of grid RF modulation. These characteristics should be compared with the triode characteristics in the Eimac data sheet [1]. The differences in the slopes in figure 5b is because the output voltage of the Io monitor is proportional to average current, and the conduction angle is smaller the greater the RF amplitude.

Pre-bunching

The SRS linac does not have a pre-buncher cavity, but pre-bunching is achieved by the DC and RF biasing of the gun grid. The linac accelerating voltage is a 4 mS, 4 MW pulse at 3 GHz. The voltage is phased locked to the 500 MHz gun grid modulation. As can be seen from figure 6, by accurate phasing of either of the grid modulation or the accelerating voltage and a large grid DC offset short current micro-pulses can be injected into the linac. The more negative the DC bias the shorter the current pulse.

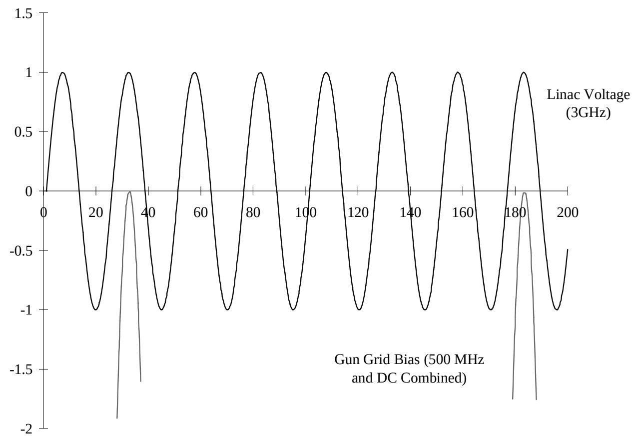

Figure 6: Linac Pre-Bunching

Future Developments

For a small but significant period, the SRS operates in single bunch mode, where only one of the 160 RF buckets in the storage ring is filled with electrons. At present this is achieved with a chopper system operating on the 10 MeV beam in the flight path between the linac and the booster synchrotron. Recently investigation has started on using the gun grid modulation system to produce the single bunch and other bunch patterns [4].

The grid modulation equipment will sit at the HT potential, whilst triggering and clock pulses will be fed via optical fibre.

Summary

The electron gun for the SRS linac injector uses the already activated cathode-grid assembly of an Eimac 8755 planar triode. The installation is simple and quick, and the cathode life is relatively long.

The measured gun characteristics are as expected and follow the original triode characteristics.

The action of the RF and DC biasing of the gun grid perform some pre-bunching for the linac.

In the future the grid modulation system will provide single bunches and any required bunch pattern.

Acknowledgements

I would like to thank Mr. Brian Taylor for the original idea of using a planar triode as the grid-cathode assembly for the SRS linac electron gun.

References

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[2] J.Willard, A High Currnt Electron Gun Suitable for use Down to 1 nanosecond Pulse Length. IEEE Trans. Nuc. Sci. June 1967.

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[4] C.W.Horrabin and D.M.Dykes, DIAMOND Low Power RF System, Proceedings of the 5th European Particle Accelerator Conference (EPAC - 96), Sitges, 1996.