PERFORMANCE OF THE CORNELL HIGH INTENSITY LINAC INJECTOR

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Summary

The Cornell High Intensity Linac Injector has been installed on the 400 MeV S-band linac which is the electron and positron source for CESR. The gun uses the EIMAC Y-796 cathode-grid assembly which is capable of peak currents in excess of 19 A. The injector uses two prebunching cavities and solenoidal focusing in a design which closely resembles the SLC injector.

Positron production rates have been achieved which significantly reduce the CESR filling time. A high current gun pulser has been built with the capability of multiple pulses during the 2.5 μsec linac pulse; this will allow filling CESR for multiple bunch operation. Details of the injector performance will be given.

Introduction

A major limitation in the performance of the Cornell Electron Storage Ring, CESR, has been the long time required to fill with electron and positron beams. These beams are provided by a 400 MeV S-band linac. A high intensity injector has been constructed for the linac to improve the filling rates.

Just as work was starting on the new injector it was decided that CESR would be converted from single bunch operation to a mode in which several bunches of each type of particles would circulate.[1] To efficiently fill the machine it would be necessary to inject from three to seven bunches during a single 2.5 μsec linac pulse. This was not possible with the old injector[2] and made the new injector a key element in the CESR luminosity upgrade.

Description of Injector

The Cornell High Intensity Linac Injector, CHILI, is based on the SLC injector built at SLAC.[3] The injector begins with a thermionic cathode triode gun

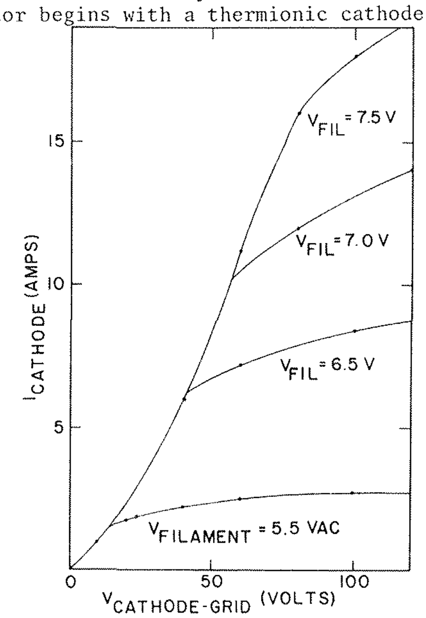

Fig. 1 Diode characteristics of Y-796 cathode-grid assembly.

also based on a SLAC design.[4] The gun uses the EIMAC Y-796 cathode-grid assembly.[5] The diode characteristics obtained by applying a 150 nsec long pulse between the cathode and the grid with no grid-anode voltage are shown in Fig. 1. The actual beam current produced by the gun is reduced by the 28% grid interception reported by Koontz.[4]

The gun is followed by two 214 MHz prebuncher cavities (Fig. 2). The prebuncher frequency is 3/40 of the 2856 MHz linac frequency and was chosen to provide the proper relationship between the linac and storage ring frequencies for synchronous transfer of up to seven evenly spaced bunches. The bunching of beam pulses by the cavities was simulated using the method described in Ref. 3, and optimum drift lengths and prebuncher gap voltages were chosen by computer optimization.

The prebuncher cavities are contained within solenoid magnets whose magnetic field increases toward the end of the injector; the beam is thereby maintained at a constant 1 cm radius while the charge density increases as the beam is bunched. Other solenoids match the divergent beam from the gun to the main solenoid and compress the beam radius before it enters the linac. The injector also has three pairs of steering magnets to ensure that the beam is centered in the linac.

Prebuncher RF System

The prebunchers are reentrant cavities with heavy capacitive loading at the accelerating gap to reduce the overall length. They were designed with the aid of the program SUPERFISH[6], have a quality factor, Q of 20,000 and a shunt impedance of 2.7 MΩ. The capacitive noses incorporate concentric grooves to suppress multipacting.

The inside and outside walls of the cavities were rolled from oxygen free, high conductivity (OFHC) copper sheet. The cavities were assembled by tungsten inert gas (TIG) welding in a glove box with an argon atmosphere.[7] No filler rod was used.

The cavities are powered by separate vacuum tube amplifiers which have a common frequency source. The amplifier and cavity are contained within feedback loops regulating the rf phase and field within the cavity. The cavity resonance is locked to the rf drive frequency by a loop controlling a tuning plunger.

Gun Pulser

A copy of the SLAC avalanche transistor pulser[4] was used during the initial tests of the injector. As the pulser could not supply more than six amperes, full advantage could not be taken of the current capability of the gun. The avalanche transistors required several microseconds to recover between firings so the pulser was also unsuited for multi-bunch operation.

A new pulser was developed which could meet all requirements for high current, rapidly repetitive operation (Fig. 3). The pulser is located on a high voltage deck at the potential of the gun grid. AC power is coupled to the deck through an isolation transformer.

The trigger for the pulser is generated by an avalanche transistor firing a laser diode[8] and is transmitted to the deck by a fiber optic link. The

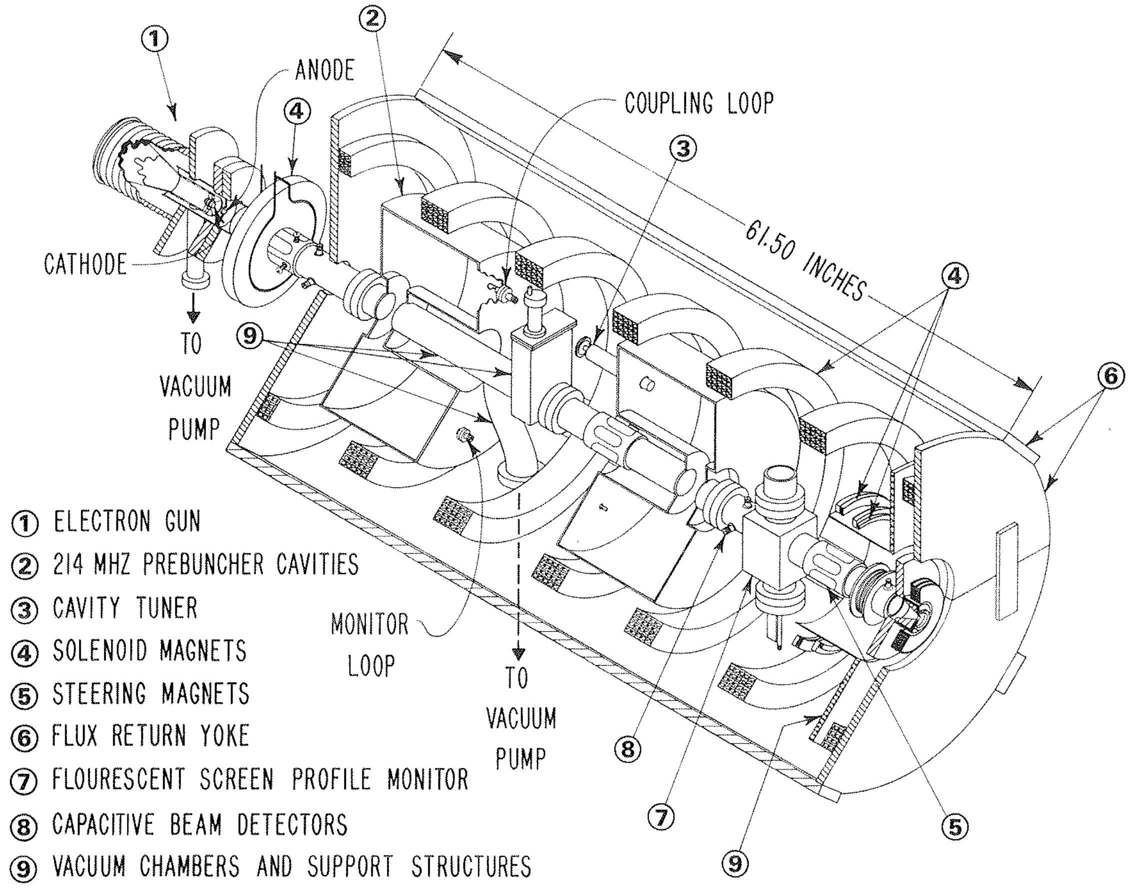

Fig. 2 Cutaway view of CHILI.

trigger is received by a PIN photodiode which fires an identical avalanche transitor stage. The avalanche transistors now in use require approximately 800 nsec between firings which is suitable for three bunch operation. An avalanche pulser has been tested on the bench which can fire at the 360 nsec interval required to inject seven bunches.

The pulses are amplified by two 8941 planar triodes[5] in cascade. Coaxial transformers are used for impedance matching between the vacuum tube stages and between the pulser and the gun. The pulser can produce a 30 A pulse with a full width of 2.5 nsec into a 12Ω load.

Performance

A fast Faraday cup was used during initial testing of the injector. The gun produced a beam pulse with a full width of 3 nsec and a peak current of 6 A, limited by current capability of the original avalanche transistor pulser. The beam was bunched to less than 200 psec full width with no loss of charge.

During the initial testing of the Y-796 cathode-grid assemblies were destroyed by the failure of a ceramic to metal braze due to overheating. Forced air circulation was provided to cool the braze and interlocks were installed to interrupt filament power if cooling is lost. No further braze failures have occurred.

Following testing the injector was attached to the linac in April 1983. Tuning of the high intensity beam proved to be straightforward. First the prebuncher phases are set with the aid of a fast beam detector in the linac to ensure that the beam is bunched into a single S-band bucket. The linac is then tuned for maximum transmission.

Unfortunately after several weeks of operation the gun emission degraded to less than one Ampere even at much greater than normal cathode temperatures. It was learned that a pressure of 10^{-8} Torr or better is needed to avoid poisoning the dispenser cathode in the Y-796. Additional pumping speed was provided, and the gun was baked at 300°C to improve the vacuum.

Emission returned, but even though the pressure at the cathode is now less than 8×10^{-9} Torr an additional 30% increase in emission can be obtained by isolating the gun from the linac vacuum. Presumably a hydrocarbon contaminant from the poorer linac vacuum is partially poisoning the cathode. Differential pumping will be added in the near future.

Beam intensities of 4×10^{10} electrons in a single S-band bunch have been accelerated to 200 MeV at the positron convertor. There is little evidence that beam induced instabilities are limiting the current. The maximum current may be limited by gun emission or improper focusing in the linac; studies are under way to improve the linac optics. Jitter in the position of the beam in the linac has been observed, but it is not yet clear if this results from beam induced transverse instabilities or merely from poor power supply regulation. The storage ring can now be filled with positrons at a rate of 2.5 mA/min compared to 1.3 mA/min with the old injector. Little tuning is required to maintain peak beam currents.

Acknowledgements

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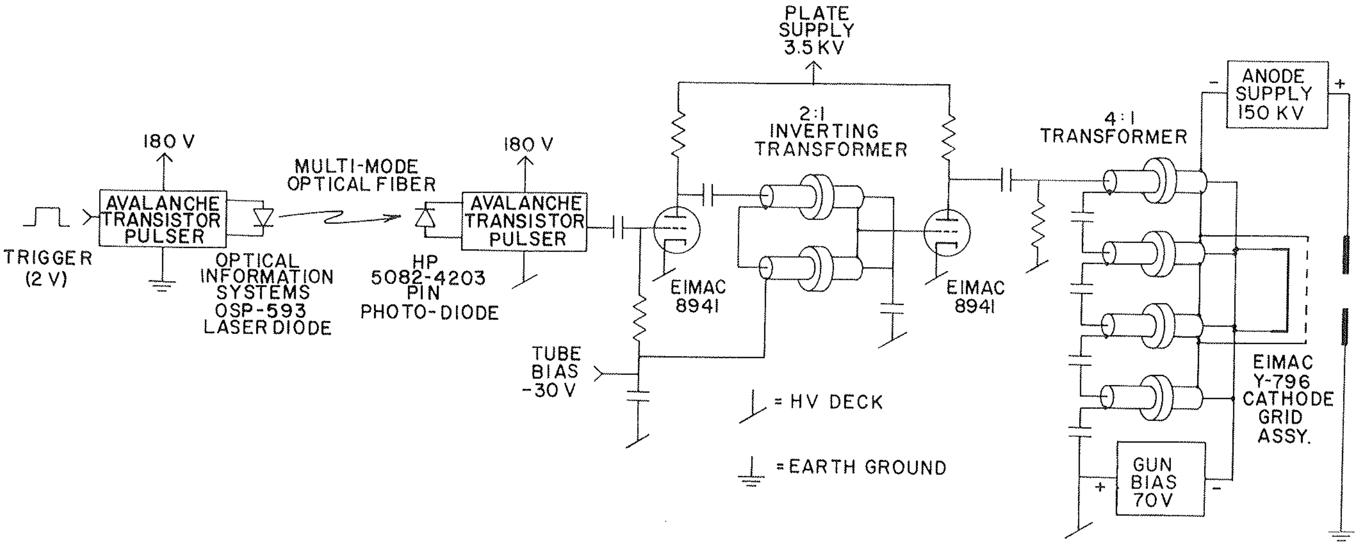

Fig. 3 CHILI pulser design.

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References

1. R.M. Littauer et al., these Proceedings.
2. M. Billing et al., 11th Intern. Conf. on High Energy Accel. (Birkhäuser Verlag, Basel), p. 26.
3. M.B. James and R.H. Miller, IEEE Trans. Nucl. Sci. NS-28, 3461 (1981); M.B. James et al., IEEE Trans. Nucl. Sci. NS-30, 2992 (1983).
4. R.F. Koontz, Proc. 1981 Linear Accel. Conf., p. 62.
5. EIMAC, Division of Varian, Salt Lake City, Utah 84104.
6. K. Halbach and R.F. Holsinger, Part. Accel. 7, 4, 213 (1976).
7. C. Firenze, U.S. Patent Pending.
8. Optical Information Systems, Inc., Elmsford, NY 10523.