100% DUTY FACTOR ELECTRON LINAC

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Abstract

An electron linac has been designed and specified with the beam characteristics tabulated below. It uses three currently available 200 kW CW klystrons and standing wave 805 MHz cavities of LAMPF design, operating with manageable heat dissipation of 0.5 kW per cavity.

Beam energy (max.):	40 MeV (duty factor 50%)
	$\leq$30 MeV (duty factor 100%)
Mean beam power:	160 kW at 30 MeV, CW.
Short-pulse mode:	160 kW at 2 x 10^5 pps, 10 ns.
Fast neutron flux (short-pulsed):	5 x 10^{14}/second.
Monochromated photon flux:	2 x 10^8/second (50 keV resol.)

At energies above 30 MeV, in order not to exceed power dissipation constraints, duty factor must be reduced. The continuous beam gives the machine outstanding capacity to service a tagged photon monochromator, and a high intensity, high PRF pulsed source of fast neutrons.

Introduction

An electron linac has been designed [1] to provide a 100% duty factor for 5 mA of electrons at 30 MeV. Alternatively, the linac may reach 40 MeV with 50% duty factor, or provide 10-nanosecond pulses at a repetition rate up to 2 x 10^5 per second. Maximum beam power is 160 kW in either CW or pulsed mode.

The linac is designed to operate at room temperature, using commercially available klystrons, and 805 MHz resonant cavities of LAMPF design.[2]

The primary design goal was to achieve a long duty factor machine at energies up to 50 MeV, with emphasis on CW capability for photonuclear studies at giant resonance energies. No speculative design features were attempted. Hence the design sacrifices some elegance and economy in favor of safety of using cavities and klystrons within operating conditions already proven in practice at LAMPF or elsewhere. The resulting machine should be straightforward to assemble and rugged to operate. Our experience using the Electron Prototype of LAMPF indicates that a high degree of reliability and operational stability can be expected from this design. The high duty factor and beam power make such a design a logical successor to the passing generation of TW electron linacs.

RF Cavities

LAMPF standing wave, side-coupled $\pi/2$-mode cavities designed for 805 MHz operation at $\sim$ 90°F [2] were chosen. Their layout is shown in Fig. 1. External water cooling ducts enable the cavities to dissipate 0.5 kW time-averaged power per cell. If CW operation is required, then the beam energy gain per cell is limited by this constraint to $\sim$ 0.3 MeV. To obtain an energy of 25 MeV at CW from the β=1 cavities, we require 71 cells, as shown. By operating with duty factor f, we may opt for higher peak power, and peak beam energy of $25/\sqrt{f}$ MeV without altering cavity cooling requirements. The net energy gradient of this structure is thus $0.6/\sqrt{f}$ MeV per meter.

Graded-β tanks consisting of 47 cells of similar design are used to provide a fixed beam energy of 4.4 MeV in CW mode. Their total power dissipation (24 kW) is well below cooling capacity.

The tanks receive RF power by way of bridge couplers; standard beryllium oxide windows couple to the klystron waveguide.

Klystrons

The Varian VA 862A klystron (805 MHz), factory-modified by substitution of a 10-inch collector for its standard 6-inch anode is rated to operate CW at 200 kW delivered power (or at 1.25 MW peak power in pulsed mode). Two such tubes supply the β=1 tanks, each tube thus providing up to 12.5 MeV in available CW beam energy. Alternatively, the tube modulators can be pulsed in order to provide up to 60 MeV at 17% duty factor.

For interchangeability, the same tube type was chosen to supply the graded-β tanks at low power.

Ceramic coupling windows on these tubes have undergone successful tests in long-duty operation at 200 kW. Consideration of window power-carrying capacity was one constraint in setting 200 kW as the maximum available power per tube.

As at LAMPF, conventionally engineered modulators operate under feedback stabilization referenced to probes sampling resident power in the cavities. Amplitude stability of 0.25% is projected, with loop response time of $\leq$ 2 μs. The phase of each klystron may be varied independently with reference to the master oscillator.

Injector

A standard triode electron gun (similar to Arco Model 12) is proposed, operated at 100 kV. The gun can deliver up to 5 mA (time-averaged or d.c.), or 10 nsec pulses of 10 A peak. The gun is followed by a conventional pre-buncher and buncher whose power is derived from the first klystron via a divider and phase-shifter network. Solenoid coils over the first half of the graded-β tanks are employed to minimize space-charge dispersion of pulsed beams.

Pulsed Beam

In the case of most electron linacs whose klystrons are limited to pulse length $\sim$ 4 μs and duty factor $\sim$ 0.1%, the total beam power available in nanosecond-pulsed mode is limited by klystron PRF. In the present design, we are constrained only by the mean RF power available. Hence with an injector offering 10 ns, 2.8 A pulses, we can pulse the gun at 2 x 10^5 pps while leaving the klystrons in CW operation, obtaining a total beam power of 160 kW, just as

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in CW mode. This beam power in pulsed mode can generate a flux of 5 x 10^{14} photoneutrons per second (4π) for high resolution fast neutron spectroscopy - one to two orders of magnitude in excess of the capability of competitive linac sources of fast neutrons in pulsed mode.

Monochromated Photons

Among numerous diverse applications of the CW beam in nuclear research,[3] coincidence experiments will be the species most significantly enabled by this linac. In particular, a "tagged" photon monochromator can be built with 50 keV resolution and an estimated effective flux of photons for reaction studies of 2.5 x 10^{8} per second. This markedly exceeds previously available fluxes of monochromatic photons in this energy range.

References

1. "The Ames Laboratory Electron Linear Accelerator" Ames Lab Internal Report, (1972).

2. E.A. Knapp, IEEE Trans. Nuc. Sci. NS-16, 329 (1969).

3. J.E.E. Baglin, IEEE Trans. Nuc. Sci. NS-18, 572 (1971).

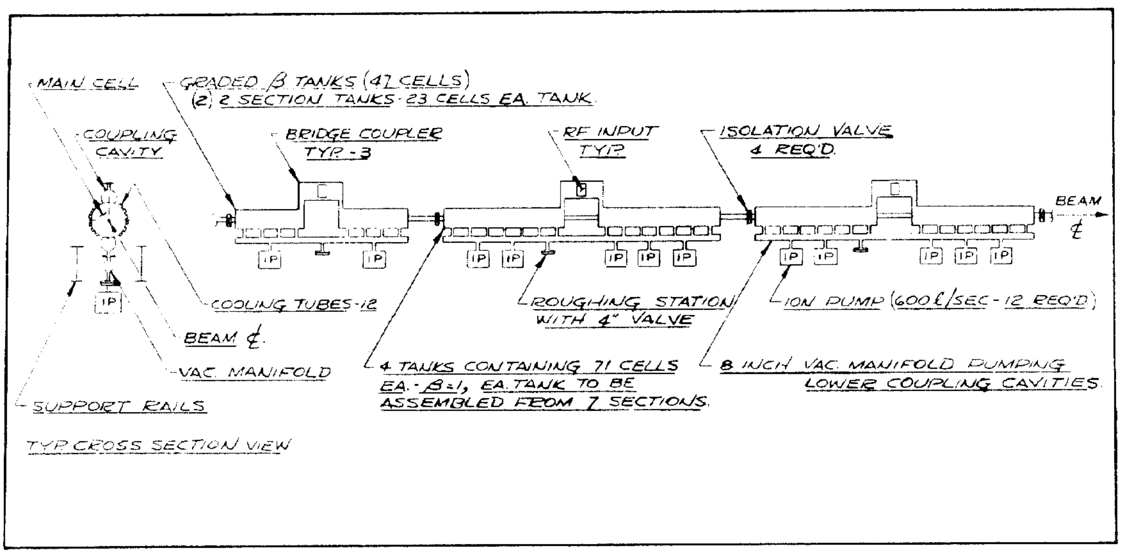

Fig. 1 Ames Laboratory Linac - Accelerator Structures Schematic.