IEEE Transactions on Nuclear Science, Vol. NS-26, No. 3, June 1979

A COMPACT STANDING-WAVE ELECTRON LINAC WITH RF DRIVE SYSTEM USING 3 dB HYBRID JUNCTION

V.F.Vikulov, A.A.Zavadtsev, B.V.Zverev, V.E.Kalyuzhny, V.I.Kaminsky, N.N.Nechaev, V.V.Ruzin, N.P.Sobenin, V.V.Stepov

Moscow Physics Engineering Institute

Abstract

Design and preliminary performance of a compact electron standing-wave linac of 5.5 MeV energy and 60 mA pulse beam current are given.

The accelerating guides are fed with RF power from a tunable magnetron through a 3 dB hybrid junction. The RF drive system is designed to provide a frequency stabilization coefficient up to 15.

Two versions of the accelerating system with different coupling cells have been investigated.

\+ + + + +

Standing wave electron linacs are widely used in radiography, radiotherapy and for industrial applications.[1-3] They differ from conventional traveling wave linacs in the design of the accelerating structure and the RF driver system. Biperiodic structures are used for acceleration and RF power is fed into accelerating guides from magnetron type generators.

On the basis of existing design, an RF driver system with a 3 dB hybrid junction was chosen. This system was developed for two different linac designs. One has accelerating guides with off-axis coupling cells, the other with on-axis coupling cells.[4]

Isolation is needed if accelerating guides are fed from magnetrons. For this purpose ferrite isolators or circulators are usually used. Significant insertion loss, rather large dimensions and poor reliability make them a poor choice for this application, however.

In the chosen RF driver system the accelerating structure consists of two identical guides, which are connected to the output ports of a 3 dB hybrid junction. The hybrid steers reflected power from the accelerator guides into a separate dummy load so the magnetron appears to be isolated. The main advantages of this RF drive system are design compactness, small RF power loss and good operating reliability.

Setting of the hybrid junction coupling value slightly over 3 dB enables the magnetron frequency and power to follow changes in accelerating guide parameters due to the beam loading, heating, etc. By this method a decrease in long term and interpulse frequency fluctuations by 15-20 times is obtained.[5,6]

Theoretical and experimental research has been done for different biperiodic slow wave structures. The choice has been made in favor of an on-axis coupled cell structure for the first linac design (Fig. 1a).

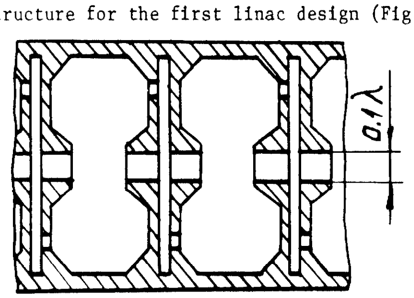

Fig. 1a. Biperiodic accelerating type, with on-axis coupling cells.

An off-axis ring coupling cell structure is used for the second linac design (Fig. 1b).[7] The measured values

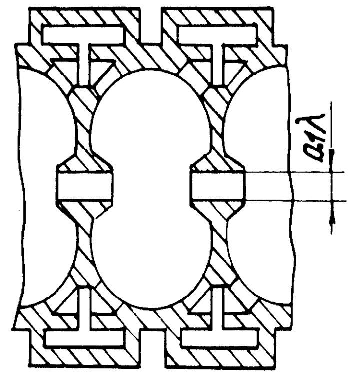

Fig. 1b. A type of biperiodic accelerator, with off-axis ring coupling cells.

of shunt impedances for these structures are correspondingly 61 MΩ/m and 68 MΩ/m at a frequency of 2800 MHz and coupling coefficients of 0.025 and 0.05. The structure employing on-axis coupling cells has smaller transverse dimensions which makes it easier to provide external electromagnetic focussing. Moreover, this structure is less complicated to fabricate and tune.

Block diagrams of the two accelerator systems with 3 dB hybrid junction driver systems are shown in Figs. 2a and 2b. The first system has been designed for a

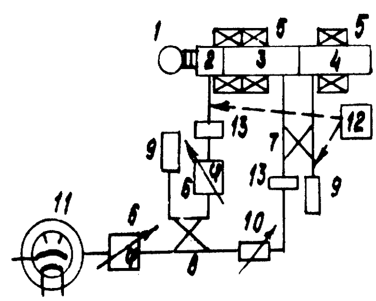

Fig. 2a. Standing-wave linac block diagram: three-guide linac with variable energy.

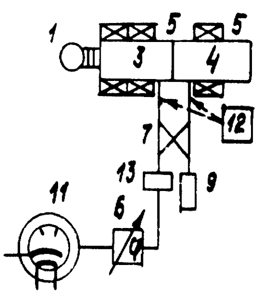

Fig. 2b. Standing-wave linac block diagram: two-guide linac.

1 - electron gun; 2 - buncher guide; 3,4 - accelerating guides; 5 - focusing coils; 6 - phase shifter;

0018-9499/79/0600-4292$00.75 © 1979 IEEE

7 - 3 dB hybrid junction; 8 - directional coupler; 9 - dissipating load; 10 - attenuator; 11 - magnetron; 12 - vacuum pump; 13 - RF window.

current of 60 mA. The second structure is fixed energy, 6.2 MeV, and has a beam current of 50 mA. Both linacs are fed with 1.2 MW RF peak power.

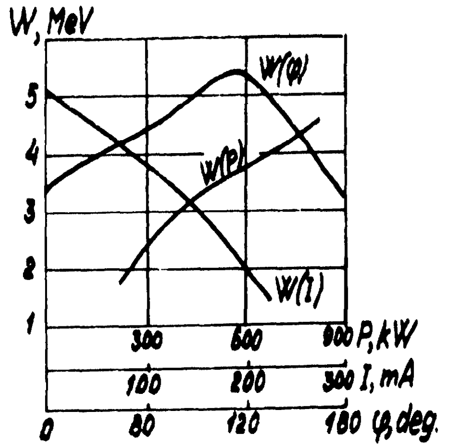

Fig. 3. Calculated parameters of standing wave linac.

Figure 3 shows calculated electron energy (W) vs. input RF power (P), beam current (I), and phase slip between the electron bunches and RF field in the first regular guide (ϕ). This data is valid for the accelerator shown in Fig. 2a. This accelerator has a separate buncher guide fed through an 8 dB directional coupler. Energy variation is obtained by varying the phase slip ϕ with a phase shifter and RF power P with an attenuator.

The linac shown in Fig. 2b has a bunching section incorporated into the first guide, so this linac is more compact. The first guide consists of two graded β_{PH}, and six $\beta_{PH} = 1$ accelerating cells. The overall length of the accelerating system is 76 cm.

The variable energy linac consists of a buncher with three accelerating cells and two regular guides with seven accelerating cells each. Its overall length is 86 cm.

The relative detuning of the guides in the $\pi/2$ mode should not exceed 0.1 MHz to secure designed fields in the guides and stable magnetron operation. Moreover, the value of guide detuning in the neighboring two modes should not exceed 0.2 to 0.5 MHz. In different operating regimes these tolerances are controlled by a thermostabilization system. 40 kV diode type guns with either dispenser or direct heating cathodes were used as electron injectors. The focusing system consists of three coils wound with aluminum foil. Two of them were placed near the buncher guide and produce a magnetic field of 1200 gauss. The third coil placed at the second regular guide provides a magnetic field of 800 gauss. Vacuum of a few times 10^{-7} Torr was maintained in the accelerator by an ion pump. Two ceramic wave-guide windows separate the accelerator vacuum system from the RF system.

Preliminary tests of the variable energy standing wave linac have been completed. The energy-time dependence over the RF pulse duration is shown in Fig. 4a. Figure 4b shows oscillograms of field energy built up with and without beam loading.

The RF power-driver supply system provided stable excitation with the magnetron at operating frequency within the energy range of 1.5 to 5 MeV. In the 1 to 1.5 MeV range the guide resonant frequency shift due to beam loading resulted in an input RF power decrease. This effect could be corrected by retuning the magnetron frequency. Electron efficiency of the accelerator could be made as high as 50% by increasing the beam loading.

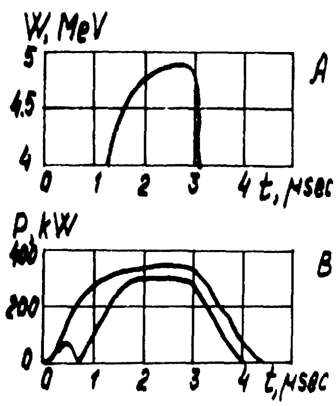

Fig. 4. Observed waveforms for the three-guide linac. A - mean energy dependence on time over RF pulse. B - field energy build-up in accelerating guide (lower curve, with beam loading).

References

1. A.Bensussan, D.T.Tran, D.Tronc; Nucl. Instr. Meth. 140, 231-235 (1977).
2. K.Irie, Y.Minova, S.Sawada; Jap. J. Appl. Phys. 12, N2 (1973).
3. K.Whitram, B.Meyer; Materials Evaluation 27, N 11 (1963).
4. A.A.Zavadtsev, B.V.Zverev, N.N.Nechaev, N.P.Sobenin; Uskoritelo, vypusk XVl, 5-7 (1977) [in Russian].
5. V.F.Vikulov, O.S.Milovanov; Uskoriteli, vypusk VIII, 61-66 (1966) [in Russian].
6. V.I.Kaminsky, N.N.Nechaev; Uskoriteli, vypusk XVI, 32-34 (1977) [in Russian].
7. O.A.Valdner, N.P.Sobenin, B.V.Zverev, I.S.Shchedrin; Spravochnik po diaphragmirovannym, volnovodam, Atomizdat, Moskva (1977) [in Russian].