

VII. TRAVELING-WAVE TUBES

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A. THREE-CM TRAVELING-WAVE AMPLIFIER TUBES

1. Helix Studies

As mentioned in the last Progress Report, a large-scale model of the helix used in the traveling-wave tube was constructed. The phase velocities of waves on this structure were measured under various conditions. Close agreement was obtained between the measurements made by moving a probe along the helix and those made by observing the input impedance variation as a metal plate was moved along the axis.

Some results of these measurements are shown in Figure VII-1. Curve A is the theoretical characteristic calculated for the corresponding helical sheath, the mean radius being denoted by \bar{a} and the pitch angle by θ . The close agreement between the measured points and this characteristic confirms the validity of the measurements.

The effects produced by various distributions of dielectric about the helix are shown by curves B, C, D and E. Curve D is particularly significant because it was measured under conditions very similar to those obtaining in the traveling-wave tubes built here. The pronounced minimum in this curve indicates that, for a certain range of beam velocities, amplification can take place at two different frequencies.

In the tubes built at this laboratory, the operating point was at a value of $2\pi\bar{a}/\lambda$ of about 0.25. Thus amplification could take place at the operating wavelength of 3.2 cm and also at a wavelength somewhat greater than twice this value. Since the coupling to the beam, and hence the gain, is greater at the lower frequency, and since the helix is mismatched, one should expect the tube to oscillate at this low frequency. This effect has actually been observed in the tubes which oscillated at a wavelength of 9 cm when adjusted to amplify at 3.2 cm.

The predominance of the dielectric slowing at the lower frequencies is attributed to the physical distribution of the dielectric about the helix. At low frequencies the fields penetrate farther into the dielectric where there is relatively more material than there is near the helix wall. This reasoning indicates that a more uniform type of helix support is desirable,

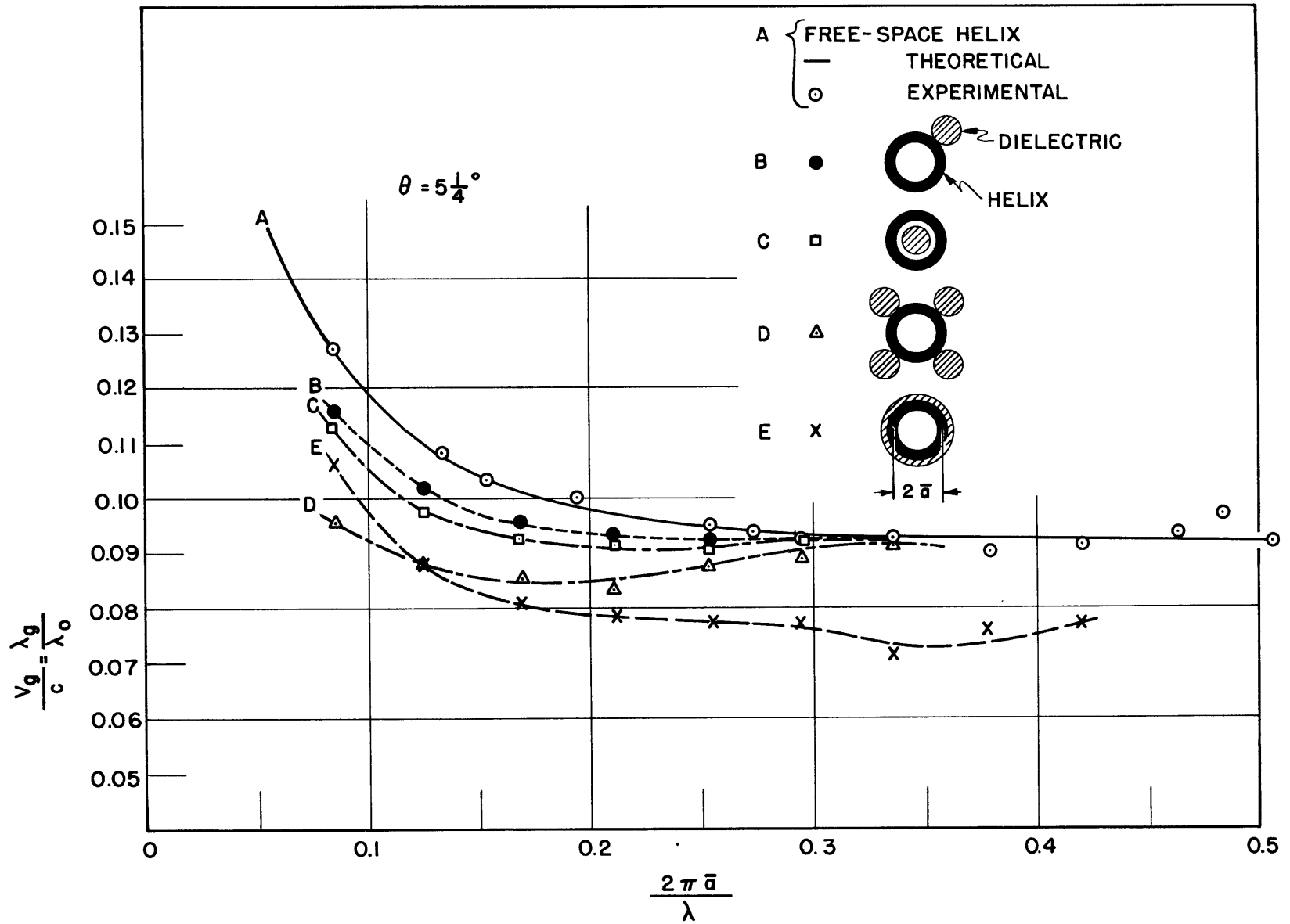


Fig. VII-1. Propagation on a charge-free helix.

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and curve E of Figure VII-1 bears out this conclusion. Although the phase velocities of all frequencies are diminished, the dispersive character of the curve is restored.

In practice, however, available glass tubing suitable for supporting the small helices is proportionally much thicker than the tubing used for the measurement of curve F. Figure VII-2 shows the effect of varying the dielectric thickness. Note that the relatively thick dielectric reduces the dispersion again.

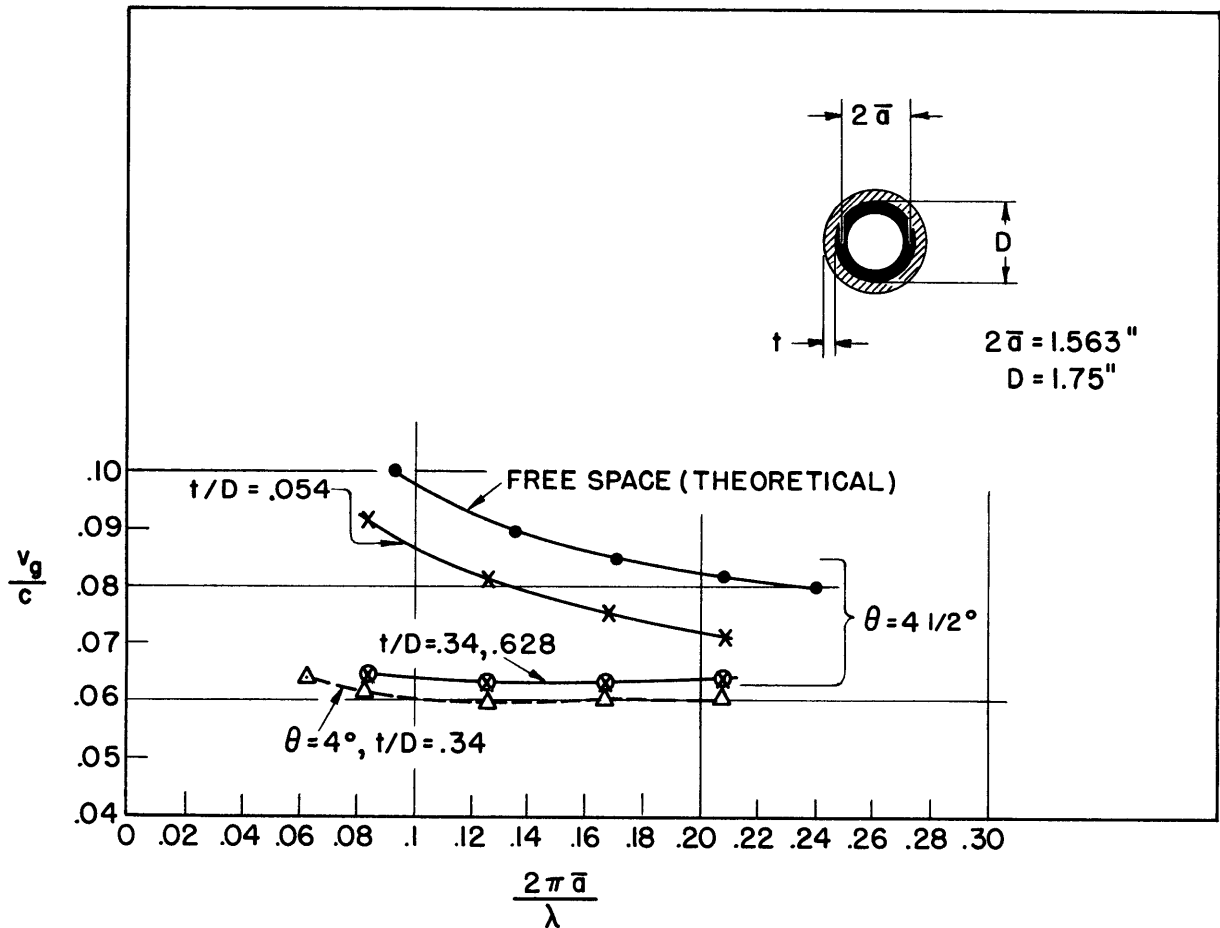


Fig. VII-2. Variation of phase velocity with pitch angle and dielectric thickness.

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The bottom curve of Figure VII-2 was measured with the helix turns pushed closer together, and we note a slight reappearance of the dispersion.

In order to support the helix without the adverse effects of the dielectric rods or tubes, a technique of making glass-wool supports is being tried. Preliminary experiments indicate that glass wool, packed into a mold of the proper shape and heated, can be "sintered" to form a relatively solid structure with preassigned dimensions. The dielectric constant of the material is somewhere between 1.1 and 1.5, depending on the tightness of packing. Experiments on the performance of this material in vacuum are now in progress.

2. Redesign of 3-Cm Traveling-Wave Tube

Closer examination of the gain of the tube as a function of helix diameter has shown that the present helices are larger than the optimum dimensions. Computations based on Rydbeck's paper⁽¹⁾ indicate a maximum in the gain parameter for $2\pi\bar{a}/\lambda \simeq .1$. This fact, along with the desirability of operating closer to the dispersive region of the helix, has led us to the use of a smaller helix. The new helices are 0.064 inches in diameter ($2\pi\bar{a}/\lambda = .155$) as opposed to the previous value of 0.107 inches. The design and construction of a new traveling-wave tube has been started. This new tube will use the smaller-diameter helix which is to be supported in a glass tube. The center loss section included in previous tubes will be omitted.

It has been found that helices more accurate in pitch can be wound on a smooth drill rod than on the threaded rod formerly used. A carriage carrying the spool of wire, and guiding the mandrel and wire, is mounted on the tool post of a lathe and the helix is wound using the lead screw of the lathe. The larger helices (0.107 inches diameter), which were formerly accurate in pitch to within about 5 per cent, can be wound in this way to within 1 per cent accuracy. The smaller helices are accurate to about 3 or 4 per cent. Because of the difference in actual pitch, this represents about the same absolute magnitude of error.

B. VELOCITY-MODULATED-INPUT TRAVELING-WAVE AMPLIFIER

Construction of a three-centimeter helix-type traveling-wave tube with velocity-modulation input has been started. Instead of exciting the helix directly, the electron beam is to be velocity-modulated by means of a cavity

1. "The Theory of the Traveling-Wave Tube", O.E.H. Rydbeck, Ericsson Technics, 46(1948).

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resonator of the type used in klystrons. Output power will be taken from the helix in the conventional manner. The proposed construction is shown in Figure VII-3.

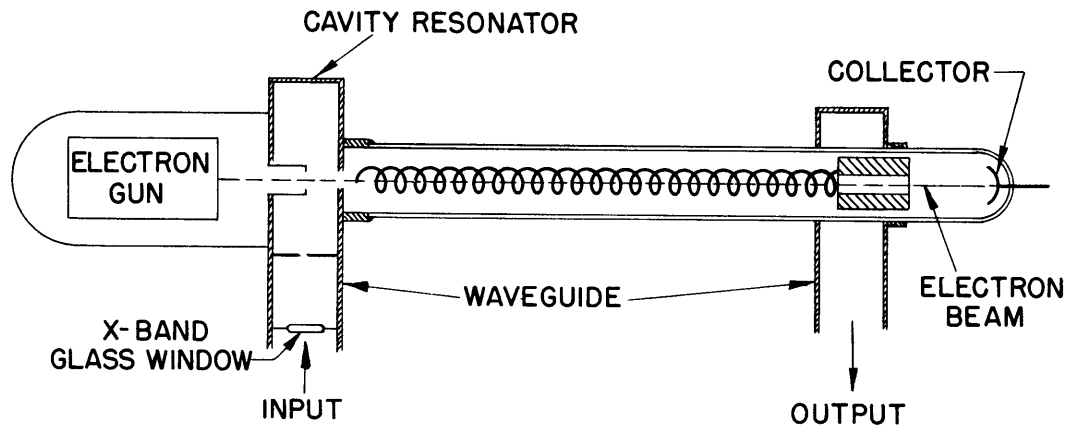


Fig. VII-3. Velocity-modulated-input traveling-wave amplifier.

The cavity resonator has been designed and constructed. It will be iris-coupled to the waveguide for excitation.

A Pierce-type electron gun has been designed, built and tested. Some mechanical refinements will be incorporated in future models. The guns are designed so that they fasten on the outside of the cavity to assure good mechanical alignment.

The intention is to use about four inches of helix, roughly half of that used in conventional tubes constructed in this laboratory, since the klystron-type bunching will supposedly accomplish the same thing as the first half of the helix. The helix has been designed for a velocity corresponding to 2,000 volts in free space. It is .070 inch in outer diameter, has 60 turns/inch, and is wound of .006-inch wire. Several helices have been wound. The helix will be supported in a close-fitting glass tube. In view of the experiments described under "Helix Studies", this will slow the velocity of waves along it to a value roughly corresponding to 1,500 volts.

An attempt is being made to work out the first-order theory of the tube. Analyses of the ordinary traveling-wave tube assume a homogenous electron beam. In this case the work is considerably complicated by the velocity distribution of the electron beam entering the helix.

C. EIGHT-MM TRAVELING-WAVE OSCILLATOR

All effort in the last quarter has been devoted towards learning how to make molybdenum-to-glass seals. These seals are needed because of the

extreme accuracy with which the beam must be focused. The use of Kovar is ruled out because of its large permeability which causes distortion of the magnetic focusing field.

Corning 706 glass apparently makes an excellent seal to molybdenum. Our technique (after Little of BTL) is first to oxidize the molybdenum by heating in air, and then to seal it to the glass in a neutral atmosphere (N_2). This technique allows us to control the amount of oxidation and to keep other parts of the molybdenum from "burning".

To date, we have been able to make butt seals between glass and molybdenum cylinders 3/4-inch O.D. x .020-inch wall, and waveguide windows about 5/32-inch diameter and .020 inch thick. Both of these are made with induction heating; they are rugged enough to stand immersion in liquid Na.

The waveguide-window technique cannot yet be considered finished, since we still do not have a satisfactory method of brazing the window into a copper block. The present plan is illustrated in Figure VII-4.

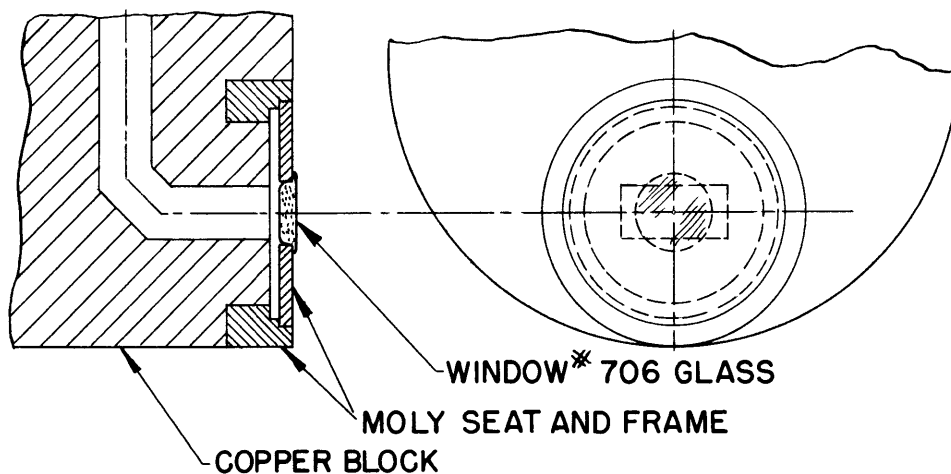


Fig. VII-4. Detail of waveguide window.

A stiff molybdenum seat is interposed between the copper block and the thin window frame. This serves to prevent bending of the frame because of differential expansions between it and the block. Most of our difficulties with this scheme lie in our inability to make a consistently good braze-joint between the molybdenum parts.

The molybdenum cylinders for the butt joint are machined out of 3/4-inch diameter machinable molybdenum rod. Use of machinable molybdenum rather than ordinary molybdenum rod reduces the number of cracked pieces considerably.