



## High-Power, High-Efficiency Ka-Band Space Traveling-Wave Tube

Improved designs of critical components contribute to increased power and efficiency.

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The L-3 Communications Model 999H traveling-wave tube (TWT) has been demonstrated to generate an output power of 144 W at 60-percent overall efficiency in continuous-wave operation over the frequency band from 31.8 to 32.3 GHz. The best TWT heretofore commercially available for operation in the affected frequency band is characterized by an output power of only 35 W and an efficiency of 50 percent. Moreover, whereas prior TWTs are limited to single output power levels, it has been shown that the output power of the Model 999H can be varied from 54 to 144 W.

A TWT is a vacuum electronic device used to amplify microwave signals. TWTs are typically used in free-space communication systems because they are capable of operating at power and efficiency levels significantly higher than those of solid-state devices. In a TWT, an electron beam is generated by an electron gun consisting of a cathode, focusing electrodes, and an anode. The electrons pass through a hole in the anode and are focused into a cylindrical beam by a stack of periodic permanent magnets and travel along the axis of an electrically

conductive helix, along which propagates an electromagnetic wave that has been launched by an input signal that is to be amplified.

The beam travels within the helix at a velocity close to the phase velocity of the electromagnetic wave. The electromagnetic field decelerates some of the electrons and accelerates others, causing the beam to become formed into electron bunches, which further interact with the electromagnetic wave in such a manner as to surrender kinetic energy to the wave, thereby amplifying the wave. The net result is to amplify the input signal by a factor of about 100,000. After the electrons have passed along the helix, they impinge on electrodes in a collector. The collector decelerates the electrons in such a manner as to recover most of the remaining kinetic energy and thereby significantly increase the power efficiency of the TWT.

The increase in power and efficiency of L-3 Communications Model 999H TWT over those of prior TWTs are attributable to several factors:

- Beam-focusing components feature new designs for improved thermal capa-

bility and increased operating stability.

- Advanced computational modeling of the interaction of the microwave signal with the electron beam made it possible to modify designs of components to attain high efficiency over a wide range of power levels.
- Improved wide-band waveguide-to-circuit coupling and wide-band, high-power radio-frequency windows were developed.
- A four-stage depressed collector was optimized by use of MICHELLE, a Naval Research Laboratory computer code for modeling guns and collectors in TWTs.

*This work was done by Richard Krawczyk, Jeffrey Wilson, Rainee Simons, Wallace Williams and Kul Bhasin of Glenn Research Center and Neal Robbins, Daniel Dibb, William Menninger, Xiaoling Zhai, Robert Benton, and James Burdette of L-3 Communications Electron Technologies, Inc. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17900-1.*

## Gratings and Random Reflectors for Near-Infrared PIN Diodes

Quantum efficiency would be increased.

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Crossed diffraction gratings and random reflectors have been proposed as means to increase the quantum efficiencies of InGaAs/InP positive/intrinsic/negative (PIN) diodes designed to operate as near-infrared photodetectors. The proposal is meant especially to apply to focal-plane imaging arrays of such photodetectors to be used for near-infrared imaging. A further increase in quantum efficiency near the short-wavelength limit of the near-infrared spectrum of such a photodetector array could be effected by removing the InP substrate of the array.

The use of crossed diffraction gratings and random reflectors as optical devices for increasing the quantum efficiencies of quantum-well infrared photodetectors (QWIPs) was discussed in several prior *NASA Tech Briefs* articles. While the optical effects of crossed gratings and random reflectors as applied to PIN photodiodes would be similar to those of crossed gratings and random reflectors as applied to QWIPs, the physical mechanisms by which these optical effects would enhance efficiency differ between the PIN-photodiode and QWIP cases:

- In a QWIP, the multiple-quantum-well layers are typically oriented parallel to the focal plane and therefore perpendicular or nearly perpendicular to the direction of incidence of infrared light. By virtue of the applicable quantum selection rules, light polarized parallel to the focal plane (as normally incident light is) cannot excite charge carriers and, hence, cannot be detected. A pair of crossed gratings or a random reflector scatters normally or nearly normally incident light so that a significant portion of it attains a component of polarization normal to