



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

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

John H. Glenn Research Center, Cleveland, Ohio

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

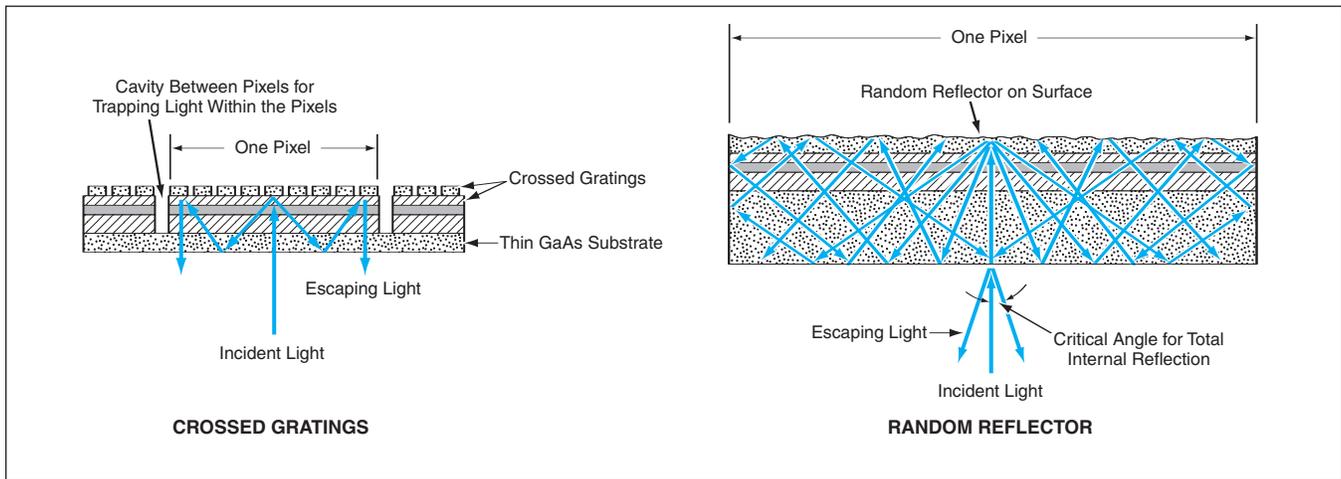
Quantum efficiency would be increased.

NASA's Jet Propulsion Laboratory, Pasadena, California

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



Crossed Diffraction Gratings or a Random Reflector would be fabricated on the back (here, the top) face of a PIN photodiode in each pixel of an imaging array of such photodiodes.

the focal plane and, hence, can excite charge carriers.

- A pair of crossed gratings or a random reflector on a PIN photodiode would also scatter light into directions away from the perpendicular to the focal plane. However, in this case, the reason for redirecting light away from the perpendicular is to increase the length of the optical path through the detector to increase the probability of absorption of photons and thereby increase the resulting excitation of charge carriers.

A pair of crossed gratings or a random reflector according to the proposal would be fabricated as an integral part of photodetector structure

on the face opposite the focal plane (see figure). In the presence of crossed gratings, light would make four passes through the device before departing. In the presence of a random reflector, a significant portion of the light would make more than four passes: After each bounce, light would be scattered at a different random angle, and would have a chance to escape only when it was reflected, relative to the normal, at an angle less than the critical angle for total internal reflection. Given the indices of refraction of the photodiode materials, this angle would be about 17°. This amounts to a very narrow cone for escape of trapped light.

This work was done by Sarath Gunapala, Sumith Bandara, John Liu, and David Ting of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Optically Transparent Split-Ring Antennas for 1 to 10 GHz

Advantages include ultra-wide-band operation, miniaturization, and excellent impedance matching.

John H. Glenn Research Center, Cleveland, Ohio

Split-ring antennas made from optically transparent, electrically conductive films have been invented for applications in which there are requirements for compact antennas capable of operation over much or all of the frequency band from 1 to 10 GHz. Primary examples of such applications include wireless local-area networks and industrial, scientific, and medical (ISM) applications. These antennas can be conveniently located on such surfaces as those of automobile windows and display screens of diverse hand-held electronic units. They are fabricated by conventional printed-circuit techniques and can easily be integrated with solid-state amplifier circuits to enhance gain.

The structure of an antenna of this type includes an antenna/feed layer supported on the top or outer face of a dielectric (e.g., glass) and, optionally, a ground layer on the bottom or inner face of the substrate. The ring can be in the form of either a conductive strip or a slot in the antenna/feed layer. The ring can be of rectangular, square, circular, elliptical, or other suitable shape and can be excited by means of a microstrip, slot line, or coplanar waveguide. For example, the antenna shown in the figure features a square conductive-strip split ring with a microstrip feed.

In general, an antenna fed at its external boundary in the manner of this inven-

tion presents very high impedance, thereby creating an impedance-matching problem. Splitting the ring — that is, cutting a notch through the ring — offers a solution to the problem in that the notch fixes the location of maximum electric field, which location is directly related to the impedance. Thus, an excellent impedance match can be achieved through proper choice of the location of the notch.

In geometric layout, such a ring antenna structure is typically between $\frac{1}{4}$ and $\frac{1}{3}$ the size of a patch antenna capable of operating in the same frequency range. This miniaturization of the antenna is desirable, not only because it contributes to overall miniaturization of equipment, but