the upper part of Figure 2, the small-signal gain ($S_{21}$), was found to be >10 dB from 144 to 170 GHz, while input and output return losses ($S_{11}$ and $S_{22}$) are both approximately 10 dB at 165 GHz.

For the power measurements, the amplifier circuit was biased at a drain potential of 2.1 V, a drain current of 250 mA, and gate potential of 0 V (these biases were chosen to optimize the output power). As shown in the lower part of Figure 2, the output power ranged from a low of about 11.8 dBm ($≈$15 mW) to a high of about 14 dBm ($≈$25 mW). The peak power output of about 14 dBm was achieved at 150 GHz at an input power of 6.3 mW, yielding a large-signal gain of slightly less than 8 dBm.

This work was done by Lorene Samoska of NASA’s Jet Propulsion Laboratory, and Vesna Radisic, Catherine Ngo, Paul Janke, Ming Hu, and Miro Micovic of HRL Laboratories, LLC. Further information is contained in a TSP (see page 1). NPO-30127

Figure 1. This Three-Stage MMIC HEMT Amplifier occupies a chip area with dimensions of 1.1 by 1.9 mm.

Figure 2. The Small-Signal $S$ Parameters and Power Output of the amplifier were measured over its design frequency range.

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**Piezoelectric Diffraction-Based Optical Switches**

*Switching times can be short enough for demanding applications.*

*Ames Research Center, Moffett Field, California*

Piezoelectric diffraction-based optoelectronic devices have been invented to satisfy requirements for switching signals quickly among alternative optical paths in optical communication networks. These devices are capable of operating with switching times as short as microseconds or even nanoseconds in some cases.

The basic principle of this invention can be illustrated with reference to a simple optical switch shown schematically in the figure. Light of wavelength $\lambda$ is introduced via an input optical fiber. After emerging from the tip of the input optical fiber, the light passes through a uniform planar diffraction grating that is either made of a piezoelectric material or is made of a non-piezoelectric material bonded tightly to a piezoelectric substrate. A voltage can be applied to

The Period of the Diffraction Grating Is Varied between two values by switching between two values of voltage applied to the piezoelectric substrate, thereby switching between two different angles of mth-order diffraction. Output optical fibers are positioned to intercept the diffracted light at the two angles.
the piezoelectric member via electrodes at its ends to vary the spatial period of 
the grating. Two output optical fibers are positioned near the grating, oppo-
site the input fiber.

The angle of diffraction of \( \lambda \)-wavelength light to any given order, \( m \), de-
pends upon the wavelength, the angle of 
incidence, and the spatial period of the 
grating. Hence, for a given fixed angle of 
incidence, one can change the angle of 
\( m \)-th-order diffraction by varying applied 
voltage. The relative positions and orien-
tations of the input fiber, the grating, and 
the output optical fibers are chosen in 
conjunction with the grating period so 
that (1) when no voltage or a given fixed 
voltage is applied, the \( m \)-th-order-dif-
fracted light of wavelength \( \lambda \) impinges on 
one of the output optical fibers and (2) 
when a different given fixed voltage is ap-
plied, the \( m \)-th-order-diffracted light of 
wavelength \( \lambda \) impinges on the other out-
put optical fiber. Thus, by switching the 
applied voltage between the two given 
fixed values, one switches the light be-
tween the two output optical paths.

It is also possible to make the device 
described above perform the following 
additional functions:

• If only one output optical fiber is used 
to intercept \( m \)-th-order-diffracted light 
and the input light includes multiple 
wave lengths, then the output wave-
length can be selected by applying a 
Corresponding voltage to the piezo-
electric member.

• For given fixed values of the angle of 
incidence, diffraction angle, and wave-
length, one can choose a discrete value 
of applied voltage to select a given dif-
fraction order.

• For given fixed values of the diffraction 
angle and wavelength, it is possible to 
vary the applied voltage to switch 
among different angles of incidence in 
order to select among different inputs.

Of course, it is possible to design de-
vices more complex than that illustrated 
in the figure. For example, a device 
could contain crossed piezoelectric grat-
ings for switching between an input op-
tical fiber and multiple output optical 
fibers terminated in a planar array.

Other examples could include devices 
that produce more complex switching 
effects by means of curved gratings, 
chirped gratings, and/or multiple piezo-
electric actuators that bend or twist grat-
ing surfaces or that vary grating spatial 
periods along multiple coordinate axes.

This work was done by Stevan Spremo, 
Peter Fuhr, and John Schipper of Ames Re-
search Center. Further information is con-
tained in a TSP (see page 1).

Inquiries concerning rights for the commer-
cial use of this invention should be addressed 
to the Patent Counsel, Ames Research Center, 
(650) 604-5104. Refer to ARC-14638.