and uses echoes off of the reflector plate with (*BS*) and without the sample present (*M*"), as well as using the echo off of the sample front surface (*FS*). (The FS echo may require specialized signal processing to "de-noise" and amplify it if it is received off of a foam front surface.)

*This work was done by Ron Roth for Glenn Research Center. 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-18262-1/3-1.*

# Compact Microwave Fourier Spectrum Analyzer

## Large delays needed for time-domain autocorrelations would be realized photonically.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A compact photonic microwave Fourier spectrum analyzer [a Fourier-transform microwave spectrometer, (FTMWS)] with no moving parts has been proposed for use in remote sensing of weak, natural microwave emissions from the surfaces and atmospheres of planets to enable remote analysis and determination of chemical composition and abundances of critical molecular constituents in space.

The instrument is based on a Bessel beam (light modes with non-zero angular momenta) fiber-optic elements (see figure). It features low power consumption, low mass, and high resolution, without a need for any cryogenics, beyond what is achievable by the current state-of-the-art in space instruments. The instrument can also be used in a wide-band scatterometer mode in active radar systems.

The basic advantage of the proposed instrument is its wide bandwidth along with high resolution, enabling microwave hyperimaging of the planetary atmospheres and surfaces. For example, the analyzer will have similar resolution to the Cassini Titan Radar Mapper operating in the scatterometer mode, and will have at least two orders of magnitude wider bandwidth, compared with the same instrument operating in the radiometer mode. This will allow collecting a hundred times more data during the same observation period.

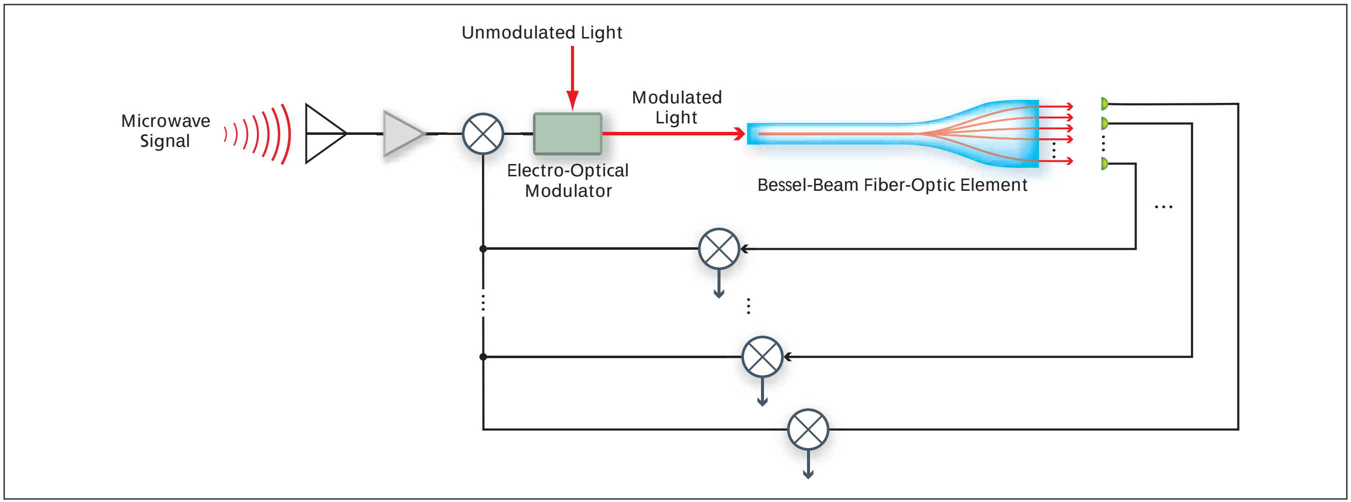
The analyzer has significant advantages for remote detection of chemical components from space. It uses microwave radiation to record the rotational spectrum of a molecule in the microwave spectral region, i.e., between approximately 6 GHz and 40 GHz. For instance, FTMWS can be used for the accurate remote detection of water vapor as well as for the study of hydrogen isotopic ratio.

The analyzer has a very long, mile-range, maximum delay realized with photonics techniques. This capability is ultimately crucial for achieving a high resolution with the Fourier transform spectrum analyzer. To obtain the 1-MHz spectral resolution necessary for resolving the microwave emission spectrum of water in remote sensing, it would ordinarily be necessary to use microwave delay lines having lengths up to 300 m. Such long microwave delay lines would not be practical. However, the instrument would exploit the fact that compact delay lines can be realized photonically.

It has Fellgett (multiplex) advantage taken from Fourier spectroscopy. A typical microwave spectrum analyzer sequentially measures the microwave power within each of a number of narrow spectral bands. The new instrument would simultaneously measure the time-domain autocorrelations of the microwave emission signal of interest using a number of different delays, then calculate the spectrum of that signal by use of a fast Fourier transform. Hence, the instrument would constantly and simultaneously provide data on all the bands of the spectrum.

It has all the advantages of a static Fourier transform spectrometer. There are no moving parts, which eliminates many potential mechanical problems onboard the spacecraft. The instrument has no need for a reference laser since the detector array samples the interferogram always at the same points. The analyzer obtains full interferogram at once so it is insensitive to the flicker noise or fluctuations of the input signal. This is critical, e.g., for spectroscopy of a constantly changing planetary environment.

As shown in the figure, the incoming




The **Microwave Spectrum Would Be Translated** to the optical spectrum, wherein compact delay lines can be realized by use of highly dispersive optical elements.

microwave signal would be amplified and applied to the input terminal of an electro-optical modulator, which would impress the microwave signal as modulation onto a beam of light. The light would enter a Bessel-beam fiber-optic element, which is essentially an optical waveguide that tapers to a wider aperture at its output end. A Bessel-beam fiber-optic element acts as a highly dispersive radiator horn, roughly equivalent to a bundle of optical fibers of different lengths. The dispersion in a Bessel-beam fiber-optic element is so great as to afford delays ranging from about 10 ps to about 1 µs. In this instrument, the light arriving at each location on the output plane of the dispersive optical element would have a different delay, and so an array of photodiodes would be placed on that output plane to sample signals at various increments of delay. The variously delayed microwave outputs of the photodiodes would be used to obtain the required autocorrelation data.

*This work was done by Anatoliy Savchenkov, Andrey Matsko, Dmitry Strekalov, and Lute Maleki 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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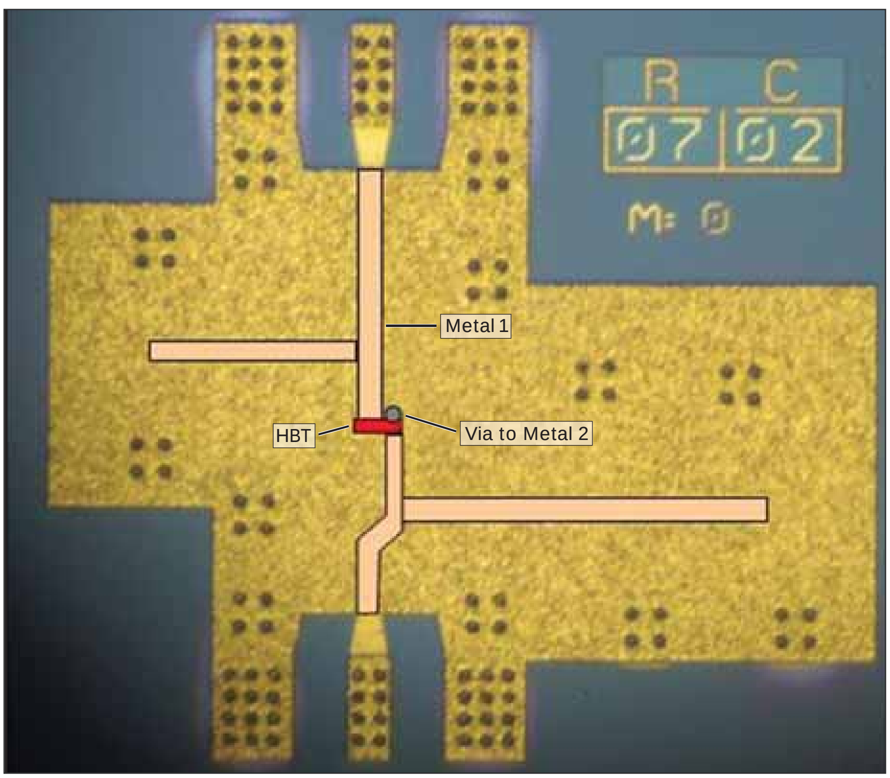
*Refer to NPO-43992, volume and number of this* NASA Tech Briefs *issue, and the page number.*

# InP Heterojunction Bipolar Transistor Amplifiers to 255 GHz

**These amplifiers can be used in millimeter-wave imaging systems for weapons detection and airport security, and for radar instruments.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Two single-stage InP heterojunction bipolar transistor (HBT) amplifiers operate at 184 and 255 GHz, using Northrop Grumman Corporation's InP HBT MMIC (monolithic microwave integrated circuit) technology. At the time of this reporting, these are reported to be the highest HBT amplifiers ever created. The purpose of the amplifier design is to evaluate the technology capability for high-frequency designs and verify the model for future development work.




A microphotograph shows the **255-GHz Amplifier MMIC**. A second metal serves as a ground plane and covers most of the circuit area. The transmission lines and HBT device are "drawn" in the photograph. Die size is 0.55 mm × 0.55 mm.

MMIC amplifier operating frequencies have pushed past 200 GHz and into submillimeter wave frequencies. The main driver has been in demand for millimeter-wave radiometers and high-resolution, all-weather imaging systems.

MMIC power amplifiers have a variety of applications for ground-based and future space-based telescopes for astrophysics, as well as in local oscillators for heterodyne receivers in Earth and planetary science instruments. They can be used in millimeter-wave imaging systems to provide sensitive hidden-weapons detections, airport security imaging systems, or other homeland security portable imaging sensors. Power amplifiers can also be used in transmitters for radar instruments and commercial laboratory power sources.

While HEMT amplifiers are traditionally used for low noise receivers due to their low noise properties, HBT amplifiers can be used as power sources due to the nature of their material properties, traditionally higher breakdown voltages and potentially higher efficiency.

A demonstration of the MMIC HBT amplifier showed results approaching the sub-millimeter-wave regime (~300 GHz) and showed the highest reported gain of 3.5 dB for a single-stage HBT amplifier at 255 GHz. The common emitter topology was chosen due to its stability at high frequencies. Distributed transmission lines and matching components were realized using an inverted microstrip configuration, and were implemented in a two-metal process with BCB (benzocyclobutene) dielectric. The primary advantage of this configuration is low inductance to ground compared with traditional microstrip designs.