

Aperture (Slot) Coupling is utilized in two- and one-membrane designs that are amenable to incorporation into thin structures and to integration with membrane-supported transmit/receive modules.

crostrip line is 0.12 mm wide and has a characteristic impedance of 50 Ω. The aperture-coupling slot, etched in the ground plane, is 0.48 mm wide and 79.5 mm long. In order to maximize coupling, the microstrip line is extended beyond the middle of the slot by a length of 36 mm, which corresponds to a transmission-line electrical length of about a quarter wavelength. The other end of the microstrip line is transformed to a 50-Ω coplanar waveguide line, which is used for connection to a transmit/receive module. Some plated-through vias are added to the outer conductors of the coplanar waveguide to suppress parallel-plate modes. The measured and calculated 10-dB-return-loss bandwidth of the antenna is 100 MHz.

By eliminating the radiating patch and the upper membrane that supports it, and performing two other simple modifications, one can convert the two-membrane antenna described above to a paper-thin single-membrane antenna, shown in the lower part of the figure. One modification is to increase the slot length to 104.95 mm; the other is to extend the microstrip to 36.68 mm past the middle of the slot. With these modifications, the slot now becomes a half-wavelength radiator with a nearly omnidirectional radiation pattern. In one potential use, such a paper-thin antenna could be pasted on an automobile window to enable omnidirectional communication.

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WGM-Based Photonic Local Oscillators and Modulators

Efficient devices for detecting low-power terahertz radiation are proposed.

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Photonic local oscillators and modulators that include whispering-gallery-mode (WGM) optical resonators have been proposed as power-efficient devices for generating and detecting radiation at frequencies of the order of a terahertz. These devices are intended especially to satisfy anticipated needs for receivers capable of detecting low-power, narrow-band terahertz signals to be used for sensing substances of interest in scientific and military applications. At present, available terahertz-signal detectors are power-inefficient and do not afford the spectral and ampli-

tude resolution needed for detecting such signals.

The proposed devices would not be designed according to the conventional approach of direct detection of terahertz radiation. Instead, terahertz radiation would first be up-converted into the optical domain, wherein signals could be processed efficiently by photonic means and detected by optical photodetectors, which are more efficient than are photodetectors used in conventional direct detection of terahertz radiation. The photonic devices used to effect the up-conversion would include a tunable

optical local oscillator and a novel electro-optical modulator.

A local oscillator according to the proposal would be a WGM-based mode-locked laser operating at a desired pulse-repetition rate of the order of a terahertz. The oscillator would include a terahertz optical filter based on a WGM microresonator, a fiber-optic delay line, an optical amplifier (which could be either a semiconductor optical amplifier or an erbium-doped optical fiber amplifier), and a WGM Ka-band modulator (see figure). The terahertz repetition rate would be obtained through har-

monic mode locking: for example, by modulating the light at a frequency of 33 GHz and locking each 33d optical mode, one would create a 1.089-THz pulse train. The high resonance quality factors (Q values) of WGM optical resonators should make it possible to decrease signal-generation threshold power levels significantly below those of other optical-signal-generation devices.

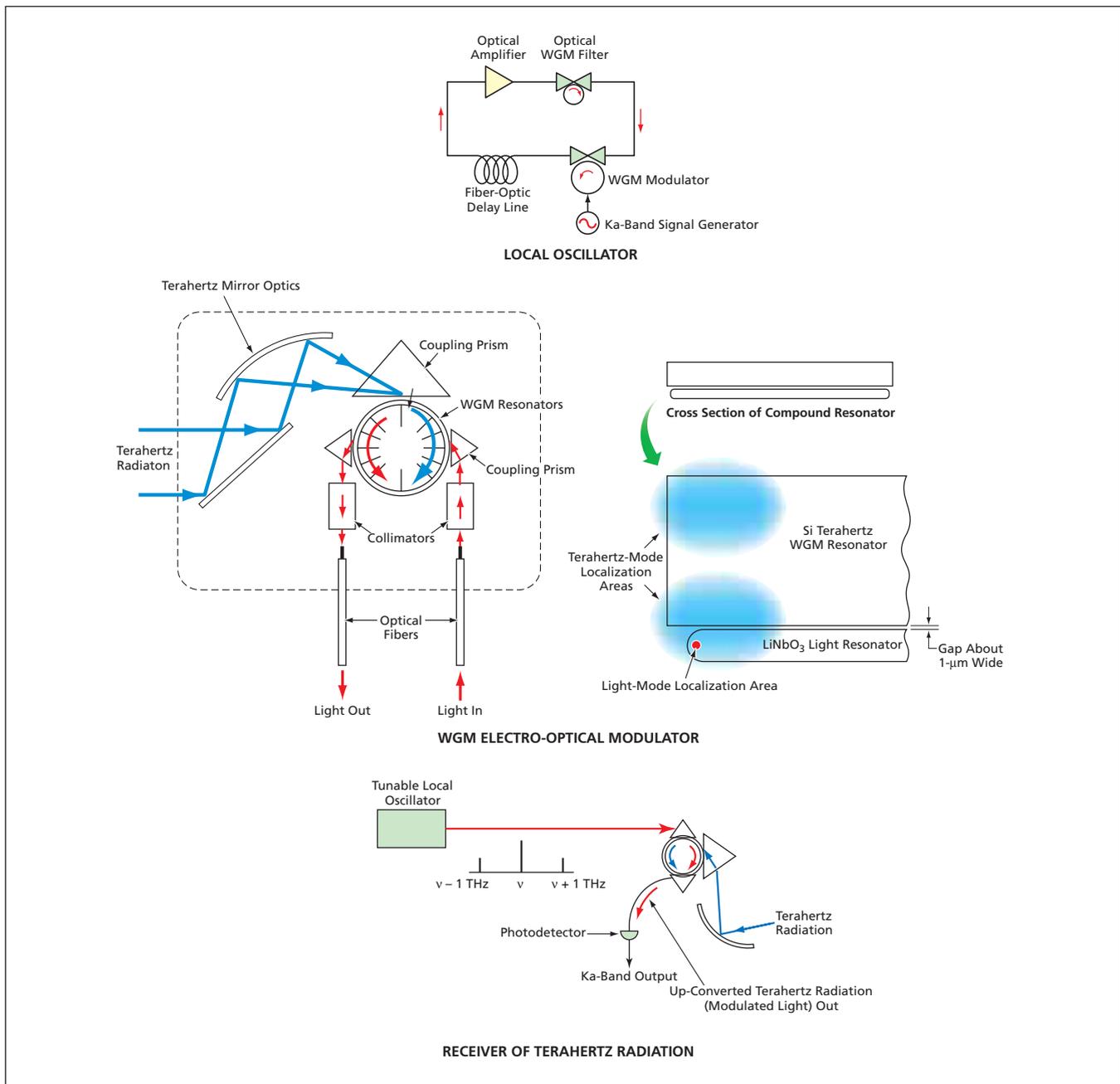
An electro-optical modulator as proposed would be a triply resonant compound WGM device. The modulator would comprise a periodically poled LiNbO_3 WGM optical resonator stacked almost in contact with an Si

WGM terahertz resonator. It would be necessary to use these two resonators because LiNbO_3 would afford the needed combination of high Q for the optical modes and enough nonlinearity for efficient interaction between light and terahertz radiation, while Si would afford the needed high Q for terahertz radiation.

Because Si absorbs light, it would be necessary to minimize penetration of light into the Si resonator. Because LiNbO_3 absorbs terahertz radiation more than Si does, the portion of the LiNbO_3 volume wherein the light and the terahertz radiation interact should be less

than the volume of the terahertz mode. These requirements would be satisfied by, among other things, positioning the two resonators with a gap of $\approx 1 \mu\text{m}$ between them and utilizing evanescent-field coupling between the light and the terahertz radiation. The periodicity of the poling of the LiNbO_3 would be chosen to ensure the required matching of phases between the light and the terahertz radiation.

This work was done by Andrey Matsko, Lute Maleki, Vladimir Ilchenko, and Anatoly Savchenkov of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-41139



A WGM-Based Local Oscillator and Electro-Optical Modulator would be components of a photonic receiver for detecting terahertz radiation.