Laser light is introduced via the input optical fiber and focused into the input coupling prism. The input coupling prism is positioned near (but not in contact with) the resonator disk so that by means of evanescent-wave coupling, the input laser light in the prism gives rise to laser light propagating circumferentially in guided modes in the resonator disk. Similarly, a portion of the circumferentially propagating optical power is extracted from the disk by evanescent-wave coupling from the disk to the output coupling prism, from whence the light passes through the collimating ball lens into the output optical fiber.

The lens-tipped optical fibers must be positioned at a specified focal distance from the prisms. The optical fibers and the prisms must be correctly positioned relative to the resonator disk and must be oriented to obtain the angle of incidence ($55^\circ$ in the prototype) required for evanescent-wave coupling of light into and out of the desired guided modes in the resonator disk. To satisfy all these requirements, precise alignment features are formed in the silicon substrate by use of a conventional wet-etching process. These features include a 5-mm-diameter, 50-µm-deep cavity that holds the disk; two trapezoidal-cross-section recesses for the prisms; and two grooves that hold the optical fibers at the correct positions and angles relative to the prisms and disk. The fiber grooves contain abrupt tapers, near the prisms, that serve as hard stops for positioning the lenses at the focal distance from the prisms.

There are also two grooves for prism-adjusting rods. The design provides a little slack in the prism recesses for adjusting the positions of the prisms by means of these rods to optimize the optical coupling.

This work was done by Hung Nguyen, John Pouch, and Felix Miranda of Glenn Research Center, and Anthony F. Levi of the University of Southern California. 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-17694-1.

### Diffractive Combiner of Single-Mode Pump Laser-Diode Beams

Multiple beams can be combined without inducing multifrequency lasing.

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

An optical beam combiner now under development would make it possible to use the outputs of multiple single-mode laser diodes to pump a neodymium:yttrium aluminum garnet (Nd:YAG) non-planar ring oscillator (NPRO) laser while ensuring that the laser operates at only a single desired frequency. Herefore, an Nd:YAG NPRO like the present one has been pumped by a single multimode laser-diode beam delivered via an optical fiber. It would be desirable to use multiple pump laser diodes to increase reliability beyond that obtainable from a single pump laser diode. However, as explained below, simplistically coupling multiple multimode laser-diode beams through a fiber-optic combiner would entail a significant reduction in coupling efficiency, and lasing would occur at one or more other frequencies in addition to the single desired frequency.

Figure 1 schematically illustrates the principle of operation of a laser-diode-pumped Nd:YAG NPRO. The laser beam path is confined in a Nd:YAG crystal by means of total internal reflections on the three back facets and a partial-reflection coating on the front facet. The wavelength of the pump beam — 808 nm — is the wavelength most strongly absorbed by the Nd:YAG crystal. The crystal can lase at a wavelength of either 1,064 nm or 1,319 nm — which one depending on the optical coating on the front facet. A thermal lens effect induced by the pump beam enables stable lasing in the lowest-order transverse electromagnetic mode (the TEM$_{00}$ mode). The frequency of this laser is very stable because of the mechanical stability of the laser crystal and the unidirectional nature of the lasing. The unidirectionality is a result of the combined effects of (1) a Faraday rotation induced by an externally applied magnetic field and (2) polarization associated with non-normal incidence and reflection on the front facet.

In order to restrict lasing to a single frequency, it is necessary to confine the pump beam within the region occupied by the TEM$_{00}$ mode of the NPRO laser beam near the front facet inside the crystal. In practice, this means that the pump beam must be focused to within a given solid angle ($\Omega$) and area ($A$).
Wide-Band, High-Quantum-Efficiency Photodetector
This device could detect single photons.

NASA’s Jet Propulsion Laboratory, Pasadena, California

A design has been proposed for a photodetector that would exhibit a high quantum efficiency (as much as 90 percent) over a wide wavelength band, which would typically be centered at a wavelength of 1.55 µm. This and similar photodetectors would afford a capability for detecting single photons — a capability that is needed for research in quantum optics as well as for the practical development of secure optical communication systems for distribution of quantum cryptographic keys.

The proposed photodetector would be of the hot-electron, phonon-cooled, thin-film superconductor type. The superconducting film in this device would be a meandering strip of niobium nitride. In the proposed photodetector, the quantum efficiency would be increased through incorporation of opti-