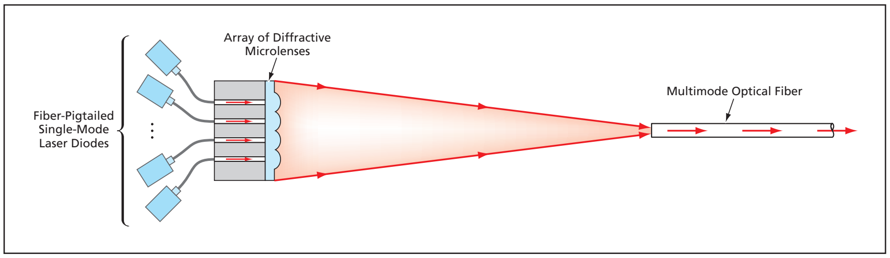

Figure 2. **Multiple Single-Mode Laser-Diode Beams** are focused onto a single narrow spot by use of an array of diffractive microlenses.

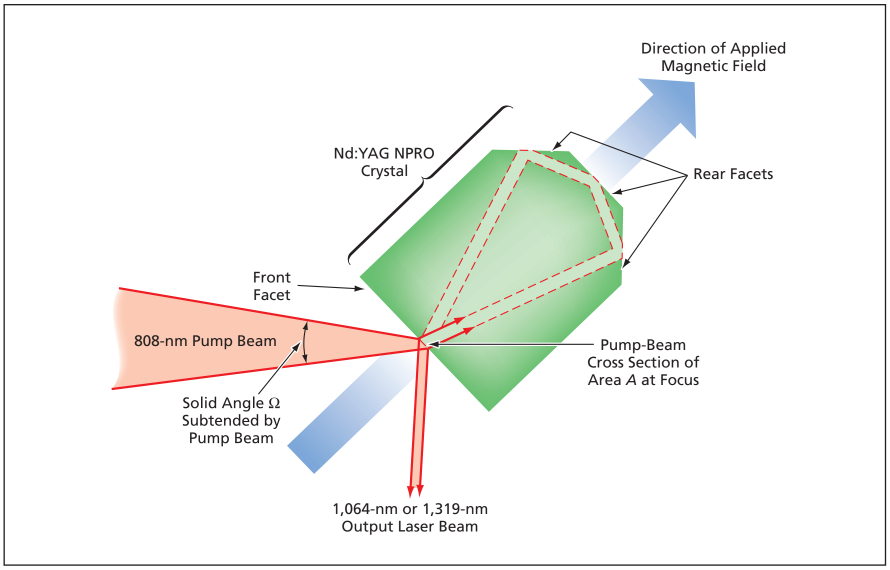

Figure 1. A **Pump Beam of Solid Angle Ω** has a cross section of area *A* at incidence upon the front facet of an Nd:YAG NPRO laser crystal.

given pump beam has a larger A or larger Ω but its $A\Omega$ is equal to or less than the maximum $A\Omega$ for single-frequency lasing in the crystal, then an imaging lens can be used to trade A against Ω so that both A and Ω are equal to or smaller than the maximum values for single-frequency lasing. It is possible to do this because it is a basic principle of optics that $A\Omega$ is preserved in imaging by a lens.]

The $A\Omega$ of a commercial multimode 808-nm laser diode of the type used heretofore is not axisymmetric: instead, it is elliptically distributed about the optical axis and, hence, does not match the circular distribution of a multimode fiber of the type used heretofore to deliver a pump beam. As a result of this mismatch, $A\Omega$ for the pump beam emerging from the output end of the fiber is increased, typically to near the maximum single-frequency-lasing value in at least one of the planes containing the principal axes of the elliptical distribution. Consequently, it is difficult or impossible to maintain single-frequency lasing when combining the beams from two or more multimode laser diodes.

In the present approach (see Figure 2), the beams from multiple fiber-pigtailed single-mode laser diodes are coupled to single-mode optical fibers that have been placed together in a hexagonal-close-packing planar array. An array of diffractive microlenses, custom-designed and fabricated on a glass substrate by electron-beam lithography, is placed in front of the fiber array. The custom design and position of the lens array are chosen, according to the precisely measured actual positions of the fibers, so that the single-mode beams emerging from all the single-mode optical fibers are focused on the same small circular spot centered on the input face of a suitable multimode optical fiber. In use, the beam emerging from the output end of the multimode fiber would be focused onto the front facet of an Nd:YAG NPRO crystal in the usual way. It is anticipated that the $A\Omega$ of the pump light thus incident on the crystal would be less than the maximum single-frequency-lasing value.

This work was done by Duncan Liu, Daniel Wilson, Yueming Qiu, and Siamak Forouhar of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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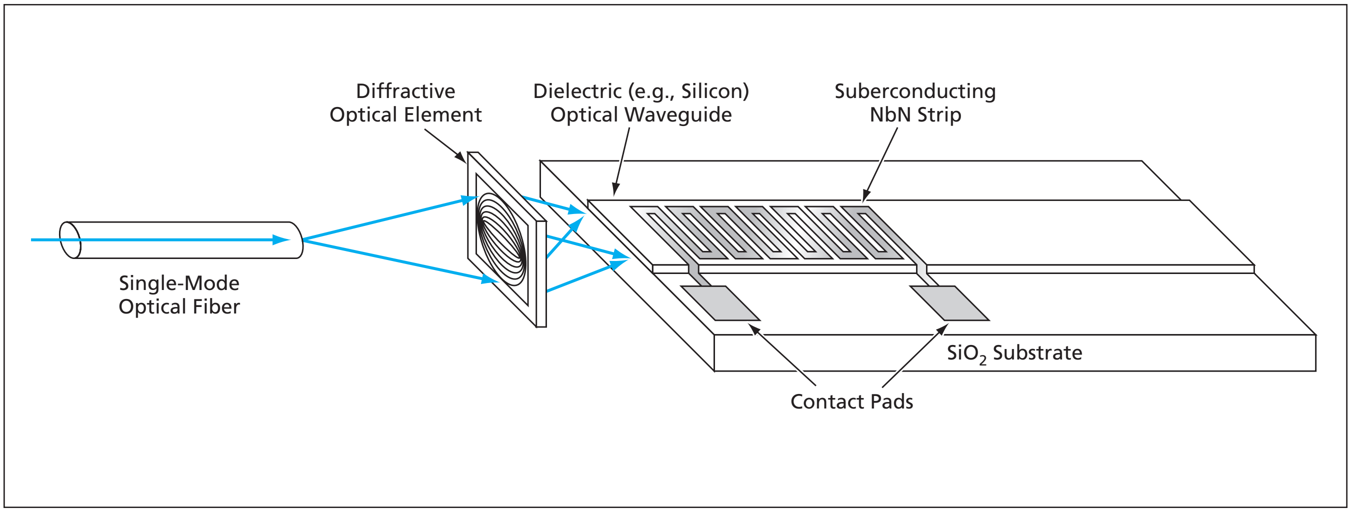
Wide-Band, High-Quantum-Efficiency Photodetector

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-



Input Light Would Be Focused Into a Waveguide, where it would propagate along, and interact with, a meandering superconducting strip made of niobium nitride.

cal components, described below, that would increase the electromagnetic coupling between the input optical field and the meandering superconducting film.

The meandering niobium nitride strip would be fabricated on top of a dielectric (e.g., silicon) optical waveguide on a silicon dioxide substrate (see figure). The input end face of the waveguide would be cut, polished, and antireflection-coated to maximize in-coupling efficiency. The thickness of the waveguide would be chosen so that at the design wavelength, there would be a single through-the-thickness electromagnetic mode, the evanescent tail of which would overlap with the niobium nitride strip. Because the waveguide would exhibit little optical loss over the length of the strip, there would be a high probability of absorption of photons by the strip. The width of the waveguide would be chosen to accommodate multiple widthwise electromagnetic modes, thereby increasing the interaction of light with the niobium nitride strip.

Light would be brought to the photodetector via an optical fiber. A point-to-line-focusing diffractive optical element would couple the light from the output end of the optical fiber into the waveguide. The diffractive optical element would be specially designed and fabricated to collimate as well as possible in the width dimension and to focus as well as possible in the thickness dimension in order to maximize the coupling into the desired waveguide electromagnetic mode.

This work was done by Deborah Jackson, Daniel Wilson, and Jeffrey Stern of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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