Extended-Range Ultrarefractive 1D Photonic Crystal Prisms

Practical applications could include miniature spectrometers and wavelength-division multiplexers.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposal has been made to exploit the special wavelength-dispersive characteristics of devices of the type described in "One-Dimensional Photonic Crystal Superprisms" (NPO-30232) *NASA Tech Briefs*, Vol. 29, No. 4 (April 2005), page 10a. A photonic crystal is an optical component that has a periodic structure comprising two dielectric materials with high dielectric contrast (e.g., a semiconductor and air), with geometrical feature sizes comparable to or smaller than light wavelengths of interest.

Experimental superprisms have been realized as photonic crystals having three-dimensional (3D) structures comprising regions of amorphous Si alternating with regions of SiO_2, fabricated in a complex process that included sputtering. A photonic crystal of the type to be exploited according to the present proposal is said to be one-dimensional (1D) because its contrasting dielectric materials would be stacked in parallel planar layers; in other words, there would be spatial periodicity in one dimension only. The processes of designing and fabricating 1D photonic crystal superprisms would be simpler and, hence, would cost less than do those for 3D photonic crystal superprisms. As in 3D structures, 1D photonic crystals may be used in applications such as wavelength-division multiplexing. In the extended-range configuration (see Figure 1), it is also suitable for spectrometry applications.

As an engineered structure or artificially engineered material, a photonic crystal can exhibit optical properties not commonly found in natural substances. Prior research had revealed several classes of photonic crystal structures for which the propagation of electromagnetic radiation is forbidden in certain frequency ranges, denoted photonic bandgaps. It had also been found that in narrow frequency bands just outside the photonic bandgaps, the angular wavelength dispersion of electromagnetic waves propagating in photonic crystal superprisms is much stronger than is the angular wavelength dispersion obtained by use of conventional prisms and diffraction gratings and is highly nonlinear.

In recent theoretical calculations leading to the present proposal, it was found that in the extended-range configurations, the 1D photonic crystal prism exhibits very strong wavelength dispersion properties over wavelength ranges covering entire photonic bands, rather than at the band edges only. The dependence of angular dispersion as a function of wavelength is also found to be less non-linear. While the wavelength dispersing capability in the extended-range configuration is not as dramatic as in the narrow-range (band-edge only) ultra-refractive configuration, it is still calculated to be over one order of magnitude stronger than that of the conventional prism.

Hence, in designing photonic crystal superprisms to effect wavelength disper-

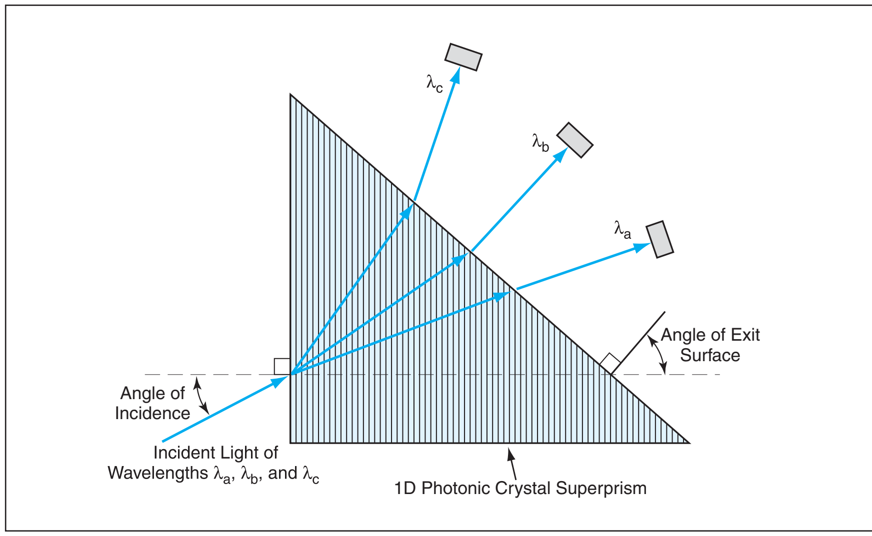

Figure 1. A **Miniature Spectrometer** could be constructed by combining a 1D photonic crystal superprism with suitably positioned photodetectors. The 1D photonic crystal superprism would function somewhat like a conventional glass prism, but the degree of its wavelength dispersion would be much greater and its design could be tailored to obtain unusual dispersive characteristics.

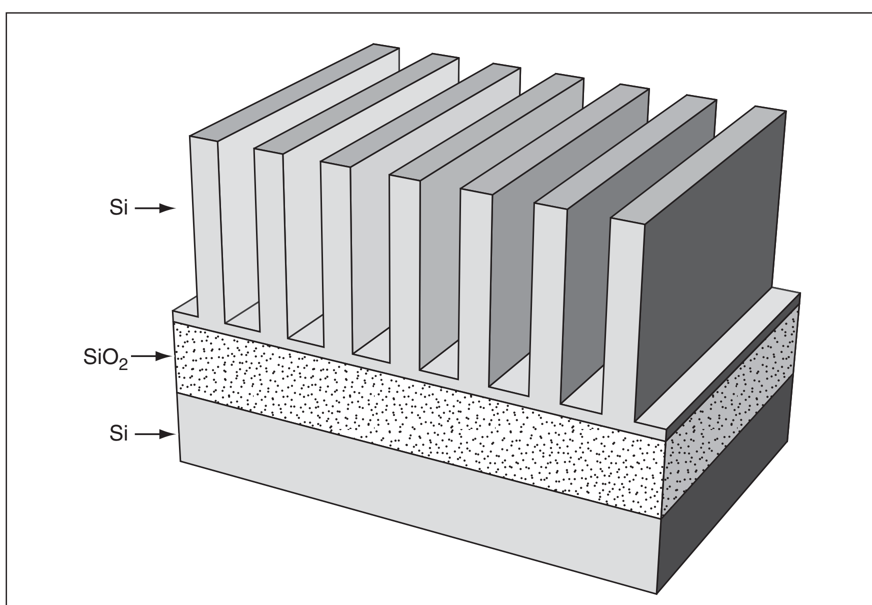

Figure 2. A **1D Photonic Crystal**, made of alternating layers of silicon and air, could be fabricated on a silicon-on-insulator substrate.

sion of polychromatic light, it would be possible to utilize broader wavelength ranges, maintain high transmissivity through use of wavelengths farther from the edges of the photonic bandgaps, take advantage of the reduction in nonlinearity to simplify the positioning of optical components, and take advantage of larger crystal spatial periods to further simplify fabrication. The design parameters that could be varied to obtain the desired properties include the angle of incidence, the angle of the exit surface, and the thicknesses of the layers.

One-dimensional photonic crystal superprisms for visible and infrared wavelengths could be fabricated on semiconductor wafers and, hence, could be integrated monolithically with other miniature optical components. In one example of this approach, a 1D photonic crystal superprism would be fabricated by patterning and anisotropic etching of one of two silicon layers of a silicon-on-insulator substrate (see Figure 2). In this case, the insulator (SiO_2) would not only provide structural support, because the index of refraction of SiO_2 is lower than that of Si, the SiO_2 layer would also act as an optical cladding layer to confine light to the 1D photonic crystal.

This work was done by David Z. Ting of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).
NPO-30594

Rapid Analysis of Mass Distribution of Radiation Shielding

Lyndon B. Johnson Space Center, Houston, Texas

Radiation Shielding Evaluation Toolset (RADSET) is a computer program that rapidly calculates the spatial distribution of mass of an arbitrary structure for use in ray-tracing analysis of the radiation-shielding properties of the structure. RADSET was written to be used in conjunction with unmodified commercial computer-aided design (CAD) software that provides access to data on the structure and generates selected three-dimensional-appearing views of the structure. RADSET obtains raw geometric, material, and mass data on the structure from the CAD software. From these data, RADSET calculates the distribution(s) of the masses of specific materials about any user-specified point(s). The results of these mass-distribution calculations are imported back into the CAD computing environment, wherein the radiation-shielding calculations are performed.

This program was written by Edward Zapp of Lockheed Martin Corp. for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-23935

Modeling Magnetic Properties in EZTB

NASA's Jet Propulsion Laboratory, Pasadena, California

A software module that calculates magnetic properties of a semiconducting material has been written for incorporation into, and execution within, the Easy (Modular) Tight-Binding (EZTB) software infrastructure. [EZTB is designed to model the electronic structures of semiconductor devices ranging from bulk semiconductors, to quantum wells, quantum wires, and quantum dots. EZTB implements an empirical tight-binding mathematical model of the underlying physics.]

This module can model the effect of a magnetic field applied along any direction and does not require any adjustment of model parameters. The module has thus far been applied to study the performances of silicon-based quantum computers in the presence of magnetic fields and of miscut angles in quantum wells. The module is expected to assist experimentalists in fabricating a spin qubit in a Si/SiGe quantum dot. This software can be executed in almost any Unix operating system, utilizes parallel computing, can be run as a Web-portal application program. The module has been validated by comparison of its predictions with experimental data available in the literature.

This program was written by Seungwon Lee and Paul von Allmen of Caltech for NASA's Jet Propulsion Laboratory.

This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-44782.

Deep Space Network Antenna Logic Controller

NASA's Jet Propulsion Laboratory, Pasadena, California

The Antenna Logic Controller (ALC) software controls and monitors the motion control equipment of the 4,000-metric-ton structure of the Deep Space Network 70-meter antenna. This program coordinates the control of 42 hydraulic pumps, while monitoring several interlocks for personnel and equipment safety. Remote operation of the ALC runs via the Antenna Monitor & Control (AMC) computer, which orchestrates the tracking functions of the entire antenna.

This software provides a graphical user interface for local control, monitoring, and identification of faults as well as, at a high level, providing for the digital control of the axis brakes so that the servo of the AMC may control the motion of the antenna. Specific functions of the ALC also include routines for startup in cold weather, controlled shutdown for both normal and fault situations, and pump switching on failure.

The increased monitoring, the ability to trend key performance characteristics, the improved fault detection and recovery, the centralization of all control at a single panel, and the simplifi-