A **Pulse of Current** greater than the optimum steady current was applied to a thermoelectric device, giving rise to transient enhancement of cooling followed by transient heating followed by gradual decay toward the steady state.

only to the point beyond which the Joule heating dominates. If a pulse of current greater than the optimum current (the current for maximum steady cooling) is applied, then the junction becomes momentarily cooled below its lowest steady temperature until thermal conduction brings the resulting pulse of Joule heat to the junction and thereby heats the junction above its lowest steady temperature.

A theoretical and experimental study of such transient thermoelectric cooling followed by transient Joule heating in response to current pulses has been performed. The figure presents results from one of the experiments. The study established the essential parameters that characterize the pulse cooling effect, including the minimum temperature achieved, the maximum temperature overshoot, the time to reach minimum temperature, the time while cooled, and the time between pulses. It was found that at large pulse amplitude, the amount of pulse supercooling is about a fourth of the maximum steady-state temperature difference. For the particular thermoelectric device used in one set of the experiments, the practical optimum pulse amplitude was found to be about 3 times the optimum steady-state current. In a further experiment, a pulse cooler was integrated into a small commercial thermoelectric three-stage cooler and found to provide several degrees of additional cooling for a time long enough to operate a semiconductor laser in a gas sensor.

taller stage of a multistage thermoelectric cooler. Steady current would be applied to the stages to produce steady cooling. Pulsed current would then be applied, enhancing the cooling of the top stage momentarily.

The principles of operation are straightforward: In a thermoelectric device, the cooling occurs only at a junction at one end of the thermoelectric legs, at a rate proportional to the applied current. However, Joule heating occurs throughout the device at a rate proportional to the current squared. Hence, in the steady state, the steady temperature difference that the device can sustain increases with current

# Hand-Held Color Meters Based on Interference Filters

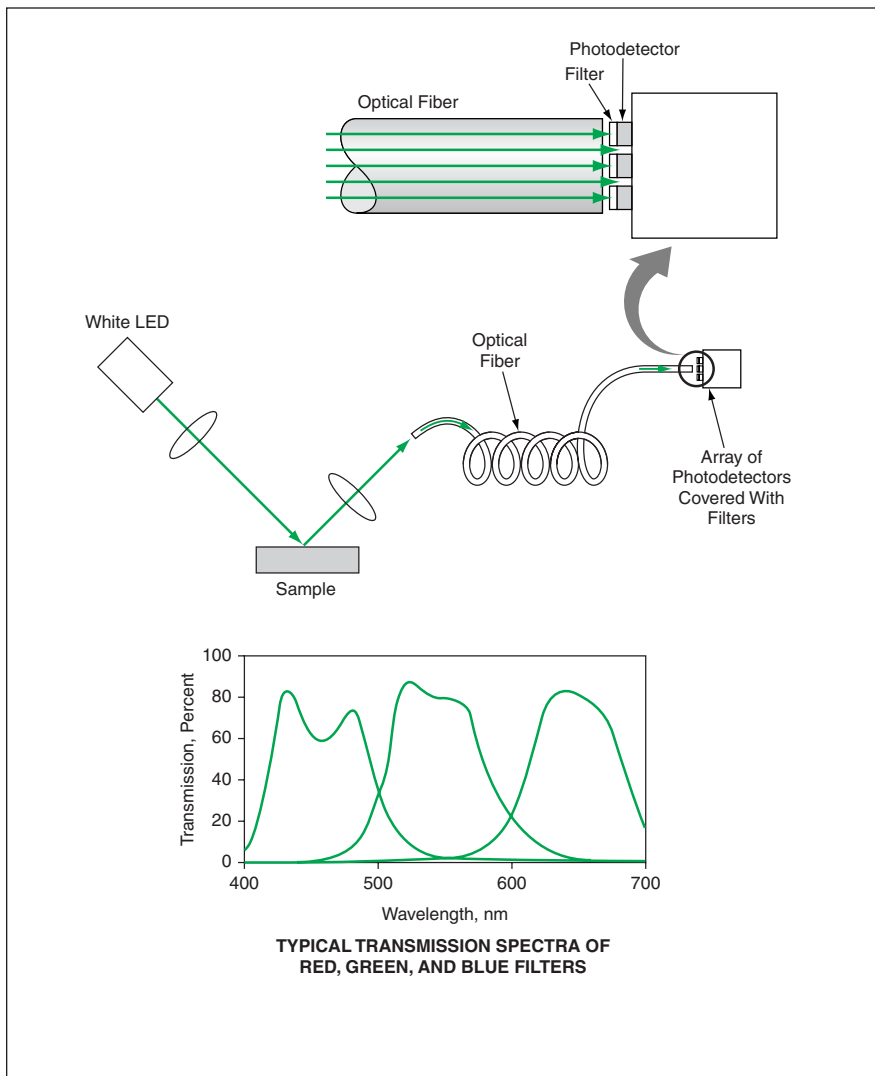### These inexpensive units measure luminous flux in several wavelength bands.

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

Small, inexpensive, hand-held optoelectronic color-measuring devices based on metal-film/dielectric-film interference filters are undergoing development. These color meters could be suitable for use in a variety of applications in which there are requirements to quantify or match colors for aesthetic purposes but there is no need for the high spectral resolution of scientific-grade spectrometers. Such applications typically occur in the paint, printing, and cosmetic industries, for example.

The figure schematically depicts a color meter of this type being used to measure the color of a sample in terms of the spectrum of light reflected from the sample. Light from a white source (for example, a white light-emitting diode) passes through a collimating lens to the sample. Another lens collects some of the light reflected from the sample and focuses the light onto the input end of optical fiber. Light emerging from the output end of the optical fiber illuminates an array of photodetectors covered with metal/dielectric-film interference filters like those described in "Metal/Dielectric-film Interference Color Filters" (NPO-20217), *NASA Tech Briefs*, Vol. 23, No. 2 (February 1999), page 70. Typically, these are wide-band-pass filters, as shown at the bottom of the figure.

Typical Transmission Spectra of Red, Green, and Blue Filters — the chart with axes Transmission, Percent (0–100) vs Wavelength, nm (400–700).

**Several Photodetectors Covered by Filters** measure incident light in several wavelength bands. In this example, there are three broad wavelength bands corresponding approximately to the primary additive colors.

The photodetector array need not be of any particular design: it could be something as simple as an assembly containing several photodiodes or something as elaborate as an active-pixel sensor or other imaging device. What is essential is that each of the photodetectors or each of several groups of photodetectors is covered with a metal/dielectric-film filter of a different color. In most applications, it would be desirable to have at least three different filters, each for a spectral band that contains one of the three primary additive red, green, and blue colors. In some applications, it may be necessary to have more than three different color filters in order to characterize subtle differences in color (or in the sensation of color) that cannot be characterized with sufficient precision by use of the primary colors alone.

*This work was done by Yu Wang 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:*

*Innovative Technology Assets Management*
*JPL*
*Mail Stop 202-233*
*4800 Oak Grove Drive*
*Pasadena, CA 91109-8099*
*(818) 354-2240*
*E-mail: iaoffice@jpl.nasa.gov*
*Refer to NPO-30858, volume and number of this* NASA Tech Briefs *issue, and the* page number.

# Calculating Mass Diffusion in High-Pressure Binary Fluids
## This model could contribute to understanding of high-pressure combustion.

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

A comprehensive mathematical model of mass diffusion has been developed for binary fluids at high pressures, including critical and supercritical pressures. Heretofore, diverse expressions, valid for limited parameter ranges, have been used to correlate high-pressure binary mass-diffusion-coefficient data. This model will likely be especially useful in the computational simulation and analysis of combustion phenomena in diesel engines, gas turbines, and liquid rocket engines, wherein mass diffusion at high pressure plays a major role.

The model recasts the kinetic theory (i.e. low-pressure) expressions into forms consistent with the principle of corresponding states. Also presented are corresponding states forms for the Stokes-Einstein hydrodynamic model for diffusion in liquids, which are used for purposes of comparison. By ansatz, the model includes an expression that reflects departures from the kinetic-theory diffusion-coefficient relationship by means of a division factor that is partly a function of the reduced species density, becomes unity in the limit of low-

pressure gases, and includes parameters to be determined empirically for higher pressures. The final model equation is

$$D_{ij}^0 = \left( D_{ij} \right)_{KT} \Big/ w_{D,j}$$

where $D_{ij}^0$ is the high-pressure infinite dilution diffusivity of species $i$ in $j$, $(D_{ij})_{KT}$ is the binary diffusivity calculated according to kinetic theory, and $w_{D,j} = 1 + \delta_{D,j}$ is the division factor. As the reduced density of species $j$ approaches zero, so does $\delta_{D,j}$. Empirical parameters have been determined