Physical Sciences

Sol-Gel Glass Holographic Light-Shaping Diffusers
**Defined areas can be illuminated diffusely with high efficiency.**

John F. Kennedy Space Center, Florida

Holographic glass light-shaping diffusers (GLSDs) are optical components for use in special-purpose illumination systems (see figure). When properly positioned with respect to lamps and areas to be illuminated, holographic GLSDs efficiently channel light from the lamps onto specified areas with specified distributions of illumination — for example, uniform or nearly uniform irradiance can be concentrated with intensity confined to a peak a few degrees wide about normal incidence, over a circular or elliptical area.

Holographic light diffusers were developed during the 1990s. The development of the present holographic GLSDs extends the prior development to incorporate sol-gel optical glass. To fabricate a holographic GLSD, one records a hologram on a sol-gel silica film formulated specially for this purpose. The hologram is a quasi-random, micro-sculpted pattern of smoothly varying changes in the index of refraction of the glass. The structures in this pattern act as an array of numerous miniature lenses that refract light passing through the GLSD, such that the transmitted light beam exhibits a precisely tailored energy distribution.

In comparison with other light diffusers, holographic GLSDs function with remarkably high efficiency: they typically transmit 90 percent or more of the incident lamp light onto the designated areas. In addition, they can withstand temperatures in excess of 1,000 °C. These characteristics make holographic GLSDs attractive for use in diverse lighting applications that involve high temperatures and/or re-
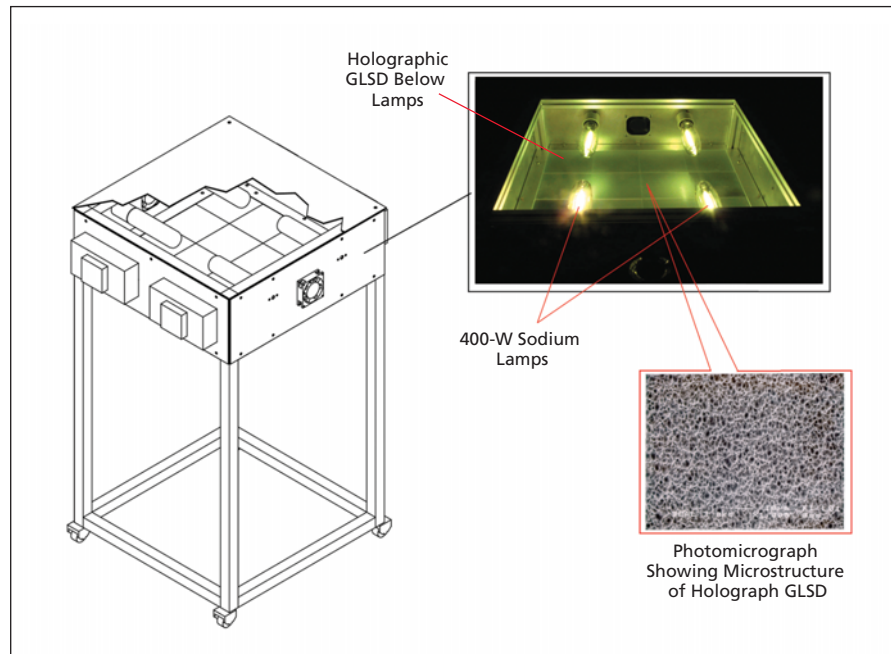
The **Holographic GLSD** in this lighting system concentrates and diffuses light from four lamps onto the framed area below. This lighting system is designed specifically for illumination experiments on growing plants under controlled conditions.

quirements for high transmission efficiency for ultraviolet, visible, and near-infrared light. Examples include projectors, automobile headlights, aircraft landing lights, high-power laser illuminators, and industrial and scientific illuminators.

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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:

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Refer to KSC-12436, volume and number of this NASA Tech Briefs *issue, and the page number.*

Automated Counting of Particles To Quantify Cleanliness
Lyndon B. Johnson Space Center, Houston, Texas

A machine vision system, similar to systems used in microbiological laboratories to count cultured microbes, has been proposed for quantifying the cleanliness of nominally precisely cleaned hardware by counting residual contaminant particles. The system would include a microscope equipped with an electronic camera and circuitry to digitize the camera output, a personal computer programmed with machine-vision and interface software, and digital storage media. A filter pad, through which had been aspirated solvent from rinsing the hardware in question, would be placed on the microscope stage. A high-resolution image of the filter pad would be recorded. The computer would analyze the image and present a histogram of sizes of particles on the filter. On the basis of the histogram and a measure of the desired level of cleanliness, the hardware would be accepted or re-

jected. If the hardware were accepted, the image would be saved, along with other information, as a quality record. If the hardware were rejected, the histogram and ancillary information would be recorded for analysis of trends. The software would perceive particles that are too large or too numerous to meet a specified particle-distribution profile. Anomalous particles or fibrous material would be flagged for inspection.

Phase Correction for GPS Antenna With Nonunique Phase Center

Position can be determined more accurately.

Lyndon B. Johnson Space Center, Houston, Texas

A method of determining the position and attitude of a body equipped with a Global Positioning System (GPS) receiver includes an accounting for the location of the nonunique phase center of a distributed or wraparound GPS antenna. The method applies, more specifically, to the case in which (1) the GPS receiver utilizes measurements of the phases of GPS carrier signals in its position and attitude computations and (2) the body is axisymmetric (e.g., spherical or round cylindrical) and wrapped at its equator with a single- or multiple-element antenna, the radiation pattern of which is also axisymmetric with the same axis of symmetry as that of the body.

The figure depicts the geometric relationships among the GPS-equipped object centered at position $\mathbf{r}_B$, the ith GPS satellite at position $\mathbf{r}_{si}$, and the phase center at position $\mathbf{r}_{pi}$ relative to the center of the body during observation of the ith satellite. The main GPS observable calculated from the phase measurement for the ith satellite is the pseudorange $\|\mathbf{v}_i\|$,

which is nominally the distance from the phase center to the ith satellite. However, what is needed to determine the position of the center of the body is another pseudorange — that which one would obtain if the phase center were at the center of the body. That pseudorange would nominally equal $\|\mathbf{r}_{si} - \mathbf{r}_B\|$. In order to determine $\|\mathbf{r}_{si} - \mathbf{r}_B\|$ from phase measurements, it is necessary to account for the phase difference attributable to $\mathbf{r}_{pi}$.

A straightforward mathematical derivation that starts with the law of cosines for this geometry and that incorporates simplifying assumptions based on the axisymmetry and on the smallness of $\|\mathbf{r}_{pi}\|$ relative to $\|\mathbf{r}_{si} - \mathbf{r}_B\|$ leads to the following equations:

$$\|\mathbf{r}_{si} - \mathbf{r}_B\| = \|\mathbf{v}_i\| + \|\mathbf{r}_{pi}\|\cos(\beta_i) \quad (1)$$

and

$$\cos(\beta_i) = \left[1 - \left(\hat{\mathbf{r}}_{sib} \cdot \hat{\mathbf{z}}_B\right)^2\right]^{1/2} \quad (2)$$

where
- β_i is the angle between $\mathbf{r}_{si} - \mathbf{r}_B$ and $\mathbf{r}_{pi}$ as shown in the figure,
- $\hat{\mathbf{z}}_B$ is the unit vector along the axis of

symmetry as shown in the figure, and
- $\hat{\mathbf{r}}_{sib} \equiv \left(\dfrac{\mathbf{r}_{si} - \mathbf{r}_B}{\|\mathbf{r}_{si} - \mathbf{r}_B\|}\right)$ is the unit vector along $\mathbf{r}_{si} - \mathbf{r}_B$.

The computation of the desired pseudorange $\|\mathbf{r}_{si} - \mathbf{r}_B\|$ begins with a coarse estimate of $\mathbf{r}_B$ — for example, a previously computed value or a value computed anew without the phase correction. The coarse estimate of $\mathbf{r}_B$ is used to obtain an estimate of $\hat{\mathbf{r}}_{sib}$, which is used in iterations of equation 1 to obtain successively refined estimates of $\mathbf{r}_B$. Optionally, one can also obtain successively refined estimates of $\hat{\mathbf{r}}_{sib}$ from the iterations, though in most GPS applications, the error in the initial estimate of $\hat{\mathbf{r}}_{sib}$ should be negligible.

The iterations follow one of two courses, depending on whether or not $\|\mathbf{r}_{pi}\|$ and the attitude of the body are known *a priori*. If the attitude is known, then $\hat{\mathbf{z}}_B$ is known and can be inserted in equation 2, which yields $\cos(\beta_i)$ for use in equation 1. Then $\|\mathbf{r}_{pi}\|$ and $\cos(\beta_i)$ can be used in equation 1 without fur-
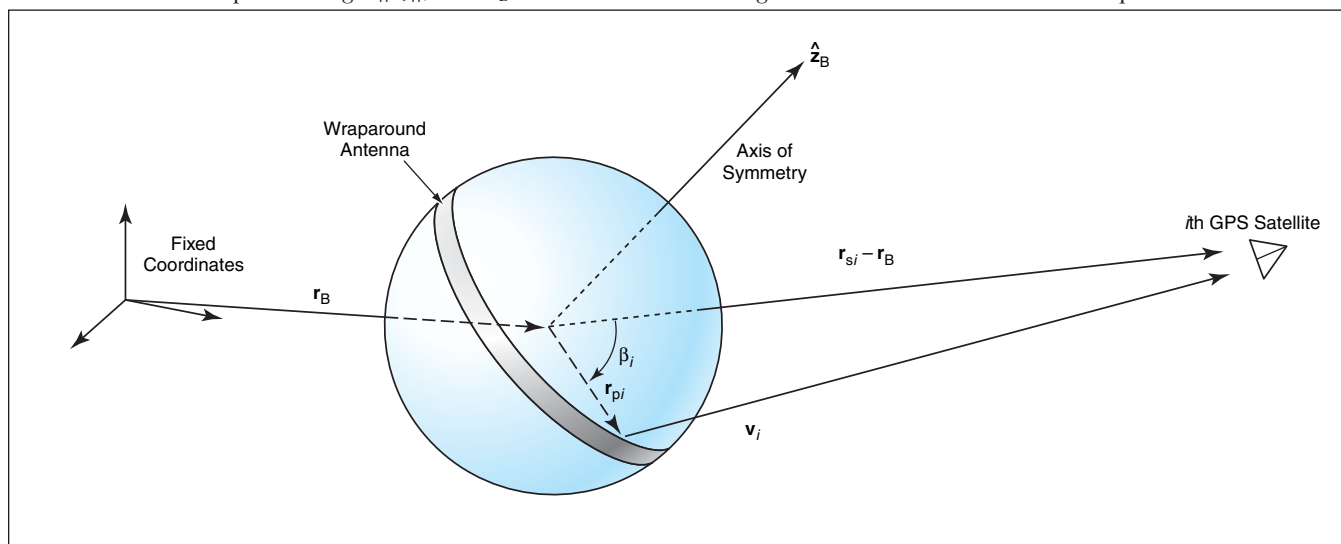
An **Axisymmetric Body With a Wraparound GPS Antenna** at its equator contains a GPS receiver that measures the phase of the signal from the ith GPS satellite at a nonunique phase center at position vector $\mathbf{r}_{pi}$ relative to the center of the body. For simplicity, $\|\mathbf{r}_{pi}\|$ is depicted as equal to the radius of the wraparound antenna, but it could differ.