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of the fiber-optic bundle is aligned with the optical axis of the interferometer by use of the reflection from the front face of the bundle.

2. One of the sheet arrays of microscopic lenses is placed in front of the fiber-optic bundle and similarly aligned with the interferometer optical axis by use of the reflection from its front face. As a result, the optical axes of the lens array and the fiber-optic bundle are parallel with each other.
3. The axial position of the lens sheet is adjusted until the interferometric image of light reflected from the front face of the fiber-optic bundle indicates that the lenses are at the proper focal distance.
4. The lateral (relative to the optical axis) position of the lens sheet is adjusted until the interferometric image shows that at least one lens is centered on the end of at least one optical fiber. The lateral coordinates of the six-axis positioner are measured. The lateral position of the lens sheet is further adjusted until another lens/fiber pair is thus centered, and the corresponding coordinates are measured. The two sets of coordinates are used to compute the translation and rotation needed to effect the lateral alignment of the remaining lens/fiber pairs.
5. Guided by the foregoing coordinate measurements, the final adjustments of the lens sheet are made.
6. The lens sheet is bonded to the fiber-optic bundle.
7. The fiber-optic bundle is turned around so that what was previously the back face is now the front face.
8. The retroreflecting mirror is aligned with the optical axis of the interferometer.
9. Steps 1 through 7 are repeated to effect the alignment and bonding of the second lens sheet to what is now the front face of the fiber-optic bundle.

This work was done by Duncan Liu 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:

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Refer to NPO-40021, volume and number of this NASA Tech Briefs *issue, and the page number.*

Automatic Control of Arc Process for Making Carbon Nanotubes

Lyndon B. Johnson Space Center, Houston, Texas

An automatic-control system has been devised for a process in which carbon nanotubes are produced in an arc between a catalyst-filled carbon anode and a graphite cathode. The control system includes a motor-driven screw that adjusts the distance between the electrodes. The system also includes a bridge circuit that puts out a voltage proportional to the difference between (1) the actual value of potential drop across the arc and (2) a reference value between 38 and 40 V (corresponding to a current of about 100 A) at which the yield of carbon nanotubes is maximized. Utilizing the fact that the potential drop across the arc increases with the interelectrode gap, the output of the bridge circuit is fed to a motor-control circuit that causes the motor to move the anode toward or away from the cathode if the actual potential drop is more or less, respectively, than the reference potential. Thus, the system regulates the interelectrode gap to maintain the optimum potential drop. The system also includes circuitry that records the potential drop across the arc and the relative position of the anode holder as function of time.

This work was done by Carl D. Scott of **Johnson Space Center**, *Robert B. Pulumbarit of Lockheed Martin, and Joe Victor of Hernandez Engineering. Further information is contained in a TSP (see page 1).*
MSC-23134

Curved-Focal-Plane Arrays Using Deformed-Membrane Photodetectors

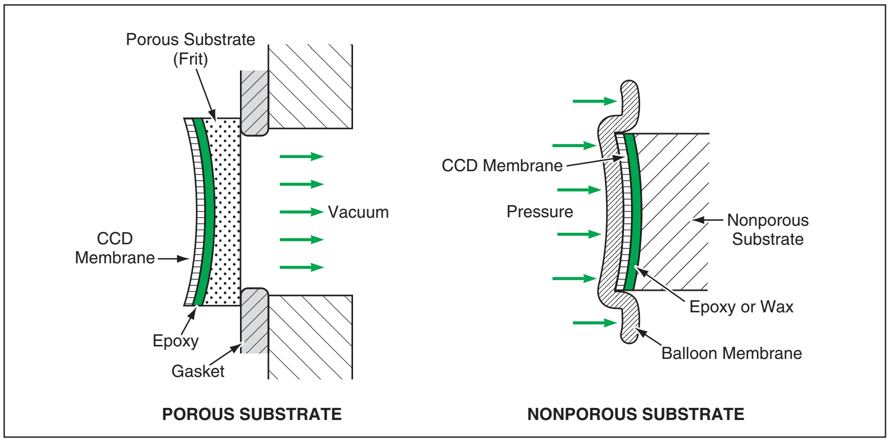
It would not be necessary to perform fabrication processing of curved substrates.

NASA's Jet Propulsion Laboratory, Pasadena, California

A versatile and simple approach to the design and fabrication of curved-focal-plane arrays of silicon-based photodetectors is being developed. This approach is an alternative to the one described in "Curved Focal-Plane Arrays Using Back-Illuminated High-Purity Photodetectors" (NPO-30566), *NASA Tech Briefs*, Vol. 27, No. 10 (October 2003), page 10a.

As in the cited prior article, the basic idea is to improve the performance of an imaging instrument and simplify the optics needed to obtain a given level of performance by making an image sensor (in this case, an array of photodetectors) conform to a curved focal surface, instead of designing the optics to project an image onto a flat focal surface. There is biological precedent for curved-focal-surface designs: retinas — the image sensors in eyes — conform to the naturally curved focal surfaces of eye lenses.

The present approach is applicable to both front-side- and back-side-illuminated, membrane photodetector arrays and is being demonstrated on charge-coupled devices (CCDs). The very-large-



A **Flat Membrane CCD** would be pressed against, and bonded to, a curved substrate in either of two ways.

scale integrated (VLSI) circuitry of such a CCD or other array is fabricated on the front side of a silicon substrate, then the CCD substrate is attached temporarily to a second substrate for mechanical support, then material is removed from the back to obtain the CCD membrane, which typically has a thickness between 10 and 20 μm. In the case of a CCD designed to operate in back-surface illumination, delta doping can be performed after thinning to enhance the sensitivity. This approach is independent of the design and method of fabrication of the front-side VLSI circuitry and does not involve any processing of a curved silicon substrate.

In this approach, a third substrate would be prepared by polishing one of its surfaces to a required focal-surface curvature. A CCD membrane fabricated as described above would be pressed against, deformed into conformity with, and bonded to, the curved surface. The technique used to press and bond the CCD membrane would depend on the nature of the supporting material (see figure). For example, if the third substrate were made of quartz frit, the substrate would be prepared by suffusing it with epoxy. Then one would take advantage of the porosity of the frit by applying a partial vacuum to the opposite surface of the frit, causing atmospheric pressure to push the CCD membrane against the curved surface. The curing of the epoxy would bond the CCD membrane to the curved surface.

Alternatively, if the third substrate were made of a nonporous material, the curved substrate surface would be prepared by coating it with a wax or an uncured epoxy. The CCD membrane would be pressed against the coated, curved surface by use of a suitably pressurized balloon. The CCD membrane would then become bonded to the curved surface by curing of the epoxy or freezing of the wax.

This work was done by Shouleh Nikzad and Todd Jones of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

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