



## Rollable Thin Shell Composite-Material Paraboloidal Mirrors

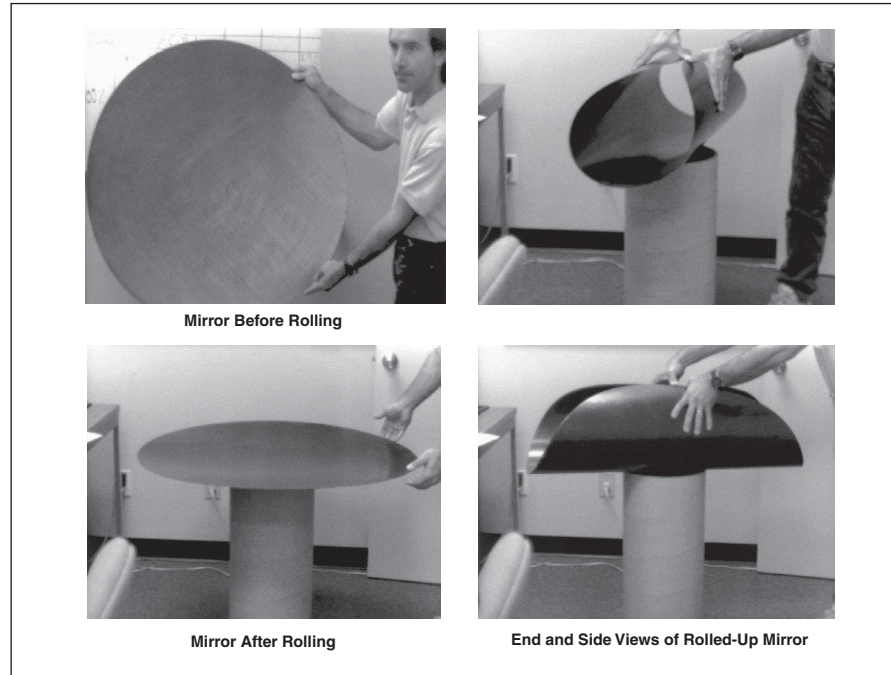
These lightweight focusing mirrors can be stored in fairly narrow cylinders.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experiment and calculation have demonstrated the feasibility of a technique of compact storage of paraboloidal mirrors made of thin composite-material (multiple layers of carbon fiber mats in a polymeric matrix) shells coated with metal for reflectivity. Such mirrors are under consideration as simple, lightweight alternatives to the heavier, more complex mirrors now used in space telescopes. They could also be used on Earth in applications in which gravitational sag of the thin shells can be tolerated.

The present technique is essentially the same as that used to store large maps, posters, tapestries, and similar objects: One simply rolls up the mirror to a radius small enough to enable the insertion of the mirror in a protective cylindrical case. Provided that the stress associated with rolling the mirror is not so large as to introduce an appreciable amount of hysteresis, the mirror can be expected to spring back to its original shape, with sufficient precision to perform its intended optical function, when unrolled from storage.

A simple calculation yields a qualitative indication of the level of stress in, and the likelihood of permanent deformation of, a rolled mirror. The calculation in question is an estimate of the stress in a rolled flat sheet of the same composite material and thickness as those of the mirror shell. The compressive or tensile stress ( $S$ ) in the radially innermost or radially outermost surface layer, respectively, is given by  $S = Et/2r$ , where  $E$  is the modulus of elasticity of the composite-material shell or flat sheet,  $t$  is the thickness of the shell or flat sheet, and  $r$  is the radius of curvature



A Thin-Shell Composite-Material Mirror was rolled, then unrolled without introducing visible permanent distortion of its optical surface.

to which the shell or sheet is rolled. For a typical mirror diameter ( $D = 2$  m) and shell thickness ( $t = 1$  mm) rolled to a radius such that diametrically opposite points on the edge of the mirror just come into contact ( $r = D/2\pi$ ), this equation yields  $S \approx 0.016E$ . This is a relatively small amount of stress and, as such, would not be expected to cause an appreciable permanent deformation.

The figure depicts stages of a demonstration in which a composite-material

mirror of  $D = 90$  cm,  $t = 1$  mm, and a focal ratio ( $f$  number) of 1 was manually rolled as described above. Visual inspection after unrolling revealed no hysteresis. Further optical testing of the unrolled mirror was underway at the time of reporting the information for this article.

*This work was done by Aden Meinel, Marjorie Meinel, and Robert Romeo of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-20987*

## Folded Resonant Horns for Power Ultrasonic Applications

Ultrasonic actuators can be made shorter.

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Folded horns have been conceived as alternatives to straight horns used as resonators and strain amplifiers in power ultrasonic systems. Such systems are used for cleaning, welding, solder-

ing, cutting, and drilling in a variety of industries. In addition, several previous *NASA Tech Briefs* articles have described instrumented drilling, coring, and burrowing machines that utilize

combinations of sonic and ultrasonic vibrational actuation. The main advantage of a folded horn, relative to a straight horn of the same resonance frequency, is that the folded horn can

be made shorter (that is, its greatest linear dimension measured from the outside can be made smaller). Alternatively, for a given length, the resonance frequency can be reduced. Hence, the folded-horn concept affords an additional degree of design freedom for reducing the length of an ultrasonic power system that includes a horn.

Figure 1 depicts an ultrasonic actuator that includes a straight stepped horn, one that includes an inverted

straight stepped horn of approximately the same resonance frequency, and one that includes a folded stepped horn of approximately the same resonance frequency. The main role of the straight stepped horn is to amplify longitudinal strain at its outermost end. In the folded version, one can exploit bending strain in addition to longitudinal strain, and by adjusting the thickness of the folds, one can increase or decrease the contributions of bending displacements

to the overall displacement at the tip. In this case, the folded-horn concept not only yields a shorter horn, but by enabling utilization of bending displacements, it also affords an additional degree of design freedom. Figure 2 shows an experimental folded-horn actuator of 16-kHz resonance frequency alongside a straight-horn actuator of 20-kHz resonance frequency.

*This work was done by Stewart Sherrit, Stephen Askins, Michael Gradziel, Xiaoqi Bao, Zensheu Chang, Benjamin Dolgin, and Yoseph Bar-Cohen of Caltech and Tom Peterson of Cybersonics Inc. for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-30489*

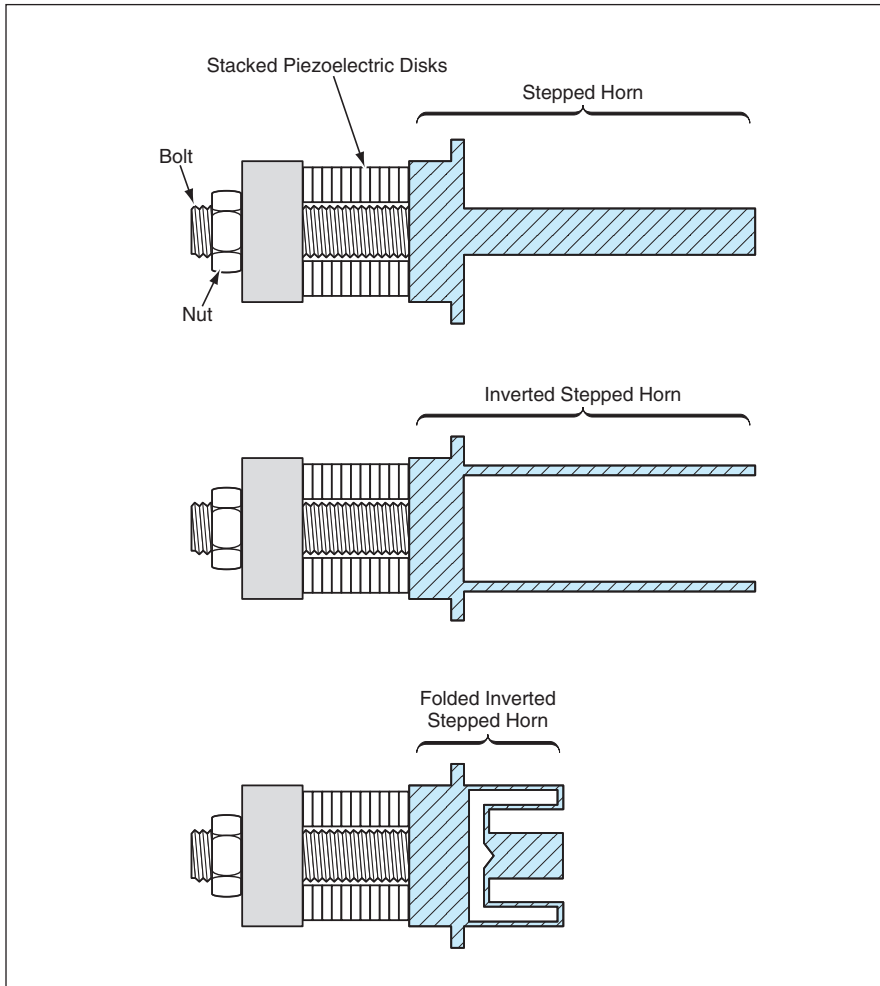


Figure 1. Three Similar Power Ultrasonic Actuators are depicted partly in cross sections to illustrate a progression of designs from a straight stepped horn to a folded inverted stepped horn.

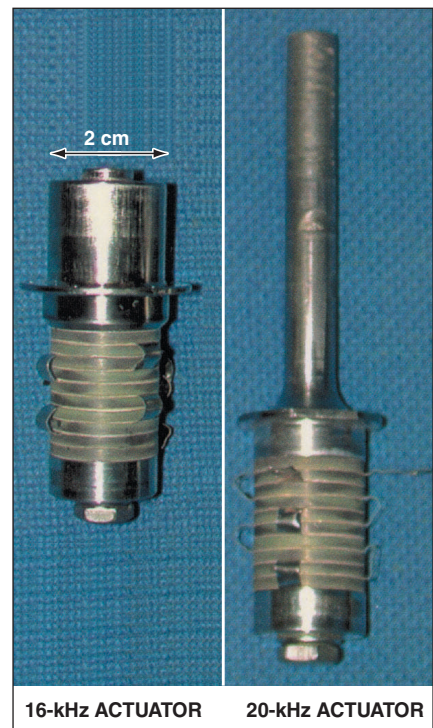


Figure 2. The Overall Length of the 16-kHz Horn is Shorter than the 20-kHz horn by virtue of being folded. The distance the acoustic wave travels has been designed to be the same. The lower frequency in the folded horn is due to reduced clamping and bending at the folds.