Section 3
DEVELOPMENTS IN MICROFABRICATION

3.A Improvements in Nonconcentricity Measurement of Target Shells

An improved technique has been developed for characterizing the thickness uniformity of target shells used as fuel containers in laser fusion experiments. A requirement for these target shells is that they have walls uniform in thickness to preserve implosion symmetry.[1] The usual interferometric technique[2,3] for characterizing shell uniformity has been modified to improve the detection sensitivity to shell concentricity defects. This modification, which simply involves adding gas to the shell, can provide up to five times the sensitivity to this type of defect. No additional equipment is required to achieve the improvement. Interpretation of the shell interferograms is made by knowing the shell material, diameter and average wall thickness, and the gas index of refraction.

Figure 14 is a cross section of a nonconcentric shell of diameter D and average wall thickness t_O. A transmission interferometer visually displays the optical path difference (O.P.D.) between light rays passing through the shell (ray 1) and rays passing by the shell (ray 2). The O.P.D. is displayed as contours spaced at one-wavelength intervals. These contours, or interference fringes, are concentric with the geometric center of the shell if the nonconcentricity ratio $\Delta t/t_O = 0.0$. If $\Delta t/t_O > 0.0$, the O.P.D. contours are not concentric with, but displaced from, the geometric center of the target by a distance S. The quantity S/D is the interferogram asymmetry ratio which is measured by the interferometer operator.

A first order, non-refracting analytical analysis of this problem gives

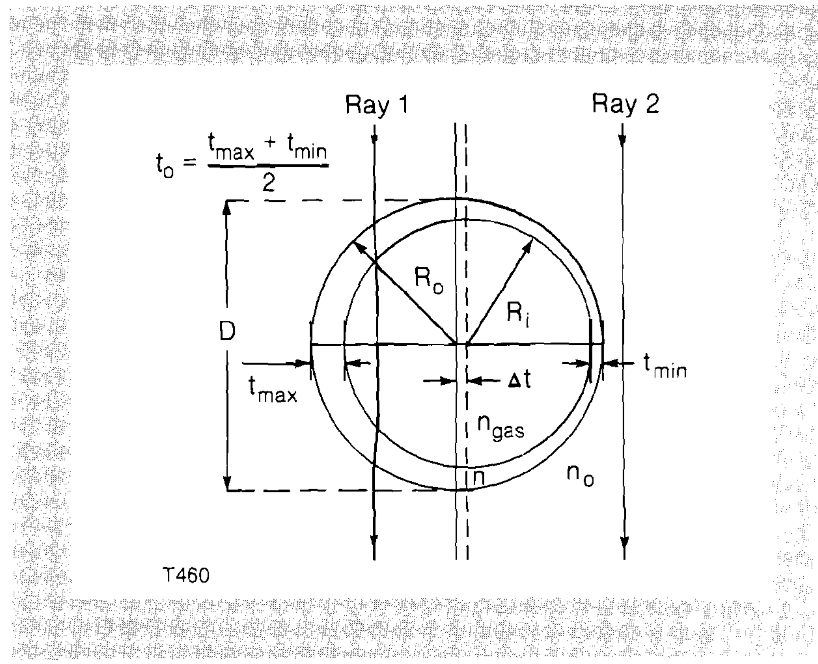


Fig. 14
Diagram of a nonconcentric transparent shell illustrating important features. Examples of collimated light passing through and around the shell are given by rays 1 and 2.

the following relationship between the nonconcentricity ratio $\Delta t/t_o$ and the interferogram asymmetry ratio S/D.

$$\frac{\Delta t}{t_o} = \frac{Q\left(1 + \frac{2t_o}{D}\right) - 1}{Q\,\frac{t_o}{D}} \cdot \frac{S}{D} \tag{3}$$

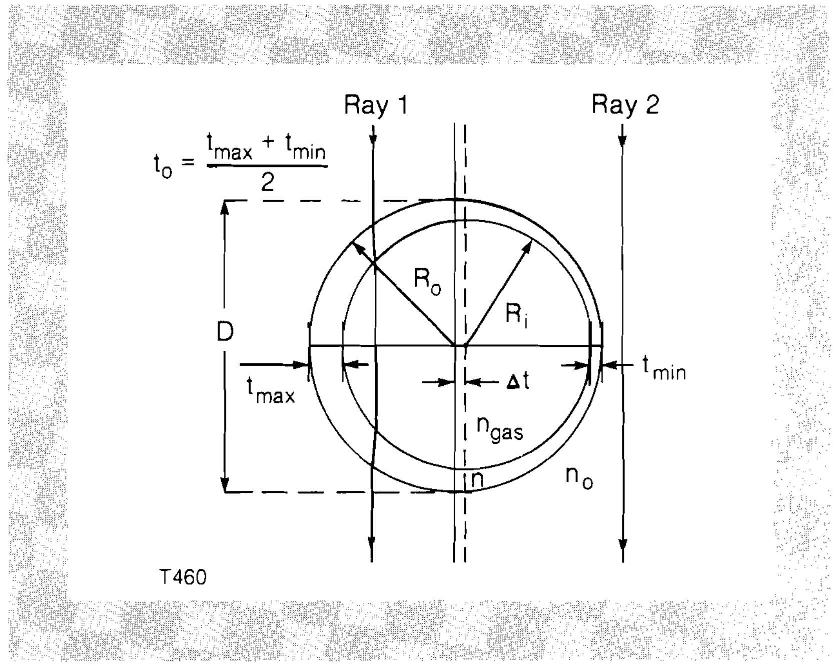
where

$$Q = 1 - \left[\frac{P(n_{gas} - 1)}{n - 1}\right] \tag{4}$$

Here P is the shell gas fill pressure in atmospheres, n_{gas} is the gas refractive index for 1 atmosphere pressure and n is the refractive index of the target shell.

These analytical results were compared with an exact computer ray trace computation. Rays were traced through target shells having various nonconcentricity ratios and gas fills. The results of the analytical model and the exact ray trace solution are shown in Fig. 15. They exhibit similar behavior. The simplicity of the first order analytical model makes it suitable for indicating trends only. Because physical processes such as refraction are ignored, this model is limited to predicting that increased gas pressure within a target shell increases the observed asymmetry ratio S/D for a fixed value of $\Delta t/t_o$. The ray trace verification of this prediction demonstrates that enhanced interferometric sensitivity to small values of $\Delta t/t_o$ result for high pressure gas fills in shells.

The universal (dimensionless) series of curves in Fig. 15 for the more accurate ray trace treatment may be used to derive target shell nonconcentricity information from interferometrically measured fringe asymmetry for a reasonably broad range of gas fill pressures. The gas pres-



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The universal (dimensionless) series of curves in Fig. 15 for the more accurate ray trace treatment may be used to derive target shell nonconcentricity information from interferometrically measured fringe asymmetry for a reasonably broad range of gas fill pressures. The gas pressures plotted in Fig. 15 are normalized by the ratio of target shell diameter to shell thickness D/t_0. Complications in interpreting the measurement of target shell concentricity result at very high gas fill pressures. The cross-hatched area on the right side of Fig. 15 indicates this region where care must be exercised.

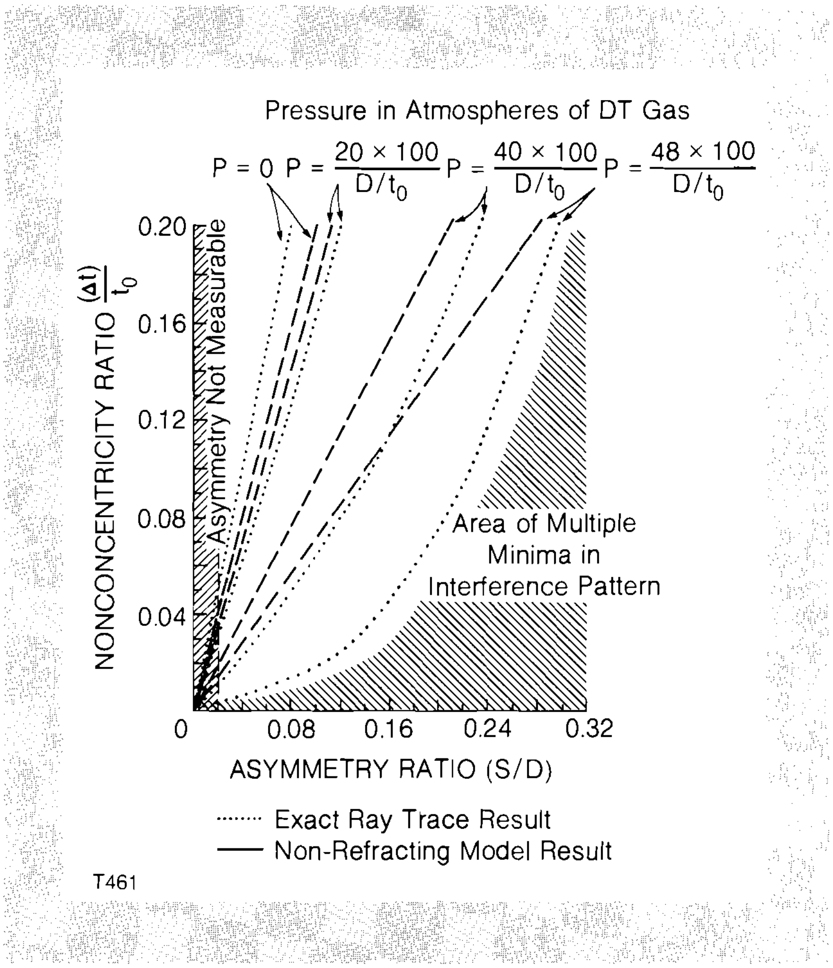

Fig. 15
Universal curves relating nonconcentricity and fringe asymmetry are plotted for glass shells. Both the analytic model and ray-trace results are shown.

A capillary mounted target shell[4] has been used to experimentally verify our improved nonconcentricity characterization procedure. A measured pressure of gas is introduced into the shell through the hollow stalk. Figure 16a shows an interferogram of a glass shell mounted on the capillary stalk and filled with one atmosphere of air.

The asymmetry ratio measured from Fig. 16a is $S/D = 0.08$ which, from Fig. 15, corresponds to a nonconcentricity ratio of $\Delta t/t_0 = 0.20$. An interferogram of this same glass shell at a fill pressure equivalent to 34 atmospheres of a DT mixture is shown in Fig. 16c. The measured asymmetry, now much larger, is equal to $S/D = 0.30$. The measurable quantity, shell asymmetry, has been increased in size by a factor of 3.75 simply by adding 34 atmospheres of gas to the shell. This increased detection sensitivity to small nonconcentricity defects is the improvement obtained from the modified approach. Small defects previously not visible in the interferograms can now be measured. Computer-generated contour plots from shells having the same dimensions and fill pressures as shown in Figs. 16a and 16c are reproduced in Figs. 16b and 16d respectively. The computer-generated plots show shell contours at 0.1 fringe increments, but are otherwise similar to the experimentally measured interferograms.

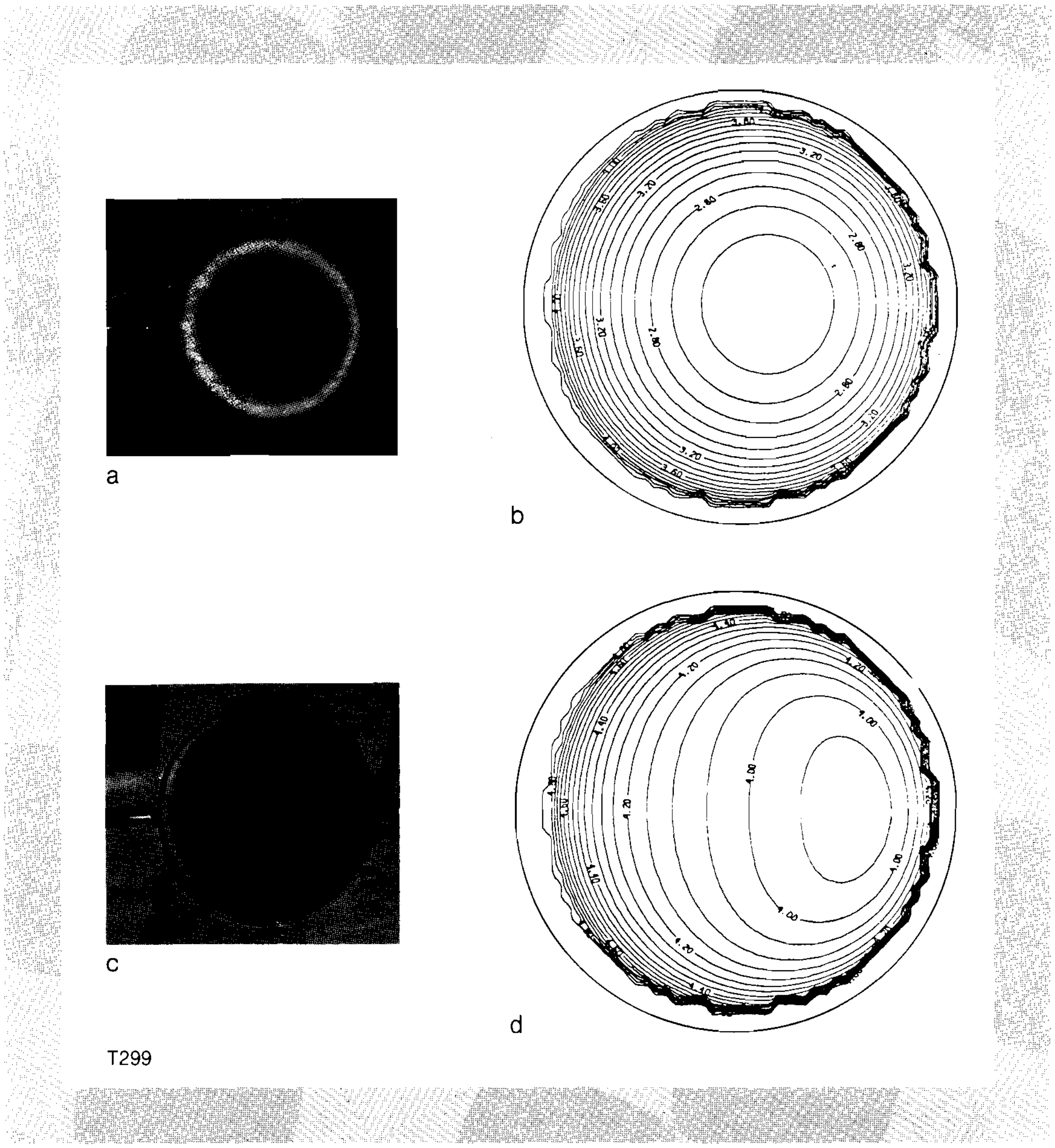

Fig. 16
Comparison of experimental and analytical examples of shell nonconcentricity: (a) Interferogram of shell with 1 atmosphere air pressure. (b) Computer-generated contour plot of O.P.D. for a shell with 1 atmosphere pressure. (c) Interferogram of the same shell as in (a) but with a gas refractive index equivalent to 34 atmospheres of DT. (d) Computer-generated contour plot of O.P.D. as in (b) but with 34 atmospheres of DT.

The above comparison between measured and modeled results for the gas-filled shells shows excellent agreement. Predictions made from the simple analytical analysis, that improved detection sensitivity is derived by adding gas to target shells, have been verified. A non-dimensional series of curves, which shows the increased detectability to shell nonconcentricity gained by adding gas to the shell, has been given.

REFERENCES

1. G. Fraley, W. Gula, D. Henderson, R. McCrory, R. Malone, R. Mason and R. Morse, *Plasma Physics and Controlled Nuclear Fusion Research*, Paper IAEA-CN-33/F5-5, page 543 (1974).