Adaptive Liquid Filled Membrane Lens

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Introduction

Liquid filled membrane lens is made by using elastomeric membrane, this membrane is made using polydimethylsiloxane (PDMS). When volume of lens is changed or redistributed , the shape of lens surface can be changed accordingly. As a result, the reshaping of the lens surface causes the focal length of the lens to change without physical motion.

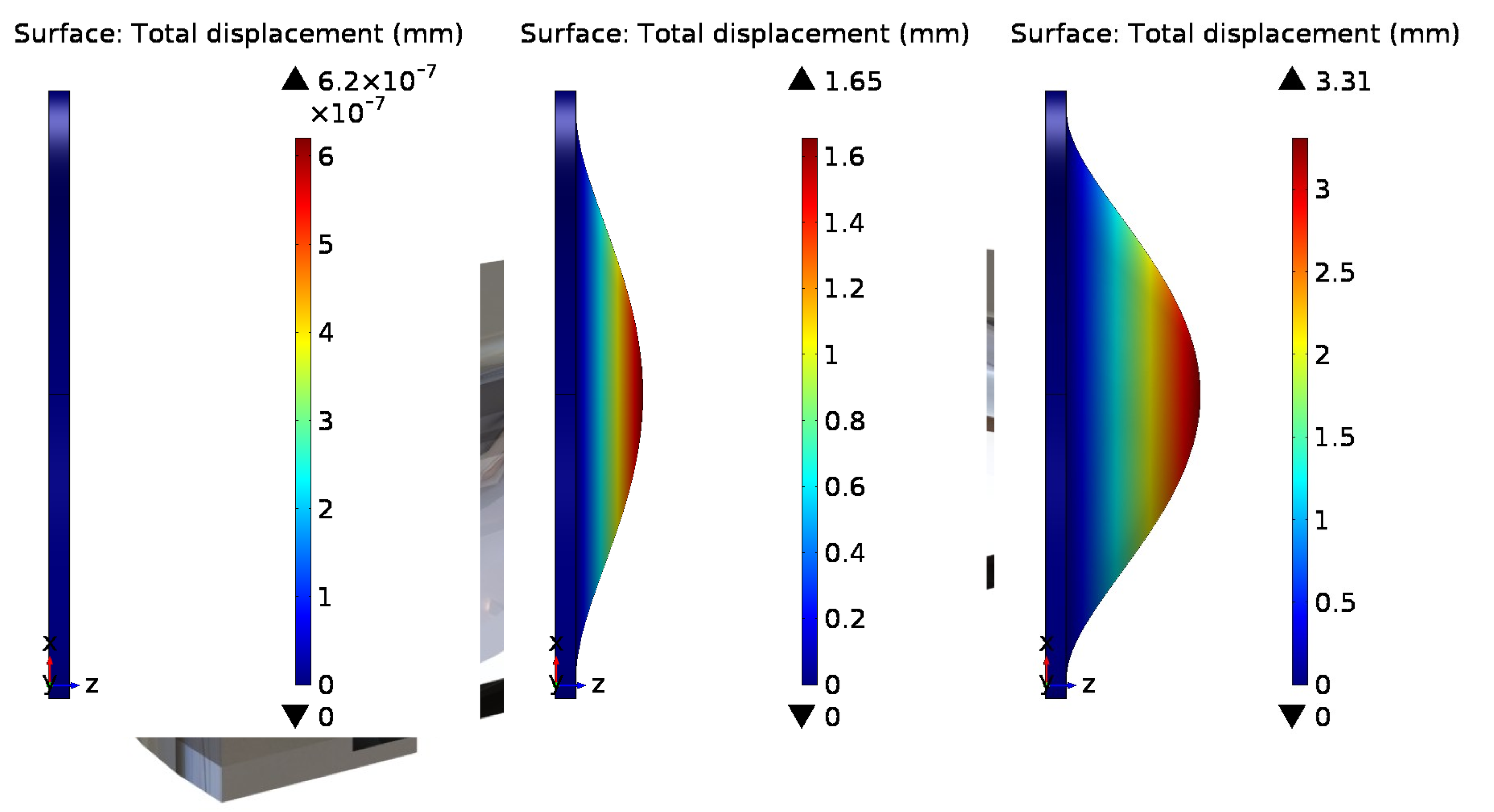
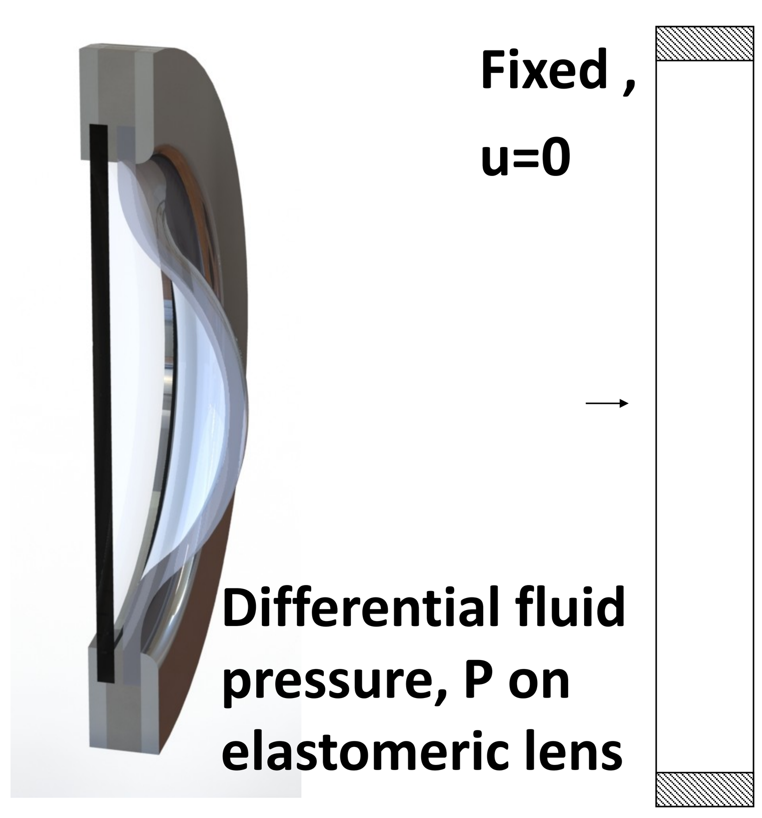


Figure 1: Deflection in lens at 0 Pa(left) 450Pa (middle) 900Pa (right).

Properties Circular PDMS membrane

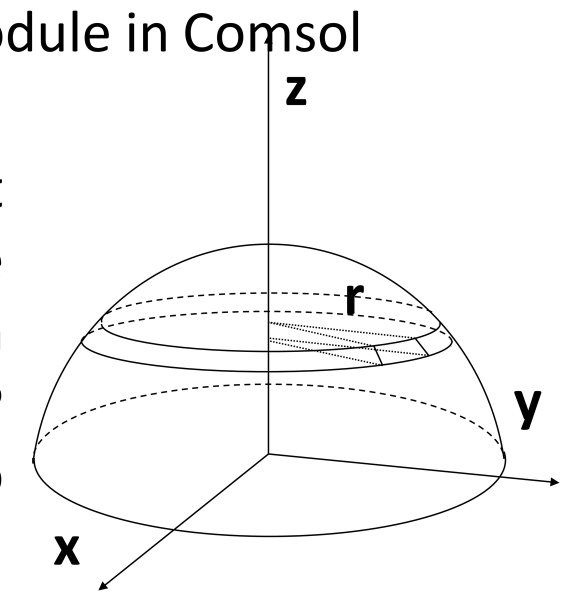
Diameter	15mm
Thickness	0.5mm
Refractive index	1.5
Tensile strength	2.24MPa
Young's Modulus	360-370MPa
Poisson Ratio	0.5
Transmission	400-900nm (100um thick)



Equations

The model is solved using solid mechanics module in Comsol Multiphysics

Displacement and velocity field is zero at initial condition , fixed constrains were applied at the and . edge at the top, bottom (u=0) and face. Differential pressure P (shown in Figure 2) is applied across the two faces.



$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial}{\partial r}\right)=-\frac{P}{S} \qquad z=-\frac{P}{4S}(a^2-r^2)$$

$$z=-\frac{\rho g a}{S}\left(\left(y^2-\frac{y^3}{6a}-\frac{4}{3}ay\right)+k\left(y^2-2ay\right)\right)$$

$$k=\frac{P}{2\rho g a}, k>30,$$ Gravity effect may be neglected

$$k=\frac{P_o+\frac{2S}{R}}{2\rho g a} \qquad P=P_o+\frac{2S}{R}$$

Knollman's analysis, the maximum error in displacement is

$$\Delta z_{\max}<h\left(\frac{h}{2a}\right)^2, h<<2a$$

For small aperture if displacement is such that z_{max} <.1um (Very small value within the tolerance of surface roughness of conventional spherical glass lens).

Results

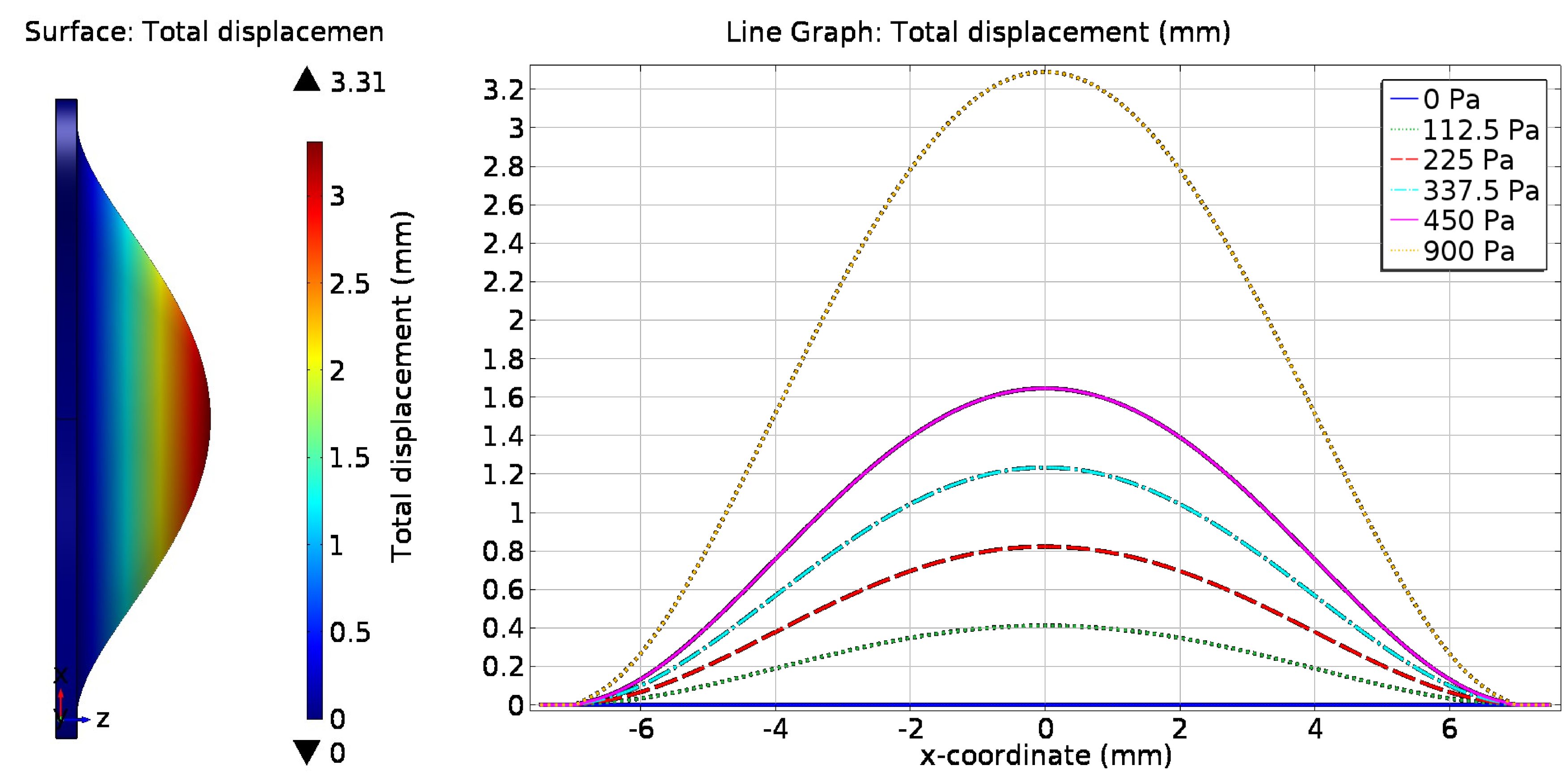


Figure 2: Deflection in PDMS membrane.

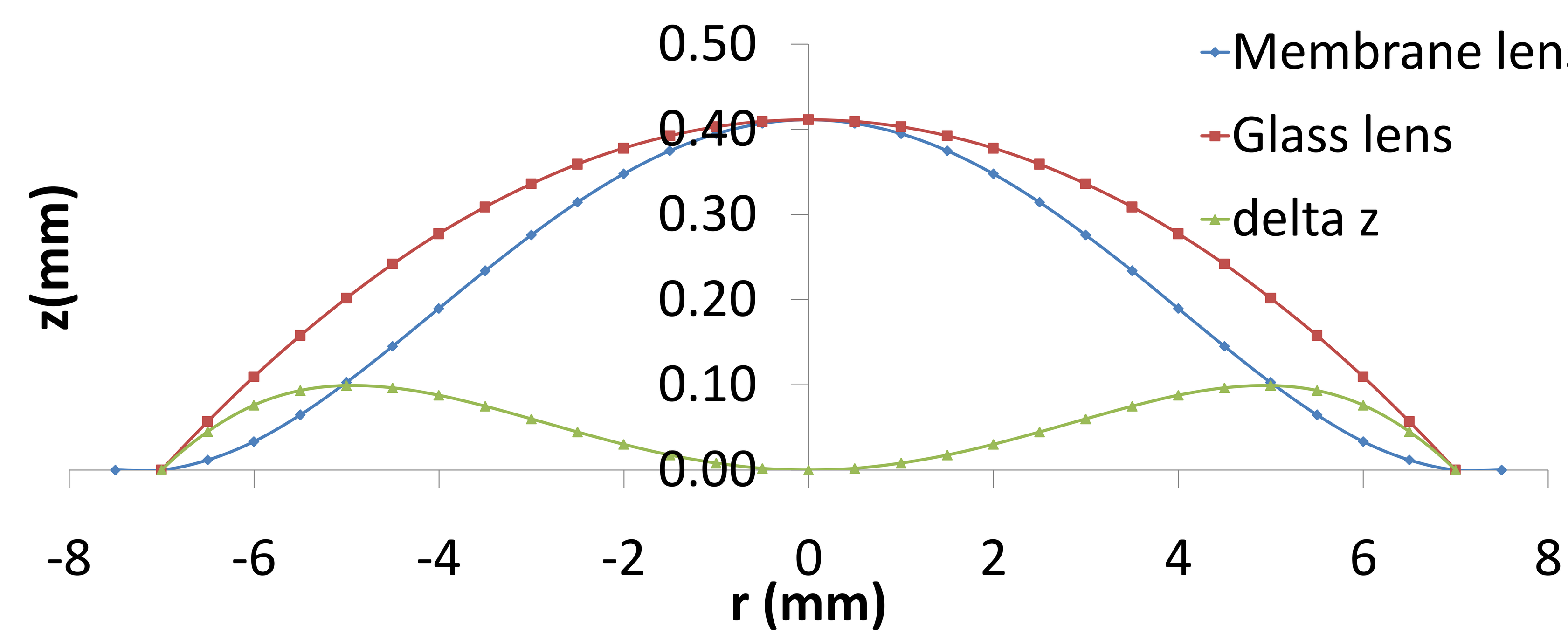


Figure 3: Comparison in spherical glass and membrane lens(112.5Pa).

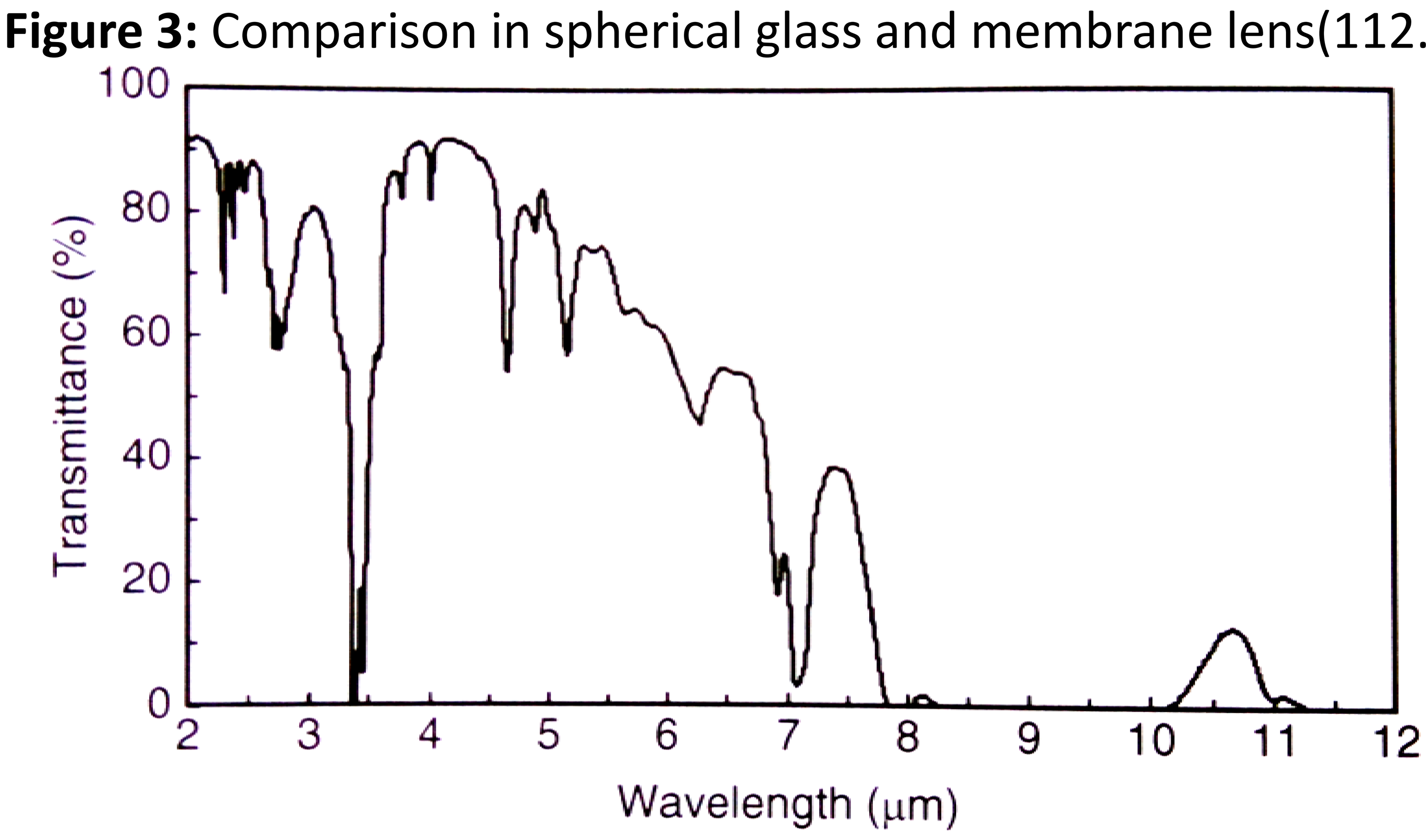


Figure 4: IR Transmittance of PDMS membrane (thickness 100um).

r = Radial distance, P = Pressure, S = Elastic Constant, ρ = Density, a = radius, y =coordinate and h = height .

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