# Solar concentrating dishes based on elastic and elasto-plastic membranes

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**Abstract:** The ability of pressurized membranes to approximate a paraboloid of revolution is investigated. The optical performance of different membrane materials is analyzed computationally and experimentally, showing concentrations of up to 3070 suns.

**OCIS codes:** (220.0220) Optical design and fabrication; (220.1770) Concentrators; (350.6050) Solar energy

## Introduction

Current 3D solar concentrators based on inflated membranes suffer from severe concentration limitations beyond very small rim angles, and may need multiple facet designs to overcome these constraints [1]. Figure 1 depicts the standard single-membrane approach, a reflective film is clamped to a circular support frame and, successively, a vacuum is applied to deform it as close as possible to a parabolic shape. However, the shape obtained by this procedure, known as Hencky surface [2], is not parabolic, and using this surface as an optical concentrator leads to serious spherical aberrations that can hardly be corrected by a secondary mirror [3].

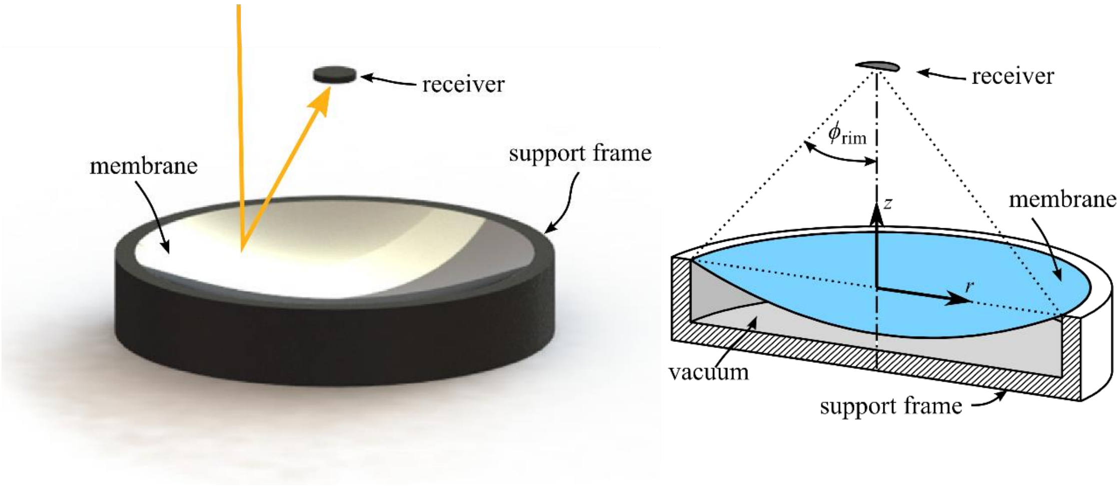

Figure 1. Concentrator based on pneumatic reflecting membrane.

## FEM and Monte-Carlo Simulations

In the presented work [4], a series of approaches to improve the geometry of pressurized circular membranes and, therefore, their ability to approximate a parabolic shape are investigated with the goal of designing an affordable, high-precision and lightweight solar concentrator. Simulations performed using finite element structural analysis and Monte-Carlo ray tracing show that materials reaching the plastic range during deformation perform particularly favorable due to a different strain distribution than in elastic materials. The beneficial effect of plastic deformation can be further enhanced if membranes are deformed more than in the intended final state and then released again (overstretching). Simulations predict possible concentration increases by a factor 10 compared to purely elastic deformed membranes.

## Experimental Validation

In order to validate the simulated results a circular steel frame is built on which the different membranes can be mounted. Two different highly reflective foils are chosen for analysis, namely aluminized biaxially oriented PET and silvered aluminum. Whereas the former shows purely elastic behavior in the examined range of rim-angles up to 20°, the latter exhibits significant plastic deformations. High-precision 3D scans of the membranes at different pressure levels precisely determine the resulting shapes. Figure 2 shows the geometric concentration ratio at 95% intercept $C_{\mathrm{g},95}$ versus rim-angle $\phi_{\mathrm{rim}}$ as determined by means of Monte-Carlo ray tracing for simulated and scanned surfaces. Comparing the two membranes in terms of achievable concentration ratios does confirm the trends predicted by the simulations. While anisotropy in the real aluminum membrane detrimentally affects the concentration, still a maximum concentration of $C_{\mathrm{g},95} = 1489$ is reached at $\phi_{\mathrm{rim}} = 18.4°$, which corresponds to a factor 7 higher than that of the PET membrane.

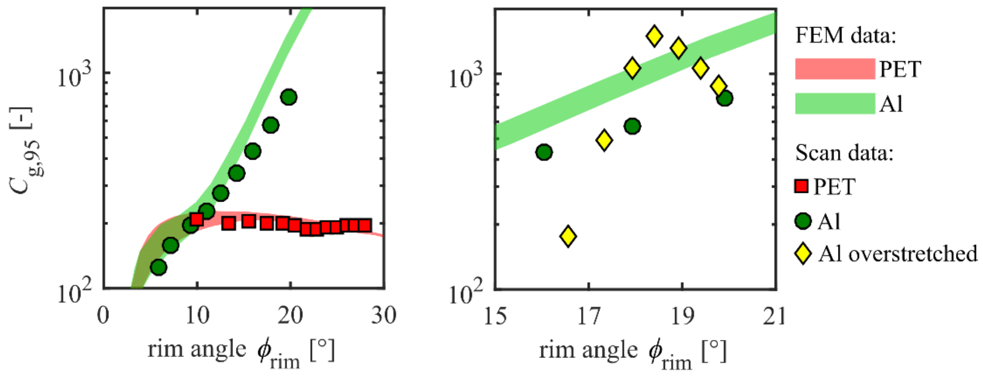

Figure 2. Geometric concentration ratio at 95% versus rim-angle as determined by Monte-Carlo ray tracing for simulated (filled areas) and scanned (individual points) surfaces [4].

## References

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