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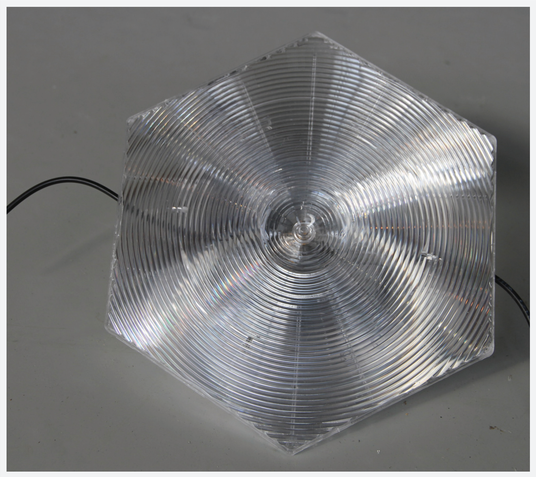
# RELIABILITY OF PMMA UNDER CONCENTRATION

## The Sun Simba™ Light-guide Solar Optic

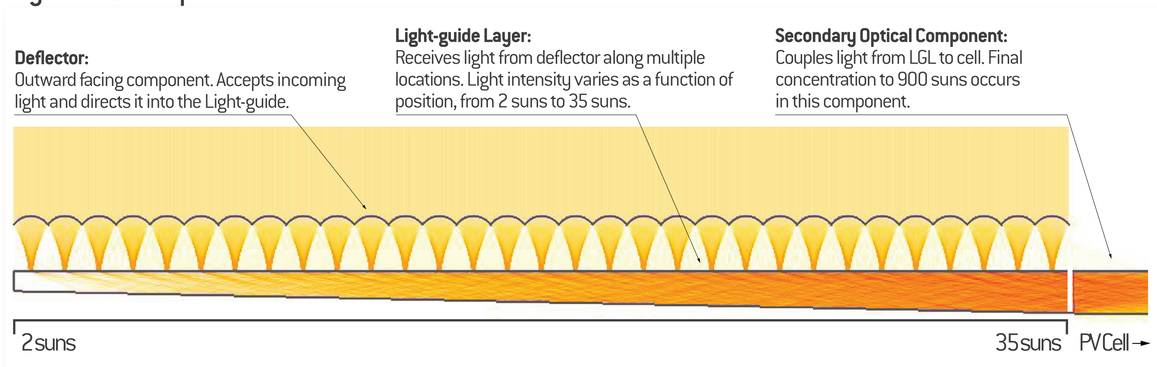


Morgan Solar's CPV system operates using TIR within a PMMA waveguide. Studies of PMMA reliability in regards to solar application have been performed and show that certain grades show excellent durability[1]. However PMMA has not been extensively studied when it is operating at concentration.

Here we examine the optical transmission of PMMA as used in the Morgan Solar CPV system. The material stack is replicated for both outdoor and indoor experiments, showing different degradation rates depending on the incident spectral shape.

[1] D. Miller et. al. Durability of poly(methyl methacrylate) lenses used in concentrating photovoltaic modules, Proc. SPIE ,7773, 777303 (2010)

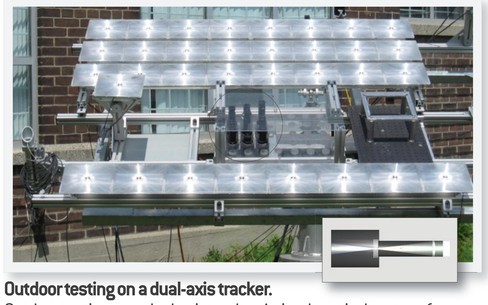
## System Description



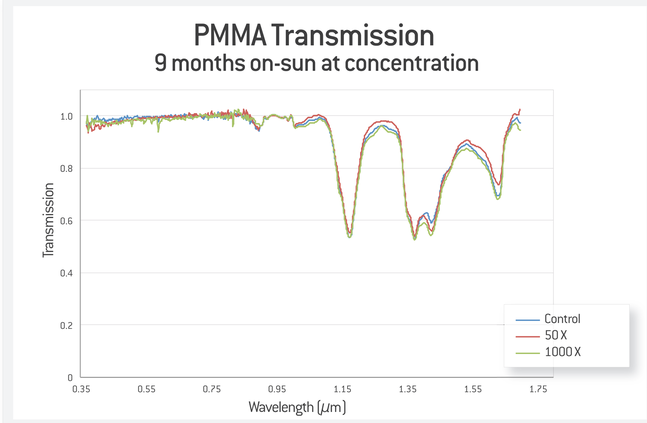

## Materials

The deflector (DEF) and Light-guide Layer (LGL) are composed of PMMA., with an absorber additive package to protect against UV damage. The secondary optical component is composed of B270 glass to handle high concentration, and bonded to the high-efficiency cell.

## Outdoor Testing



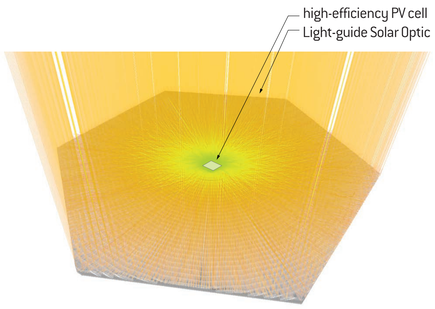
**Outdoor testing on a dual-axis tracker.**
Outdoor testing on a dual-axis tracker. A simple optical system focuses sunlight 1000X onto the sample. The lens is composed of B270 glass for UV transmission. A sheet of PMMA with UV absorbers is placed in front of the lens to mimic the spectral transmission of the deflector.




The testing setup was placed on the sun tracker system with routine alignment verification. After 9 months continuous tracking at 1000X concentration, equivalent to 17 years of normal operation, we observe a decrease of 8% in transmission at 400nm.

Inherent outdoor testing uncertainties and potential sources of error include tracking accuracy (broaden exposed area, effectively reducing total irradiance) and local weather (Toronto has lower DNI than SW California, and is at a higher latitude, therefore receiving less UV). Additionally, unknown heritage and composition of PMMA UV filter layer.

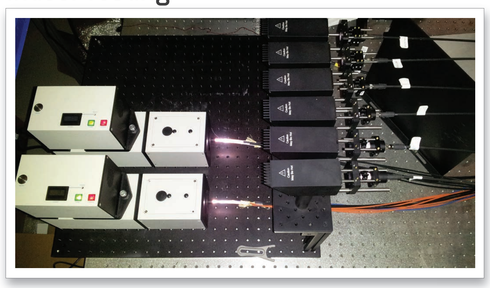
To corroborate the findings, experiments under more controlled conditions were conducted indoors.

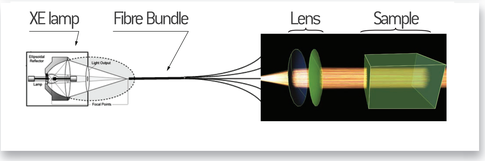


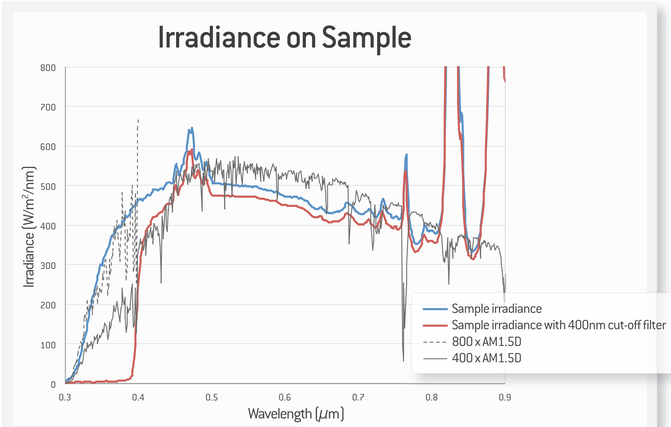

## Raytrace

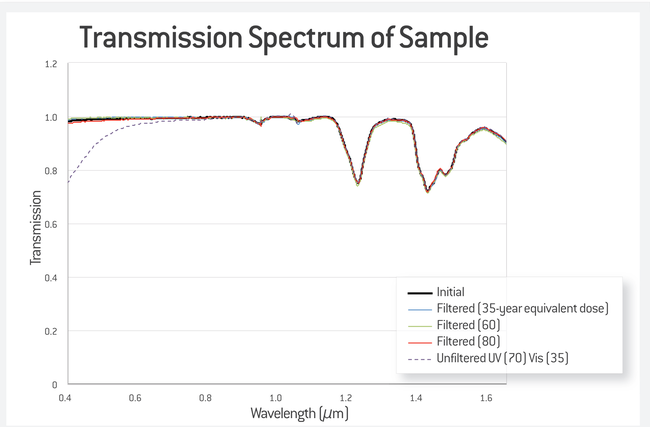
This 3D raytrace image, generated using optimization software, illustrates incident light being captured, concentrated and directed to a high-efficiency PV cell at the Light-guide's center.

## Indoor Testing






**Instrument Setup:** Broad-band Xe lamp was used to closely match solar spectrum. Output from the lamp was coupled to a fiber-bundle, up to 500mW per fiber. Light focused onto sample at concentration up to 400X (visible). UV filter with cut-off wavelength of 400nm was placed before some samples to emulate spectral transmission of primary optical component of Sun Simba.

**Measurement:** Sample transmission spectrum were measured bi-weekly for two months. Incident spectrum was measured at the same time to account for lamp, fiber and lens degradation. Transmission measurement system uses a smaller spot size to measure only the central portion of the illuminated area.

**Spectrum incident on samples**
Shape of the spectrum incident on samples is a good match to the AM1.5D in the visible. Concentration factor begins at 400X at start of experiment. The Xe lamps contain a larger fraction of UV than the AM1.5D spectrum. Ultraviolet portion of the incident spectrum is 800X AM1.5D UV.

**Transmission spectrum of light-guide material with filtered and unfiltered light**
Material under a filtered spectrum shows almost no degradation even after the equivalent of 80 years of 1 sun illumination (solid lines).
Material under unfiltered light (dashed line) is shown with the equivalent of 35 years of 1-sun illumination and almost 70 years of UV exposure. The transmission at 400nm drops by 15%. This amount of yellowing results in a 4.5% decrease in top-cell current production with an AM1.5D spectrum.

## Conclusion

The results presented here are at extreme concentration level for PMMA, and well beyond standard levels of acceleration. Due to the intense concentration, a thermally induced degradation of the PMMA top layer which may not be present during normal operation may occur. The relationship between concentration and degradation rate (ie. linear, super-linear etc.) will be established to corroborate extent of acceleration and estimation of damage.

Spectral filtering to eliminate the UV portion of the spectrum can greatly reduce yellowing of PMMA, even under concentration. To better understand the rate and extent of damage a greater resolution at early aging need to be established. Therefore, more measurements will be taken early during testing.

Actual service conditions will contain variations in temperature as well as in spectrum; making accelerated testing that completely mimics natural conditions difficult. Due to this natural variability in temperature and spectrum, outdoor experiments will be repeated with UV-filtering PMMA of known composition and a more rigorous tracking and focusing system.

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