Reliability Characterization of an Exposed Spherical Ball Lens in a Dish-Based CPV System

Blake Coughenour[a], Brian Wheelwright[a], David Lesser[b], Roger Angel[a, b]
The University of Arizona [a]College of Optical Sciences and [b]Steward Observatory

Abstract

Our CPV solution uses a 3.1x3.1 m square paraboloidal reflector to bring sunlight initially to a high power point focus [1]. A spherical lens at this focus reformats the concentrated sunlight onto secondary optical concentrators so as to uniformly illuminate 36 triple-junction cells at 1200x geometric concentration [2]. This 120 mm diameter ball lens (Figure 1) made of fused-silica acts as the entrance aperture into our self-contained Power Conversion Unit (PCU) where the triple-junction cells are integrated with a closed-circuit active cooling system. As originally envisaged, the ball lens would be preceded by a protective window, transmitting at a lower flux level comparable to that of the glass vacuum tubes of trough reflectors. However, based on current experience, such a window may not be necessary. The lens in operation without a window is seen in Figure 2, at the entrance to the PCU. In over 200 hours of on-sun reliability testing, our prototype system has consistently generated 2 kW of power, with no measureable deterioration of the ball lens surface. Efforts are being undertaken to develop field-relevant accelerated lifetime testing to understand optical durability, surface scatter, and corrosion of anti-reflective coatings on the glass substrate. Soiling is of particular concern, chiefly due to high flux levels incident on particulates present at the ball lens surface (Figure 3). We present some initial analysis of our field-tested ball lens and soiled fused-silica slides under high concentration. Our goal is to understand the long-term effects of particle accumulation and surface reflectivity loss, with the intent of mitigation.

Optical System

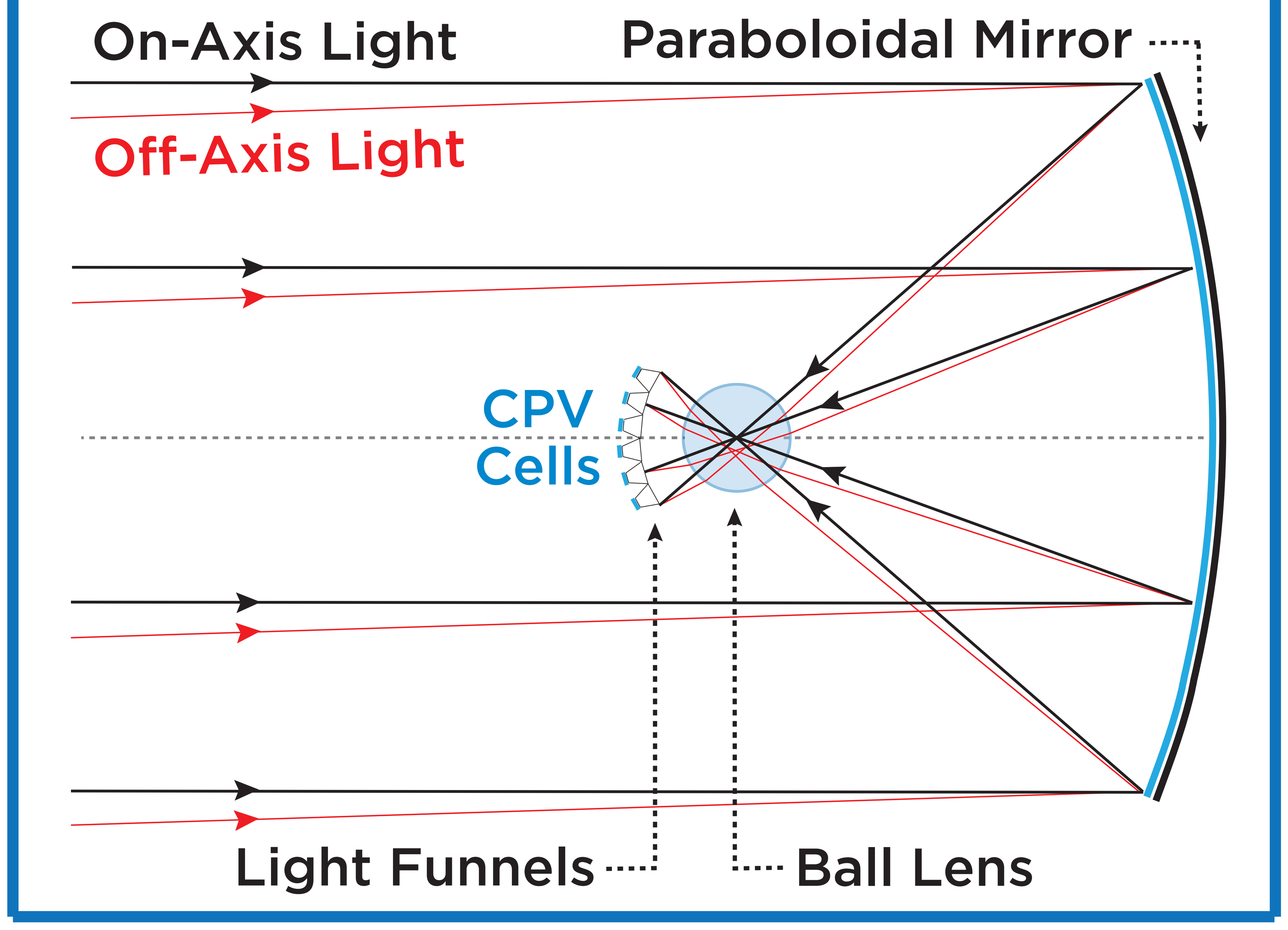



Figure 1: Ball Lens

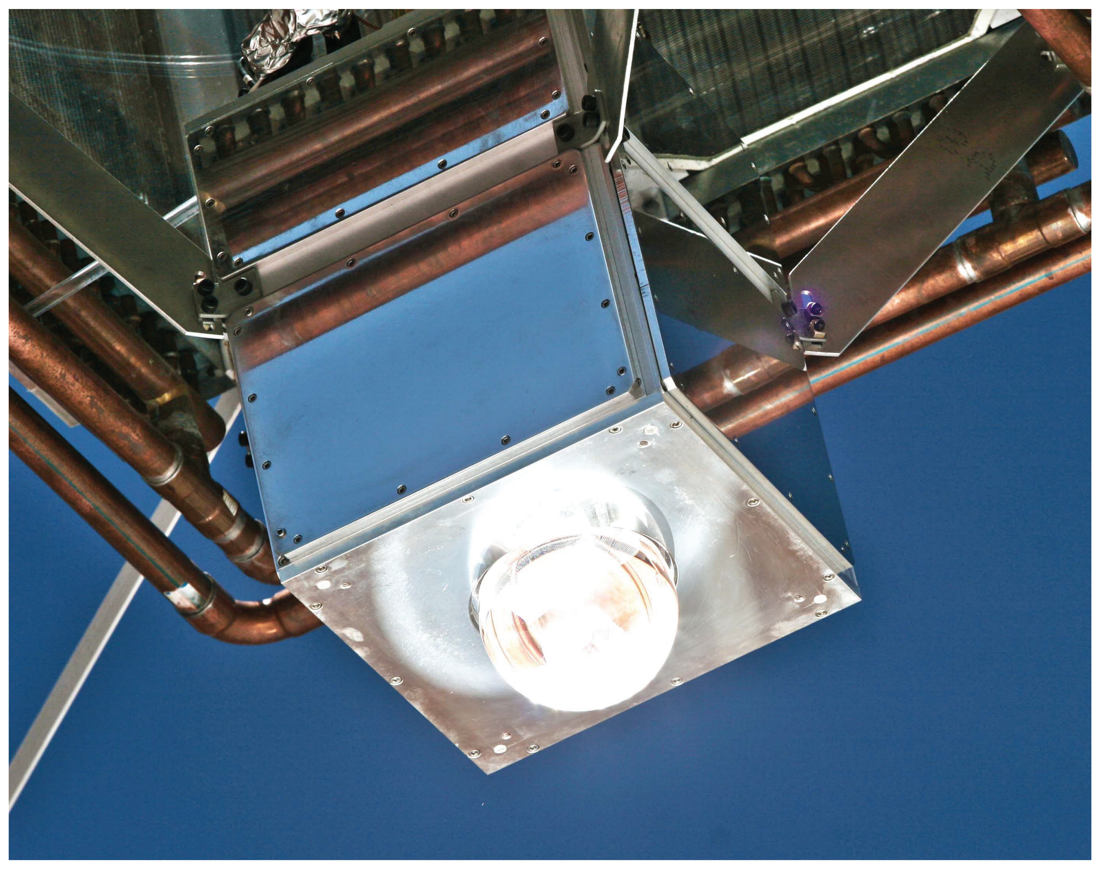


Figure 2: Ball Lens in Operation

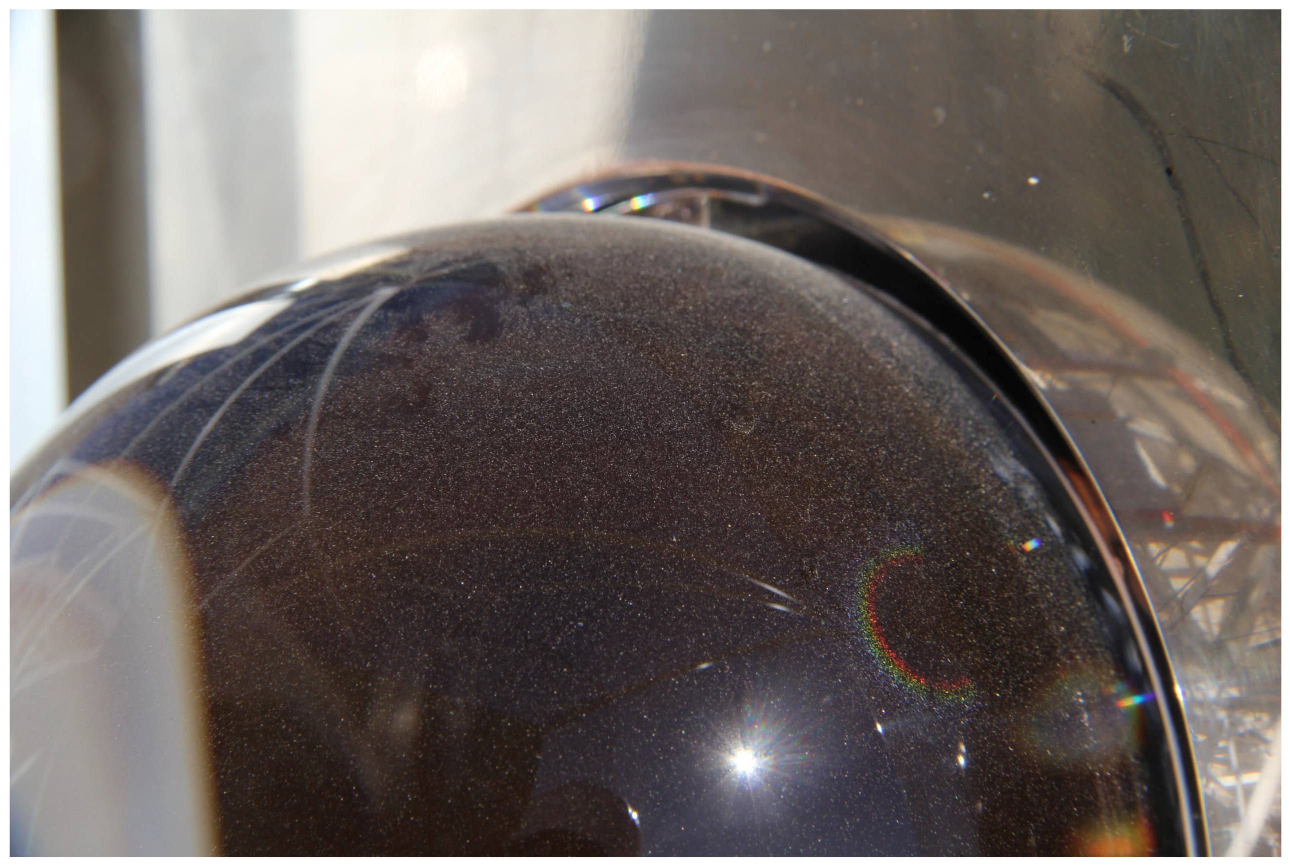


Figure 3: Dust Accumulation on Ball Lens

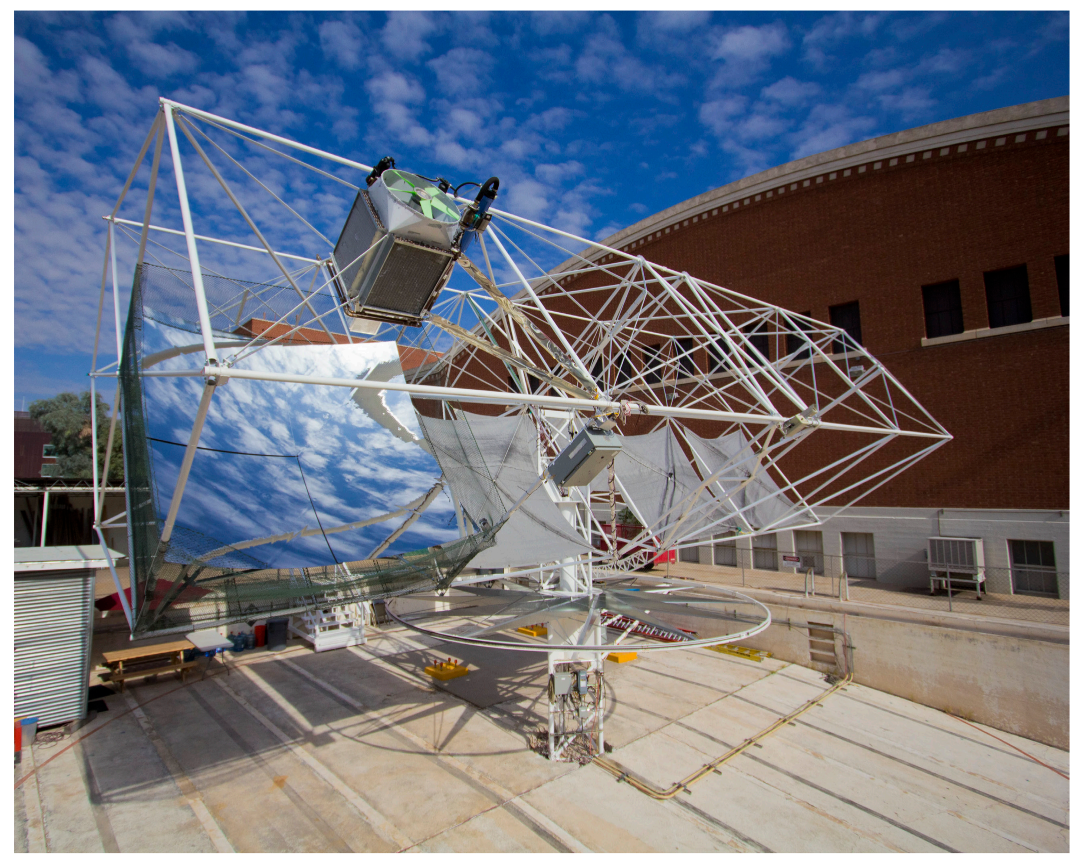
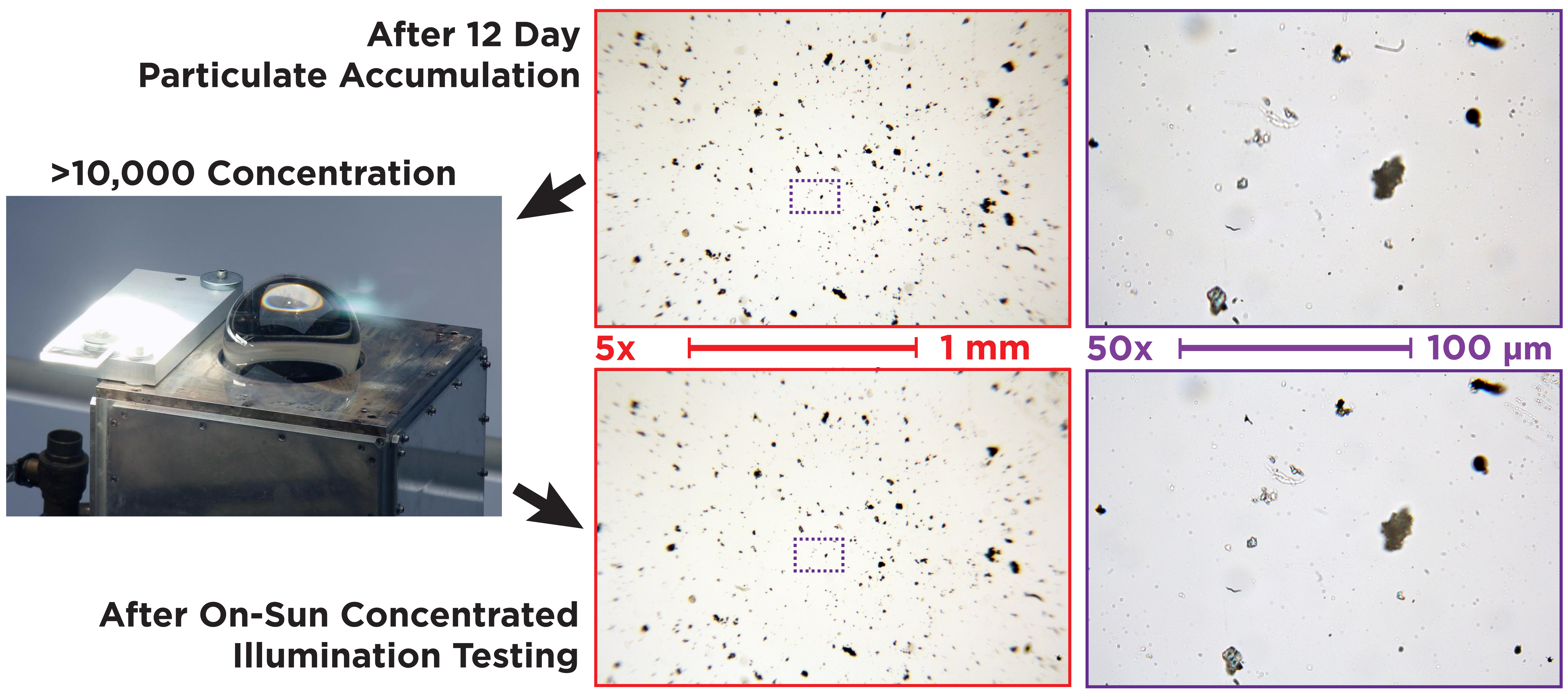


Figure 4: 20kW Solar Tracker Unit

Soiled Fused Silica under High Concentration

In this test, we sought to simulate and image the effects of concentrated sunlight passed through a Fused-Silica ball lens after it had been soiled with several days of particulate accumulation. To do this, we took Fused-Silica slides and subjected them to 12 days of horizontal dust accumulation at our solar tracker installation. After taking pictures of the particulates, we mounted the slides near the focus of our tracker and illuminated the slides with nearly the same concentration factor as the ball lens experiences for a few minutes. Re-examining the slides, we noticed very little change in the concentration of surface particulates, which are easily removed with water. This suggests that the solar flux the ball lens experiences is insufficient to damage the un-coated surface. We will soon revisit this test to simulate a soiled AR coating on a ball lens.



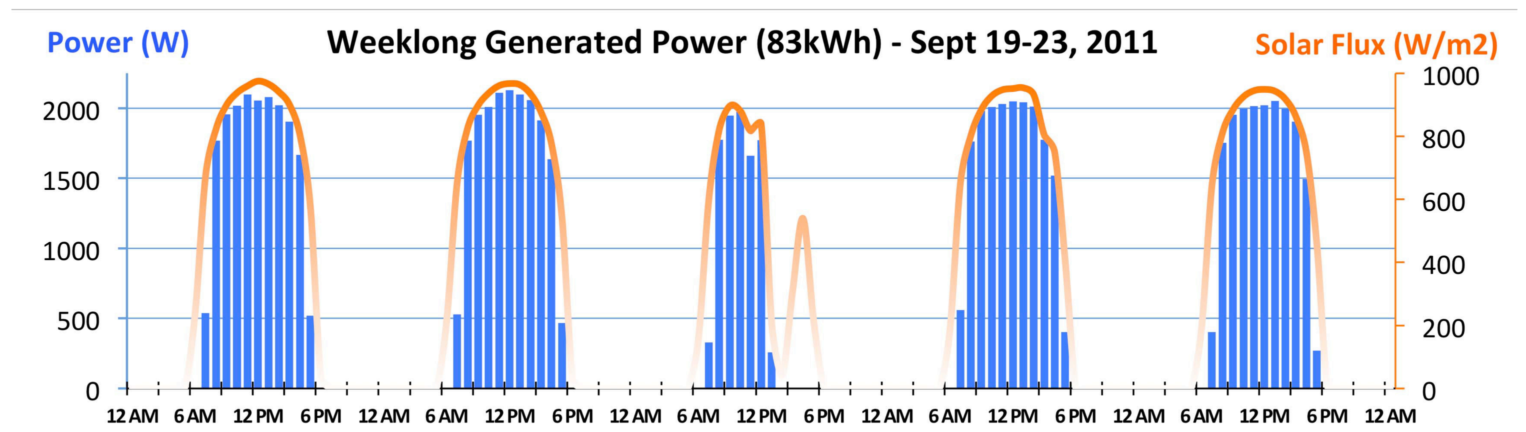
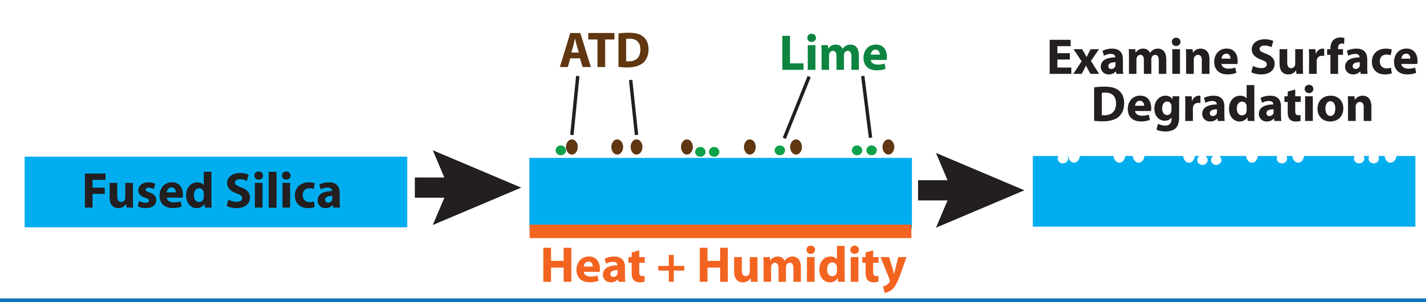


Figure 5: Example of Consistent Power Generation

Accelerated Testing

We recognize the importance of validating our concentrator's optical system lifetime under environmental conditions and understanding the consequent operation and maintenance implications and expect to work closely with NREL to develop appropriate testing procedures. One facet of our current test plan will involve exposing optical elements to Arizona Test Dust (ATD) powder at high humidity and temperature to see etching of the fused silica and it's AR coating by hydrated lime scabs. Over time, we will measure transmission degradation and use scanning electron microscopy to characterize etch pits in the glass substrate and coating. By using concentrated doses of ATD and lime, we hope to gauge the long-term effects on optical transmission.



References

[1] J. Roger P. Angel, Tom Connors, Warren Davidson, Matt Rademacher, Blake Coughenour, Guillaume Butel, and David Lesser "Development and On-Sun Performance of Dish-Based HCPV" in 7th International Conference on Concentrating Photovoltaic Systems: (CPV-7), 4-6th April, 2011, Las Vegas, Nevada, (USA), AIP Conf. Proc. 1407, pp. 34-37

[2] G. Butel, T. Connors, B. Coughenour, and R. Angel, "Design, Optimization and Characterization of Secondary Optics for a Dish- Based 1000x HCPV System," in Renewable Energy and the Environment, OSA Technical Digest (CD) (Optical Society of America, 2011), paper SRWC3.