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Evaluation of a New Tool for Heliostat Field Flux Mapping

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Sandia National Laboratories



Objective

- **Develop accurate flux-mapping tool that is less expensive and simpler than existing methods**
- **PHLUX Method***
 - Photographic Flux Mapping Tools

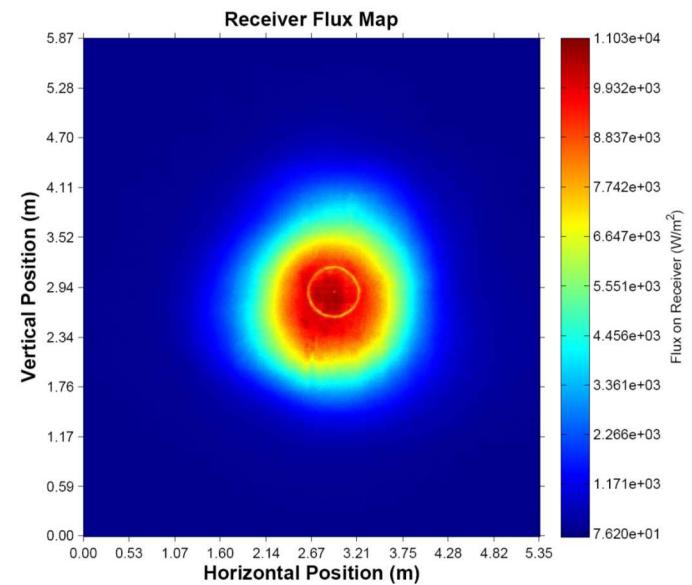
*Details in ASME ES2011 paper



PHLUX Method

- **PHLUX Tool consist of:**

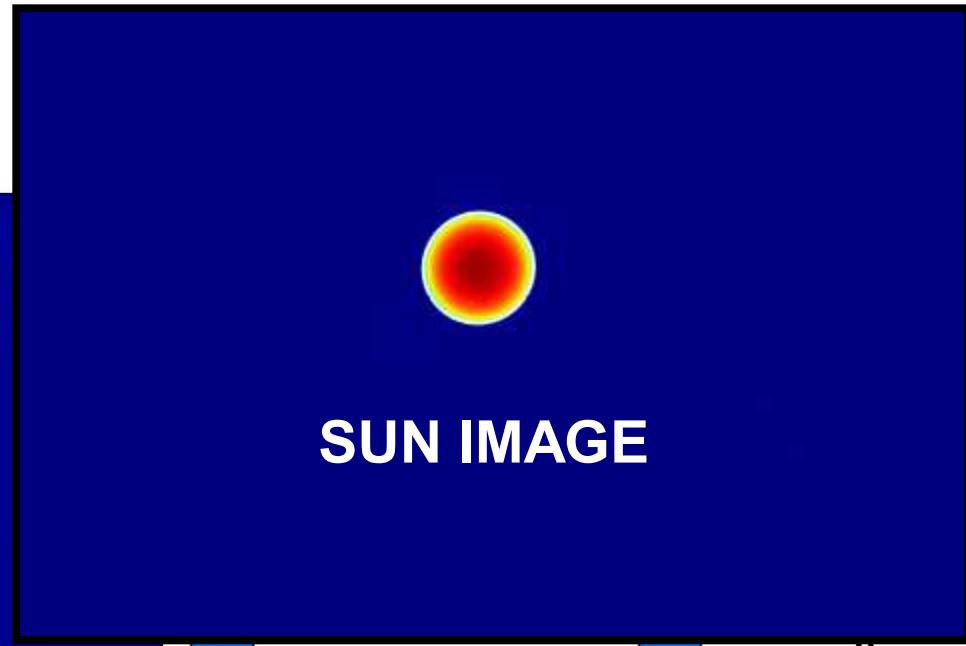
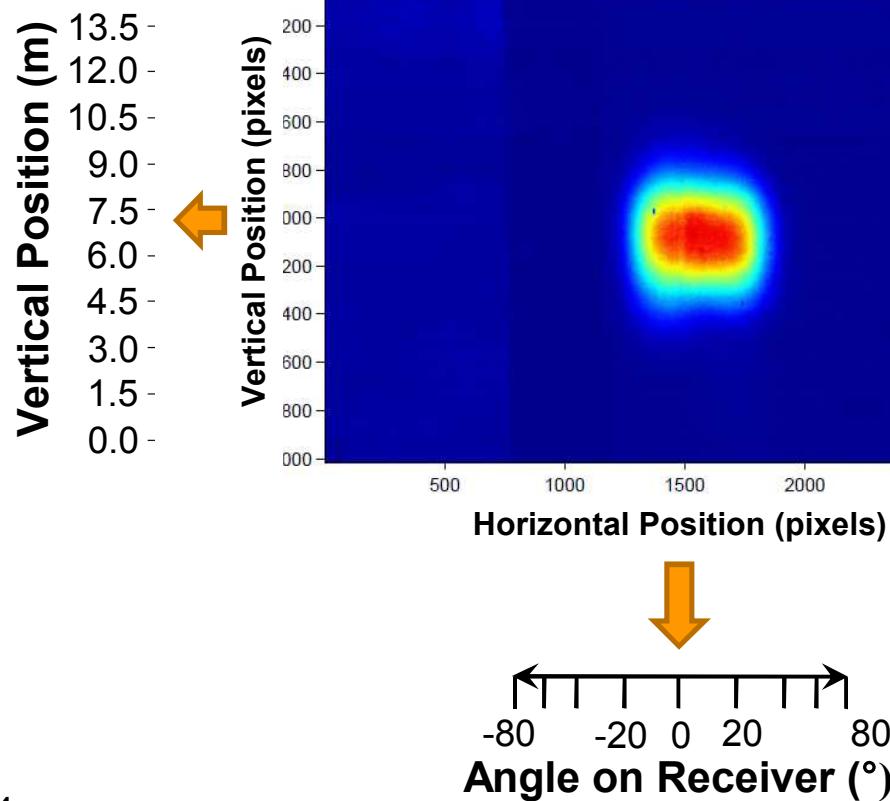
- A digital SLR camera
 - Photo of the illuminated diffuse receiver or target
- ➡ • Photo of the sun and DNI
 - Scaling (power, size)
- Algorithms/Software
 - Calculates irradiance distribution on the receiver
 - Determines length scales and angles



PHLUX Procedure



Receiver Flux Map





Testing and Validation

- **Applied PHLUX method to heliostat beams projected onto face of tower**
 - National Solar Thermal Test Facility, Sandia National Labs, Albuquerque, NM





Receiver and Sun Images

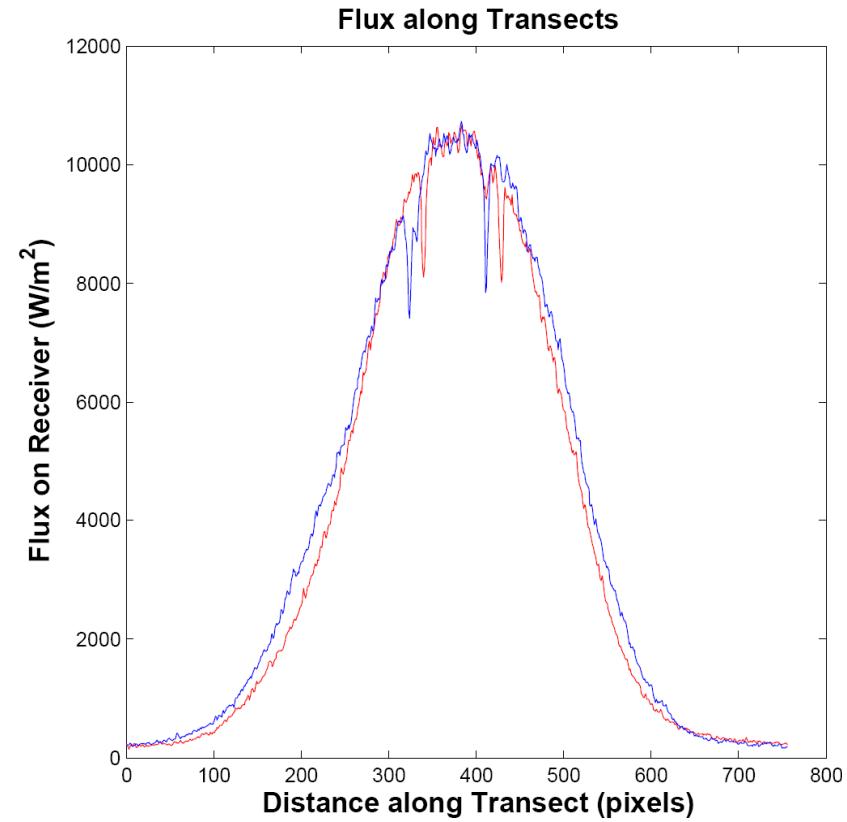
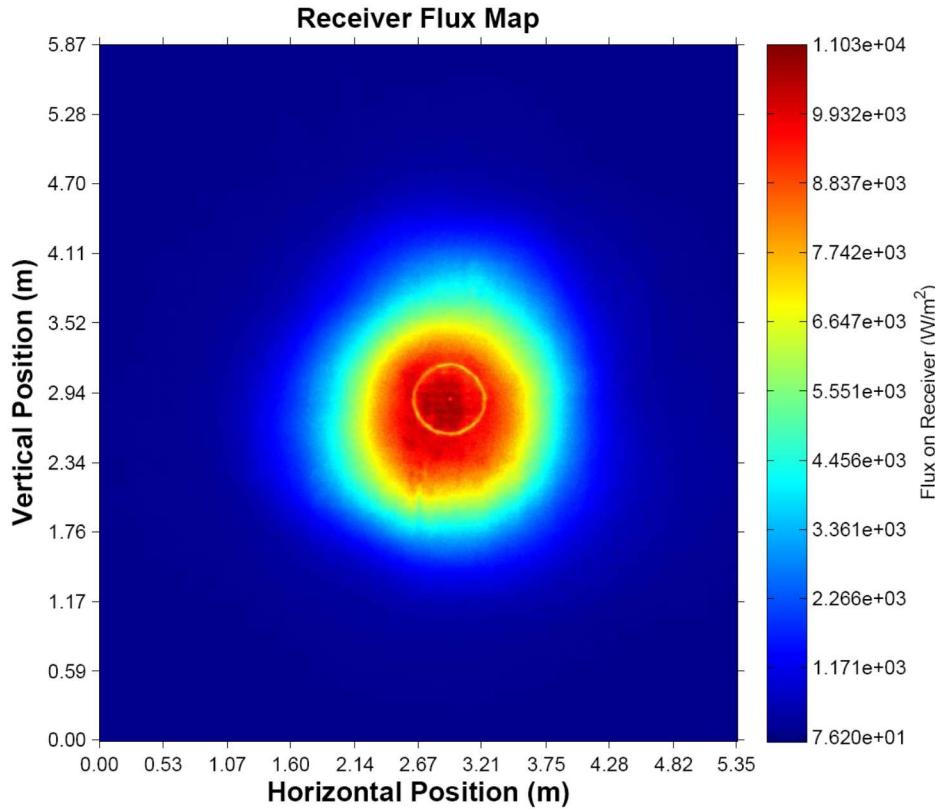


Image of beam on tower



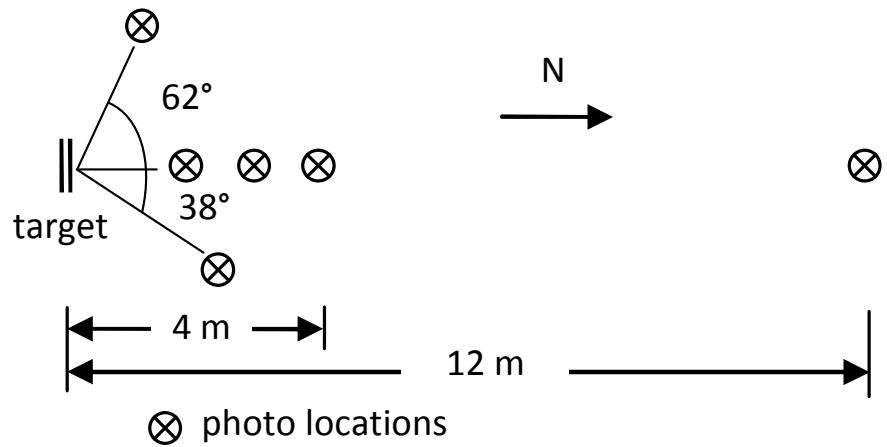
Image of sun

PHLUX Map



- Peak flux using PHLUX method was within 2% of that measured by flux gauge
- Additional tests using multiple heliostats showed that the PHLUX method yielded results that were within 10% of that measured by flux gauge

Distance and Angle Independence

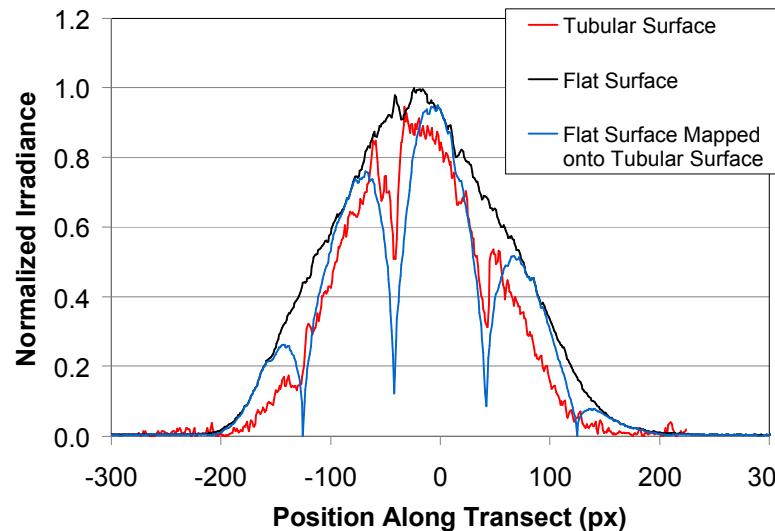
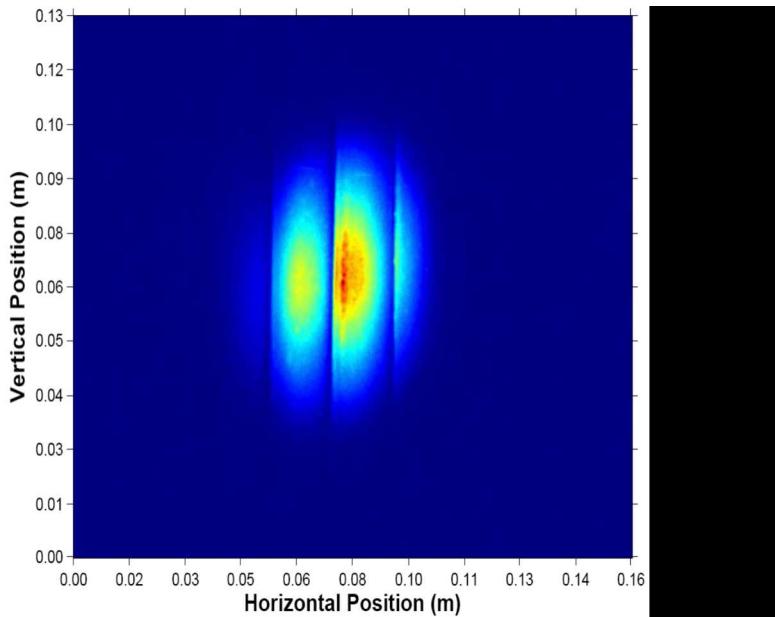


∴ PHLUX results shown to be independent of angle and distance between camera and target

Non-Planar Receiver Surfaces



∴ PHLUX method can be applied to non-planar surfaces





Summary

- **PHLUX method provides simple and inexpensive flux mapping tool**
 - Only requires digital camera and reflectivity of receiver
 - Uses image of sun (and DNI) to scale power and size
- **PHLUX method evaluated with testing**
 - Accurate to within ~2 – 10% of flux gauge readings
 - Irradiance independent of distance and angle between camera and target
 - Applicable to non-planar (tubular) surfaces
- **Web-based tool developed**
 - Seeking beta testers

Web-Based PHLUX Tool

Sandia National Laboratories: Solar Glare and Flux Mapping Tools - Mozilla Firefox

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http://www.sandia.gov/phlux

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Solar Glare and Flux Mapping Tools

Registration

Empirical Glare Analysis

PHLUX Mapping Analysis

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Solar Glare and Flux Mapping Tools

Measurement of reflected solar irradiance is receiving significant attention by industry, military, and government agencies to assess potential impacts of glint and glare from growing numbers of solar power installations around the world. In addition, characterization of the incident solar flux distribution on central receivers for concentrating solar power applications is important to monitor and maintain system performance.

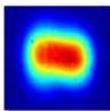
This website provides tools to analytically and empirically quantify glare from reflected light and determine the potential impact (e.g., temporary after-image, retinal burn). In addition, tools are available to empirically determine the irradiance distribution on a central receiver. Empirical results are based on digital photographs uploaded by the user. Instructions are included in each of the links below.

To access these tools, please [register](#) by following the link or clicking the menu option on the left.

Empirical Glare Analysis
Upload Glare Photos



Flux Mapping Analysis
Upload Receiver Photos



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Sandia National Laboratories: Solar Glare and Flux Mapping Tools: PHLUX Mapping Analysis - Mozilla Firefox

share.sandia.gov/glare/fluxmap.html

Step 3: Outline Transect Calculation Area and Click Done

Ellipse Definition

Axis 1, Point 1, x (pixels): 369 Axis 1, Point 1, y (pixels): 255
Axis 1, Point 2, x (pixels): 519 Axis 1, Point 2, y (pixels): 438
Axis 2 Length (pixels): 237

Done

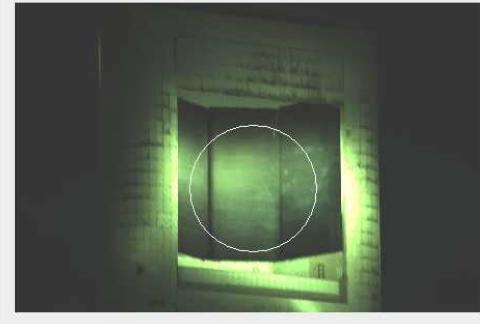
Image Adjustment

Contrast: Brightness:

Measurement Tools

Draw Ellipse Draw Circle Move Zoom In Zoom Out

Image Measurement



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Looking for beta testers for web site



Backup Slides



Next Steps

- **Continue testing PHLUX method**
 - Evaluate impact of camera settings and filters
 - Evaluate impact of different receiver geometries
- **Resolve security issues for website before public release**
- **Demonstrate calculation of reflectivity map for receivers with non-uniform reflectivity**
- **Develop stand-alone software for PHLUX method**
 - Apply to video camera recordings

PHLUX Theory

$$E_{R,i} = \frac{V_{CCD,i} E_{DNI}}{\rho_{R,i} \tan^2(\gamma/2)} \frac{\pi r_{sun_pixels}^2}{\sum_{sun} V_{CCD_sun,i}}$$

Pixel value

DNI value at time sun image was recorded

Average pixel value in sun image

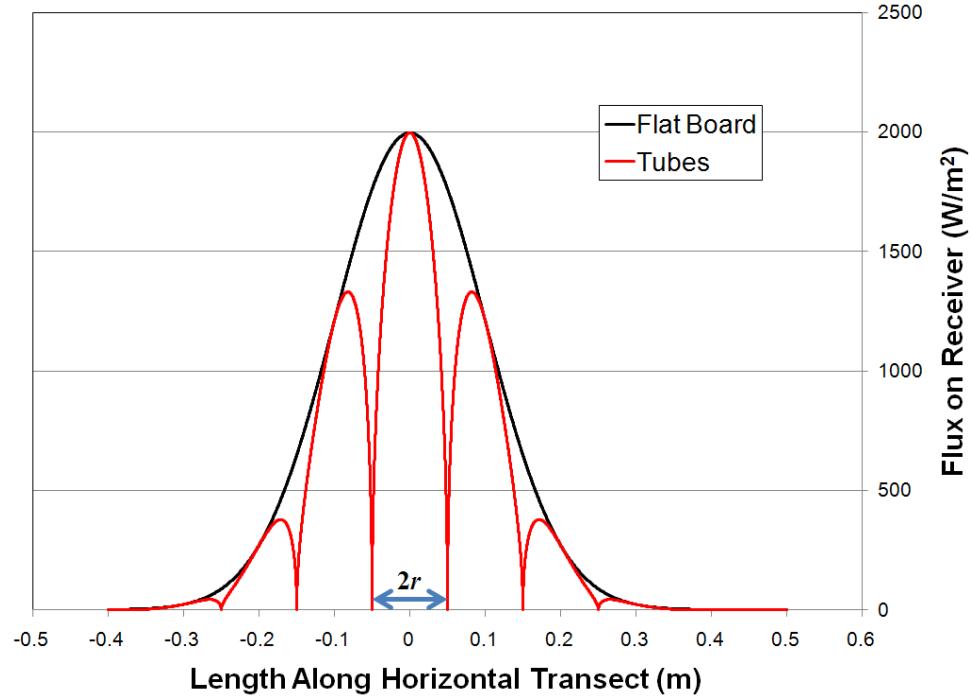
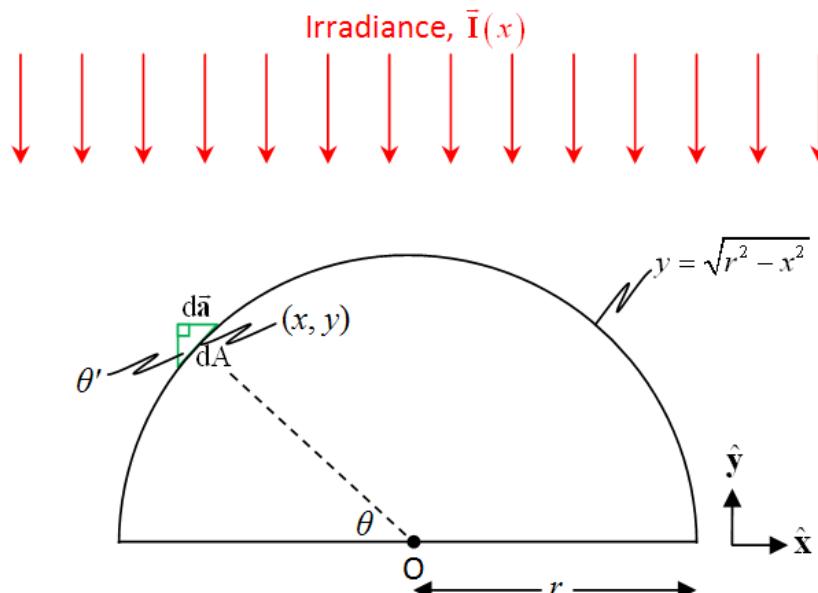
Receiver irradiance corresponding to each pixel value

Reflectivity of receiver element corresponding to pixel i^*

Subtended angle of the sun (~ 9.3 mrad)

Measurement of irradiance is independent of receiver geometry and camera angle/distance

Irradiance on Non-Planar Surface



Additional Considerations

