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Methodology to Assess Potential Glint and Glare Hazards from Concentrating Solar Power Plants: Analytical Models and Experimental Validation

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Overview

- **Introduction**
- **Safety Metrics**
- **Glint and Glare Analysis**
- **Model Validation**
- **Summary**



Introduction

- **Glint and glare may cause unwanted visual impacts**
 - Glint is momentary flash of light; glare is more continuous source of excessive brightness
 - Visual impacts range from flash blindness to retinal burn
- **Need quantified analysis of glint/glare to reduce uncertainties associated with visual impacts of CSP installations**
 - Industry, military, government agencies (e.g., California Energy Commission, Transportation Research Board)

Examples of Glint/Glare



Solar One
(10 MW_e power
tower, Daggett,
CA)



Central Receiver
Test Facility
(SNL, NM)



National Solar Thermal Test Facility
(SNL, NM)



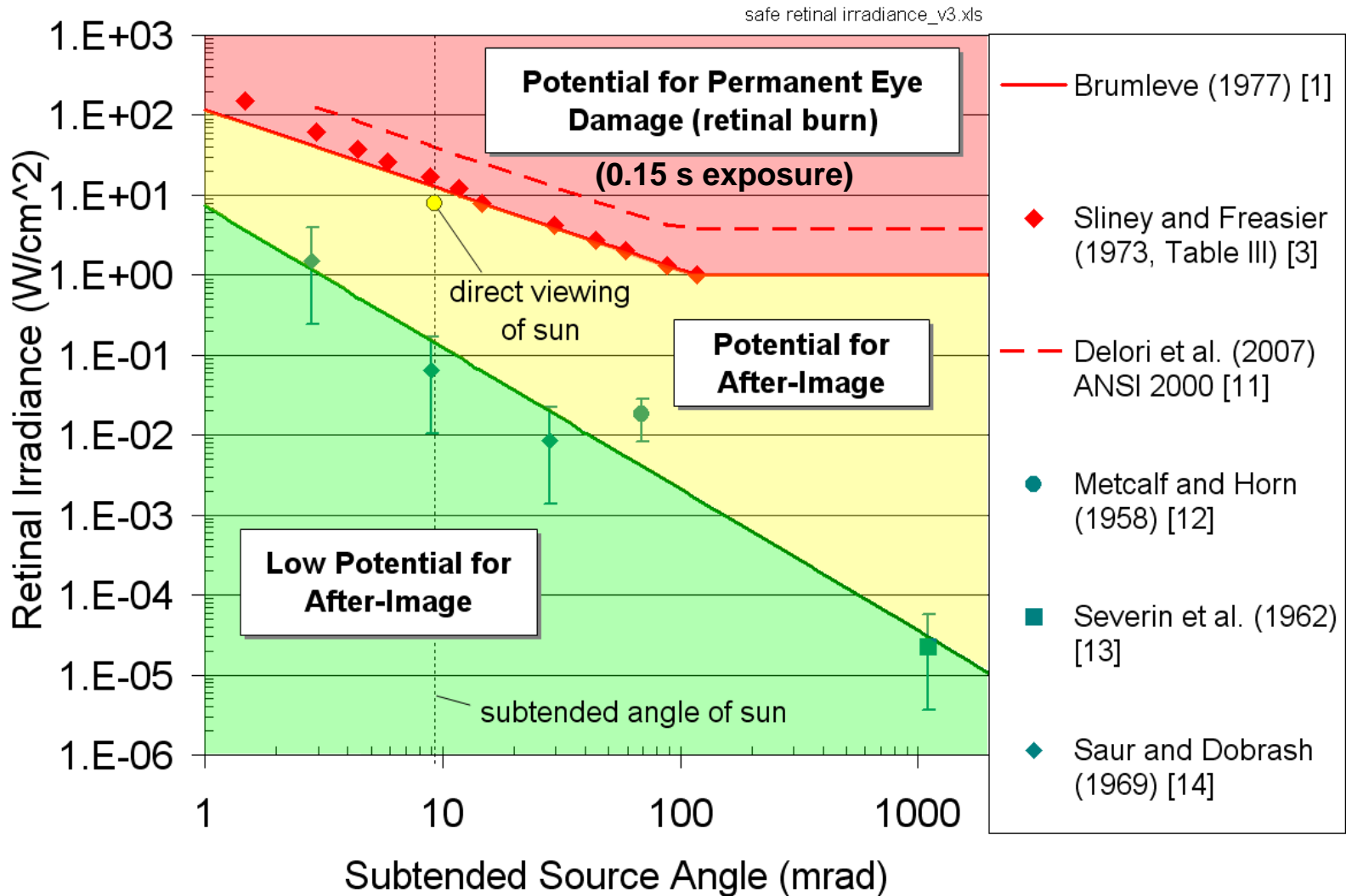
Kramer Junction
(150 MW_e parabolic trough, Mojave
Desert, CA)



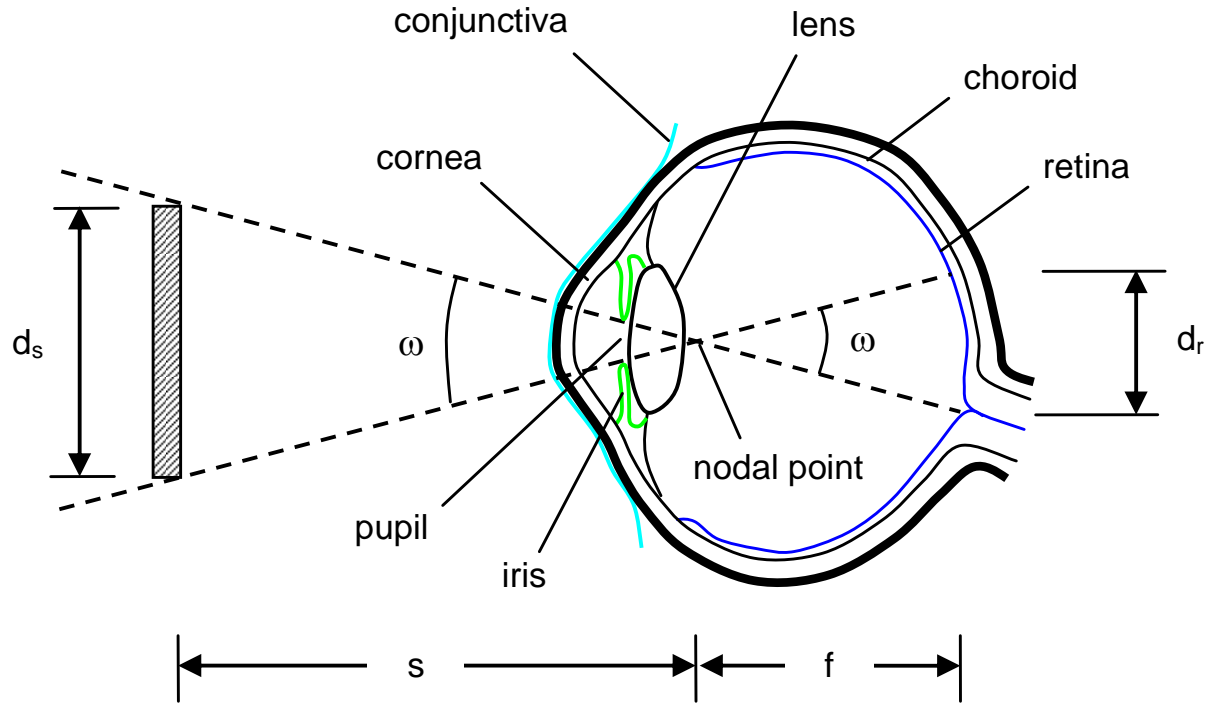
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Potential Impacts



Retinal Irradiance



- **Need to calculate**

- Retinal irradiance
 - Function of irradiance at the cornea
- Subtended angle of glint/glare source

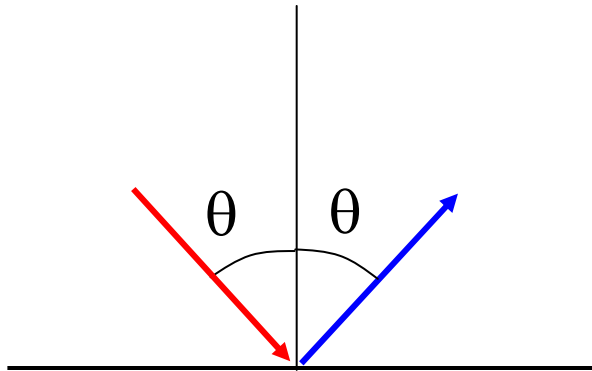


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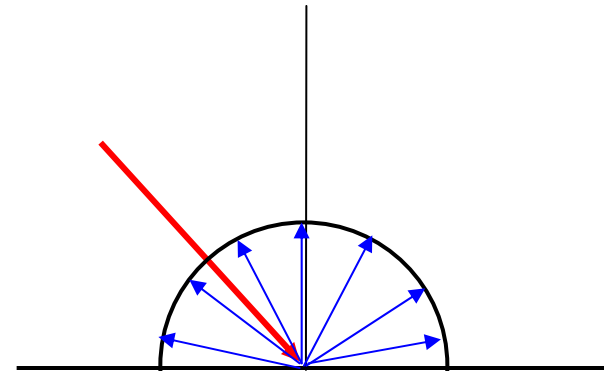
Modeling Approach

- Analyze two different types of reflection



Specular
Reflection

(polished surfaces;
e.g., mirrors)

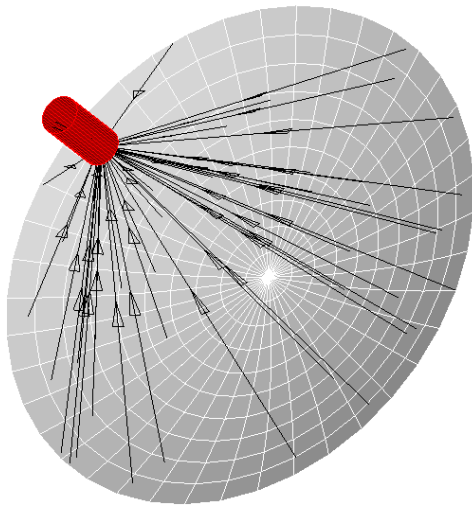


Diffuse
Reflection

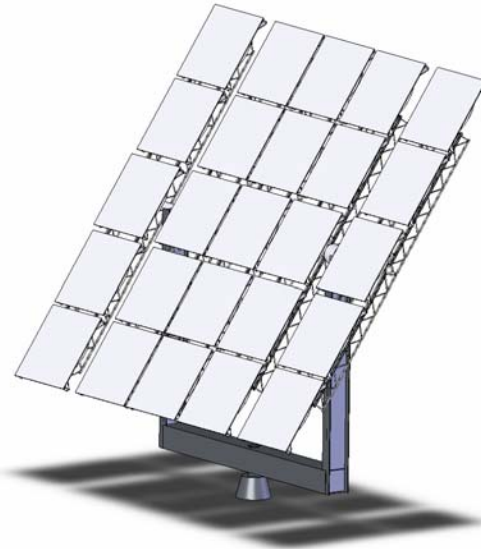
(rough surfaces;
e.g., receivers)

Specular Reflections

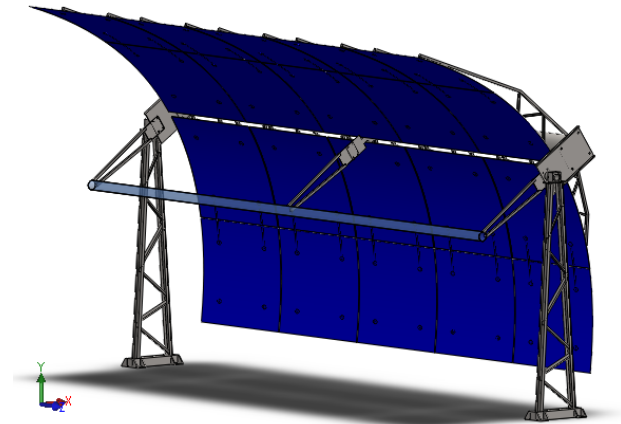
- Point Focus and Line Focus Collectors



Dish



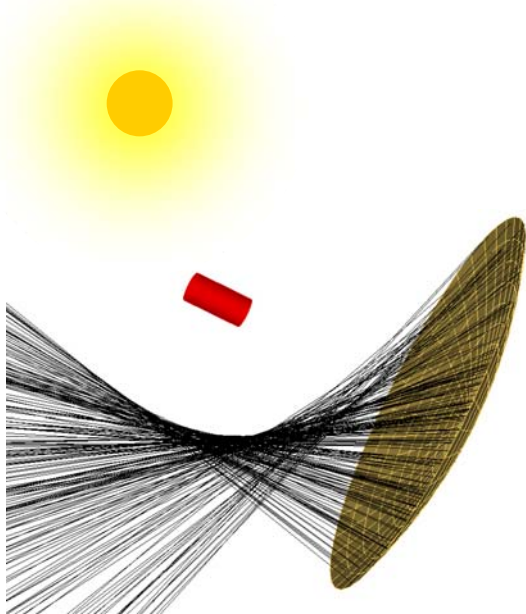
Heliostat



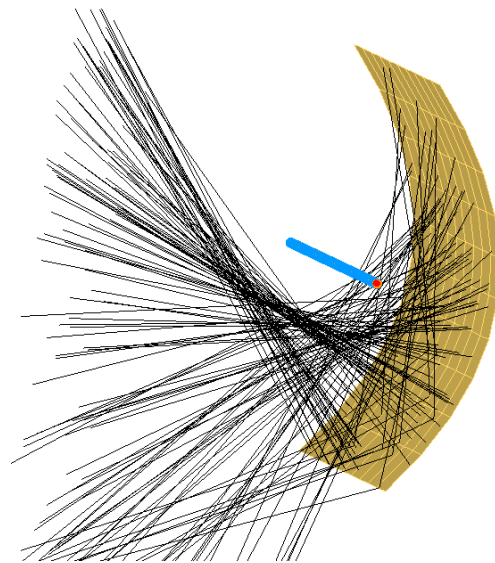
Parabolic Trough

Specular Reflections

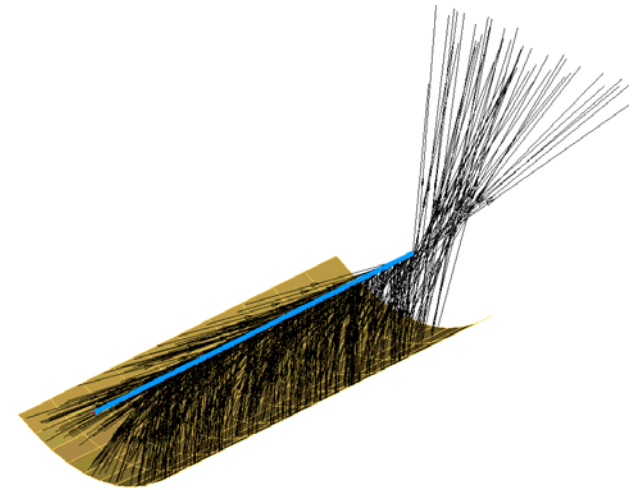
- **Potential for glint and glare from collectors**
 - Off-axis; misalignment; moving to or from stow
 - End-loss and spillage for troughs



Off-axis Dish



Off-axis Trough



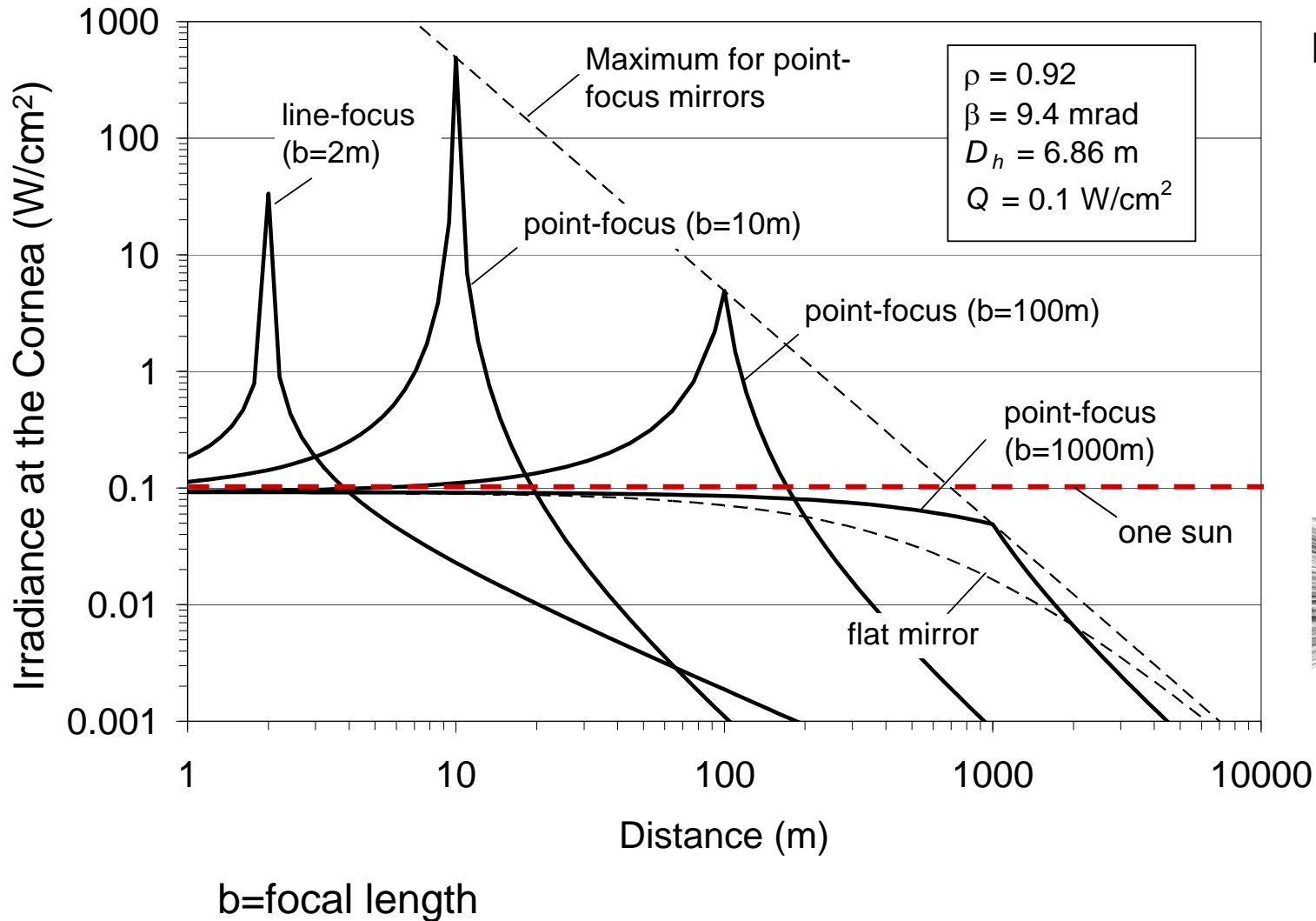
End-Loss from Trough



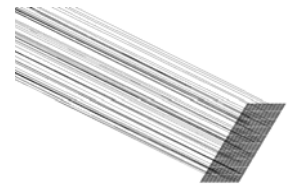
Analysis Steps

- **Calculate retinal irradiance using equations in paper for specular or diffuse reflections**
 - Collector optical properties, DNI, pupil diameter
- **Calculate subtended angle using equations in paper**
 - For diffuse reflections, source is given by size of receiver or reflecting source
 - For specular reflections, use equations
- **Identify potential impact using plot of retinal irradiance vs. subtended source angle**

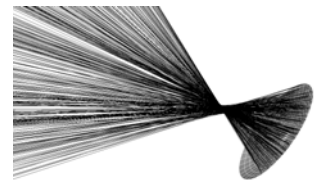
Specular Irradiance



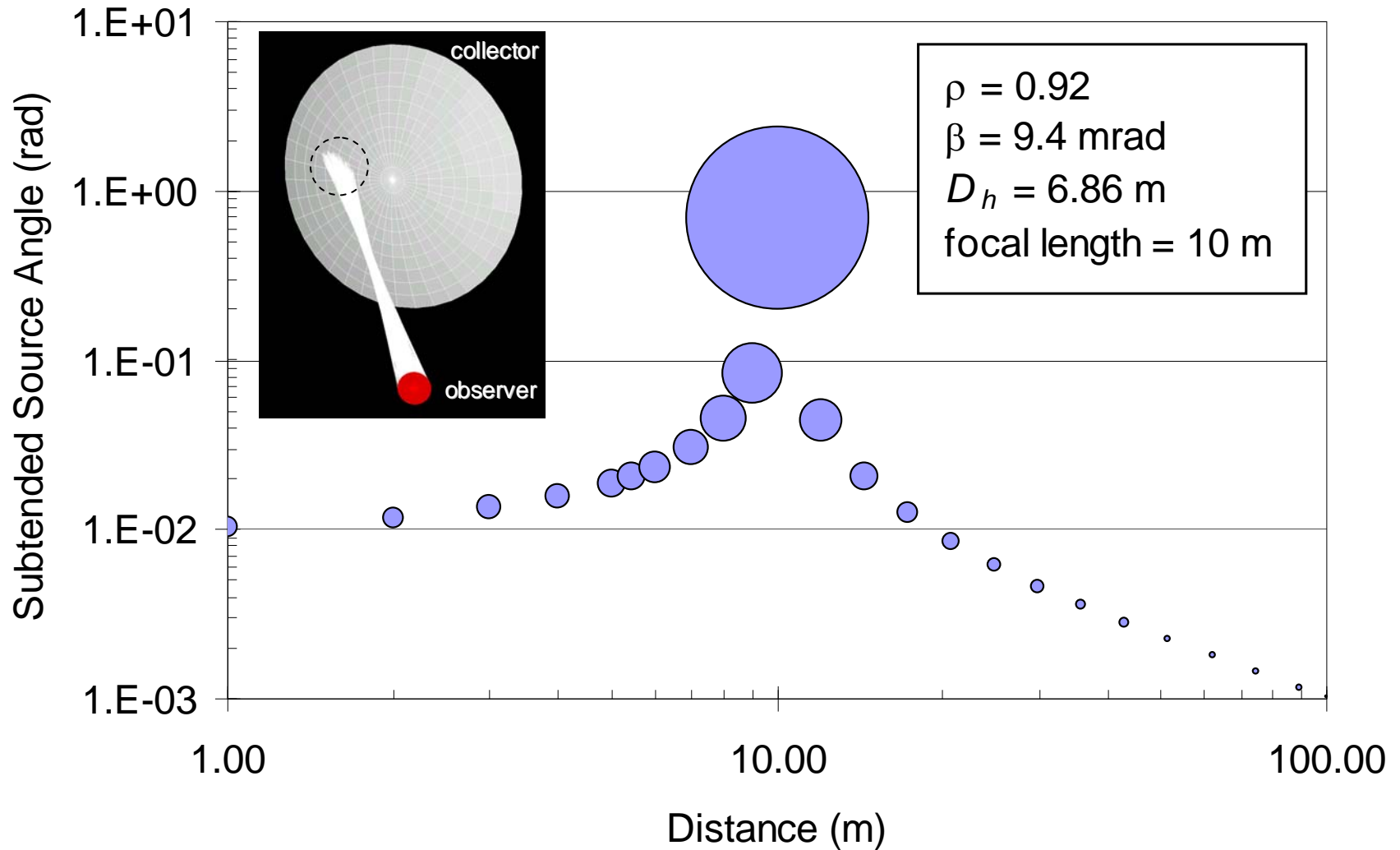
Flat Collector



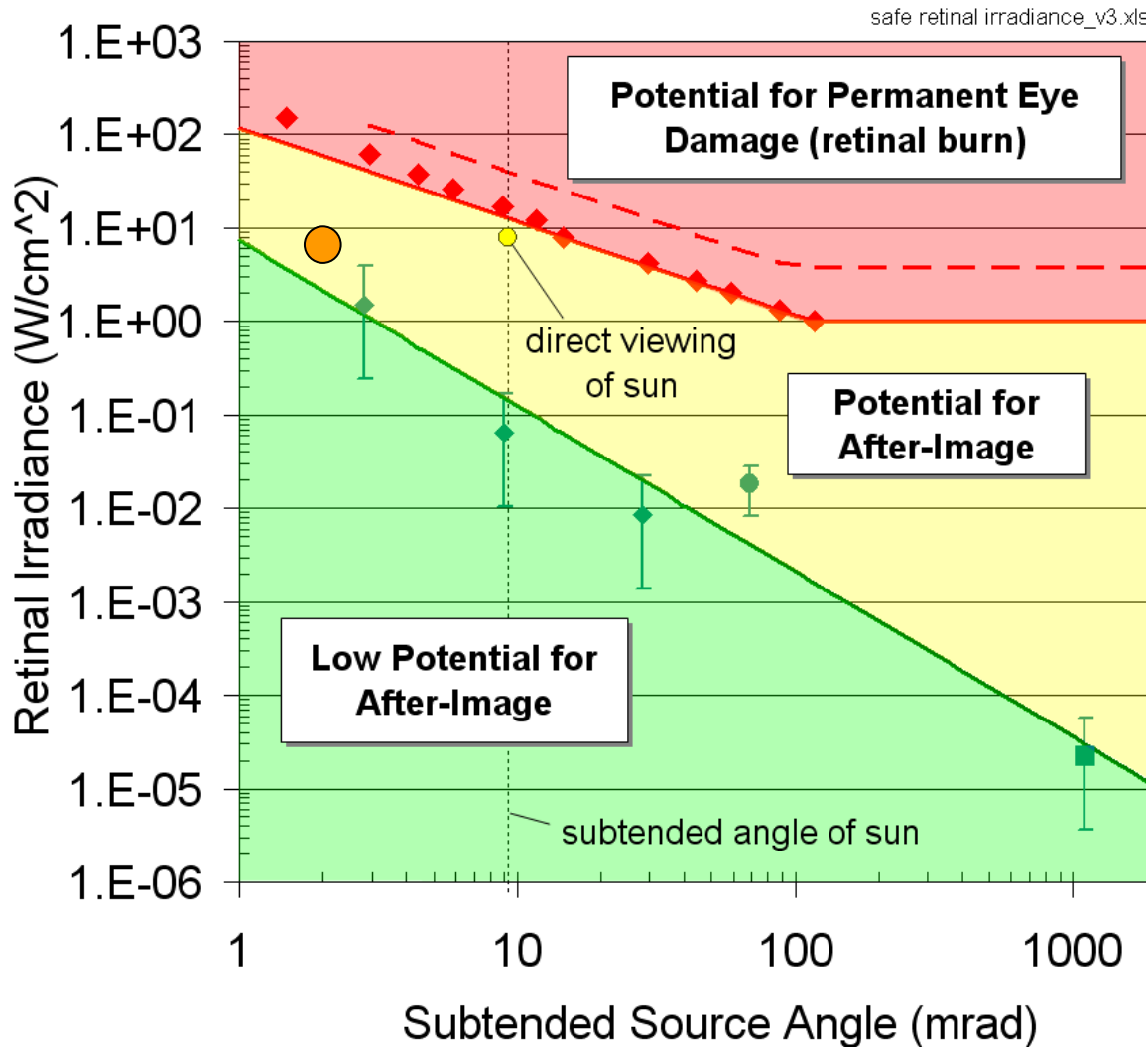
Focused Collector



Subtended Source Angle



Comparison to Safety Metrics



● $\rho = 0.92$

$\beta = 9.4$ mrad

$D_h = 6.86$ m

focal length = 10 m

50 m viewing distance

⇒ Retinal irradiance = $7 W/cm^2$

⇒ Subtended source angle ~ 2 mrad



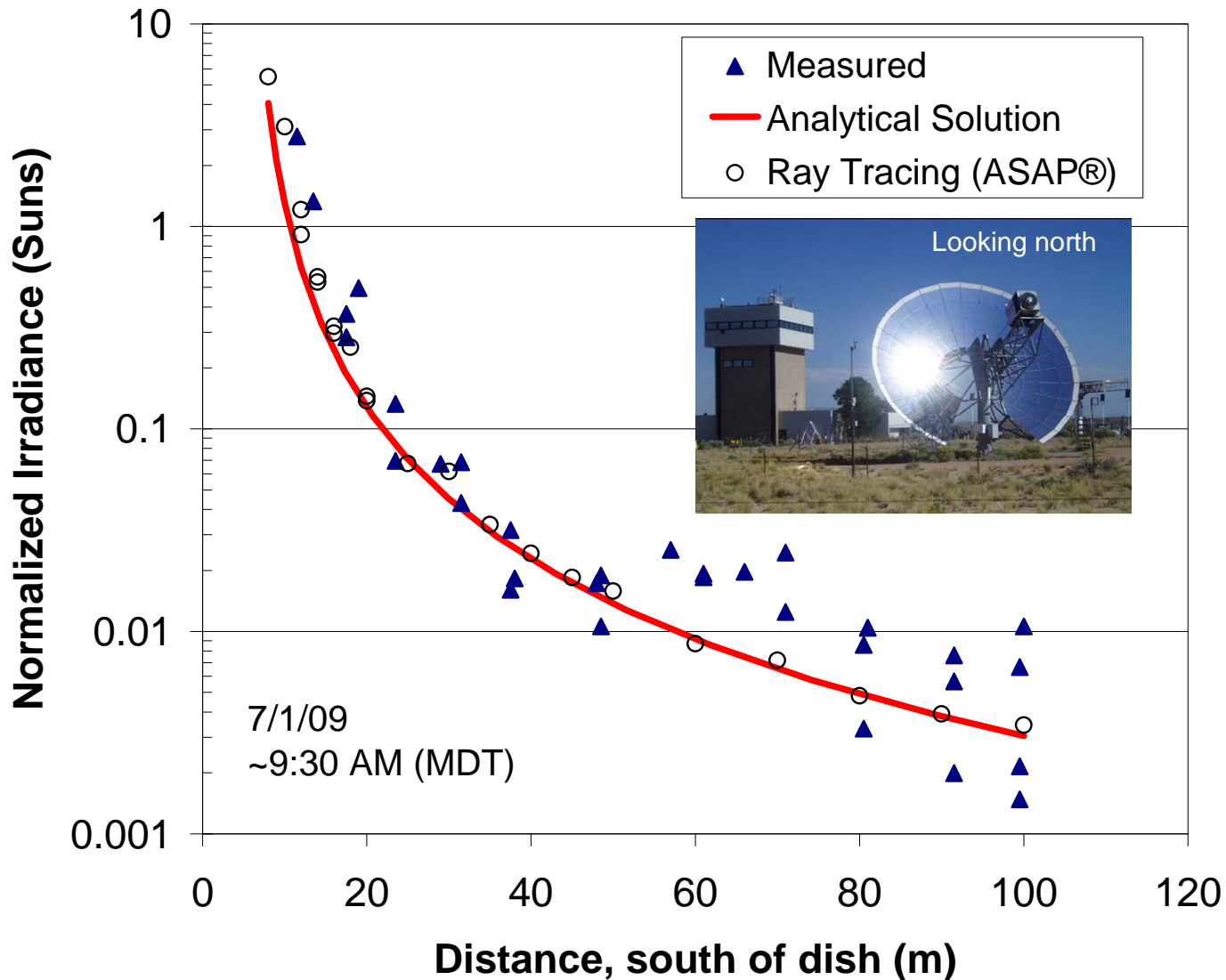
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Specular Reflection Testing



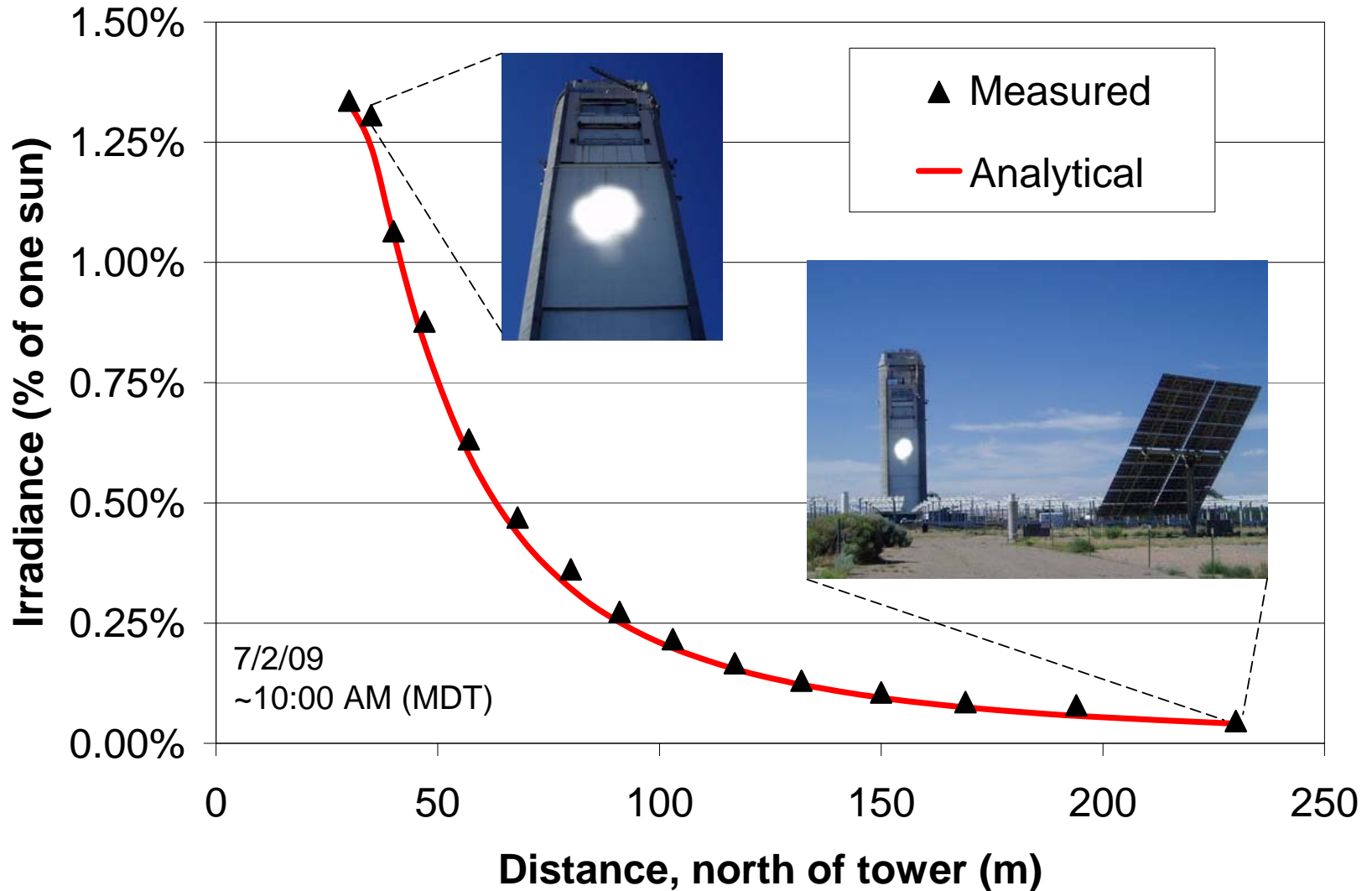
Specular Reflection Validation



Diffuse Reflection Testing



Diffuse Reflection Validation





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Summary

- **Glint and Glare can cause unwanted visual impacts**
- **Analytical models have been developed to quantify glint and glare**
 - Specular reflections
 - Point-focus and line-focus
 - Diffuse reflections
- **Safety metrics have been compiled**
 - Plot of retinal irradiance vs. subtended source angle can be used to assess potential impact of quantified glint/glare
- **Models have been validated with test data**



Ongoing Work

- **Reduce uncertainties associated with glint/glare for permitting and certification of solar power systems**
 - Transportation Research Board
 - Synthesis Report on “Investigating Safety Impacts of Energy Technologies on Airports and Aviation”
 - California Energy Commission
 - Military
 - Industry
- **Develop web-based tool for glint/glare analysis**