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FINITE ELEMENT MODELING AND RAY TRACING OF PARABOLIC TROUGH COLLECTORS FOR EVALUATION OF OPTICAL INTERCEPT FACTORS WITH GRAVITY LOADING

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Overview

- Introduction
- Finite Element Analysis
- Ray Tracing
- Conclusions and Future Work

LS-2 Introduction

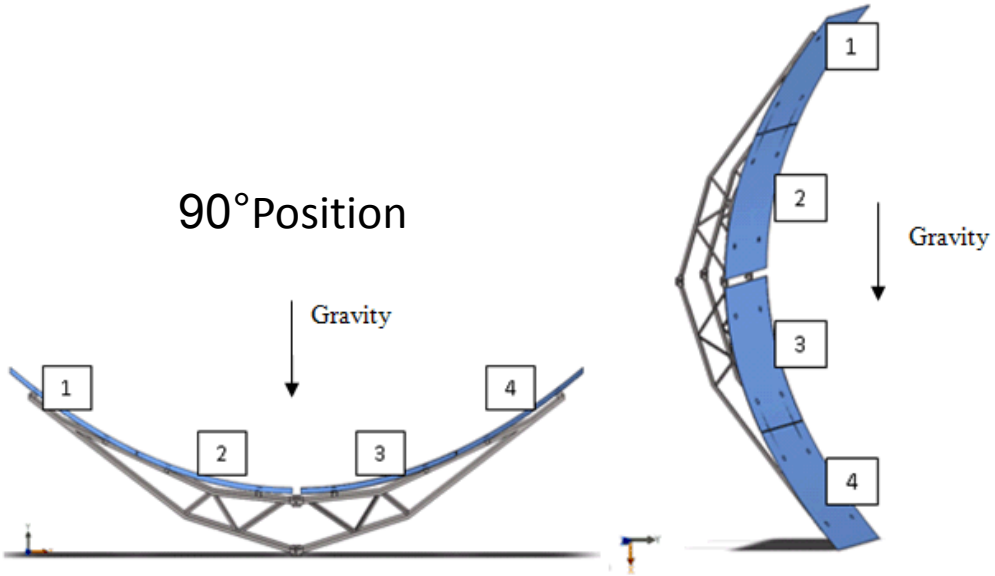


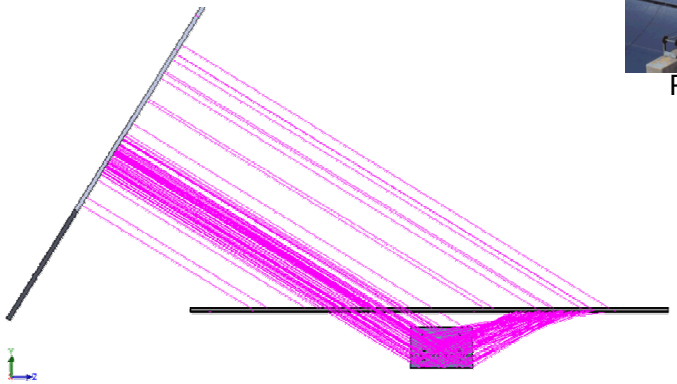
Photo courtesy of NSTTF photo database

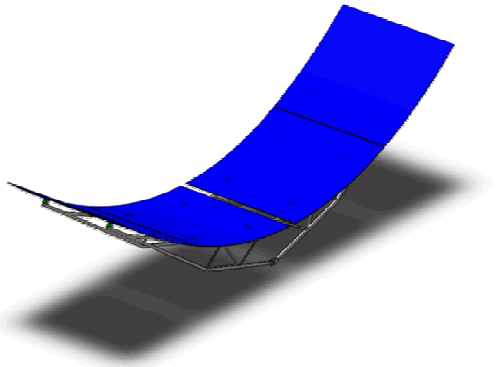
LS-2 parabolic trough (LUZ Industries)

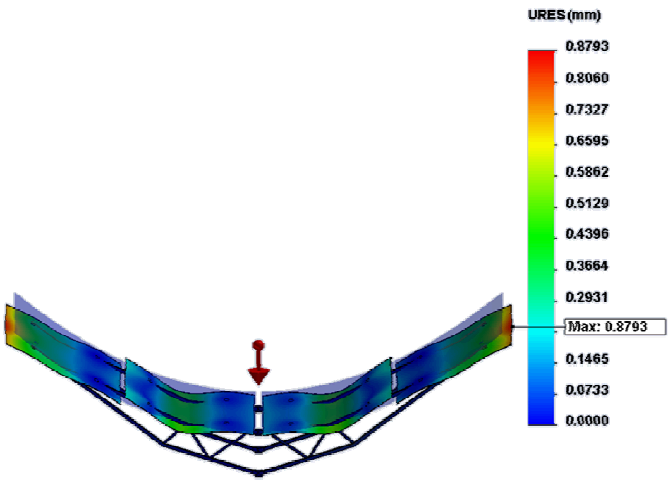
- Mirror aperture = 5 m
- Focal length = 1.49 m
- Five mirror columns on single module

Procedure

Photo courtesy of NSTTF photo database







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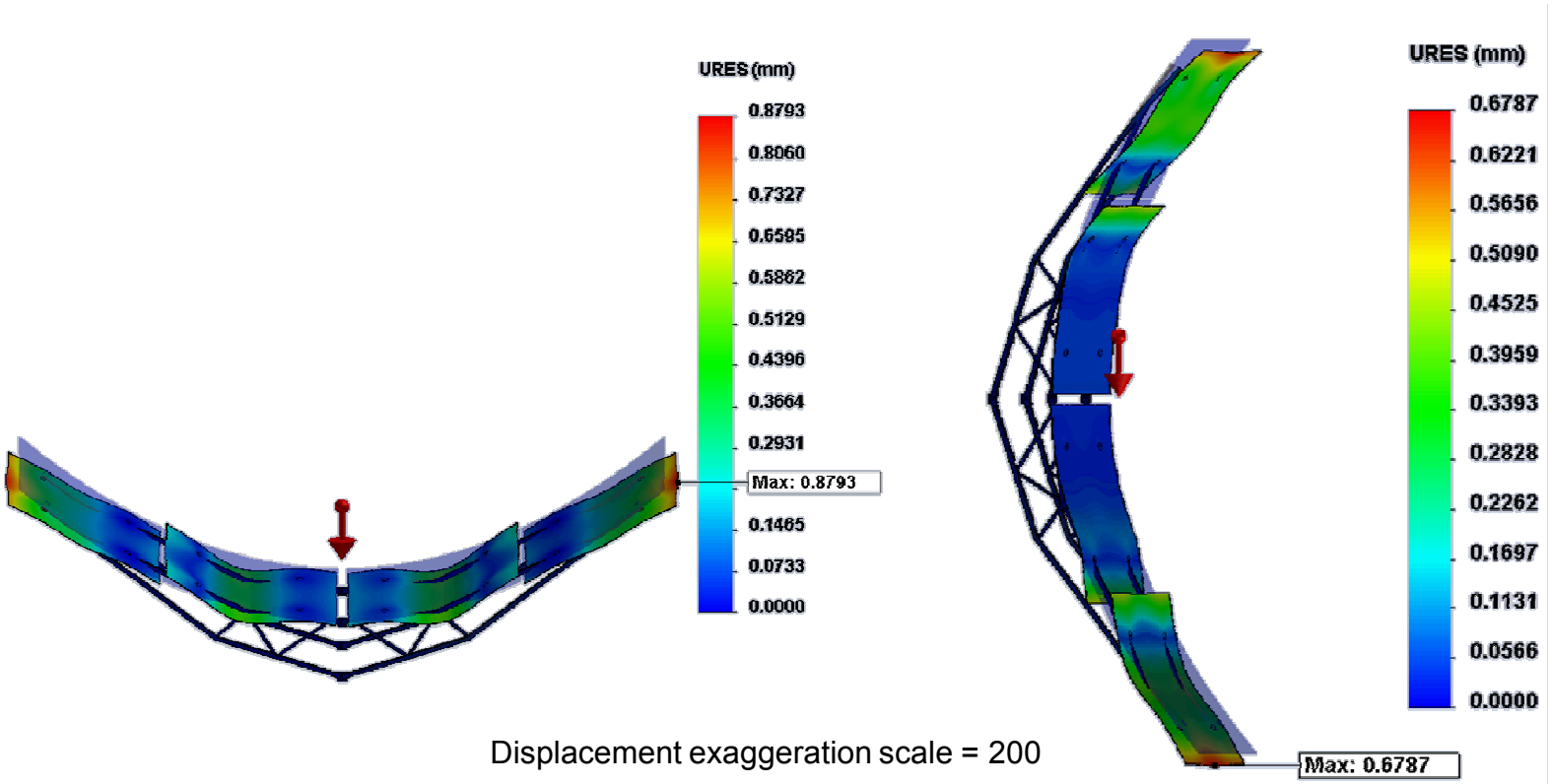
LS-2 Analysis: Predicting Deformation

- 90 degree position
- Max displacement = 0.9 mm
- 0 degree position
- Max displacement = 0.7 mm



Displacement exaggeration scale = 200

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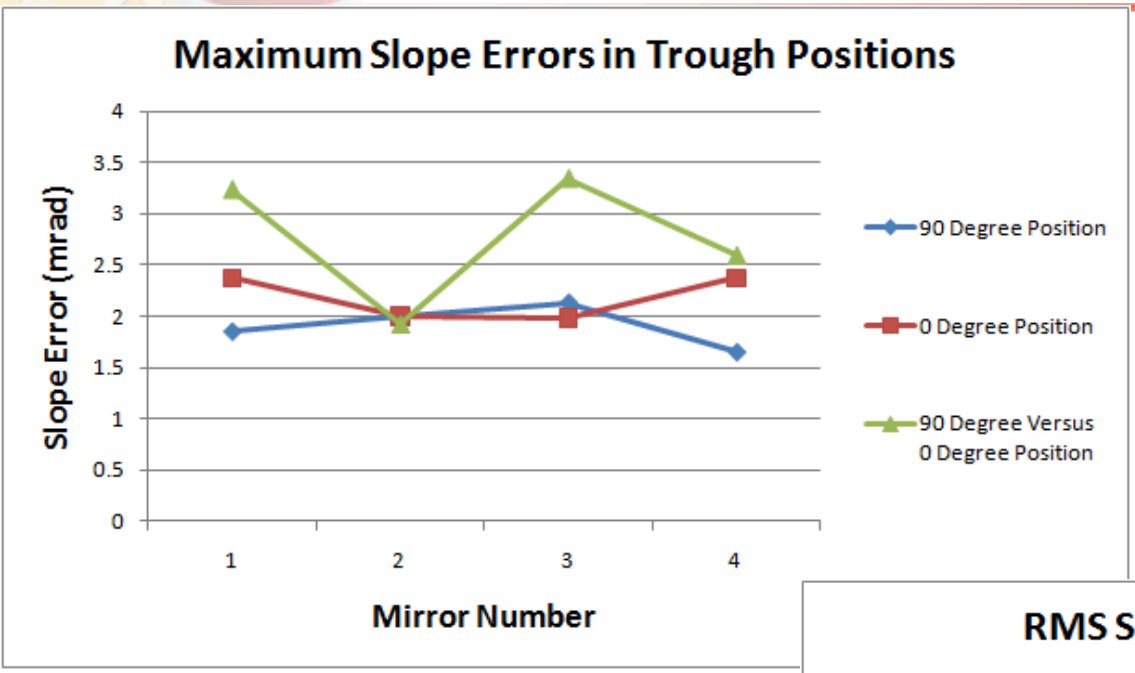
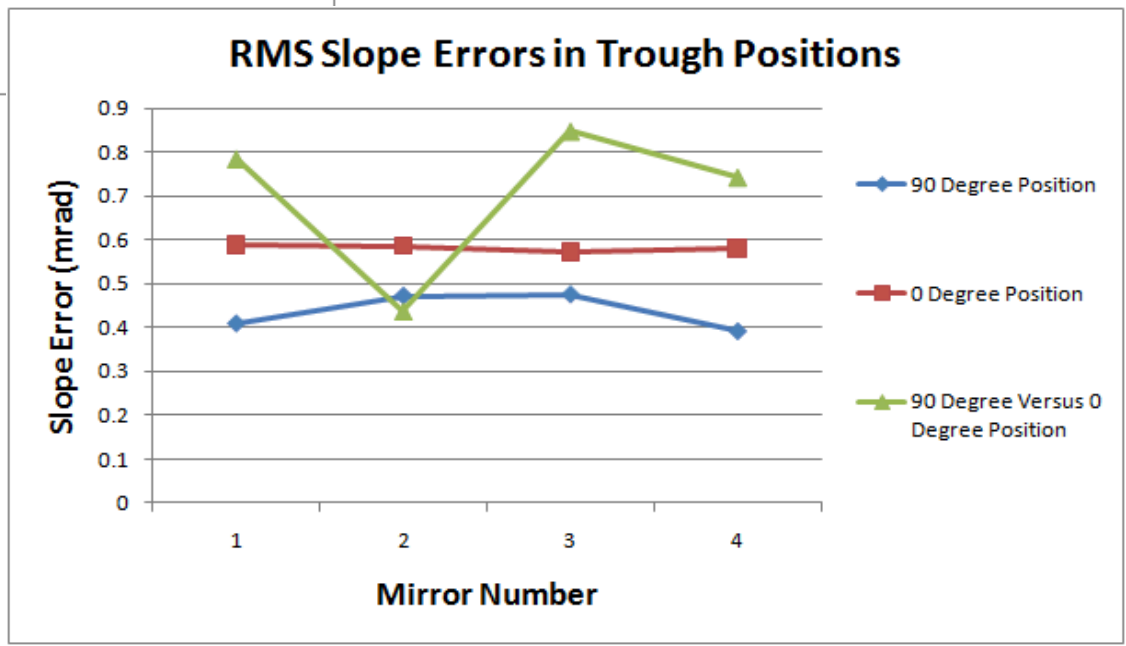
Slope Errors





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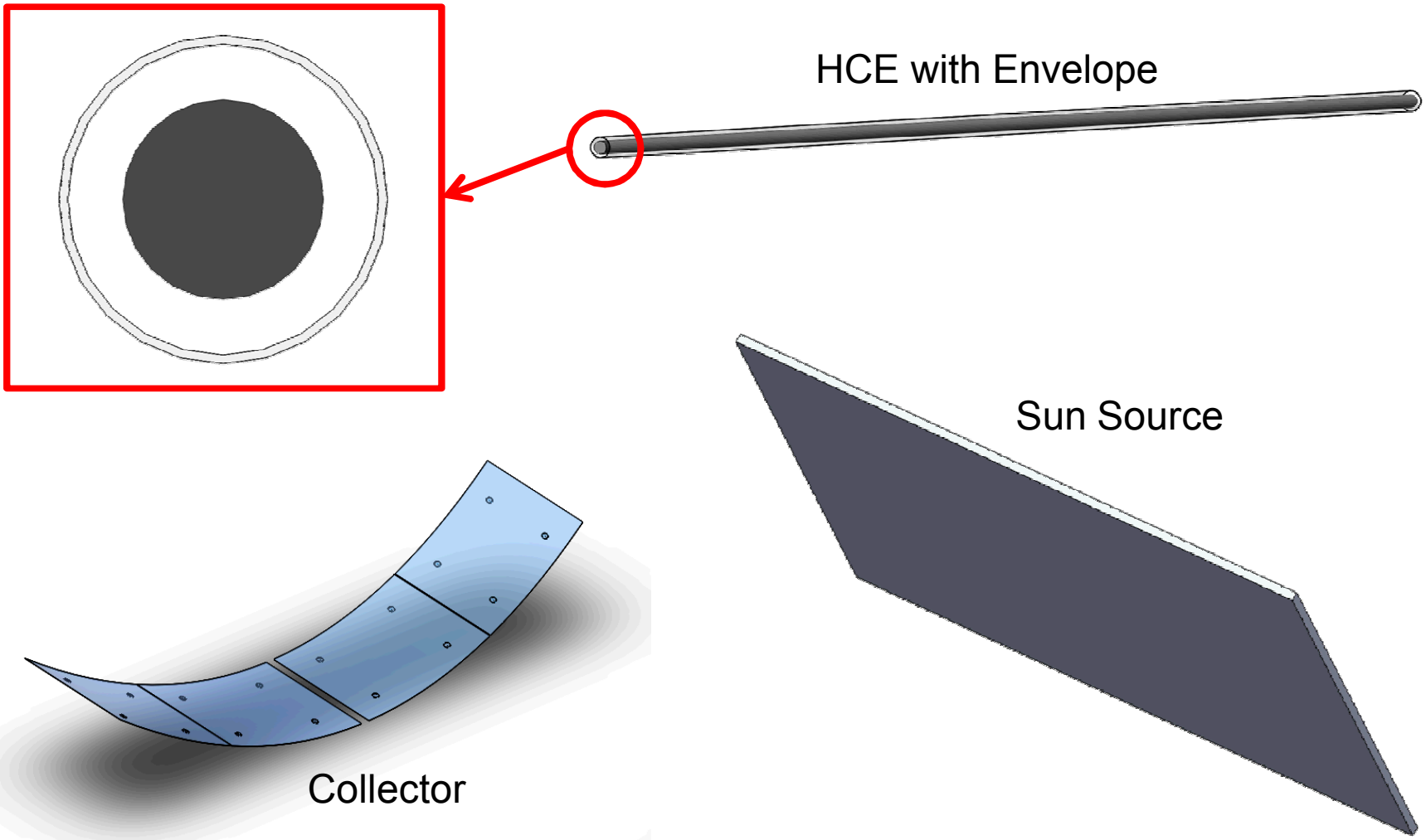
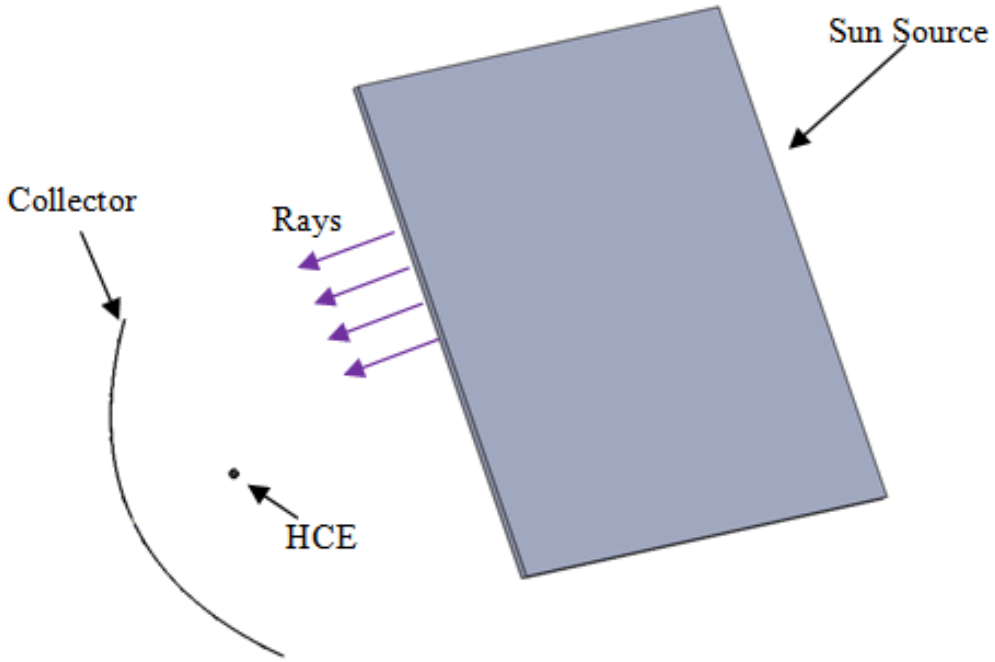
Ray Trace Modeling Components



LS-2 Analysis: Optical Performance



HCE and Envelope

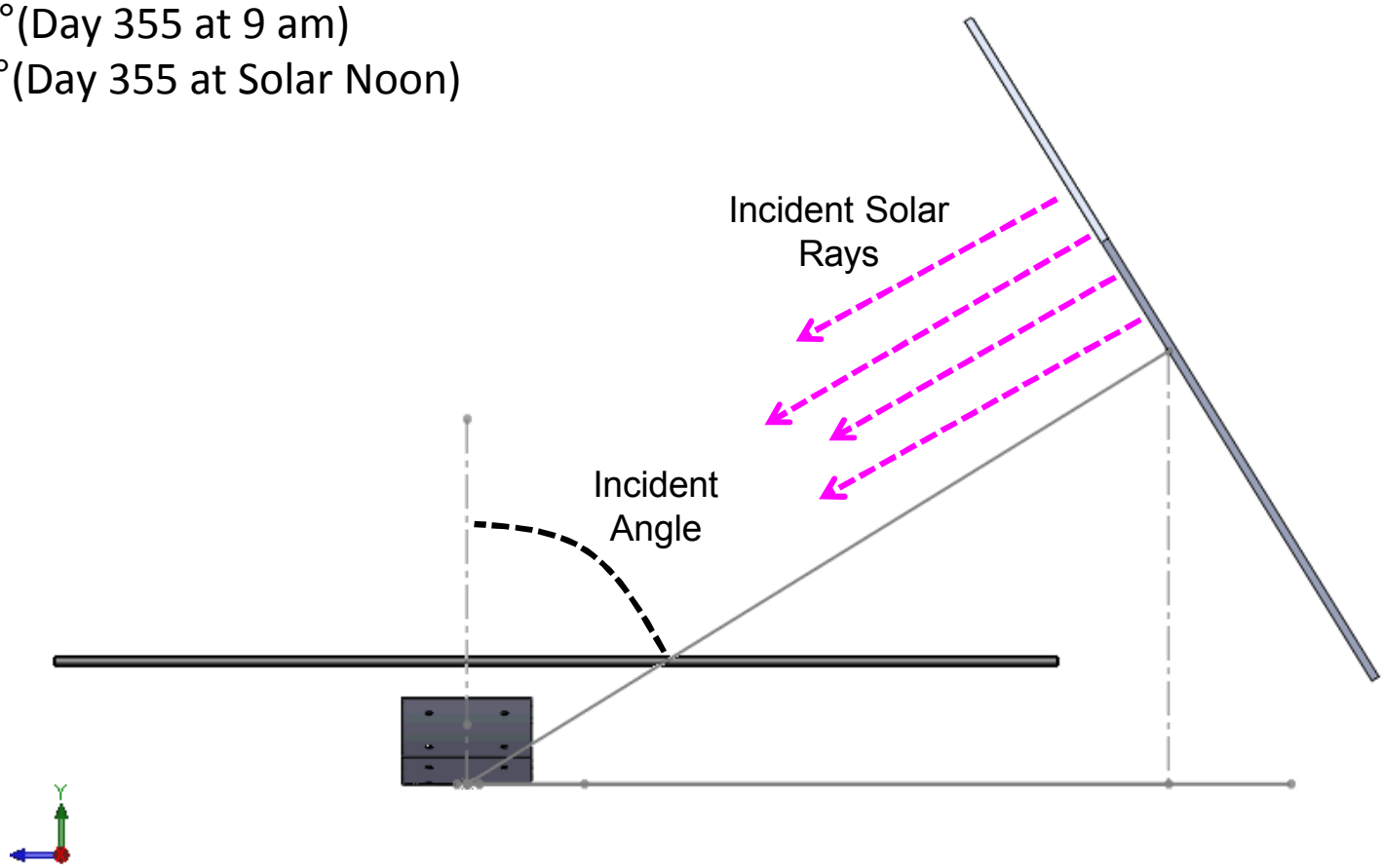
- Glass envelope medium: Schott N-BK7 (η=1.5168)
- Schott PTR-70
- HCE is 70mm

Sun Source

- Sun cone angle ~0.55°
- Direct normal irradiance (DNI) of 1000 W/m^2
- Initially emits 100,000 rays
- Scattering surface scatters each ray into 10 children rays

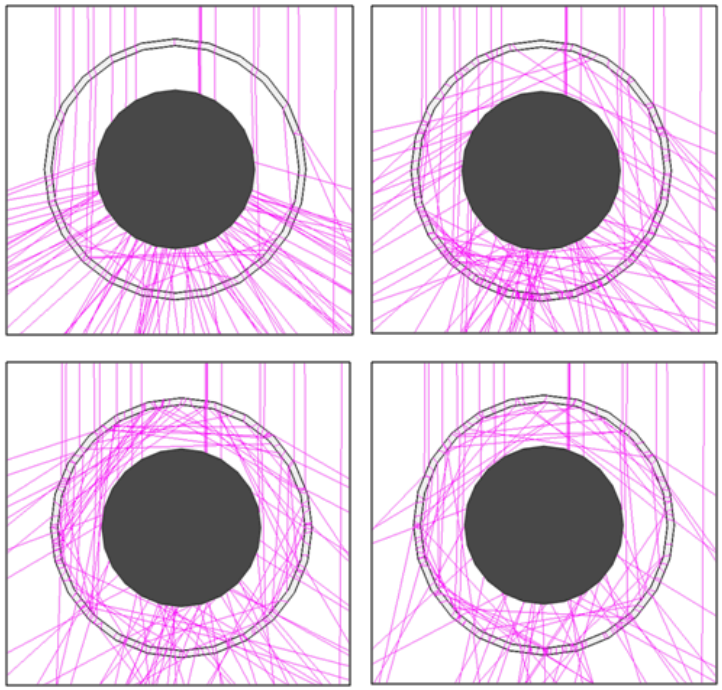
Solar Incident Angles

- 44.22°(Day 355 at 9 am)
- 58.32°(Day 355 at Solar Noon)

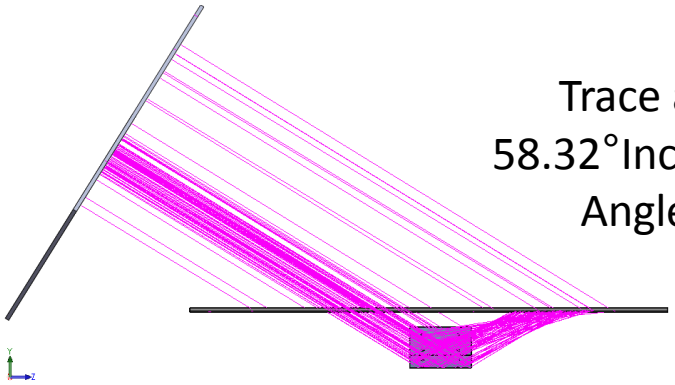


LS-2 Analysis: Optical Performance

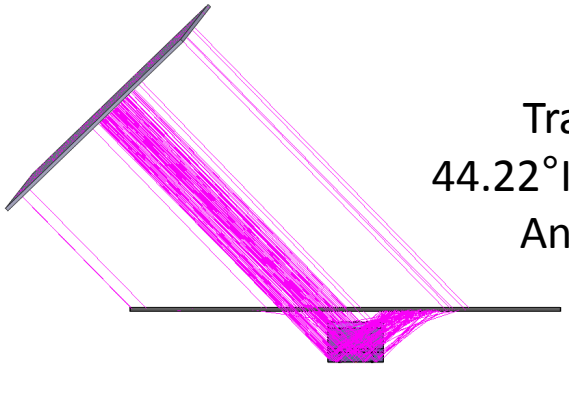
$$Intercept\ Factor = \frac{Power\ from\ the\ collector\ hitting\ the\ receiver}{Total\ power\ from\ the\ collector}$$



(Top Left) 0 mrad additional slope error;
(Top Right) 5.23 mrad additional slope error;
(Bottom Left) 10.47 mrad additional slope error;
(Bottom Right) 17.44 mrad additional slope error



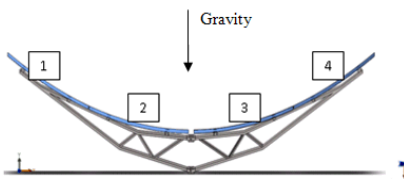
Trace at 58.32°Incident Angle

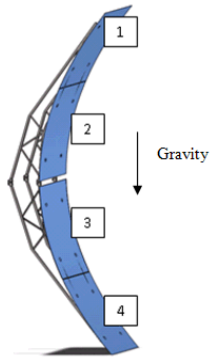


Trace 44.22°Incident Angle

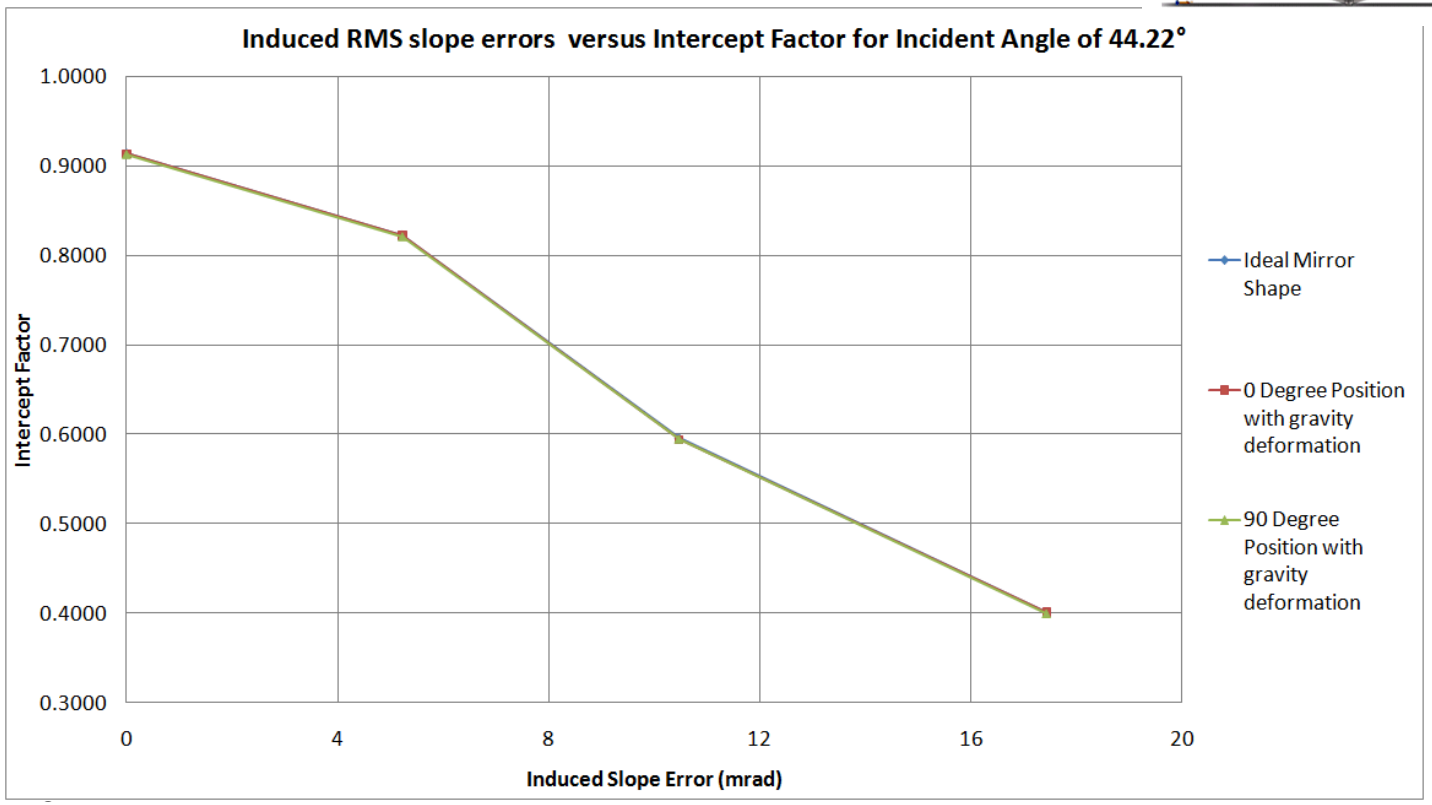
Intercept Factors at 44.22°

90°Position





0°Position



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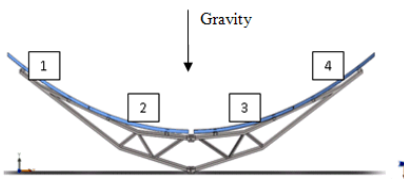
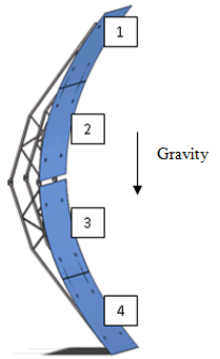
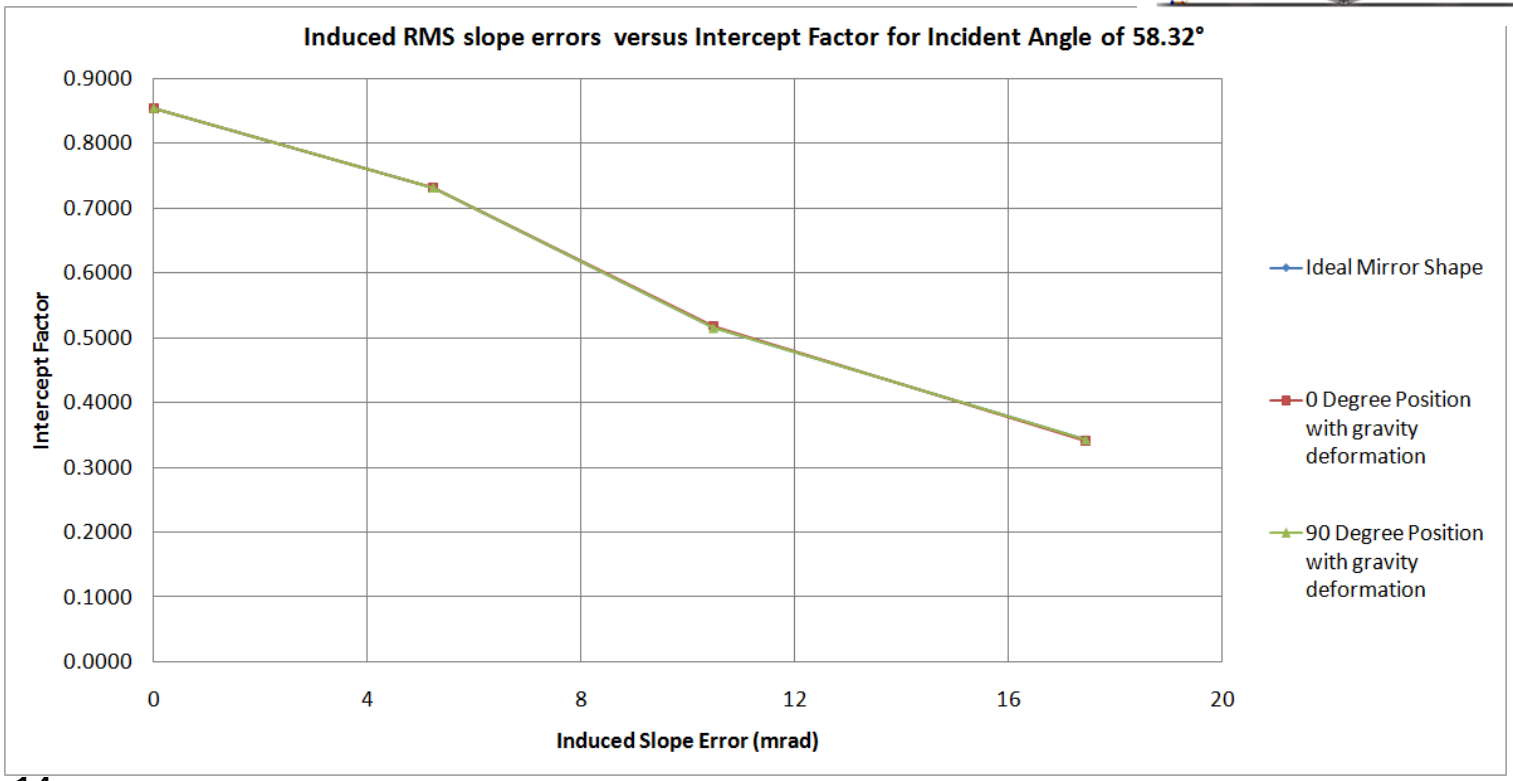
Intercept Factors at 58.32°

90°Position





0°Position



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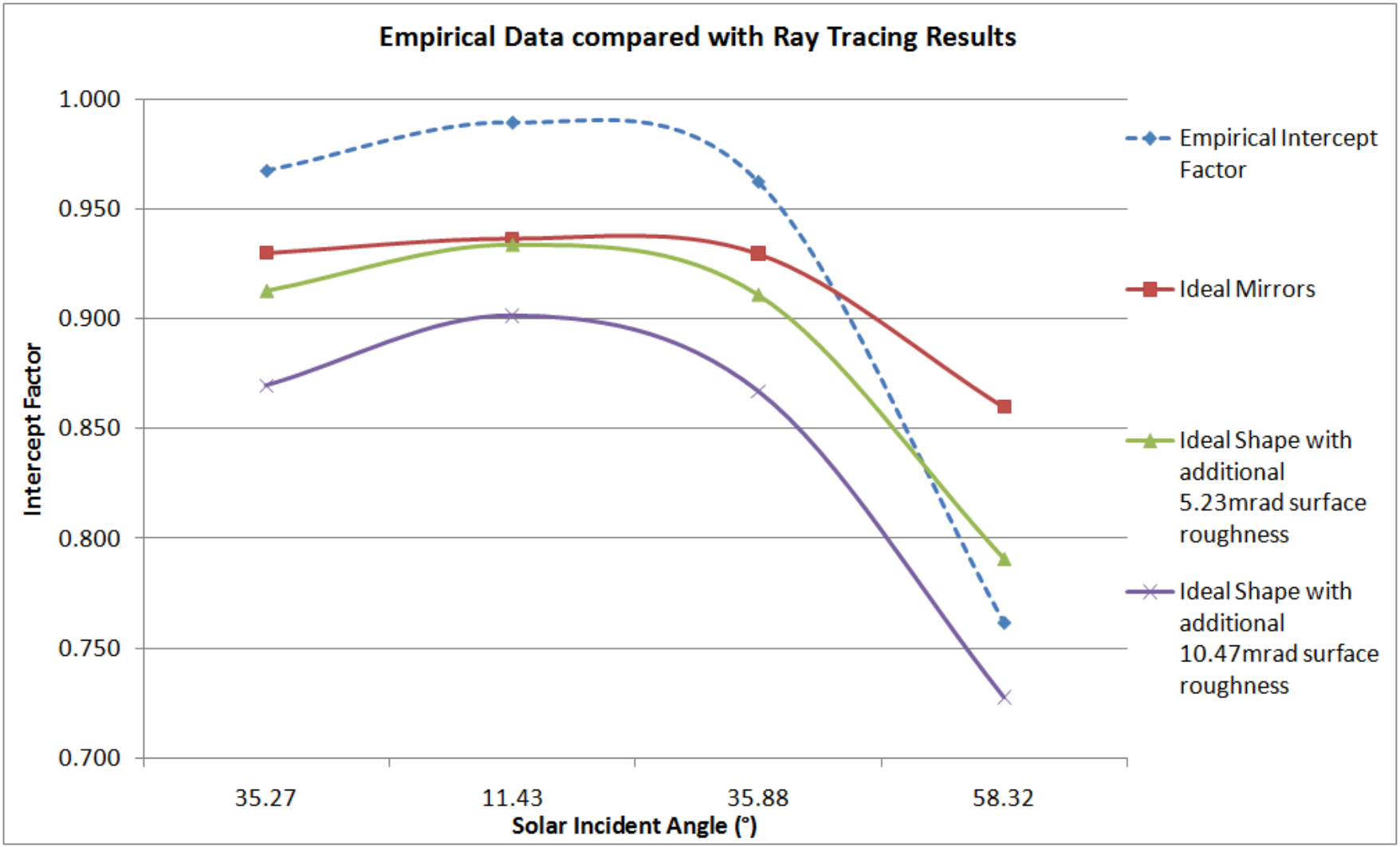
Empirical Data Comparison



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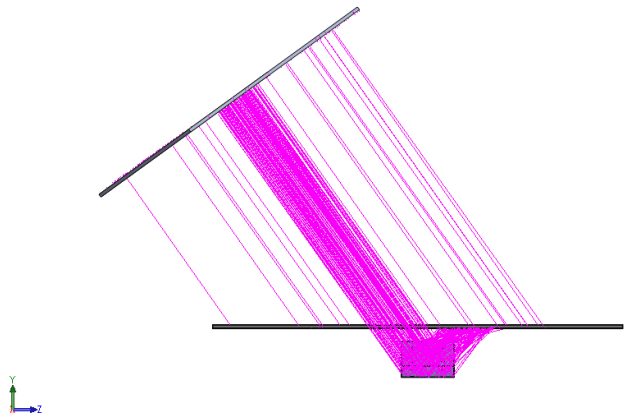
Conclusions

- **Ray tracing has been combined with FEA to evaluate the optical performance of a trough module under gravity loads**
- **Simulated intercept factors were not impacted significantly by gravity**
  - However, structural/gravity impacts of torque tube and pylons were not included
- **Reflectivity of the envelope is crucial in the ray-tracing process**

Future Work

- **Expand analysis to a full trough collector module**
- **Evaluate impacts of wind loading on optical performance**



Questions