Irradiance Modelling Using LightTools A Ray Tracing Technique

TRAINING SCHOOL III SIMULATION TOOLS AND MODELS FOR THE ANALYSIS OF PV SYSTEM PERFORMANCE BRASOV, ROMANIA, 07/07/2021

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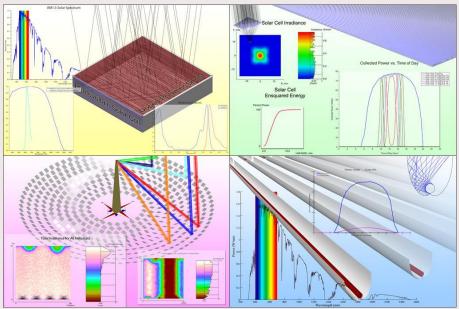
Department of Mechanical Engineering, Energy Technology

Outline

- Why use LT
- How LT work
- Solar simulation in LT
 - Basic solar panel model
 - One day scan
 - Yearly calculation
- Example and exercise

Why use LightTools

LightTools is a complete optical design and analysis software, Through Monte Carlo ray tracing, LightTools can simulate the optical performance of photovoltaic systems, especially when irradiances need to penetrate the cover layer or transmission in the light guide material (such as LSC). Moreover, with the Solar Tracker tool, LightTools can also perform one-day or full-year simulation calculations on the photovoltaic system based on the illumination data.



 $https://www.synopsys.com/optical-solutions/lighttools/application-gallery.html {\solar} solutions/lighttools/application-gallery.html {\solar} solutions/lighttools/applications/lighttools/applications/lighttools/applications/lighttools/applications/lighttools/applications/lighttools/applications/lighttools/applications/lighttools/applications/lighttools/applications/lighttools/applications/l$

How LightTools work

- Monte Carlo ray-tracing
 - Light source

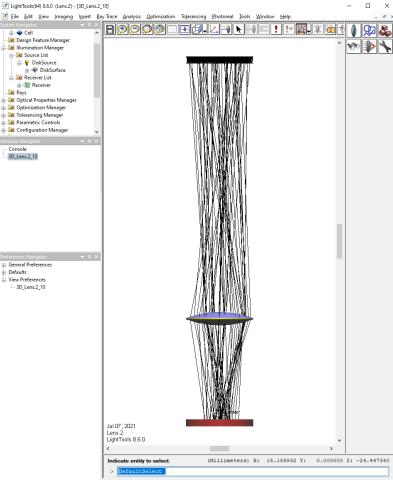
Direction, wavelength, illuminance...

• Optical system

Reflection, refraction, absorption...

• Receivers

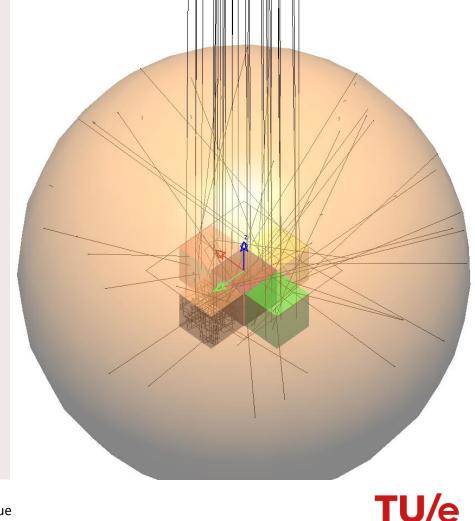
Collect data for analysis

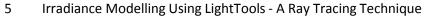




Solar system model in LightTools

- Light source
 - Solar source
 - Artificial light source
- Optical system
 - Solar cells
 - Light guide
 - Block (cover, shadow, et, al.)
- Receivers
 - Illuminance
 - Spectral distribution





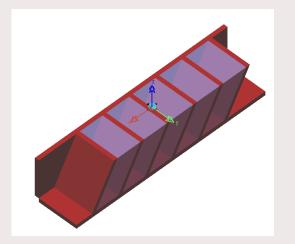
Light source

- Solar source
 - Direct light
 - Diffuse sky
- Artificial light source

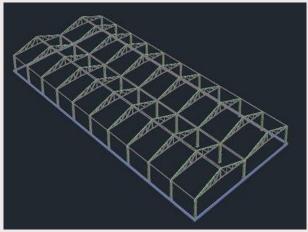
Solar Source Utility, Version 8.6.0.0	-		×
Help			
	3 🗳	C 🗾 📈	4
Setup View Insolation Data Tracking Options Other Options Summed	Source		
Direct Source Group Name Direct Sun			
Diffuse Source Name DiffuseSky	Ine	e Small Flux tead of Zero	
Data Default Meteonom (Full Year) ~	⊠ Wh Vis	en Sun is no ible	đ
Location Phoenix (USA) ~			
File Name C:\Program Files\Optical Research Associates\LightTools &			
Hour (decimal) 12 Reset Position Data If Present in Inse	olation D)ata	
Location PHOENIX (USA) Description		Set Values to	
Latitude 33.5 Longitude -112.	_	LightTools	
Timezone -7 Year 200	_		_
Month 5 Day	30	Get Values From LightTools	
Use Characteristic Day January 17th	~	Light i oois	
Output Diagnostics			
LT Azimuth Direct Insolation (W/m^2)			
LT ETZenith Direct Source Aim Area			
Sunrise Hour Direct Source Flux			
Sunset Hour Diffuse Insolation (W/m^2)			
Diffuse Source Aim Area			
System Units Diffuse Source Flux			

Optical system

- Drawing in LightTools
- Import CAD model



- Material
- Optical properties



https://designscad.com/downloads/greenhouse-workshop-20x50-3d-dwg-model-autocad/

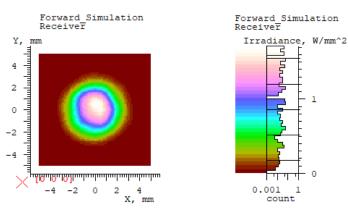
Receiver

- Illuminance
 - Mesh Dimensions illuminance display (lens, solar concentrator)
 - Mesh Result

Received power

(Optical efficiency, Power conversion efficiency)

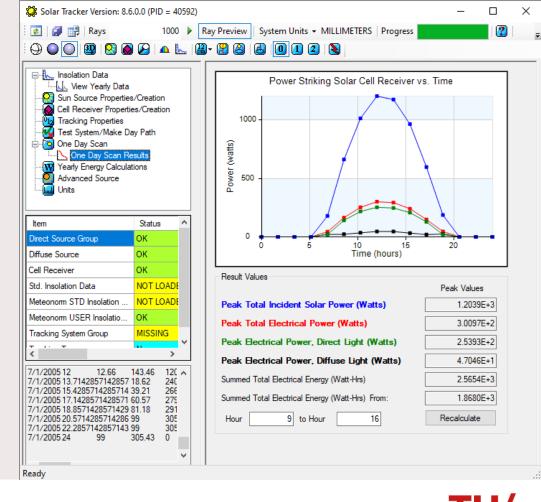
- Spectral distribution
 - Accurate received spectrum
 - Calculation with QE (Quantum Efficiency)





Solar tracker

- One day scan
 - Solar source data
 - 10 different locations
 - 2005 whole year data
 - Including direct light and diffuse light
 - Customized cell efficiency



Solar tracker

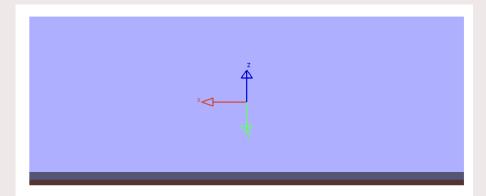
 Yearly energy calculation Using whole year solar data to simulate the performance of the solar system.

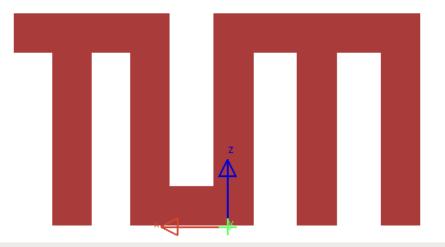
🔯 Solar Tracker Version: 8.6.0.0 (PID = 40592) — 🗆 🔿	
👔 😰 🔐 Rays 1000 🕨 Ray Preview System Units 🗸 MILLIMETERS Progress 🛛 👔	
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Insolation Data Wew Yearly Data Sun Source Properties/Creation Cell Receiver Properties/Creation Tracking Properties Tracking Properties Tracking Properties Test System/Make Day Path One Day Scan One Day Scan Results Fixed, Tilted Advanced Source Units	
Item Status	
Direct Source Group OK Use Full Year First Month 1 Last Month 6	
Diffuse Source OK Rays	
Cell Receiver OK Rays Per Source (Direct/Diffuse Traced Separately) 500	
Std. Insolation Data NOT LOADE Calculate Yearly Energy	
teonom STD Insolation NOT LOAD! Incident Yearly Energy 2684.81 KWatt-Hr Calculate	
Data File	
12 31 18 0 ^ 12 31 19 0 0 12 31 20 0 0 12 31 20 0 0 12 31 20 0 0 12 31 22 0 0 12 31 23 0 0 12 31 24 0 0 02:28:22: Calculations Completed.	
Ready	

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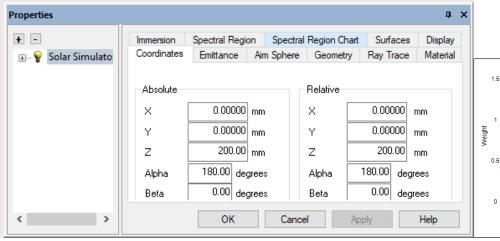
Example

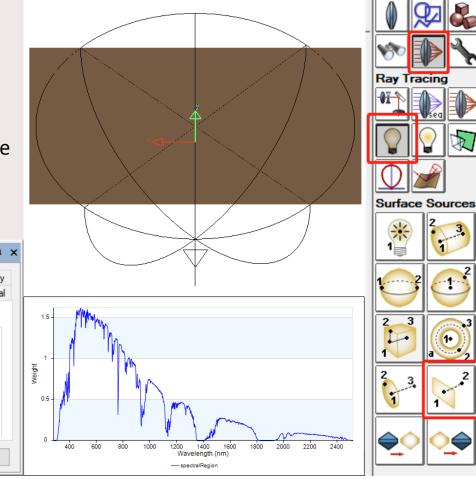
- PMMA covered silicon cell
- One day scan of a TUM logo solar panel in a sunny day (Show in LightTools)
- Yearly energy calculation of different angle solar panel in Seville (in exercise)



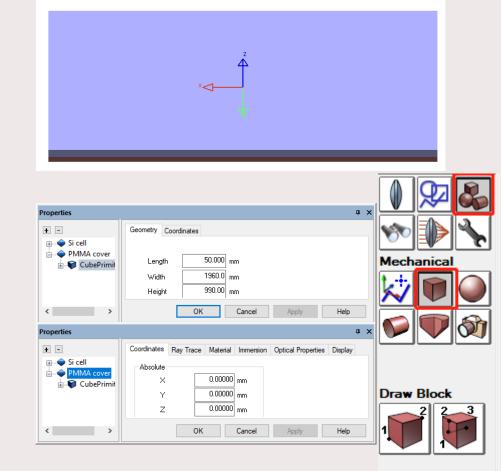


 Light source (Solar simulator) Ray Tracing > Surface Sources > RectSource Position, Size (geometry), Emittance, Spectral Region (Import)





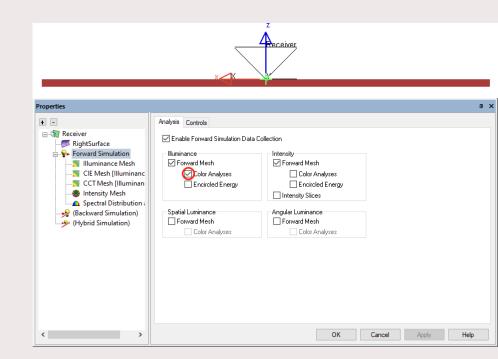
- Optical system
 - Silicon cell & PMMA cover Mechanical > Draw Block Size (geometry 1960*990*35), Position, Material
 - Optical properties PMMA: 95% Transmittance + 5% Reflectance Silicon cell: Mechanical Absorber



• Receiver

Right click > Add Surface Receiver Properties > Forward Simulation > Color Analyses (spectral distribution)

- Illuminance
- Spectral distribution



- Result
 - Running the simulation Ray Trace > Simulation Input Begin Forward Simulation
- Illuminance • Simulation Input + × Properties $\mu >$ Update Spectral Random Numbers + -Spectral Distribution Spectral Distribution Chart CRI CQS CQS Chart **Optical efficiency:** Forward ٠ Backward Hybrid Data Collection Ray Paths - Receiver 🍼 RightSurface 3.5 Enable Forward Simulation 1656 w Total Bays to Trace 100.000 Illuminance Mesh CIE Mesh [Illuminanc 100.000 Rays Currently Traced $1.9404m^2 \times 1000 w/m^2$ CCT Mesh Illuminan 2.5 0.010000 Relative Ray Power Threshold Intensity Mesh = 85.34%Spectral Distribution Lawod 15 Ray Analysis 📌 (Backward Simulation) (Hybrid Simulation) Show Preview Rays Spectral distribution Number of Rays for Preview and Region Analysis 1000 Show Ray Report 0.5 No Ray Paths will be collected. monume 0.13 seconds Last Simulation Time 400 600 800 1000 1200 1400 1600 2000 2200 2400 Wavelength (nm) - Spectral Distribution and CRI **Begin Forward Simulation** OK OK Cancel Help < > Cancel

Properties

+ -

<

- Receiver

🍼 RightSurface

Forward Simulation

(Hybrid Simulation)

Illuminance Mesh

CIE Mesh [Illuminanc

CCT Mesh [Illuminan]
Mesh Intensity Mesh

Spectral Distribution (Backward Simulation) Properties Mesh Results Beam Width Smoothing Mesh Data

1656.0 Watts

1656.0 Watts

0.00072841 W/mm^2 Contrast Ratio

Distribution Position and Extent

0.00098448 W/mm² Standard Deviation

0.00085332 W/mm^2 Average Deviation

Standard Deviation

Sigma X

Average

28,070

13.83 %

0.00000 Watts

0.14950

3.5337e-005

564.49 mm

OK

Cancel

0.041411

Clipped by Aperture

Error Estimate

Number of Samples

Total Power (Unsmoothed)

Statistics Based on Smoothed Mesh Data

1.0300 mm

At Peak

Incident

Absorbed

Irradiance Min

Max

Average

Centroid

×

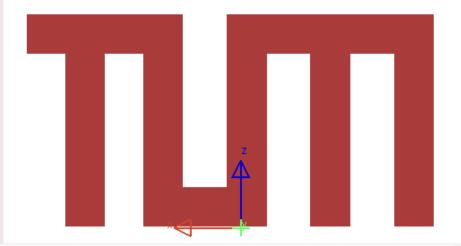
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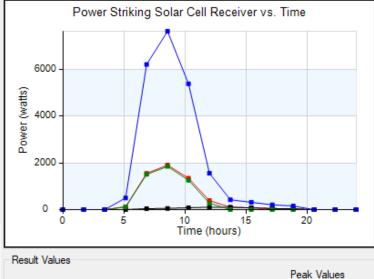
 $\mu >$

Help

TUM logo solar panel

- 3.06m x 5.88m
- Show in LightTools





Peak Total Incident Solar Power (Watts) 7.6387E+3 1.9097E+3 Peak Total Electrical Power (Watts) Peak Electrical Power, Direct Light (Watts) 1.8517E+3 1.0894E+2 Peak Electrical Power, Diffuse Light (Watts) Summed Total Electrical Energy (Watt-Hrs) 9.6110E+3 3.2972E+3 Summed Total Electrical Energy (Watt-Hrs) From: Recalculate Hour 9 to Hour 16

Thanks

Want to try LightTools? More example and exercise?

We can provide a trial account Please contact me <u>x.zhu@tue.nl</u>



