# End-to-end performance analysis of 3D printed luminescent devices for energy conversion applications


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Fall MRS

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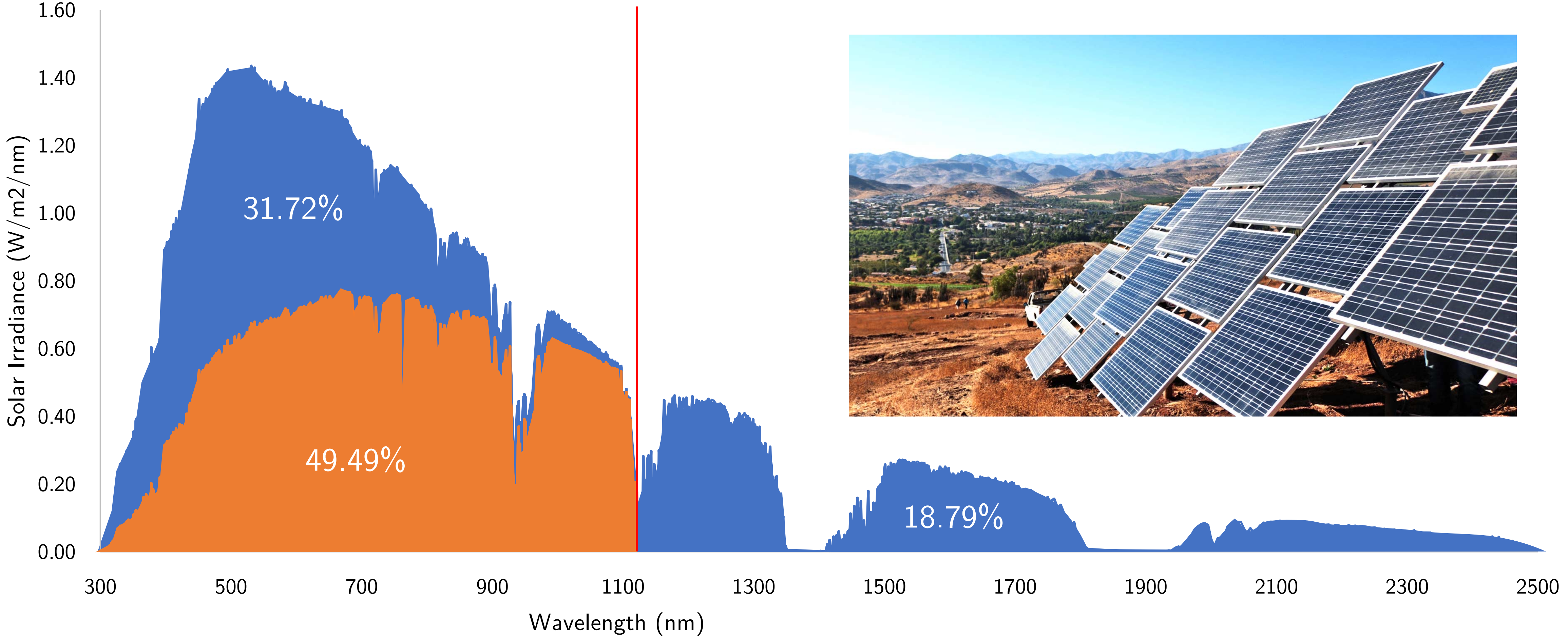
UNIVERSITY OF CAMBRIDGE

# Conventional solar devices have an efficiency limit

Solar Cell Shockley-Queisser Limit: Max efficiency = 32%



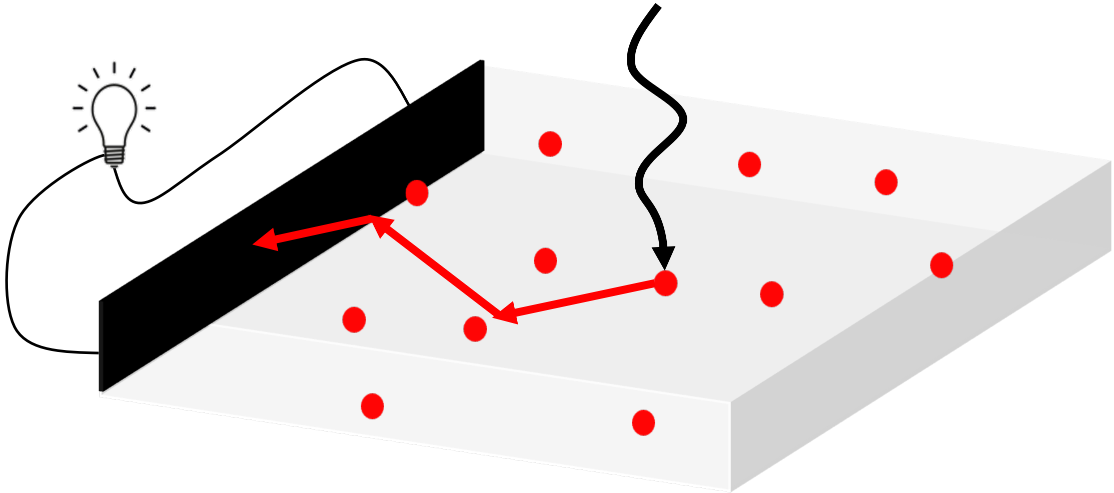



https://www.nrel.gov/grid/solar-resource/spectra.html

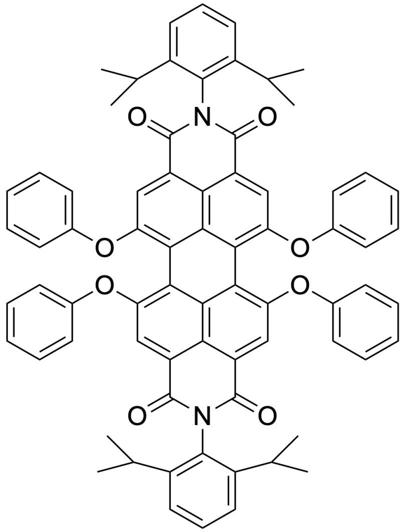
https://www.cleantechconcepts.com/2019/06/speeding-discovery-of-new-solar-cells-materials/

# Luminescent Solar Concentrators (LSCs) can help exceed this limit

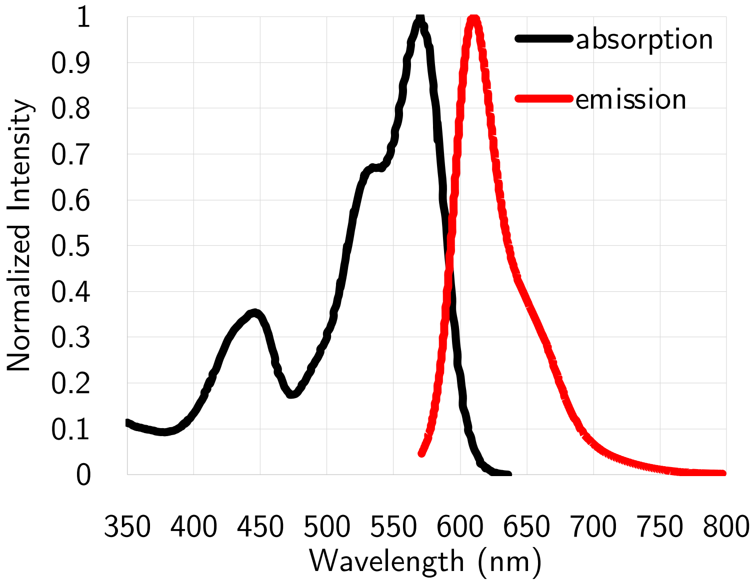
LSC Schematic

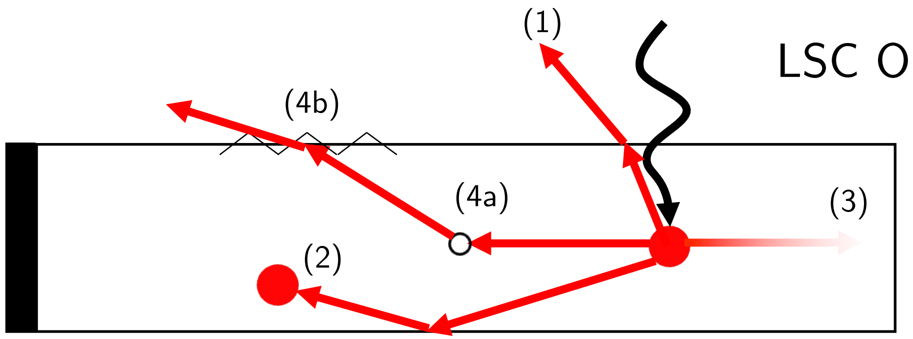


LR305



LR305 Optical Properties



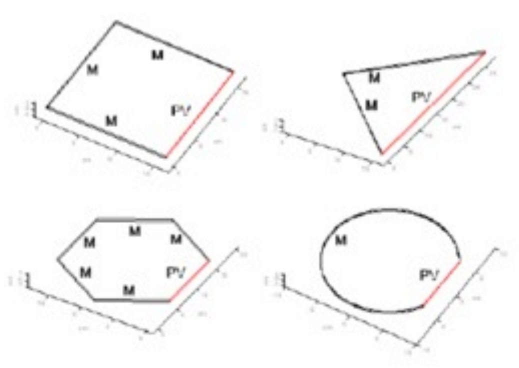




LSC Optical Loss Mechanisms

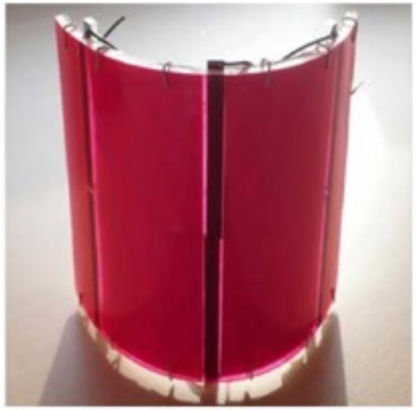
1. Escape cone
2. Reabsorption
3. Waveguide absorption
4. Waveguide/surface scattering

Image courtesy Guanpeng Lyu

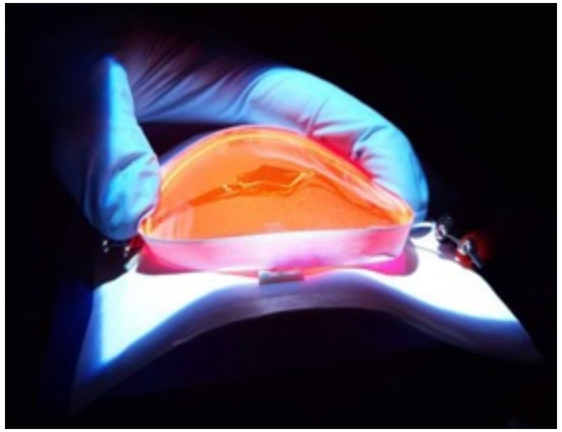
# Many device shapes and patterns have been investigated



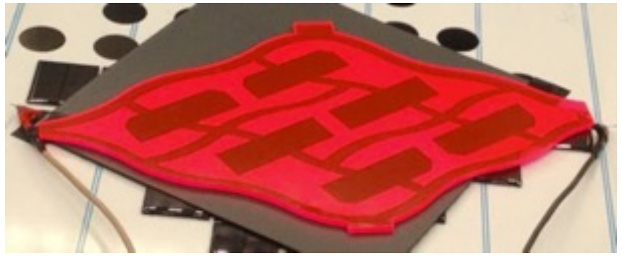
Kennedy et al. *ISES SWC* (2007)



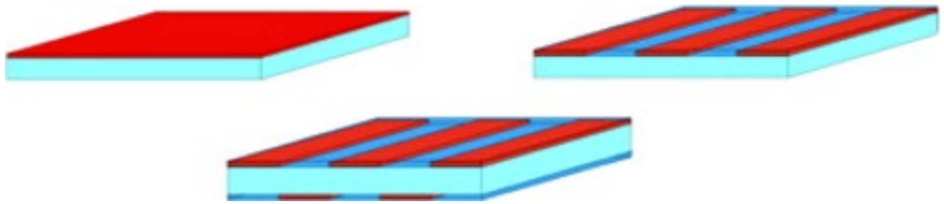
Viswanathan et al. *27$^{th}$ EU PSECE* (2012)



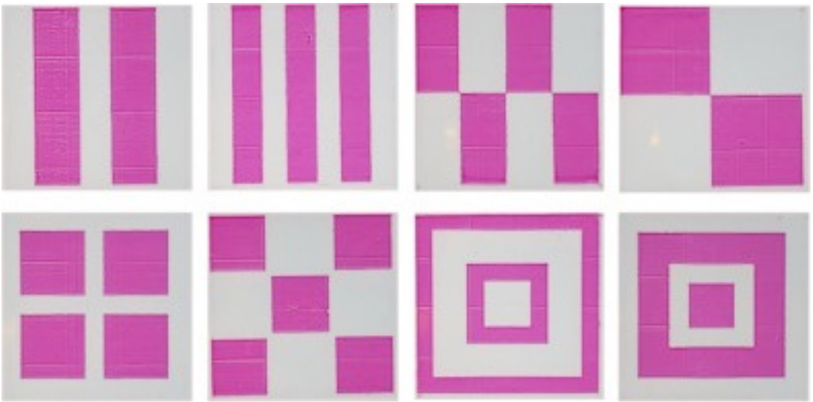
Carbone et al. *Int. J. Photoenergy* (2019)



Reinders et al. *IEEE Journal of PV* (2017)

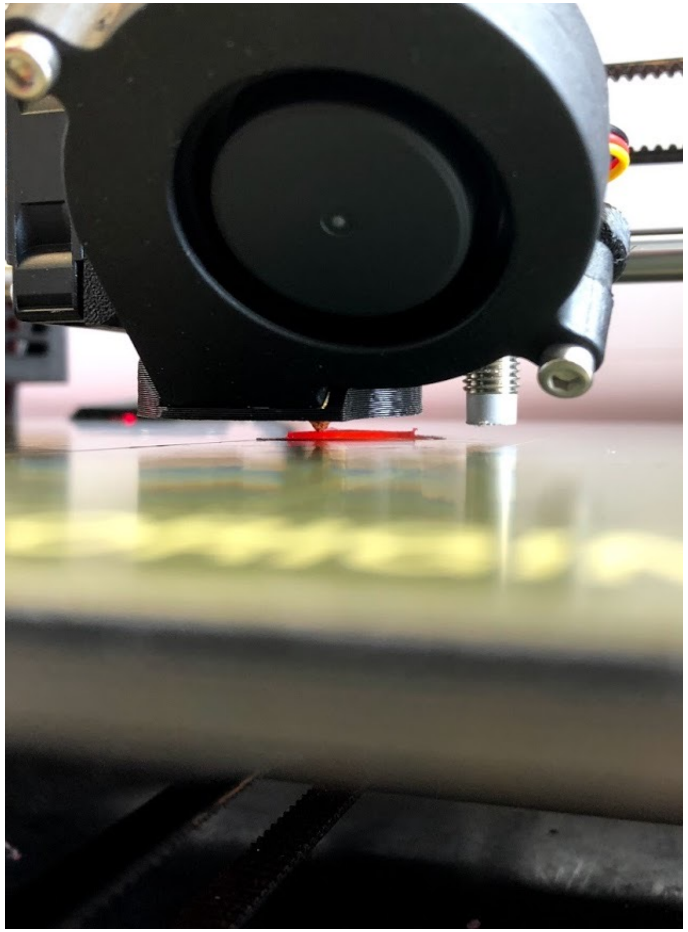


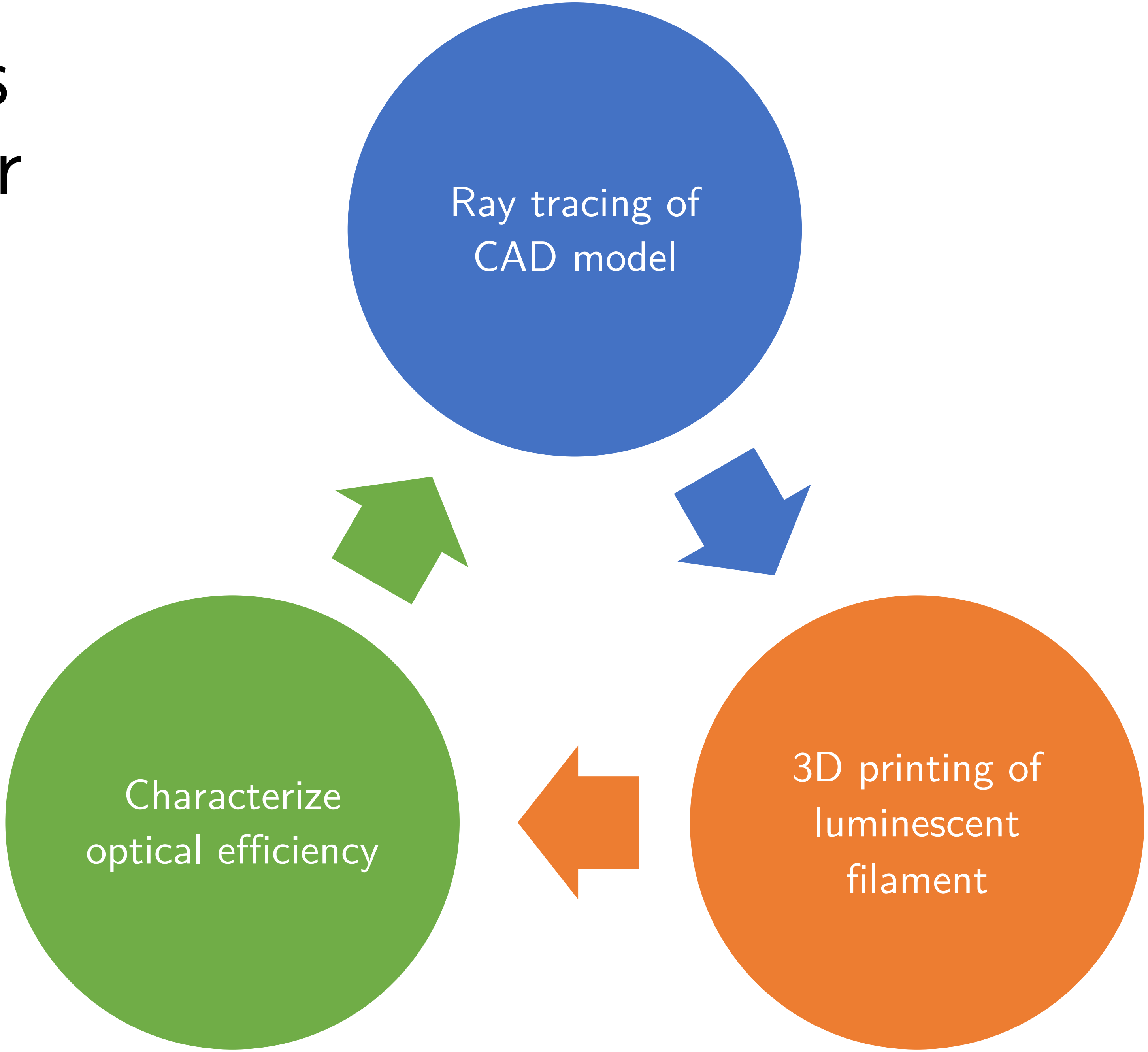
Albers et al. *Solar Energy* (2013)



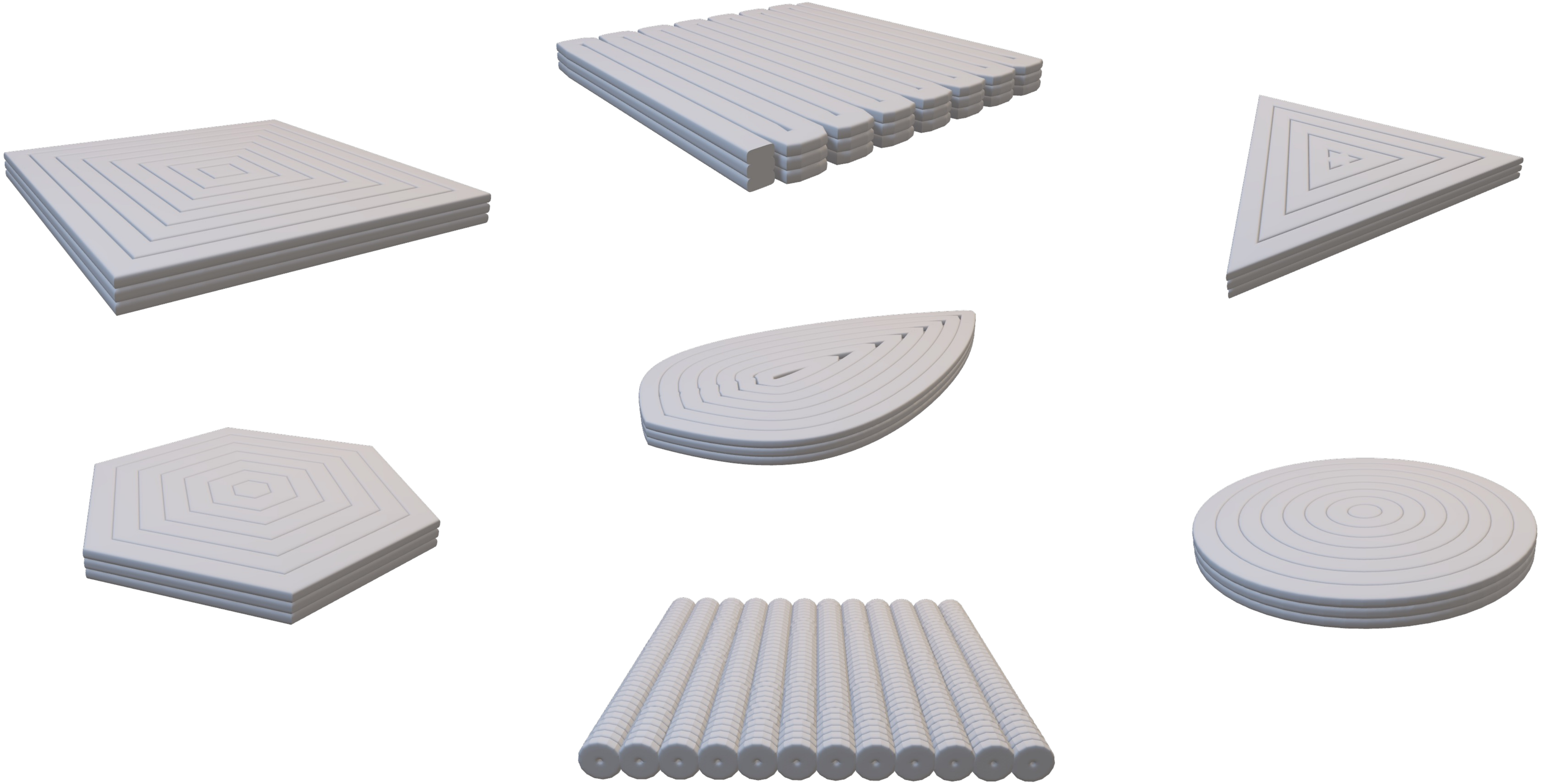
Schiphorst et al. *Energy and Buildings* (2019)

# 3D printing of LSCs opens a new frontier





# We first need accurate CAD models of 3D printed parts

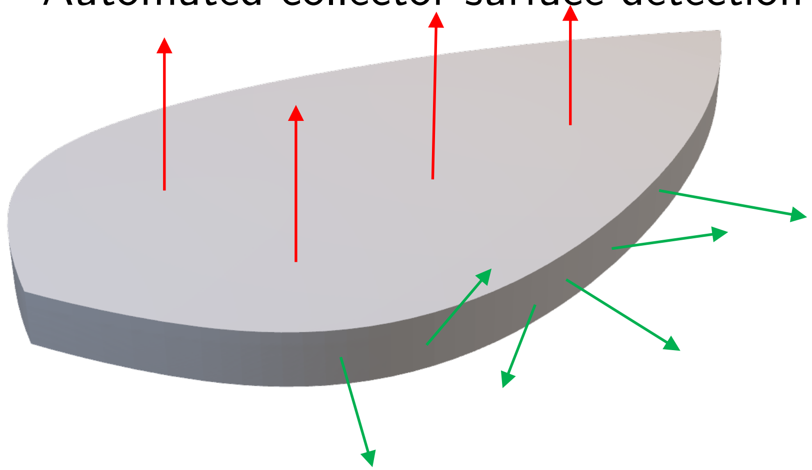


# We developed new ways to characterize unconventional LSC geometries

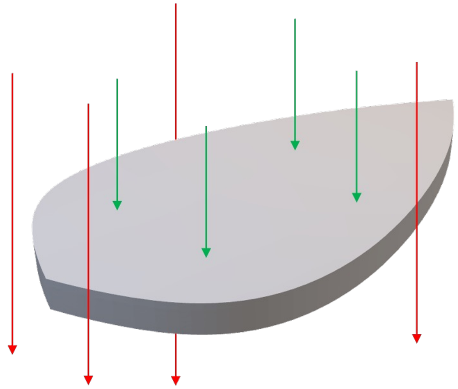
pvtrace

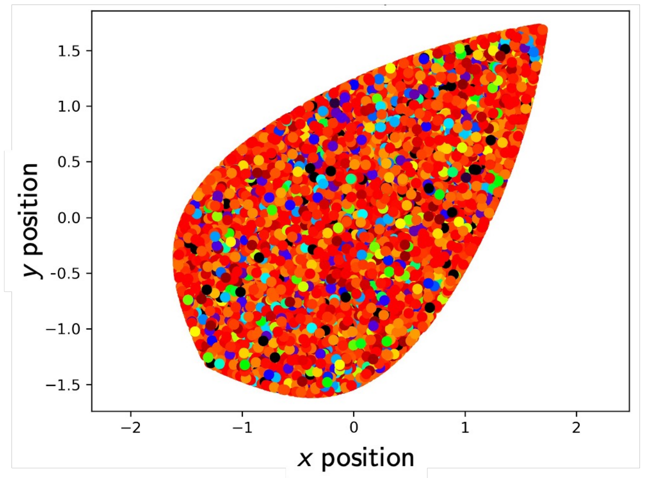
Counted rays
Ignored rays

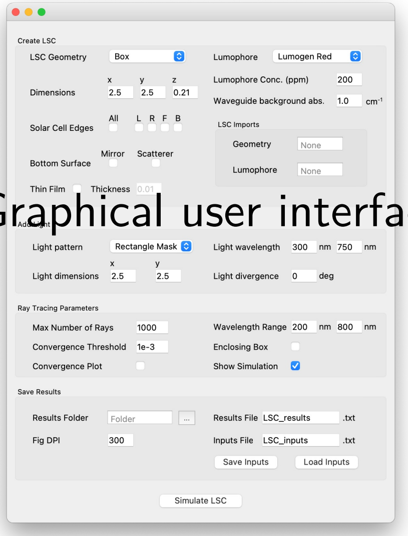
## Automated collector surface detection



## Improved light mask

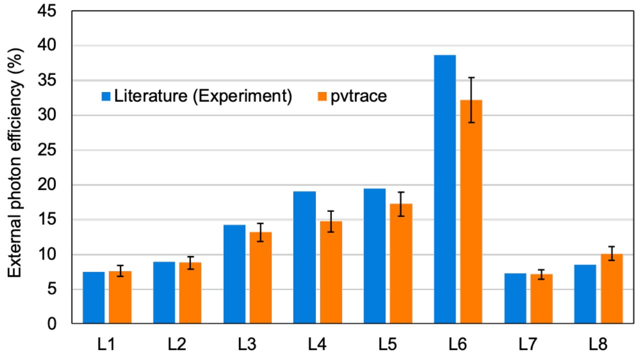





## Graphical user interface

## Predictions match experiment




## pvtrace-sv

Modifications made to Daniel Farrell's pvTrace (https://github.com/danieljfarrell/pvtrace) to allow analysis of unconventional LSC geometries.

**Ray-Trace Modeling to Characterize Efficiency of Unconventional Luminescent Solar Concentrator Geometries**


Shomik Verma,* Daniel J Farrell, and Rachel C. Evans*



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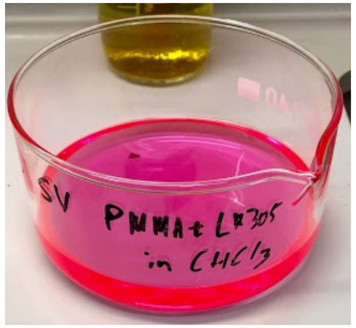
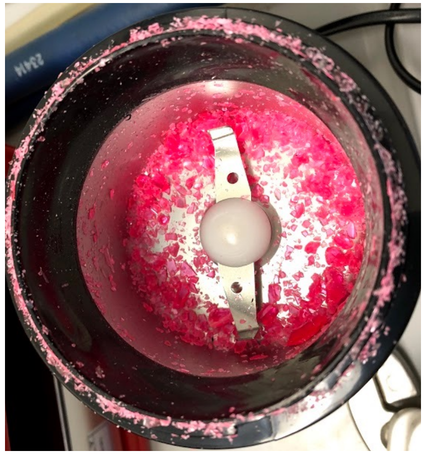
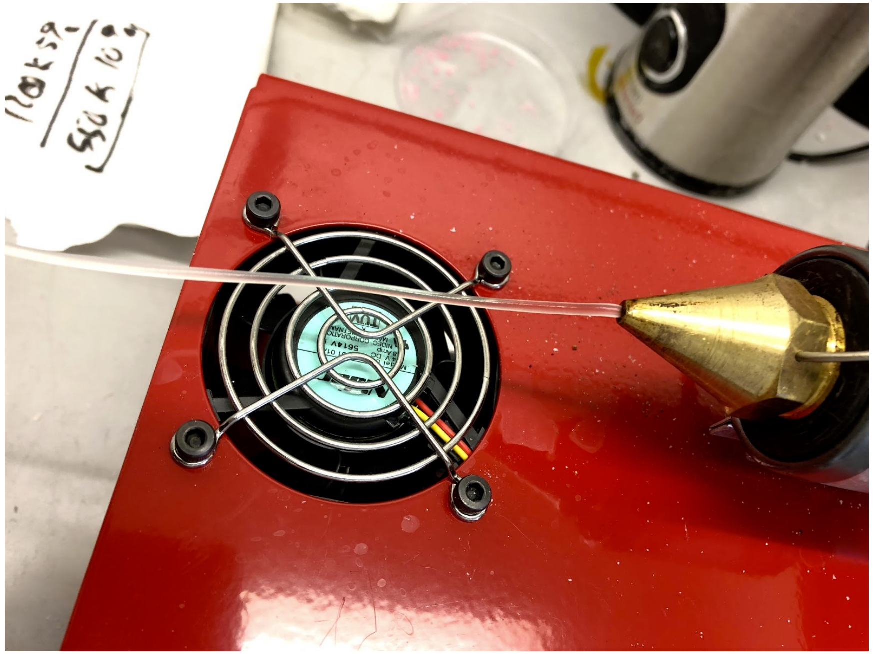
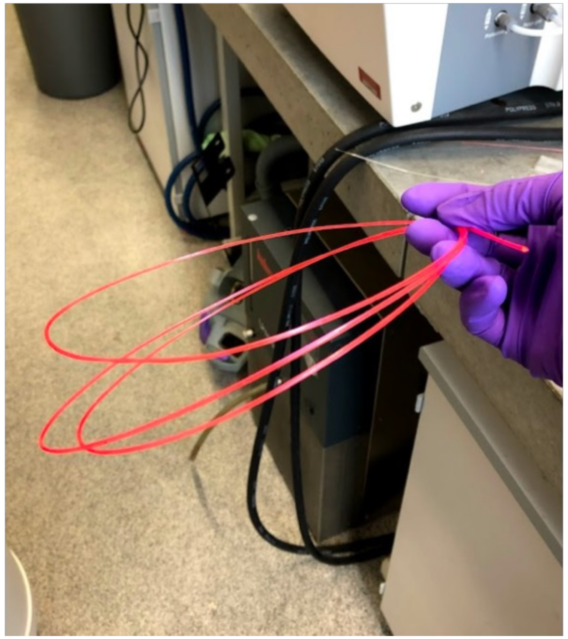
# Created luminescent filament with an extruder



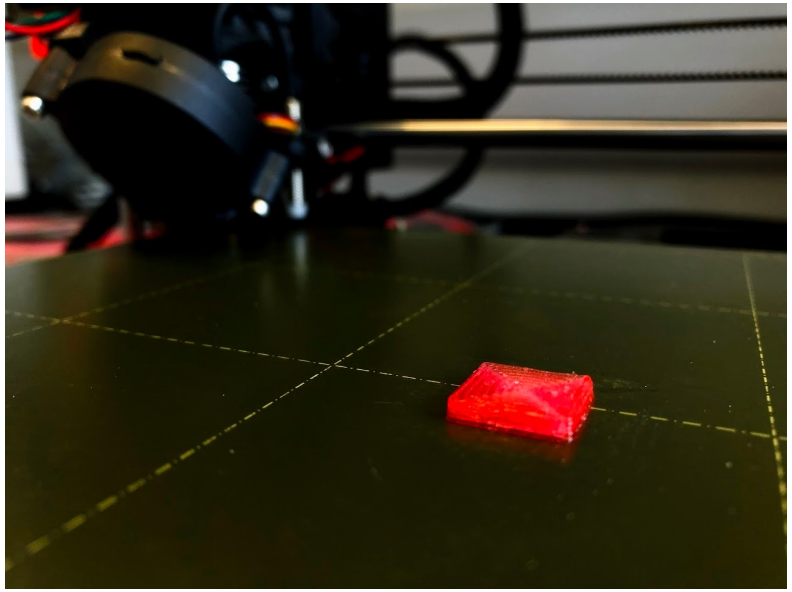



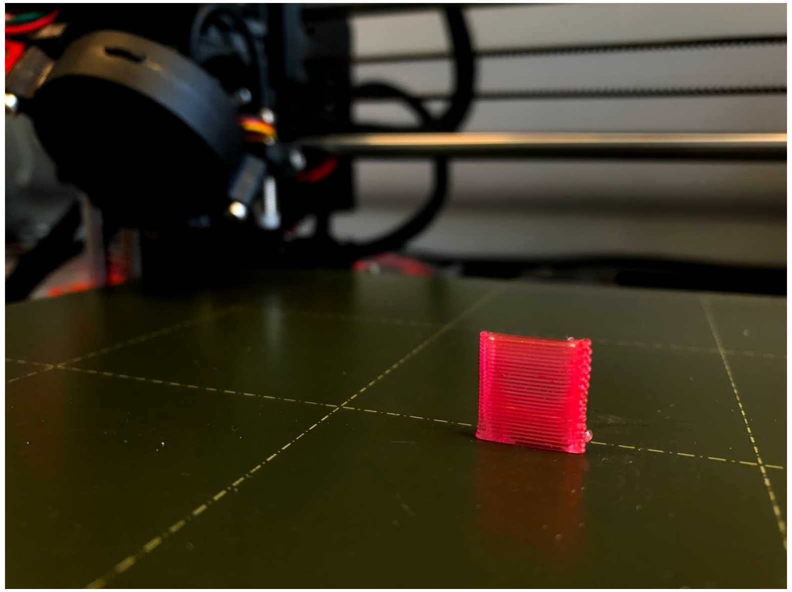
(a)

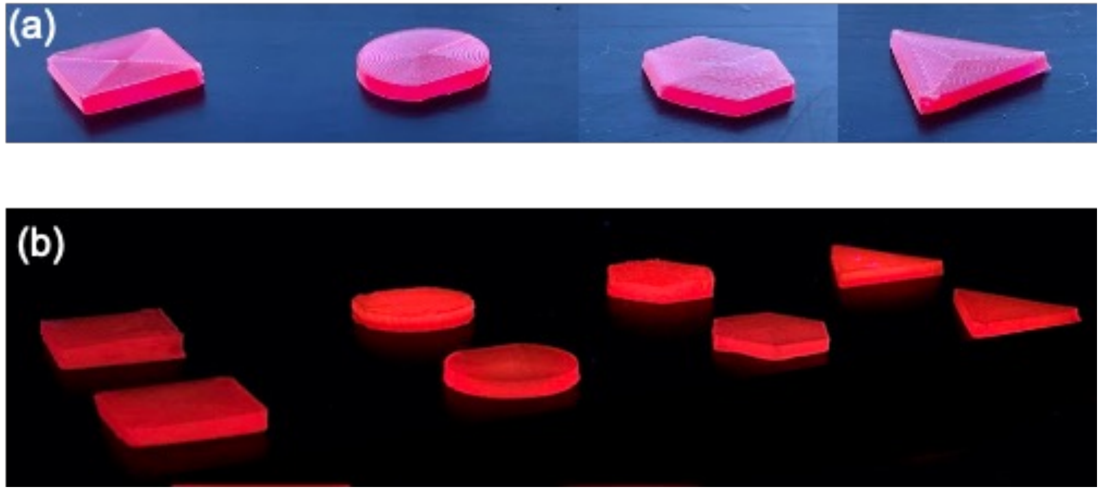


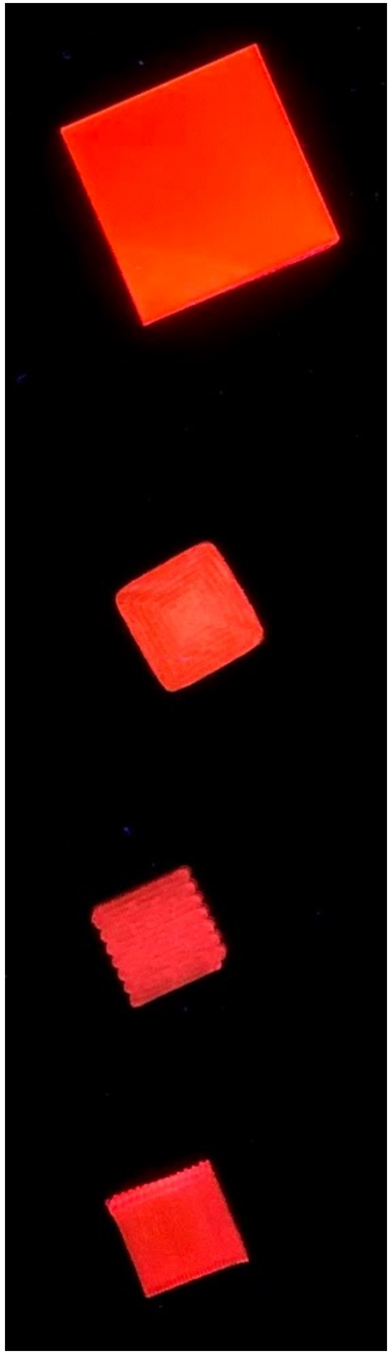
(b)

# 3D printing of luminescent parts!

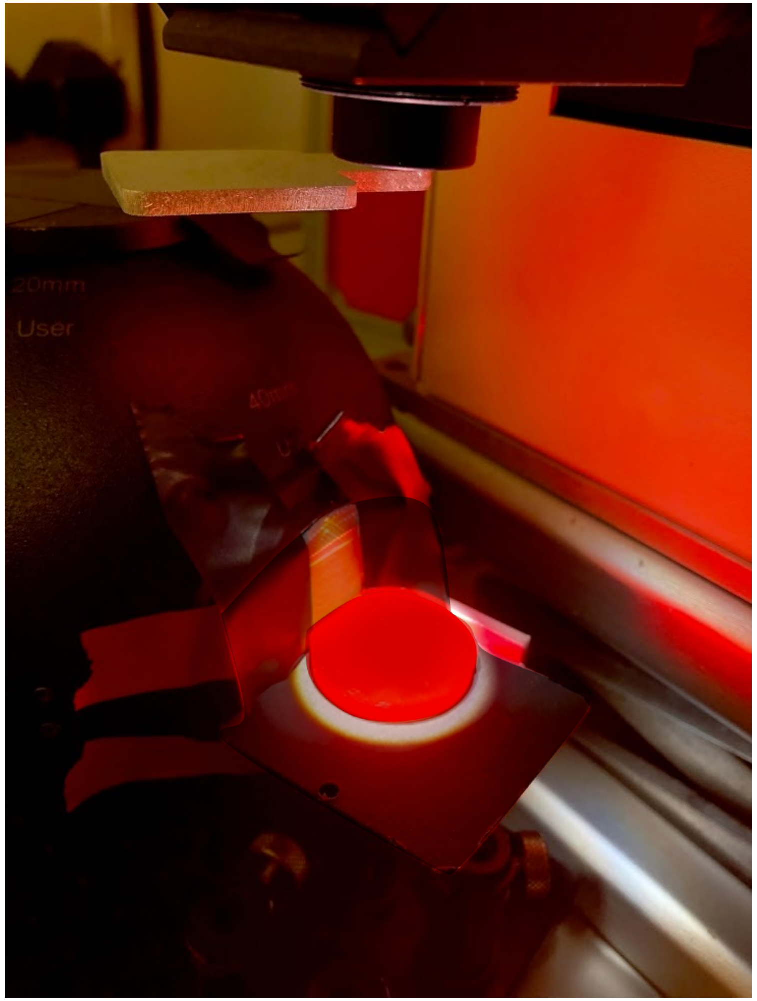


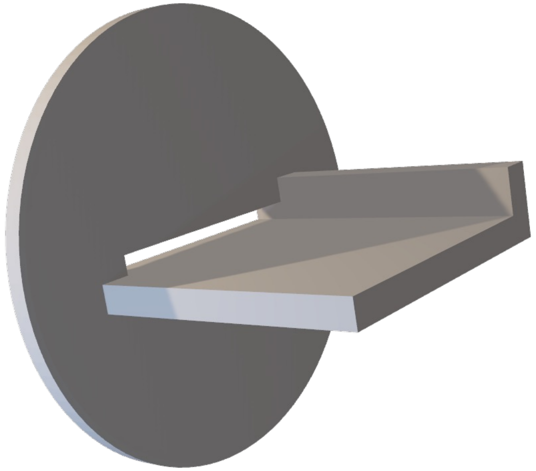




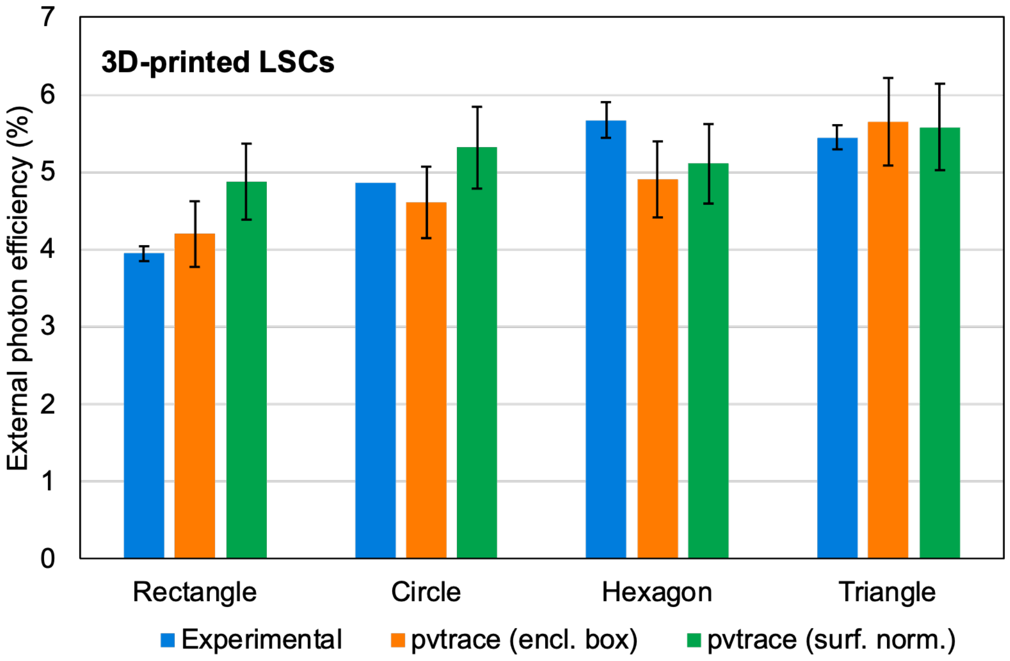
# Characterizing the optical efficiency of devices



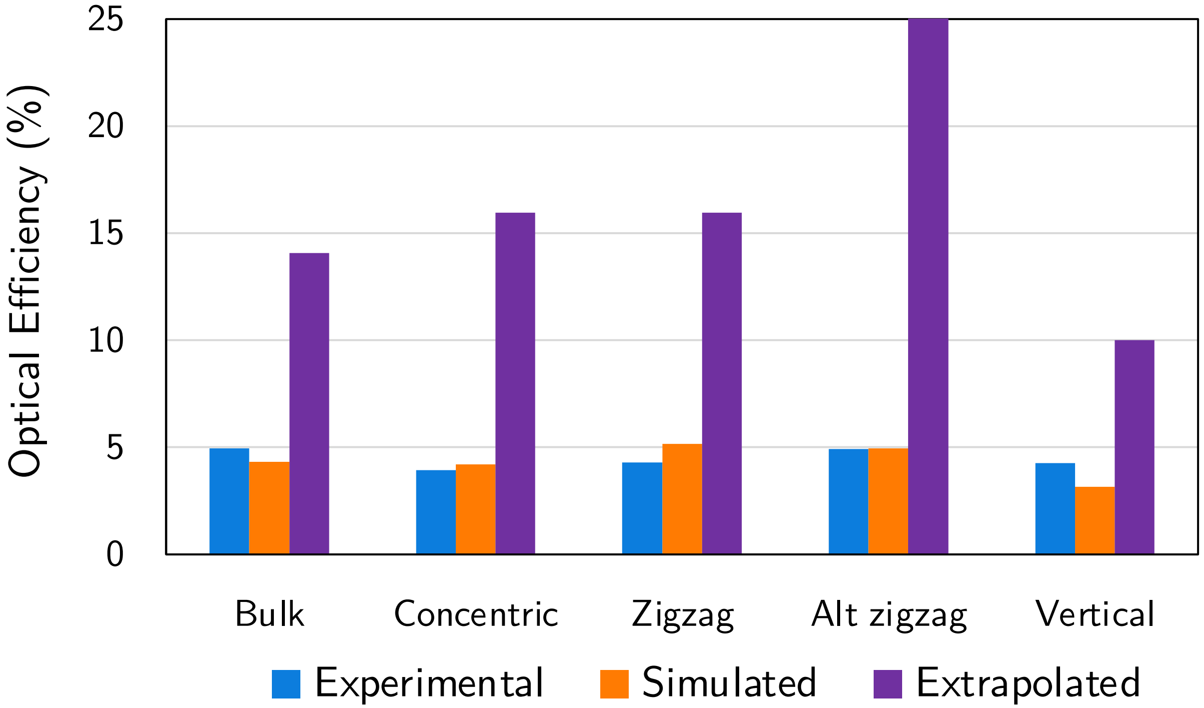



# Comparing experimental efficiency with predictions

Comparing different shapes



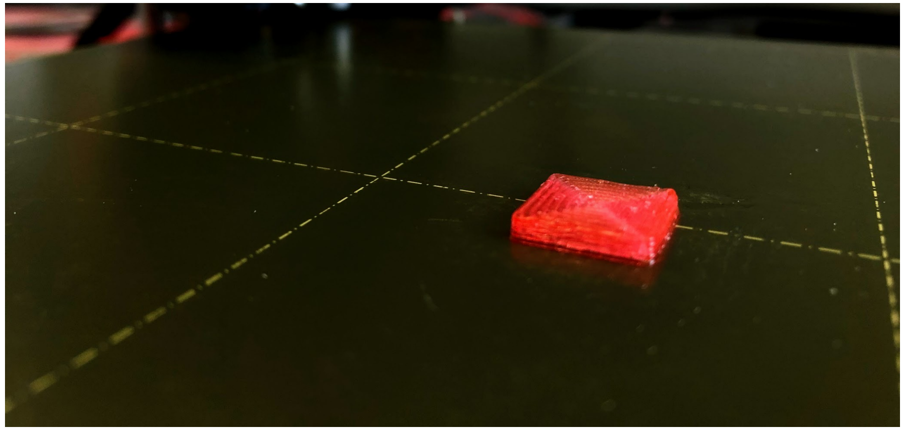

Comparing printing patterns and extrapolating

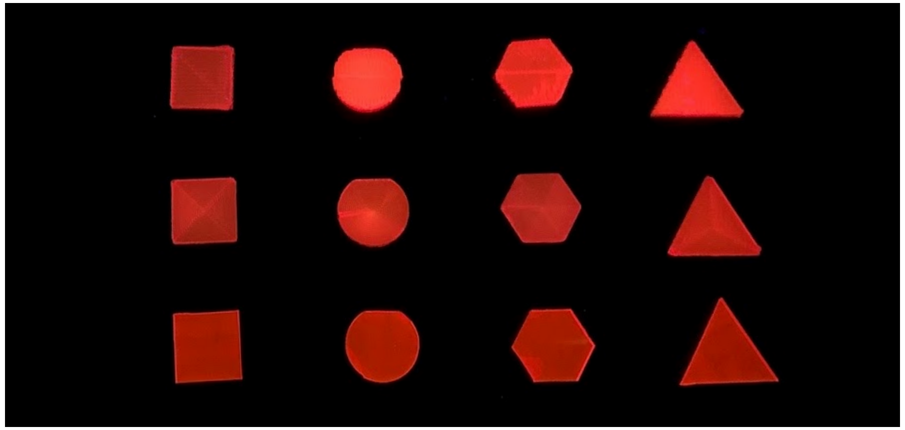



Some 3D printed geometries can outperform bulk parts!

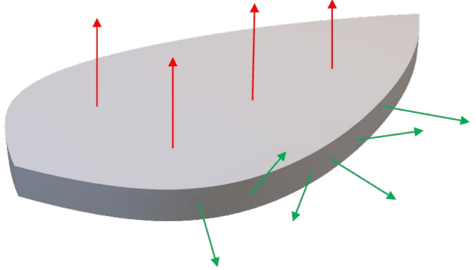
# We have developed a robust methodology for end-to-end performance analysis

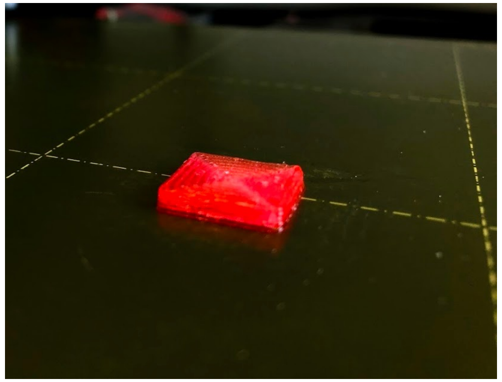
- Ray tracing simulation
- Luminescent filament generation
- Optical efficiency characterization
- Future work in printing alternative 3D designs is warranted

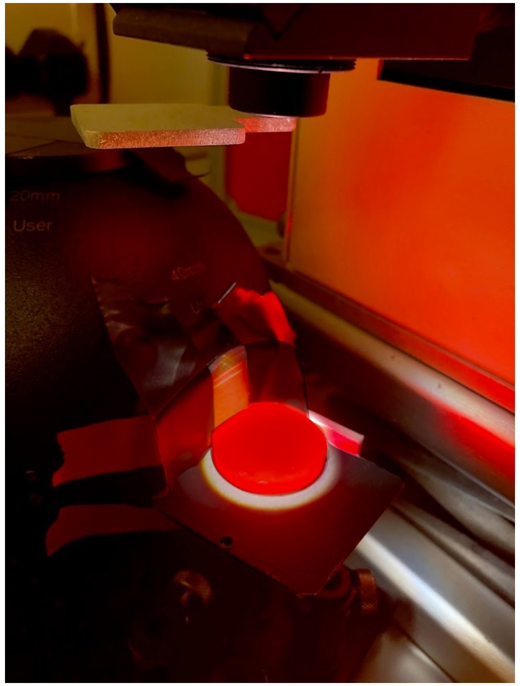




# Thanks!



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