# A Novel Scanning Lens Instrument for Evaluating Fresnel Lens Performance: Equipment Development and Initial Results

Rebeca Herrero[1, 2], David C. Miller[2], Sarah R. Kurtz[2], Ignacio Antón[1] and Gabriel Sala[1]

[1] **Instituto de Energía Solar-Universidad Politécnica de Madrid, Spain**
[2] **National Renovable Energy Laboratory, Golden, CO, USA**

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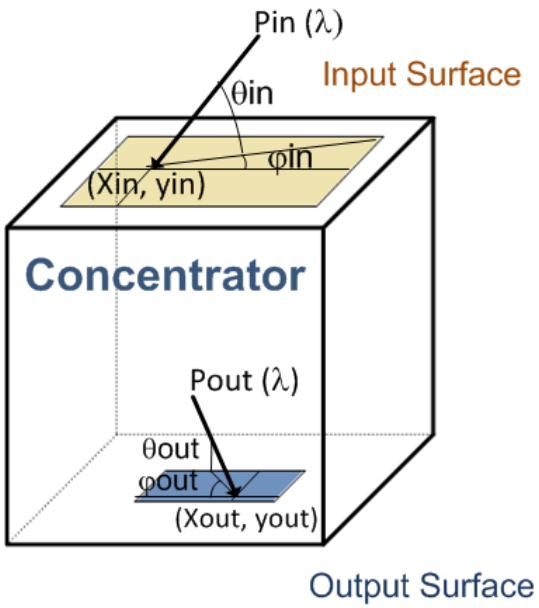
# Outline

- Optical Performance Characterization:
  - Definition
  - Light Source and Flux Measurement Device
- Lens Scanning Instrument Development
- Lens Scanning Instrument vs. CPV Solar Simulator
- Results
- Conclusions

# Optical Performance Characterization: Definition




**Transmittance Function**

$$T_{ray}\left(x_{in}, y_{in}, \varphi_{in}, \theta_{in}, \lambda\right) = \frac{P_{out}\left(x_{out}, y_{out}, \varphi_{out}, \theta_{out}, \lambda\right)}{P_{in}\left(x_{in}, y_{in}, \varphi_{in}, \theta_{in}, \lambda\right)}$$

Integrating over:

$$x, y, \varphi, \theta, \lambda$$

**Optical Efficiency**

- The optical efficiency is dependent on angular, spatial and spectral features of the light source
- The optical efficiency is dependent on the receiver used:
  - Optical coupling
  - Spectral and angular responsivity
  - Sensor size

How can we measure the optical efficiency?

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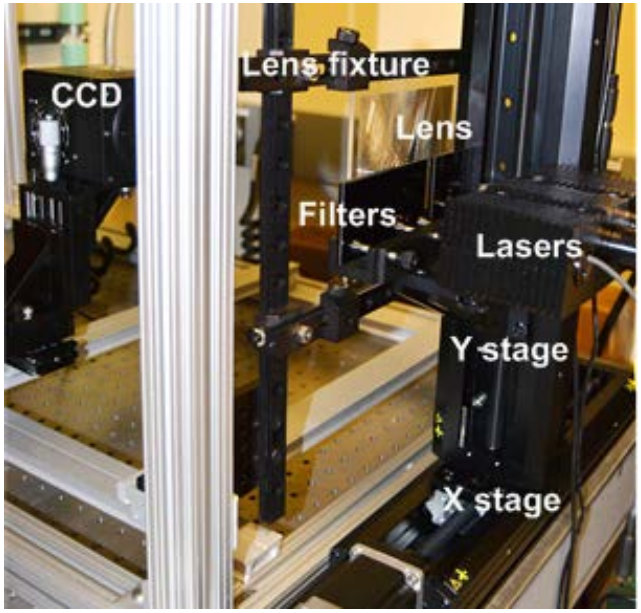
# Light Source and Flux Measurement Device

- Light Source
  - Spectrum
  - Collimated Light
  - Examples:
    - Sun
    - Xenon Flash Lamps + Optics
    - Lasers
- Flux Measurement Device
    - Thermal Sensors (*e.g,* Pyranometer)
    - Multi-Junction Solar Cells (or isotype cells)
    - CCD Si Sensor

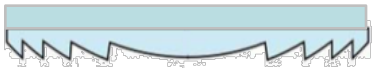
## Equipment requirements for lens performance & aging evaluation:

- Ability to quantify and diagnose local defects (vs. measure the overall lens efficiency)
- Ability to examine at different wavelengths
- Large sensor size




Scanning Lens Instrument (SLI) at NREL

# Scanning Lens Instrument Development



SoG

PMMA

INTENTIONAL DAMAGE

85C/85%RH (1000h.)

SunTest ( 1000 h. UV)

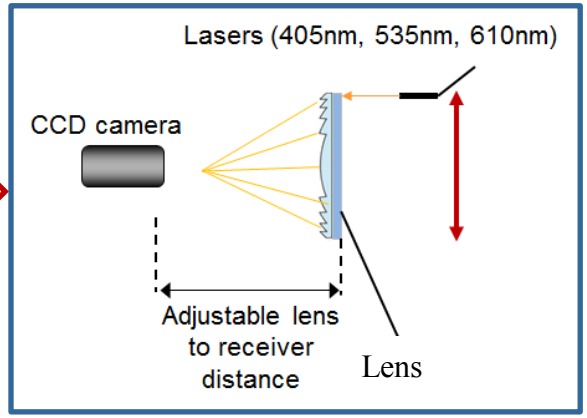
Scratched

+

Reference

MEASURE η

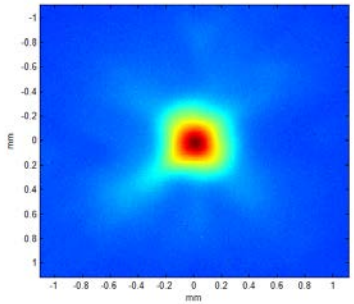
**SLI at NREL**




CCD image of laser arriving to the sensor through the lens

Integrating over (x,y)

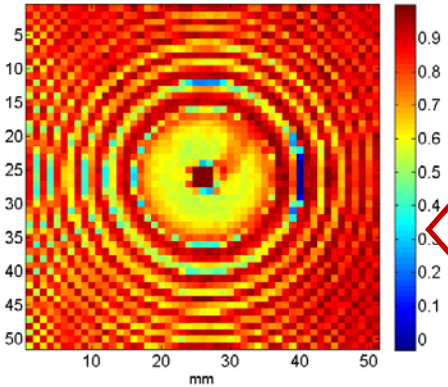
**Light spot for λ**



$$\eta(x_{in}, y_{in}, \lambda) = \frac{P_{out}(x_{out}, y_{out}, \lambda)}{P_{in}(x_{in}, y_{in}, \lambda)}$$

CCD image of laser light

Scanning lens aperture




**Map of optical efficiency for λ,**
**η Average optical efficiency for λ**

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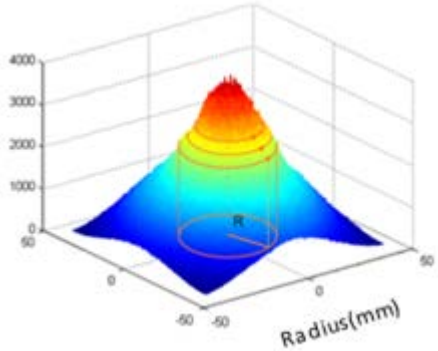
# Scanning Lens Instrument Development: Lasers

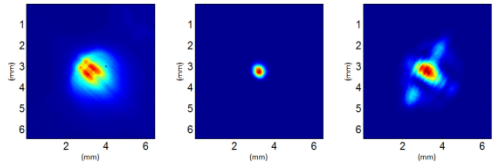
- Spatial and Angular Distribution of Lasers (405nm, 532nm, 650nm)

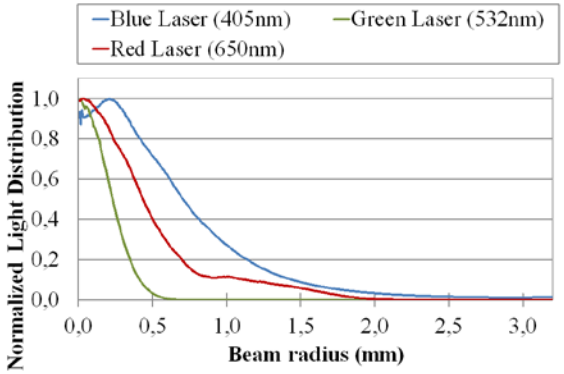



Average Profile Obtained from CCD Images

SPATIAL

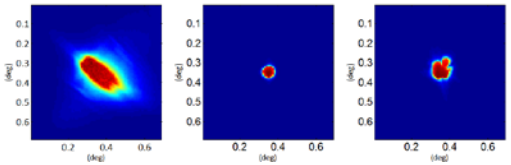
Blue (405nm) Green (632nm) Red(650nm)

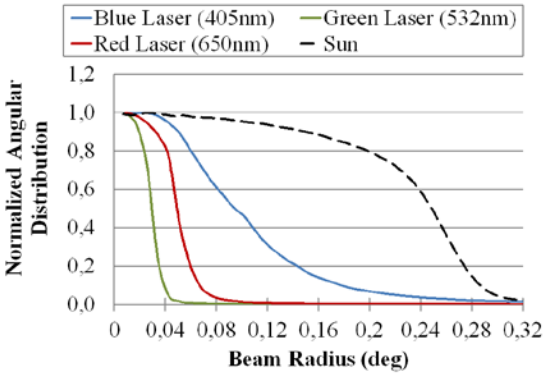





ANGULAR

Blue (405nm) Green (632nm) Red(650nm)






- Laser partially coherent
  - Refractive random surface diffuser to generate multiple light sources (reduce coherence)

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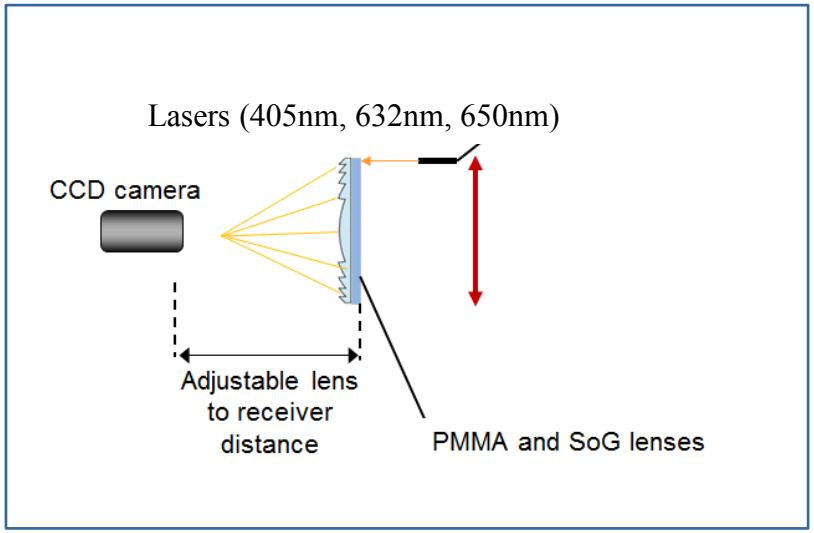
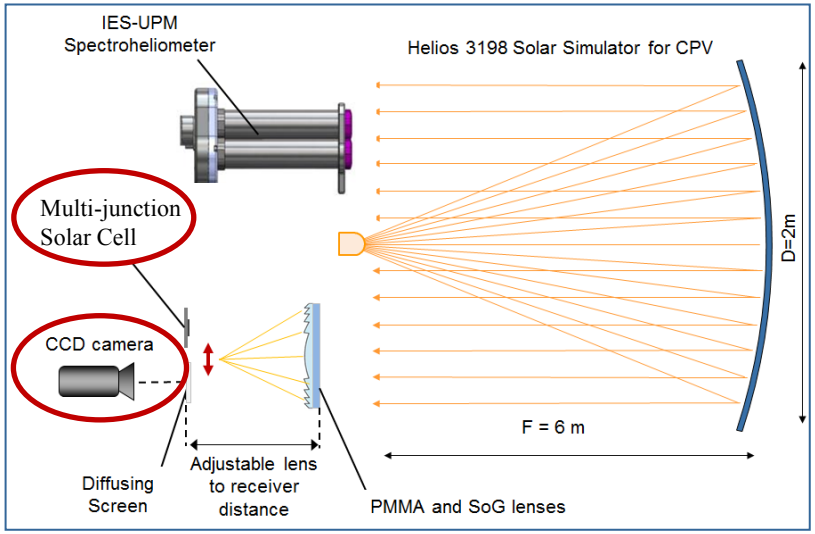
# Scanning Lens Instrument vs. CPV Solar Simulator

- Lens characterization: transmittance and optical efficiencies




**Scanning Lens Instrument (SLI) at NREL**

η Blue (405nm), η Green (532nm) , η Red (650nm)

$$\eta(x_{in}, y_{in}, \lambda) = \frac{P_{out}(x_{out}, y_{out}, \lambda)}{P_{in}(x_{in}, y_{in}, \lambda)}$$

**CPV Solar Simulator at IES-UPM**

η Top, η Middle

$$\eta(E_{in}(\lambda), L_{in}(\varphi, \theta)) = \frac{G_{out} \cdot A_{out}}{G_{in} \cdot A_{in}}$$

**RELATIVE DIFFERENCES COMPARED WITH REFERENCE SAMPLE ARE STUDIED**

Is the measured optical efficiencies at SLI in correspondence with the other characterizations?

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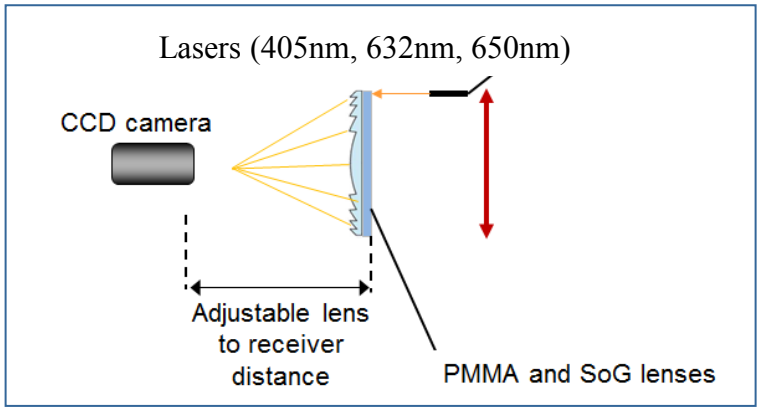
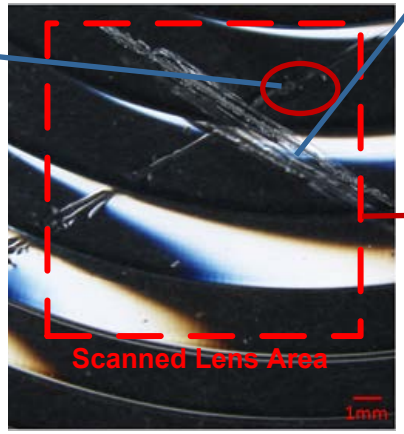
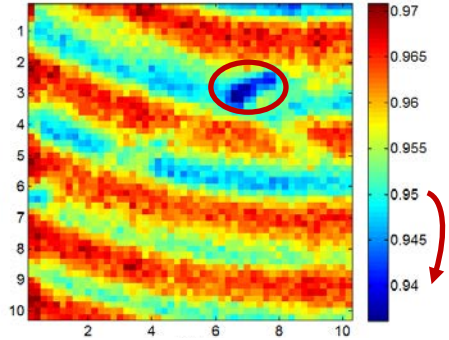
# Results: Localized Defect Quantification




Scratch in the glass surface

Scratch in the silicone




95% to 94%

Image detail of the same scratch in the silicone

Optical image of a scratched lens (front and back surfaces)

Map of optical transmission efficiency (Resolution 0.2mm for green laser 530nm)

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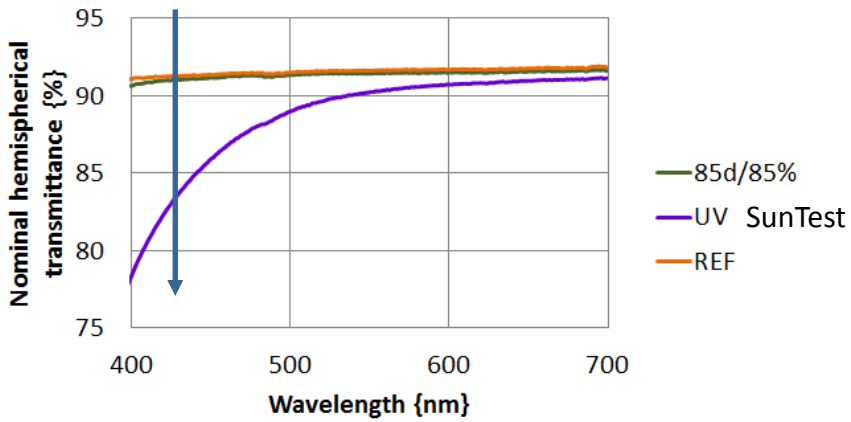
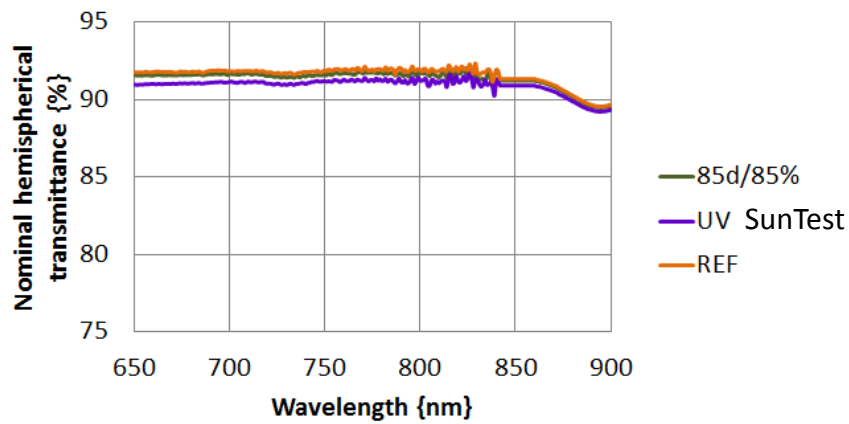
# Results I: Lenses PMMA in SLI & Other Characterizations

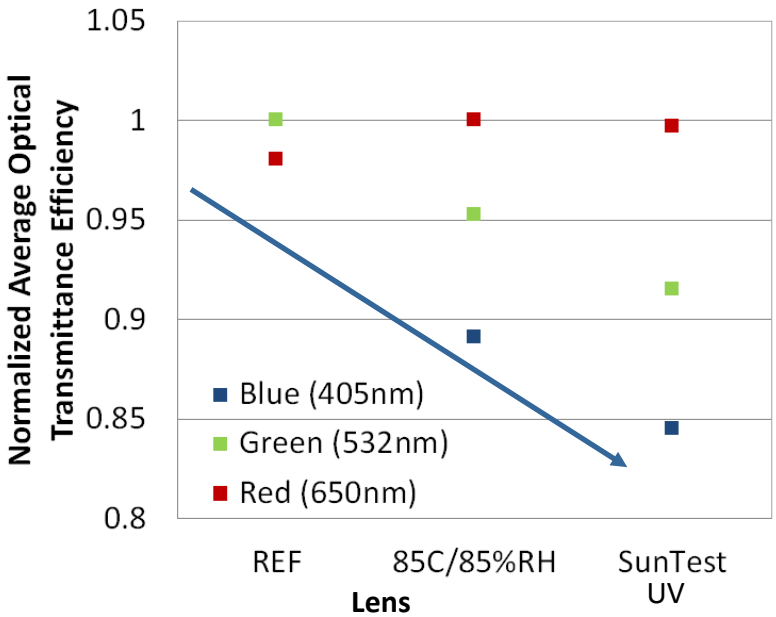
## Transmittance vs. wavelength, PMMA



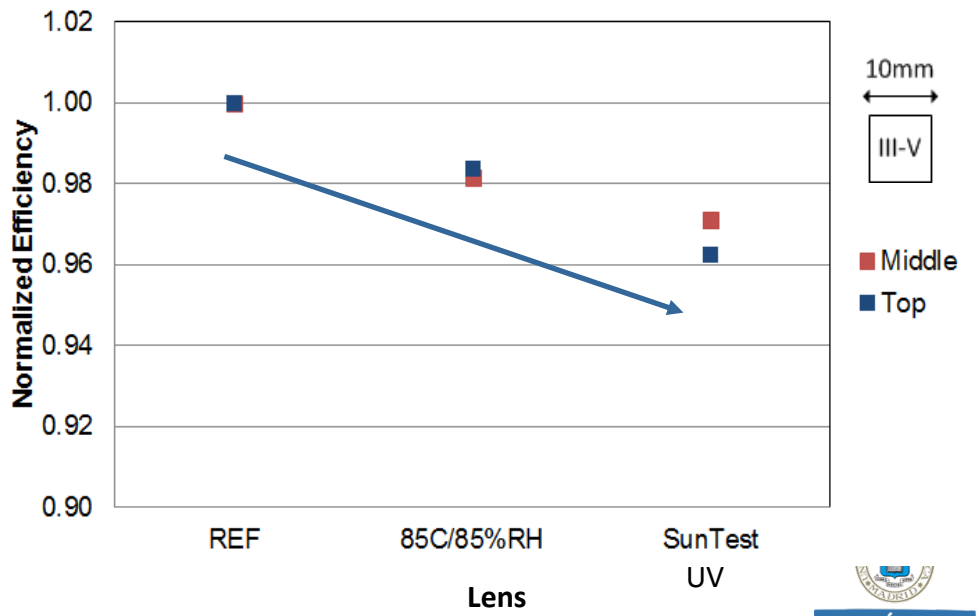

## Transmittance vs. wavelength, PMMA




## Lenses PMMA at SLI




## Lenses PMMA at CPV solar simulator

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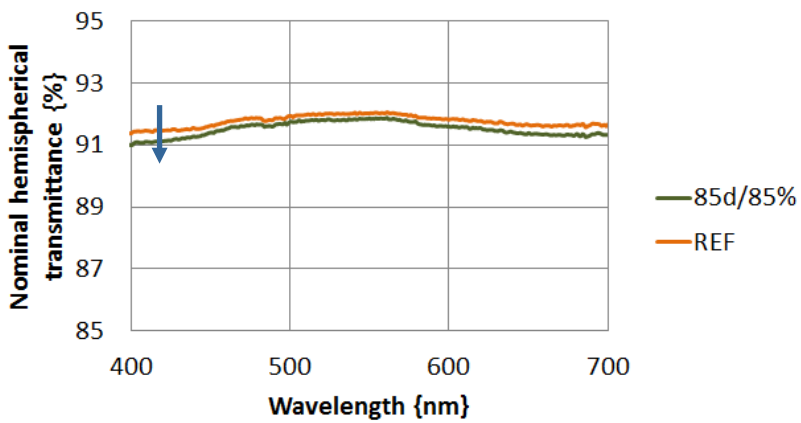
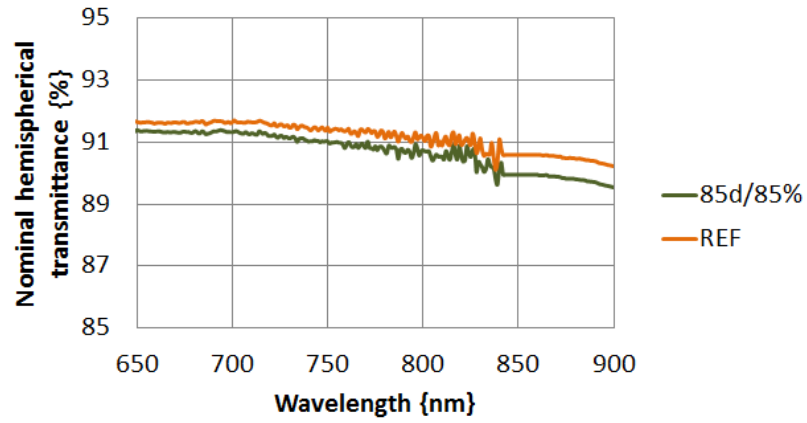
# Results II: Lenses SoG in SLI & Other Characterizations

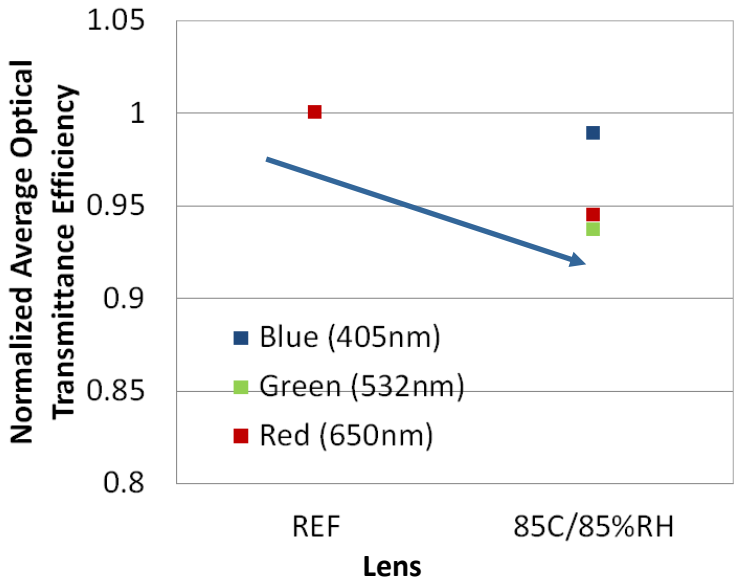
## Transmittance vs. wavelength, SoG



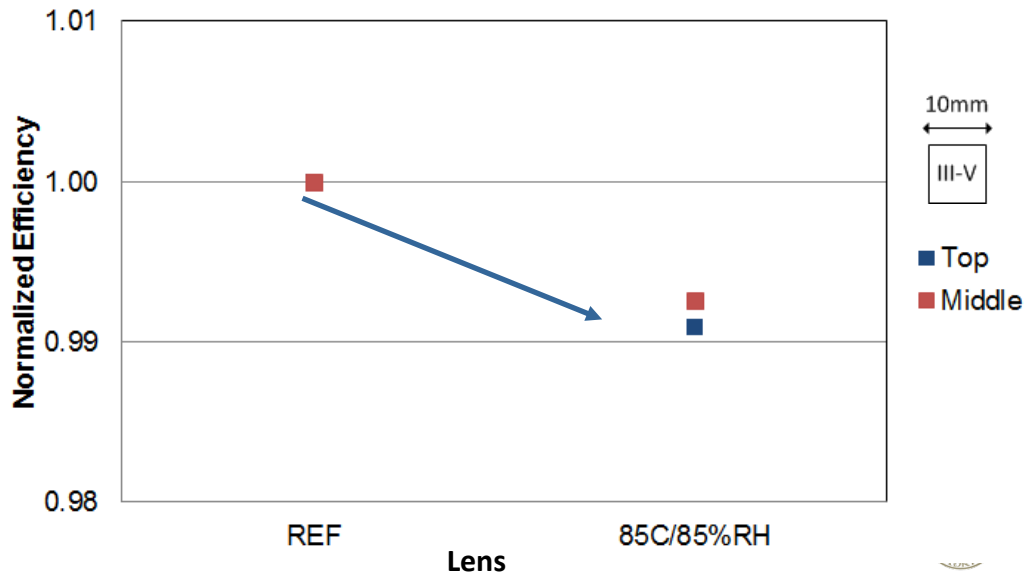

## Transmittance vs. wavelength, SoG




## Lenses SoG at SLI




## Lenses SoG at CPV solar simulator

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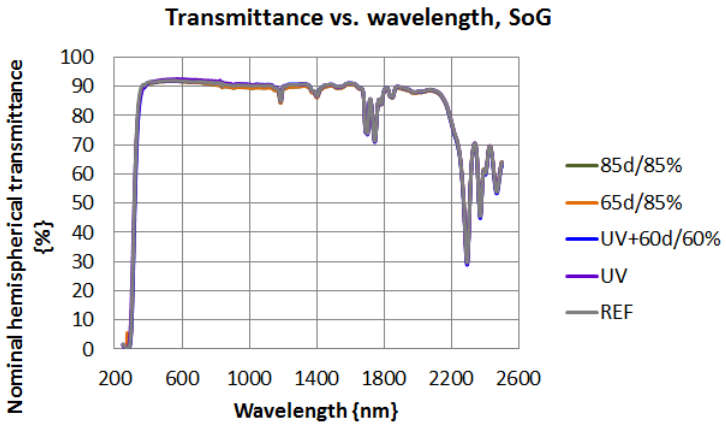
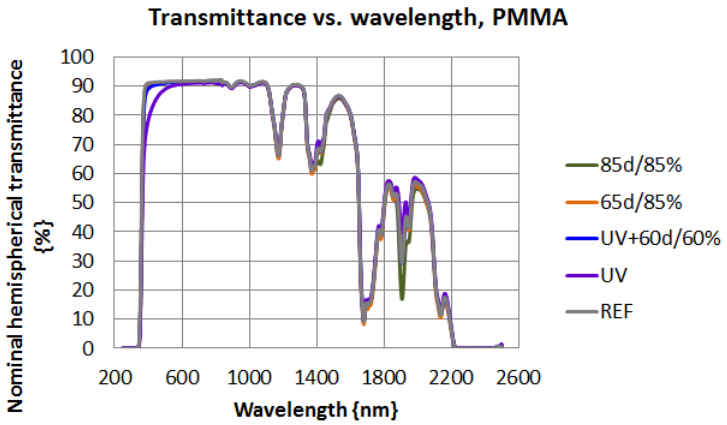
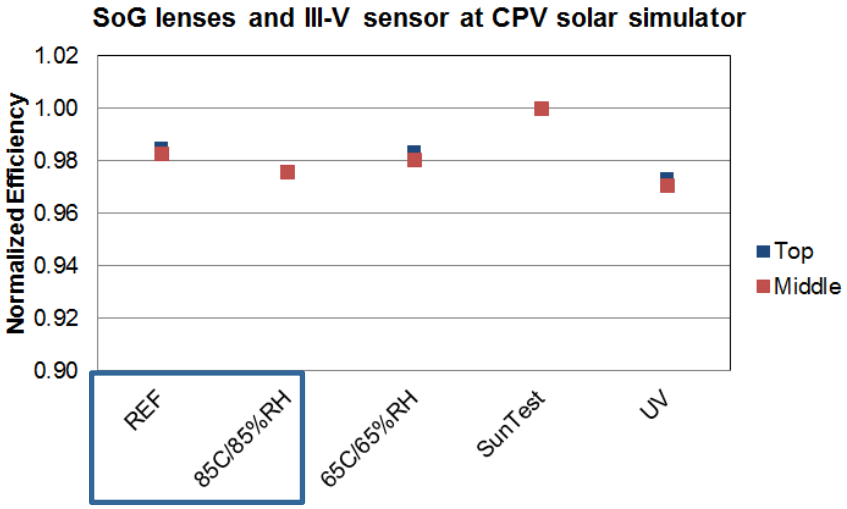
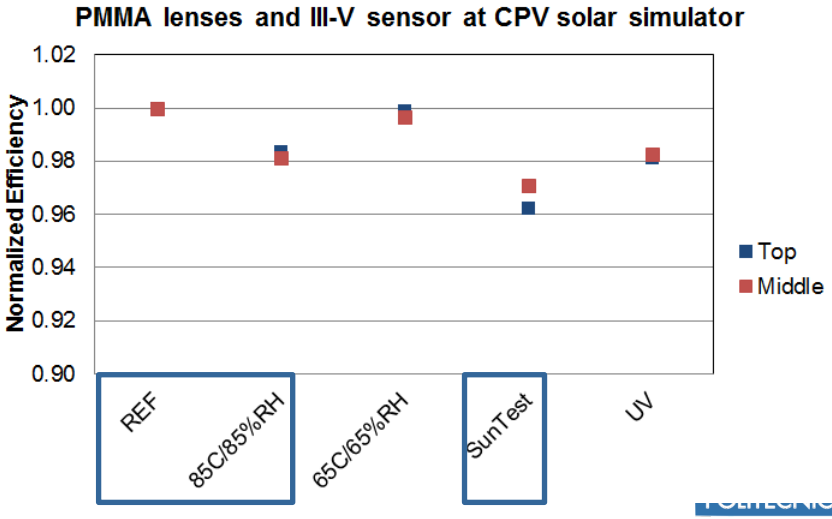
# Future Work

- Repeat SLI and Solar Simulator characterization with more lenses and aging conditions



# Conclusions

- The SLI equipment does not provide an absolute optical efficiency value, but the effects of lens aging can be quantified and diagnosed

- Component characterization and image processing has been required to validate the SLI results

- Both PMMA and SoG lenses have been measured in the SLI and Helios CPV solar simulator, with similar results to spectrophotometer transmittance

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Thank you for your attention

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