

Optimization of the solar concentrator for increasing the acceptance angle in concentrating photovoltaic (CPV) system

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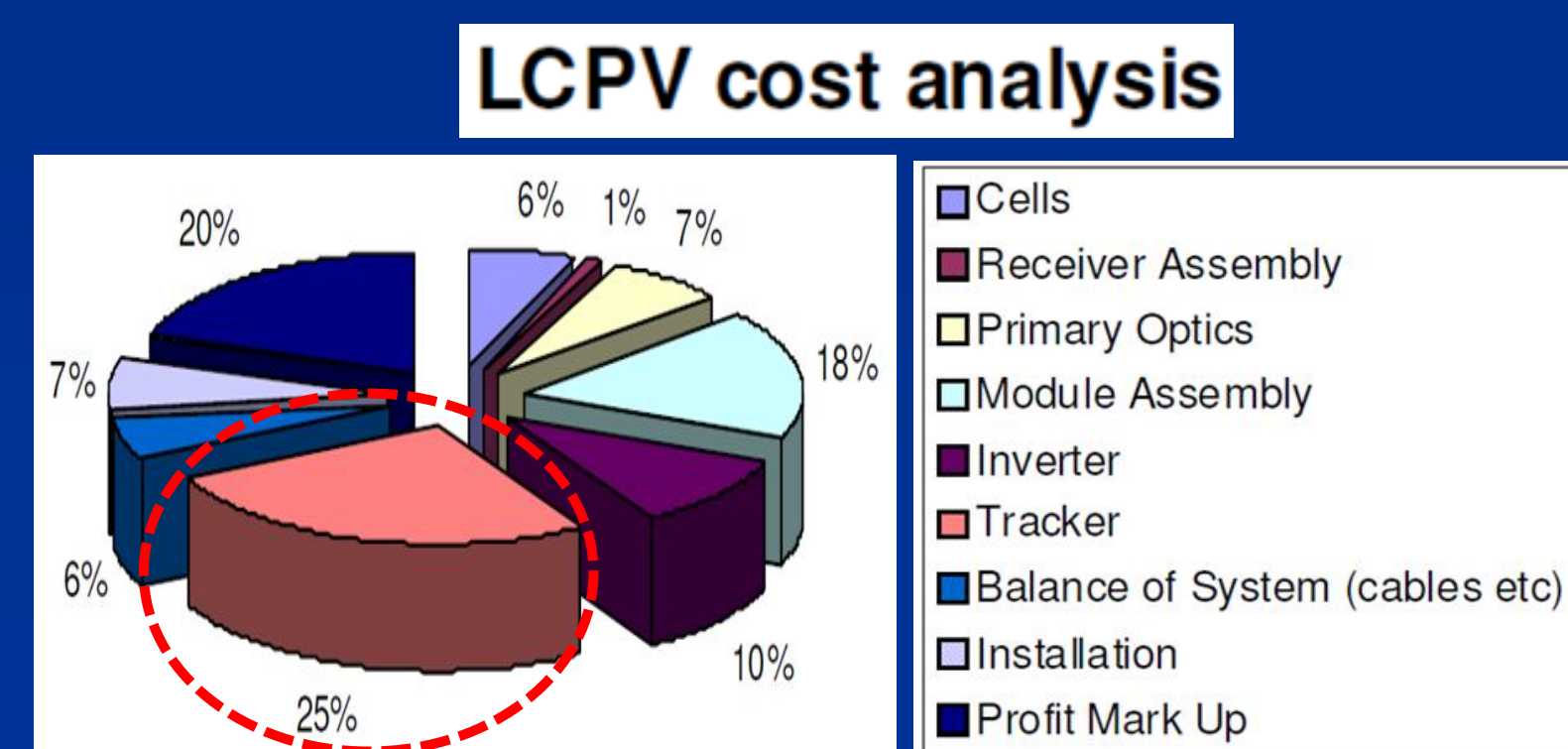
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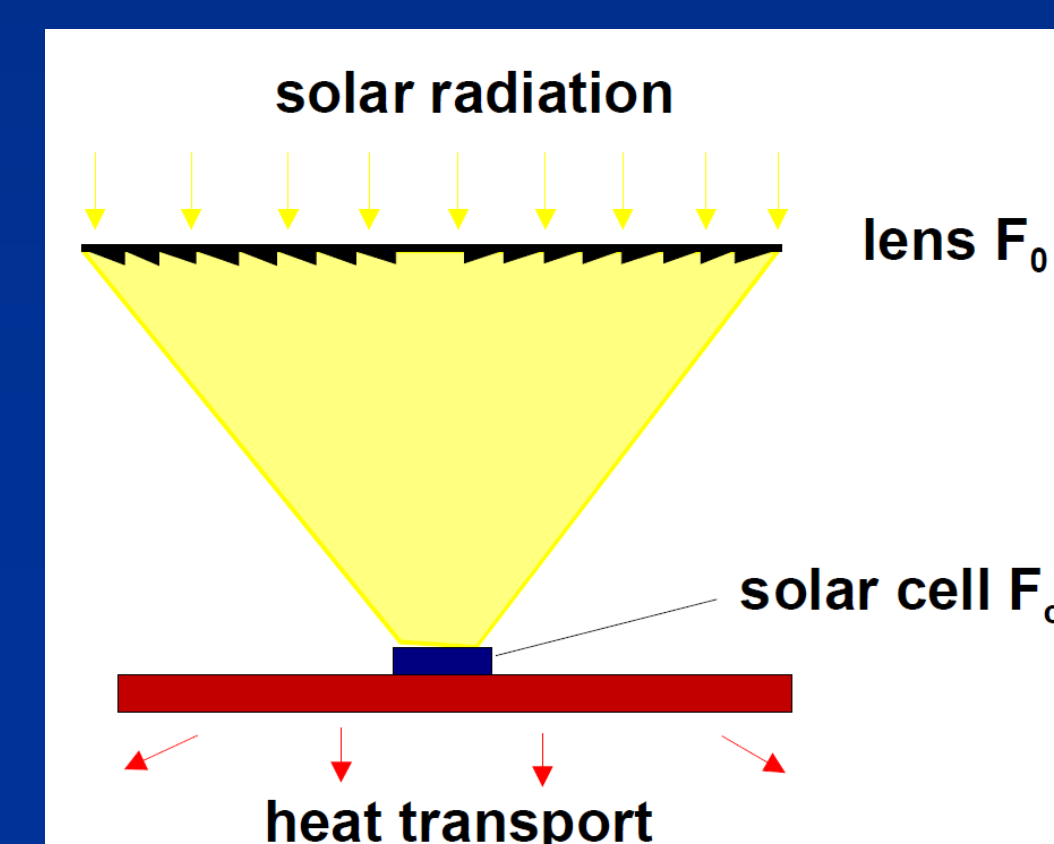
Introduction

Concentrating photovoltaic (CPV)



- High efficiency.
- Minimal cell material usage.
- Small acceptance angle.
- Rigid tracking system

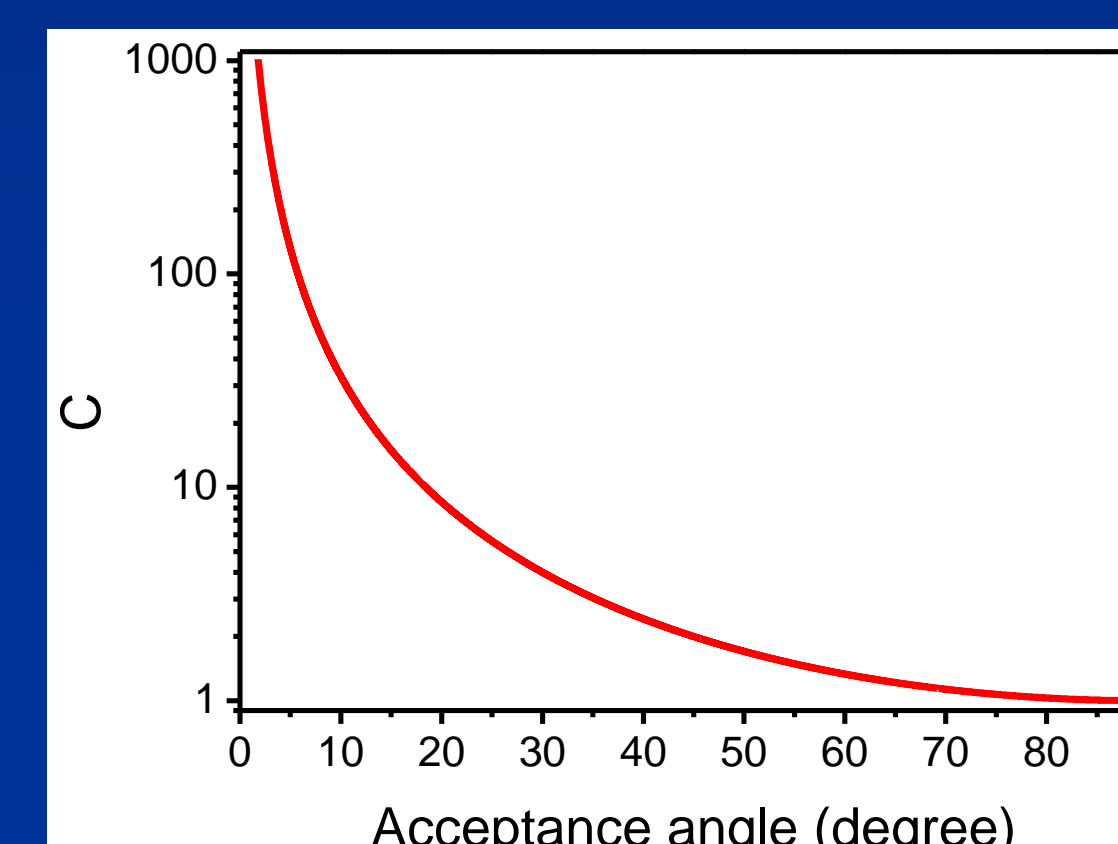
Solar Concentrator



Concentration ratio (C).

$$C = \frac{F_0}{F_c} \propto \frac{1}{\sin^2 \theta}$$

F_0 : Lens area
 F_c : Solar cell area
 θ : Acceptance angle



C	θ (degree)
2	45.00
5	26.57
10	18.43
100	5.74
500	2.56
1000	1.81

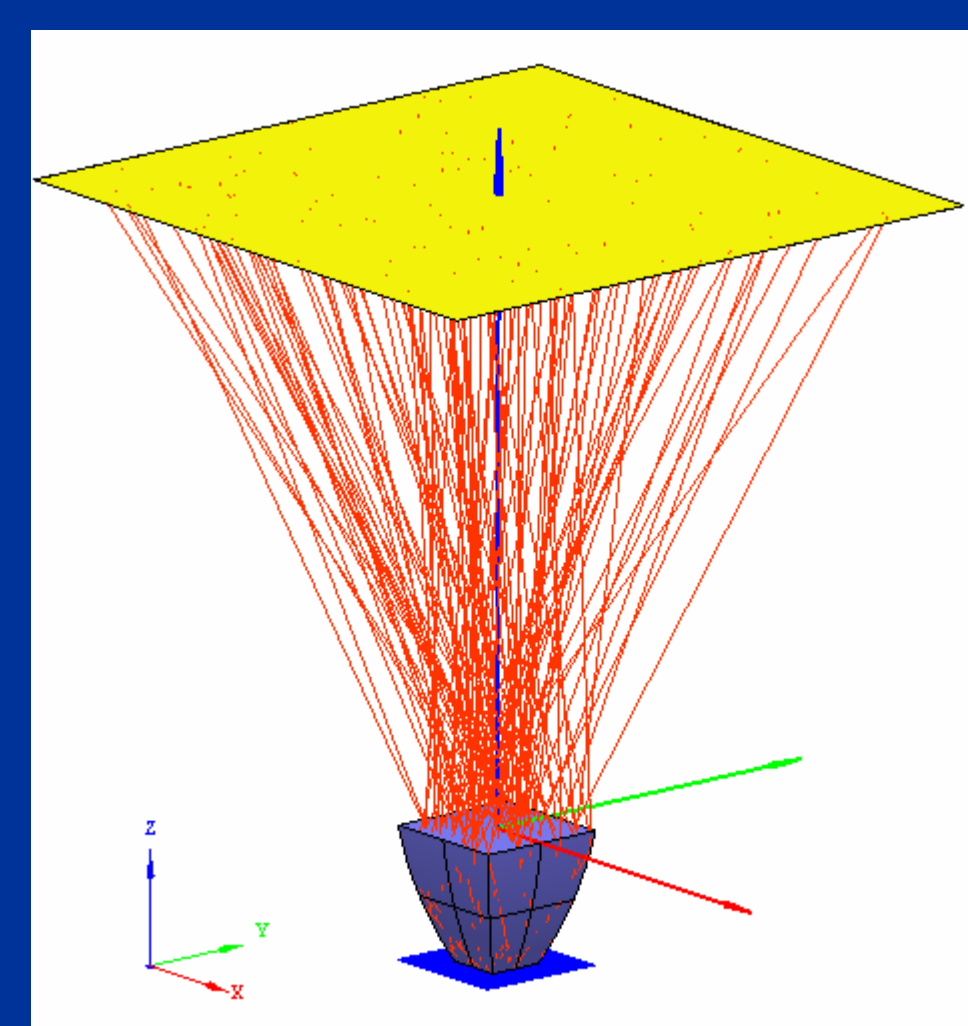
Requirement for cost-effective CPV system

- Higher concentration ratio at the fixed acceptance angle.
- Compact concentrator system - Thinner & lighter system.
- Uniform irradiance distribution.

- Primary Optical Element(POE) + Second Optical Element(SOE)
- Multi-array SOE structure

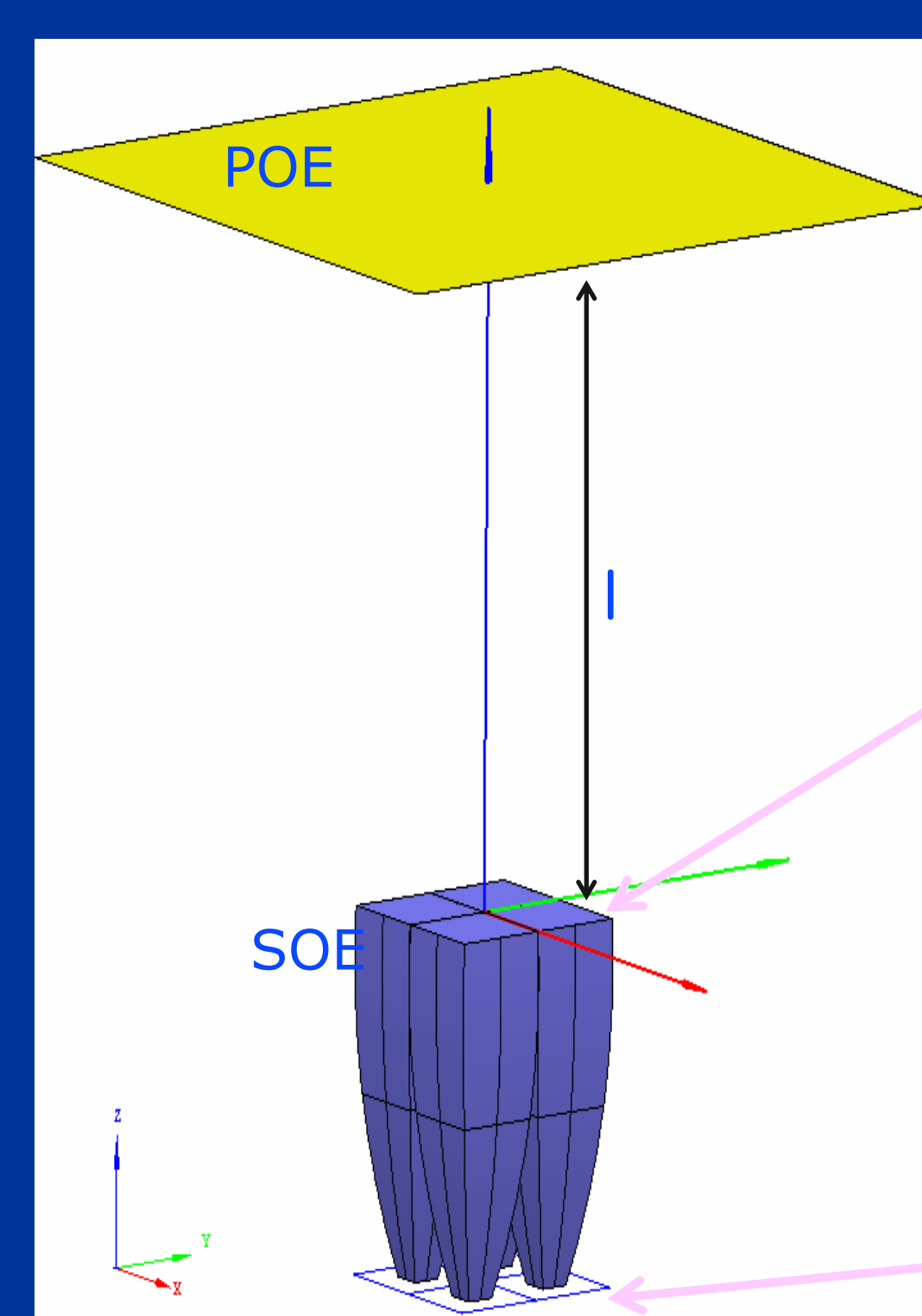
Simulation process

Solar Concentrator design



- Non-imaging optical method
- Ray-tracing algorithm
- Simulation tool: RayWiz™

Optical system & parameters



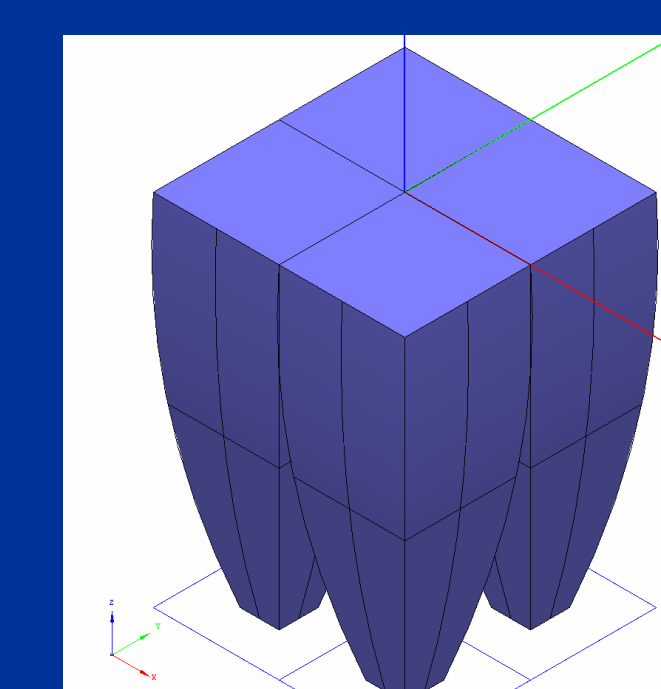
Fresnel Lens (assumption)
 100mm x 100mm
 $n = 1.49$ (PMMA)

Upper face ($r \times r$)

- $r = l \times \tan(\sin^{-1}(\sin \theta / n))$
- θ : Incidence angle
- n : Refractive index of POE
- Refractive index of SOE : 1.49 ~ 2.00
- AR coating assumption

Bottom face

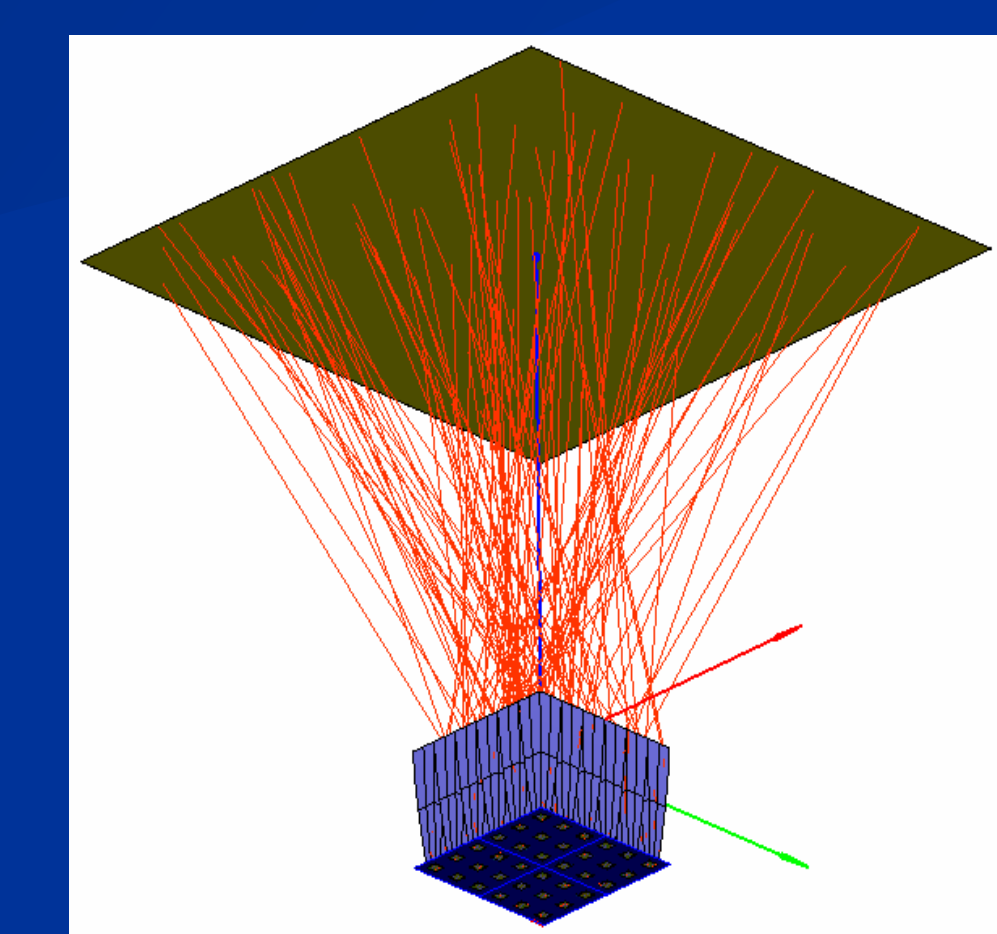
- Solar cell area



Side face

- Free form surface
- Optimization of free-form parameters
 - Height
 - Mid & bottom size
 - Refractive index of SOE
- Optical efficiency optimization

Concentration ratio (C)

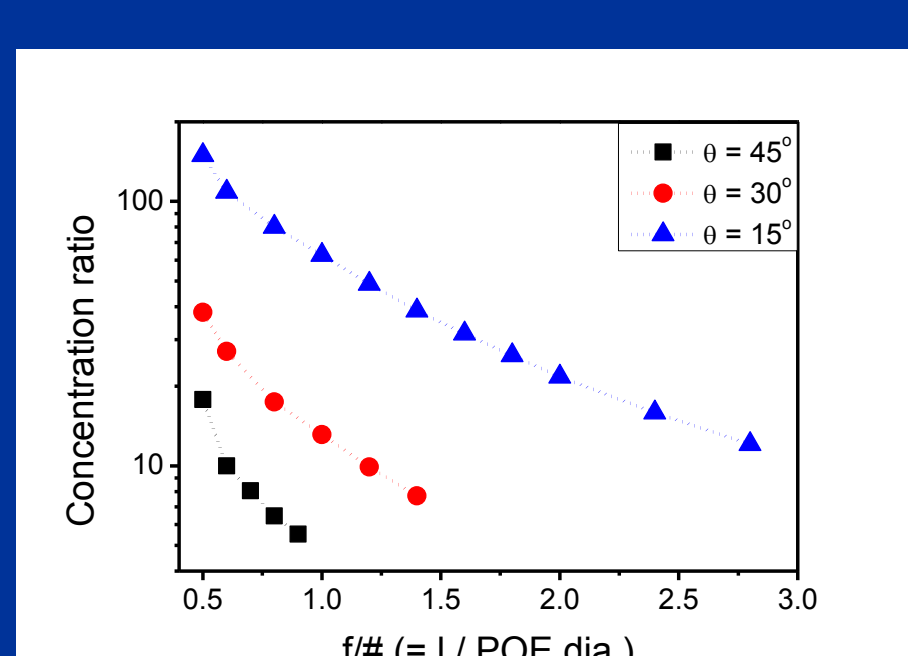
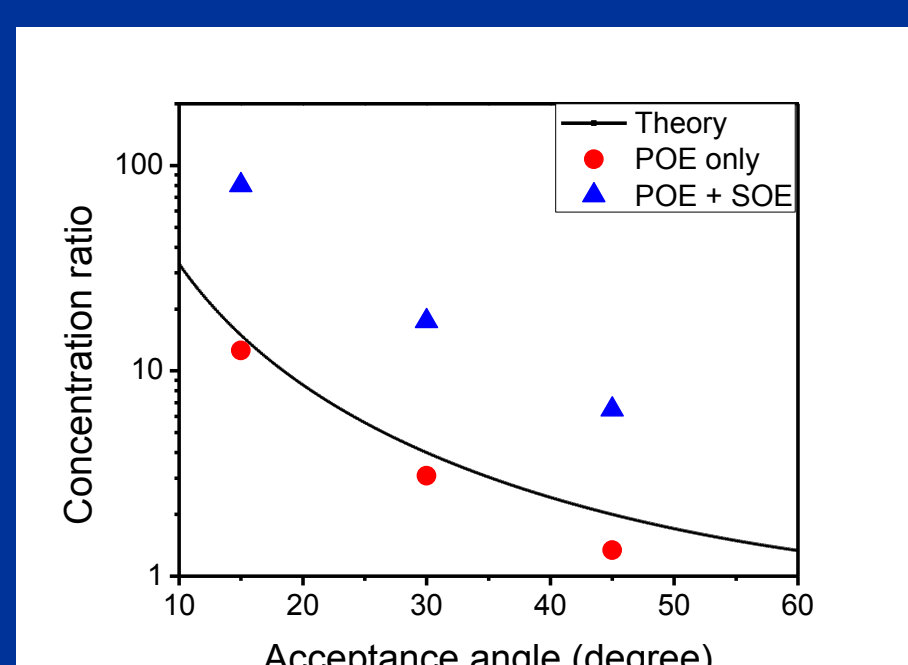


Concentration ratio in the multi-array SOE structure

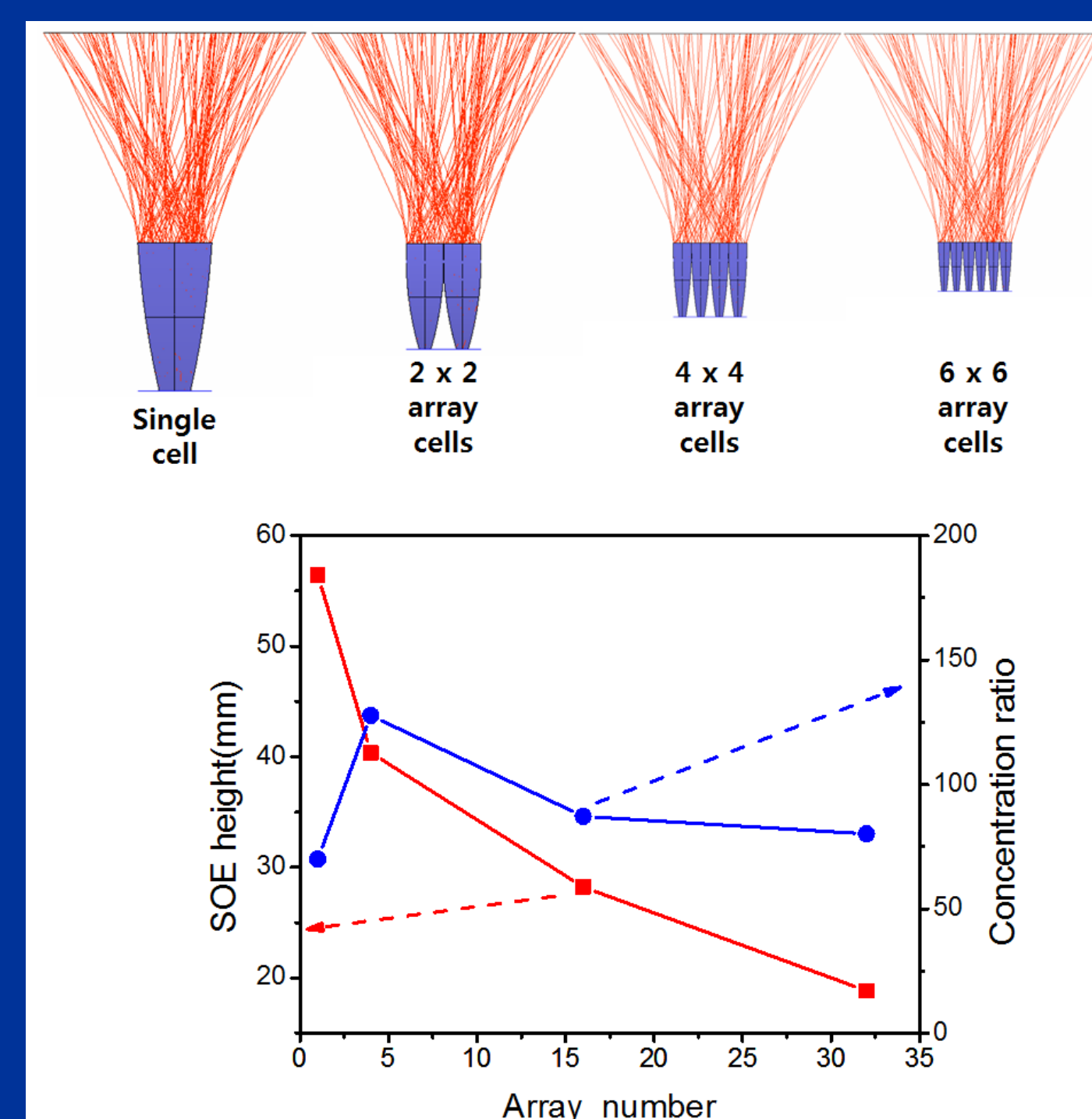
$$C = \frac{\text{Fresnel lens area}}{\sum \text{Solar cell area}}$$

Results

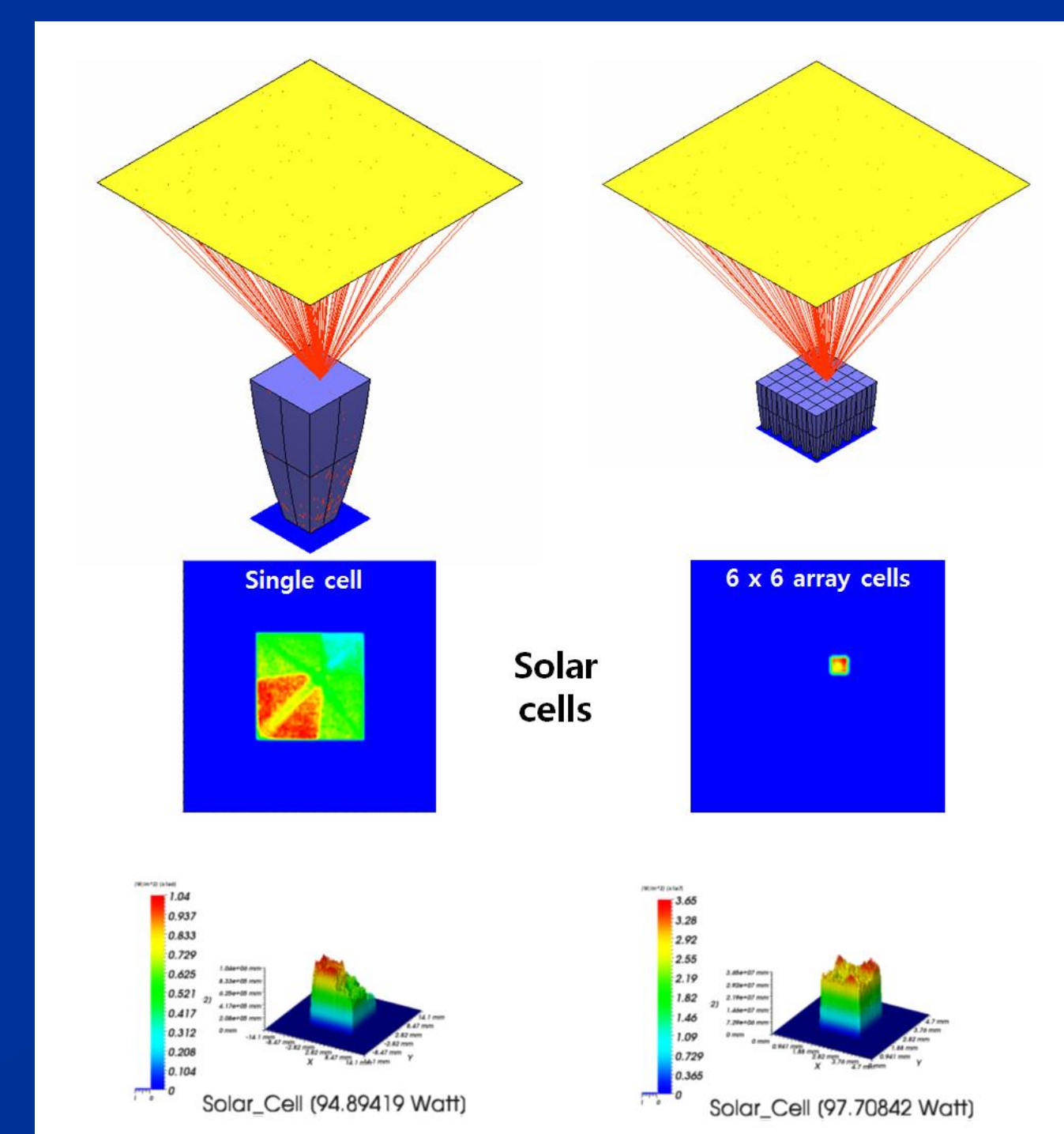
Concentration ratio



Multi-array SOE structure



Irradiance distribution



Conclusions

- With non-imaging optical method utilizing ray-tracing algorithm, SOE structure could be optimized.
- In comparison with POE only concentrator, POE+SOE concentrators have much higher concentration ratio.
- Concentration ratio was reduced with f number.
- Multi-array SOE structures have more compact size and uniform irradiance distribution than single SOE structure.
- With optimal concentrator design, less rigid tracker systems in HCPV and the non-tracking CPV system in the LCPV will be possible.