

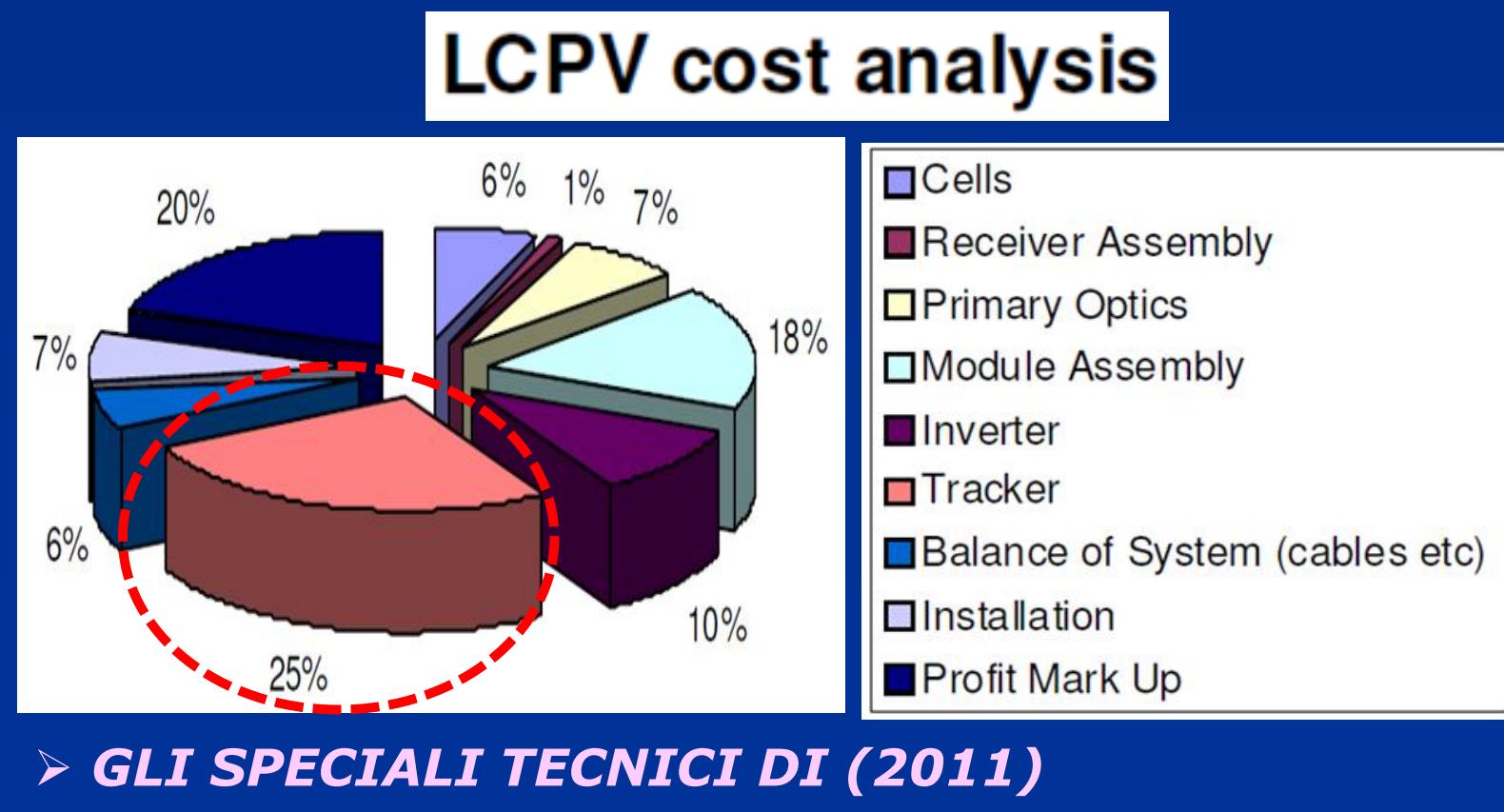
Optimization of the solar concentrator for increasing the acceptance angle in concentrating photovoltaic (CPV) system

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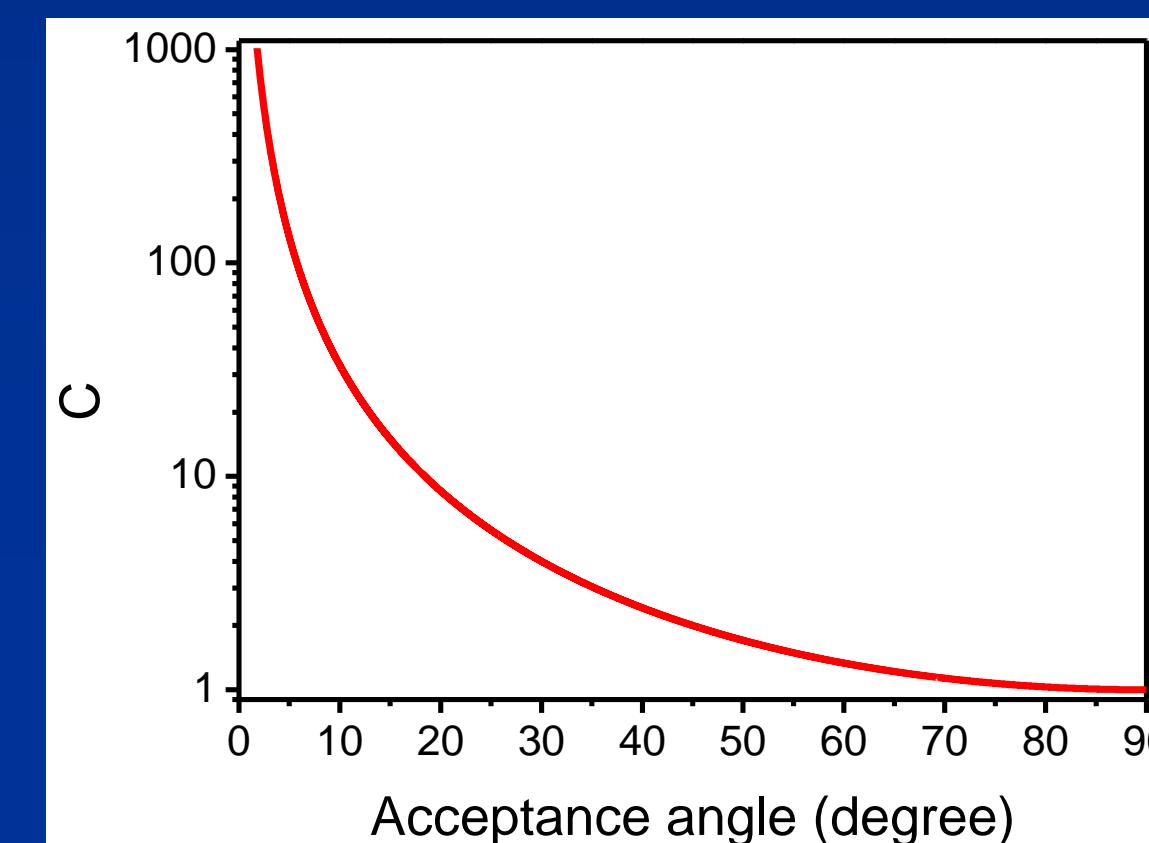
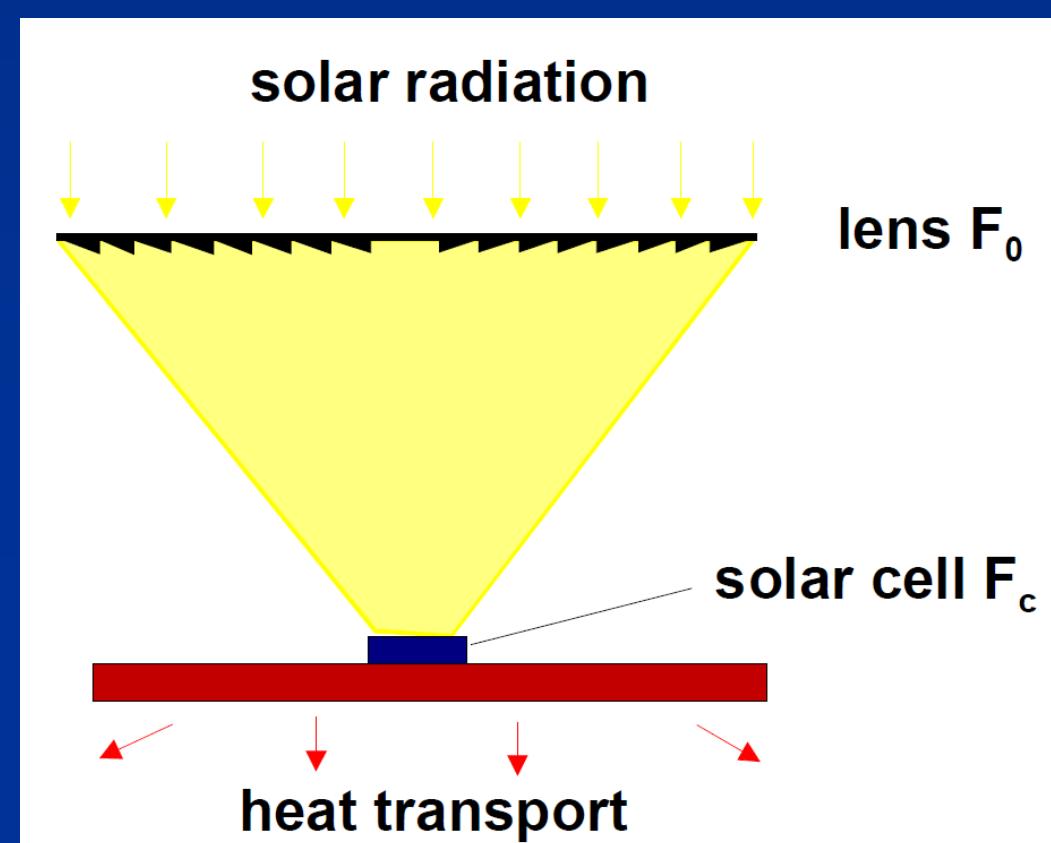
Introduction

- Concentrating photovoltaic (CPV)



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

- Solar Concentrator



- Concentration ratio (C).

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

F₀: Lens area
F_c: Solar cell area
θ : Acceptance angle

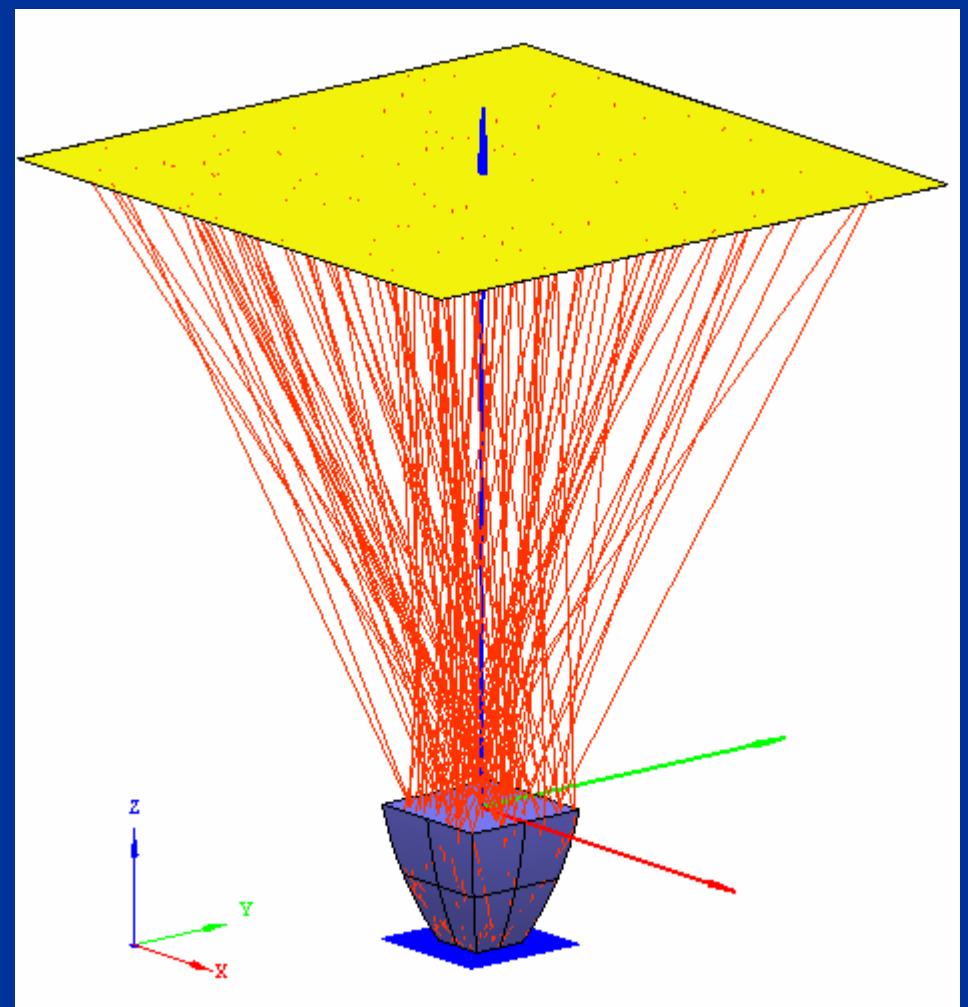
C	θ (degree)
2	45.00
5	26.57
10	18.43
100	5.74
500	2.56
1000	1.81

- 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

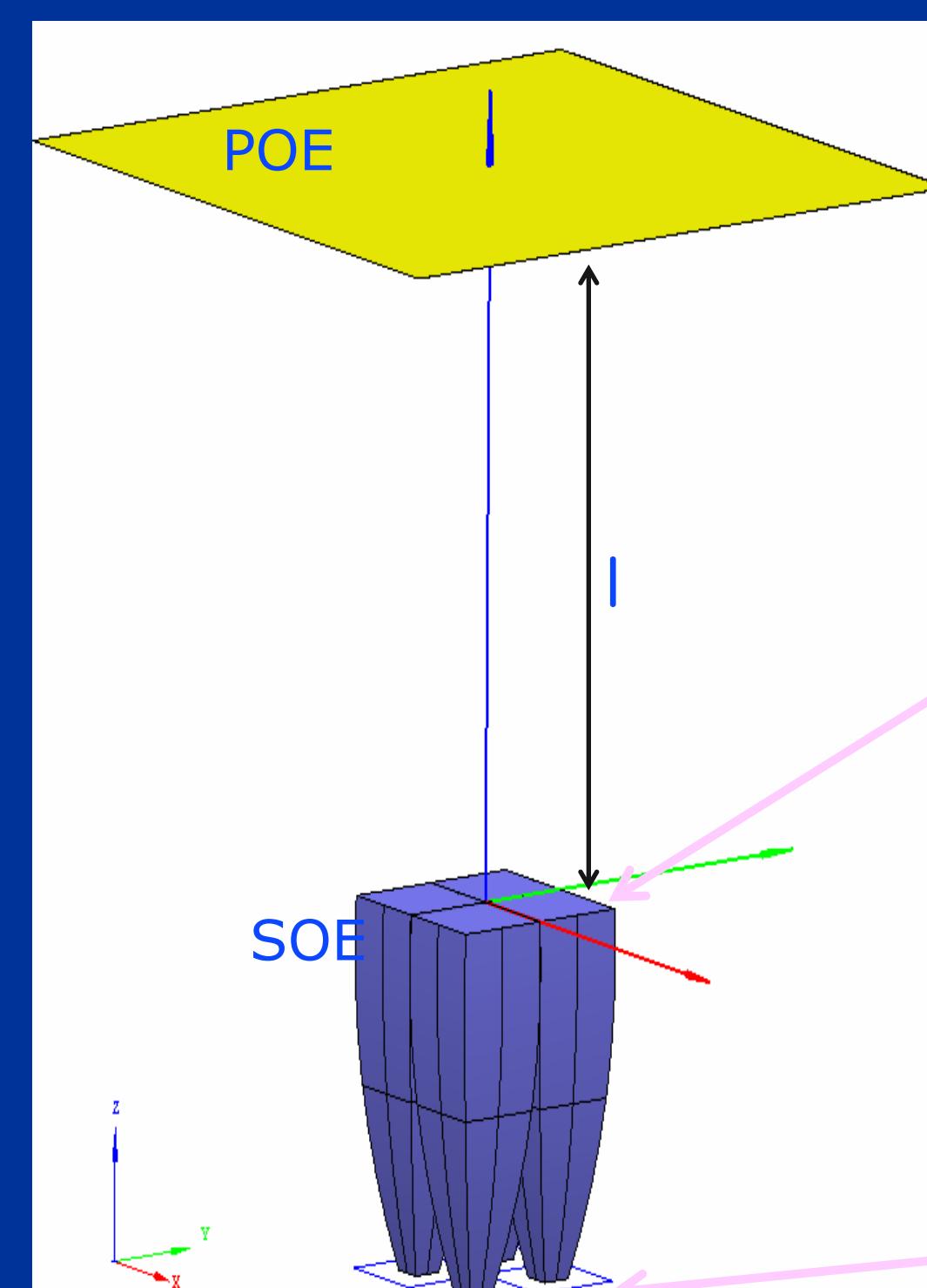
Simulation process

- Solar Concentrator design



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

- Optical system & parameters



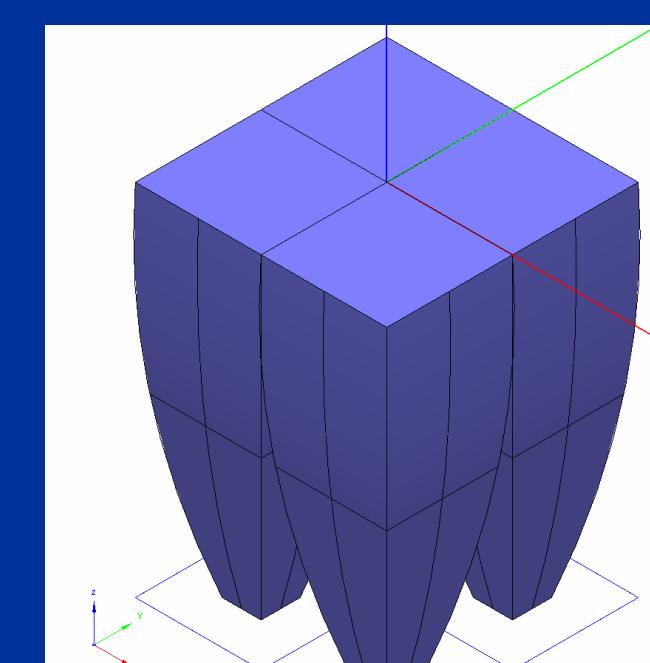
Fresnel Lens (assumption)
100mm x 100mm
n = 1.49 (PMMA)

Upper face (r x r)
✓ r = l x tan(sinθ/n)
θ: Incidence angle
n: Refractive index of POE

✓ Refractive index of SOE : 1.49 ~ 2.00

✓ AR coating assumption

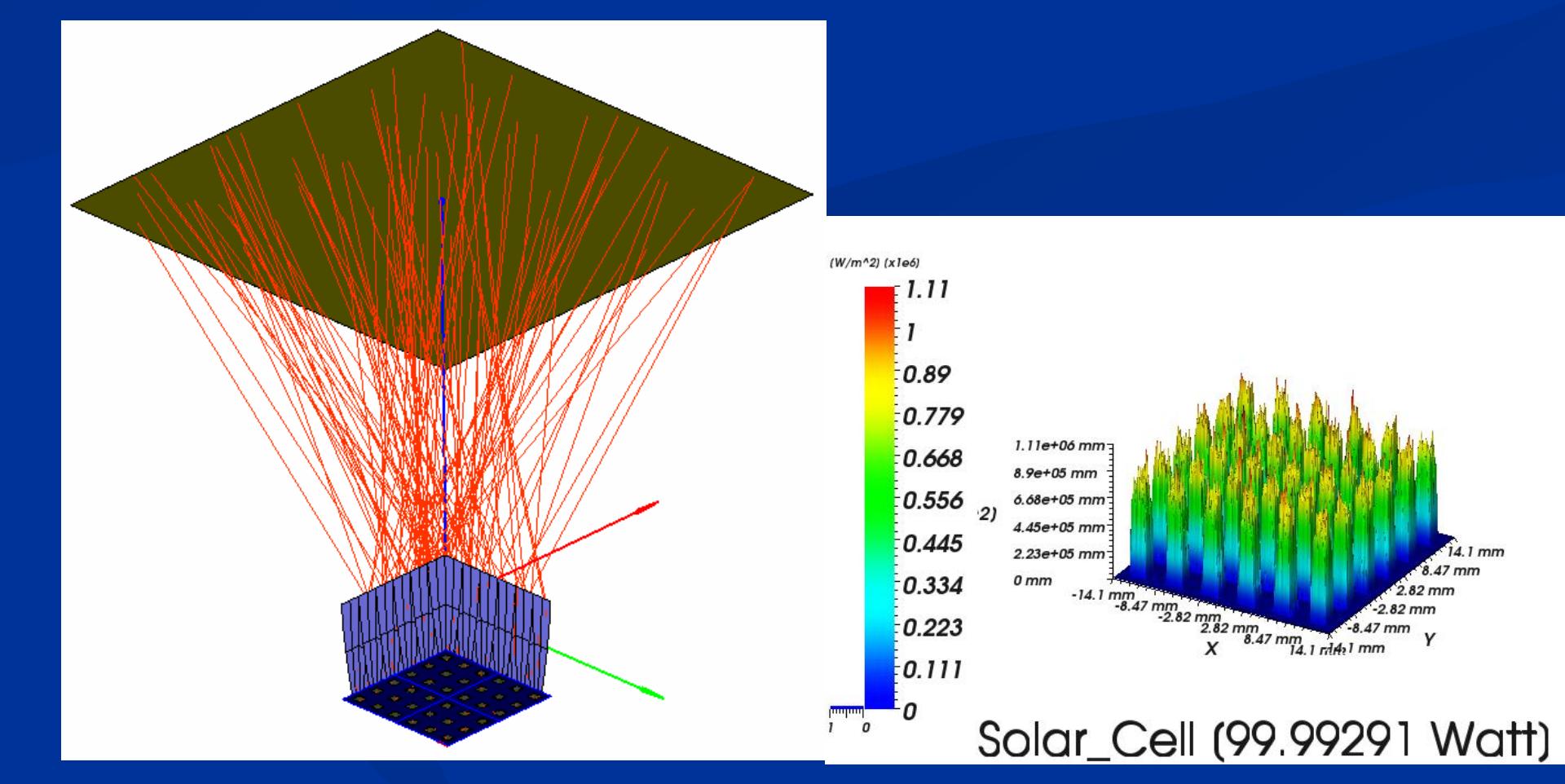
Bottom face
✓ Solar cell area



Side face
✓ Free form surface
✓ Optimization of free-form parameters

- Height
- Mid & bottom size
- Refractive index of SOE

✓ Optical efficiency optimization



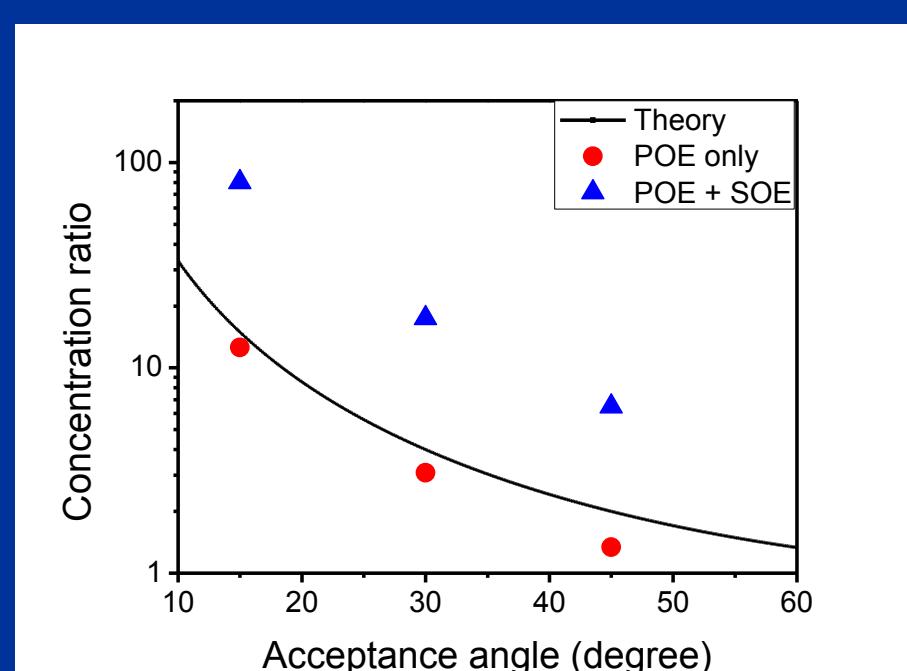
- Concentration ratio (C)

- Concentration ratio in the multi-array SOE structure

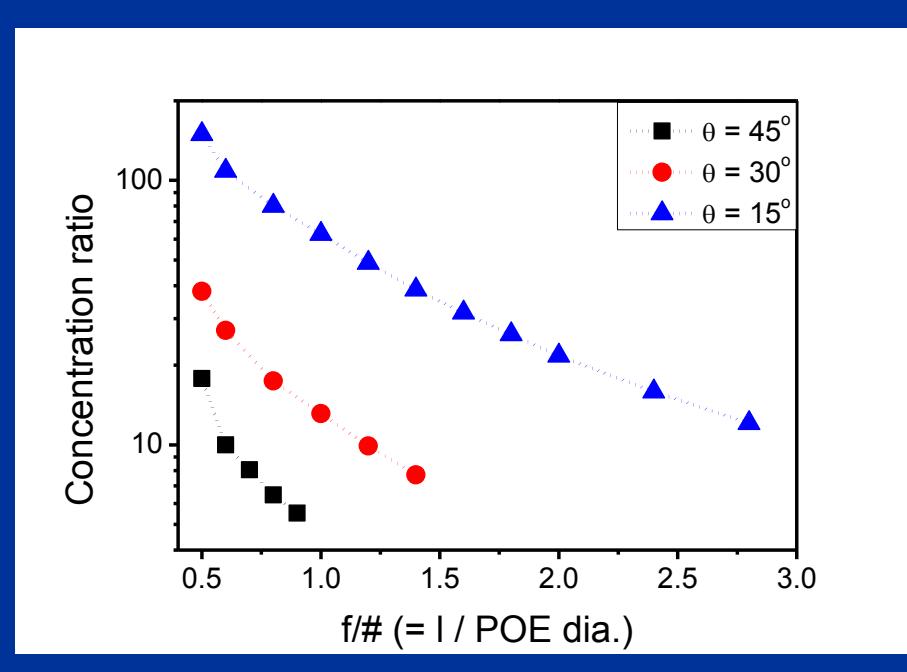
$$C = \frac{\text{Fresnel lens area}}{\sum \text{Solar cell area}}$$

Results

- Concentration ratio

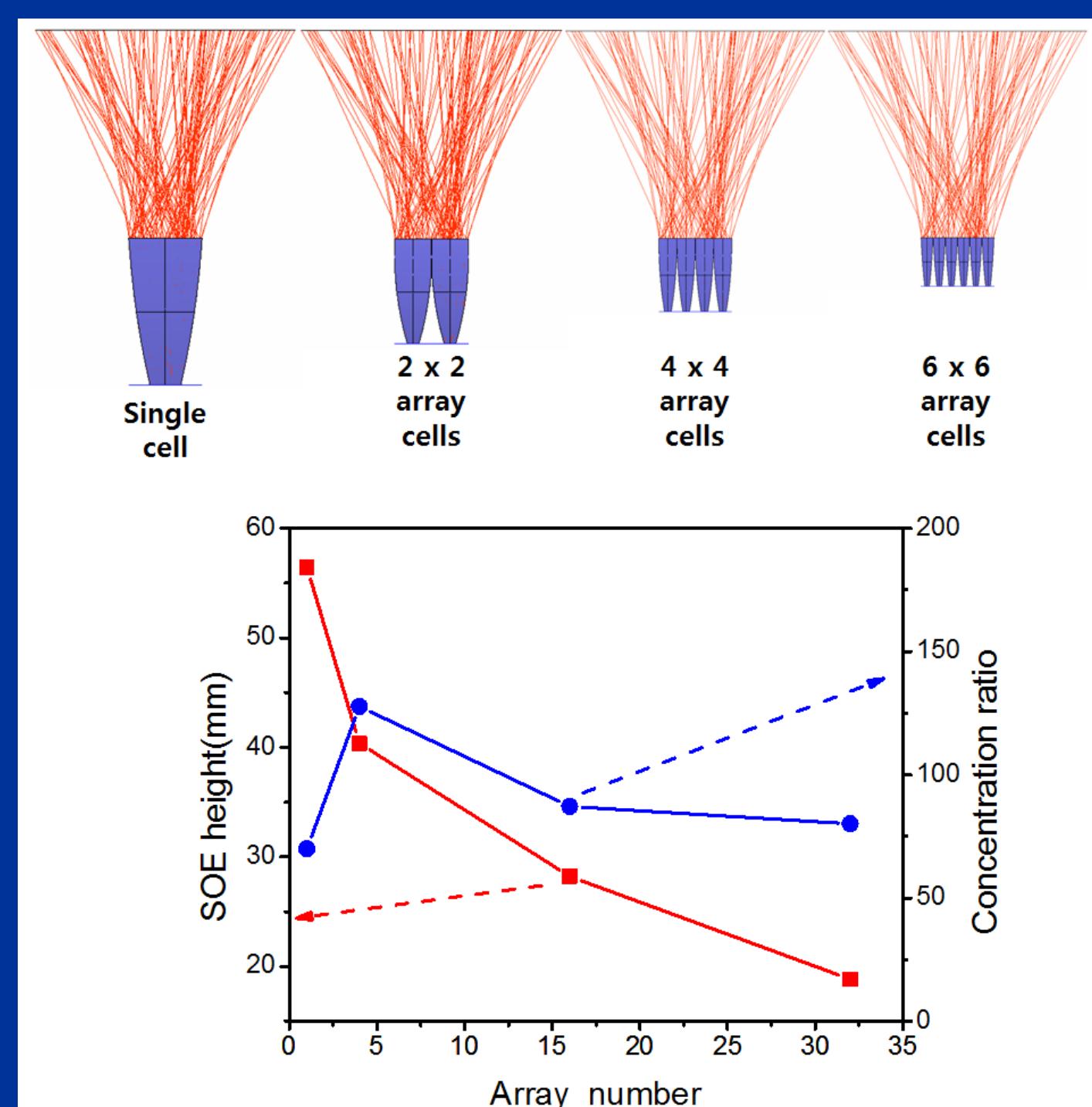


- SOE array: 6 x 6
- f/# = 0.8

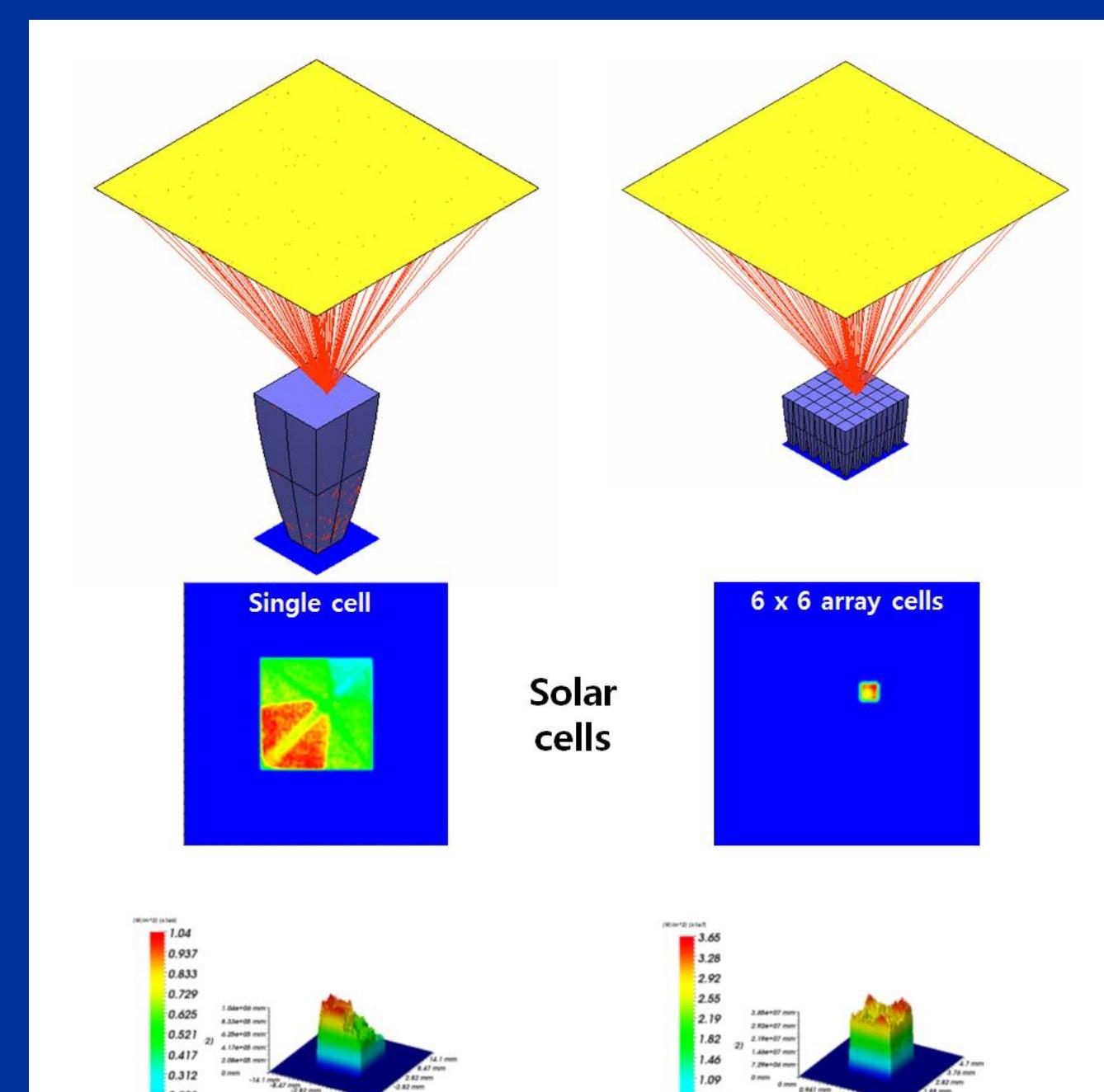


- SOE array: 6 x 6

- Multi-array SOE structure



- Irradiance distribution



- θ = 15°, f/# = 0.8
- Point focusing

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.