Unconventional Non Imaging Optics

by

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What for?

- To achieve the highest concentration
- To achieve the highest transmission efficiency

- The need to consider “etendue” conservation (matching)

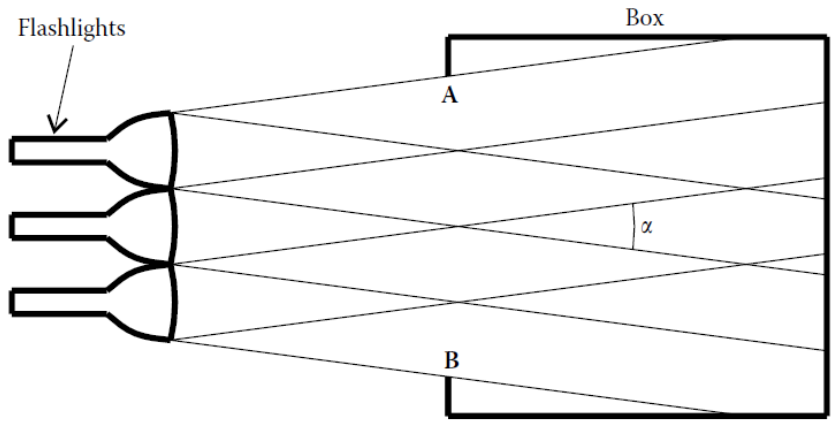
- “etendue” : a geometrical quantity, is the product of area*angular room occupied and traversed by the optical rays (solar radiation)

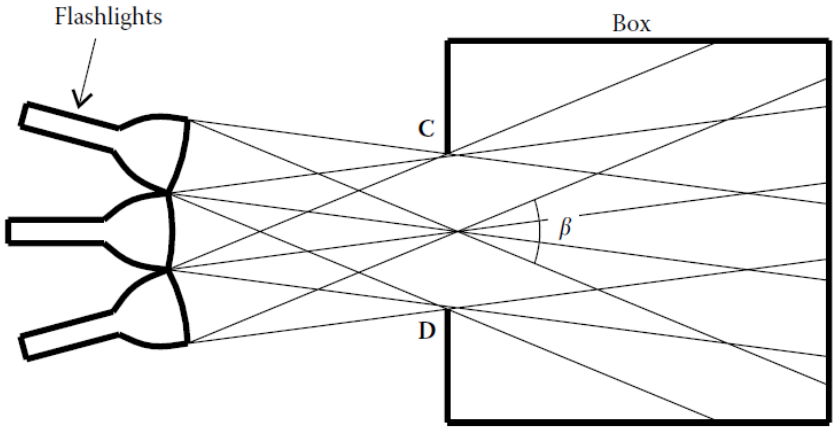
Conservation of “Etendue”

Etendue through AB (from three identical flashlights) with an angular spread α associated …

…is the same as …

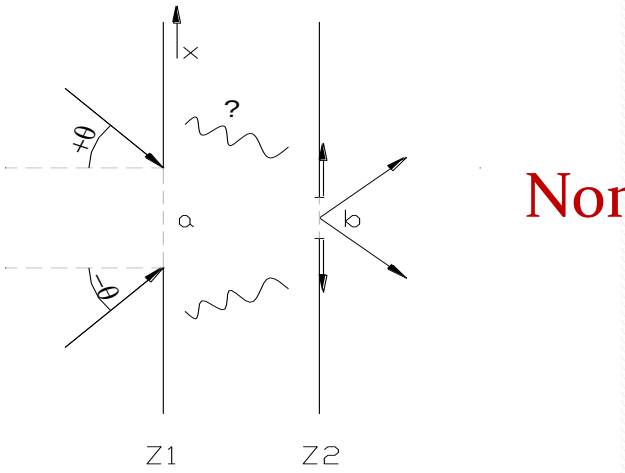
… Etendue (same three flashlights!) through the smaller area CD but now with a larger angular spread β





Maximal Concentration ?

- The problem is: given radiation incident on an aperture **a** within a certain angular range (±θ) , how much can it be concentrated- Cmax?
- Conservation of "Etendue" applied to the problem of maximal concentration



C=Cmax=a/b=1/sin (θ)

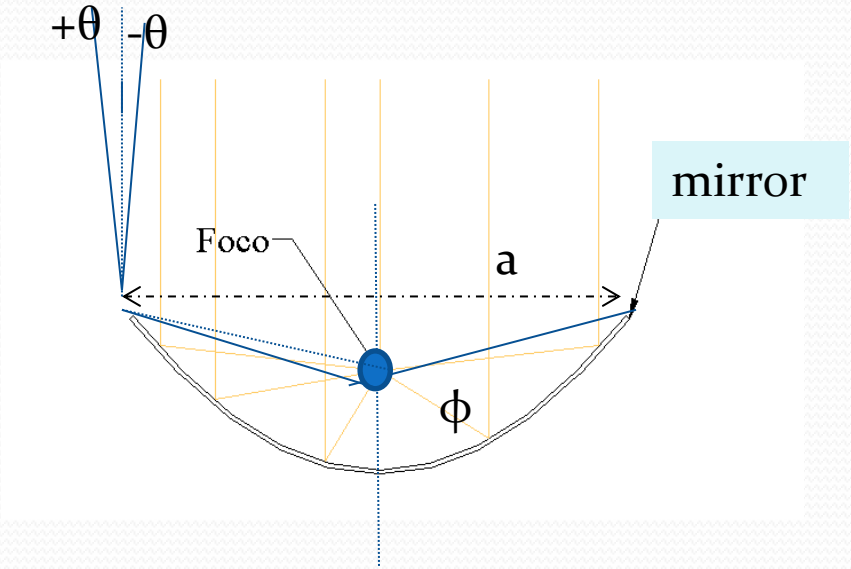
Non Imaging Optics (Ideal Optics)

In general, any optic

CAP=C*sin(θ)<=**1**

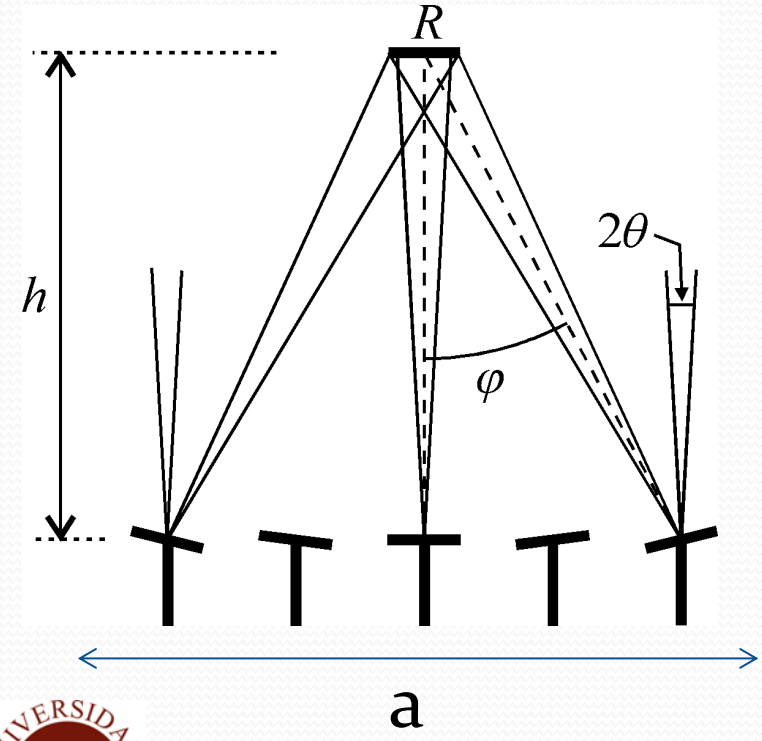
CAP= C * sin (θ) <=1

- Parabolic trough is very far from the limit , just like any imaging type optics!!!
- CAP=C*sin (θ)= sin(ϕ)/π < **0.318**



Linear Fresnel also

- CAP=C*sin(θ) < 0.45



Incident light with aperture 2*θ

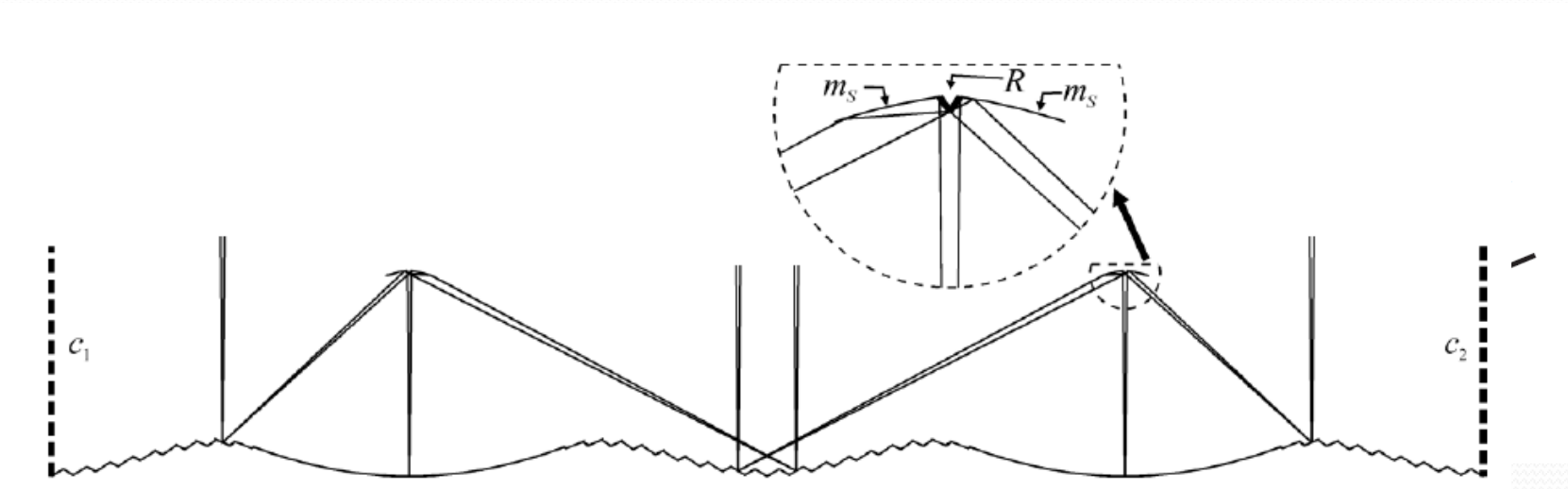
C=a/R

C/Cmax=0.45 for the best case

ψ=40.4º (rim angle)

High Concentration?

- Results in smaller heat losses
- Particularly important if receiver is **non-evacuated**!
- Example: Linear Fresnel "Etendue" matched

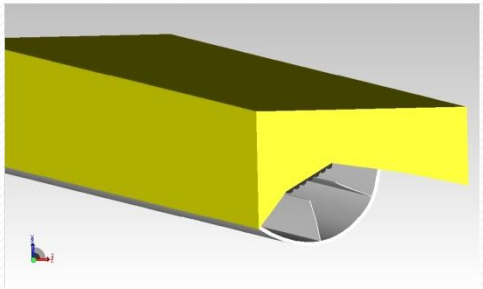


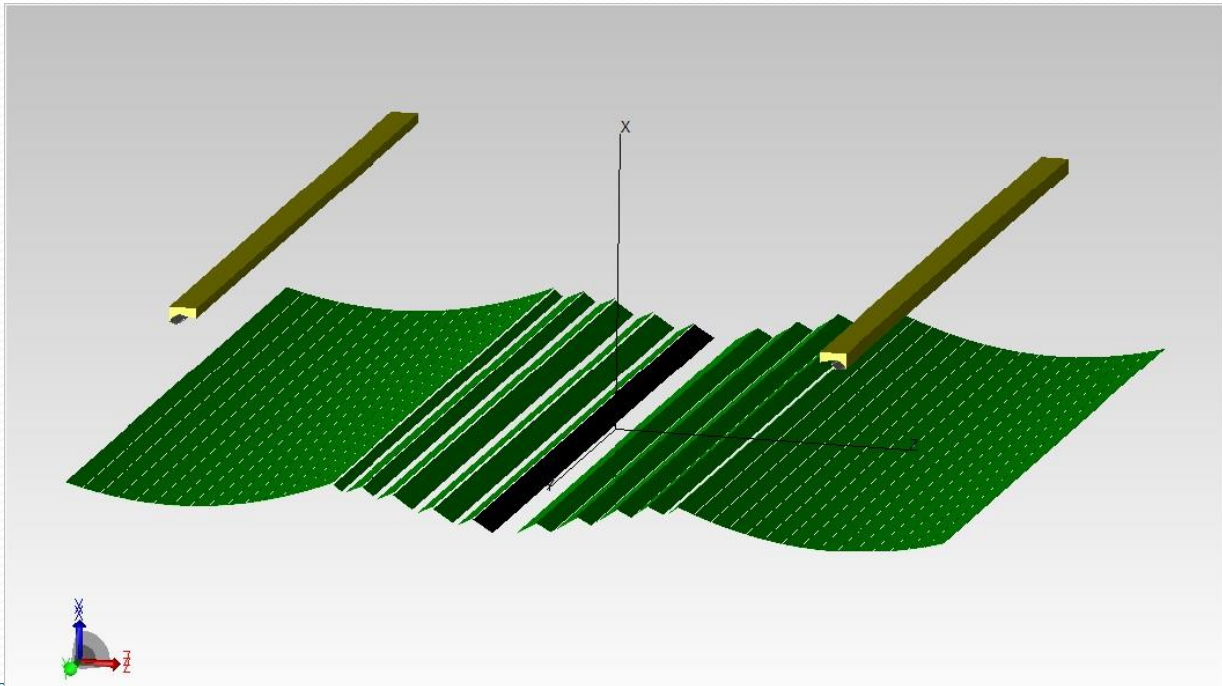
Linear Fresnel Etendue matched

CAP<0.7

Ψ~76º

~30% more electricity delivered (400ºC) than a conventional LFR of saturated steam at 270ºC)





Evacuated tubular receivers

- No longer the goal is very high C !
- Etendue matching for efficiency+
- + the possibility of having an impact on overall pipe losses, pumping power, thermal fluid volume and other costs!

- Larger parabolic troughs
- Fixed receiver parabolic troughs
- Larger primaries in Linear Fresnel concentrators
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Larger troughs : from ~6m to ~8m

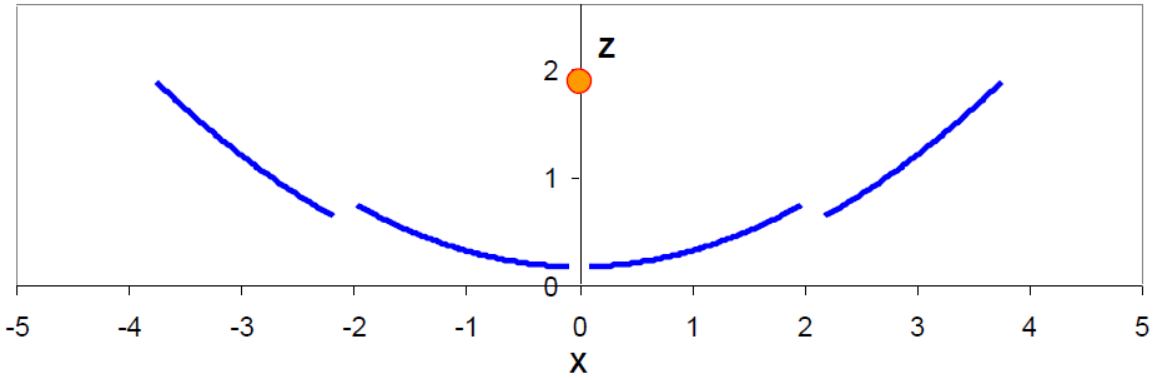
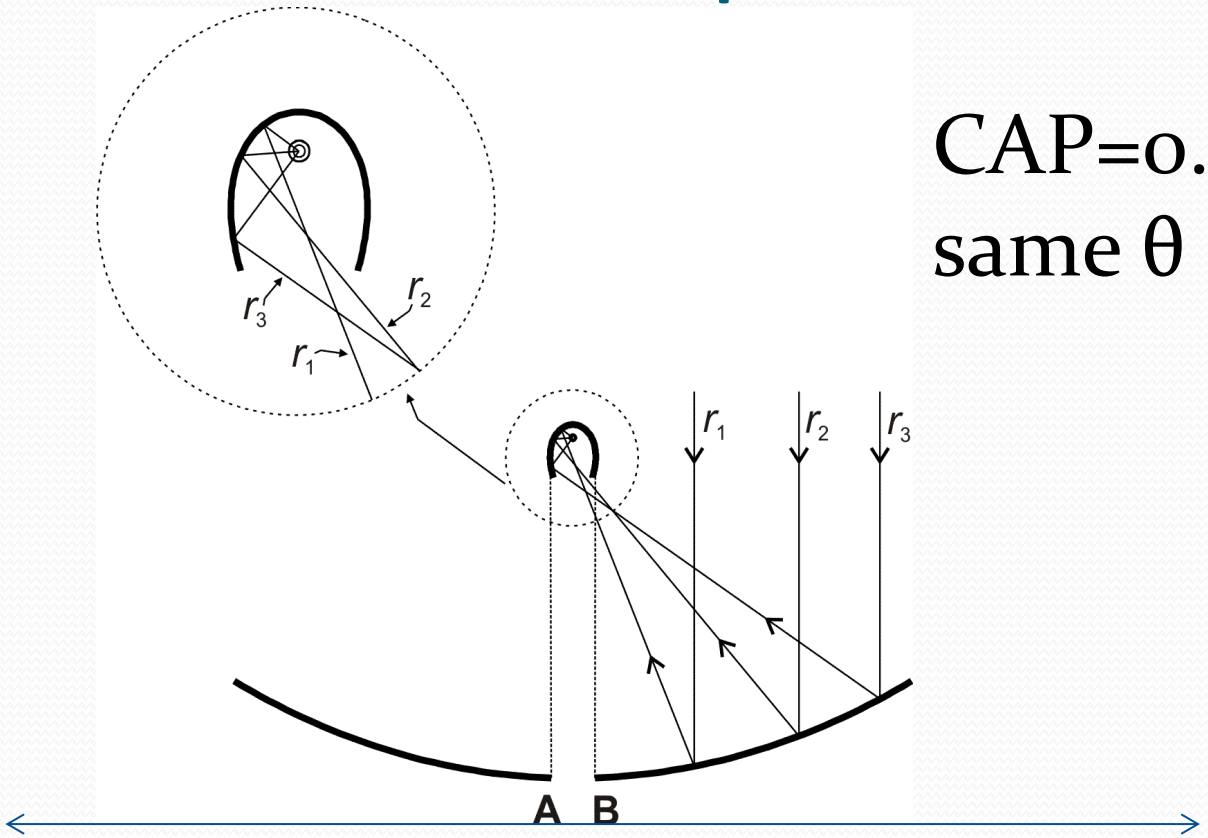


Figure 1: Geometry of the Ultimate Trough® with wind release gap between inner and outer mirror

~8m trough, same tube
and CAP <0.318 …

It means a smaller θ !

n.i.o. solution - XX-SMS (simultaneous multiple surface)

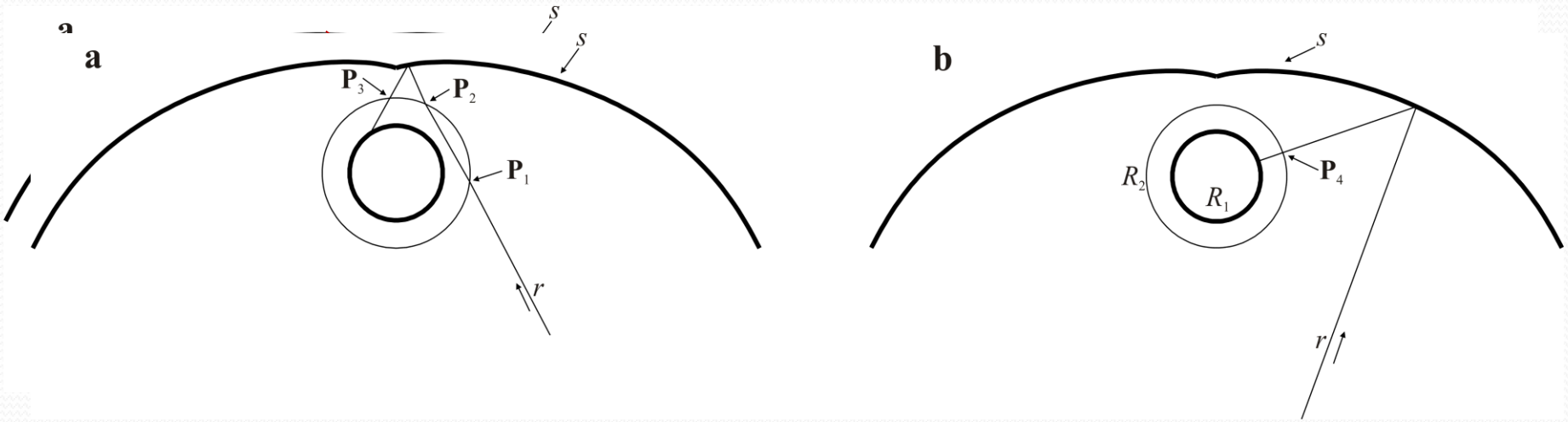


CAP=0.61
same θ

11.1 m trough

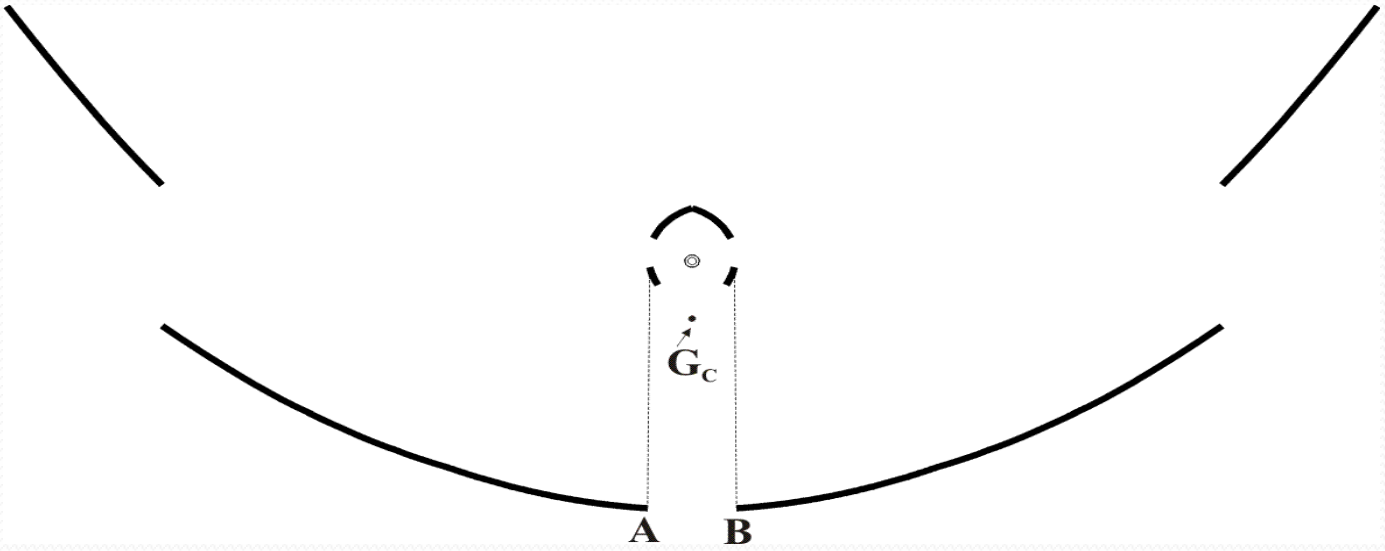
Optical losses due to the glass envelope

- It solves a major contributor to optical losses : gap and transmission losses through the glass



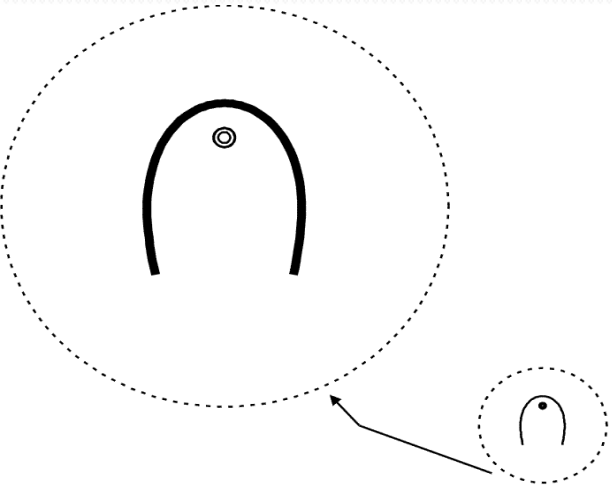
New XX- SMS for fixed receiver troughs

- 10.87 m aperture CAP=0.54

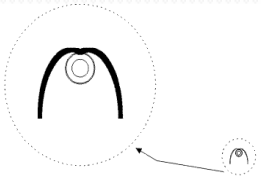


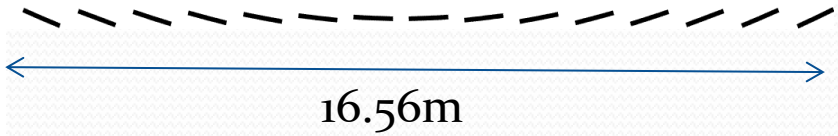
Linear Fresnel concentrators

Novatec type design : CAP=0.38



20.11 m





16.56m

XX-SMS solution
CAP= 0.57

Consequences

- Higher optical efficiency
- 20 to 40% less rows in a collector field
- Reduction: pipe lenght; thermal and pumping losses; heat transfer volume, etc

- Next; apply the same principles to 3D geometries (central receiver)

- Thank you for your attention !