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 $\alpha$ associated ...

... is the same as ...

... Etendue (same three flashlights!) through the smaller area CD but now with a larger angular spread $\beta$
Maximal Concentration?

- The problem is: given radiation incident on an aperture $a$ within a certain angular range $(\pm \theta)$, how much can it be concentrated - $C_{\text{max}}$?

- Conservation of “Etendue” applied to the problem of maximal concentration

$$C = C_{\text{max}} = \frac{a}{b} = \frac{1}{\sin (\theta)}$$

*Non Imaging Optics (Ideal Optics)*

In general, any optic

$$\text{CAP} = C \times \sin(\theta) \leq 1$$
\[ \text{CAP} = C \ast \sin(\theta) \leq 1 \]

- Parabolic trough is very far from the limit, just like any imaging type optics!!!

- \[ \text{CAP} = C \ast \sin(\theta) = \frac{\sin(\phi)}{\pi} < 0.318 \]
Linear Fresnel also

- \( \text{CAP} = C^* \sin(\theta) < 0.45 \)

Incident light with aperture \( 2^*\theta \)

- \( C = a/R \)
- \( C/C_{\text{max}} = 0.45 \) for the best case
- \( \psi = 40.4^\circ \) (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

\[ \text{CAP} < 0.7 \]
\[ \Psi \approx 76^\circ \]

\( \sim 30\% \) more electricity delivered (400\(^\circ\)C) than a conventional LFR of saturated steam at 270\(^\circ\)C)
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
Larger troughs: from ~6m to ~8m

~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 $\theta$

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

XX-SMS solution
CAP=0.57
Consequences

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

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

Thank you for your attention!