Solar Energy and Non Imaging Optics for the production of clean water

by

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Why Non Imaging Optics?
(Solar thermal applications)

Low temperatures \( T<50^\circ C \)

- Flat plate collectors
Advantages of flat plate technology

• The collectors are fully stationary, i.e. they do not need to track the apparent daily motion of the sun

• they collect diffuse solar radiation
What if we want higher temperatures? $T > 50^\circ C$

- With more sophisticated materials: a more expensive product

One possible alternative solution: Vacuum technology

Again the cost is much higher for the same quality
Is there another solution? Can we have higher temperatures?

• Thermal losses from large absorbers are large: losses are proportional to absorber area
• If we reduce the absorber area, in comparison with the glass area....
• Concentration $A_{abs} < A_{glass}$
  \[ C = \frac{A_{glass}}{A_{abs}} \]
Classical Concentrators and imaging or focusing optics

- they only collect beam (direct)
- they must track the sun!

Is there an alternative (better) solution?

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

- the solution calls for a new type of optics: **non-imaging optics**; give up the imaging part, i.e. the optics must “scramble” the incident radiation, and then it can concentrate the energy to the limit - \( C_{\text{max}}(\theta) \)-established by first principles in physics

\[
C = \frac{a}{b}
\]
One solution to the problem - CPC type optics

CPC with mirrors

•2 parabolic mirrors with Foci at the edges of segment b , with each axis parallel to the edge rays from (±θ)

\[ C = \frac{a}{b} = \frac{1}{\sin(\theta)} \]

Dielectric CPC

•same geometry, but now taking into account total internal reflection

\[ C = \frac{a}{b} = \frac{n}{\sin(\theta)} \]
Acceptance angle function and the concept of truncation
Assymetric CPCs

- $C_{max} = \frac{a}{b} = \frac{2}{\sin(\theta_1) + \sin(\theta_2)}$
Other features of Non Imaging or Anidolic Optics

- 2D; also 3D solutions

\[ C_{\text{max}} = \left( \frac{n}{\sin(\theta)} \right)^2 \]

- other absorber shapes (tubes, shaped fins, cavities, etc.)
Advantages of Non Imaging Optics in Solar

• collectors are concentrators
• but: 1) they are stationary (or require few adjustments through the year...)
  2) they collect diffuse radiation
  3) they retain the potential for low cost of flat plate collectors
    *i.e. the best of both worlds!*

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Does Nature use this type of optics?

- Yes! The *Limulus* optical system

(...) the cones in our retina(...)
Low temperature applications
\( (T < 100^\circ C) \)

\[ C = 1.12 \quad (\theta = 56 \text{ and } \theta_c = 76) \]

CPC produced by AO SOL, Portugal

www.aosol.pt

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simulation of a roof system with CPCs 1.5X: demonstration of air conditioning with solar and gas as back-up, at INETI
Other applications: solar cooking

- Box type cookers, 2 X 2D CPCs
High concentration cooker: a 3D solution

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Other applications: still higher temperatures -T>>&

- Combine non-imaging optics with focusing type optics:
  
  **second stage concentration**

  3 D solution

  ![Diagram of 3D solution]

  2 D solution

  ![Diagram of 2D solution]

  **Solar Furnace at PSA+TERC**

  >2800°C
Other applications

• Electricity, via PV conversion

• illumination: interior lighting, car lights, etc.

• radiation collection/detection: defense, astronomy, particle physics, etc.

• (....)
Other applications: **Solar U.V. for Photocatalysis**

- detoxification of contaminated wastes, with UV and a catalyst- TiO2(...) added to the waste water circulating in tubes
Catalyst in suspension - Cadox project (EU)

Prototype tested at INETI and PSA

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Final version for a collector field with 100m²

- Module of Cadox collector
SOLWATER: the fixed catalyst fin case

Application: drinking water production from contaminated surface waters

Optimal, but not ideal

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The case of the fin

- Examples of raytracing
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Conclusions

• Non Imaging Optics can solve many problems in all sorts of different applications.

• It does so in an ideal way, i.e. In the limits allowed by first principles in Physics