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

by

Manuel Collares Pereira

(Investigador Coordenador-INETI)

(Professor Catedrático Convidado- IST)

(Director de I&D-Ao Sol Energias Renováveis, lda)

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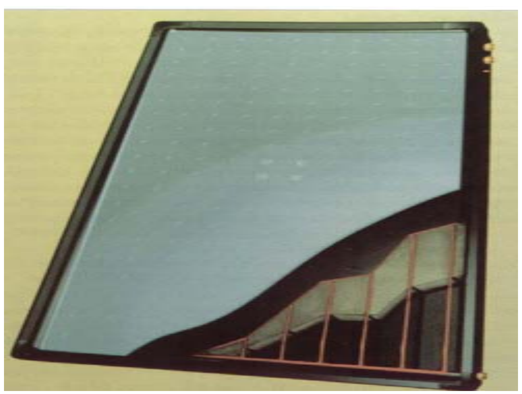
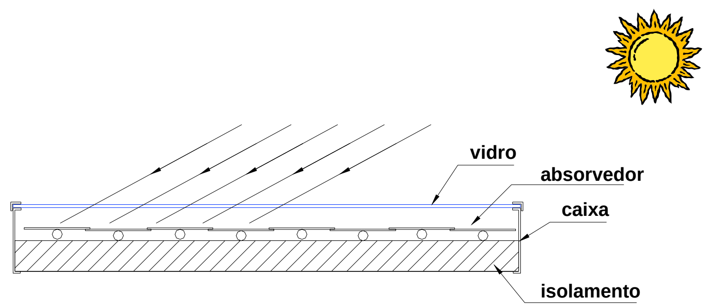
Why Non Imaging Optics?

(Solar thermal applications)

Low temperatures   T<50ºC

- Flat plate collectors





Aabs= A glass

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>50ºC

- With more sophisticated materials: a more expensive product

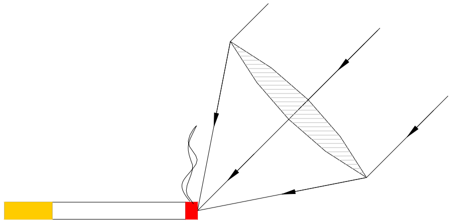
One possible alternative solution : Vaccuum technology

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 ⟶ Aabs<Aglass

C=Aglass/Aabs



Classical Concentrators and imaging or focussing optics

Fig. 1.6 Solar-1 pilot plant (10 MW_e) under test in Barstow, Calif. (U.S.A.)

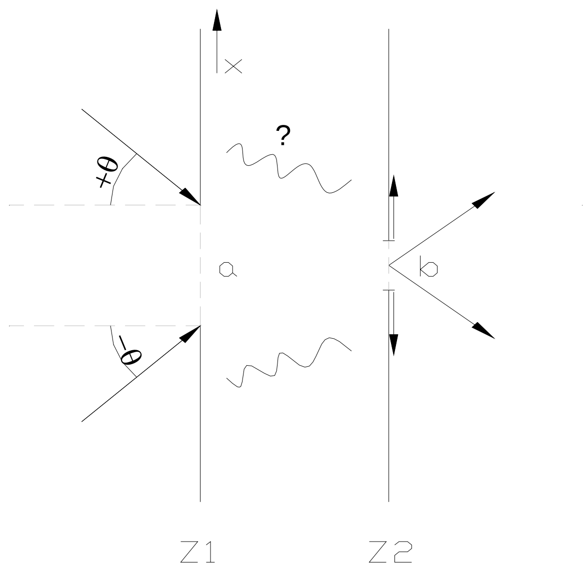
- they only collect beam(direct)

- they must track the sun!

Is there an alternative (better) solution ?

The problem is: given radiation incident on an aperture **a** within a certain angular range (±θ) , how much can it be concentrated- Cmax?

- the solution calls for a new type 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* - Cmax(θ)-established by first principles in physics

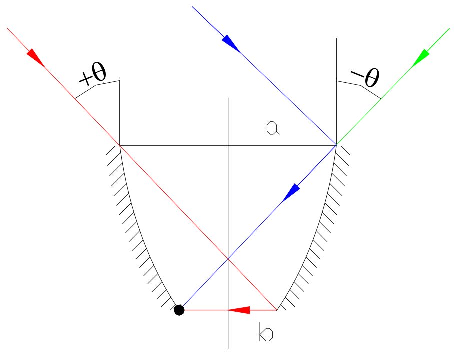


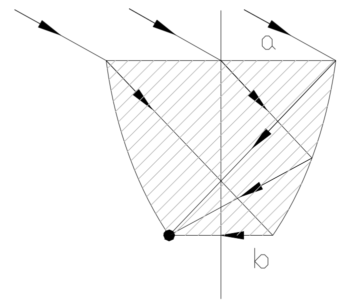
C=a/b

One solution to the problem - CPC type optics

dielectric CPC
n=1 ← air

CPC with mirrors





n>1
dielectric

CPC with mirrors

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

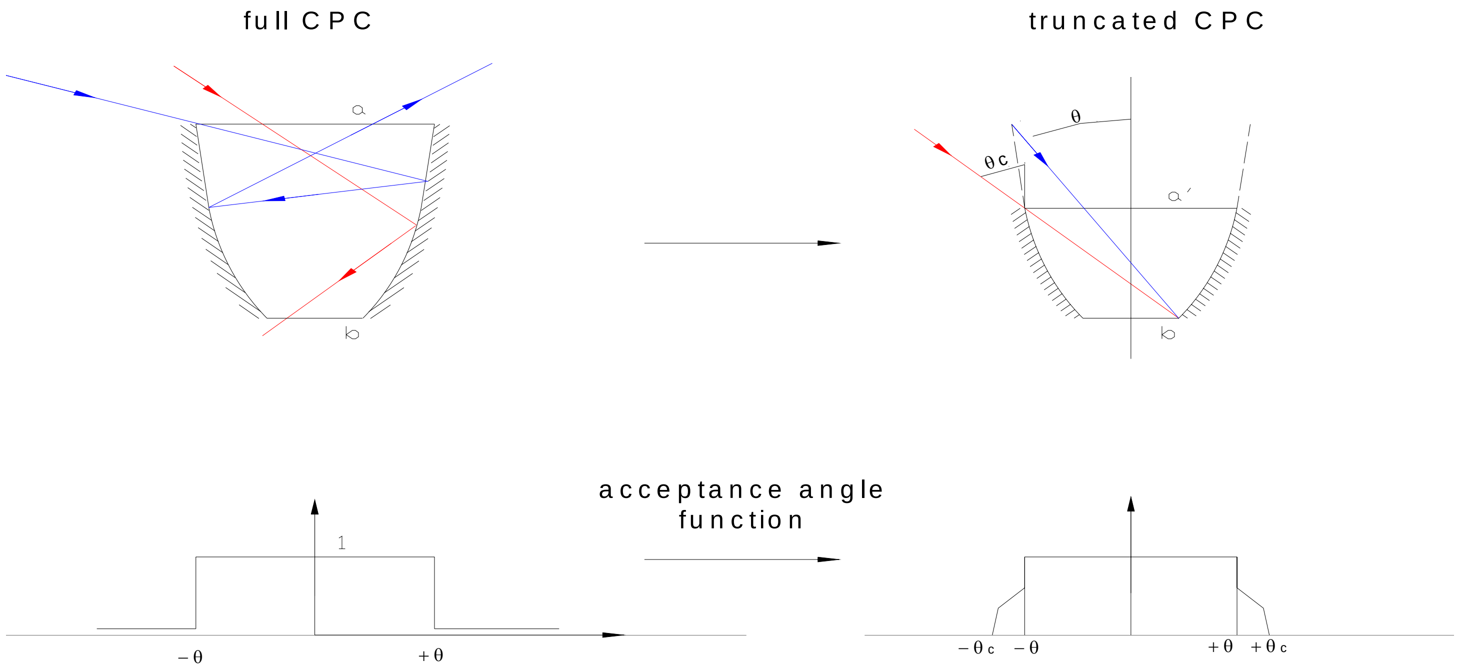
C=Cmax=a/b= 1/sin(θ)

Dielectric CPC

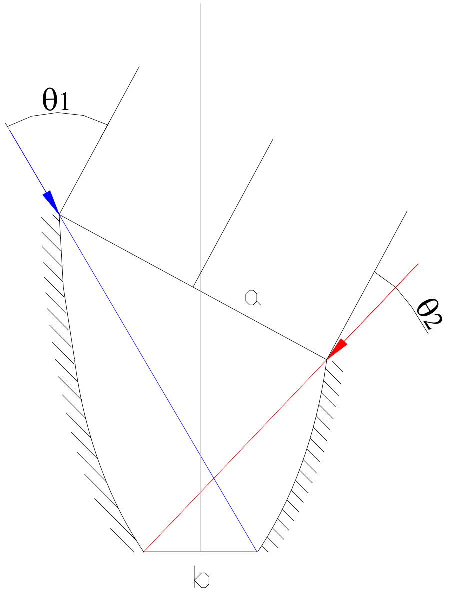
•same geometry, but now taking into account total internal reflection

C=Cmax=a/b=n/sin(θ)

Acceptance angle function and the concept of truncation



Assymetric CPCs



- $C_{max} = a/b = 2/(\sin(\theta 1) + \sin(\theta 2))$

Other features of Non Imaging or Anidolic Optics

- 2D; also 3D solutions

  in 3D Cmax= $(n/\sin(\theta))^2$

- 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

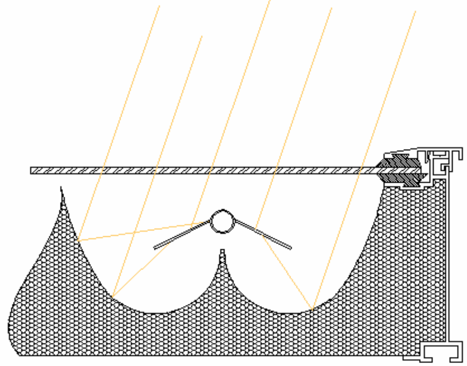
i.e. the best of both worlds!

Does Nature use this type of optics?

- Yes! The *Limulus* optical system

(...) the cones in our retina(...)

Low temperature applications (T<100ºC)



C=1.12 **(θ=56** and **θc=76)**

CPC produced by AO SOL, Portugal
www.aosol.pt

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

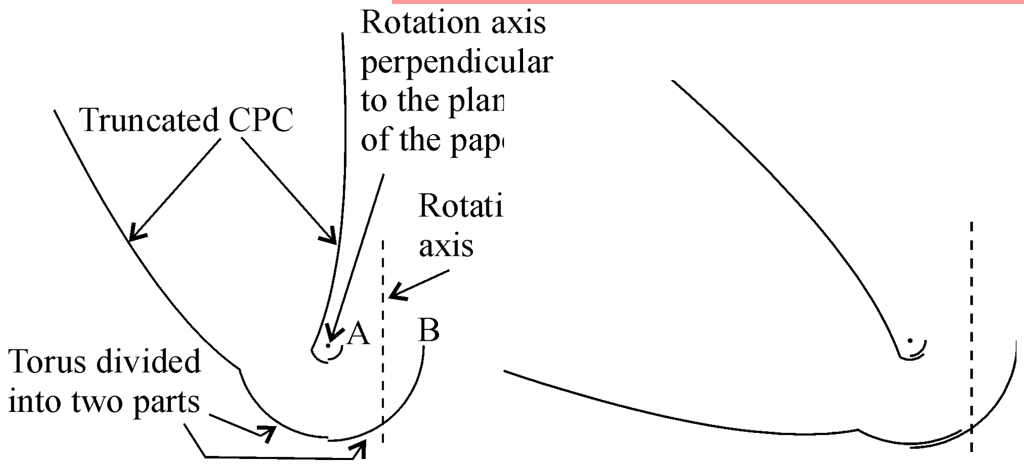
Other applications: solar cooking

- Box type cookers, 2 X 2D CPCs


Ao Sol
Energias Renováveis, Lda.

High concentration cooker: a 3D solution

INETI

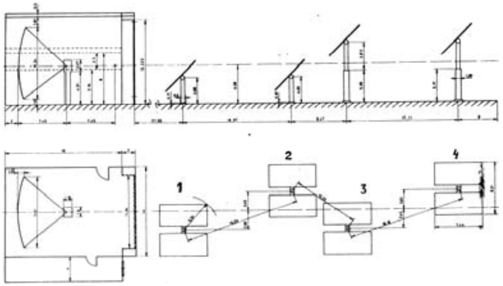


Other applications: still higher temperatures -T>>

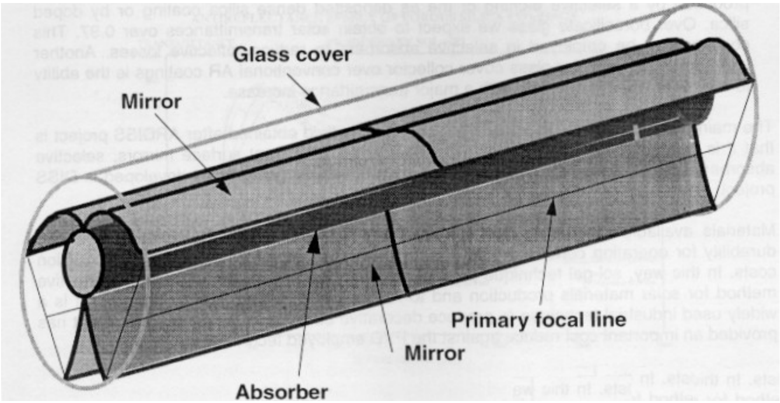
- Combine non-imaging optics with focussing type optics:

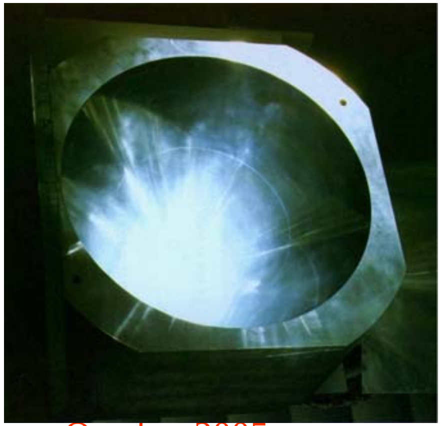
  second stage concentration

3 D solution



2 D solution





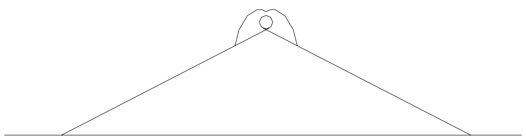
Solar Furnace at PSA+TERC

>2800ºC

Other applications

- Electricity, via PV conversion

•illumination: interior lighting, car lights, etc.

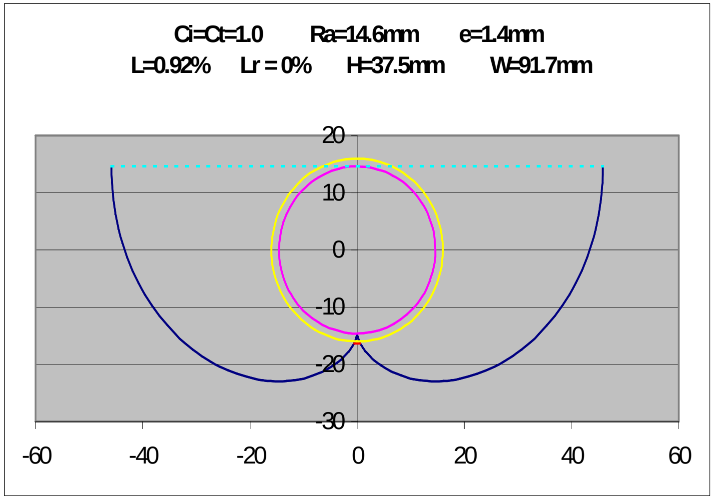


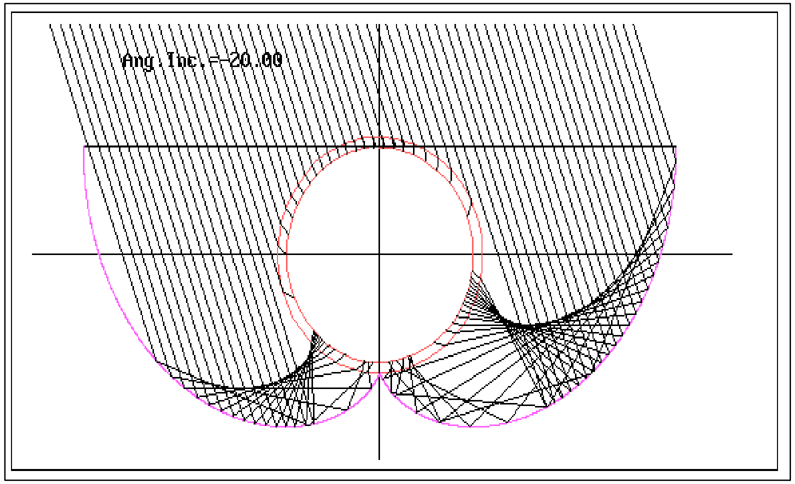
•radiation collection/detection : defense , astronomy, particle physics,etc.

•(....)

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)

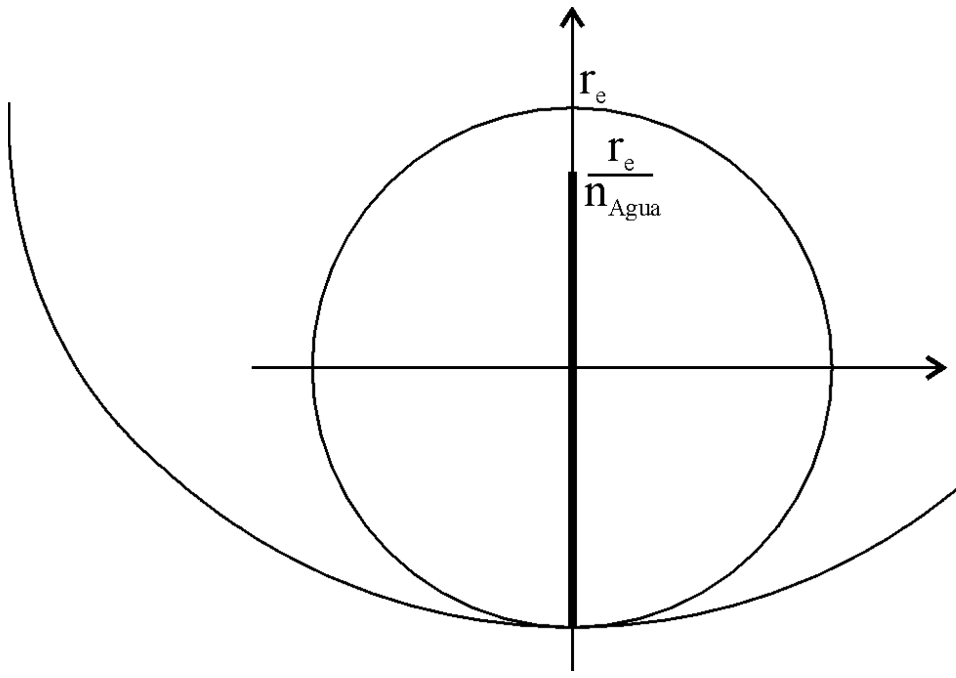
Prototype tested at INETI and PSA

Final version for a collector field with 100m2

- Module of Cadox collector

SOLWATER: the fixed catalyst fin case

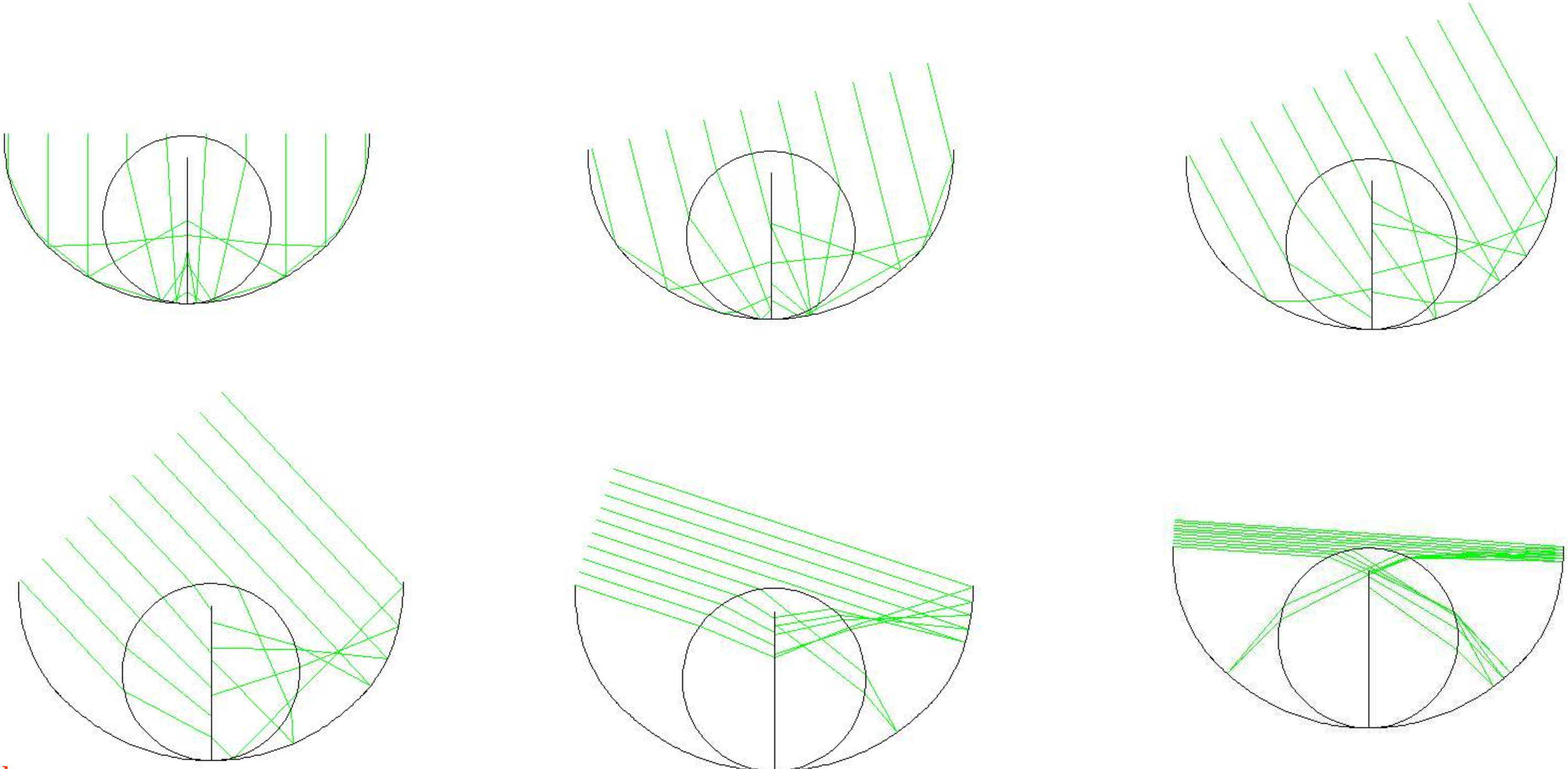
Application: drinking water production from contaminated surface waters



Optimal, but not ideal

The case of the fin

– Examples of raytracing



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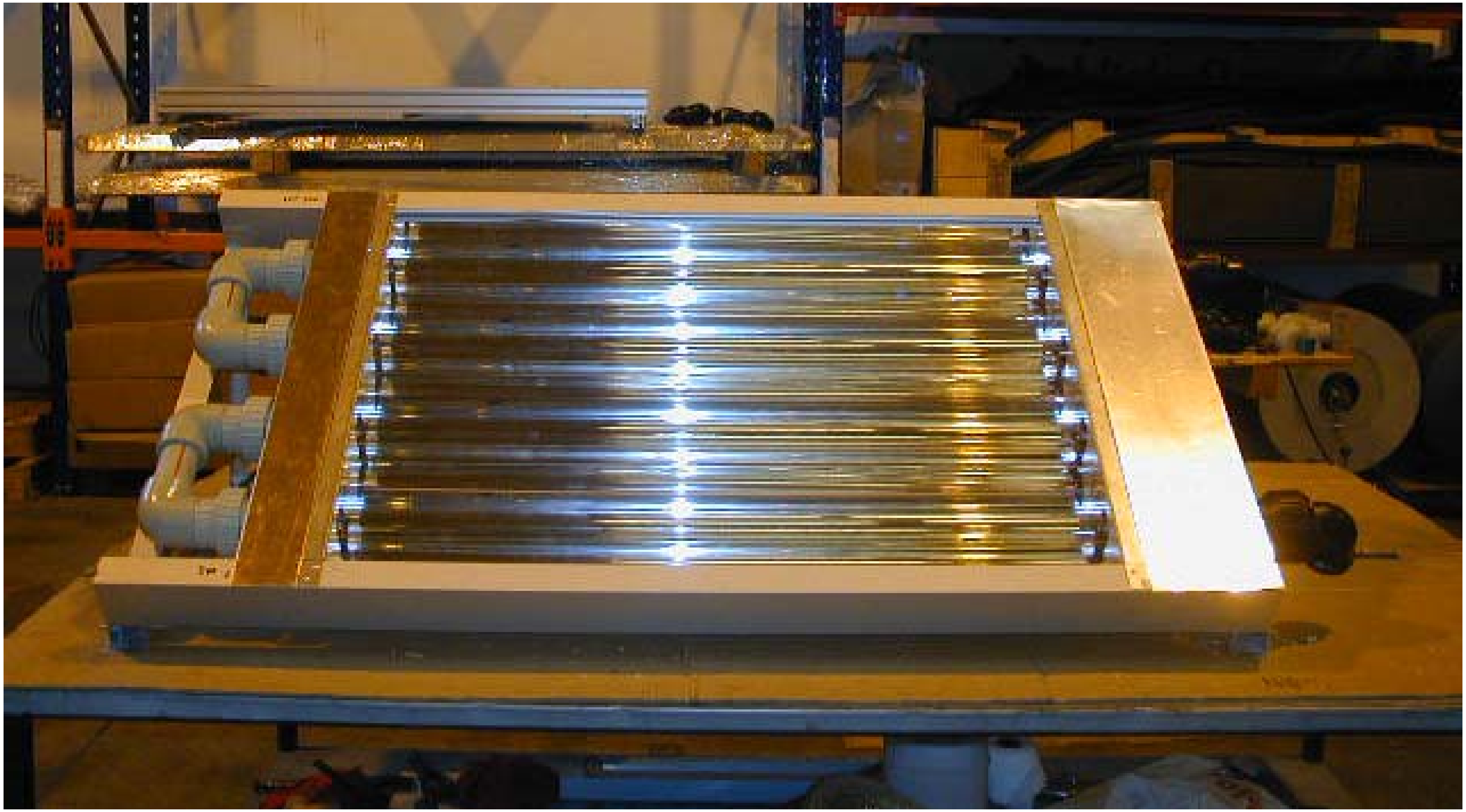

Conclusions

- 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