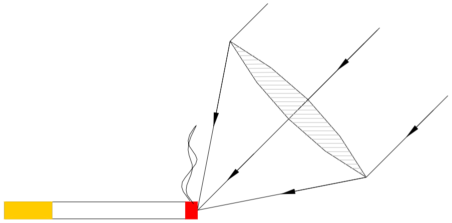
A role for Non Imaging Optics in Solar Energy Applications

- Goal: to obtain working temperatures with efficient energy collection from the incoming solar radiation
- Higher temperatures require concentration of solar radiation
- Efficient collection means no (geometrical) losses
- **Non Imaging Optics** is unique in achieving both in the limits allowed by first principles in Physics

What is concentration? Why so important?

- Thermal losses from large absorbers are large:losses are proportional to absorber area
- If we reduce the absorber area ,in comparison with the collection area....
- Concentration ⟶ Aabs<Acol

C=Acol/Aabs



Classical Concentrators and imaging or focussing optics

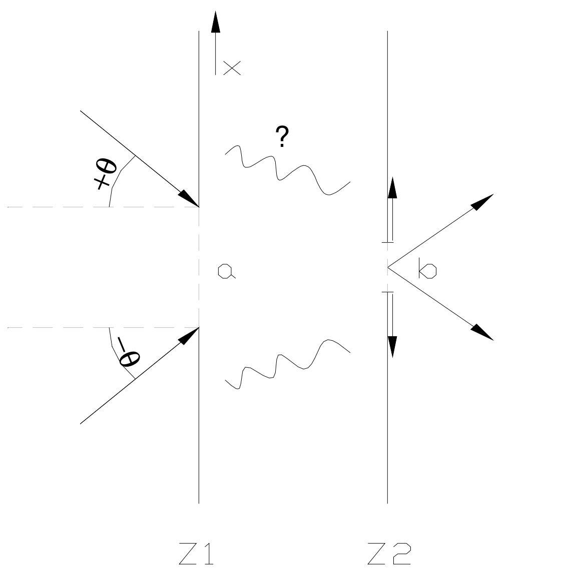
Fig. 1.6 Solar-1 pilot plant (10 MW_e) under test in Barstow, Calif. (U.S.A.)

- 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?

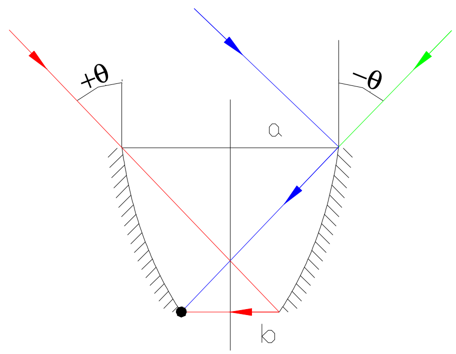
- the solution calls for a new type optics: non -imaging optics; *give up the imaging part*, i.e. the optics must "*scramble*" the incident radiation, and then it can concentrate the energy to the *limit* - Cmax(θ)-established by first principles in physics



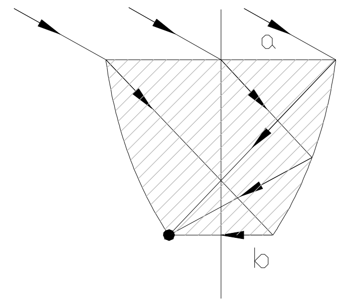
C=a/b

N.I.O solution : CPCs, Winston collectors…

CPC with mirrors



dielectric CPC
n=1



air

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)

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

Dielectric CPC

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

$C = C_{max} = a/b = n/\sin(\theta)$

Ao Sol
Energias Renováveis, Lda.

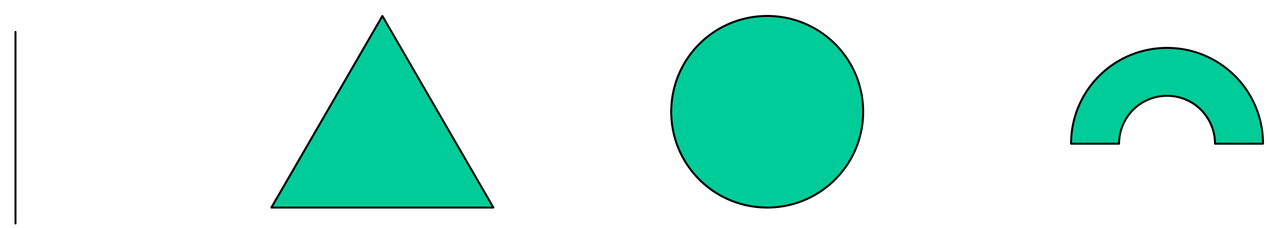
INETI

Other features of Non Imaging or Anidolic Optics

- 2D; also 3D solutions

  in 3D $C_{max} = (n/\sin(\theta))^{2}$

- other absorber shapes (tubes, shaped fins, cavities, etc.)

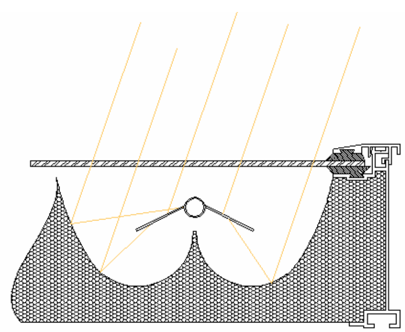


Application:Low and intermediate temperatures for water heating, heating and cooling, process heat, etc.

- collectors are concentrators with large θ; this means higher temperatures, but also
- 1) they are stationary (or require few adjustments through the year...)

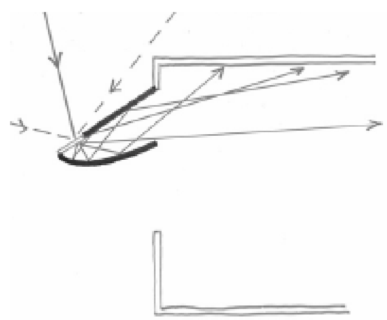
  2) they collect diffuse radiation

  3) i.e they retain the potential for simplicity and low cost of flat plate collectors

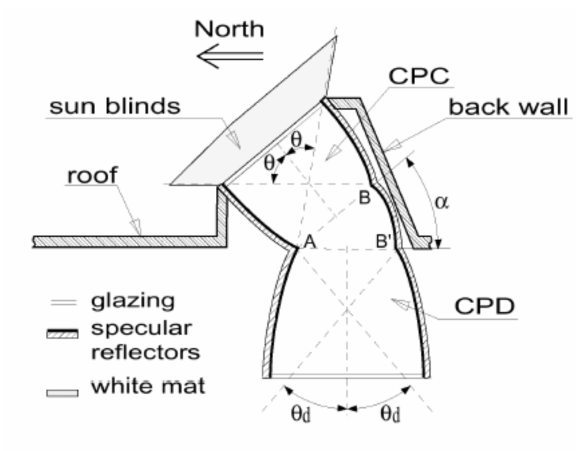


Application of Non Imaging Optics in day-lighting of buildings

Greatly enhance comfort, reduce the consumption of energy in buildings (both for lighting, heating and cooling)



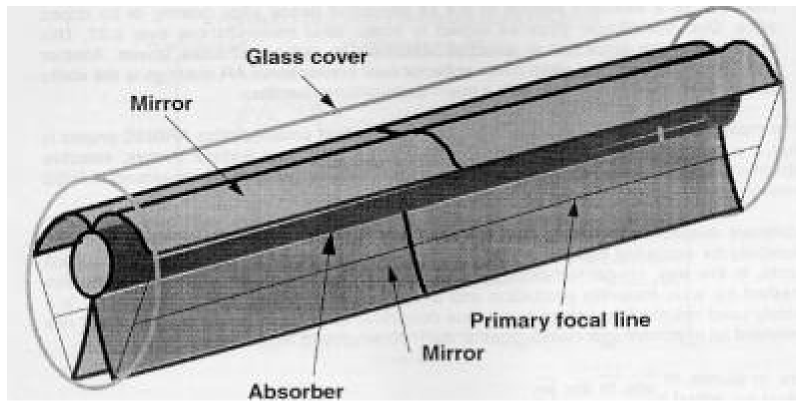
- Diffuse light guiding
- Direct light guiding, scattering, shading
- Light transport

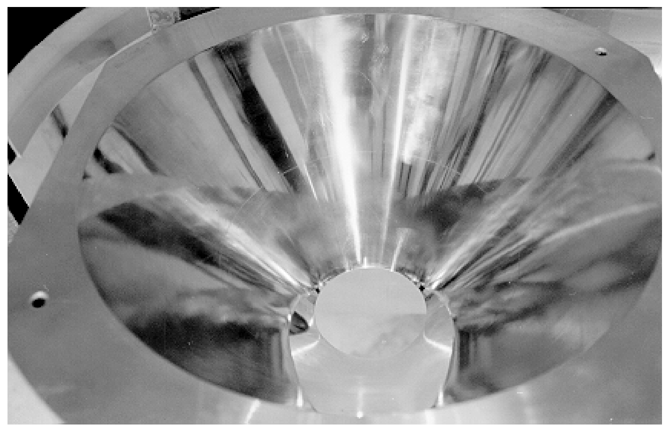


LESO-Bldg, EPFL Lausanne

N.I.O.potential at higher temperature applications: solar thermal electricity, Hydrogen production, treatment of wastes, materials processing…

- Second stage concentration:
- Enhance solar flux density/concentration for the same acceptance angle
- Relax tracking requirements for the same concentration
- Allow for complete systems easier to handle or to produce
- Allow for fixed receivers/absorbers and other eventually more useful configurations





>2800 ºC !

Ao Sol
Energias Renováveis, Lda.

INETI

Non Imaging Optics and solar cooking

- Cooking outdoors with a solar box cooker: low cost, high performance; convenience of use

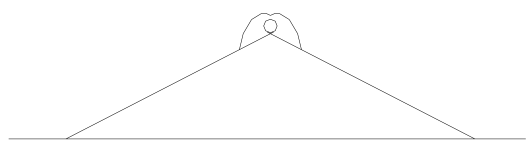
. To cook indoors: other solutions




Other applications

- Electricity, via PV conversion

•illumination: interior lighting, car lights, etc.



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

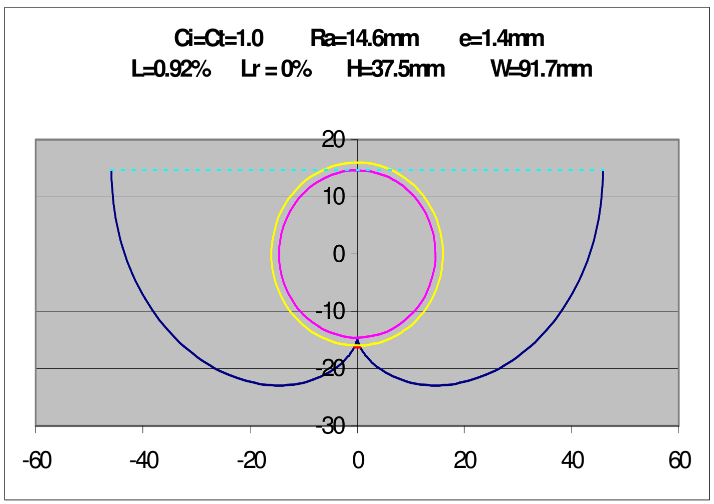
In general : N.I.O. achieves the best possible match between any source of light/radiation and any target where light is to be directed to

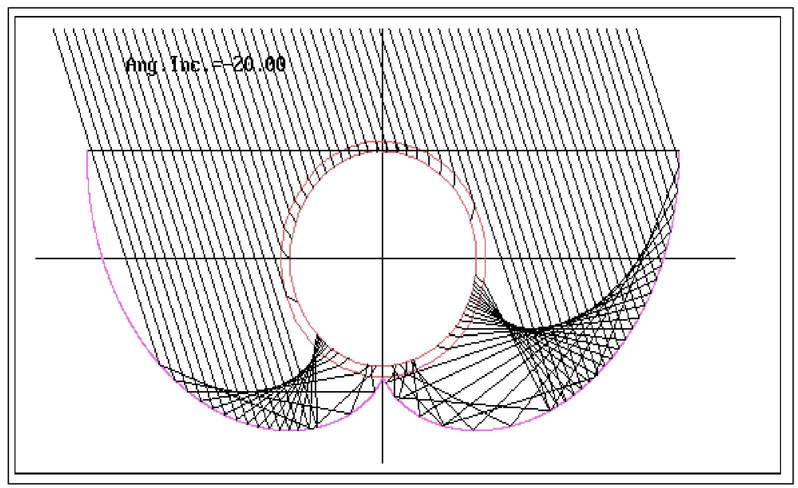
Non Imaging Optics and Photocatalysis (Photo Fenton, etc): Efficiency

- Collection efficiency and efficient solar UV energy delivery to an absorber, usually a tube; (direct and diffuse UV)
- diffuse UV implies very large acceptance angle, ($\pm\pi/2$)
- Low cost means: minimal number of tubes and connections
- N.I.O. does the job in the limits; concentrates solar radiation by a factor of **n**

One example-catalyst in suspension

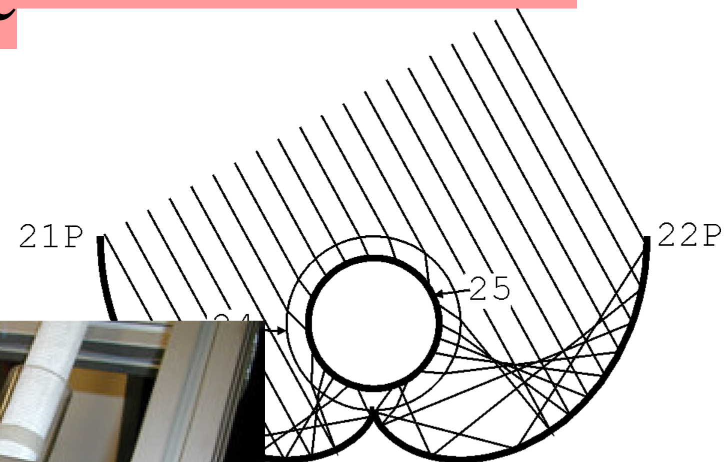
- detoxification of contaminated wastes, with UV and a catalyst- $TiO2$(...) added to the waste water circulating in tubes



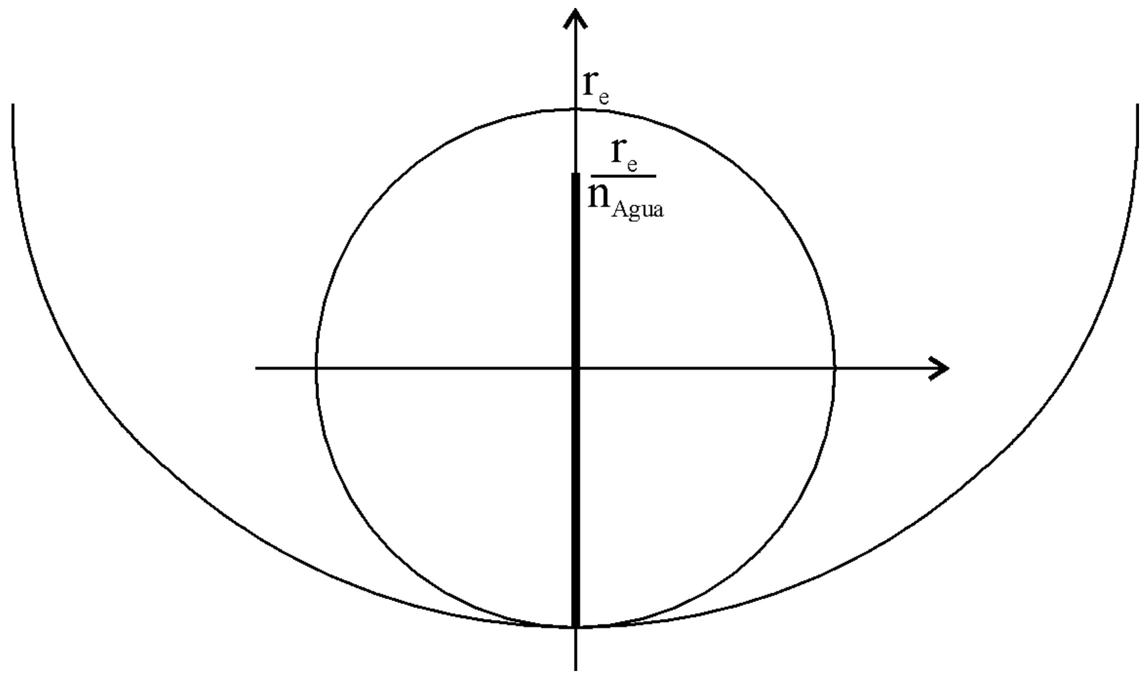


Example- Catalyst is fixed to a tube

- **The tube is inside the water to be treated; the highest flux concentration occurs for an internal radius of rext/rint=n**
- **C=Cmax=n/sin(θ)**

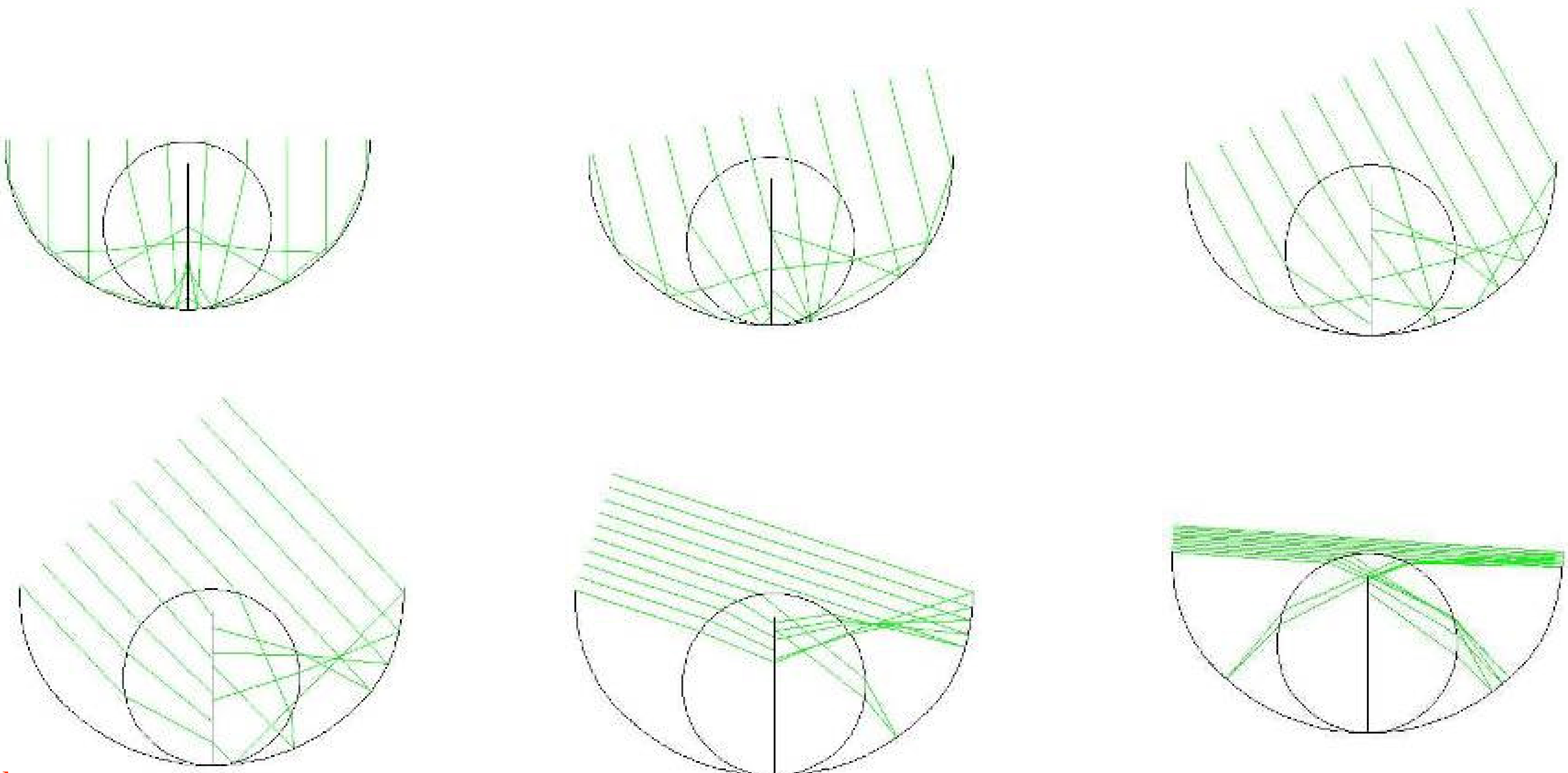


Fixed catalyst: fin case



The case of the fin

– Examples of raytracing



Conclusions

- Non Imaging Optics provides the best way to deliver solar radiation (in particular the scantly available UV) to contaminated effluents;
- best way means no geometrical losses, i.e. in the limits allowed by first principles in Physics
- This should provide the lowest cost solutions associated with the highest performances
- It is not just for solar UV: it can and should be used to deliver energy from UV lamps at the highest possible efficiency or even to the simple SODIS technique, if performance enhancement is attempted...
  - **OBRIGADO YOU FOR YOUR ATTENTION!**