Study of a space solar concentrator based on a diffractive/refractive optical combination

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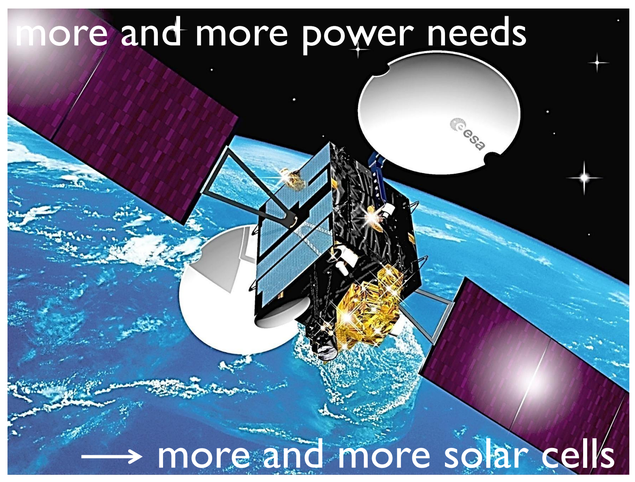
Context : satellites needs

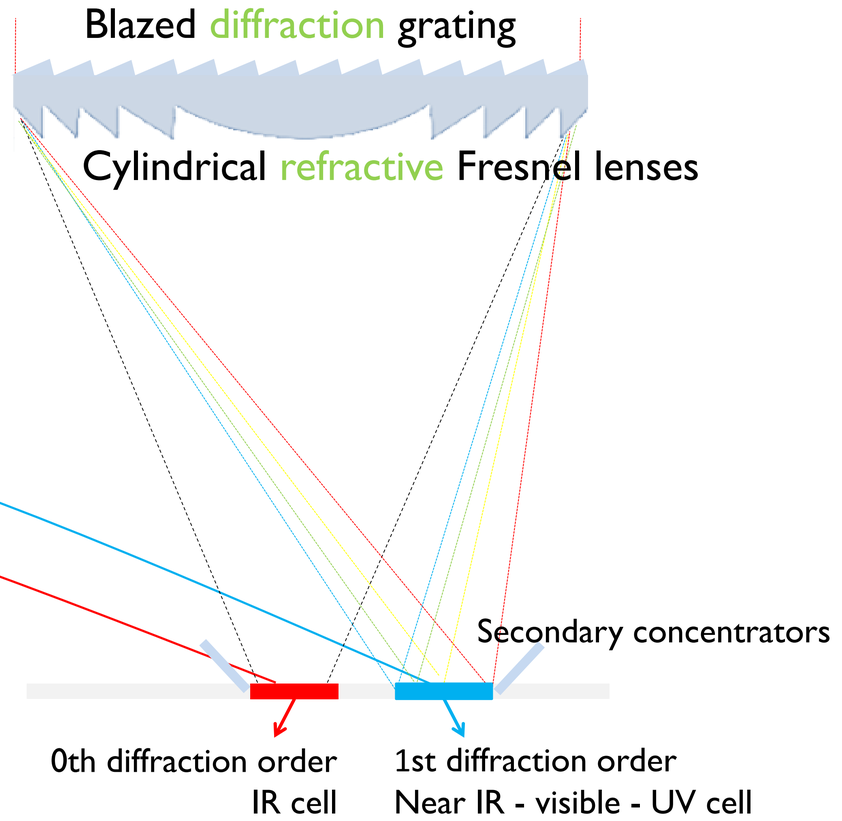


But solar cells
are very expensive

⟹

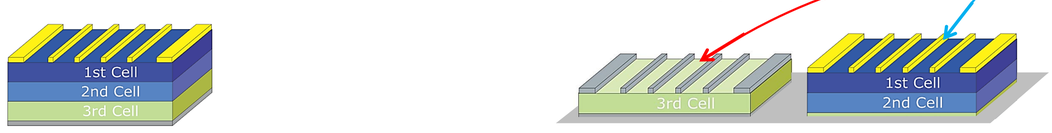
Objective:
Reduce the cost of solar panels
⟶ reduce the number of solar cells

Our solution : solar concentration based on a diffractive/refractive combination



Advantages of our approach

Existing approach ⟷ Our approach



- Condition of matching between the materials at the interfaces
  ⟶ *Limited materials choice*
- Condition of current matching between the cells (serial connection)
  ⟶*The worst cell limits the current*

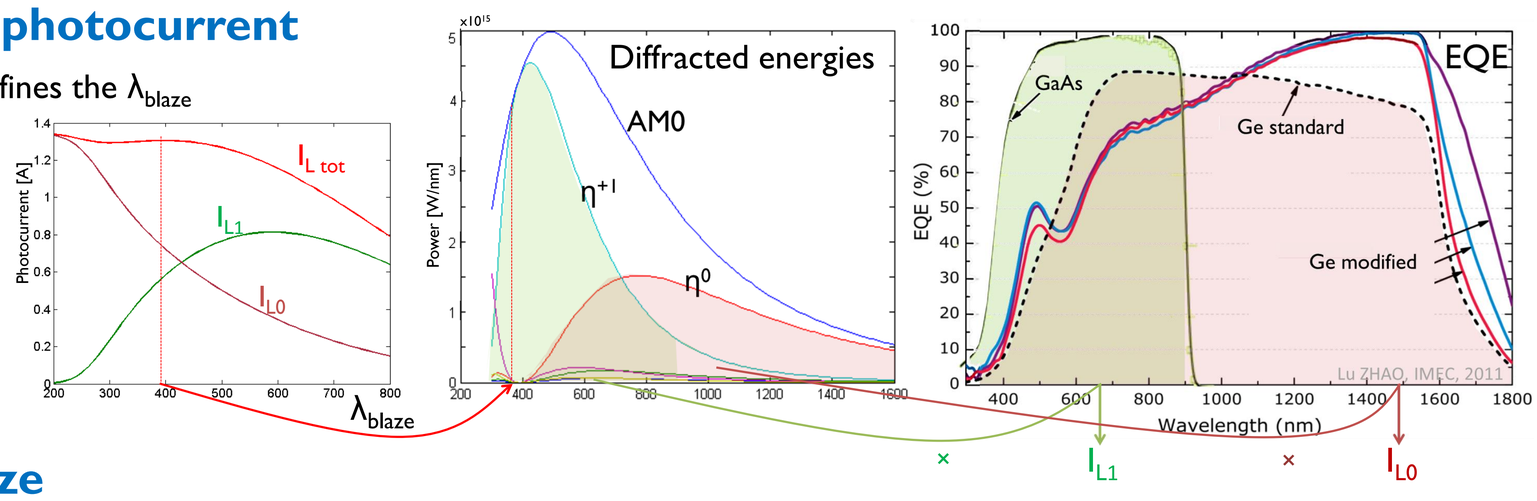
- *Free choice of materials*
- Connection of the cells in parallel
  ⟶ *use of each maximum photocurrent*
  ⟶ *theoretical higher performances*
- Single junction cells ⟶ *reduced cost/cell*
- Double surface that makes the *heat transfer easier*
- Possibility to use a *specific antireflective coating* for each cell

Design and optimization

Step 1 : maximization of the total photocurrent

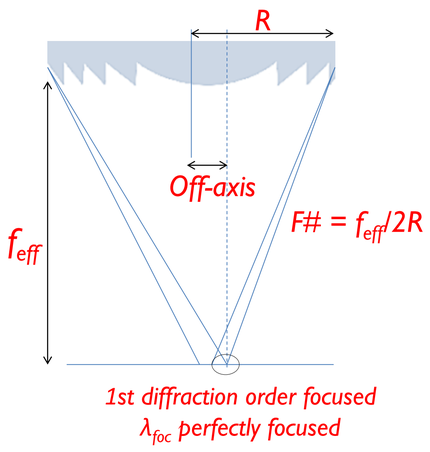
The height of the grooves of the diffraction grating defines the λ_{blaze} and imposes the diffraction efficiencies $\eta^0, \eta^{+1}\dots$

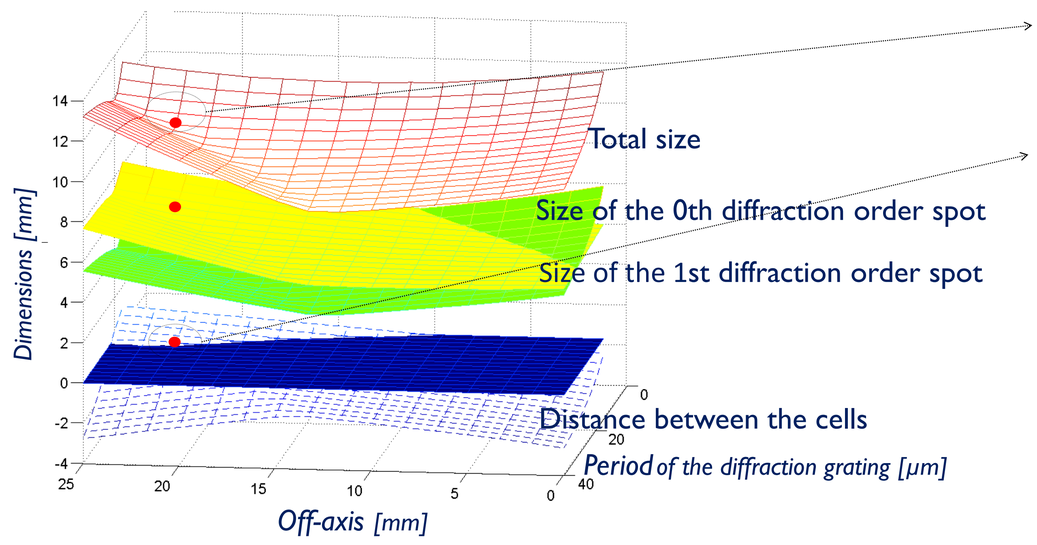
The total photocurrent is maximum for an optimal λ_{blaze}



Step 2 : minimization of the cell size

There is an optimal combination (*off-axis, period*)





Minimum size of the two focal spots
⟶ *lower cost*

No distance between the focal spots
⟶ *single optical alignment*

No overlapping of the diffraction orders
⟶ *minimum optical losses*

There are also an optimum F# ~ 3 and an optimum λ_{foc} to reach the minimum total size of cells

Results and perspectives

First results are promising

Hypothesis :

Sun divergence (0,52°), AM0 spectrum
Fresnel reflections at the interfaces, shadowing of the grooves of the lens
Diffraction efficiencies of the grating computed from scalar theory
Ideal Fresnel lens (silicone, R = 2,5cm) and ideal diffraction grating

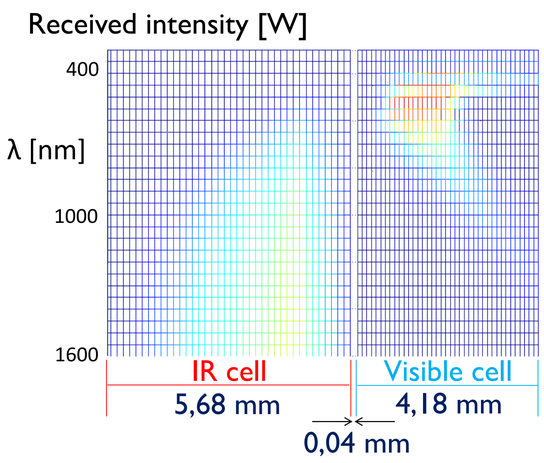
Theoretical results after optimization :

Total photocurrent = 0,69/25 + 0,51/25~1,2/25 [A/cm²]

Geometric concentration ratio :
IR cell ⟶ 8,8 × Visible cell ⟶ 11,96 ×

Optical efficiency = 75,4%

$P^{output}_{concentrator}/P^{output}_{flat\ PV\ panel}$ ~ 88%



Next steps : thermal simulation and validation

- Cell efficiency ↓ when the temperature ↑
- Space : no convection ⟶ heat transfer difficult
  ⟶ hot spots on the solar cells

⟹ A thermal simulation is necessary to know the maximal concentration that can be achieved without damaging the cells

Potential performance improvement: design and optimization of secondary concentrators