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

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Context : satellites needs

Solar concentration : # solar cells/m² ↓ → cost ↓
Space environment → specific thermal conditions → desired solar concentration about 10x

Spectrum splitting

Current matching condition → power limited by the worst cell
Lattice matching condition at the interfaces
Total power = Σ powers
Free choice of materials

Design and optimization : a lot of constraints → a compromise must be found

Maximum total output power

Maximum geometrical concentration ratio

Max 2nd order diffracted light collection recovery → large λ

Thermal constraints → C_m is limited

Different configurations have been studied : the results are promising

First configuration

Diameter = 50mm
F# = 3
λ = 30µm
Off-axis = 24mm

Output power 290W/m²
Optical efficiency > 70%
Geometrical concentration ratio 12.5x and 14.3x

With secondary concentrators

Diameter = 50mm
F# = 3
λ = 20µm
Off-axis = 32mm

Output power 290W/m²
Optical efficiency > 70%
Geometrical concentration ratio 15x and 7.5x

Symmetrical design

Diameter of each lens = 50mm
F# = 3
λ = 20µm
Off-axis of each lens = 25mm

Output power >300W/m²
Optical efficiency > 75%
Geometrical concentration ratio 9.8x and 12.2x

Next steps : thermal simulation and validation

• Cell efficiency ↓ when the temperature ↑
• Space: no convection → heat transfer is difficult → hot spots appear on solar cells

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

Hypothesis : Sun divergence (±0.26°), AM0 spectrum, cell temperature = 65°C. Fresnel reflections and shadowing of the grooves are taken into account, diffraction efficiencies of the grating are computed from the scalar diffraction theory. The shapes of the Fresnel lens (in DC93-500 silicone) and of the diffraction grating are ideal (no draft angles, no rugosity, …). Light scattering is not included in the model.