High-Concentration Wide-Angle Tracking Integration with Stacked Lens Arrays

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Why is CPV great?

- Low cost ↓ $
- High efficiency ↑ η

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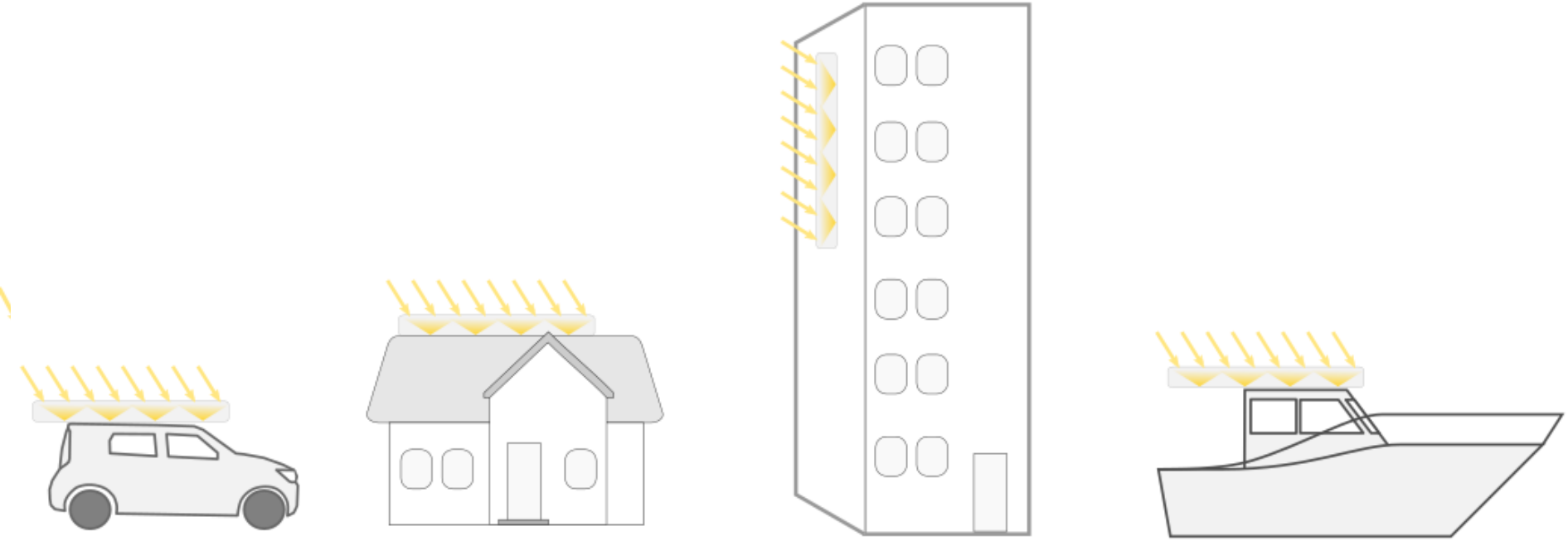
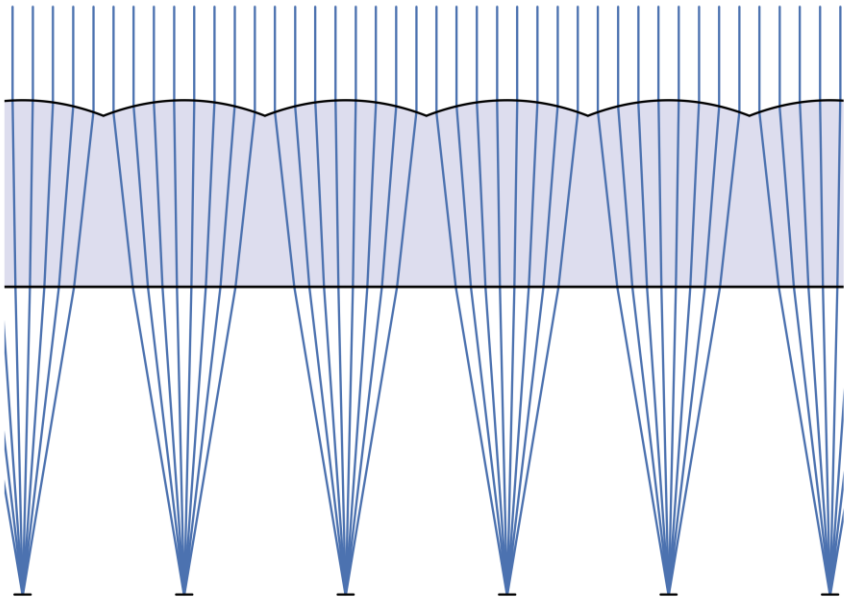
- High efficiency ↑ η

Where do we need high efficiency?



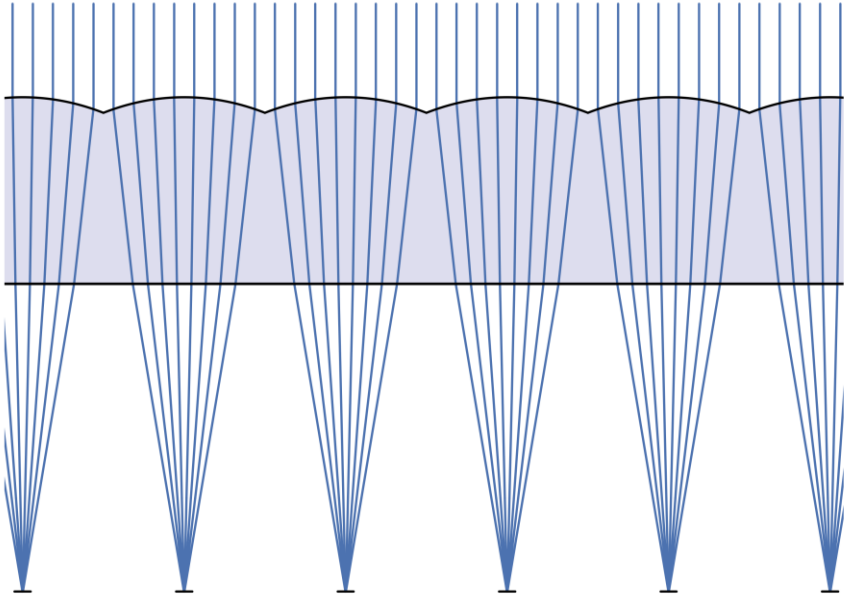
Tracking-integration

Microtracking



Microtracking

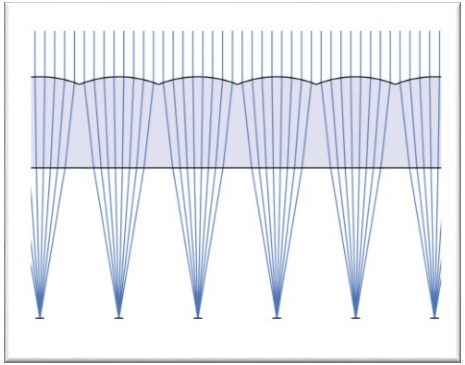
Kotsidas, P., Chatzi, E. & Modi, V. Stationary nonimaging lenses for solar concentration. Appl. Opt., AO 49, 5183–5191 (2010).



Hallas, J. M., Karp, J. H., Tremblay, E. J. & Ford, J. E. Lateral translation micro-tracking of planar micro-optic solar concentrator. in (eds. Greene, L. E. & Sherif, R. A.) 776904 (2010).

Outline

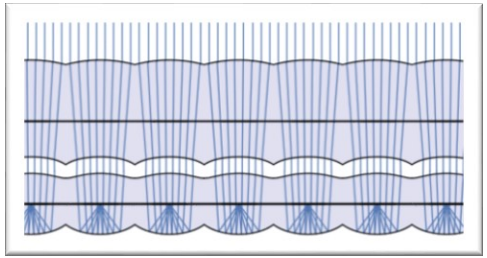
- Background



- Design method

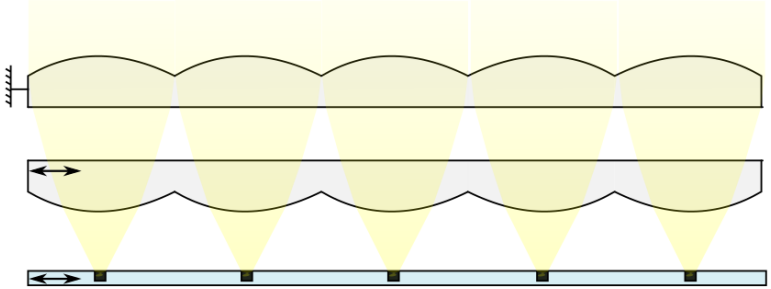
```
@jit_wrapper(numba.void(nb_dt_surface[:],nb_dt_ray))
def trace_single_ray(surfaces,ray):
    (x,y,z) = ray["position"]
    (l,m,n) = ray["direction"]
    intensity = ray["intensity"]
    wavelength = ray["wavelength"]
    field_y = ray["field_y"]
    index = ray["n"]
    n_surface = surfaces.size
    for i in range(n_surface):
```

- Results

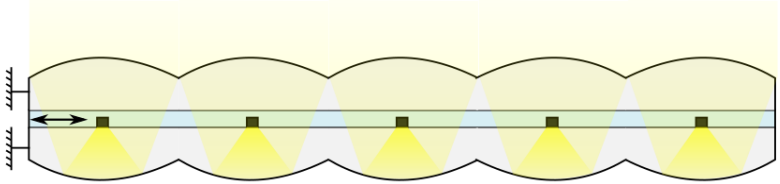


Improving the microtracking concept

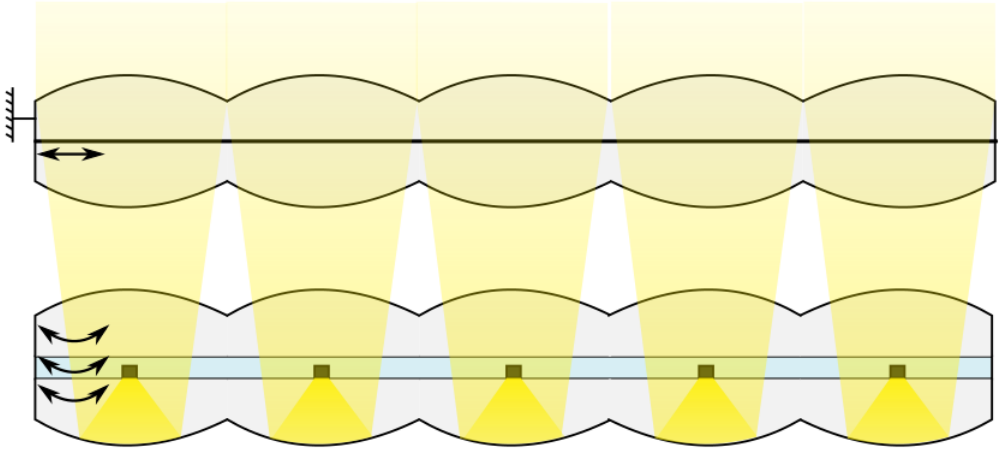
- Add an additional movable lens array.
  - Duerr, F., Meuret, Y. & Thienpont, H. Tracking integration in concentrating photovoltaics using laterally moving optics. *Opt. Express, OE* **19**, A207–A218 (2011)



- Implement a catadioptric optical stack
  - Price, J. S., Sheng, X., Meulblok, B. M., Rogers, J. A. & Giebink, N. C. Wide-angle planar microtracking for quasi-static microcell concentrating photovoltaics. *Nat Commun* **6**, 6223 (2015).

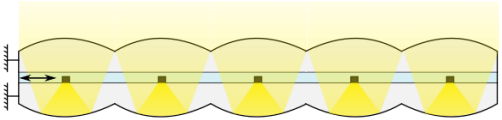


Stacking the designs together

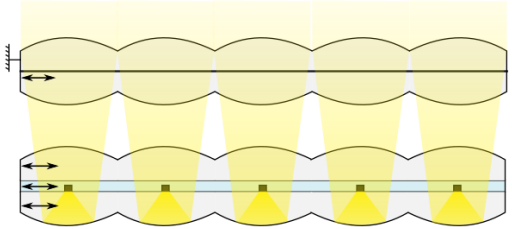


Configurations

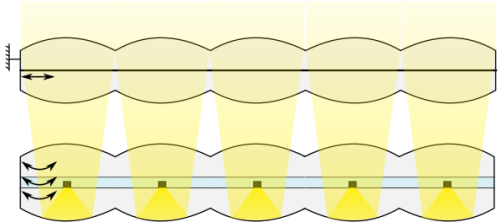
- Simple catadioptric



- Flat tracking trajectory

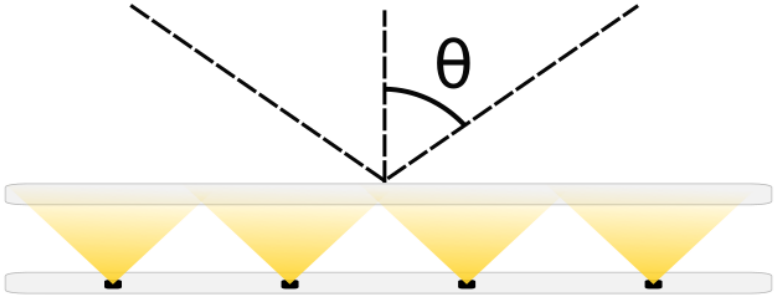


- Curved tracking trajectory



Design goals

- Maximize tracking range



- Maximize efficiency

- Maximize concentration

Optimization

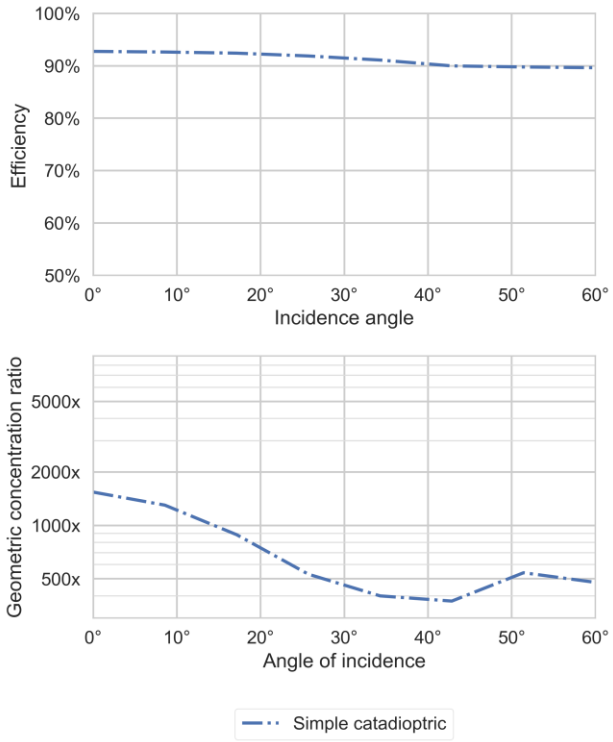
- Challenging optimization problem
  - Multi-objective
  - Non-linear
  - Non-convex
- Optimized using memetic algorithm
- Custom ray-tracer

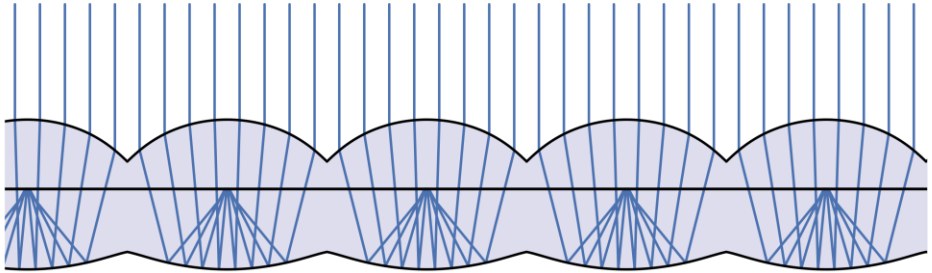
$$\min\ f(\mathbf{x}) = \sum_{i=1}^{m} \left(w_1 \frac{1}{\eta_i(\mathbf{x})} + w_2 \left(r_i(\mathbf{x})\right)^2 \right)$$

$$\text{such that } g_j(\mathbf{x}) \leq 0$$

$w_1,\ w_2$	Weights
$\mathbf{x}$	Parameters describing optical system
$\eta_i(\mathbf{x})$	Efficiency of concentrator at field number i
$r_i(\mathbf{x})$	RMS radius of rays in field number i relative to PV cell position
$g_j(\mathbf{x})$	Constraints for manufacturability

Results – Simple catadioptric





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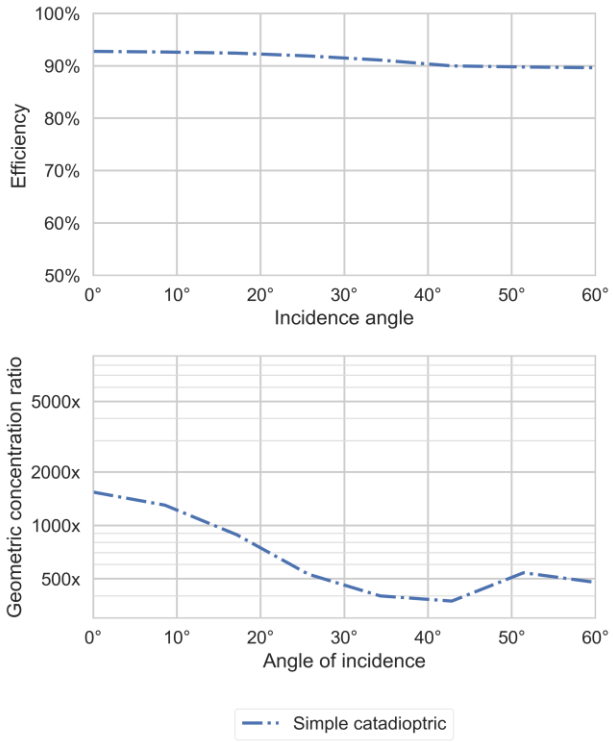
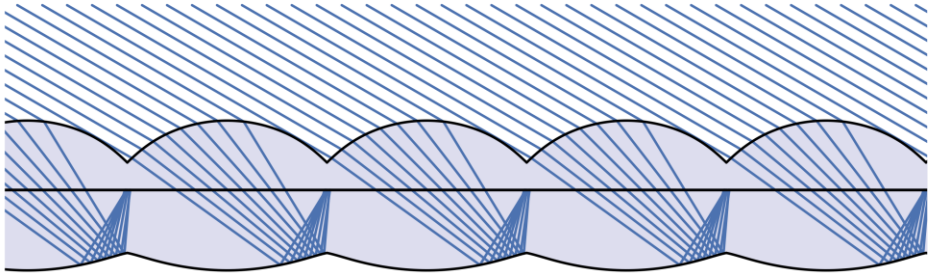
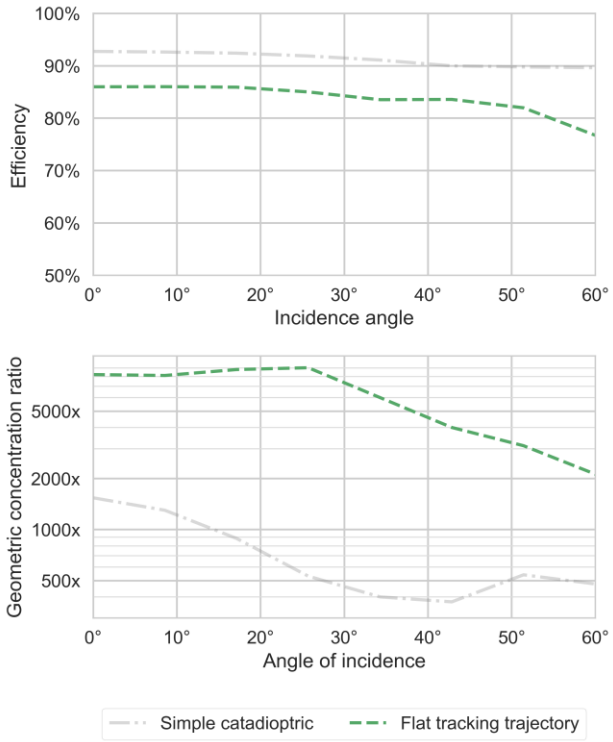
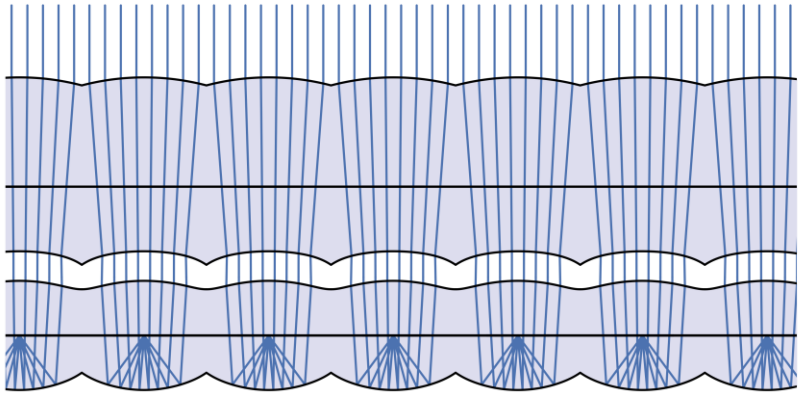




Results – Flat tracking trajectory





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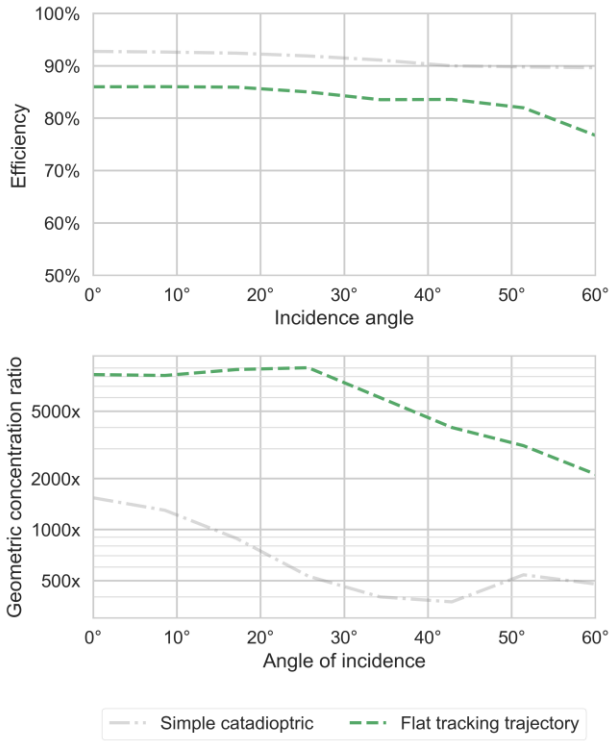
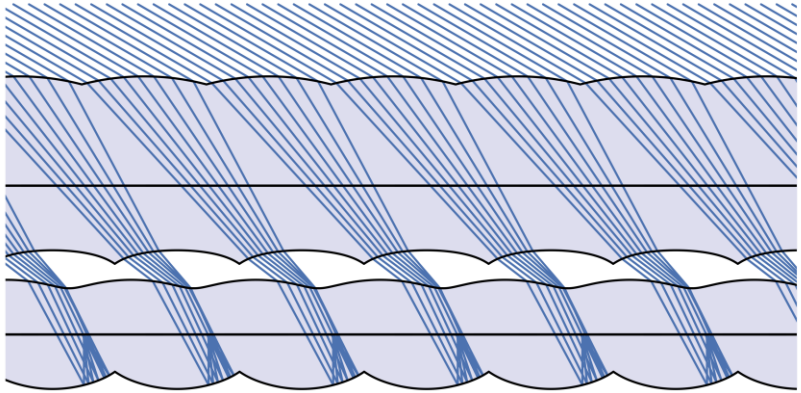
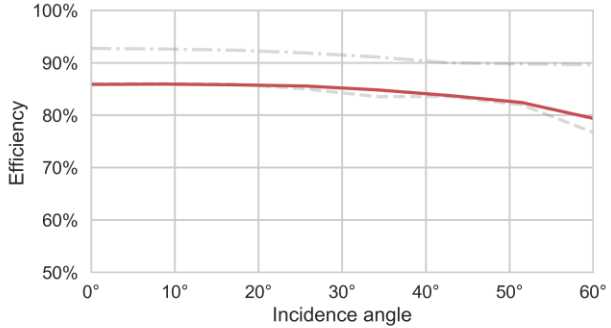
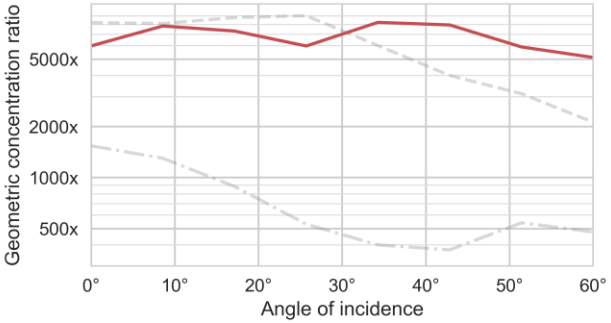


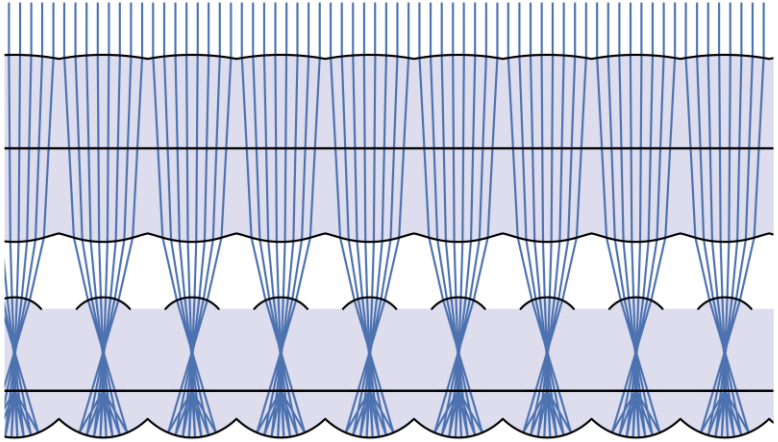


Results – Curved tracking trajectory





Simple catadioptric | Flat tracking trajectory | Curved tracking trajectory



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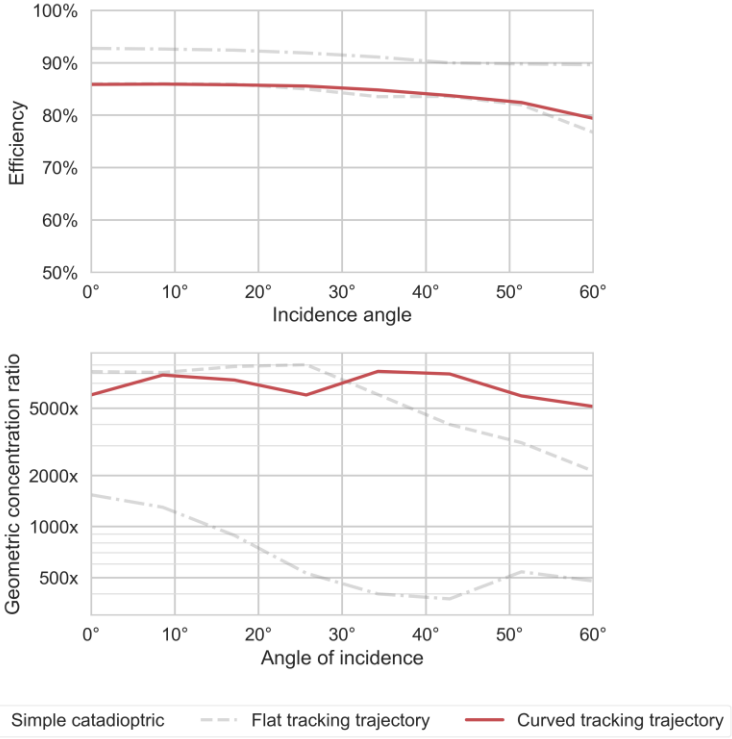
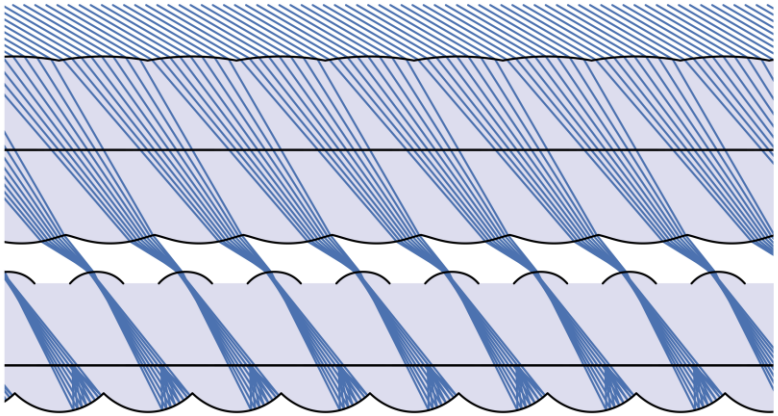
Results – Curved tracking trajectory





Why is the concentration ratio so high?

- Concentration inside dielectric
- Reflective lens array
- Low acceptance angle

Summary

- Tracking-integration is a promising way to improve flexibility of CPV.
- Tracking-integrated systems can be designed using numerical optimization.
- High-performance tracking-integrated CPV concepts are possible.

Questions, or interested in collaboration?

Talk to me afterwards, or e-mail me:

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