

The Electric Mondrian™ Toolbox Concept – A Luminescent Solar Concentrator Design Study

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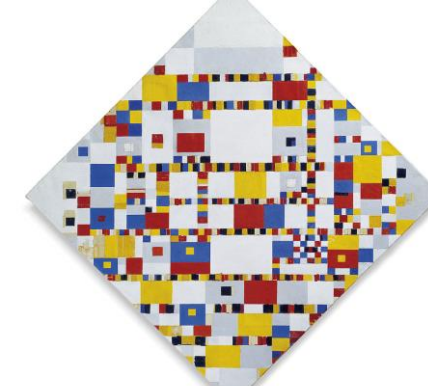
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Introduction

- Increased interest for building integrated photovoltaics (BIPV)
- Aesthetics, freedom of form and color
- Luminescent solar concentrators are good BIPV candidate
- Some examples already exist of infrastructure integrated PV (IIPV)

Inspiration

- Dutch artist Piet Mondriaan (Mondrian)
- Colorful rectangles/squares
- Victory Boogie Woogie (Gemeentemuseum The Hague)



Infrastructure integrated PV examples

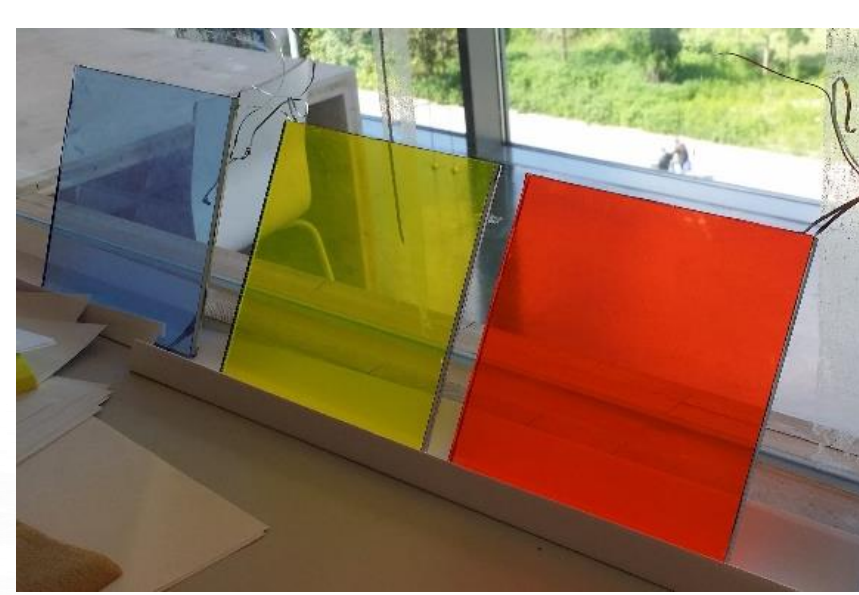
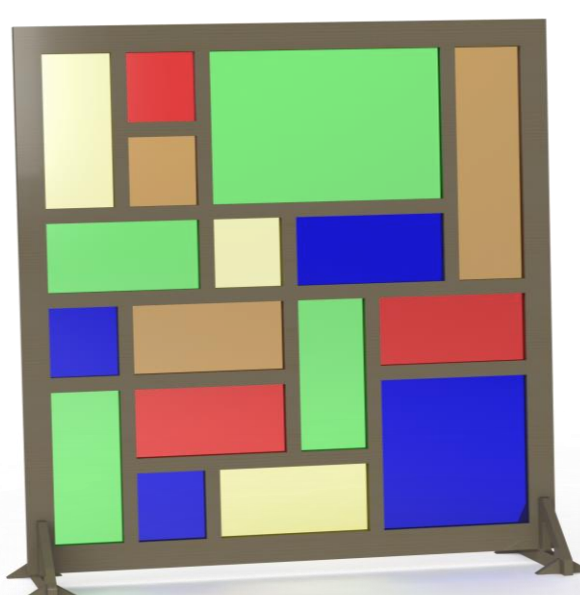
- Bus shelter, noise barriers



Project "Electric Mondrian"

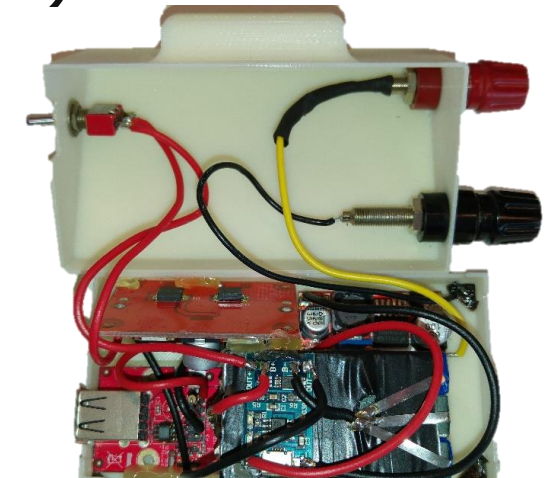
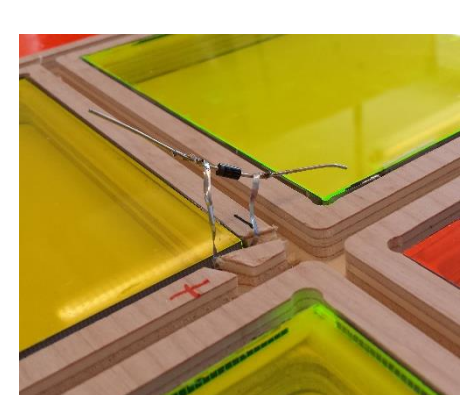
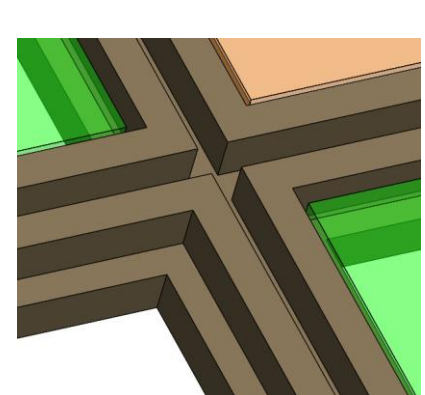
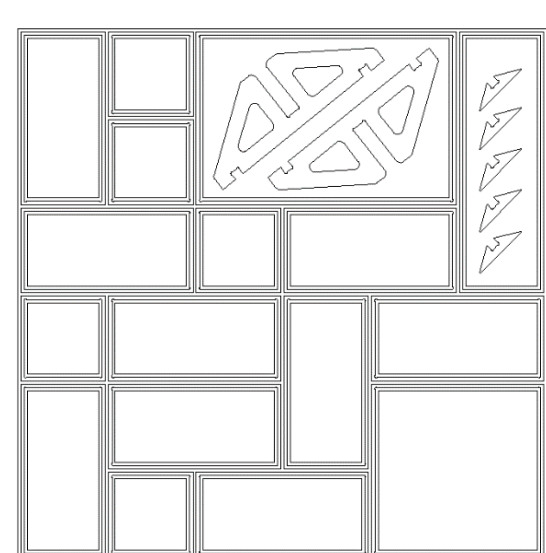
Aim:

- Realize ~1 m² size LSC window inspired by Mondrian design that generates power in sun/daylight
- Use commercial components
- Interdisciplinary project (mechanical engineering, electrical engineering, business) with students of University of Applied Sciences Utrecht



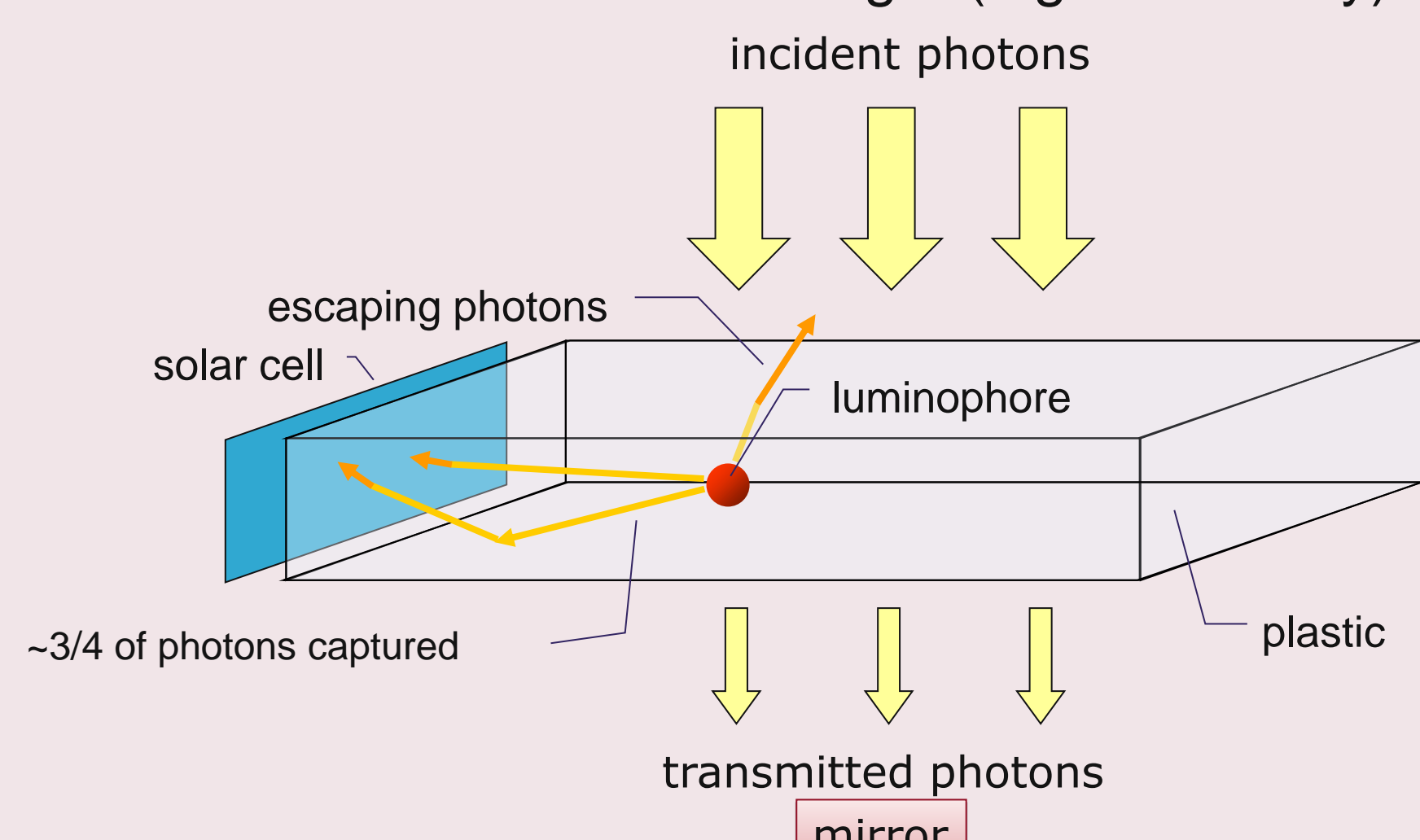
Characteristics

- ~1 m² size, wooden frame
- 17 LSC plates
 - 5 of 15x15 cm²
 - 9 of 15x30 cm²
 - 1 of 15x45 cm²
 - 1 of 30x30 cm²
 - 1 of 30x45 cm²
- 100 tabbed 18% Si solar cells of 145x5 mm² total cell area 0.0725 m² (7%)
- Cables and ducts
- Charger with Li-ion battery (3.7 V, 6150 mAh, 22 Wh), 2 USB connections (5 V, 0.5 A)



Luminescent Solar Concentrator principle

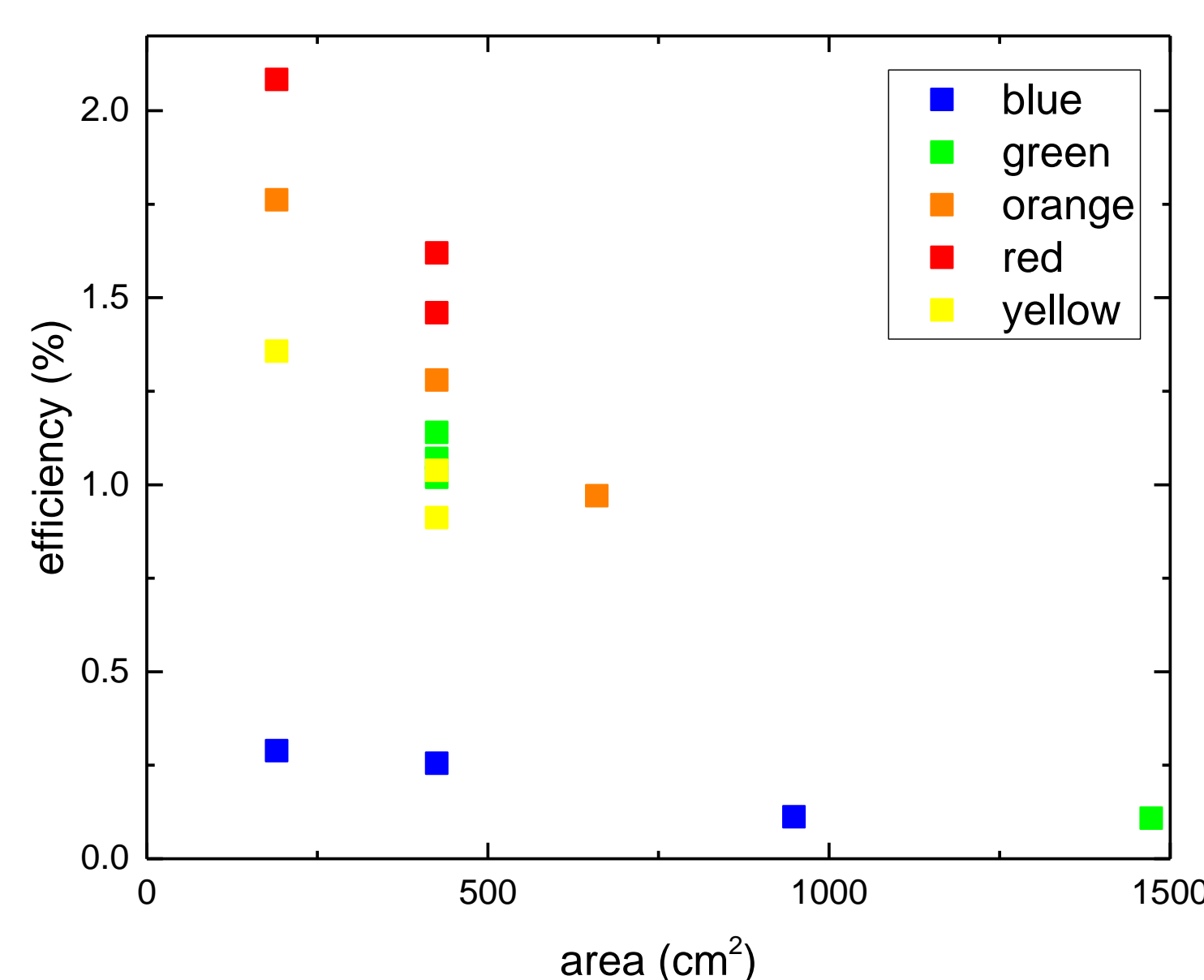
- Luminophores absorb photons and emit red-shifted photons
- Total internal reflection causes ¾ of emitted photons to remain in light guide
- Solar cells attached to sides, ideally with band gap matched to emission wavelength (high efficiency)



Experimental performance

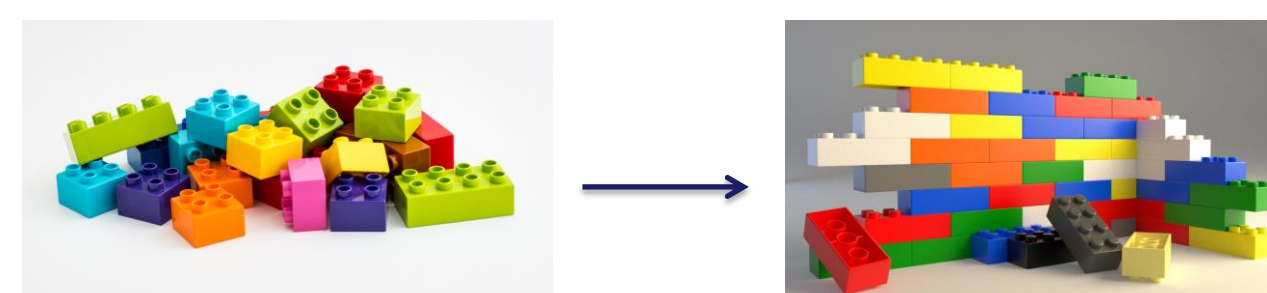
- Overall efficiency ~1% (series connection, cabling losses)
- Individual plate efficiency higher
- 10 hours in light (close to window) charges battery for charging 3 smart phones
- Most efficient: red, small plate

parameter	efficiency
emission wavelength	↑
area	↓



Toolbox

- 5 different colors: blue, green, yellow, orange, **red**
- 4 different shades (**concentration**): transparency 20, 40, 60, 80%
- 3 squares: **15x15**, 30x30, and 45x45 cm²
- 3 rectangles: **15x30**, **15x45**, and 30x45 cm²
- Plate thickness: 3, 4, **5**, **6**, **7**, 8 mm
- Total 720 possible elements for design use

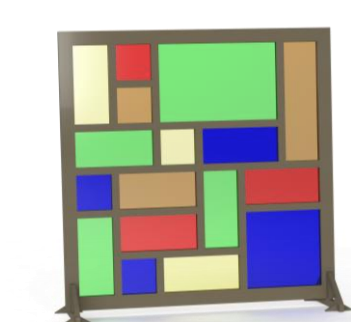
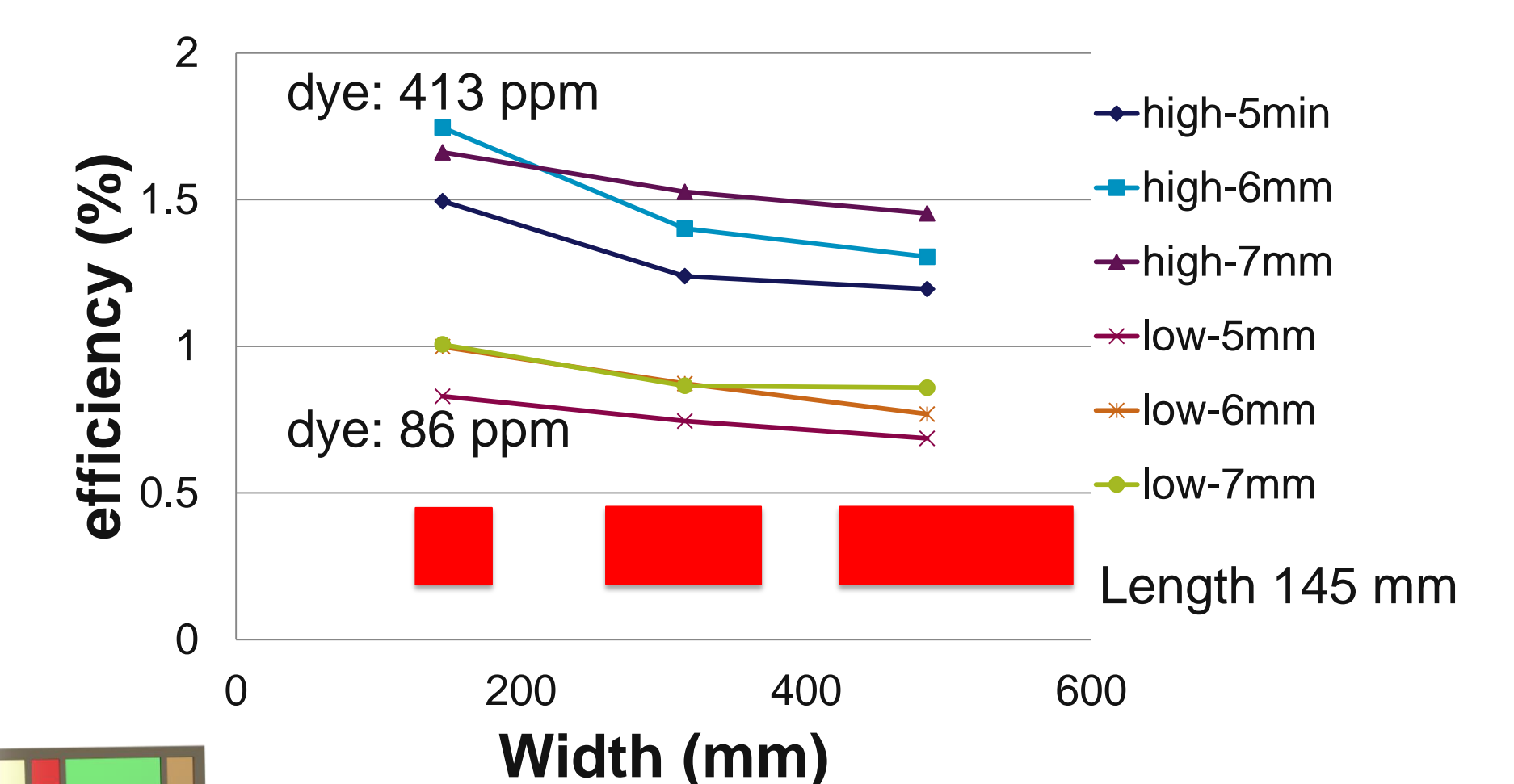
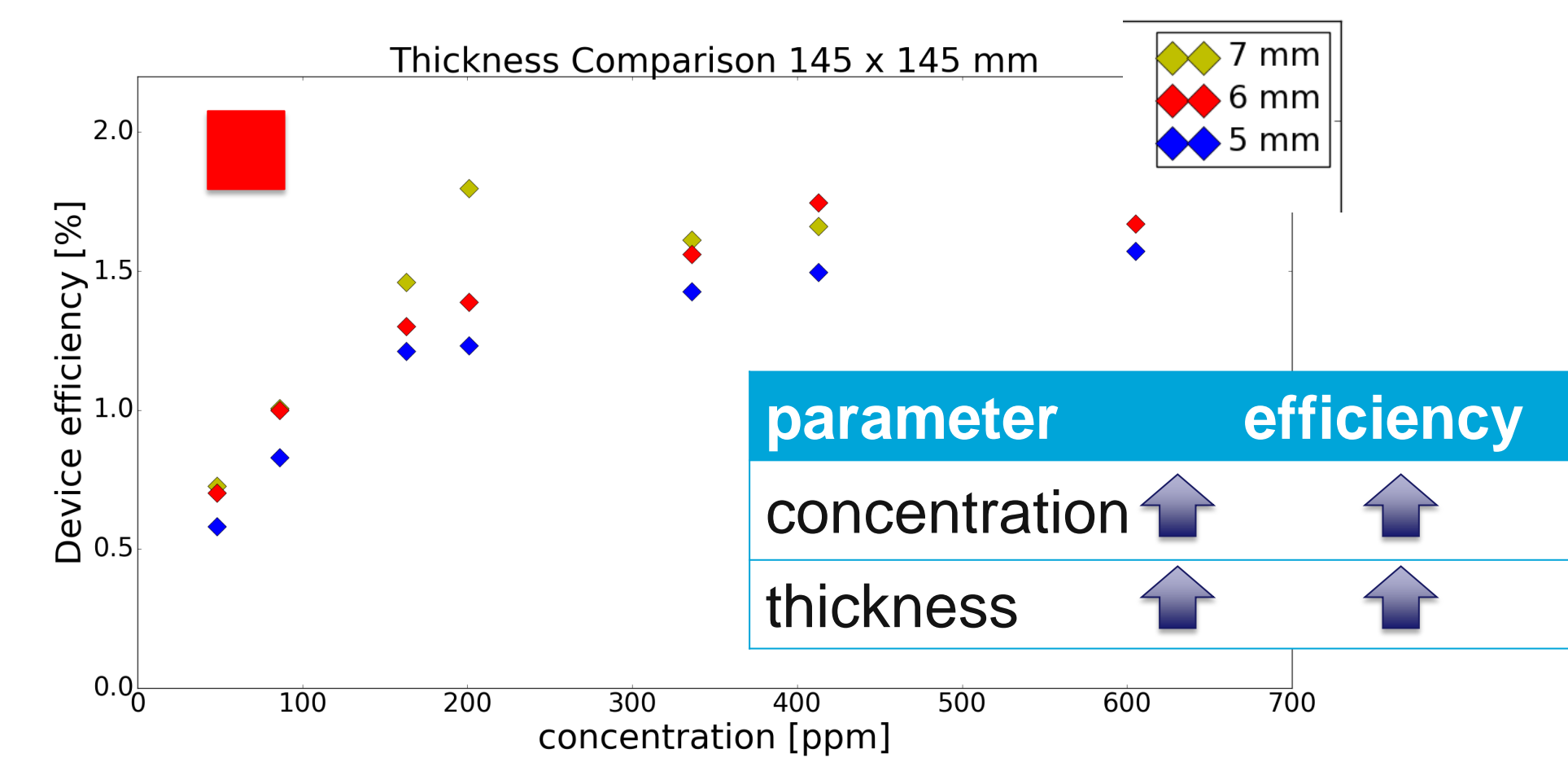


Simulations

- Ray-trace simulator: PVTrace (Farrell)
 - Absorption, emission, reflection events
 - Statistical analysis of photon databases
 - Running in Python

Color	Concentration (ppm)	Size (cm ²)	Pmax (mW)
Red	100	15x15	122
		15x30	248
		15x45	335
	
		15x30	496
Orange	...	15x45	704
	
Blue
Green

Toolbox results



Calculations for demo

Color	Number	Size (cm ²)	efficiency (%)	Power (mW)	Power total (mW)
Red	1	15x15	2	900	900
	2	15x30	1.6	1440	2880
Orange	1	15x15	1.7	765	765
	1	15x30	1.3	1170	1170
	1	15x45	1	1350	1350
Green	3	15x30	1.1	990	2970
	1	30x45	0.1	270	270
Yellow	1	15x15	1.4	630	630
	2	15x30	0.8	720	1440
Blue	2	15x15	0.3	135	270
	1	15x30	0.2	180	180
	1	30x30	0.1	180	180
Total	17				13005

Design issues

- Mixed series-parallel connection to match plate currents
- Same size and color: series
- Complex cabling, extra losses
- MPP tracker per string
- DC/DC upconverter to USB standard and battery

Estimate: 13 W for 0.81 m² aperture (1.6%) only if above issues are properly addressed

Conclusion

- Electric Mondrian™ realized and operational
- Toolbox designed, but cabling needs to be addressed for optimal power

Acknowledgements

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