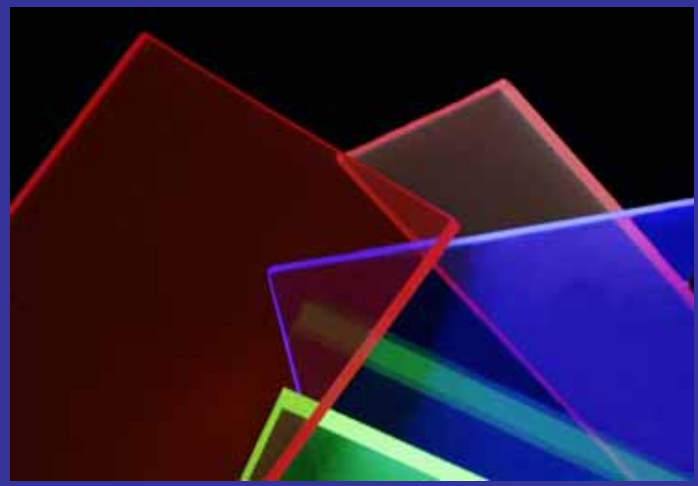
Using selectively-reflecting organic layers to enhance the output of a luminescent solar concentrator

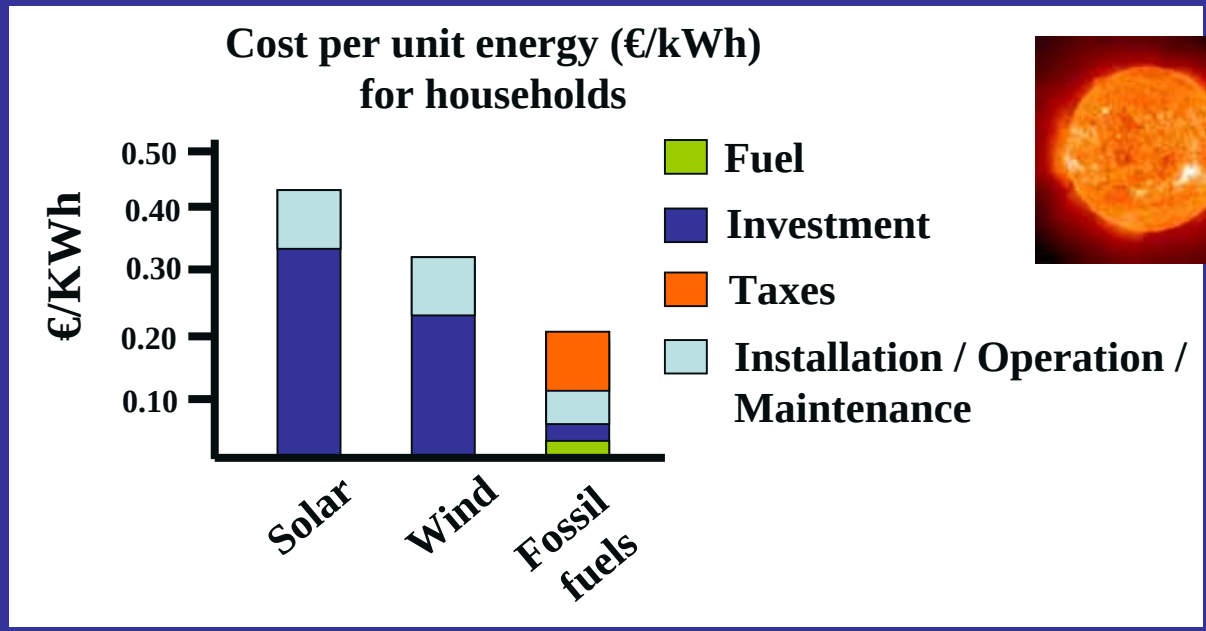


Michael Debije, TU Eindhoven

Dutch Solar Cell R&D Seminar, Utrecht

September 27, 2006

The cost of solar energy



Material	Production Efficiency [%]	Costs [€/m^2]	To be competitive with other (conventional) energy sources, costs needs to be reduced by a factor 2-3!
Amorphous Si	5 -7	200-400	
Poly-Silicon	13 -15	400-600	
Mono-Silicon	14 -17	600-800	
GaAs	20	8000	

Widespread adoption of solar energy requires competitive solar energy prices.

Conventional solar concentrators

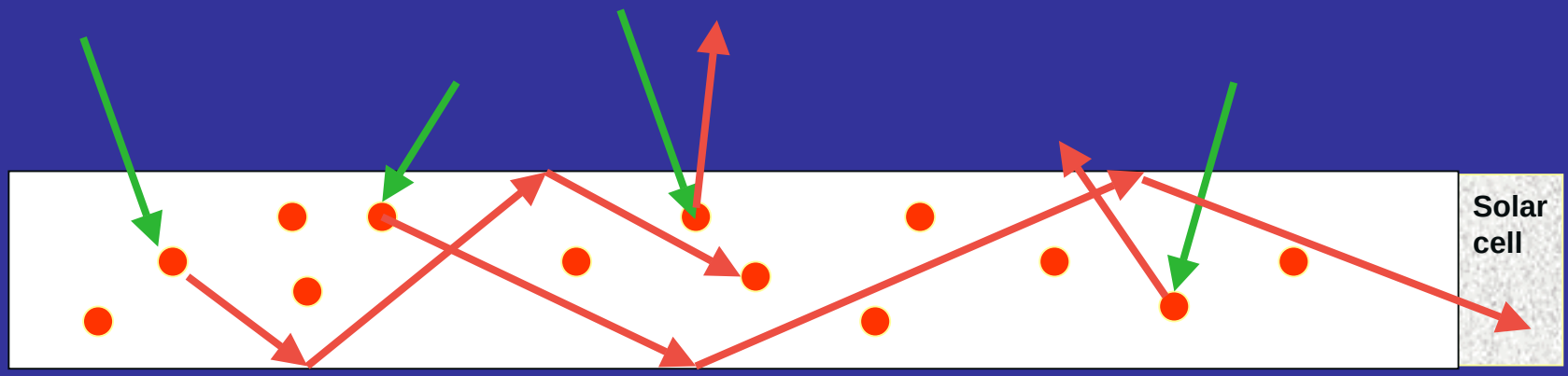
Advantages:

* minimize the size of solar cells
* allows use of more efficient cells
* cells perform more efficiently at high intensities (10-1000 suns)

Disadvantages:

*** unwieldy shapes/sizes**
*** high cost**
*** need to track the sun**
* **functions only on sunny days**
* **non-residential areas (deserts)**

Why a Luminescent Solar Concentrator?



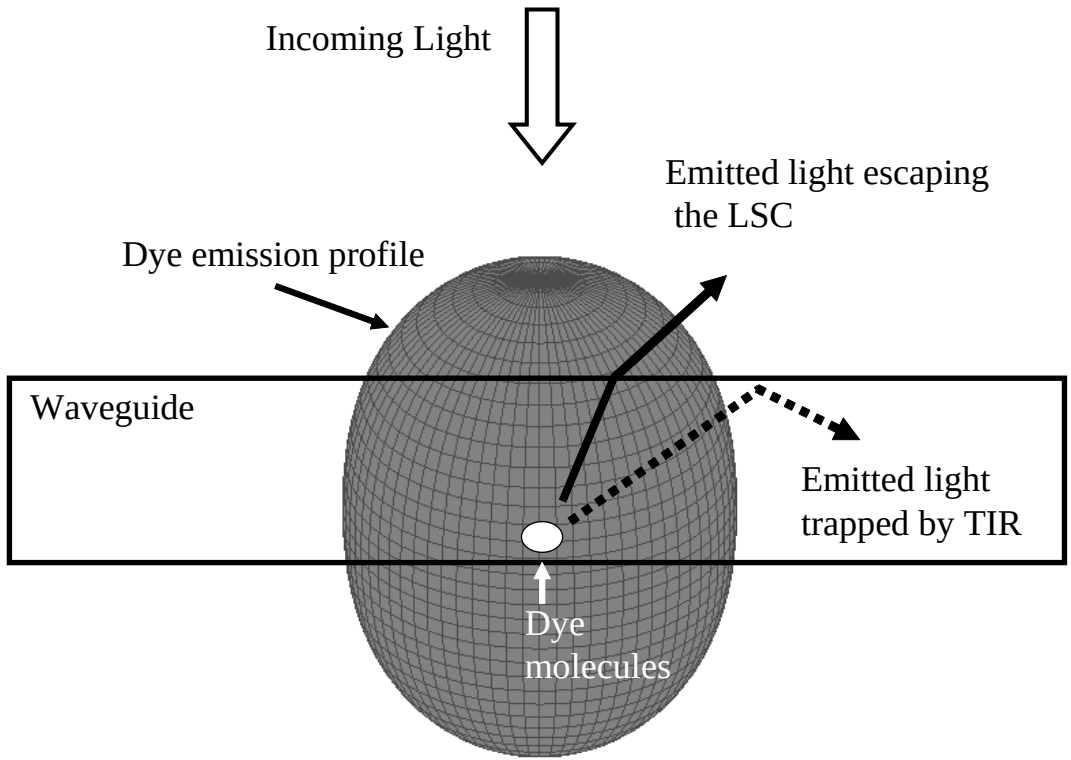
Offers several advantages:

* uses inexpensive materials
* reduces solar cell size by > 90%
* flat or flexible modules
* requires no tracking of the sun/ functions in cloudy weather

Potential disadvantages:

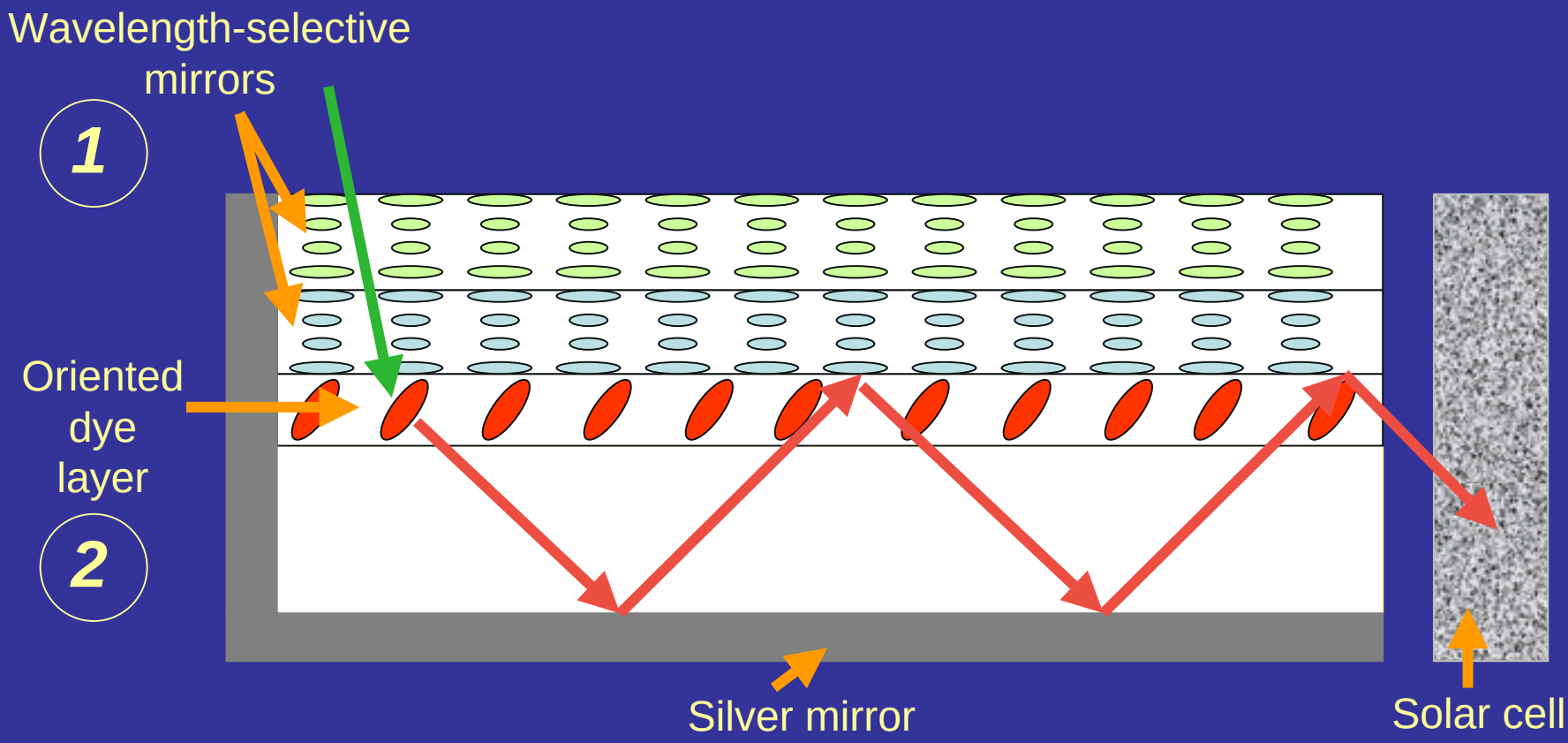
* dye limitations, lifetime and efficiency (mostly solved)
* **a significant portion of the emitted light not coupled into the waveguide**

Surface losses



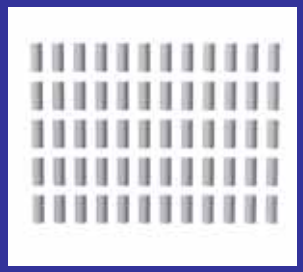
More than 50% of the light is lost through the surface

The design goal for an efficient Luminescent Solar Concentrator

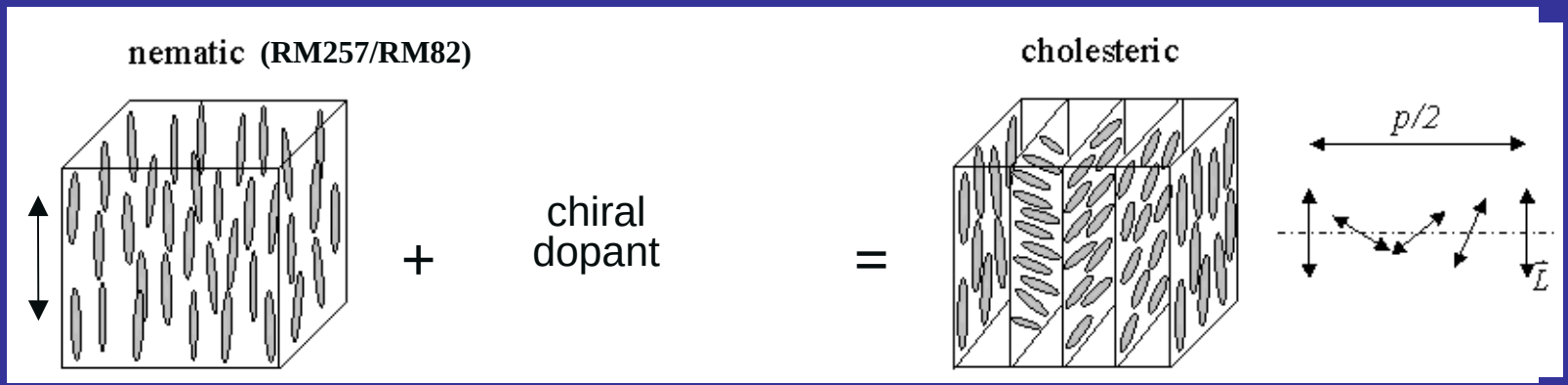


A brief overview of Liquid Crystals

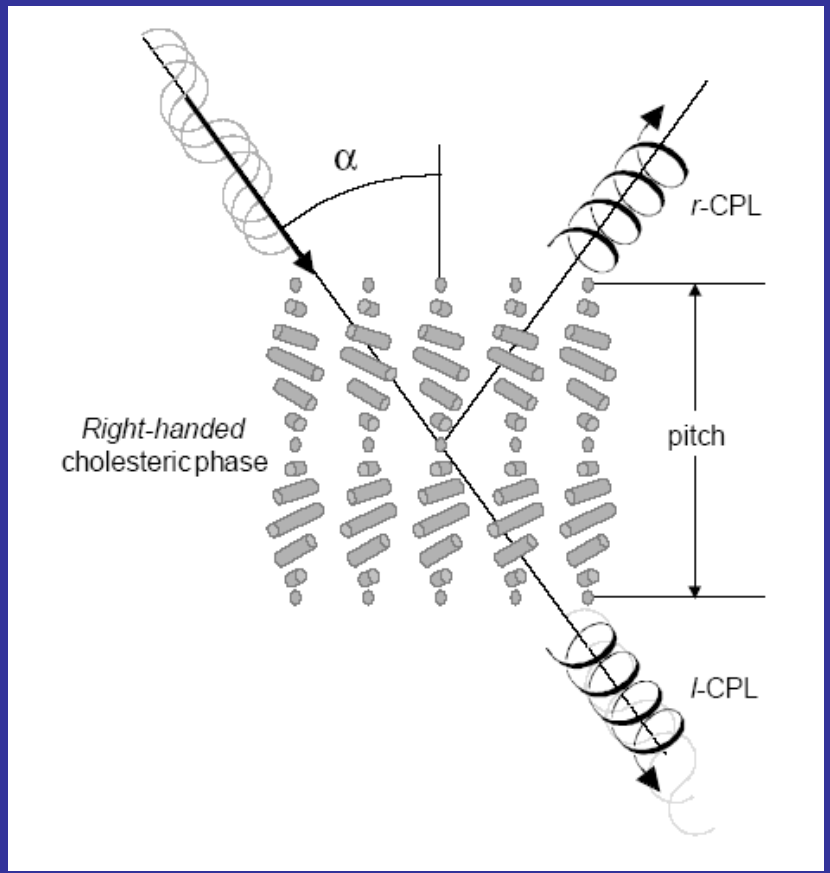
Liquid crystals are a state of matter between crystals and liquids. They have long range orders of orientation and/or position while being fluid-like.



	Crystalline	Nematic	Isotropic
Order:	Position and orientation	Orientation	None



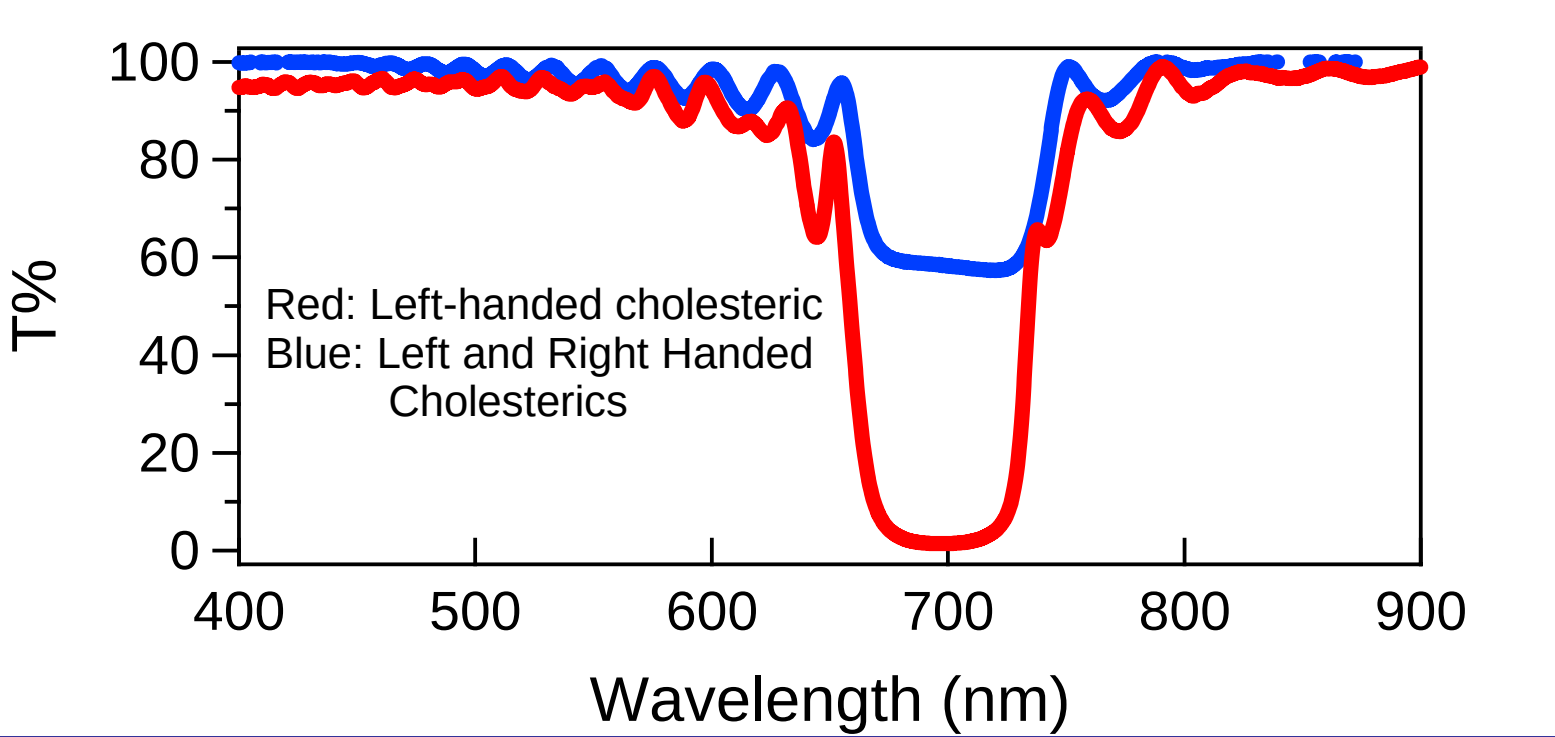
A Cholesteric Liquid Crystal



A liquid crystal doped with a right-handed chiral dopant will reflect a narrow band (~75 nm) of right-circularly polarized light of a specific wavelength. The reflected wavelength depends on the pitch of the helix, and we can adjust the pitch by the amount of chiral 'doping'.

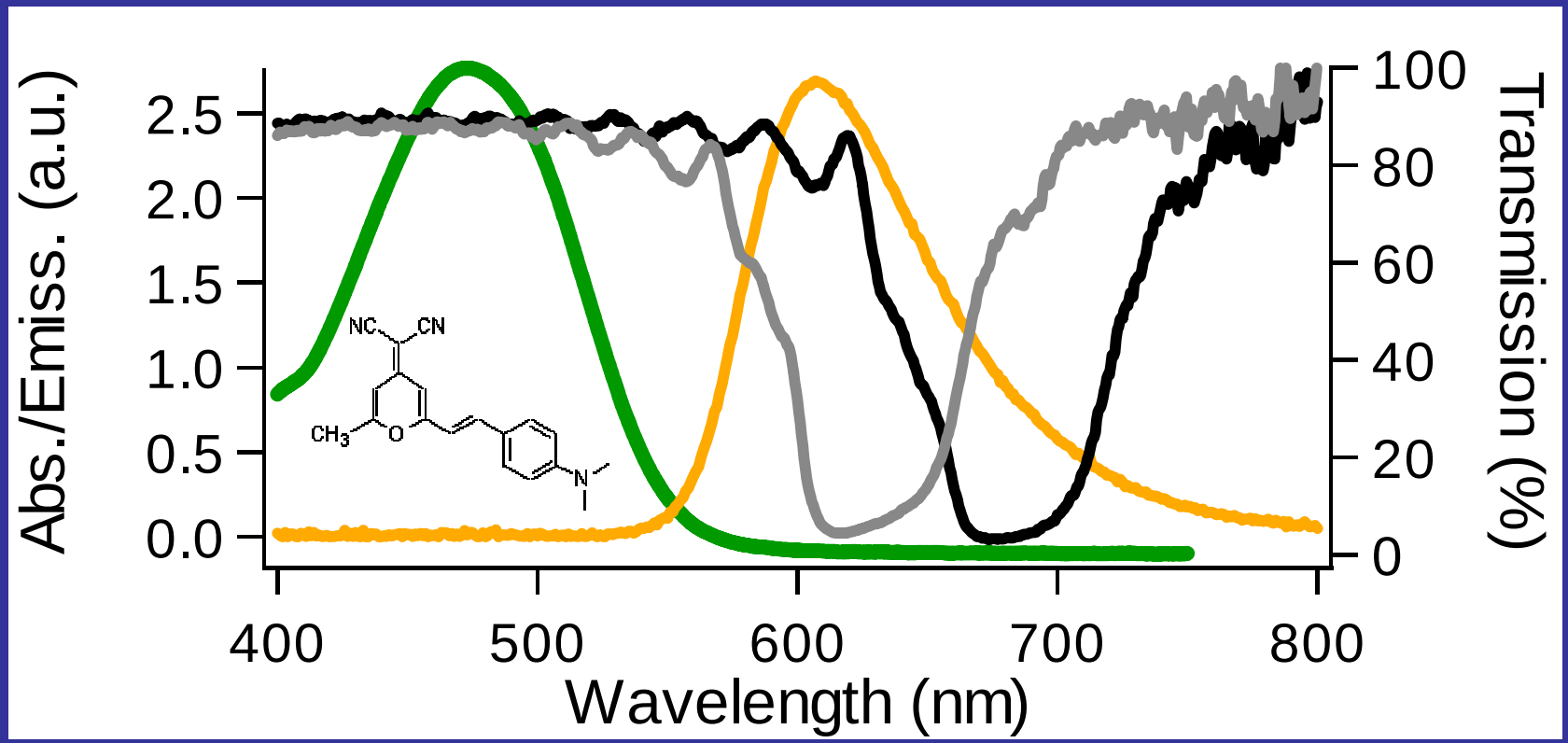
Left-circularly polarized light will pass through the cholesteric layer with no deviation.

Putting left and right together



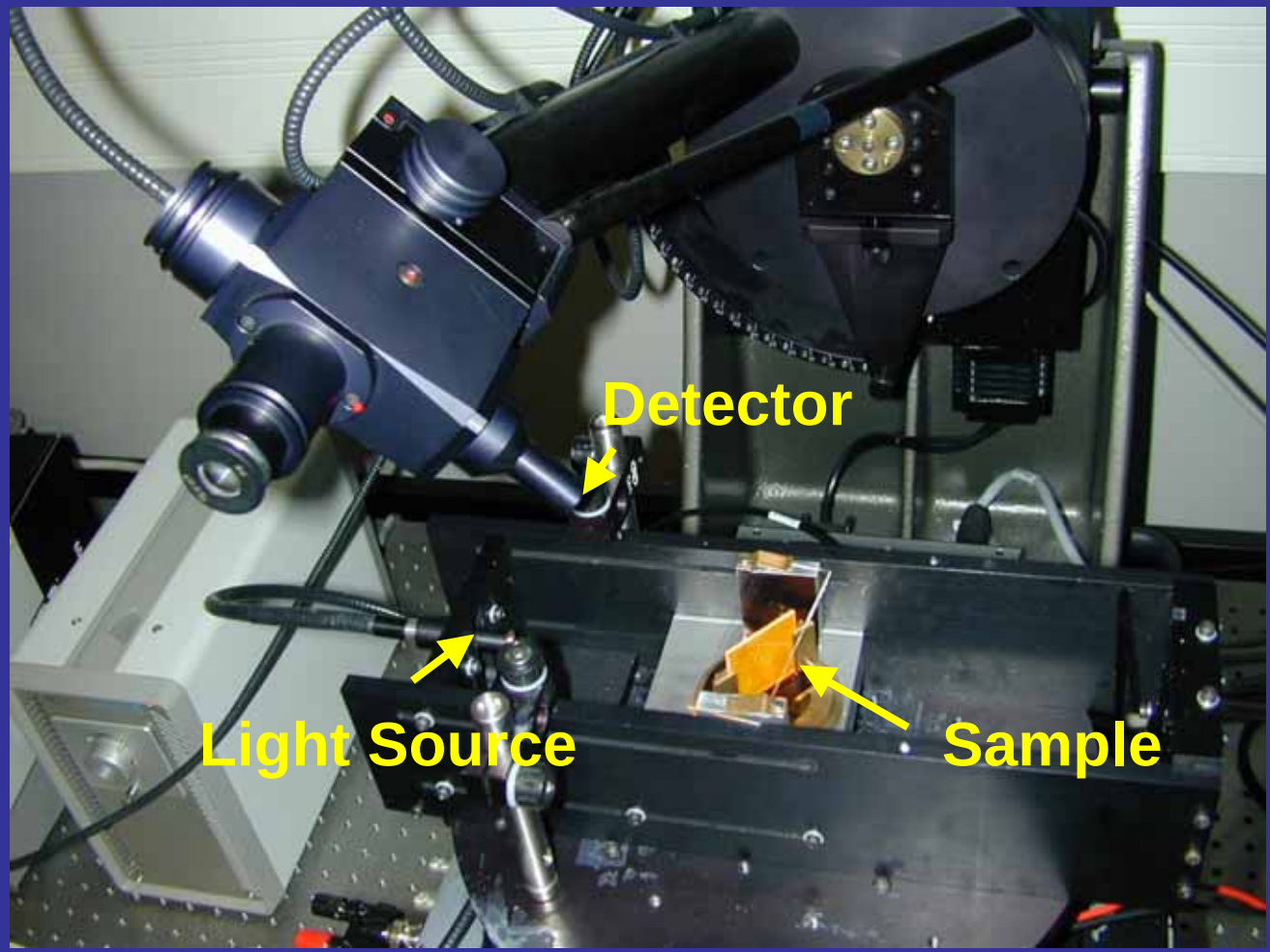
Inorganic stacks needs multiple layers (>20): expensive to apply, and difficult to do over large areas

The choice of the cholesteric

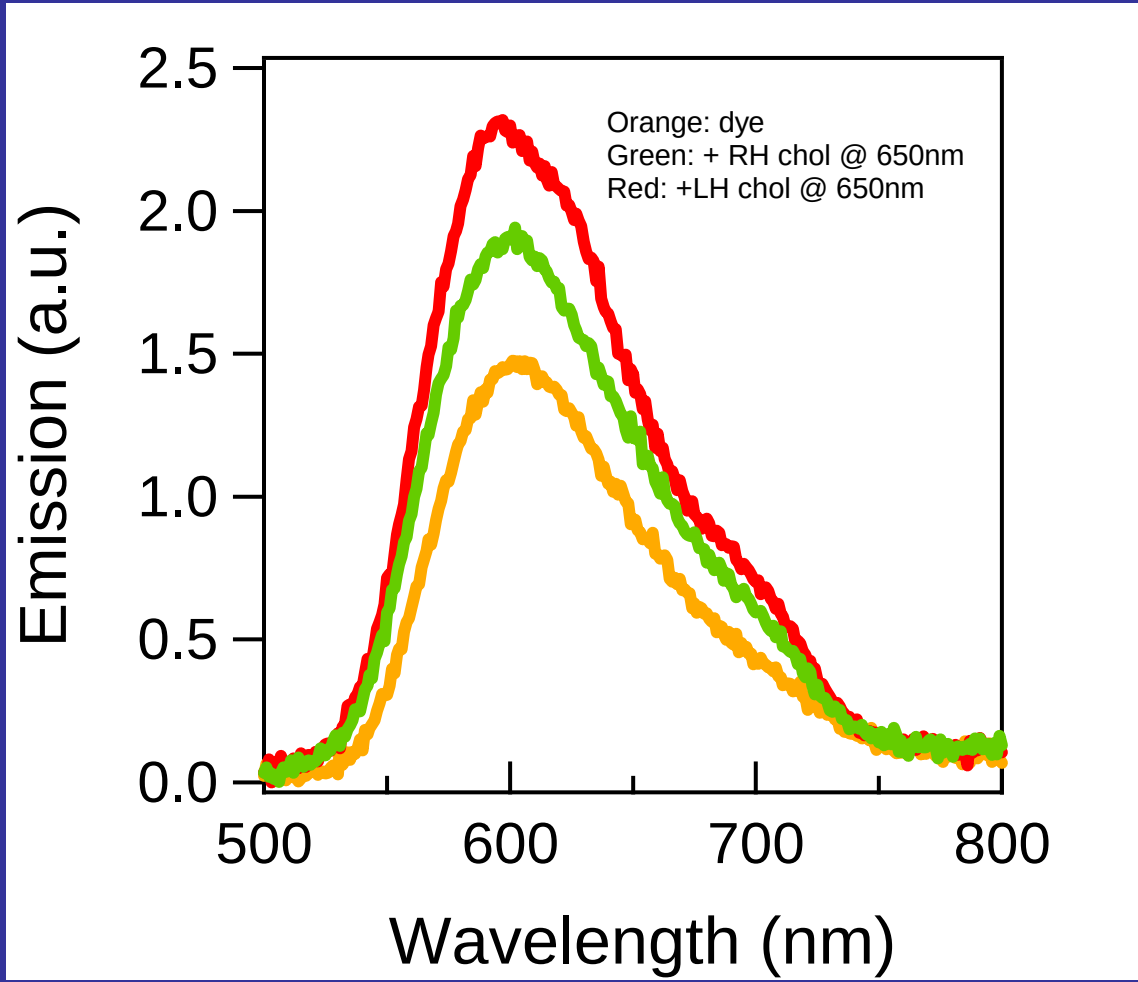


In choosing the correct pitch of the cholesteric, one desires to maximize reflection of the emitted light while minimizing reflection of the incident light.

The measurement setup



Effect of adding cholesterics



Right- and left-handed cholesteric double layers

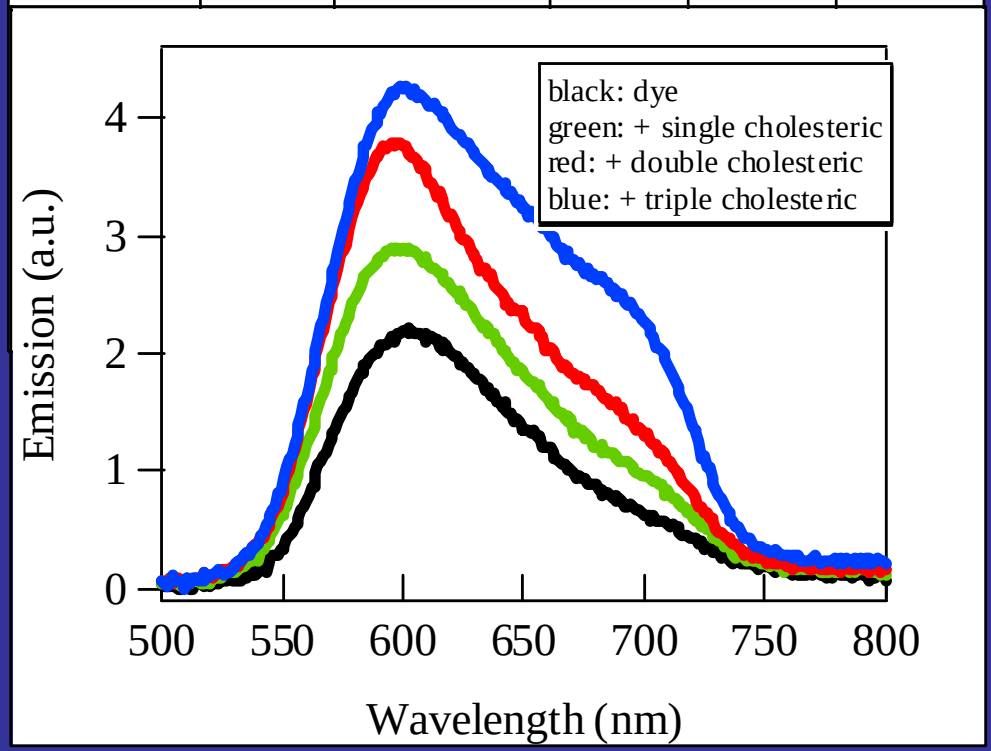
		0º		20º		40º	
Dye	l_0	1 chol.	2 chol.	1 chol.	2 chol.	1 chol.	2 chol.
DCM	550	0.88	-	0.86	-	0.91	-
	650	1.28	1.5	1.28	1.48	1.26	1.35
	700	1.3	1.46	1.33	1.5	1.34	1.53
	775	**1.54**	**1.79**	**1.54**	**1.93**	**1.59**	**1.98**

Chol. = cholesteric
λ_0 = Central reflection wavelength of cholesteric

The output of the DCM samples may be increased by more than **70%** upon application of two, opposite-handed cholesterics centered at the same wavelength.

Broadband cholesterics

Dye	l_0 (nm)	Bandwidth (nm)	0°	20°	40°
DCM	660	150	1.91	1.80	1.57
	700	225	**2.39**	**2.29**	**1.98**
	710	150	1.69	1.59	1.44
	735	150	**2.16**	**2.02**	**1.97**



We may obtain very large increases in the total integrated emission upon application of successive narrow-band cholesterics of the same handedness.

How about a right-handed broadband on a left-handed broadband?

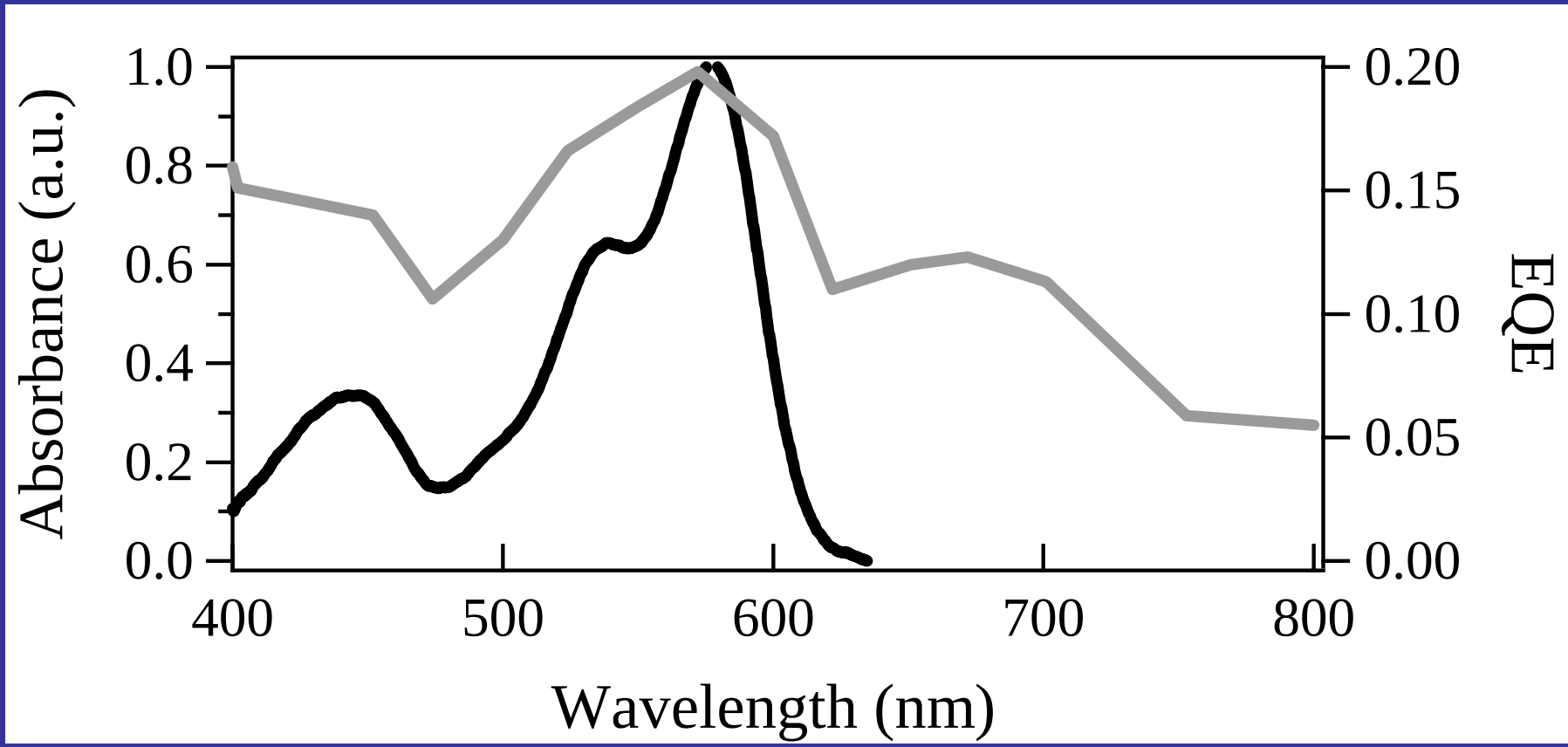
Broadband double layers?

Center	Hand.	0°	20°	40°
675	RH	1.16	1.20	1.23
675	LH	1.24	1.24	1.22
725	RH	1.69	1.71	1.67
725	LH	**1.86**	**1.87**	**1.81**

Hand.= Handedness sense of the cholesteric layer, right (RH) or left (LH)

We have made one such sample, and despite it having 4 layers, demonstrated an increase in light output at every stage

Efficiency Measurements



A single-dye system

Current efficiencies ?

Efficiencies of the LSC/PV systems dependent on the efficiency of the PV cell

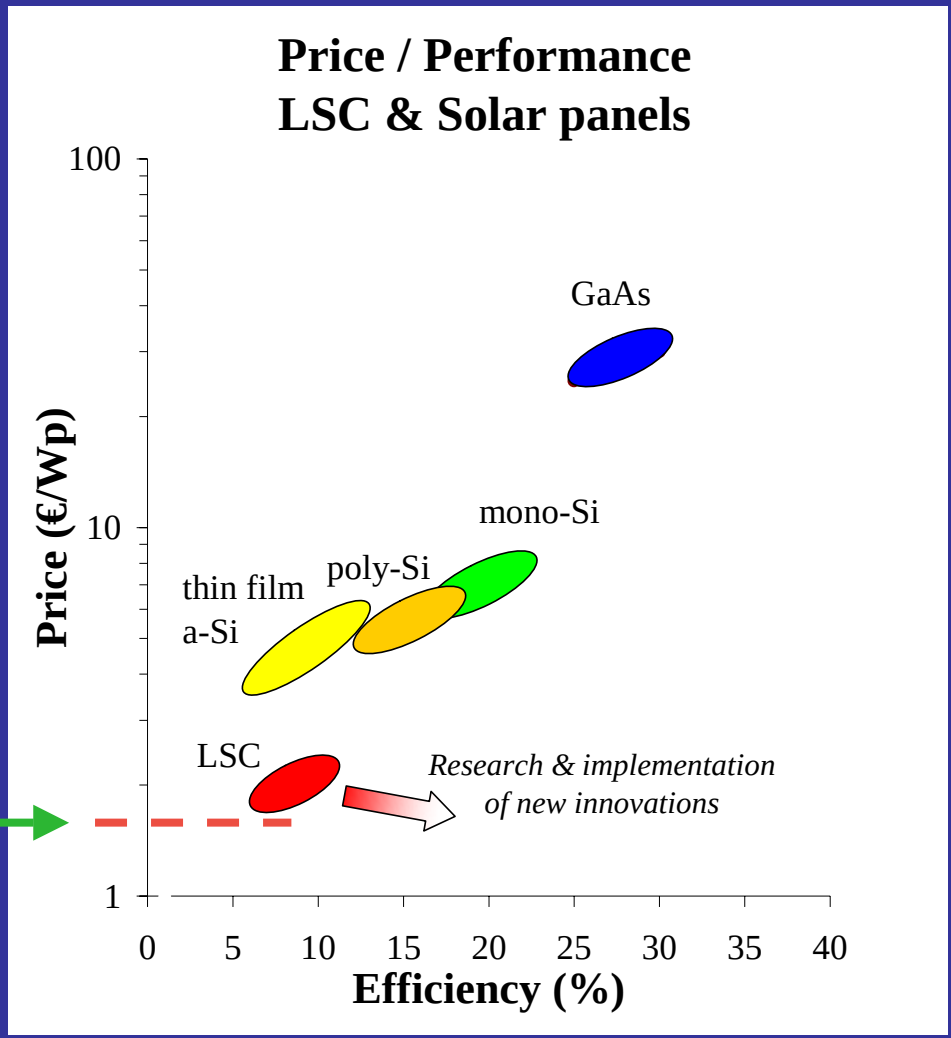
Have currently a peak EQE of ~23.3%

Highest measured LSC/PV efficiency using a ~14% multicrystalline silicon cell was 2% (2-dye system)

Efficiencies have doubled since our measurements a year ago

Need to reach 6-10% to be economically viable: requires use of more dyes to cover solar spectrum, well-tuned cholesterics, and a photovoltaic cell designed for the LSC.

The Luminescent Solar Concentrator



Electricity from the wall socket

Acknowledgements

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  - Rudy van der Blom
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