Mitigating fluorescent dye performance limitations in luminescent solar concentrators

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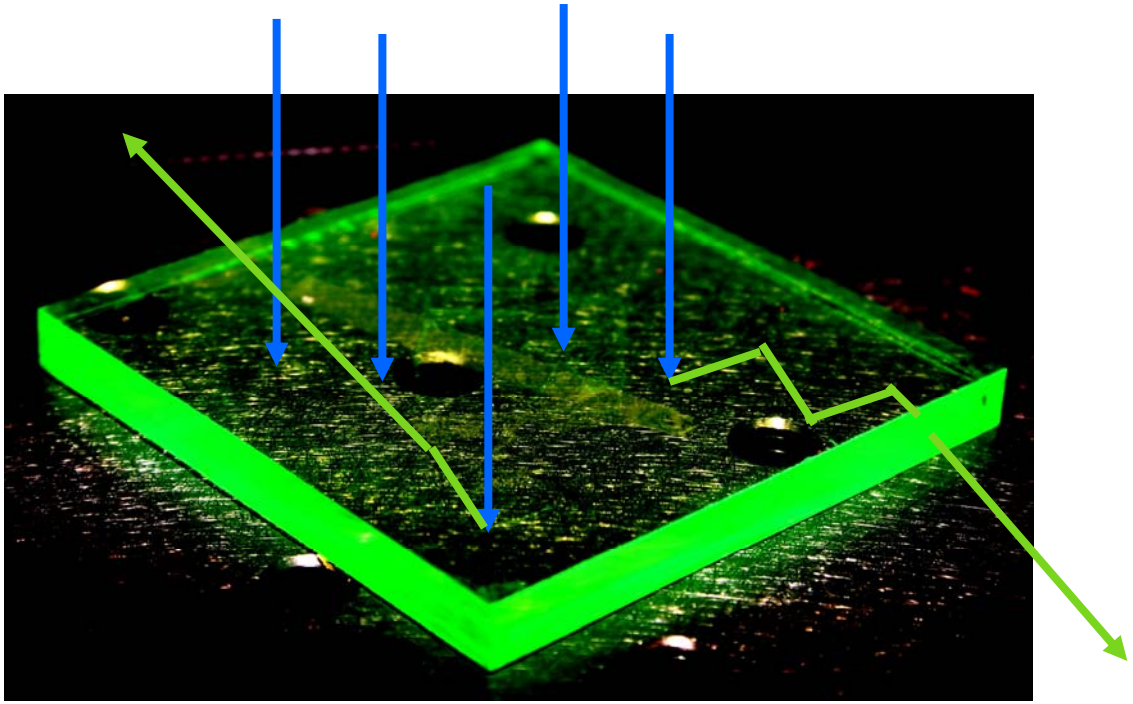
The luminescent solar concentrator



Waveguide:

Normally PMMA or polycarbonate

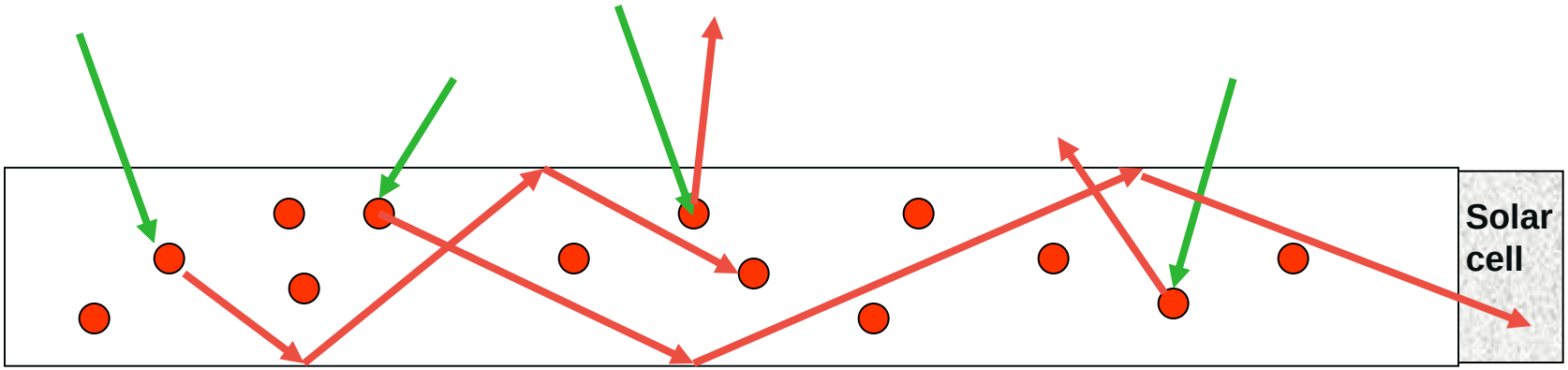
Solar Cell:

Size reduced >90%, can use higher quality cells

Luminophore:

Fluorescent or phosphorescent, organic or inorganic

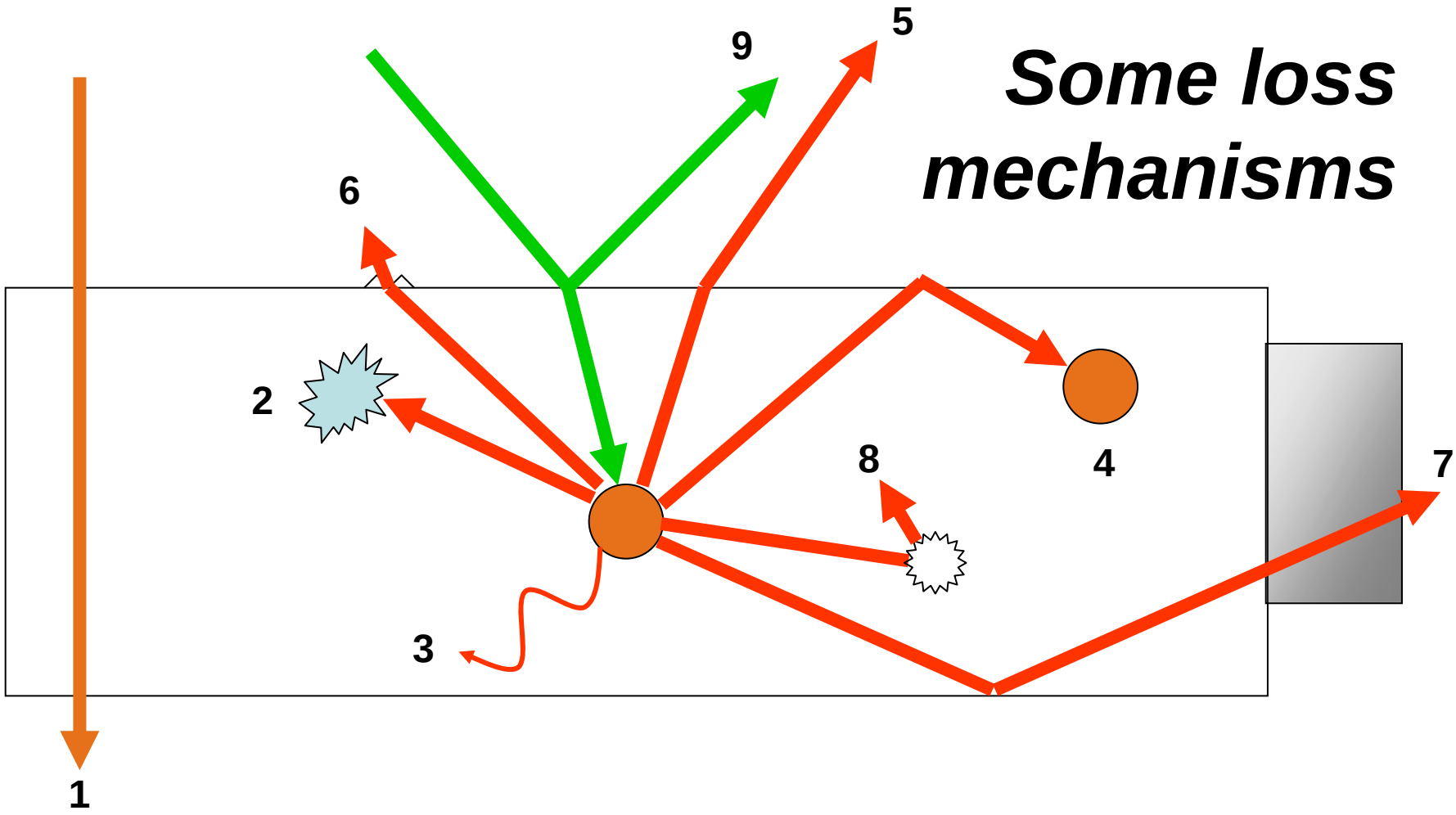
A closer look



Offers several advantages:

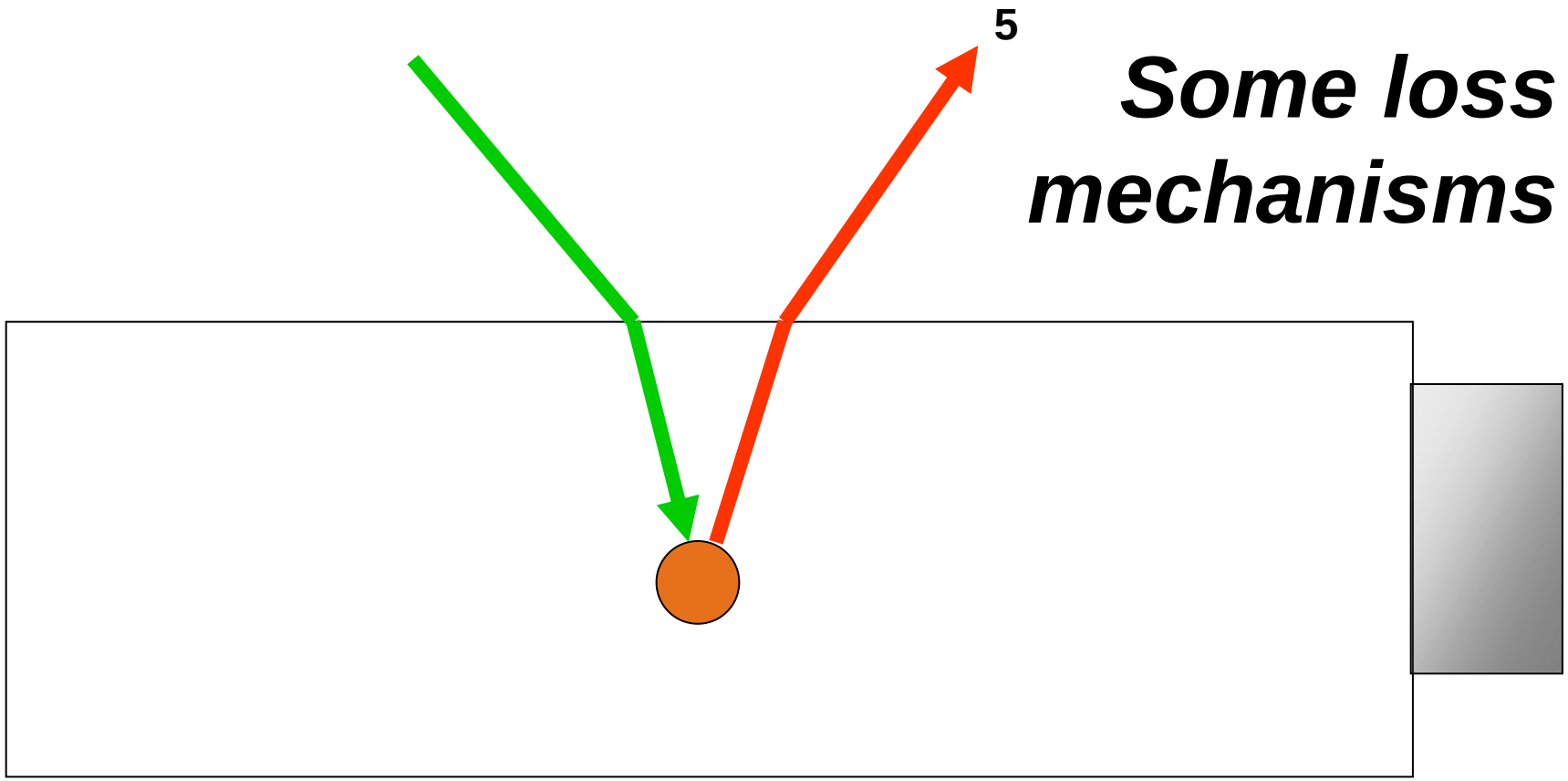
*** uses inexpensive materials and reduces solar cell size by > 90%**
*** flat or flexible modules, with no heat sink**
*** variable coloration and shapes, enhanced suitability for architectural integration**

Some loss mechanisms



1. Input light outside absorption band
2. Absorption by the waveguide
3. Non-unity quantum efficiency
4. Re-absorption of emitted light
5. Light emitted outside the capture cone
6. Non-ideal surface smoothness
7. Incomplete conversion of light by PV
8. Internal scattering
9. Reflection from waveguide surface

Some loss mechanisms



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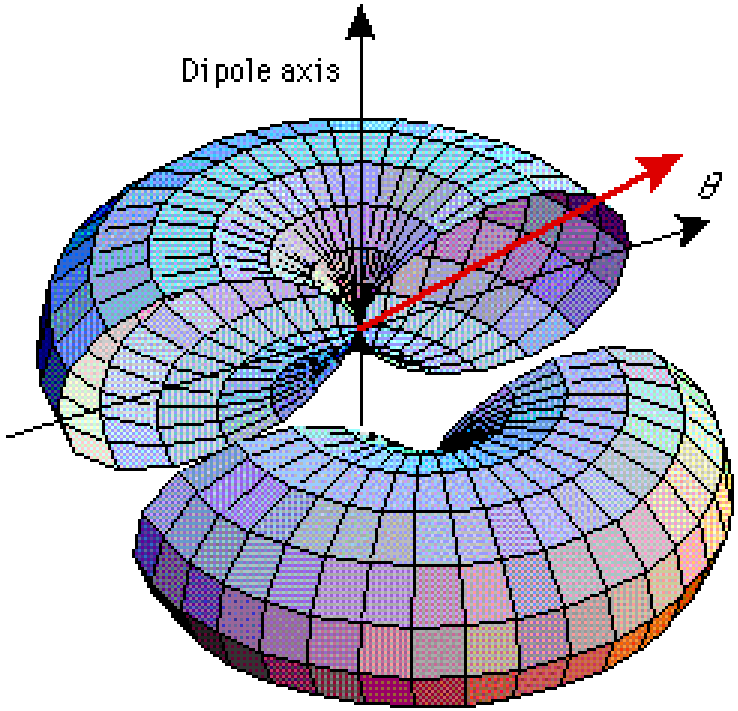
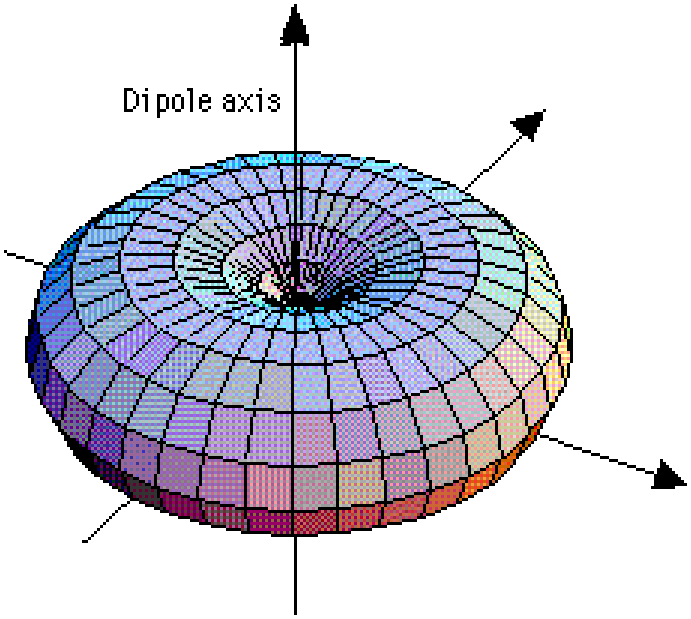
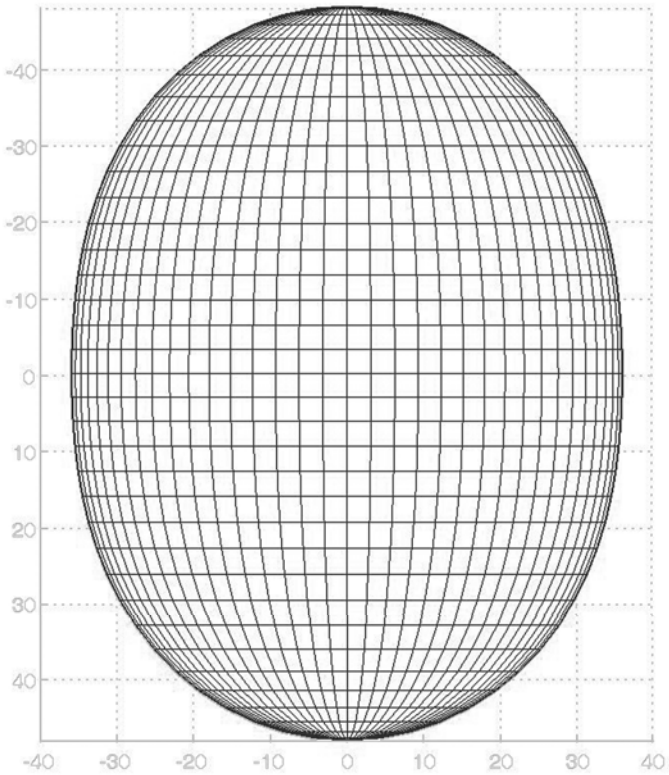
Individual dyes emit anisotropically



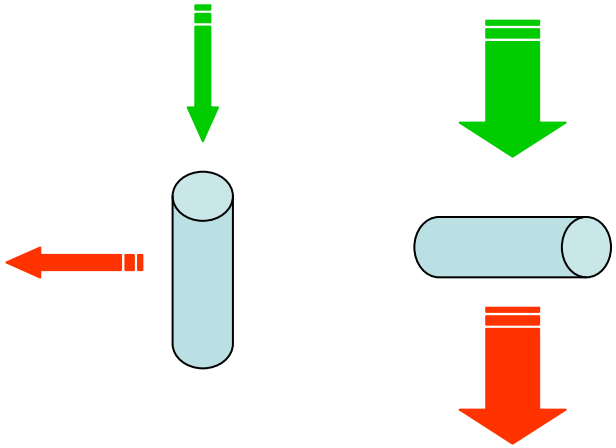


Source: Harvard University http://people.seas.harvard.edu/~jones/es151/prop_models/dipole.gif

A hypothesis

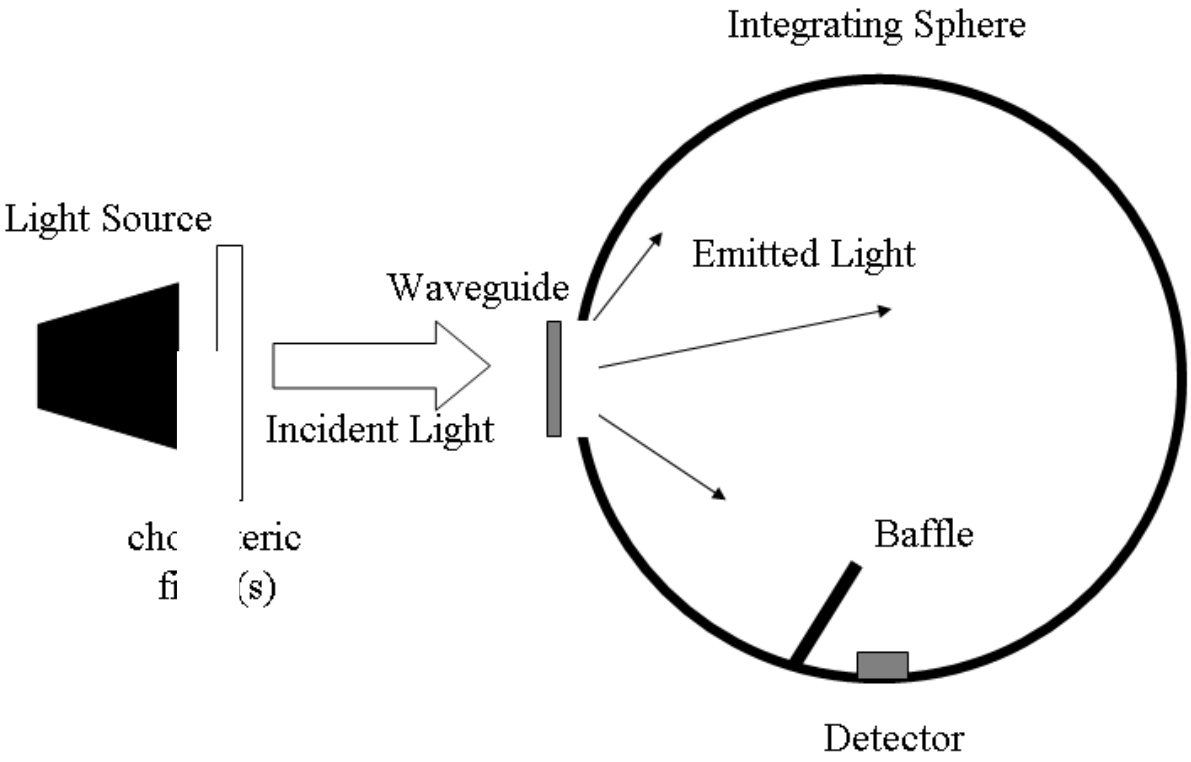


An isotropic array of dye molecules irradiated from above does not emit isotropically

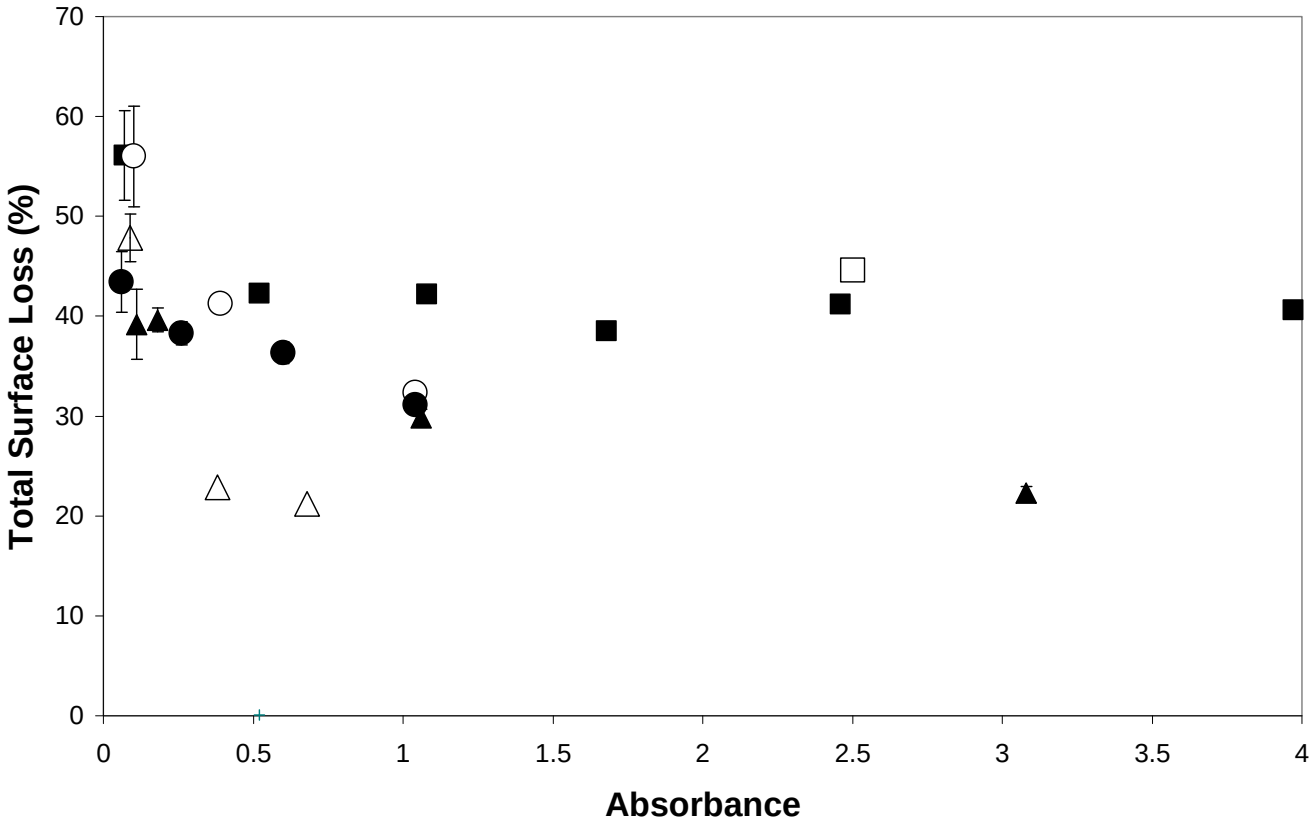


Sanchez et al, J. Appl. Phys 87, 274 (2000)

Surface losses measured



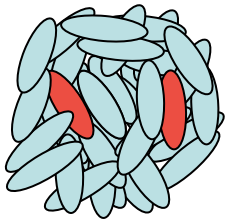
Surface losses



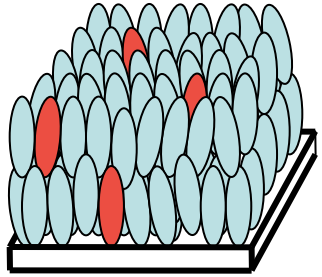
PC: filled symbols
PMMA: open symbols

filled waveguides: squares
thin layers: triangles, circles

Alignment of dyes

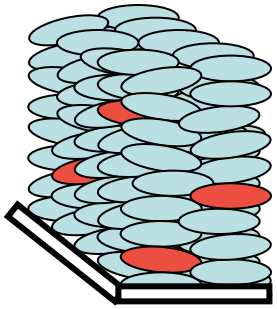


Alignment layer



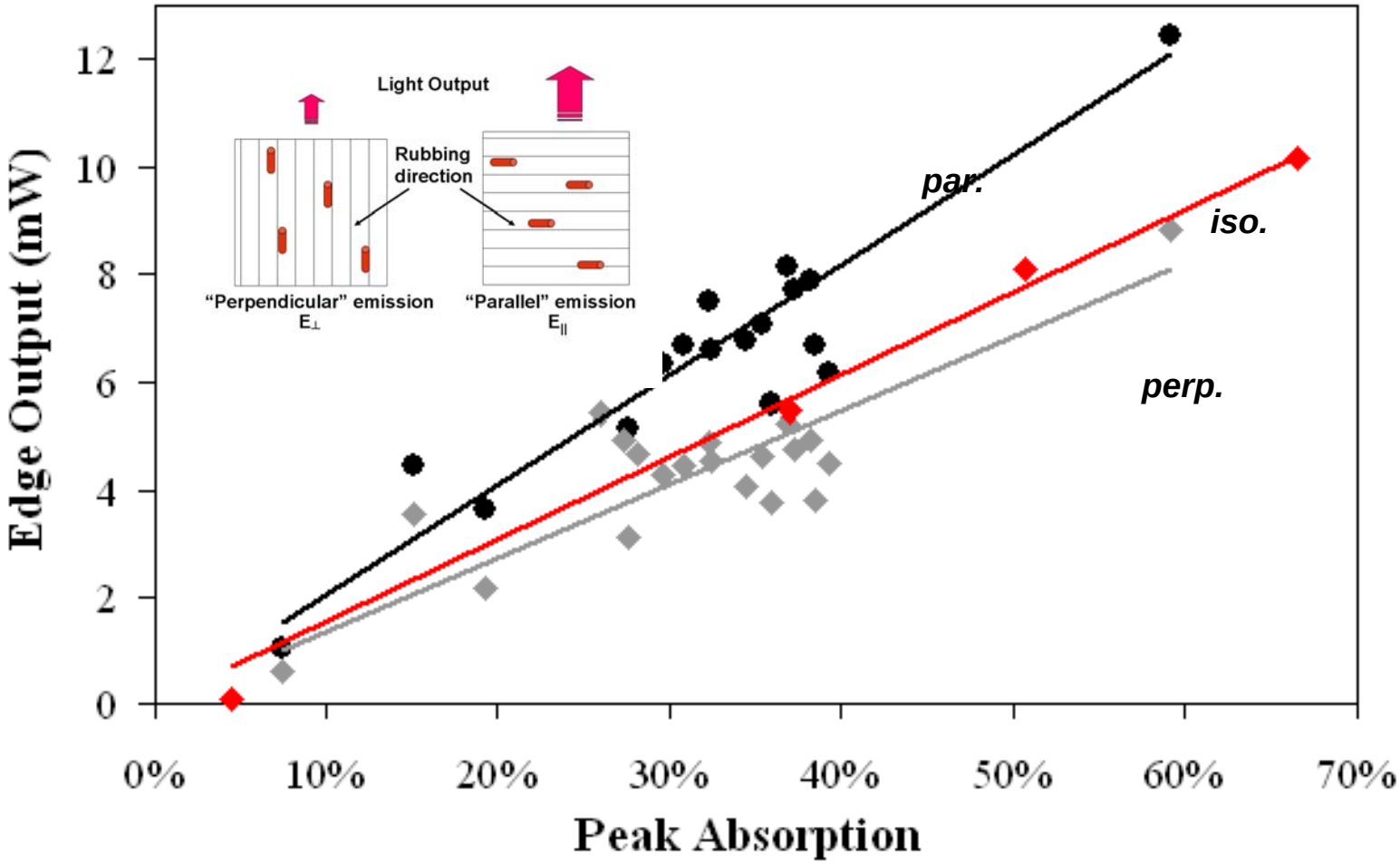
Host liquid crystal + guest dye

Dye oriented by liquid crystal (homeotropic)

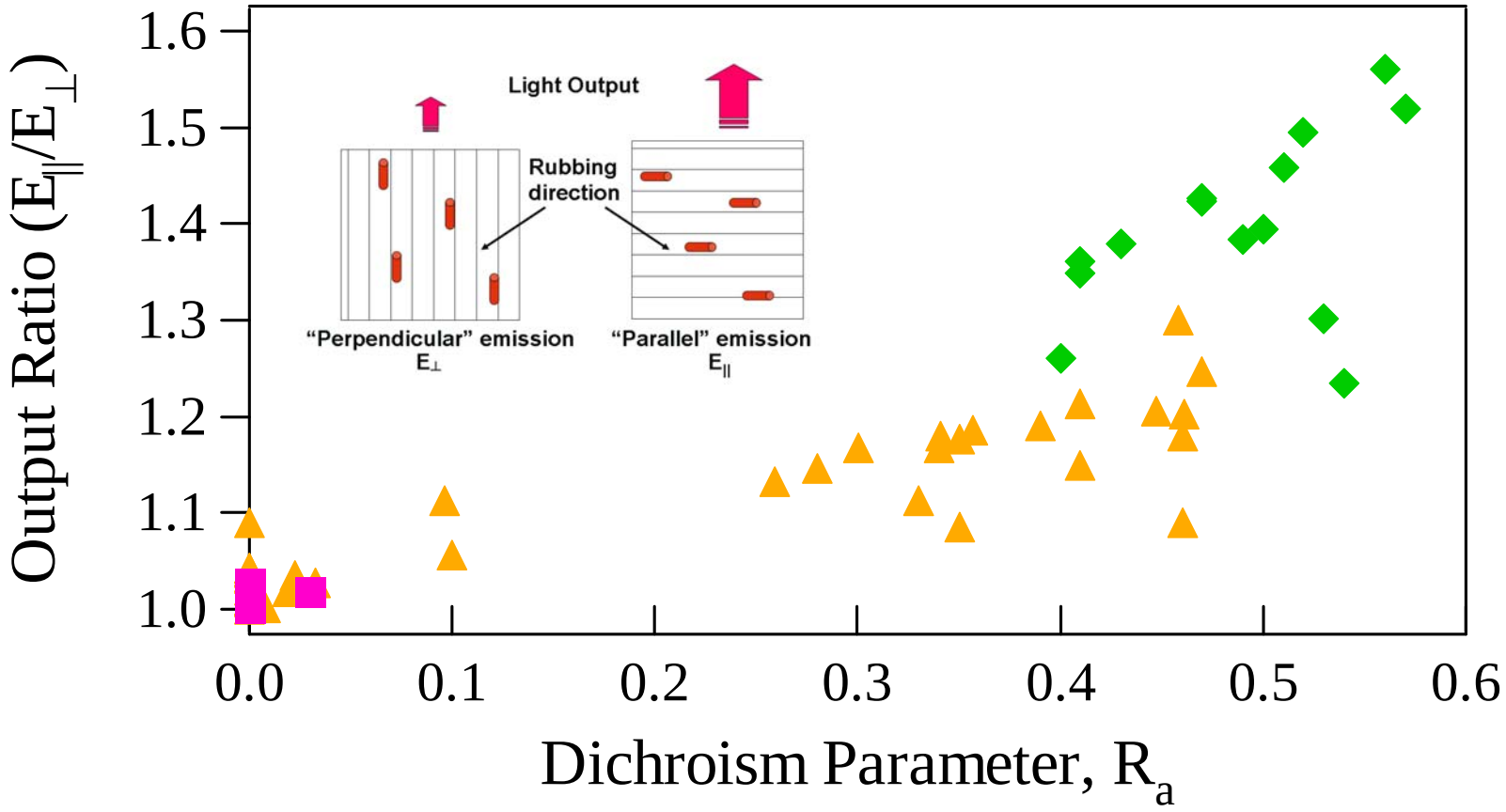


Dye oriented by liquid crystal (planar)

Comparing the two edges of planar aligned dyes to isotropic



Edge emission ratio



$R_a=(A_{\parallel}- A_{\perp}) /(A_{\parallel}+2A_{\perp})$

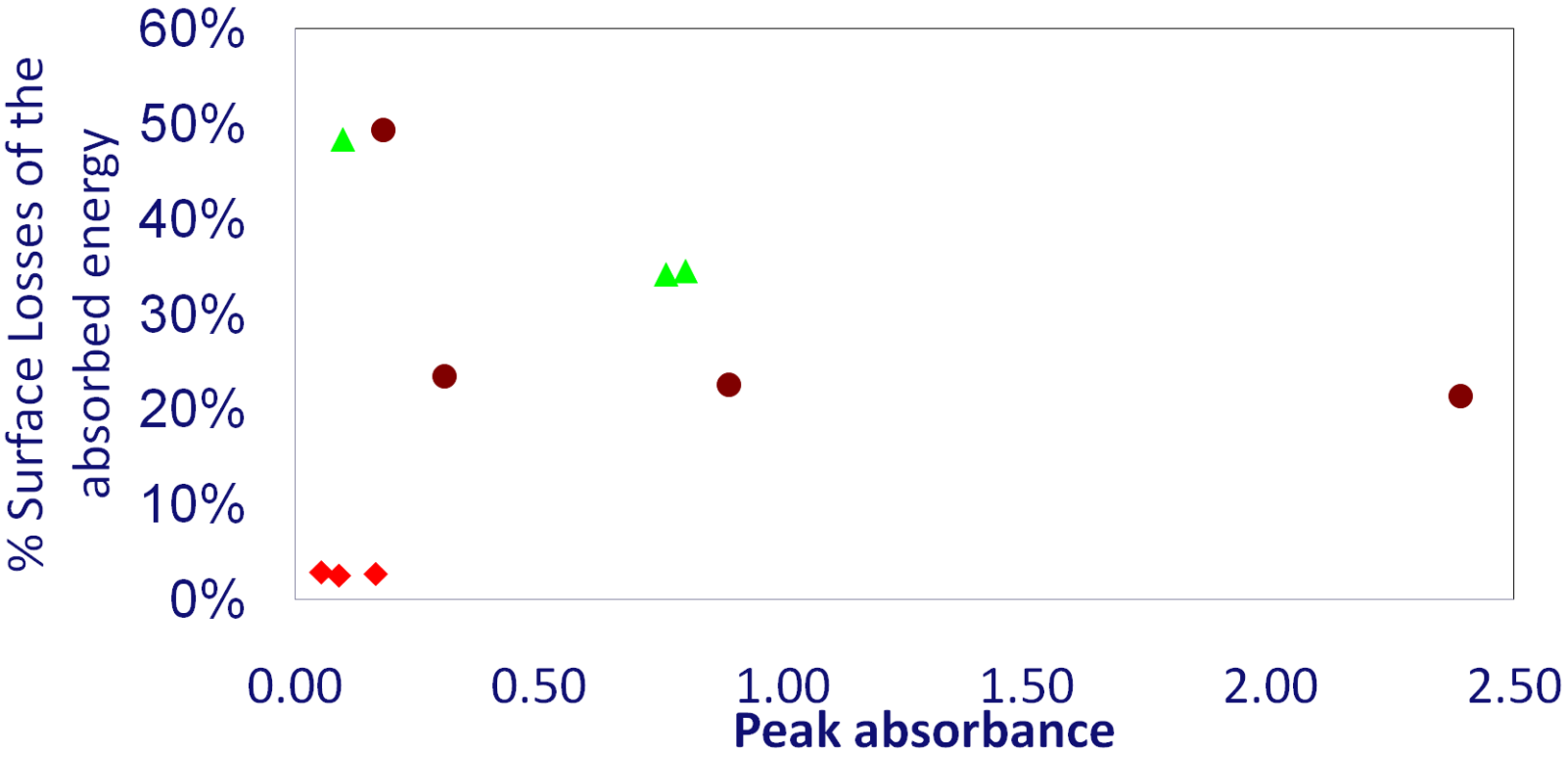
R_a = 1 perfect order

= 0 isotropic

Result:
More than 25% increase in edge emission of 2 sides compared to isotropic

TU/e Technische Universiteit Eindhoven University of Technology

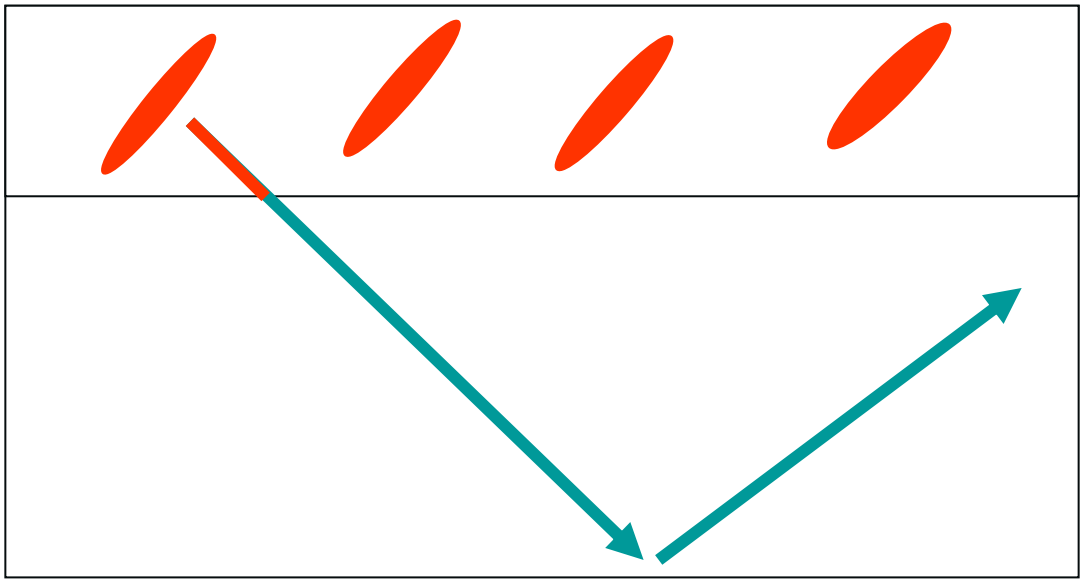
Effect on surface losses

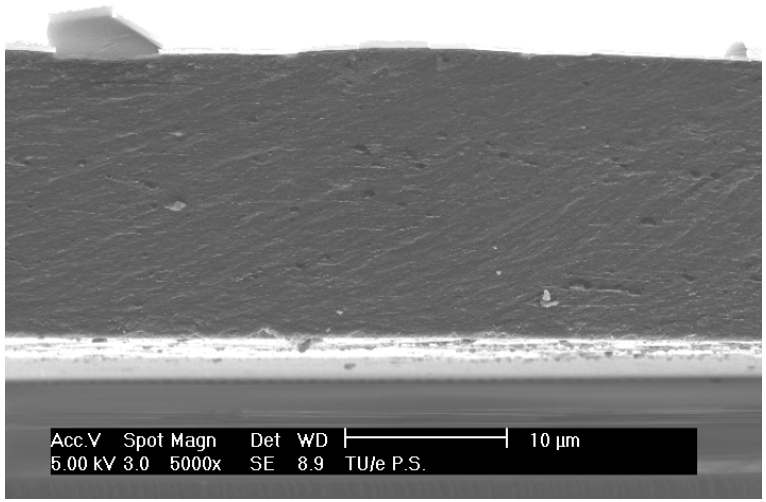


The surface energy losses and edge emissions were measured from planar (green), homeotropic (red) and isotropic (brown) dye arrays of K160.

Dramatic reduction in surface losses by homeotropically aligning the dye

Advantages of both alignments: Tilt aligned dyes?

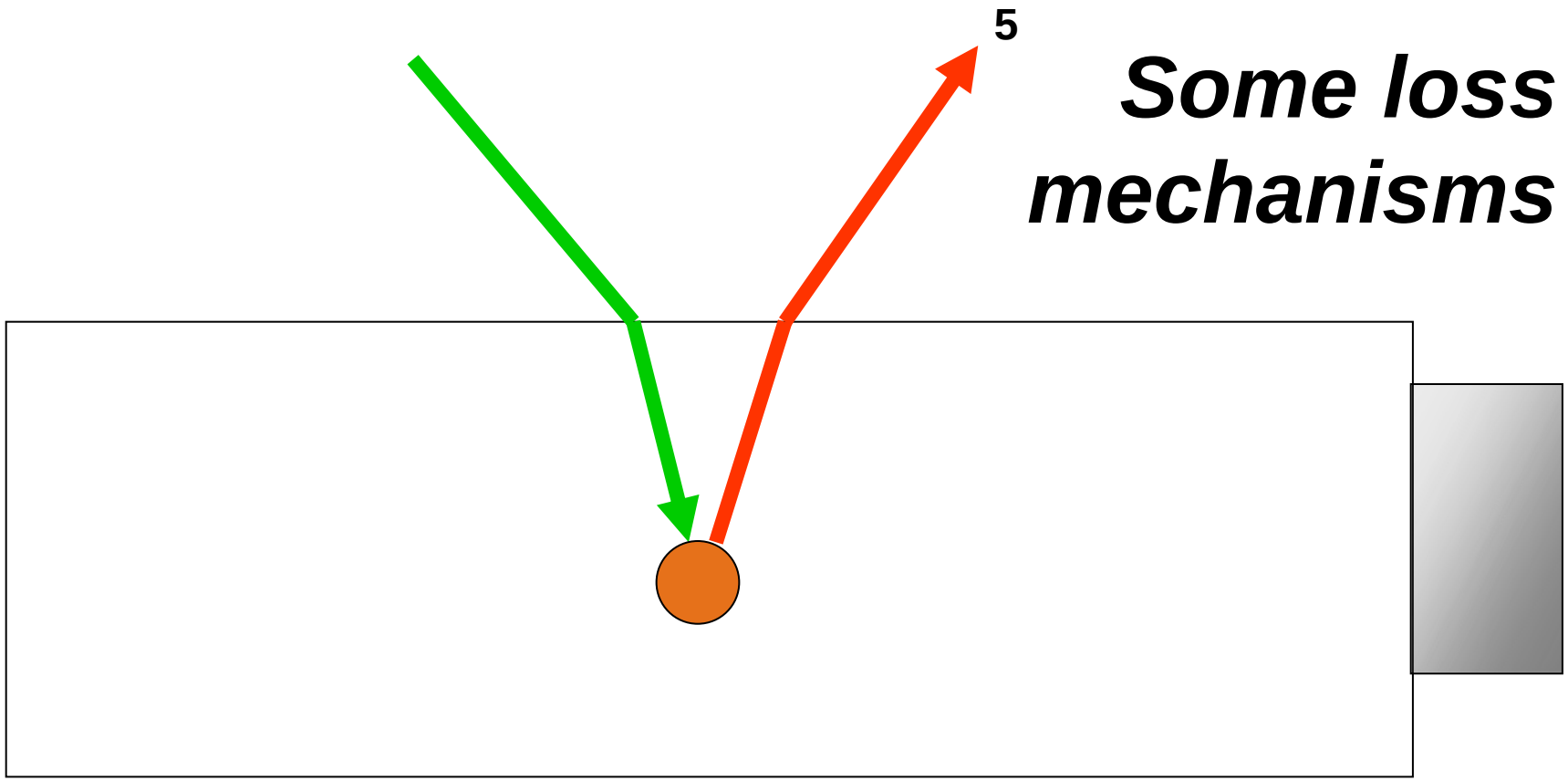




Minimize path length through dye layer
Maximize path length through clear waveguide

We can achieve tilt alignment in cells:
now for single surface

Some loss mechanisms



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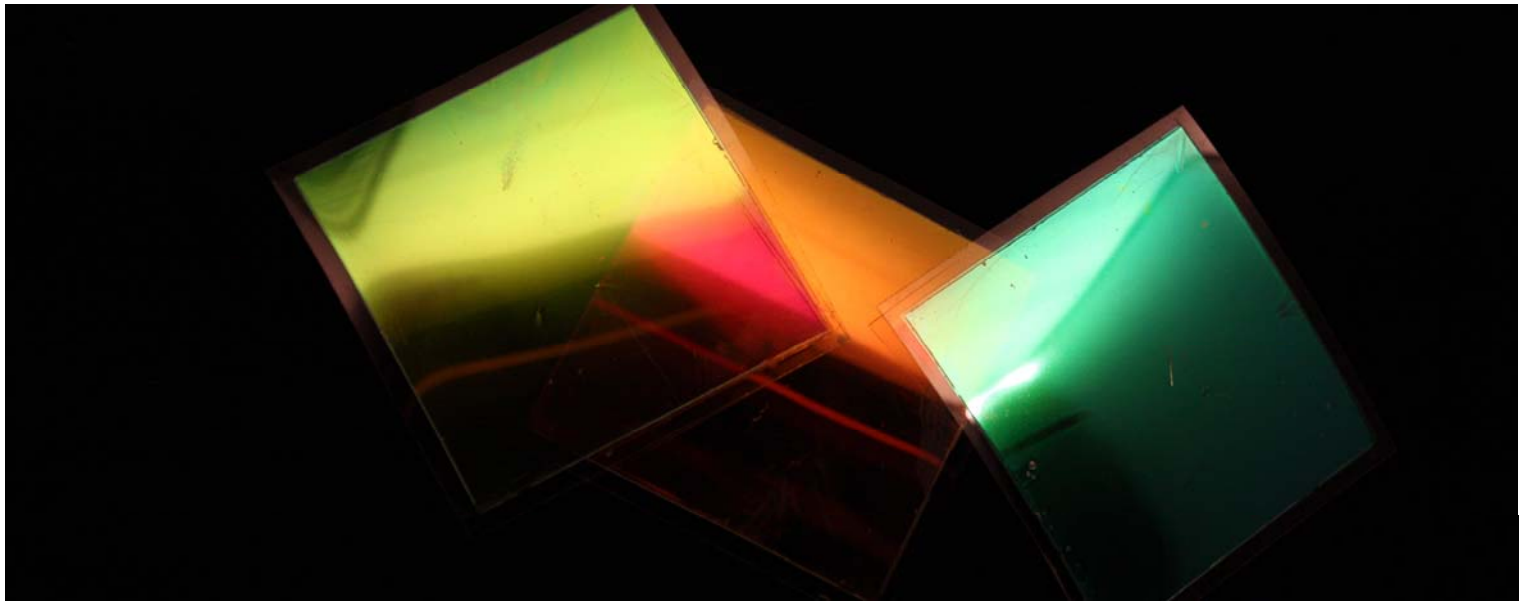
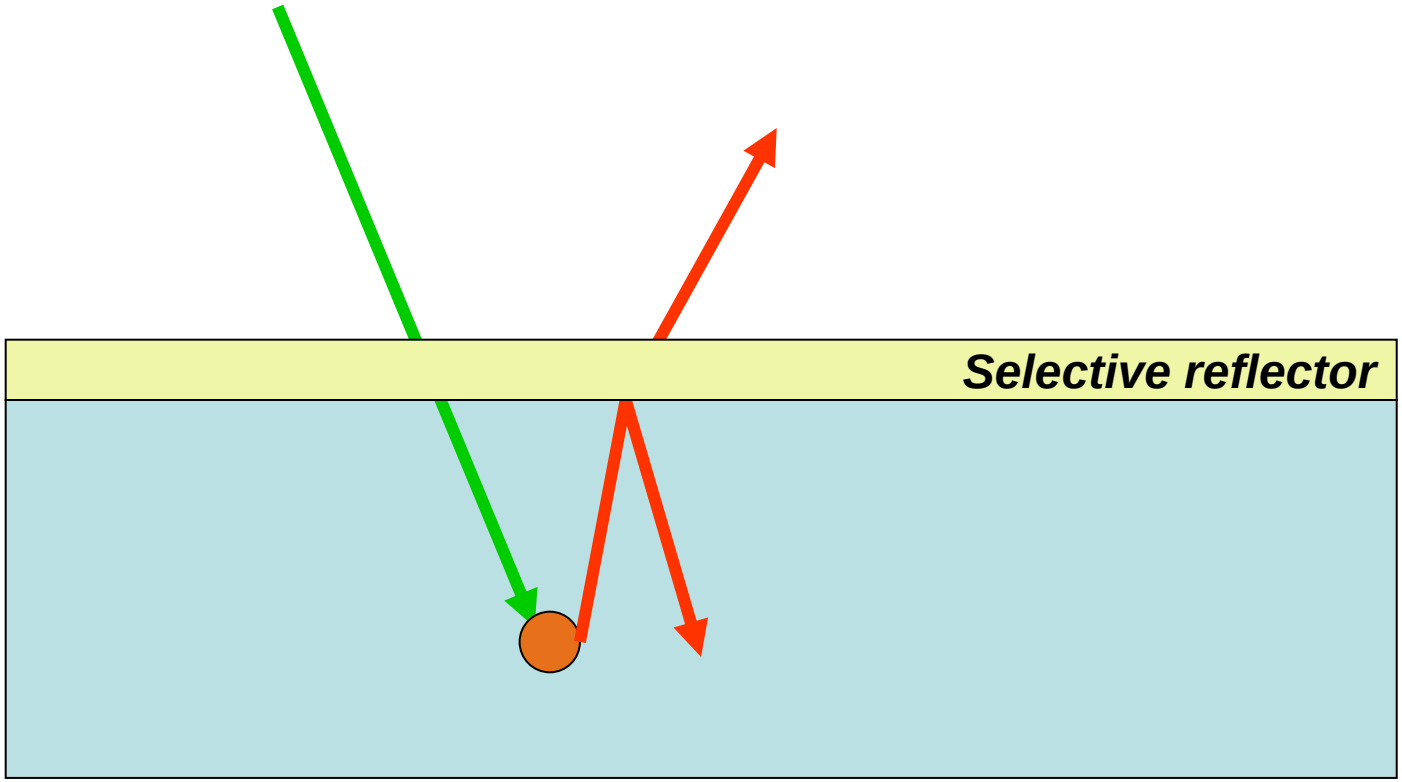
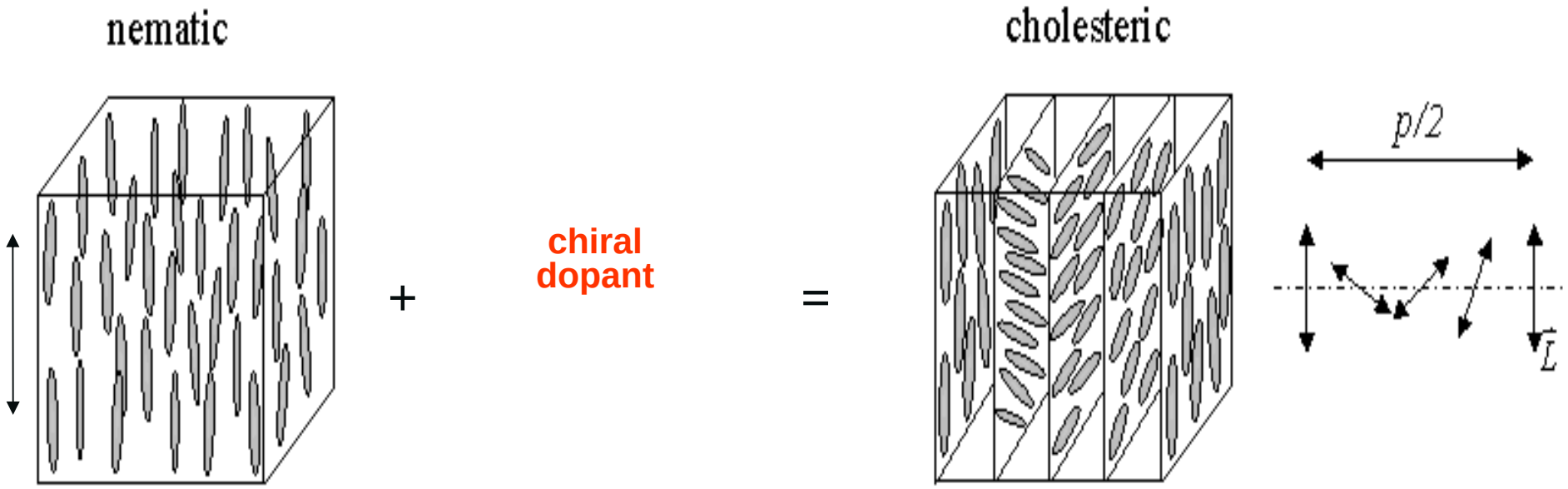
Reducing surface losses: Selectively-reflecting layers



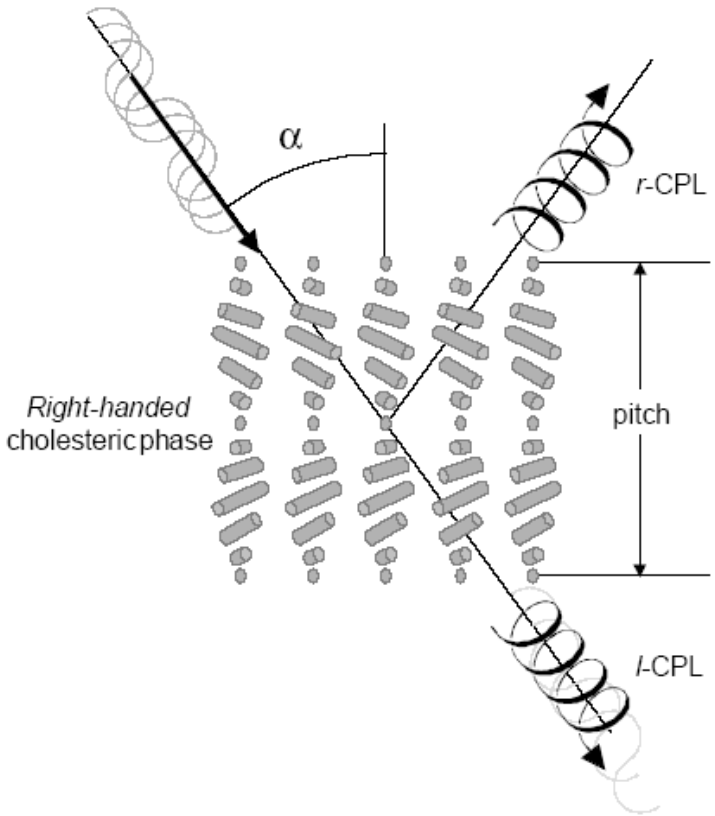
Basic concept



Cholesterics



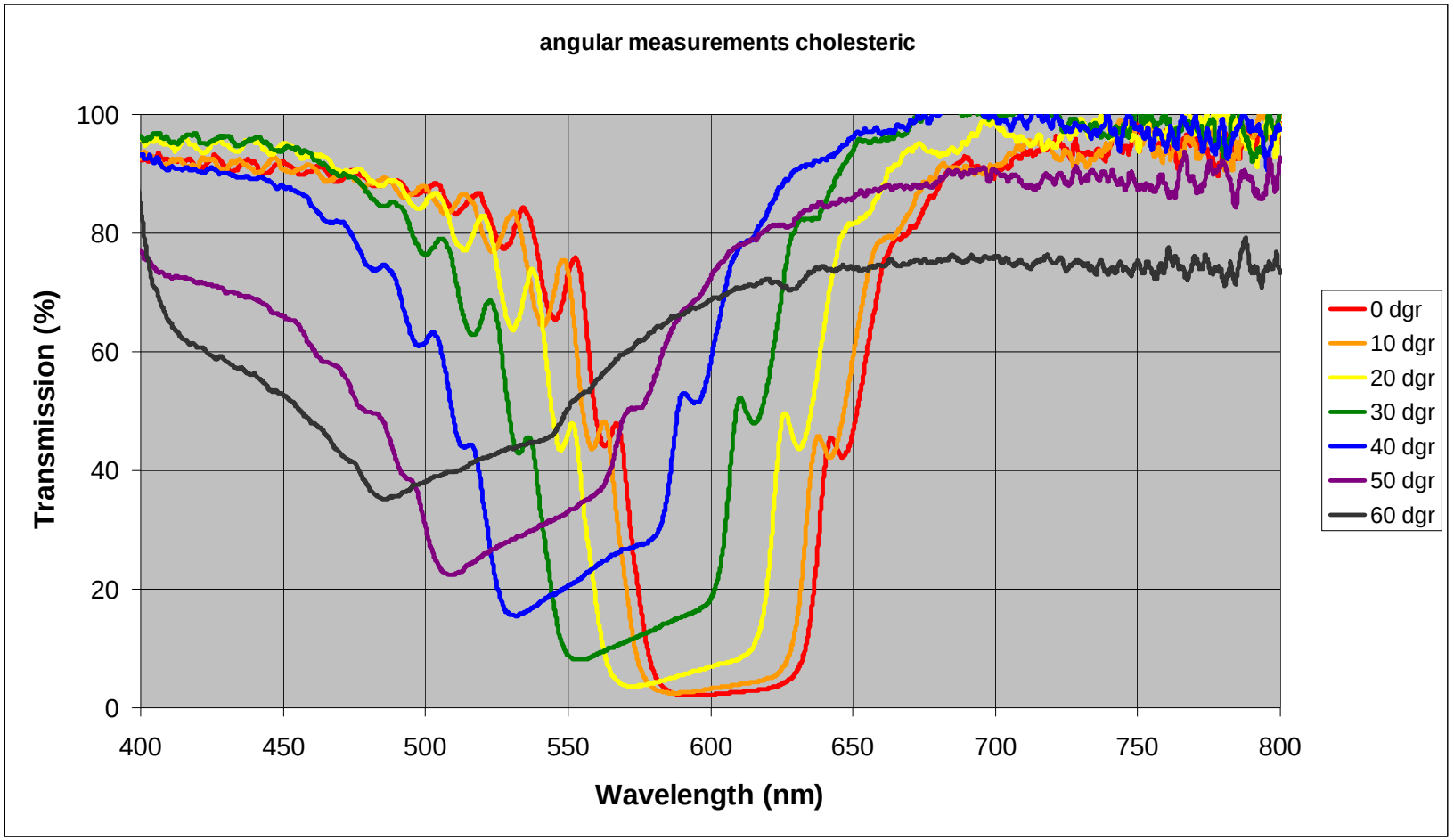
What the cholesteric does for us



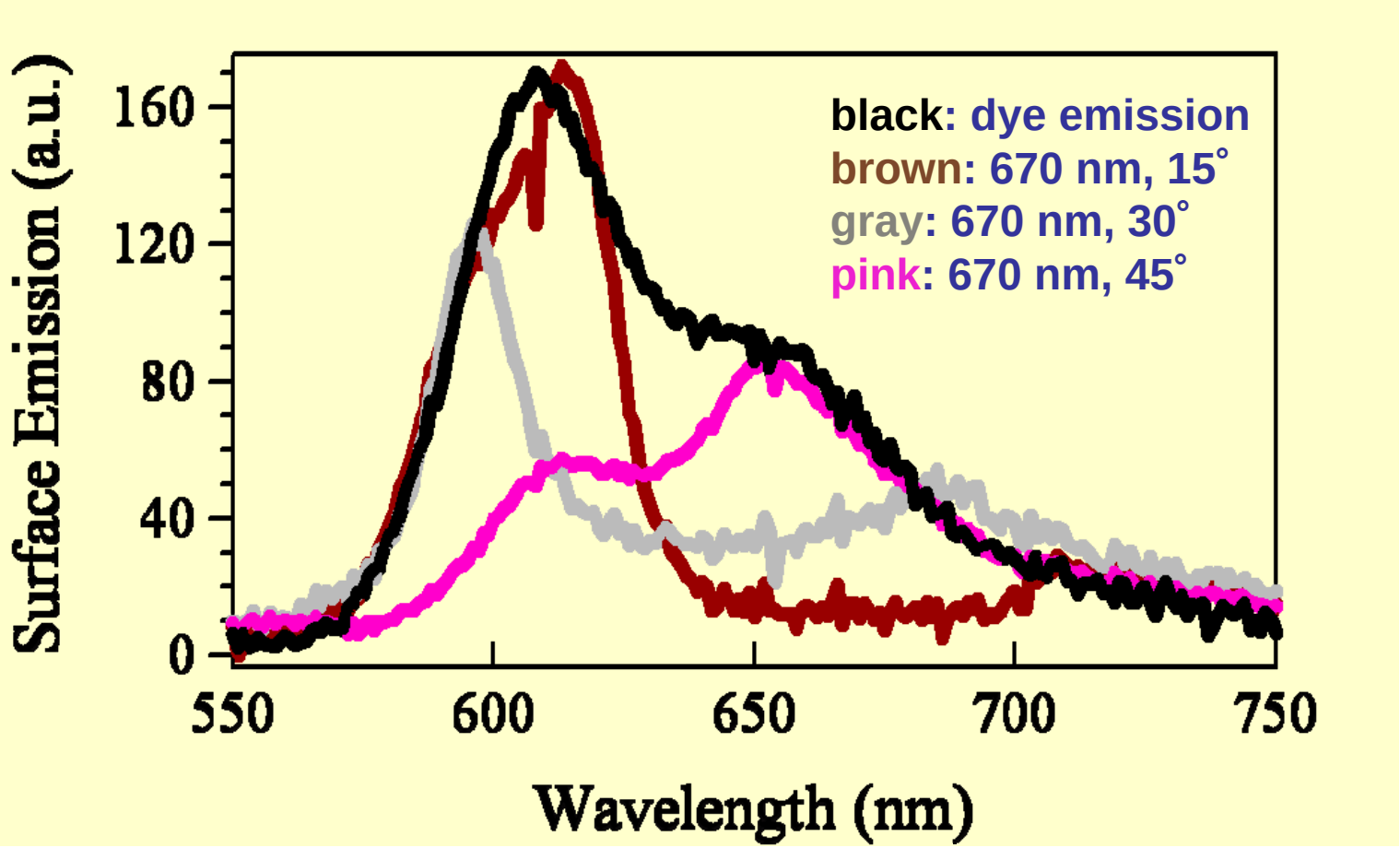
* A right-handed helix reflects a narrow band (~75 nm) of right-circularly polarized light of a specific wavelength.
* The reflected wavelength depends on the pitch of the helix
* Left-circularly polarized light will pass through this cholesteric layer with no deviation.

Ease of large-area, solution processing makes them appropriate for large-scale manufacture

Angular impact of the cholesterics

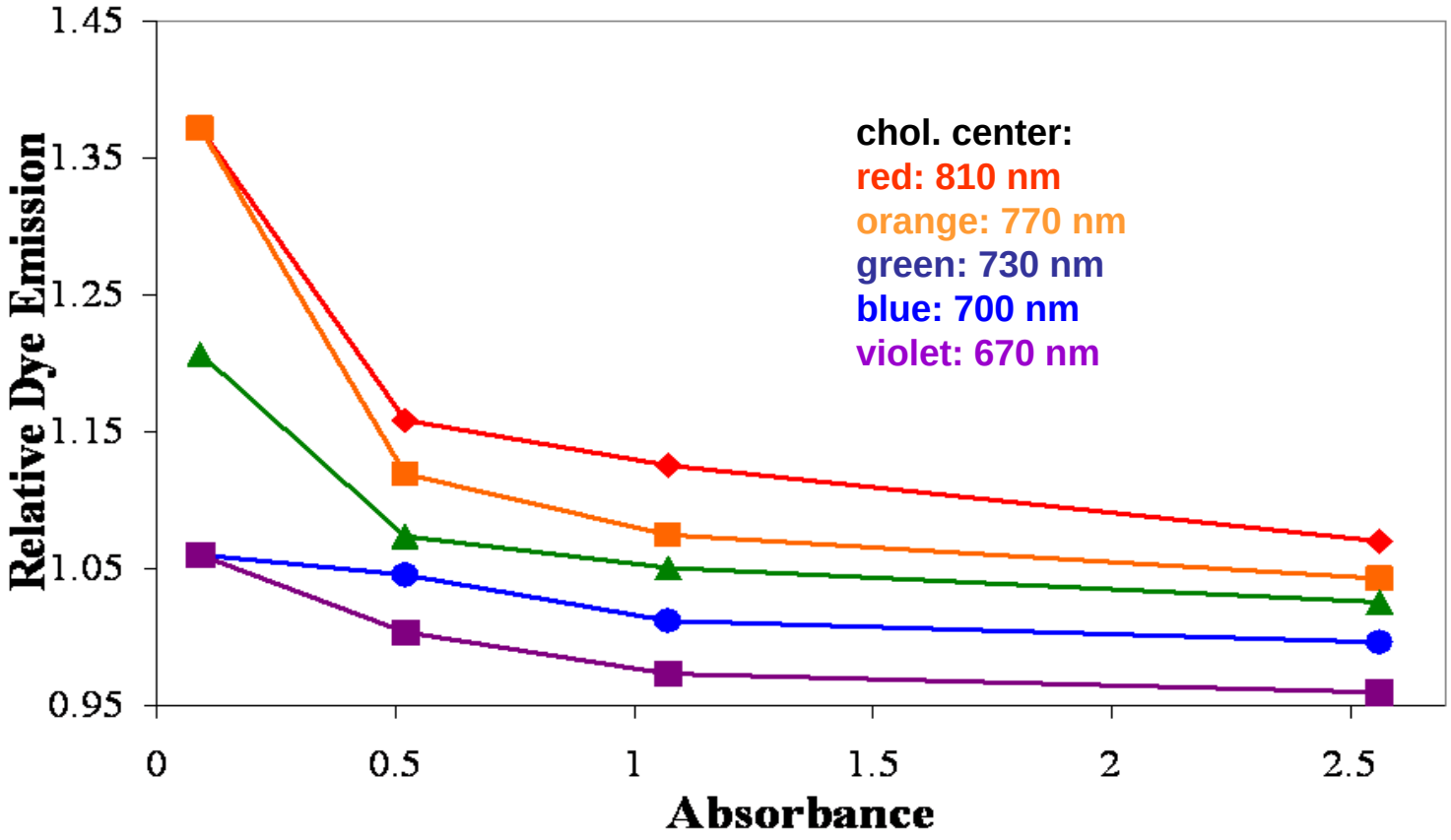


Surface loss spectra after cholesteric application



Can reduce surface energy losses by up to 40%

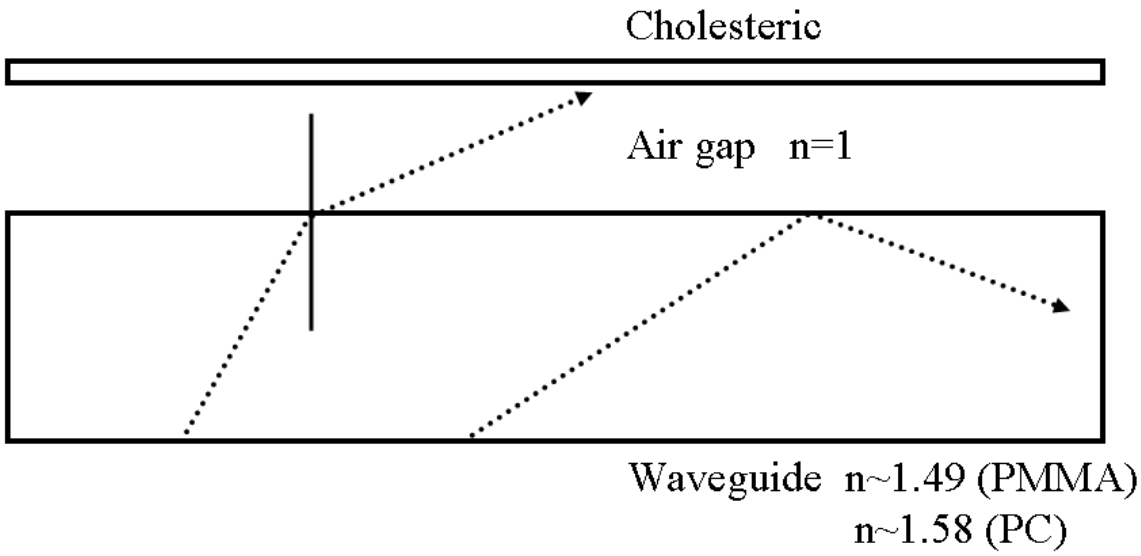
Effect on edge emission



Surface recycling to edge emission efficiency in 0.5 Abs (70% absorption) sample ~ **35%**

Why such long wavelengths for the reflection band?

Hypothesis



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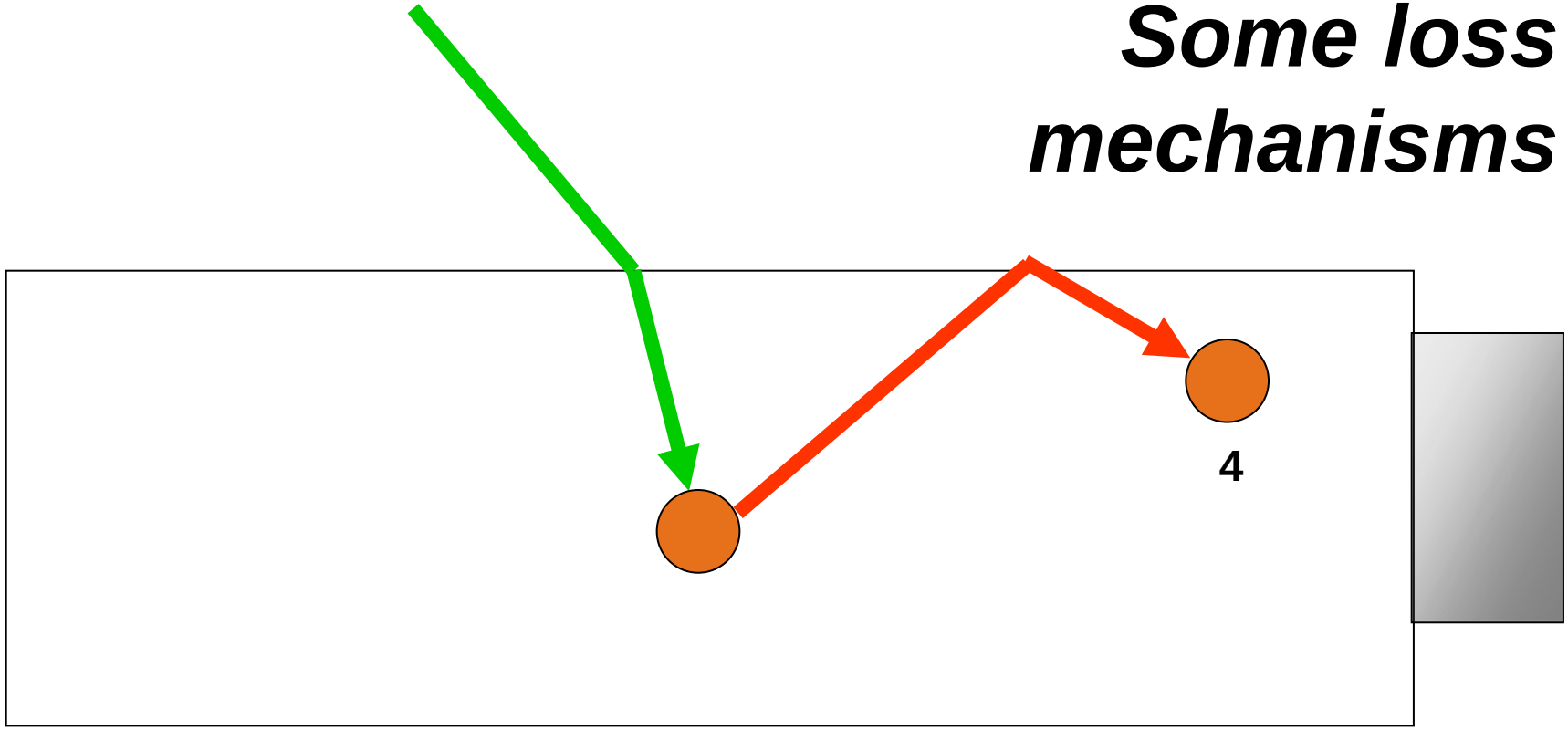

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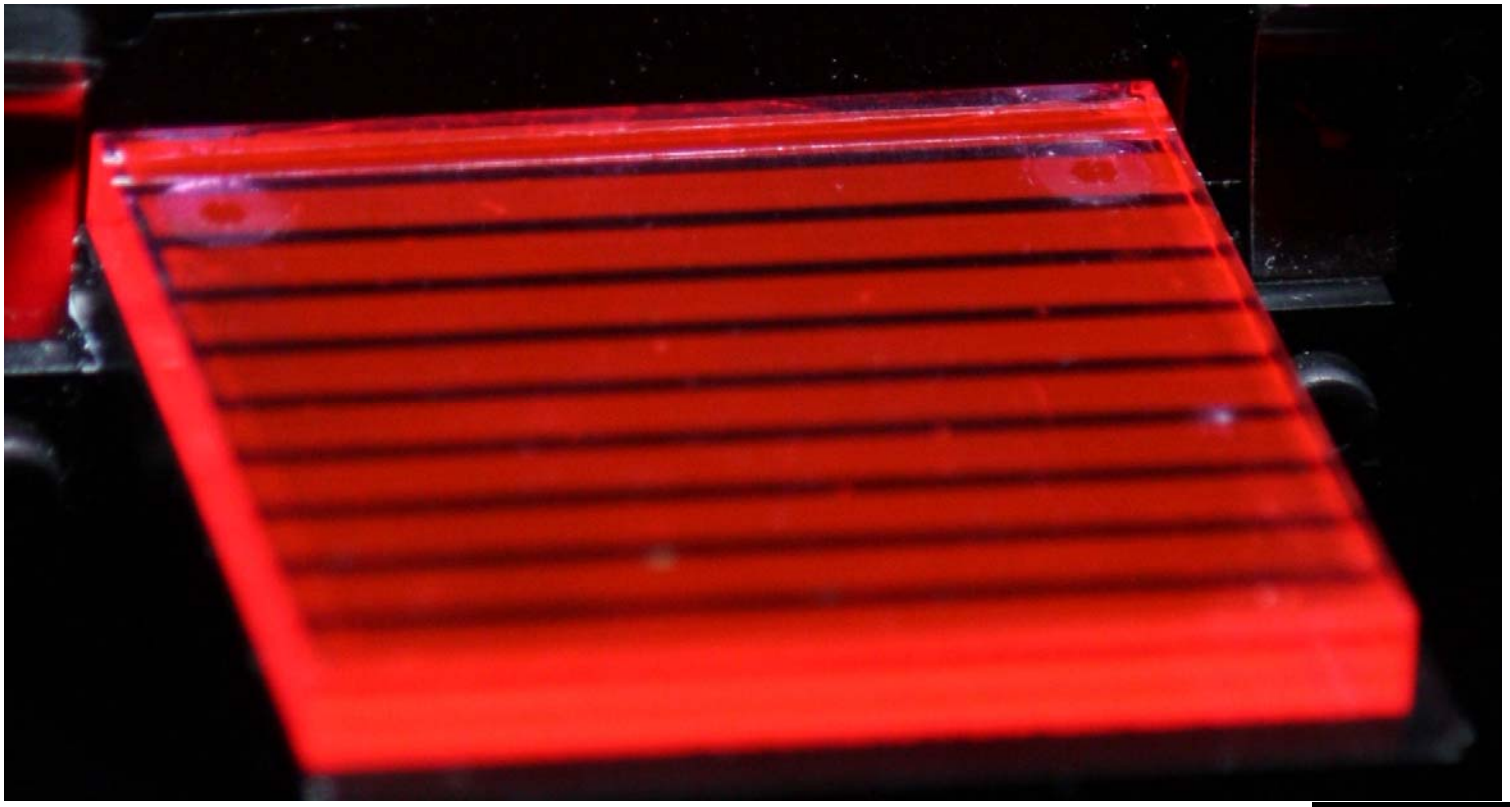
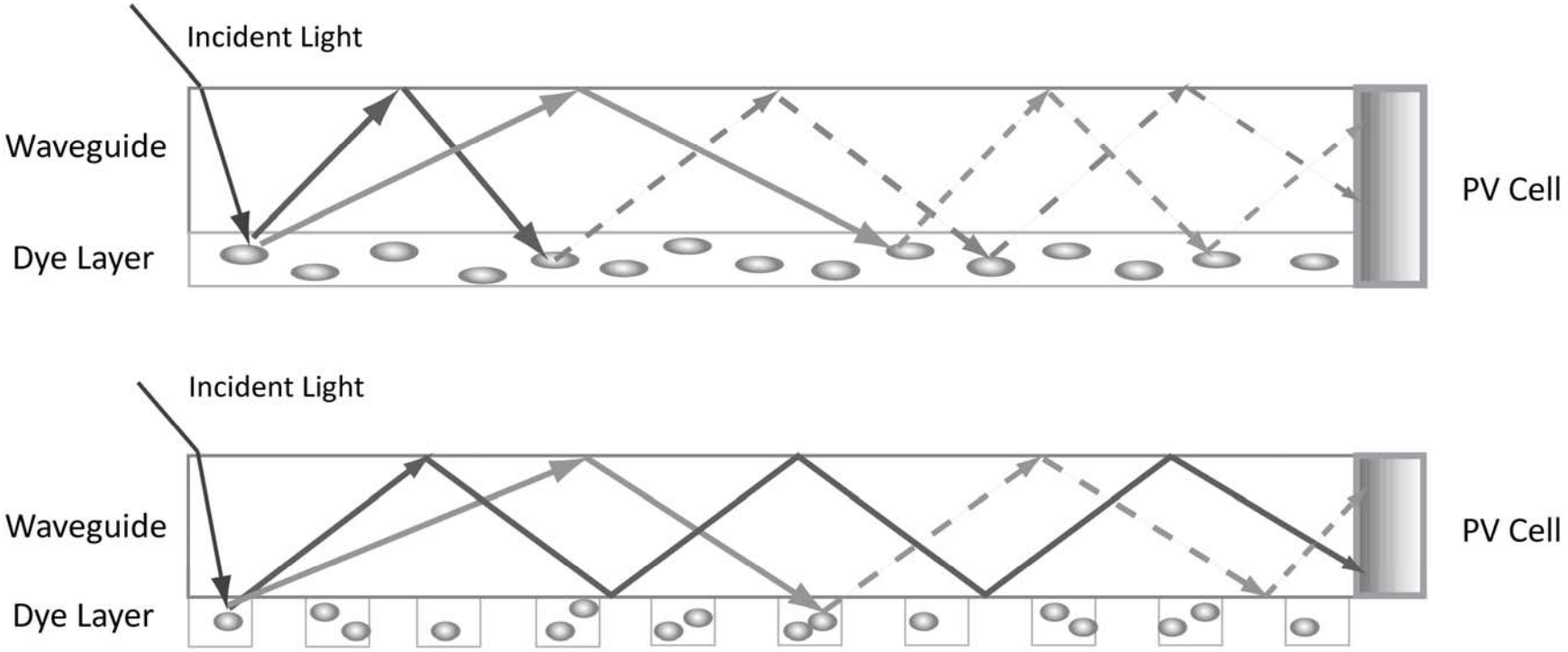
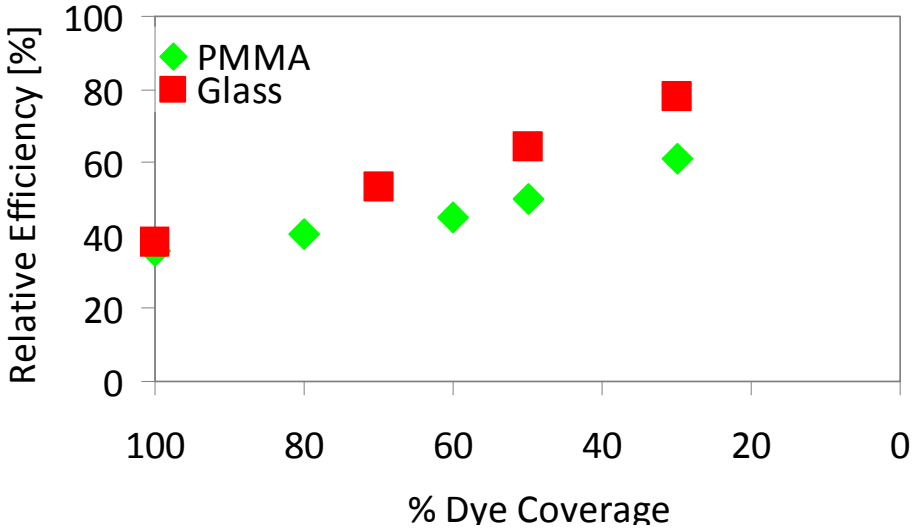
Reducing re-absorption events: Patterned dye layers



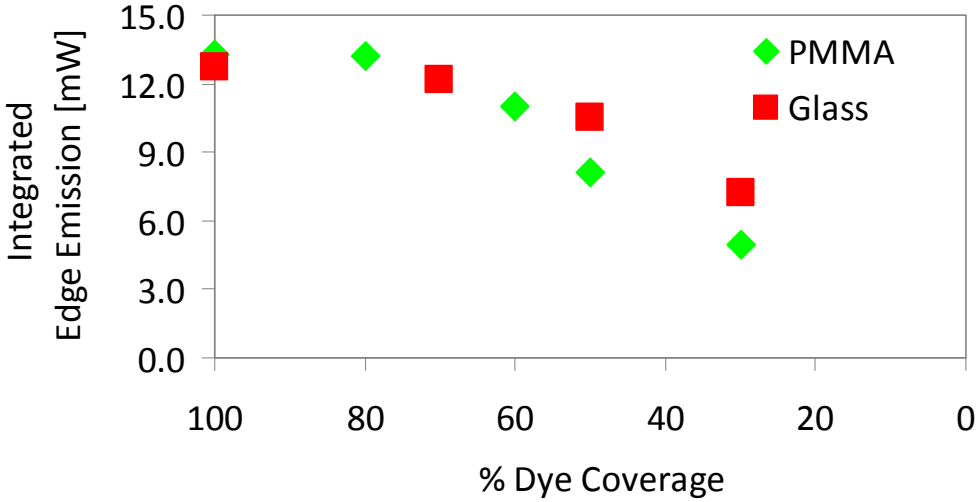
Patterned dye



Effect of the patterned layer



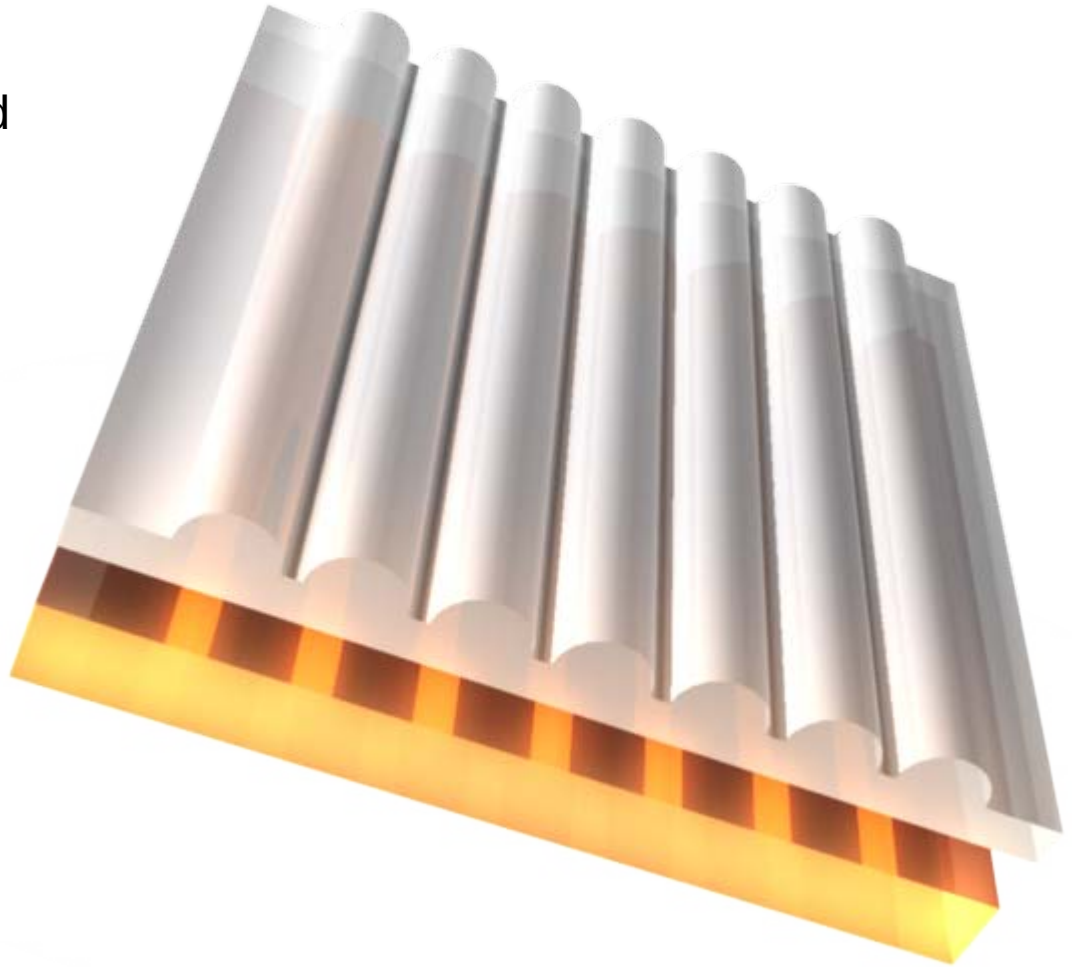
The efficiency (light emitted from four edges/ light absorbed by waveguide) doubles by reducing dye coverage from 100% to 30% (K160 dye from Risk Reactor)



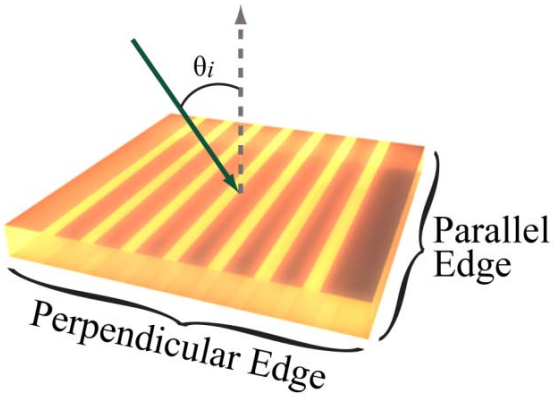
However, total emission decreases due to reduced absorption.

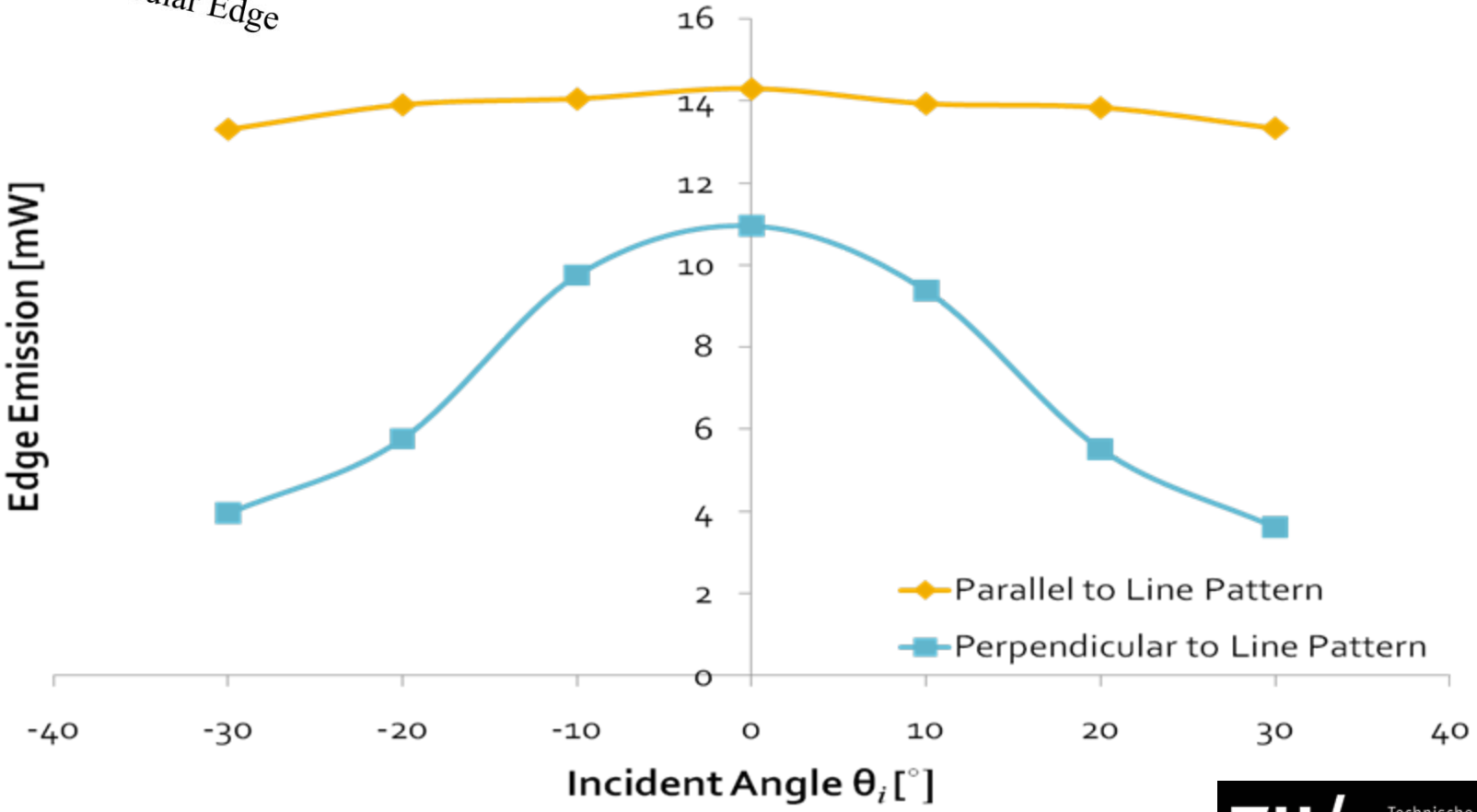
Enhancing absorption

To increase absorption, we add lenses to focus light on the dye ‘islands’.

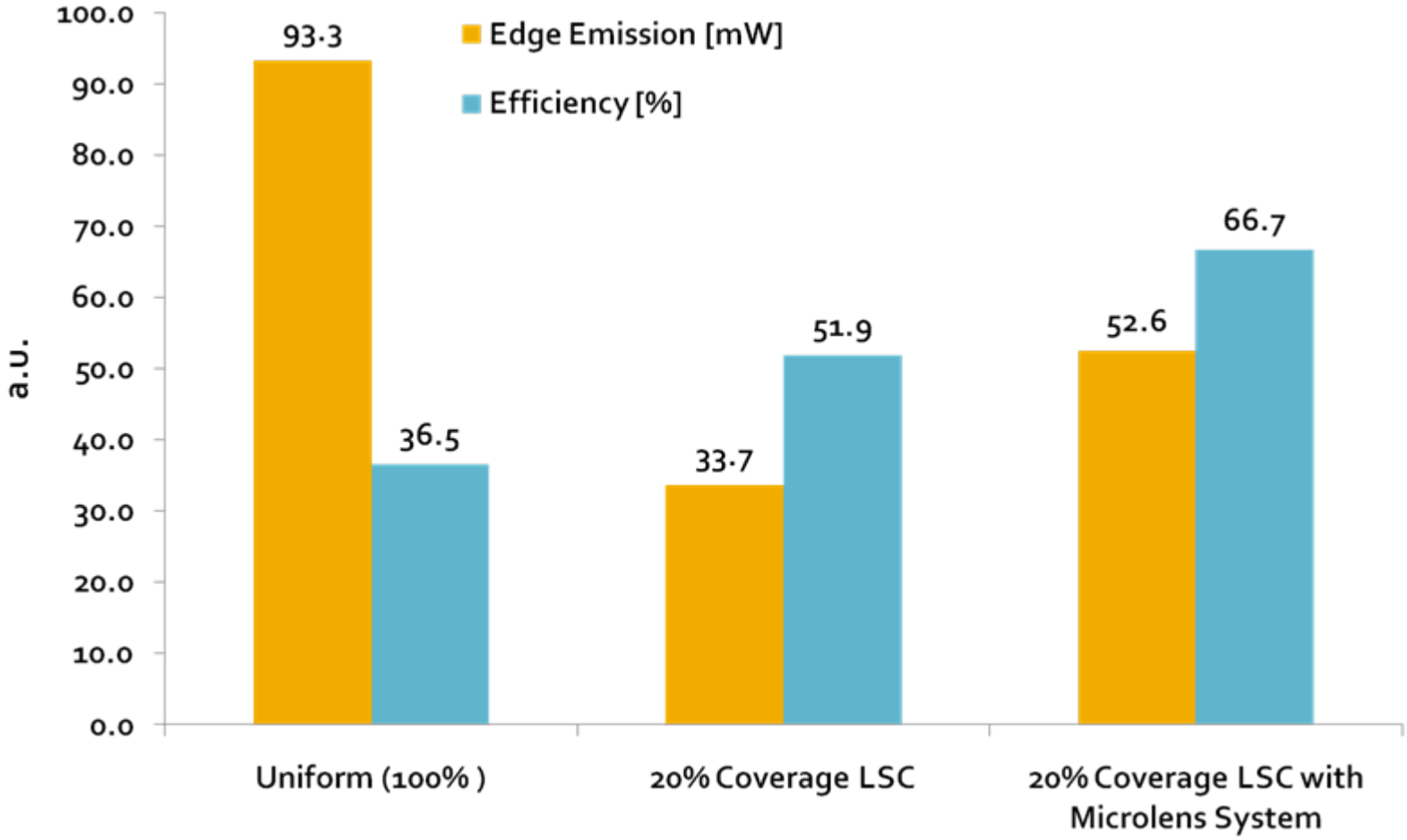


Absolute outputs



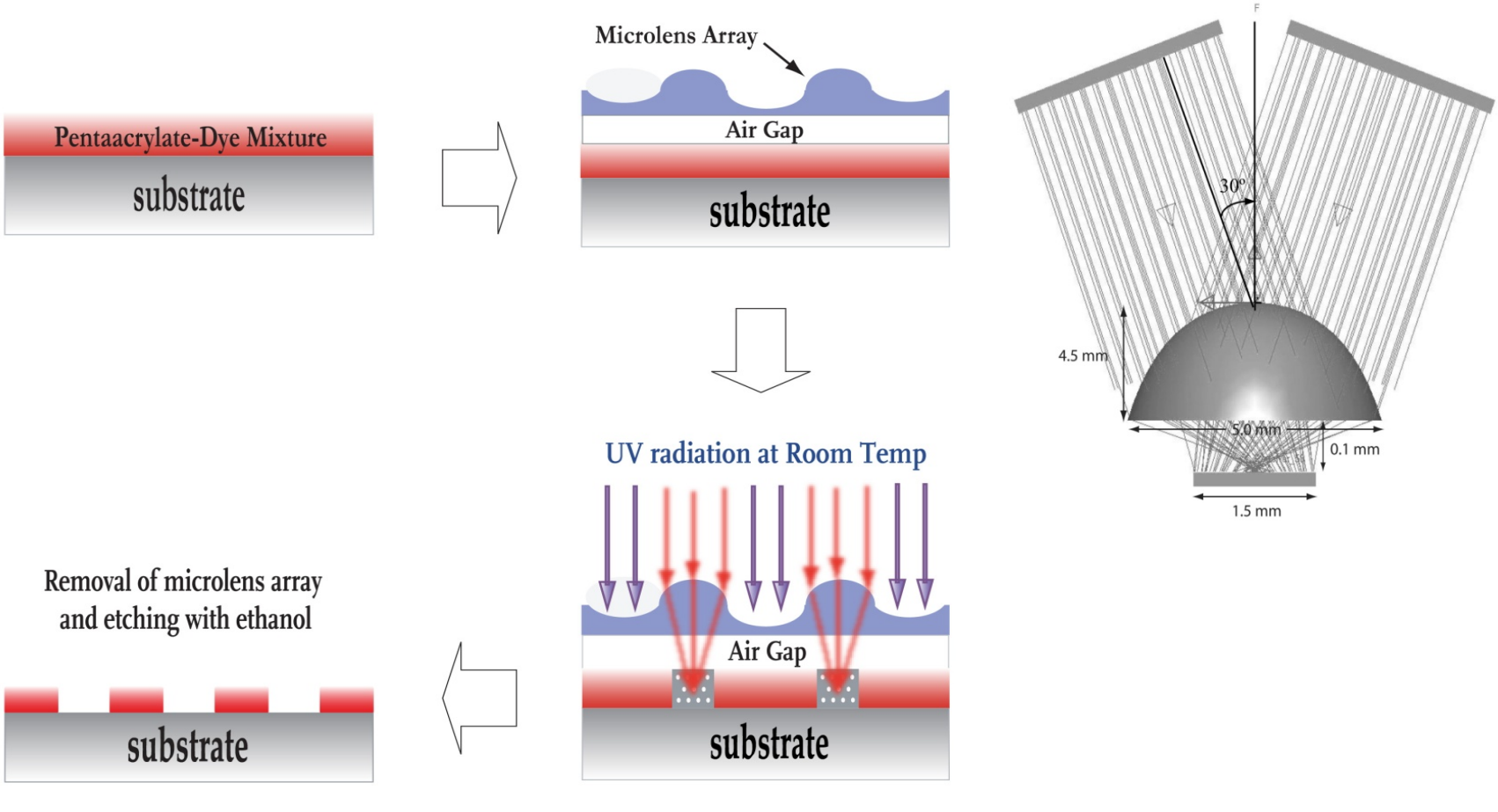


A ways to go…



Data for Red305 lines

Producing the dye ‘islands’



Summary

- We are trying to mitigate the dye performance limitations by reducing surface losses, directing emission, reducing reabsorptions and broadening absorption range of our LSCs

Acknowledgements

- Paul Verbunt
- Shufen Tsoi
- Cees Bastiaansen

- STW Vidi 07940 and SenterNovem for funding