DF optimization for FD2-XA

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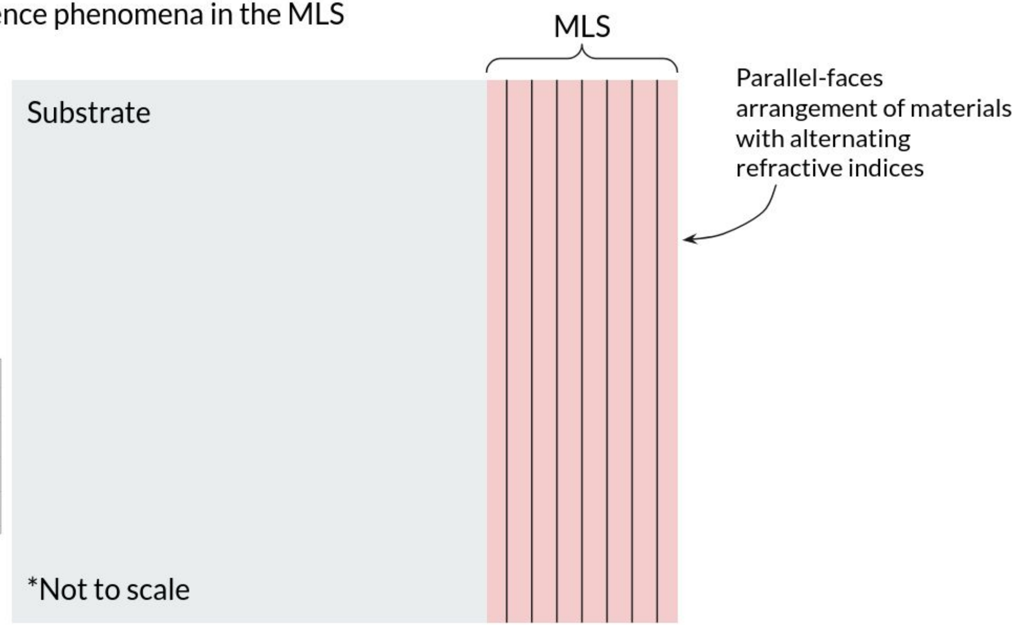
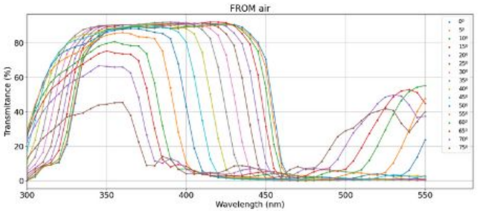
Photon Collectors WG - 25 July 2023

From 2023/02/07 talk on Photon Collectors WG

DF conceptual model

The TC emerges from the interference phenomena in the MLS





Different AOI’s result in different TCs (we already knew this), but different SM also result in different TCs

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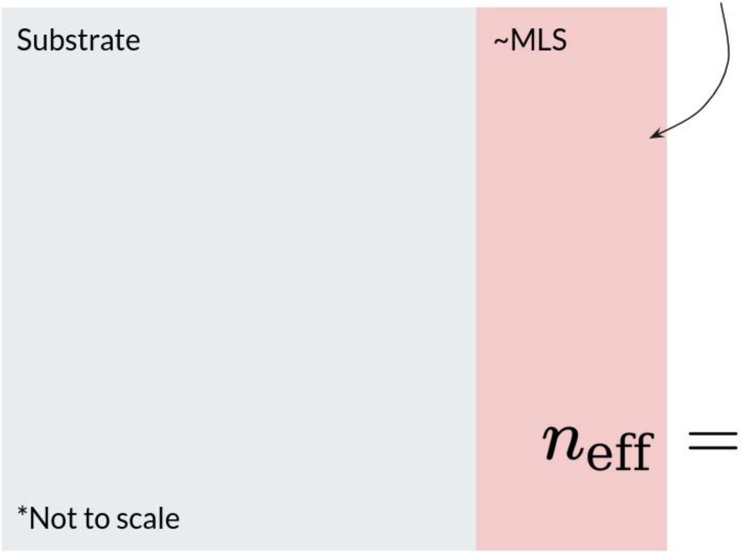
DF conceptual model

→ Substitute the MLS by an homogeneous volume with an effective refractive index



$$n_{\mathrm{eff}} = \frac{\sum_i d_i}{\sum_i \frac{d_i}{n_i}}$$

Within this model, to explain the dependence of TCs with the surrounding media, our current hypothesis is that **what determines the TC is the angle of refraction (AOR) within the ~MLS.**

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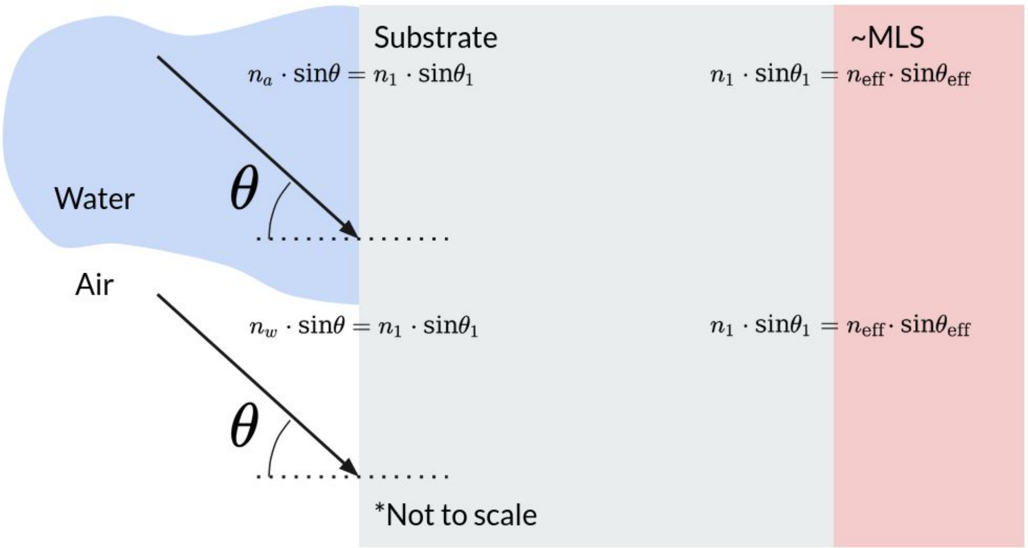
DF conceptual model



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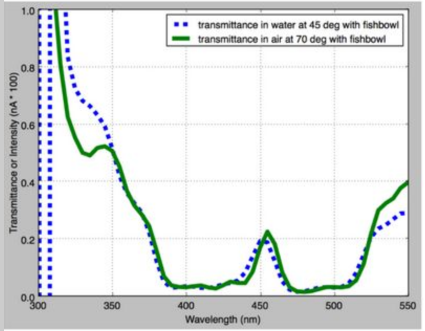
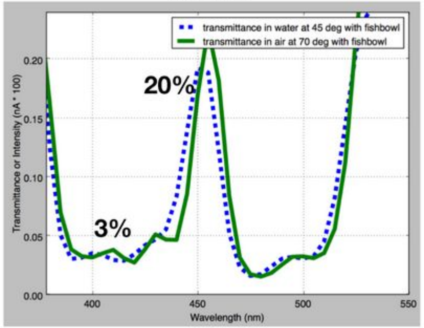
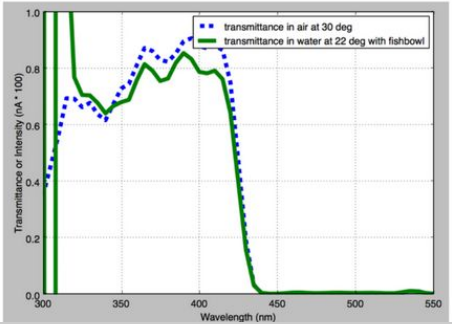
Model backups

There are **experimental** measurements and Transfer-matrix-method simulations backing up this hypothesis:

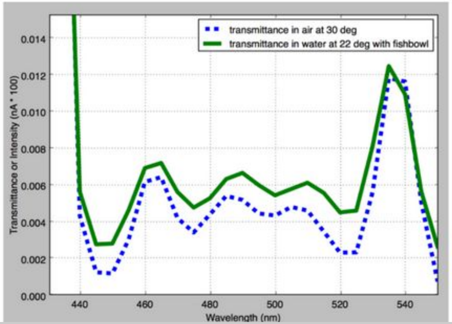


ZOOM





ZOOM



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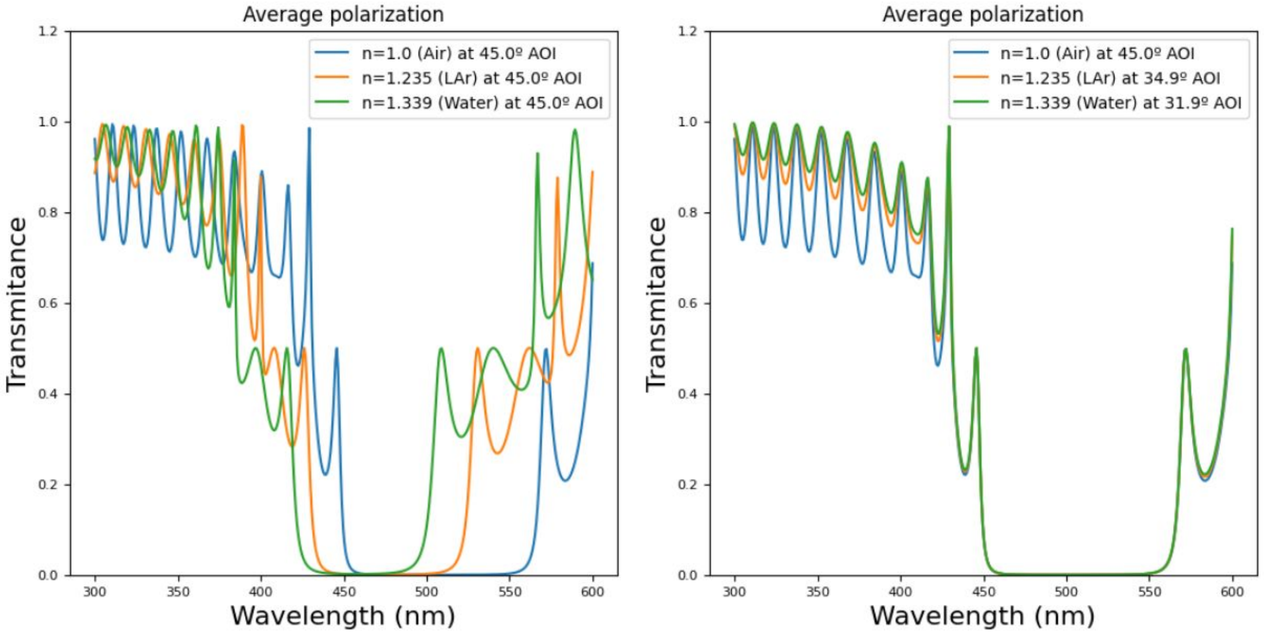
Model backups

There are experimental measurements and Transfer-matrix-method **simulations** backing up this hypothesis:



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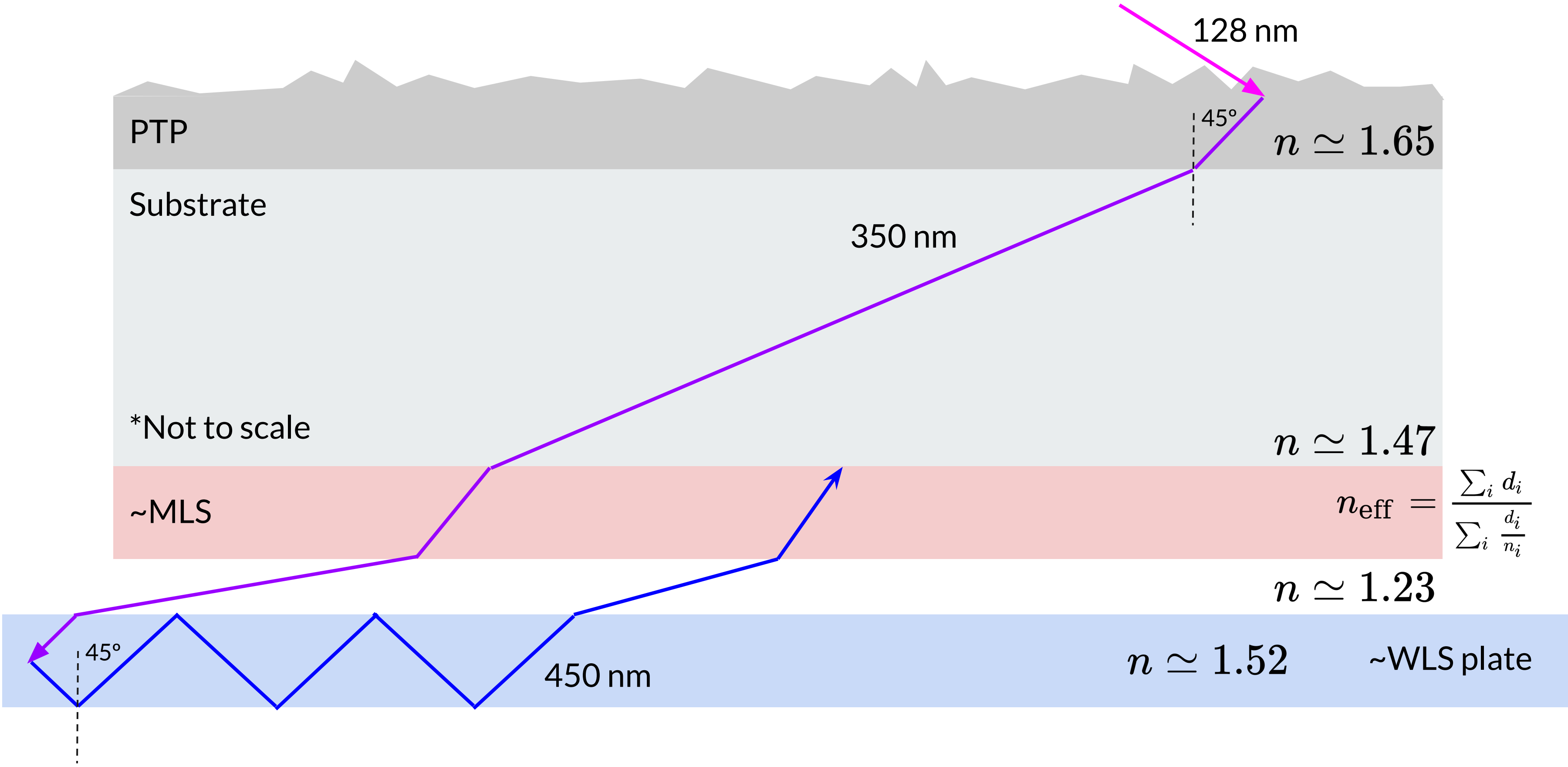
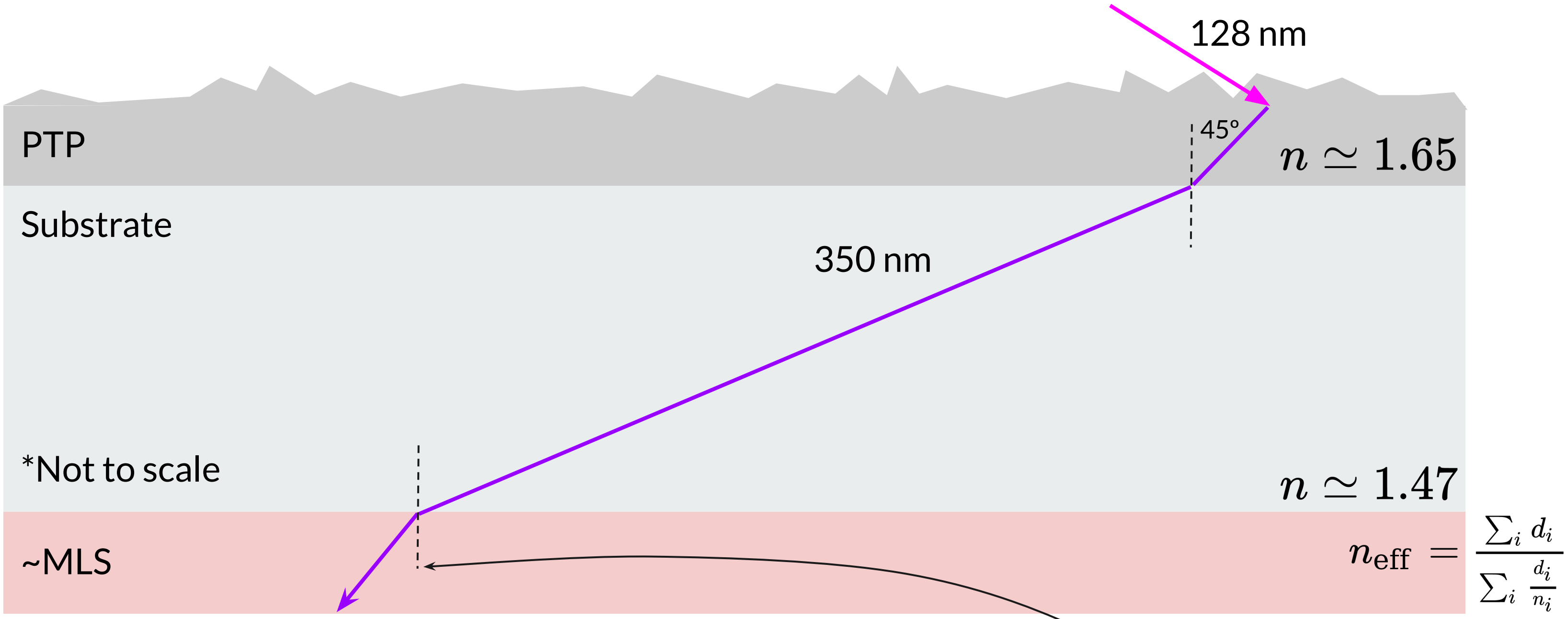
Approximate argument



Assuming $n_{\text{eff}} \simeq 1.68$

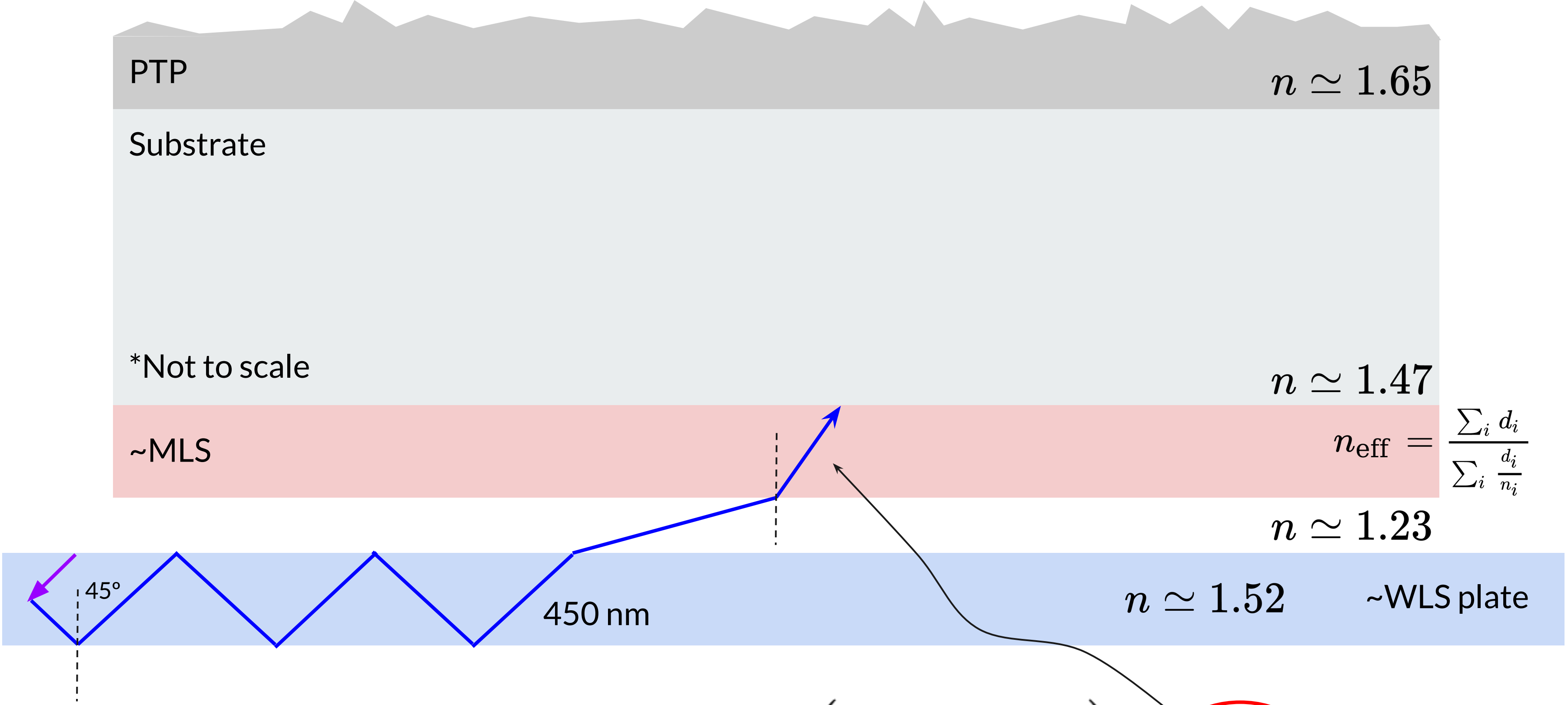
Approximate argument



$$\theta_{\text{PTP}} \simeq 45º \Rightarrow \theta_{\text{MLS}} \simeq \sin^{-1}\left(\frac{1.65}{1.68}\sin(45º)\right) = 43.99º$$

Assuming $n_{\text{eff}} \simeq 1.68$

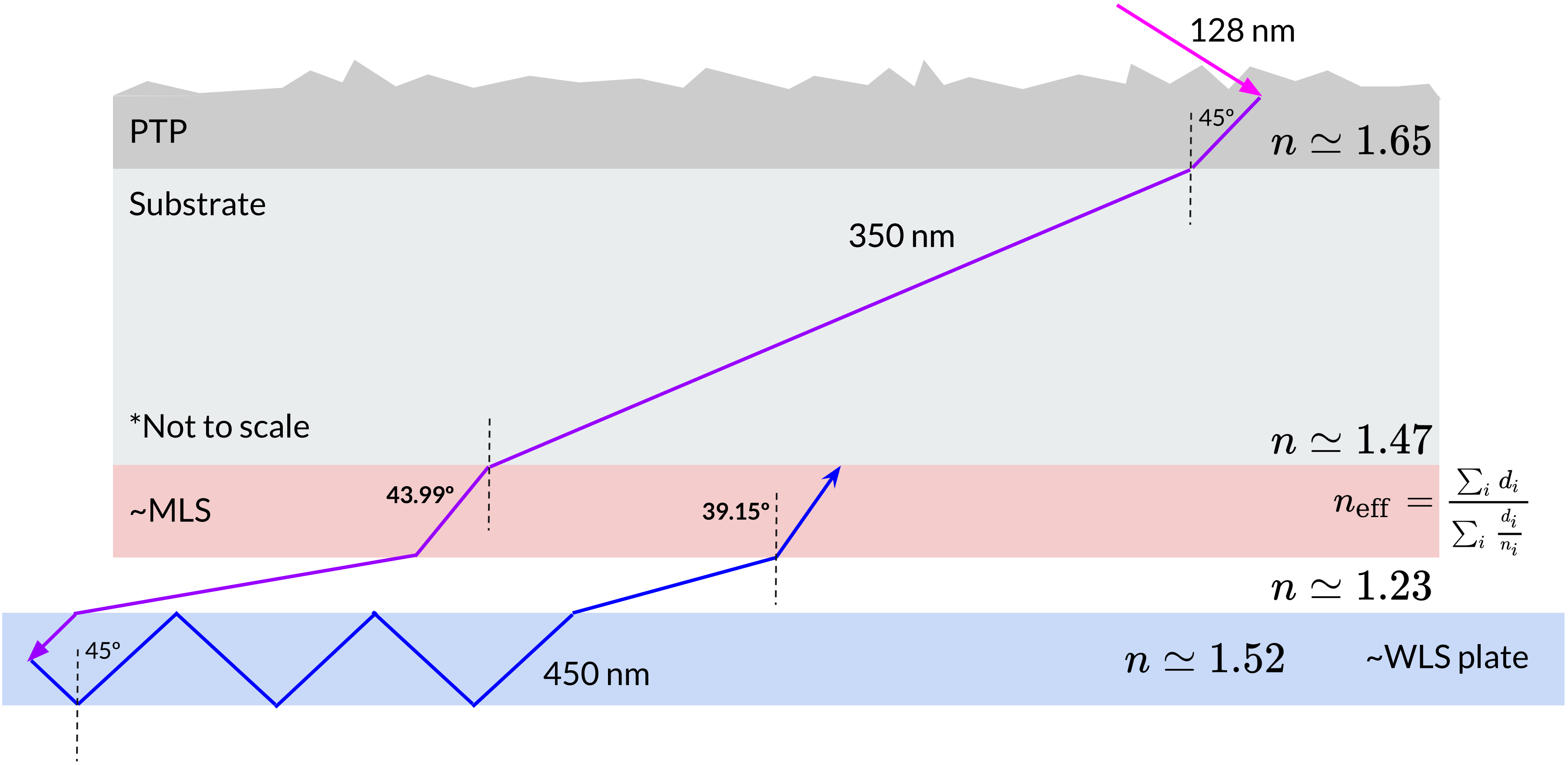
Approximate argument



$$\theta_{\rm G2p} \simeq 45º \Rightarrow \theta_{\rm MLS} \simeq \sin^{-1}\left(\frac{1.50}{1.68}\sin(45º)\right) = 39.15$$

Assuming $n_{\rm eff} \simeq 1.68$

Approximate argument



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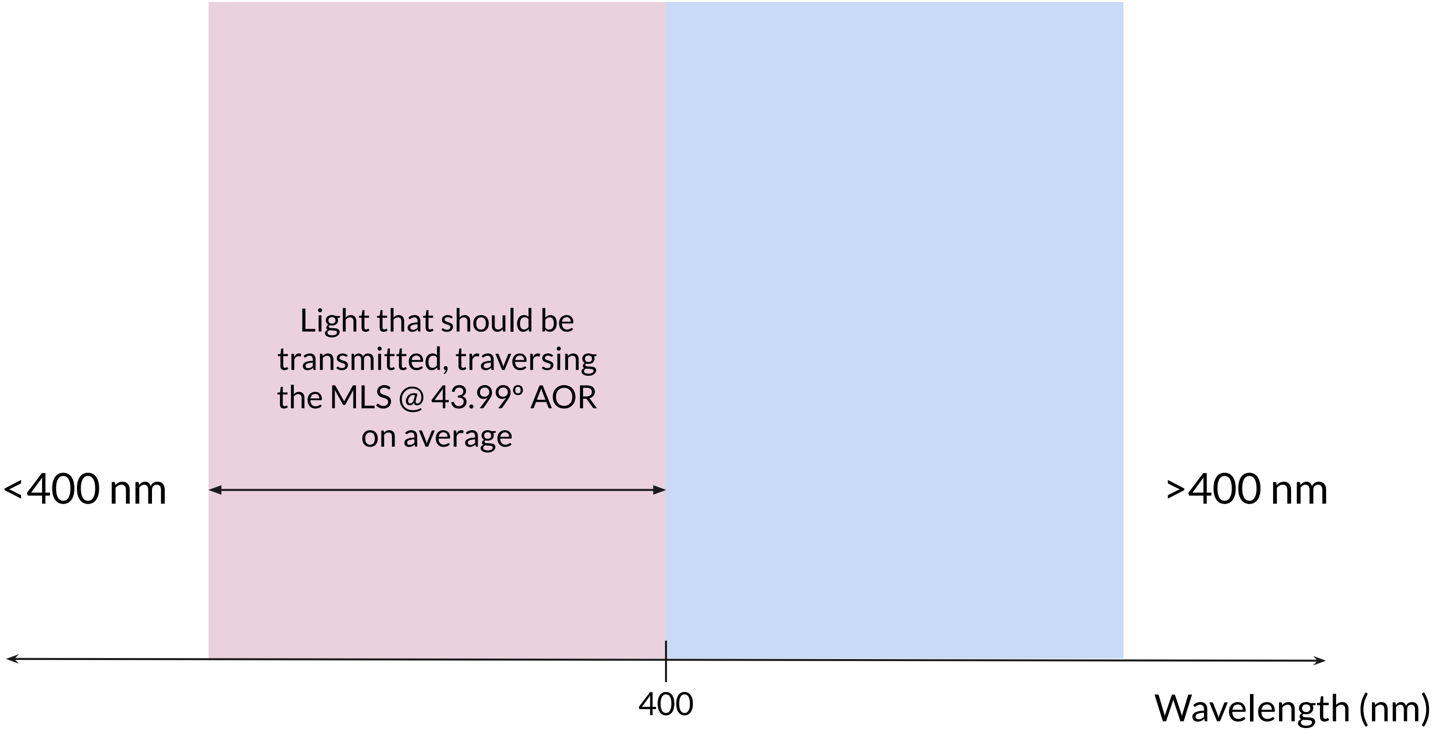
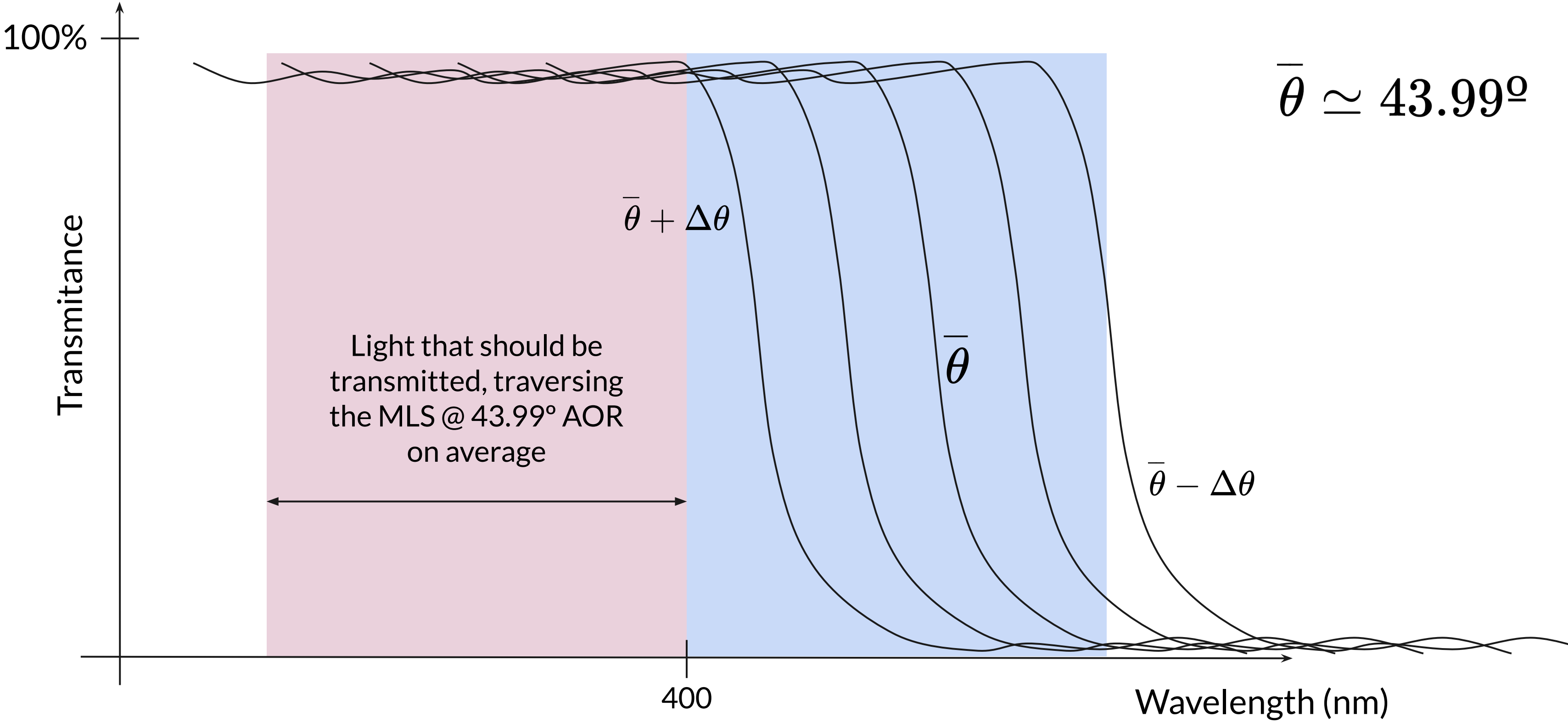


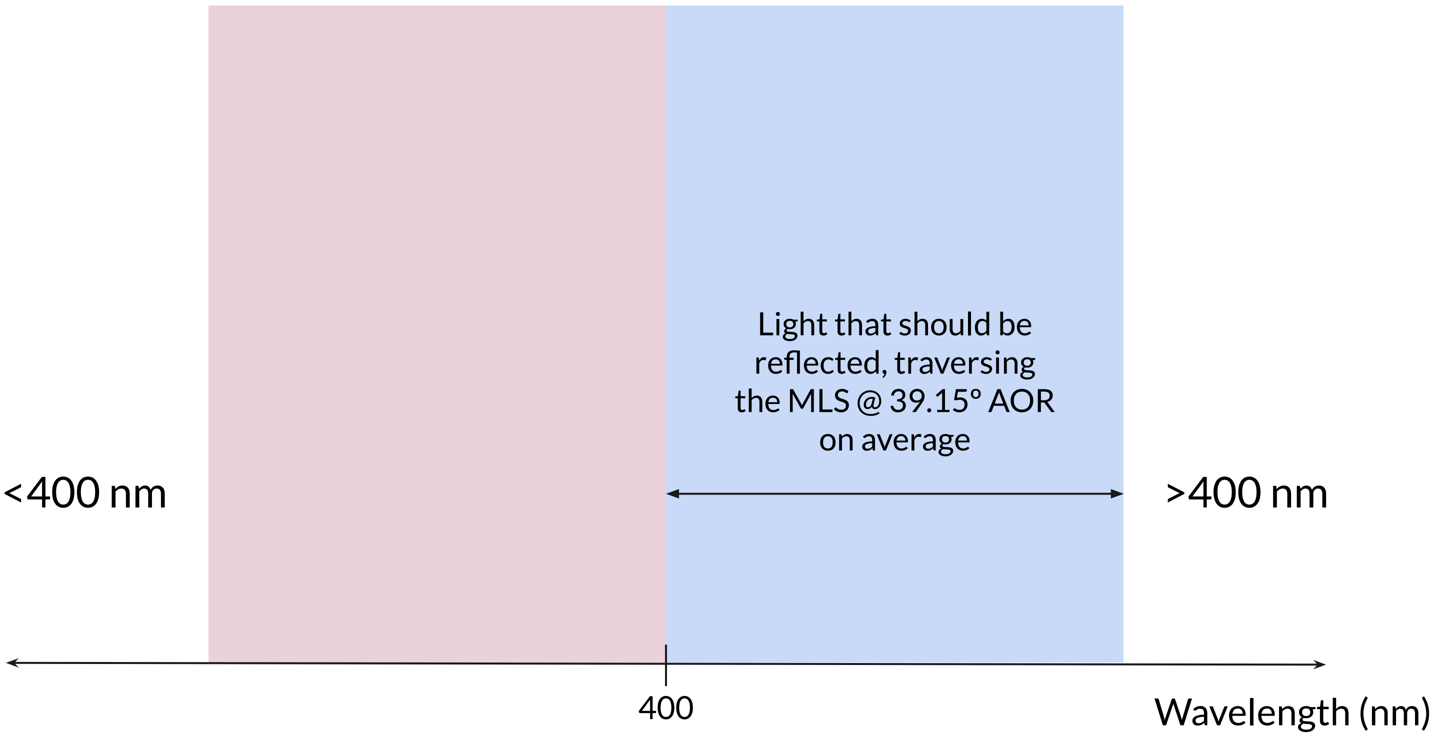
Approximate argument



$$\overline{\theta} \simeq 43.99º$$

The angle distribution of this light within the MLS will have some spread $\Delta\theta$ around the mean angle $\overline{\theta}$.
Ideally, all of the transmission curves within that angle spread should be **transparent** to the **PTP light**.

Approximate argument



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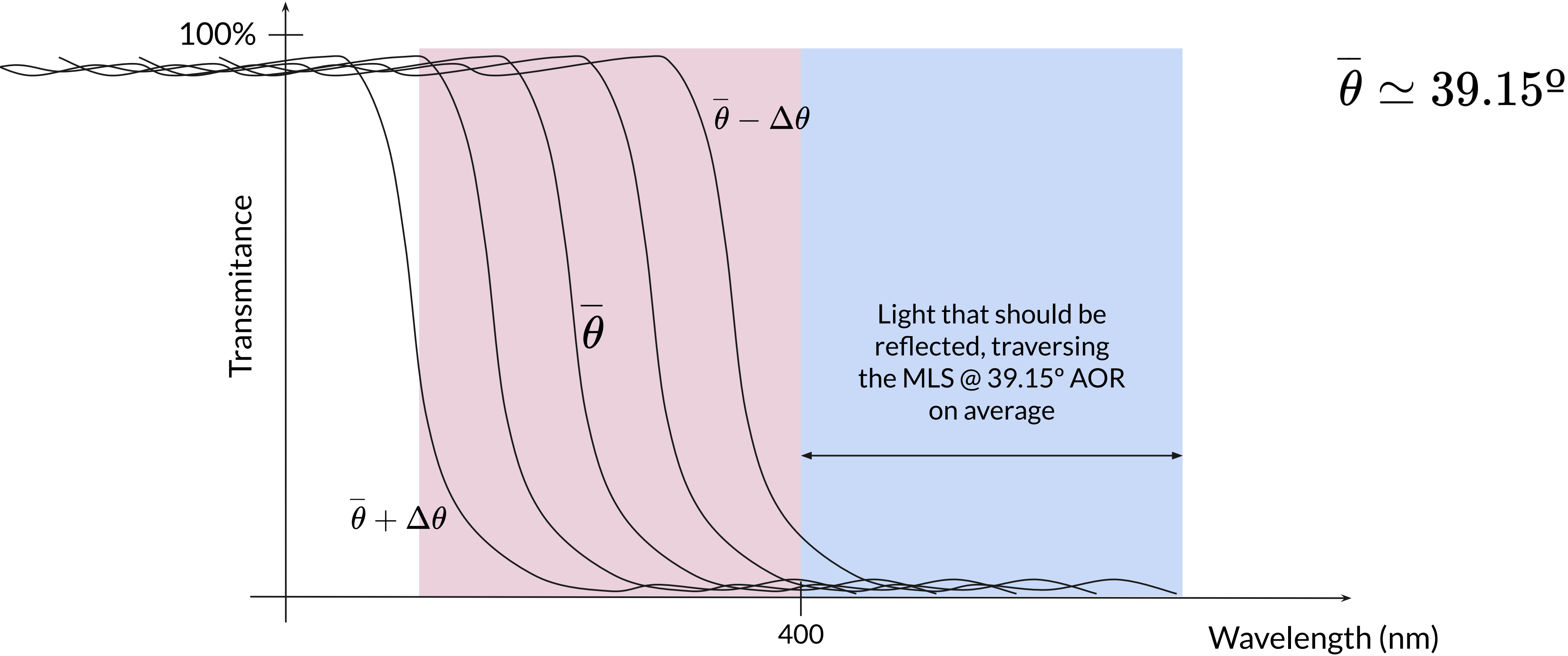
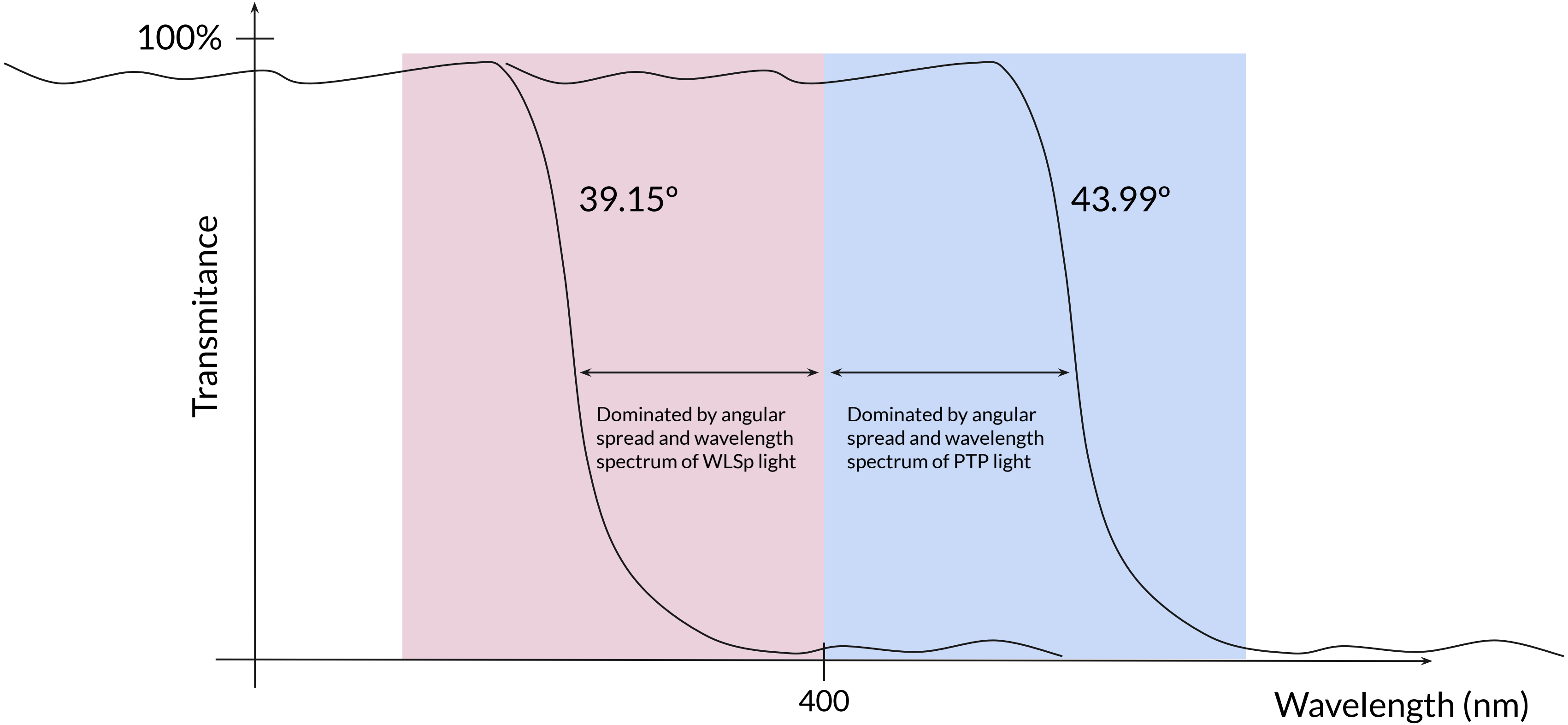
Approximate argument



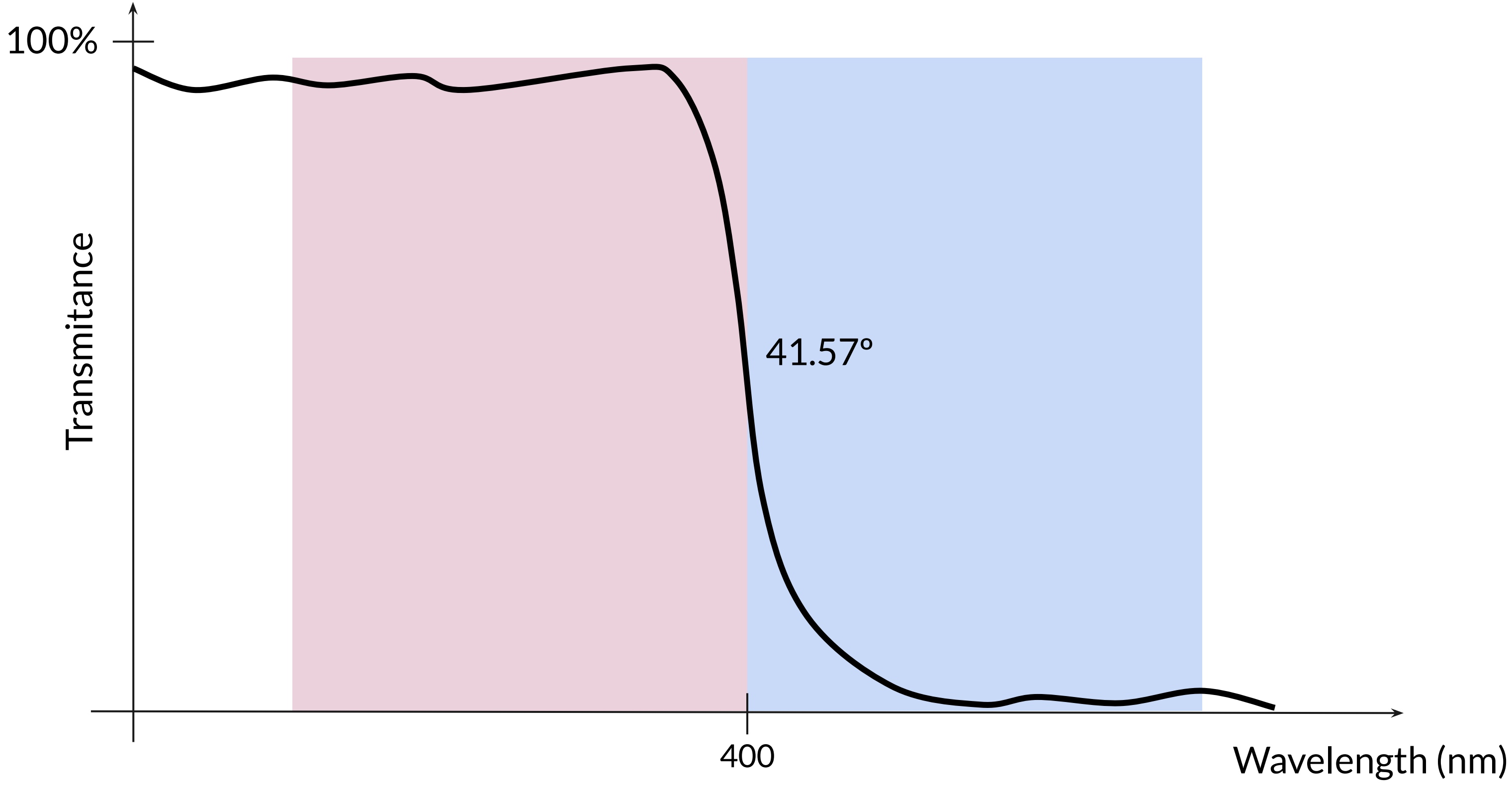
The angle distribution of this light within the MLS will have some spread $\Delta\theta$ around the mean angle $\overline{\theta}$.
Ideally, all of the transmission curves within that angle spread should be **reflective** to the **WLSp light**.

Approximate argument



A first approximation taking into account both types of light should give an optimal cutoff at 400 nm at (39.15+43.99)/2 º AOR in the MLS.

Approximate argument



A first approximation taking into account both types of light should give an optimal cutoff at 400 nm at (39.15+43.99)/2 º AOR in the MLS.

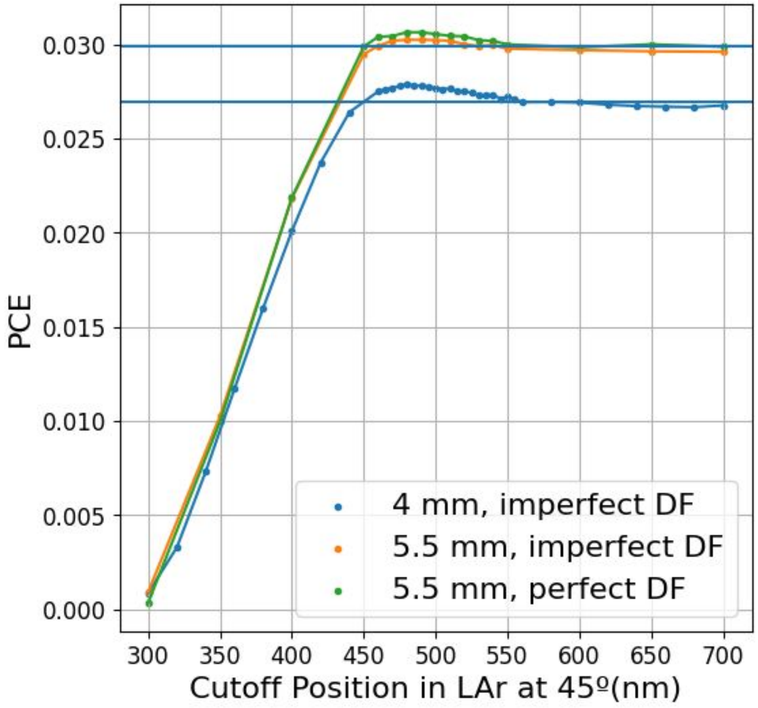
Approximate argument

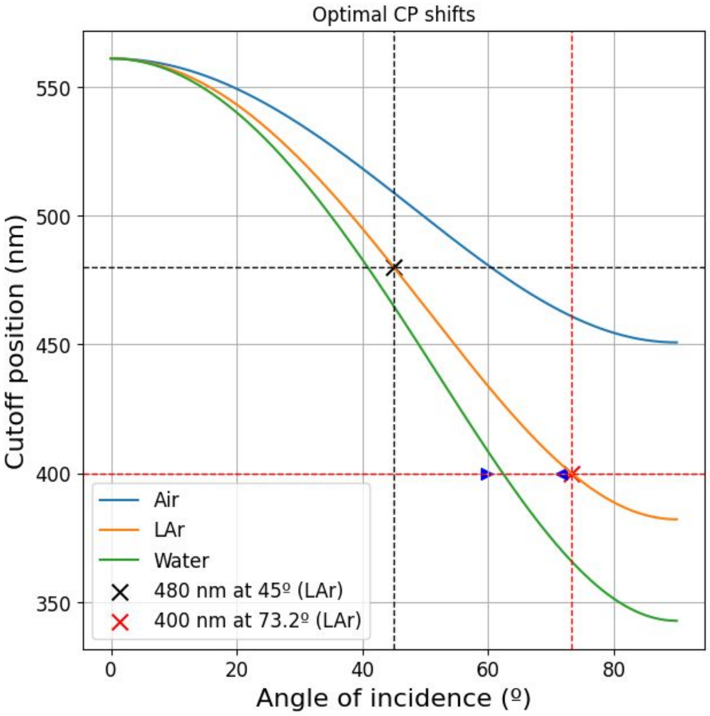
I.e. what we are stating is that, optimally (approximately) the transmission curve (TC) that has a cutoff at 400 nm should be 'seen by' the photons that traverse the MLS with 41.57° AOR.

$$\theta_{\mathrm{MLS}} = 41.57^{\circ} \Rightarrow \theta_{\mathrm{LAr}} \simeq \arcsin\left(\frac{1.68}{1.23}\sin(41.57^{\circ})\right) \simeq 65^{\circ}$$

Equivalently, the TC which has a cutoff at 400 nm should be 'seen by' photons that impinge on the DF with 65° AOI from LAr

Simulation results





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Conclusions

- The root issue:

  If we optimize filters for 45º in LAr, **we are overlooking the fact that light is emitted at 45º (average) in high-rindex media**, such as PTP (1.65) and G2p WLSp (1.502). Photons will typically have >>45º AOI in LAr

- If this is taken into account, filters should be optimized for very high AOI

- However, typically we have observed that higher AOI not only implies an angle shift, but also way worse transmission/reflection specifications.

- This specs. worsening is not captured by the angle shifts introduced in the simulation. Therefore the PCE 'overshoot' over the PCE baseline may not be achievable in practice.