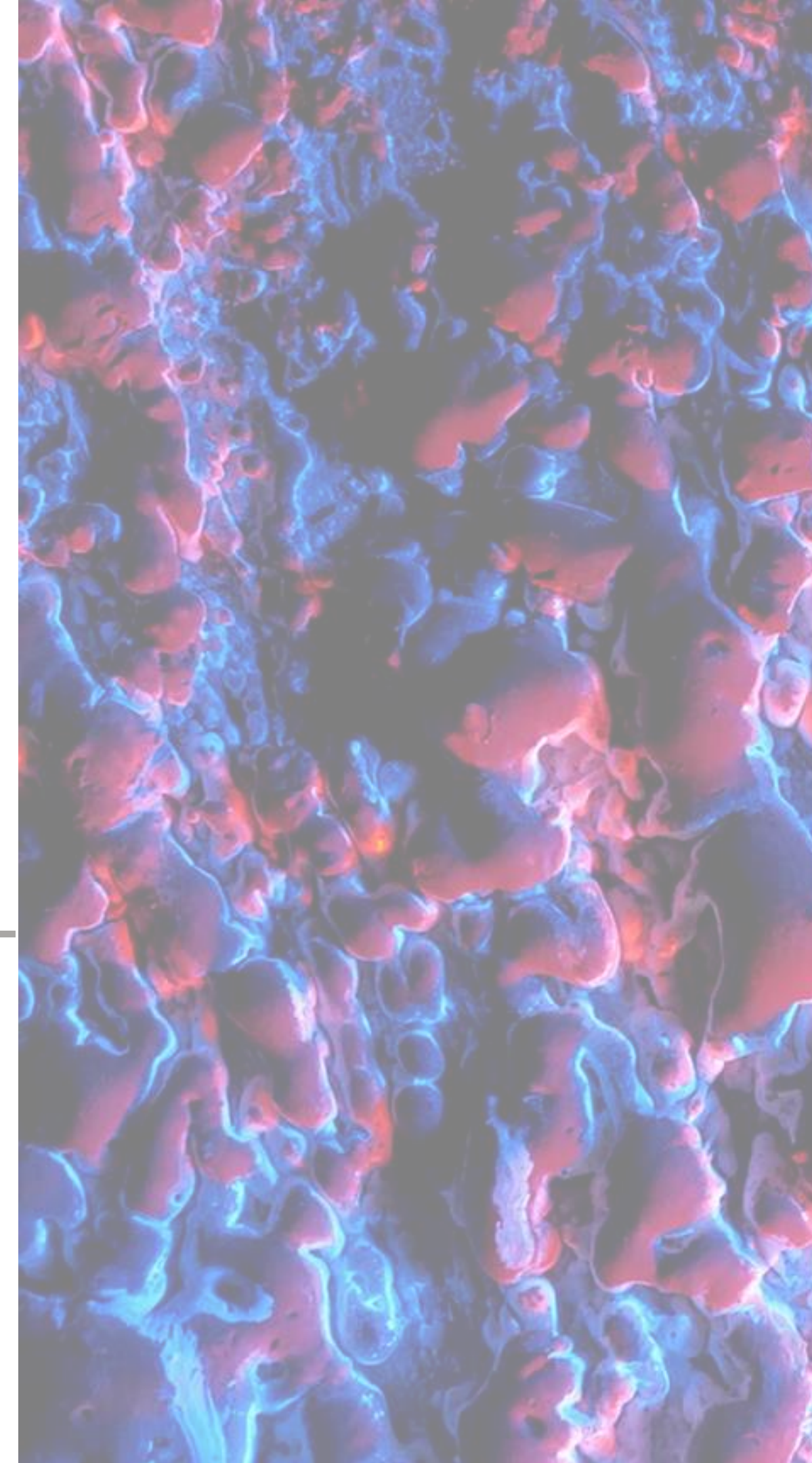




Dielectric UV filters for protection of fire-resistant glass based on intumescent layers

R. M. L. Silva, H. Hashim, D. Roy, C. O. Fernandes, K. Oliveira, X. L. Pinheiro, M. A. Esteves, A. Capelo, M. T. Donato, F. A. C. Oliveira, C. Ferreira, I. N. Alves, T. C. Diamantino, M. A. Barreiros, J. Rocha, J. P. Teixeira, P. M. P. Salomé.



Transparent technology



Solar cells

Perovskite
Organic



Electronic billboards

OLEDs



Consumer electronics

Plastic
Organic components

Transparent technology



Solar cells

Perovskite
Organic



**Fire-resistant
glazing**

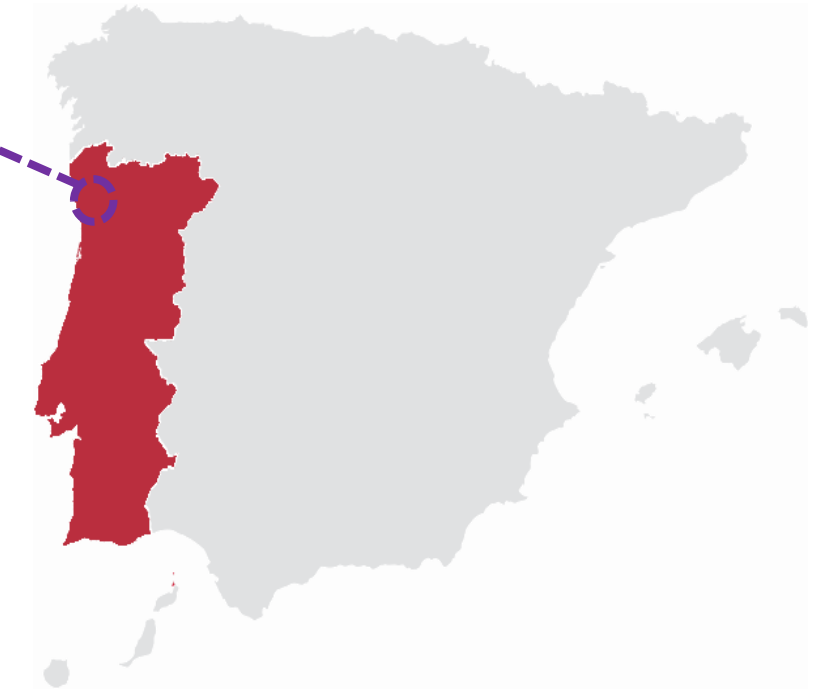
Intumescent material
in laminated glass



Consumer
electronics

Organic components
Plastic

INL – Braga, Portugal





Glass doors

INL counts with fire-resistant glass doors and windows protecting the workers of the laboratories and the 1200 m² cleanroom

Fire-resistant glazing facade

The glazing façade provides a natural illumination and beautiful view from inside and outside the building



Fire SAFETY

**Extended UV exposure,
causing:**

- **Fire protection performance loss**
- **Clarity loss/opacity**
- **Softening**

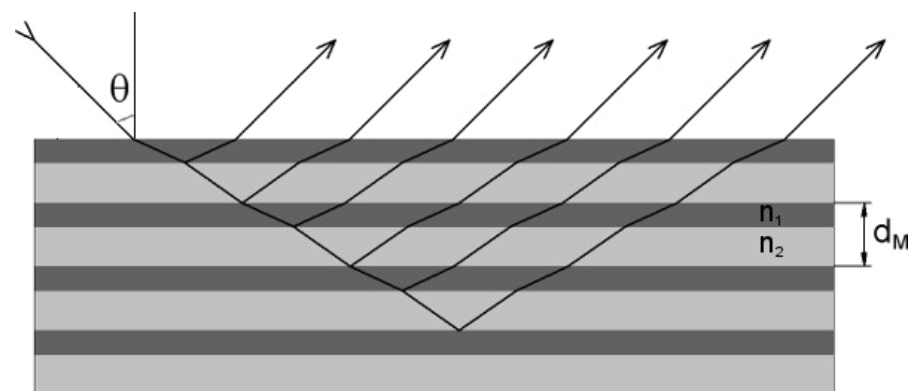


What do we need?

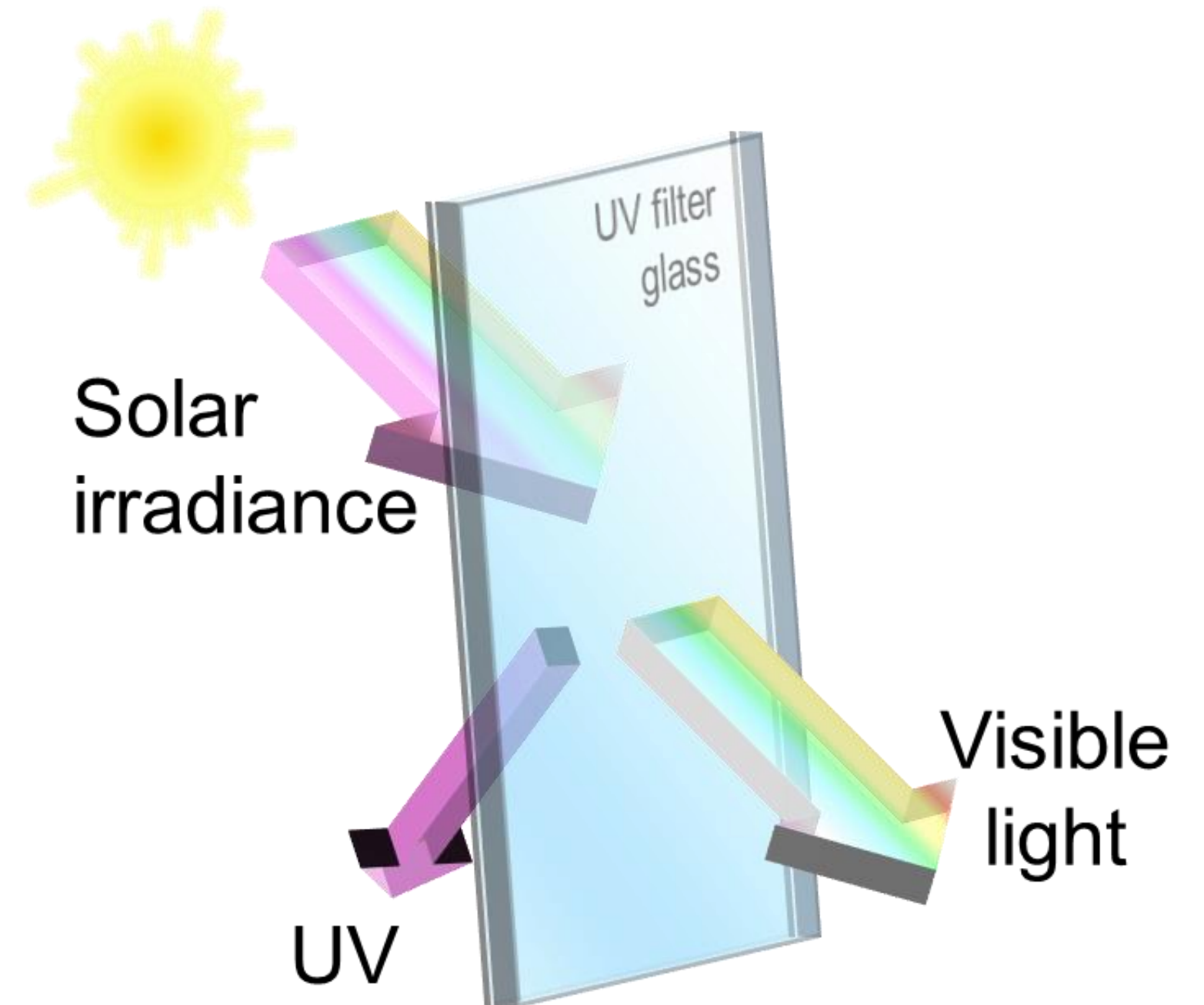
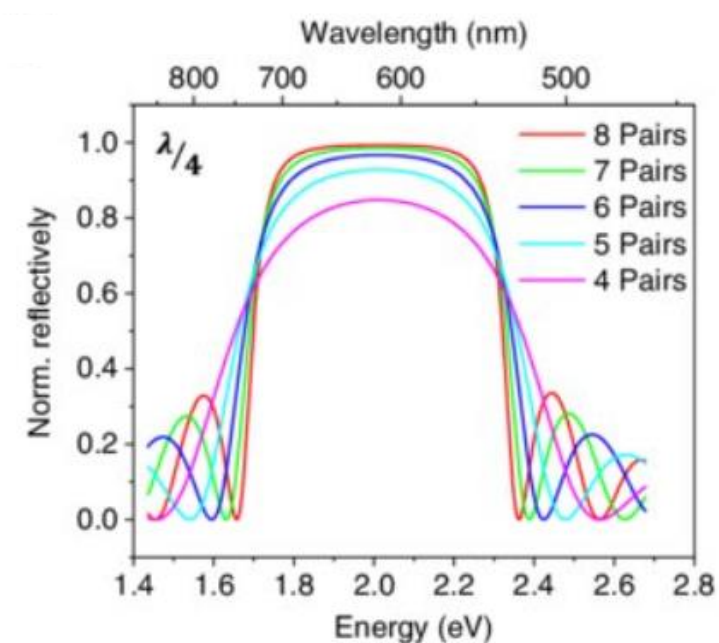
UV protection!!!

Distributed Bragg-reflector

- High-n / Low-n double-layers (TiO₂/SiO₂)
- Nanoscale films – coating with negligible weight



C. C. Palekar and A. Rahimi-Iman.
Phys. Status Solidi RRL, Volume
15, Issue 7, July 2021

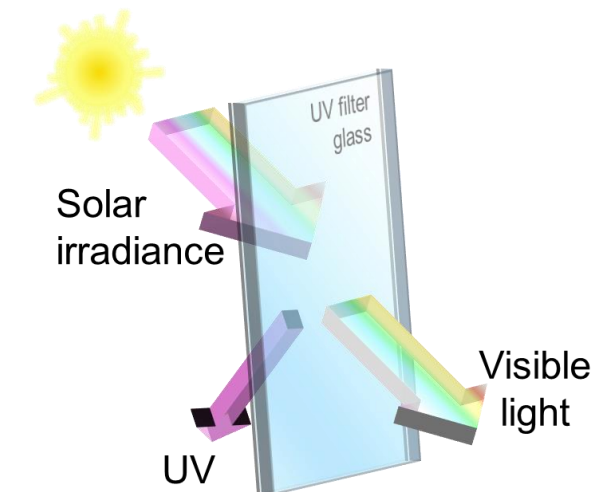


What do we need?

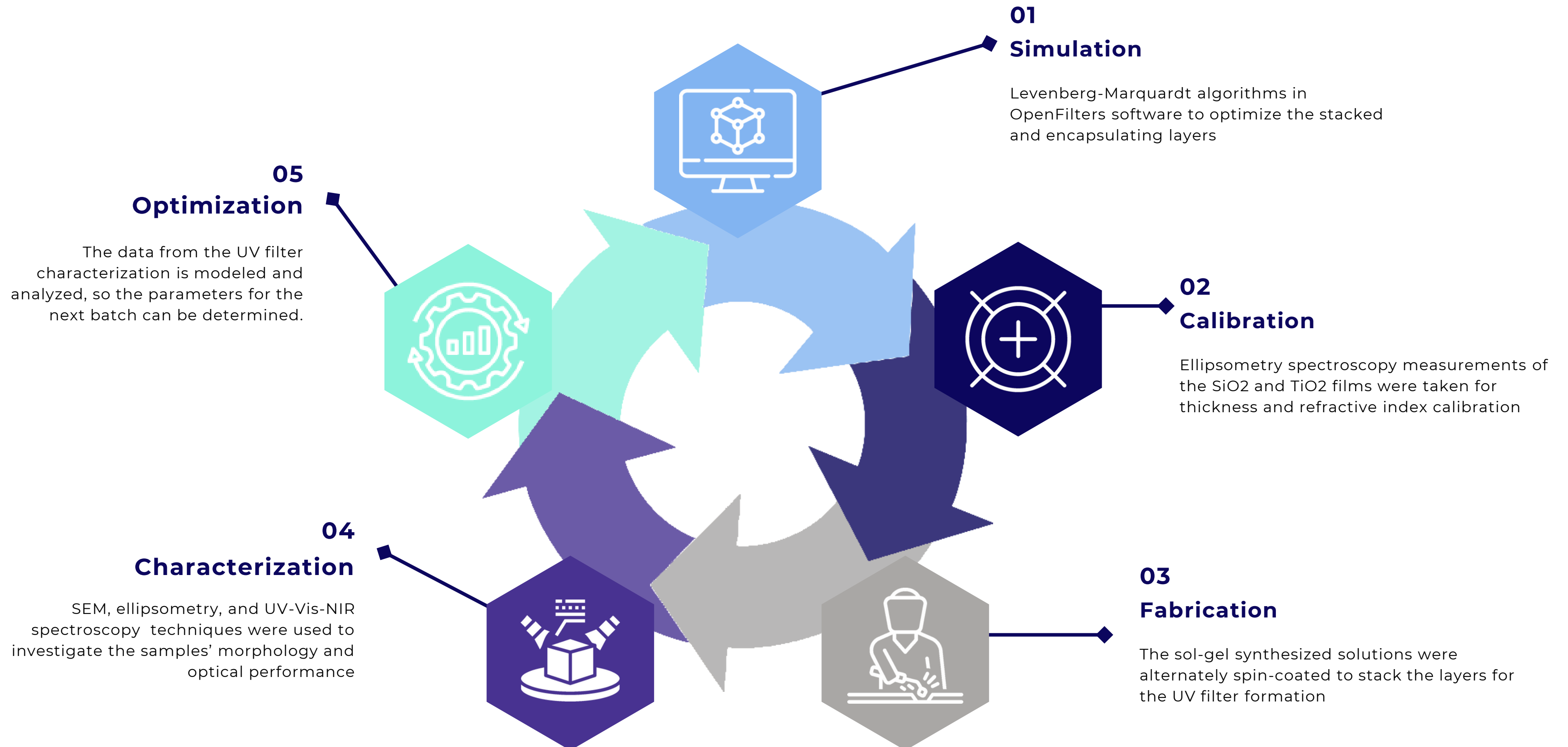
The coating needs to grant:

1. High transmittance of the visible light
2. Low transmittance of the UV radiation
3. Negligible weight
4. Low-cost fabrication

**Nanoscale
thickness control**



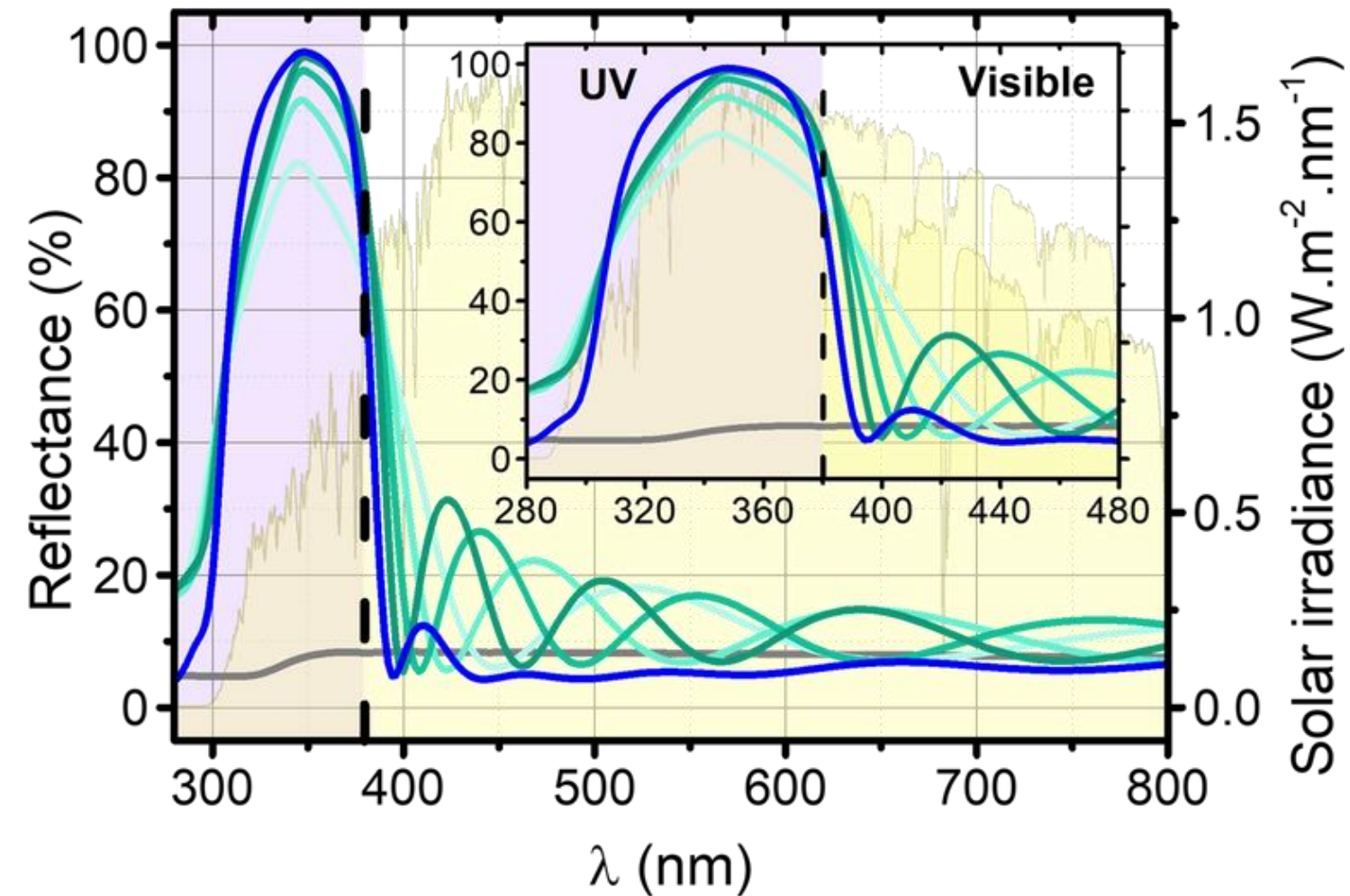
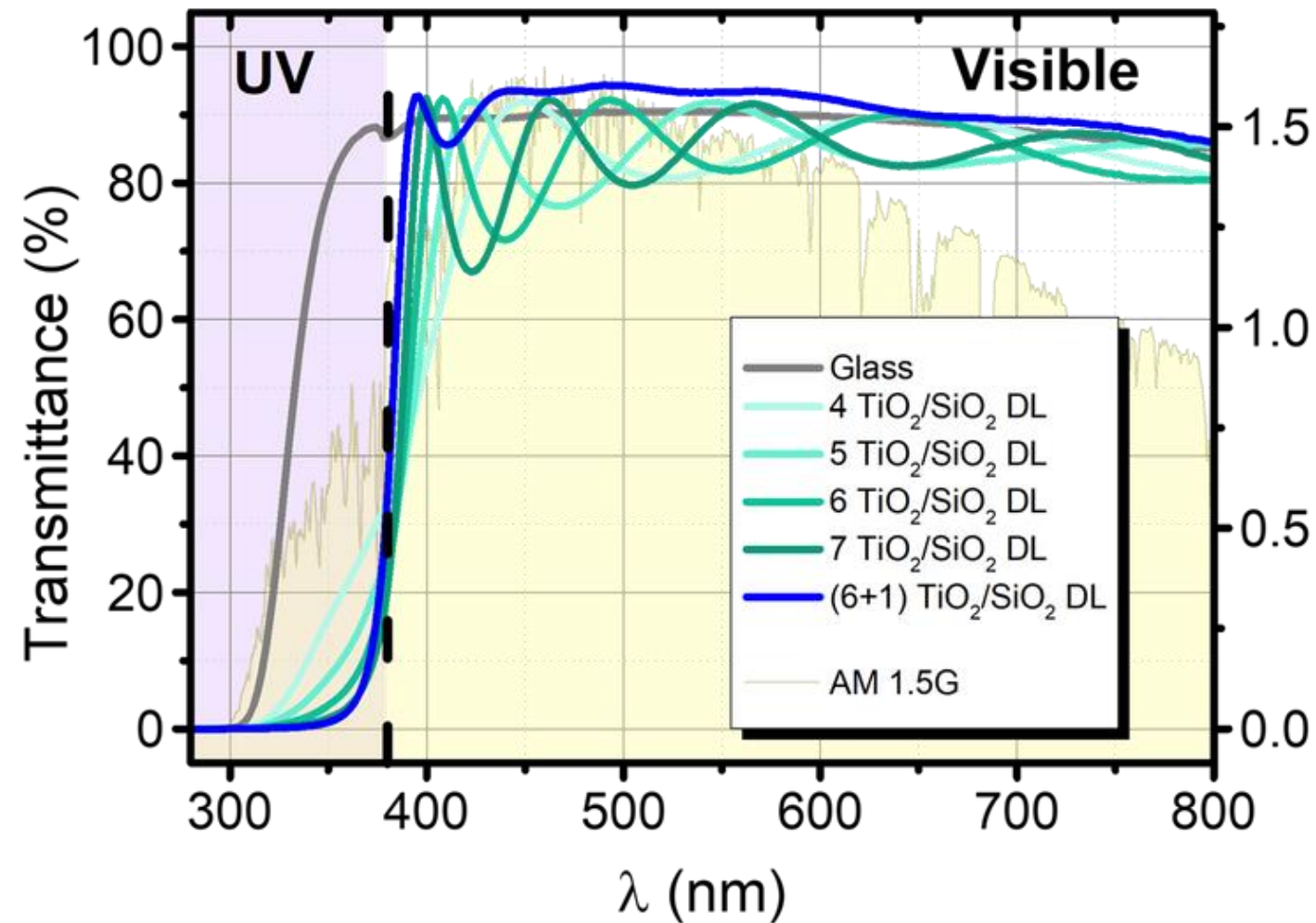
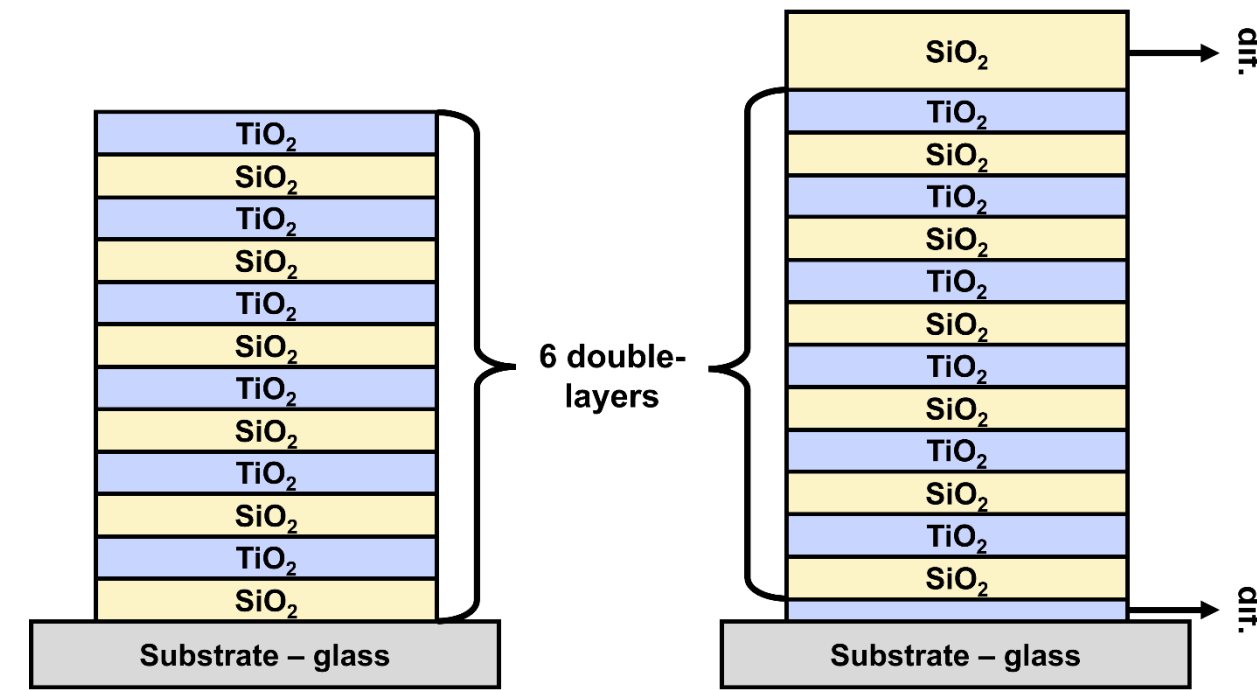
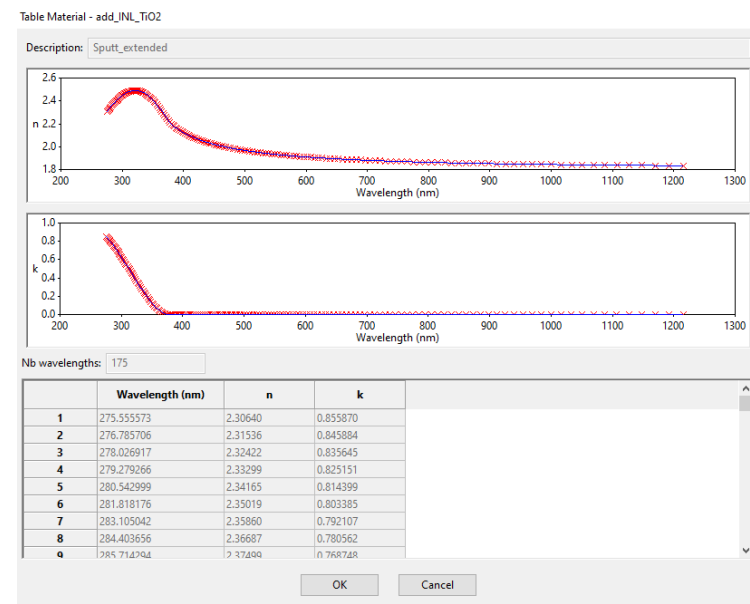
Process



Simulations

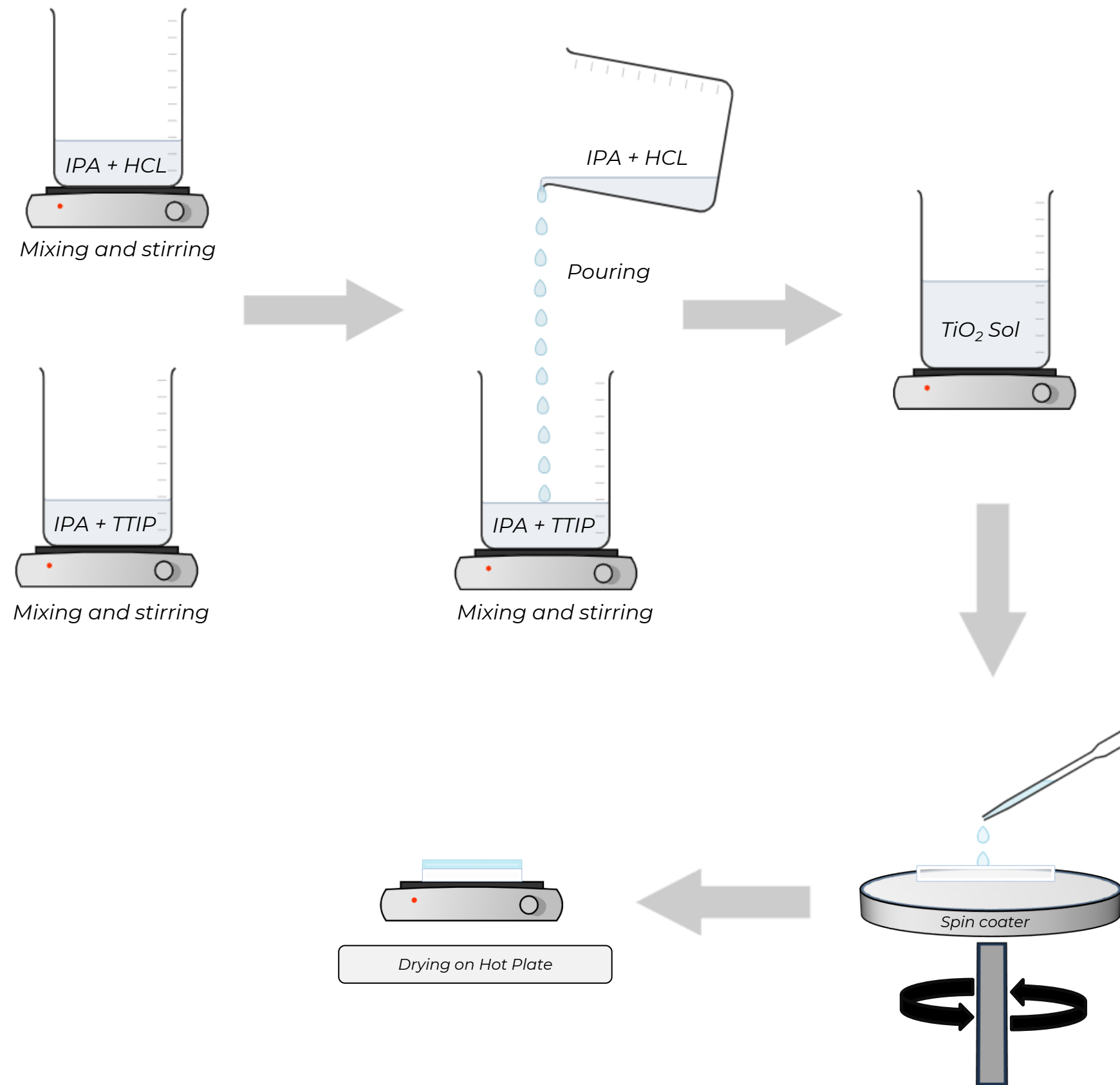
OpenFilters

Open source



Films coating for calibration

- **Sol-gel solutions synthesis**
- **Spin coating**
- **Solvent evaporation**
- **Analysis and dilution for thickness control**





THICKNESS CONTROL!!!

NOA Group



Nanoscale precision

Common glass

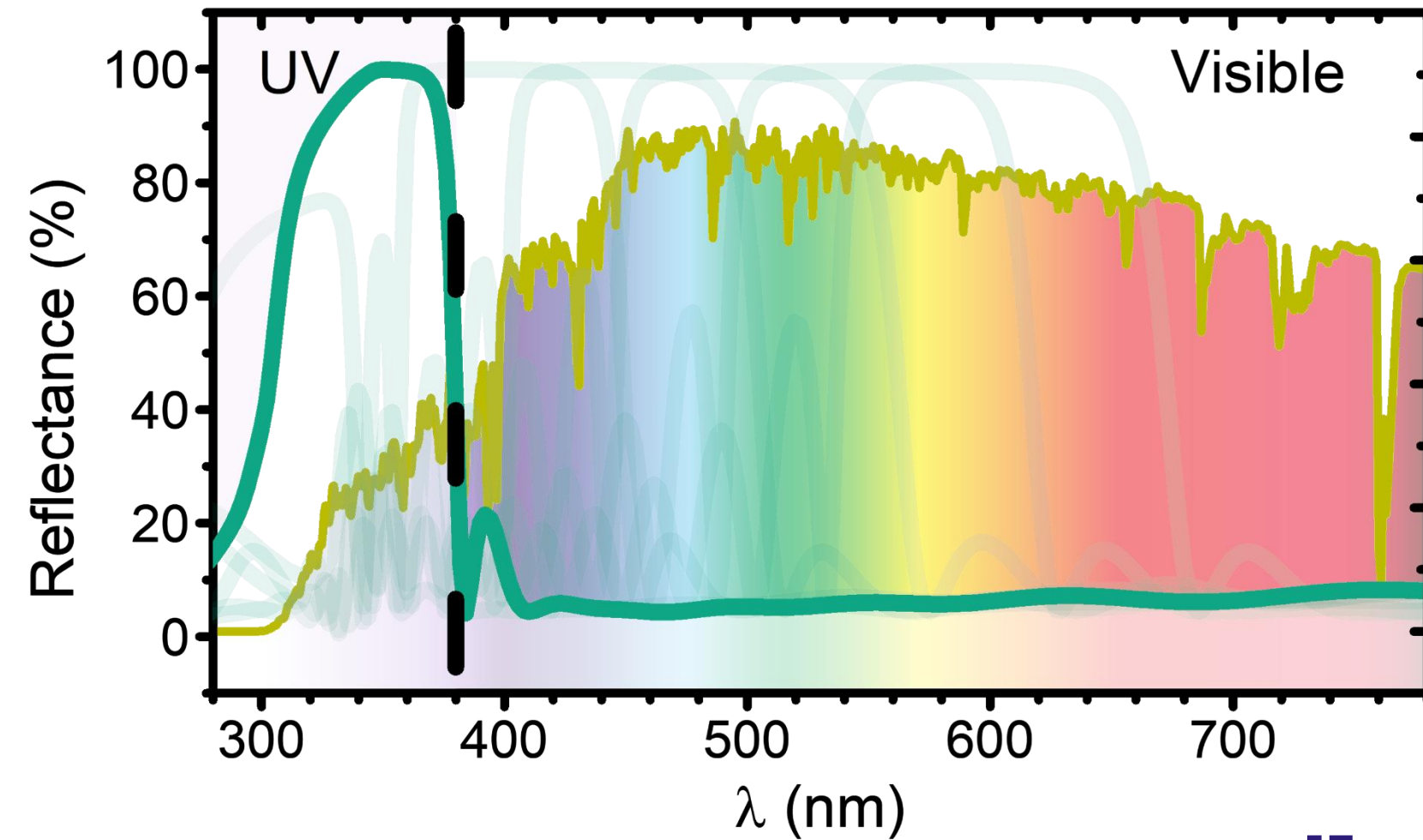
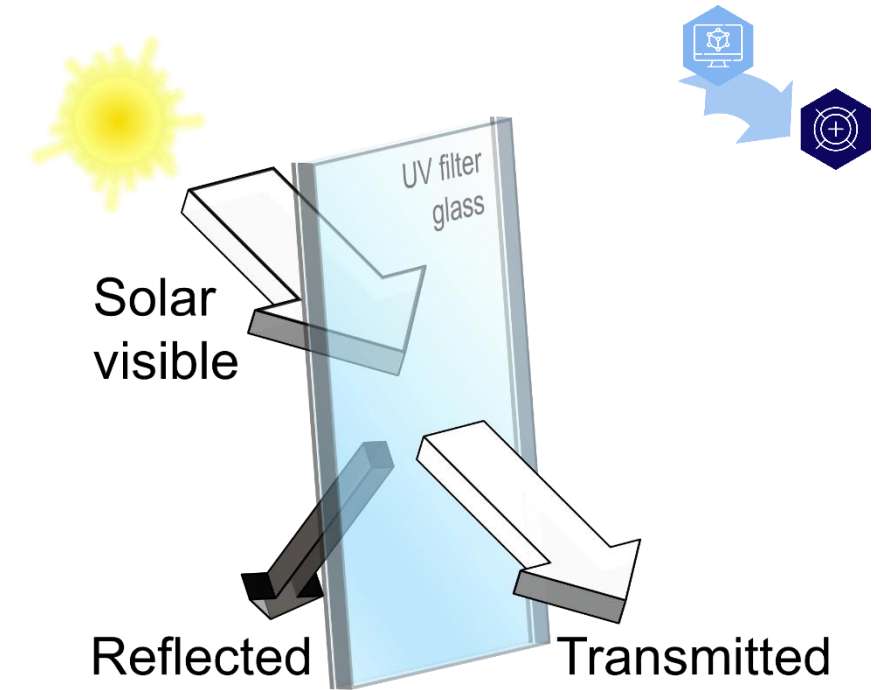


Nanoscale precision

From simulations - What we need:

$$t_{\text{TiO}_2} = 37 \text{ nm} / t_{\text{SiO}_2} = 59 \text{ nm}$$

Targeted reflected wavelength (λ_t) = 340 nm

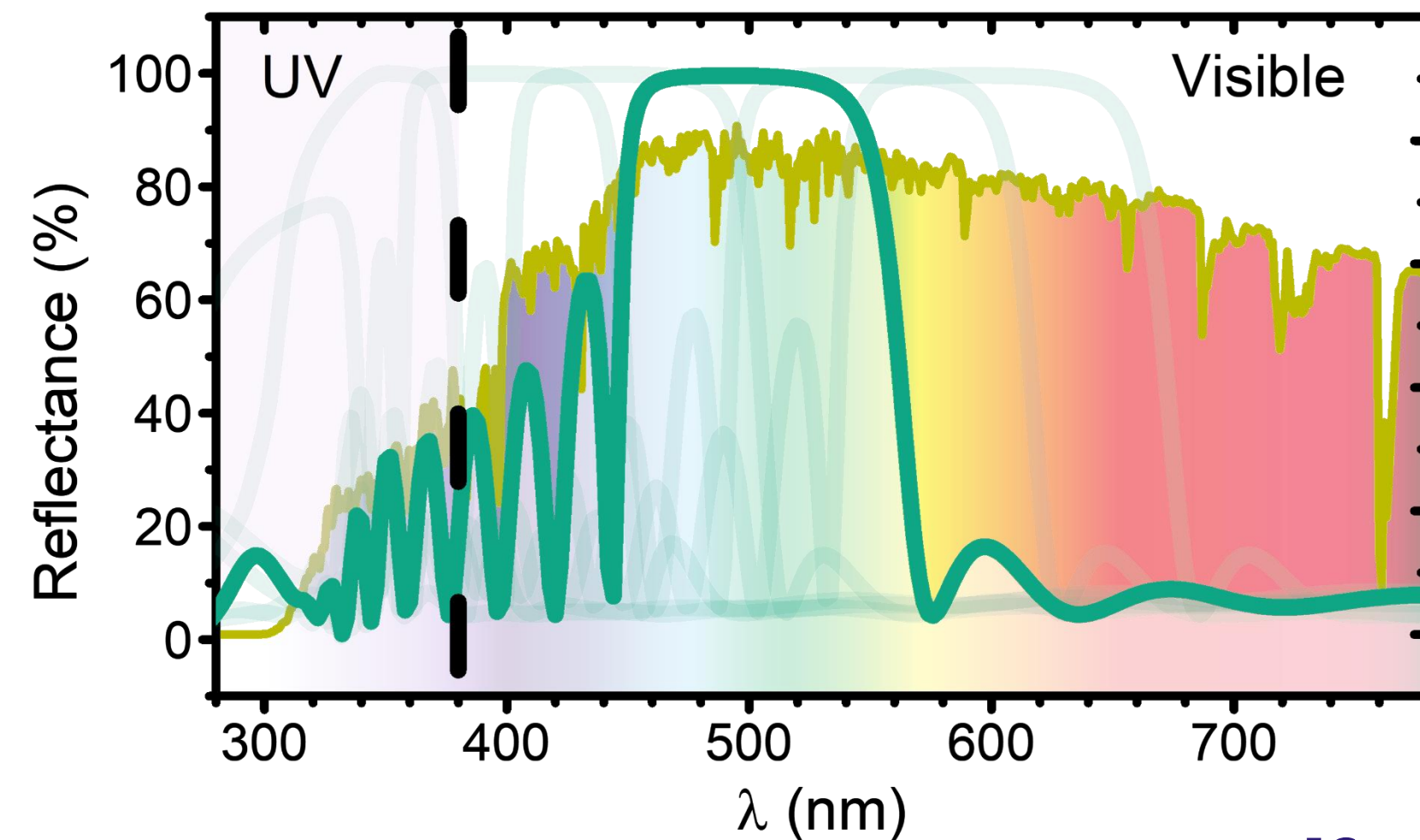
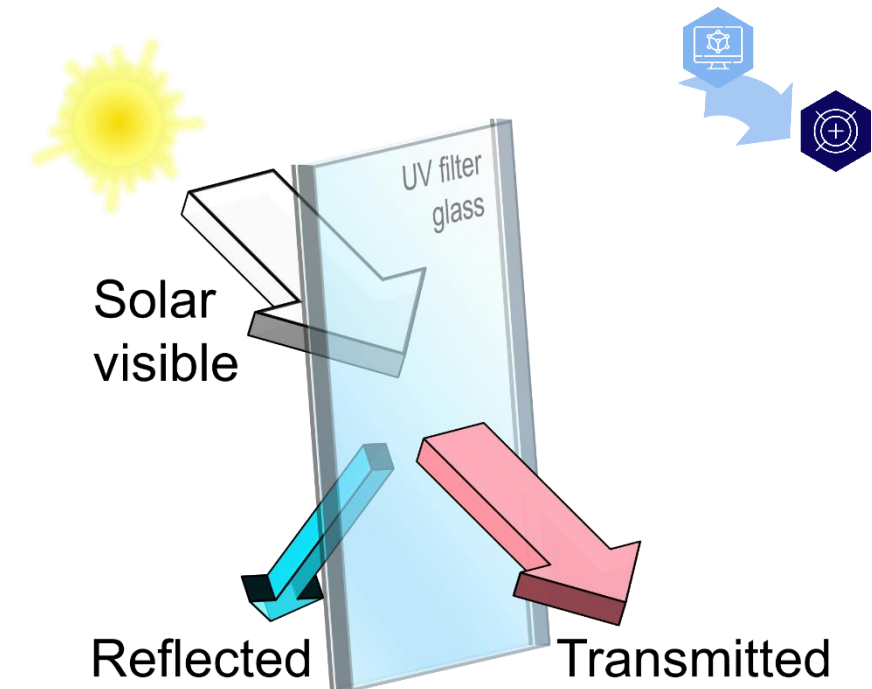


Nanoscale precision

From simulations - What we need:

$$t_{\text{TiO}_2} = 37 \text{ nm} / t_{\text{SiO}_2} = 59 \text{ nm}$$

Thickness variation (Δt) \approx 25-30 nm (+)

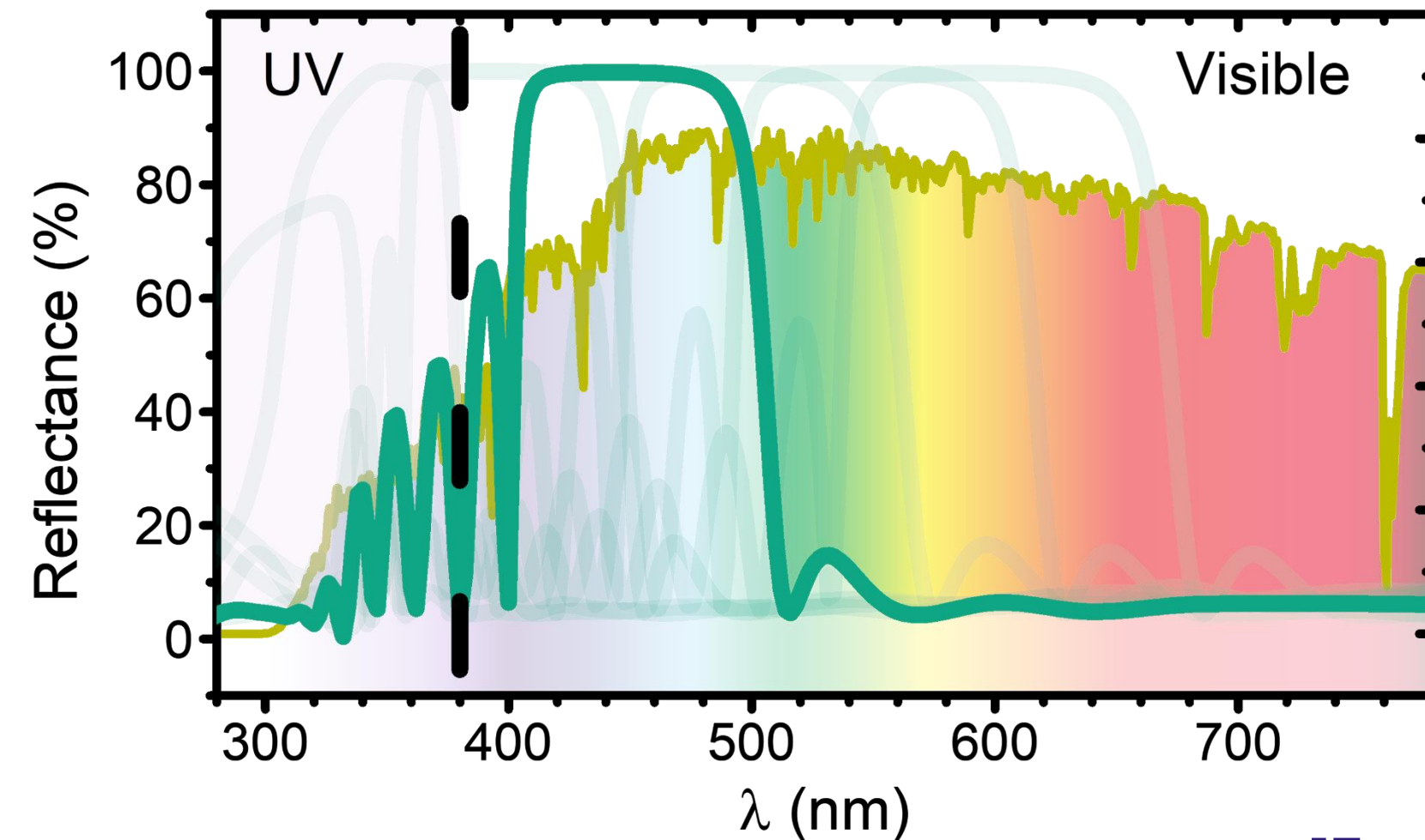
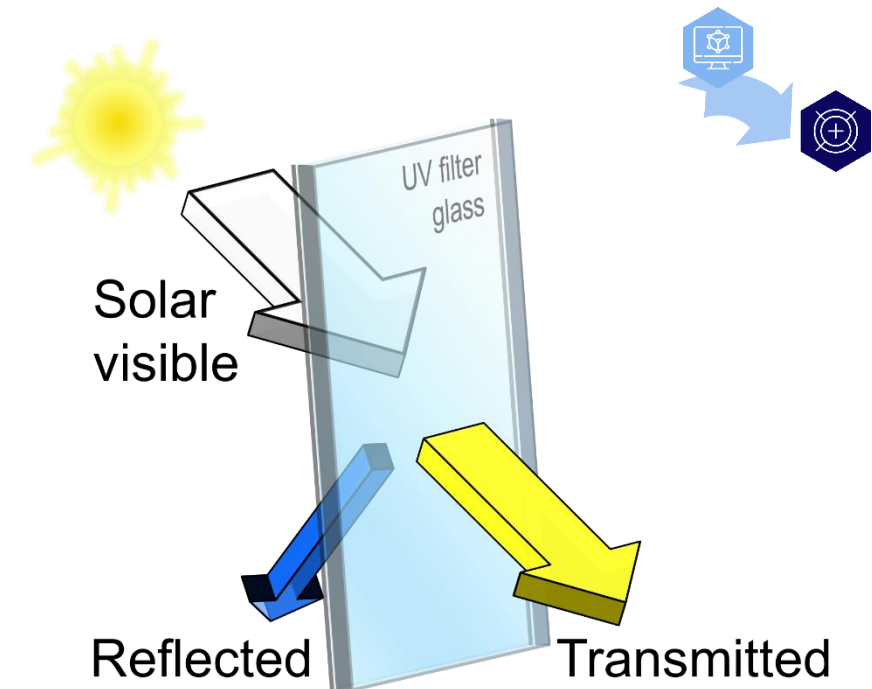


Nanoscale precision

From simulations - What we need:

$$t_{\text{TiO}_2} = 37 \text{ nm} / t_{\text{SiO}_2} = 59 \text{ nm}$$

Thickness variation (Δt) \approx 20 nm (+)

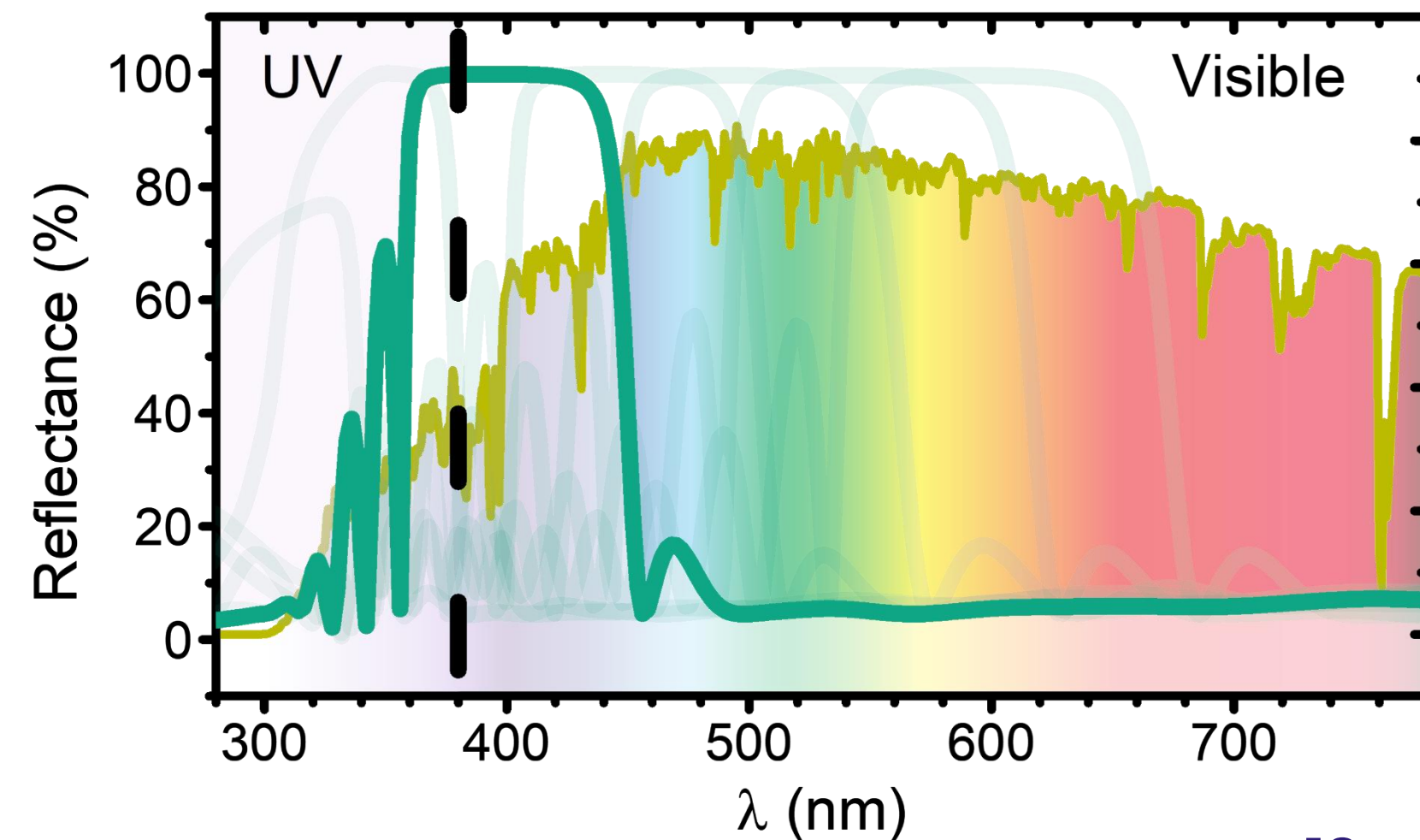
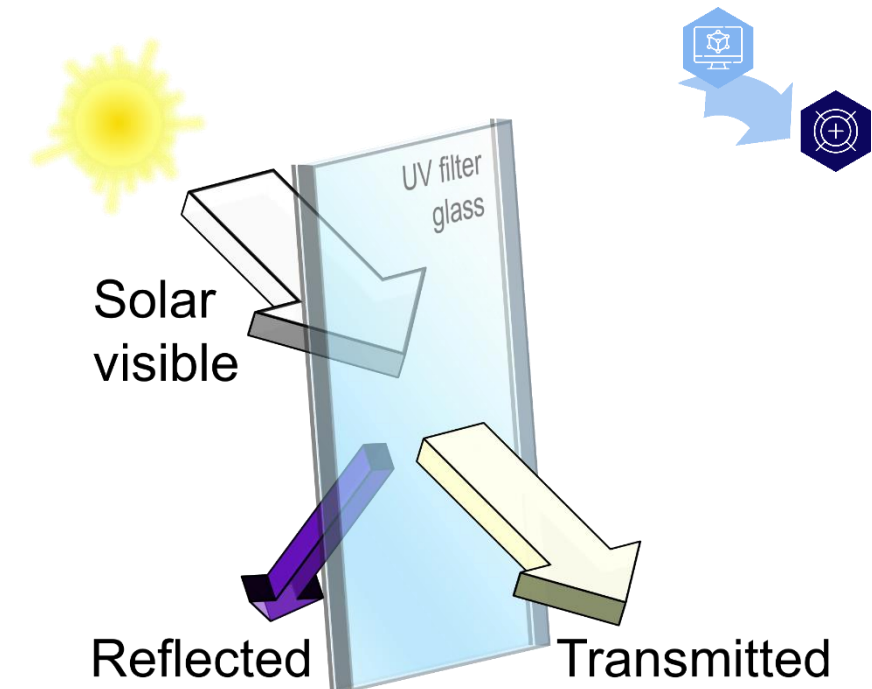


Nanoscale precision

From simulations - What we need:

$$t_{\text{TiO}_2} = 37 \text{ nm} / t_{\text{SiO}_2} = 59 \text{ nm}$$

Thickness variation (Δt) $\approx 10 \text{ nm}$ (+)

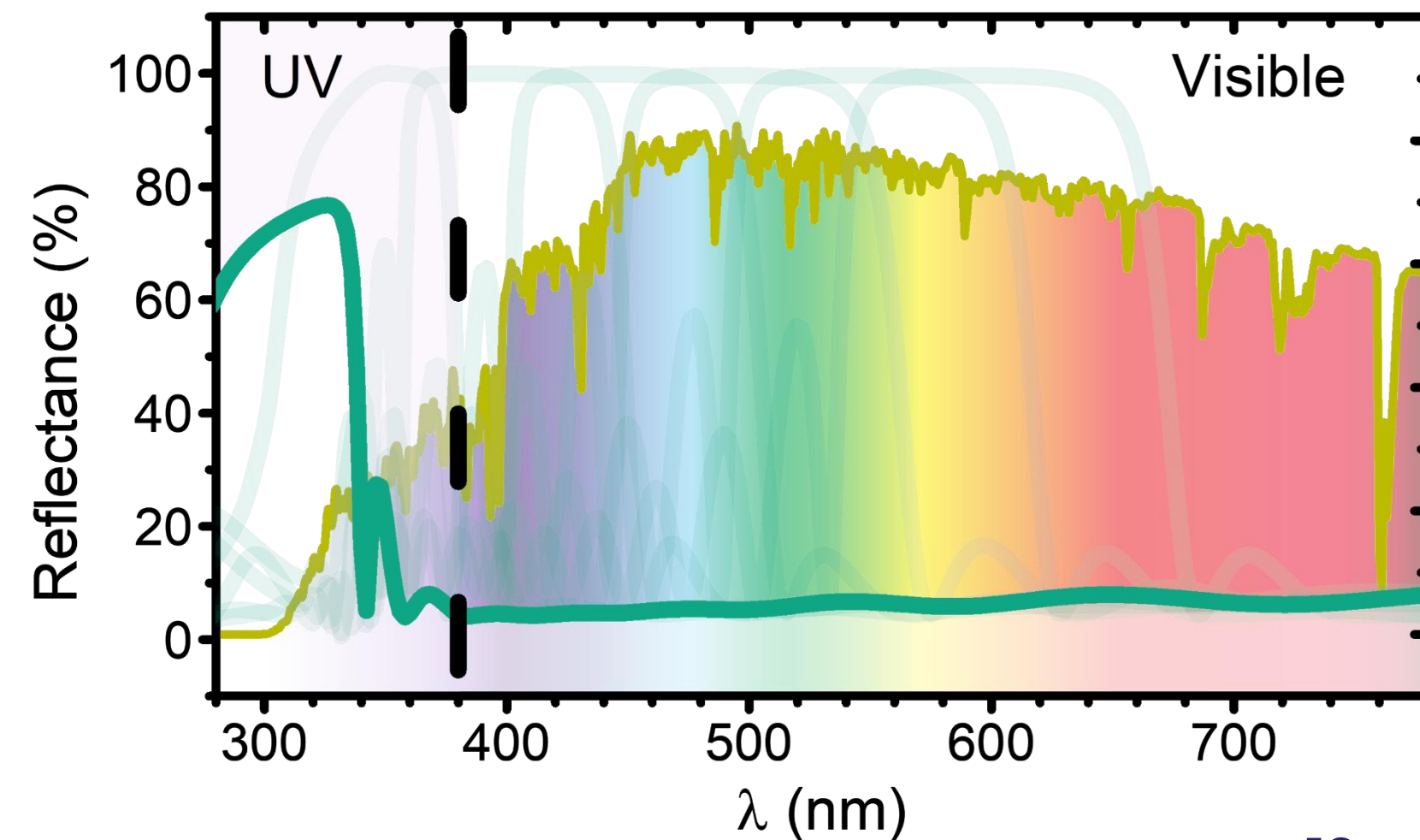
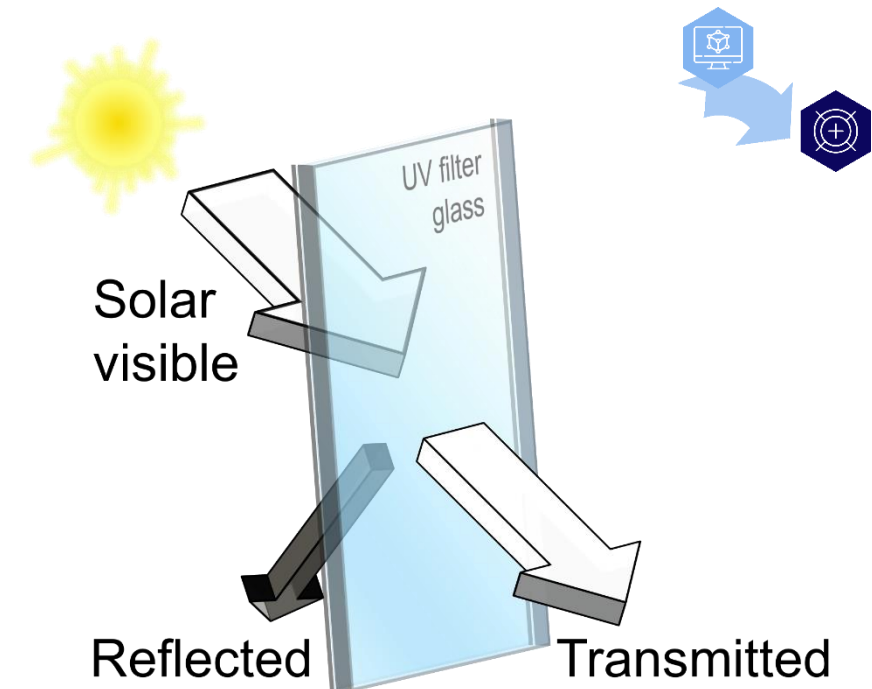


Nanoscale precision

From simulations - What we need:

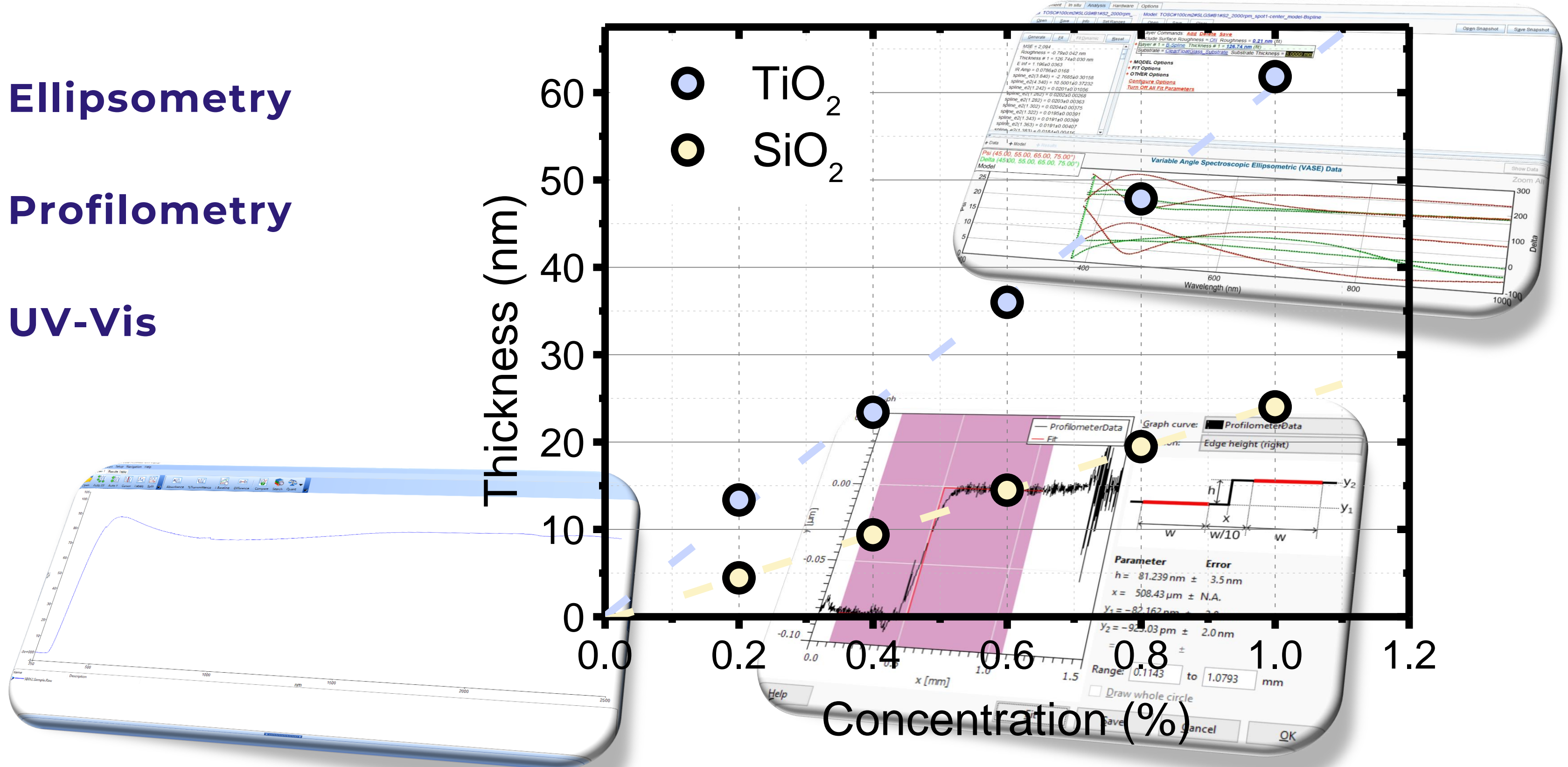
$$t_{\text{TiO}_2} = 37 \text{ nm} / t_{\text{SiO}_2} = 59 \text{ nm}$$

Thickness variation (Δt) $\approx 7 \text{ nm}$ (-)



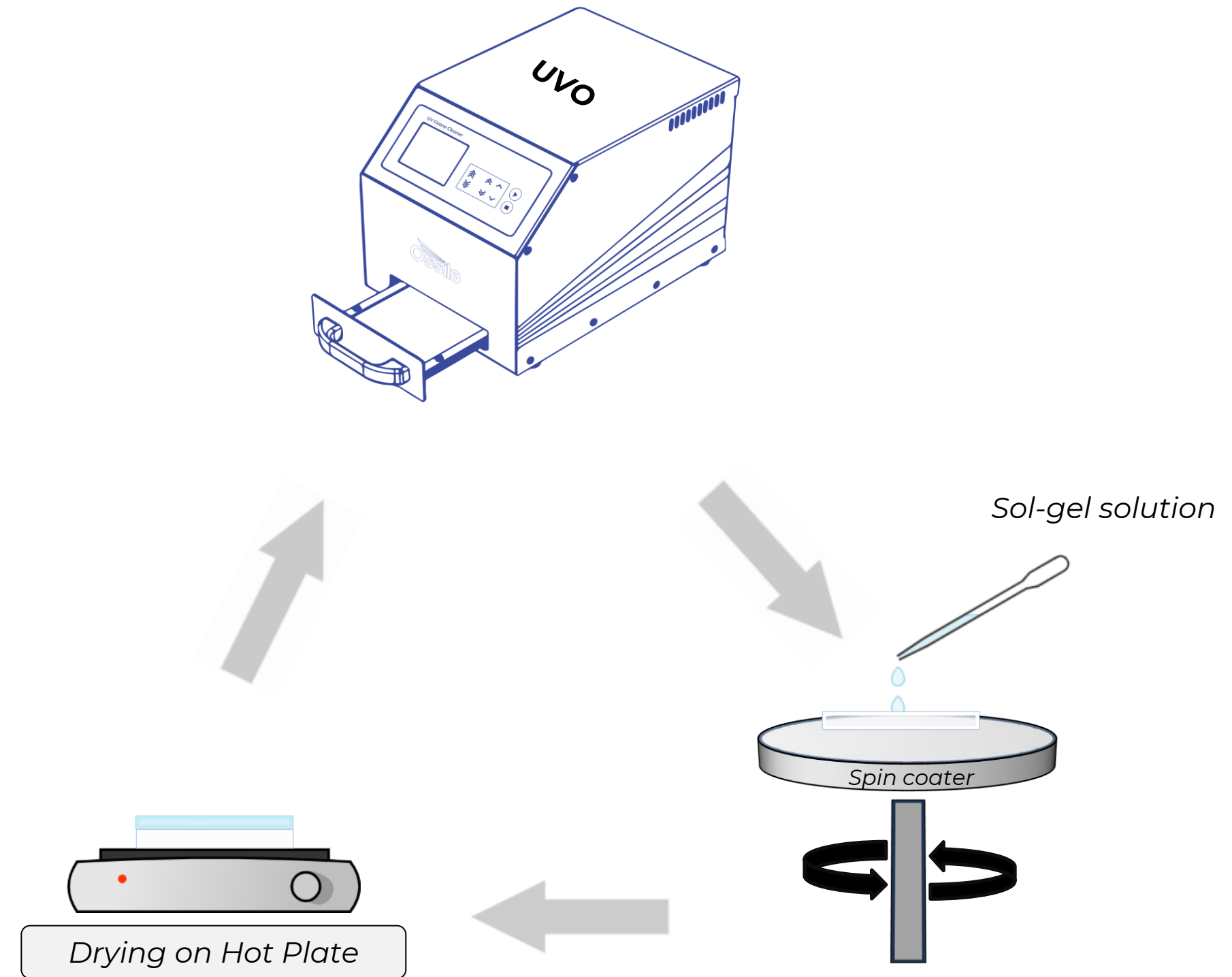
Films calibration

- Ellipsometry
- Profilometry
- UV-Vis



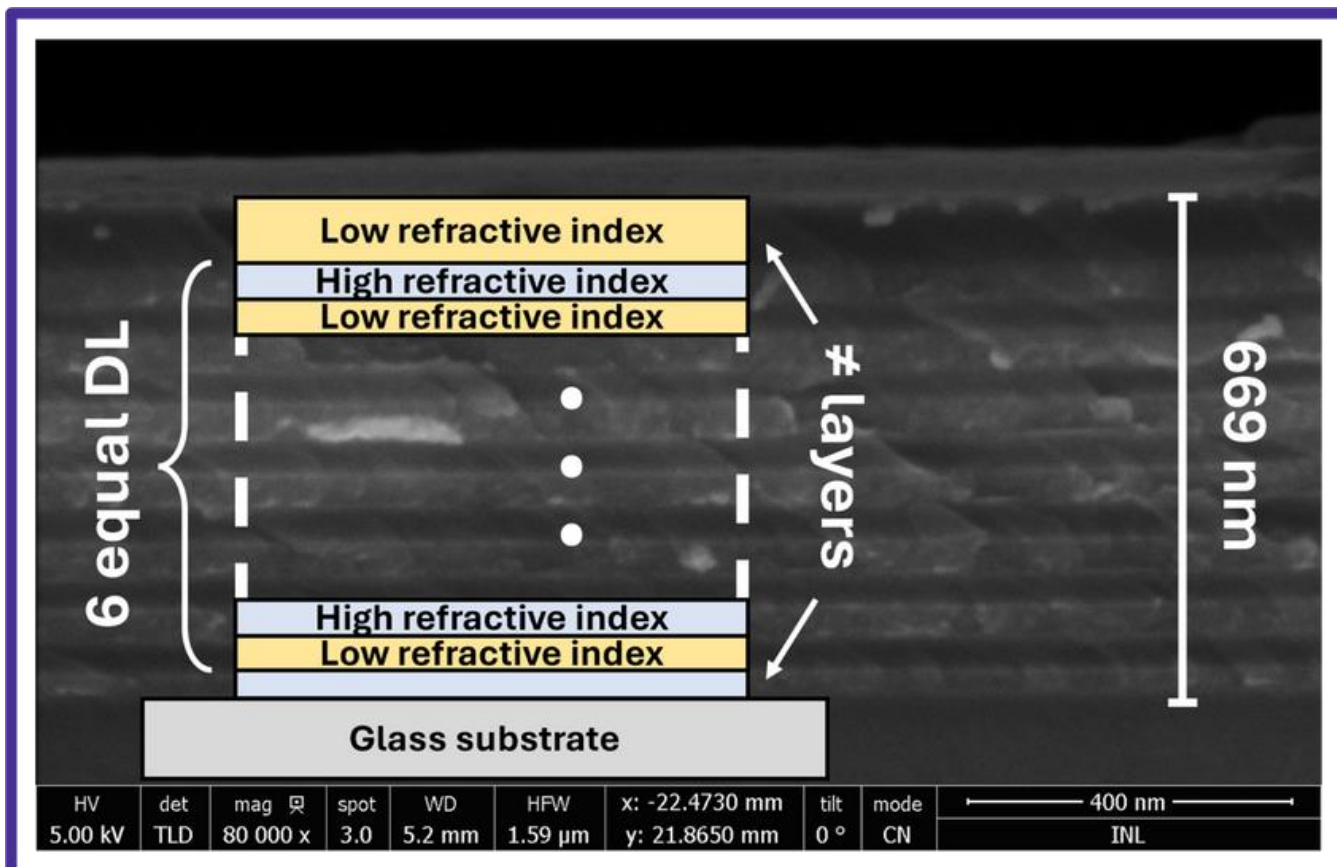
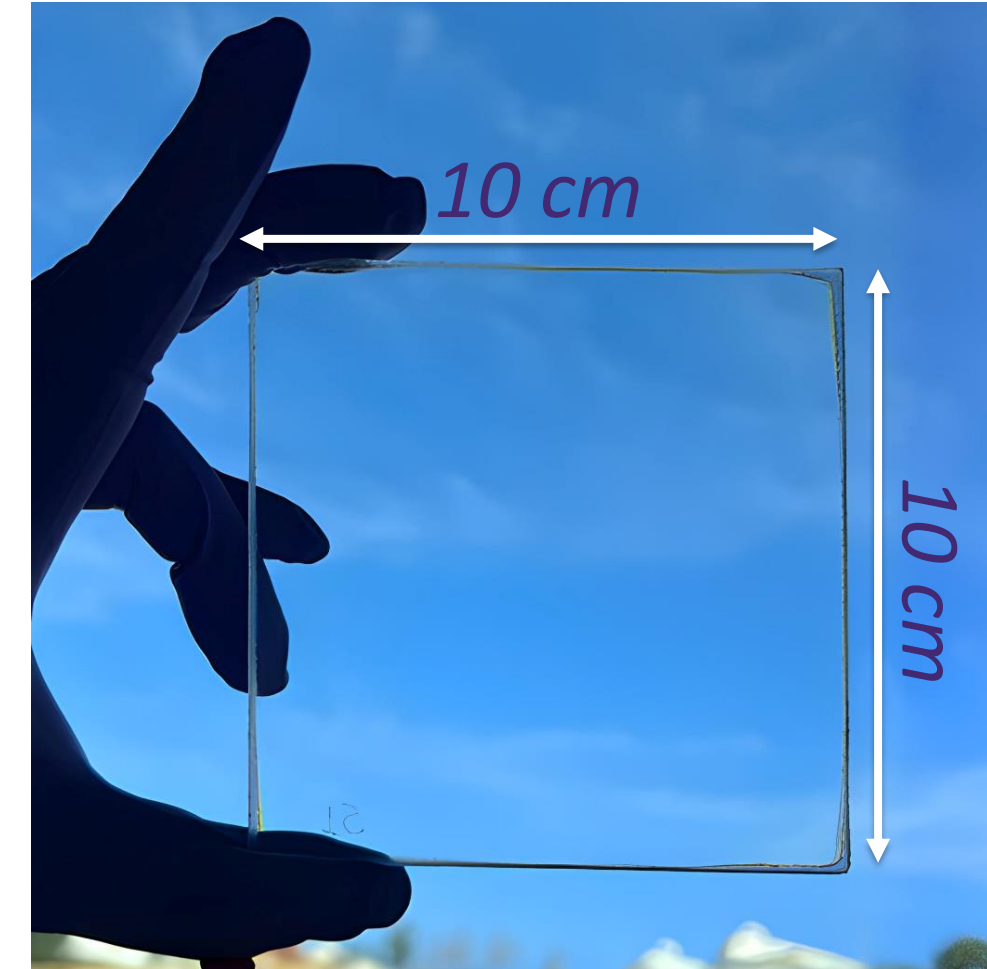
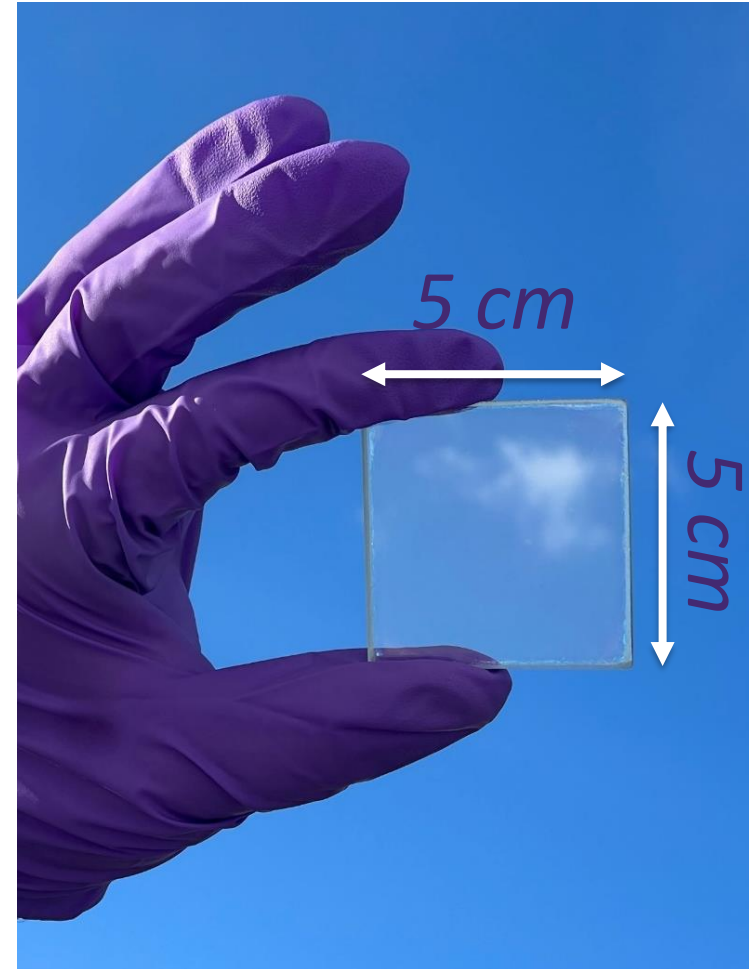
UF filter fabrication

- **Surface treatment**
- **Spin coating**
- **Solvent evaporation**
- **Repeat**



UV filter characterization

- 6+1 double-layers: 14 films stacked
- Substrates of CFG
 - 2.5x2.5 cm²
 - 5x5 cm²
 - 10x10 cm²



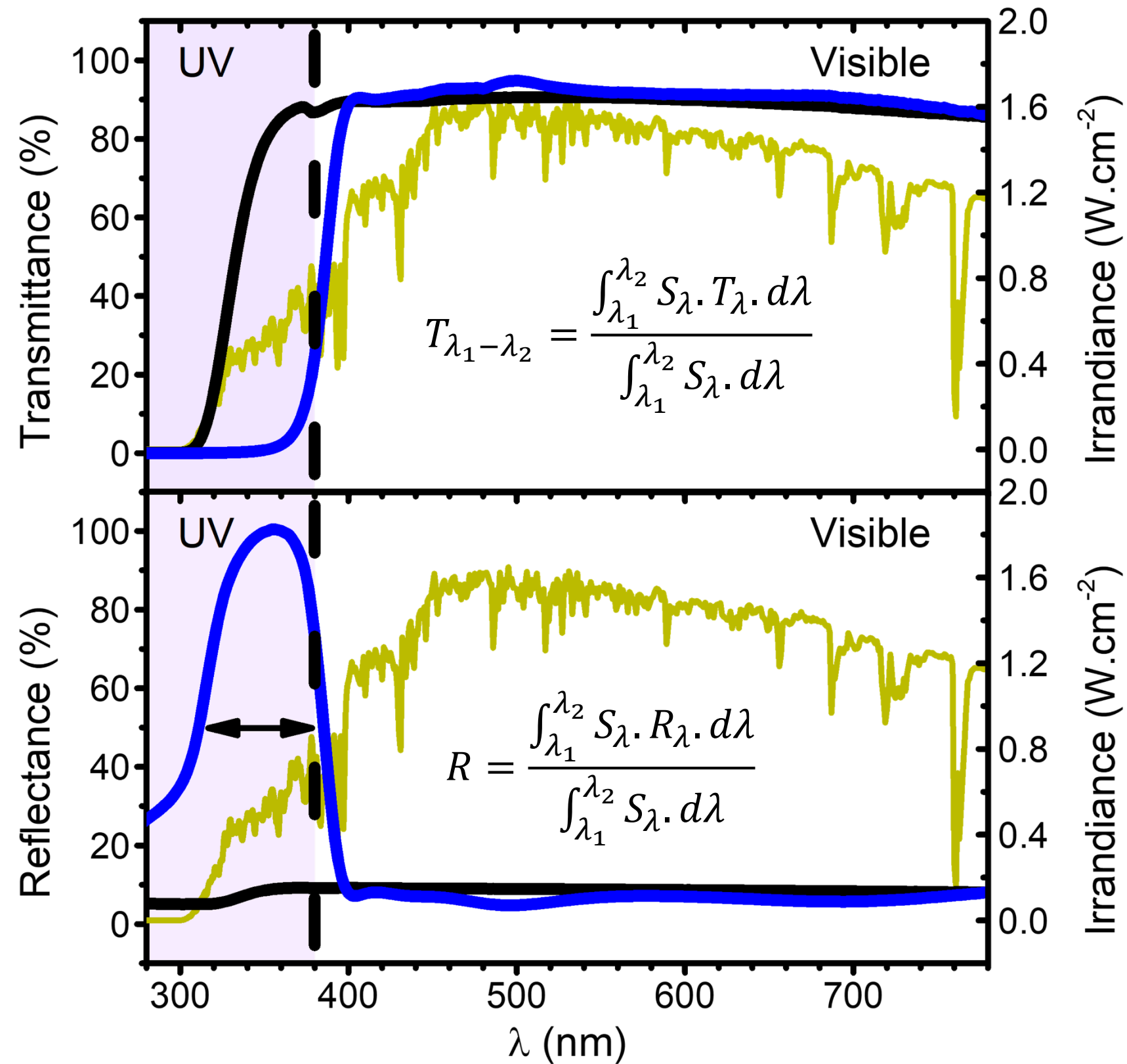
SEM cross-section of the UV filter with **6+1 DL** stacked

- Nominal thickness: ~679 nm
- Measured thickness: ~669 nm

**Thickness
precision**

>98.5%

Results - optimization

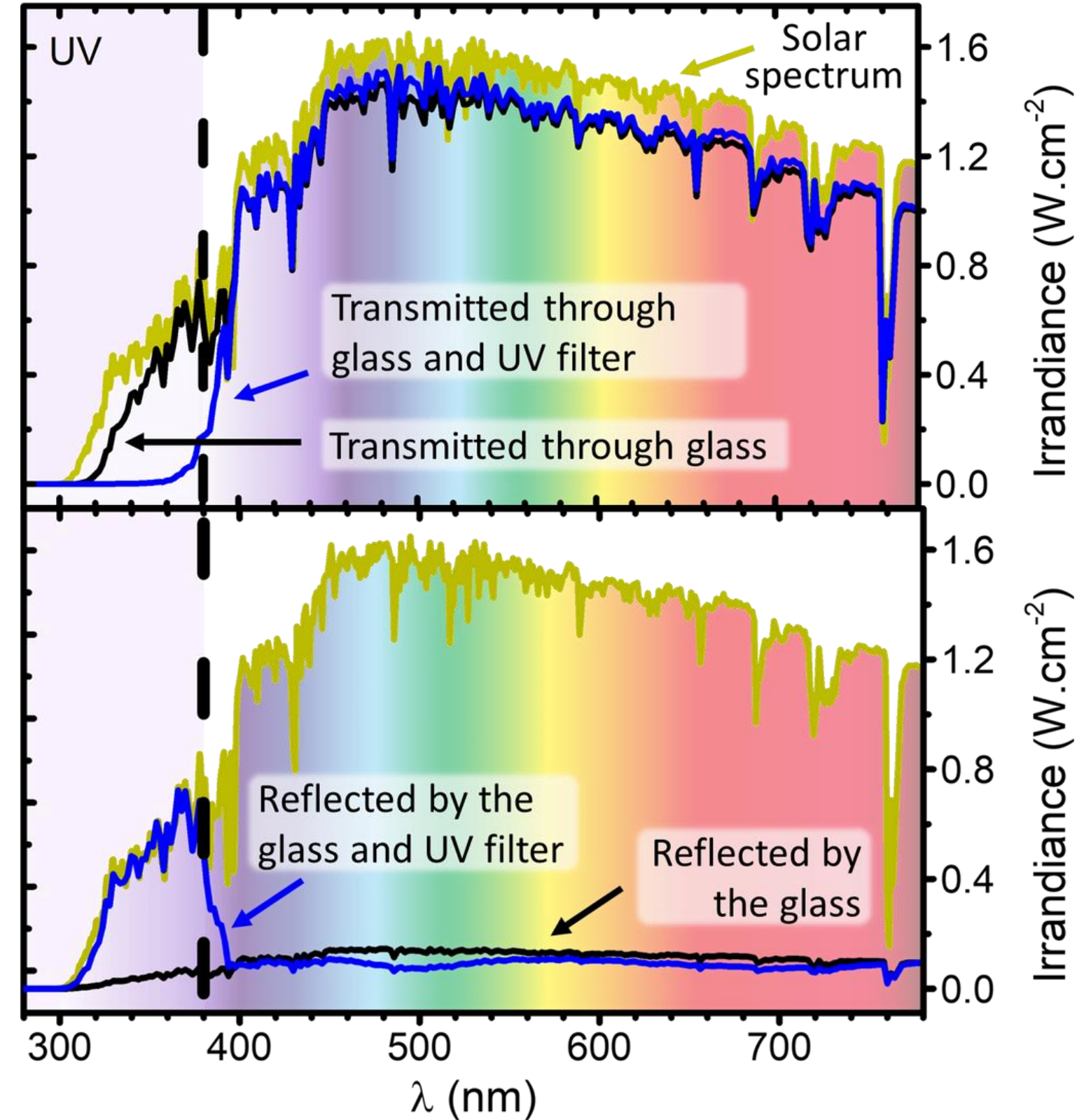
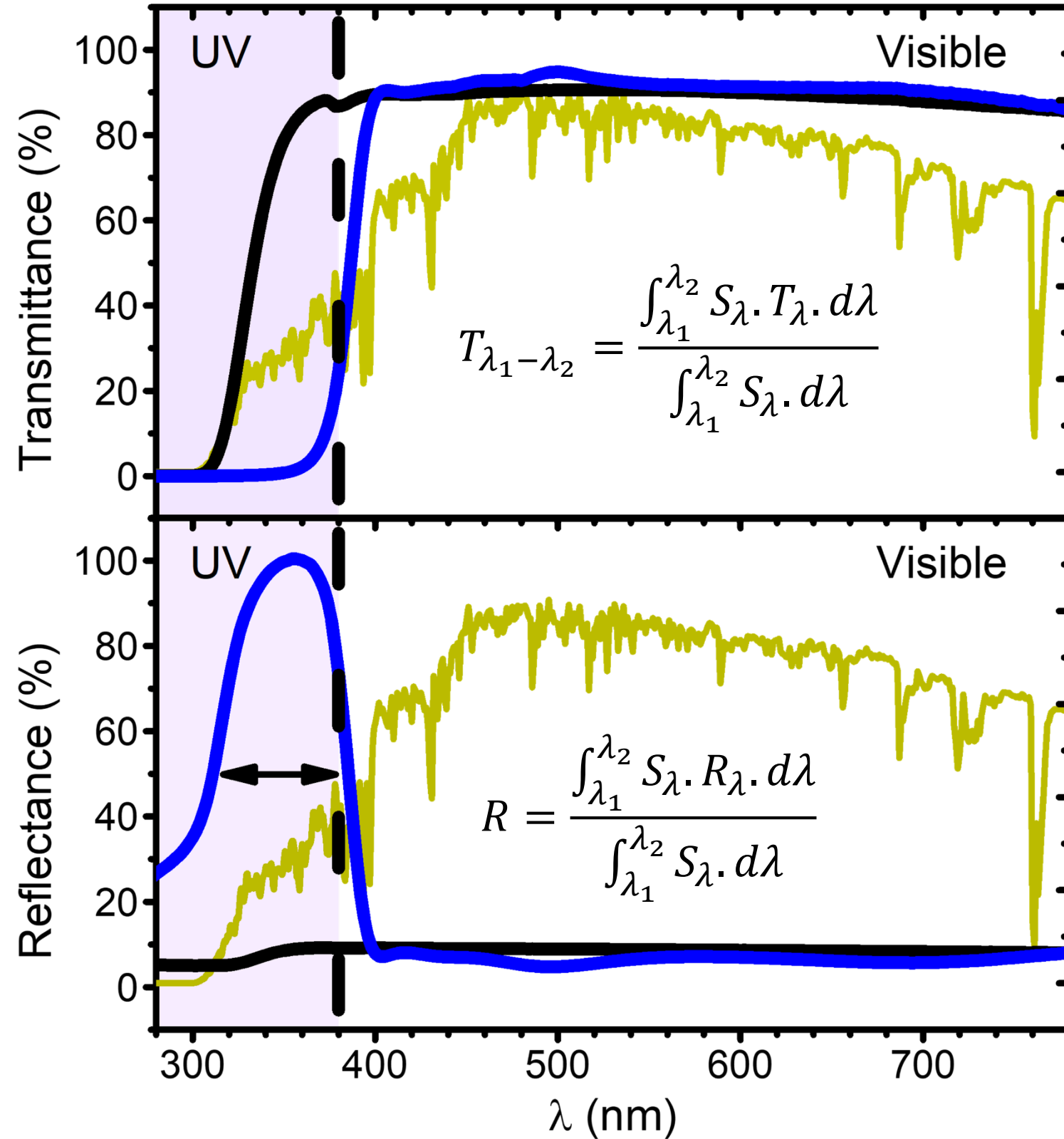


Light range	UV	Visible
	(<380 nm)	(380 - 780 nm)
Transmit (%)		
Glass	71	89
Glass + UV filter - sim	3	88
Glass + UV filter - exp	7	88
Reflect (%)		
Glass	8	9
Glass + UV filter - sim	78	8
Glass + UV filter - exp	90	9

Structure	λ at T \approx 10% λ_L (nm)	λ at T \approx 90% λ_H (nm)	Transm edge $\Delta\lambda = \lambda_H - \lambda_L$ (nm)
4 DL (simul)	340	438	98
5DL (simul)	358	416	58
6 DL (simul)	368	404	36
7 DL (simul)	373	398	25
6+1 DL (simul)	370	392	22
6+1 DL (exp)	372	402	30



Results - optimization



Results - optimization

Structure	R ₀ (%)		W (Δλ _{stopband})	FWHM (R=50%)	Transmission edge
	Eq.	data			
4 DL (simul)	84.6	82.2	139	89	98
5DL (simul)	93.5	91.7	120	88	58
6 DL (simul)	97.3	96.2	109	84	36
7 DL (simul)	98.9	98.2	102	82	25
6+1 DL (simul)	-	99.0	97	74	22
6+1 DL (exp)	-	99.9	97	74	30

$$R_0 (8DL) = 99.6\%$$

$$W = 97nm$$

$$R_0 = \left[\frac{(n_H/n_L)^{2N} - n_S}{(n_H/n_L)^{2N} + n_S} \right]^2$$

$$W = \frac{4}{\pi} \cdot \lambda_0 \cdot \arcsin \left(\frac{n_H - n_L}{n_H + n_L} \right)$$

Conclusions

We fabricated UV filter coating on glass substrate that has:

1. High transmittance of the visible light



2. Low transmittance of the UV radiation



3. Negligible weight



4. Low-cost fabrication



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CEES
2025



THANK YOU

for your presence and attention

