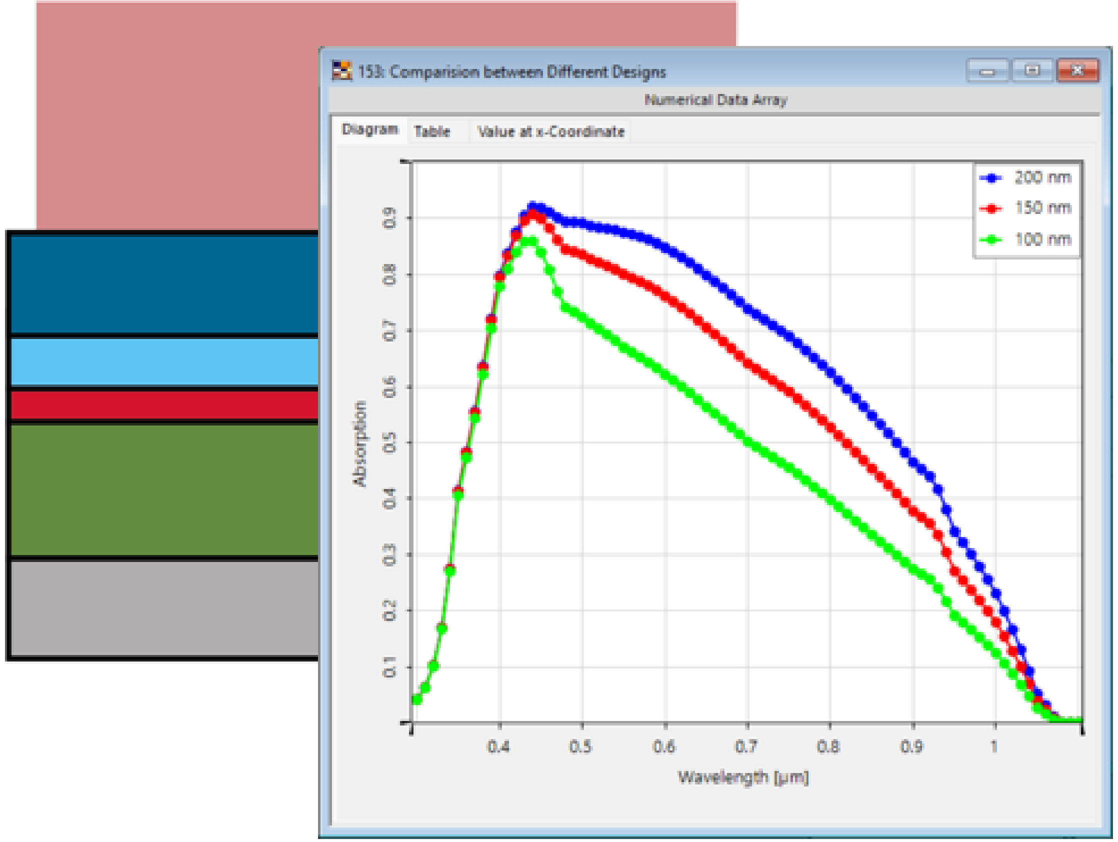
Absorption in a CIGS Solar Cell

Abstract



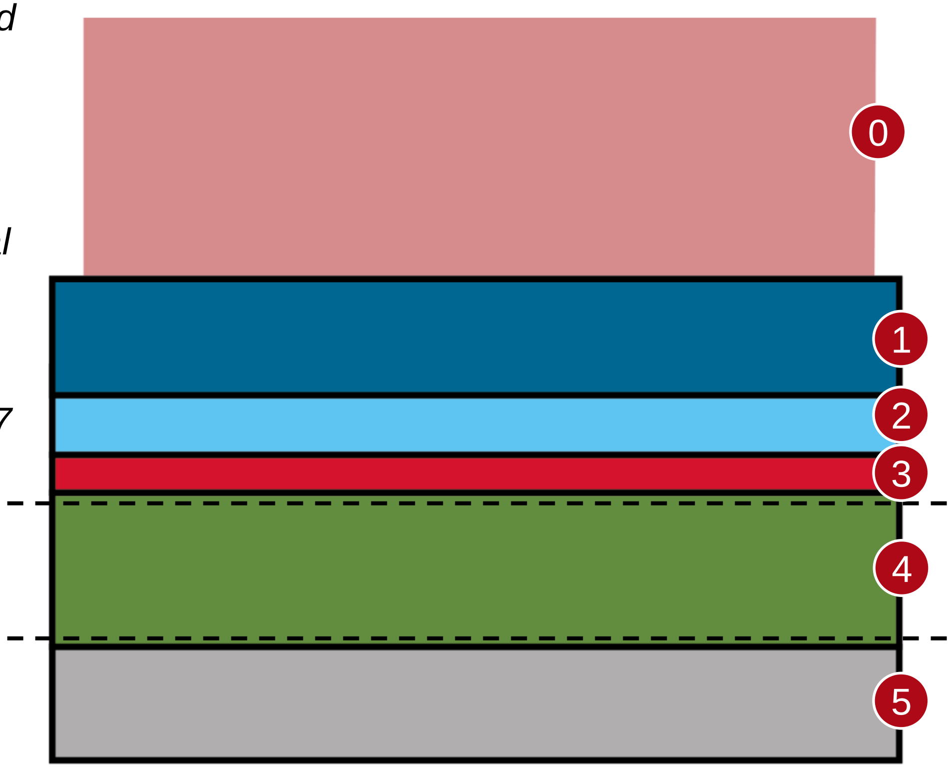
Solar cells are a fundamental technology in the field of renewable energy. To optimize efficiency, most common designs use thin-layer structures and media with high absorption coefficients – as it is precisely this absorbed optical energy what will eventually be transformed into an electric current. Solar cells based on copper indium gallium selenide (CIGS) have become quite common as they can be made much thinner without losing absorption efficiency, compared with cells based on other materials.

Modeling Task

plane wave

homogeneous spectrum from 300 nm to 1100 nm

__System from:__ J. Goffard et al., "Light Trapping in Ultrathin CIGS Solar Cells with Nanostructured Back Mirrors," in IEEE Journal of Photovoltaics, vol. 7, no. 5, pp. 1433-1441, Sept. 2017, doi: 10.1109/JPHOTOV.2017.2726566.



solar cell

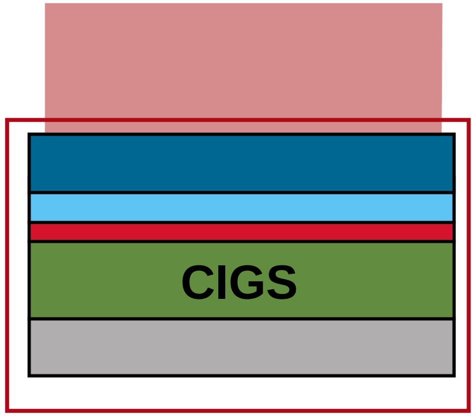
nr.	Material	thickness
0	fused silica*	-
1	ZnO:Al	100 nm
2	i-ZnO	70 nm
3	ZnS	50 nm
4	CIGS	100/150/200 nm
5	molybdenum	substrate

* we assume that the solar cell is protected by a layer of fused silica with anti-reflection coating.

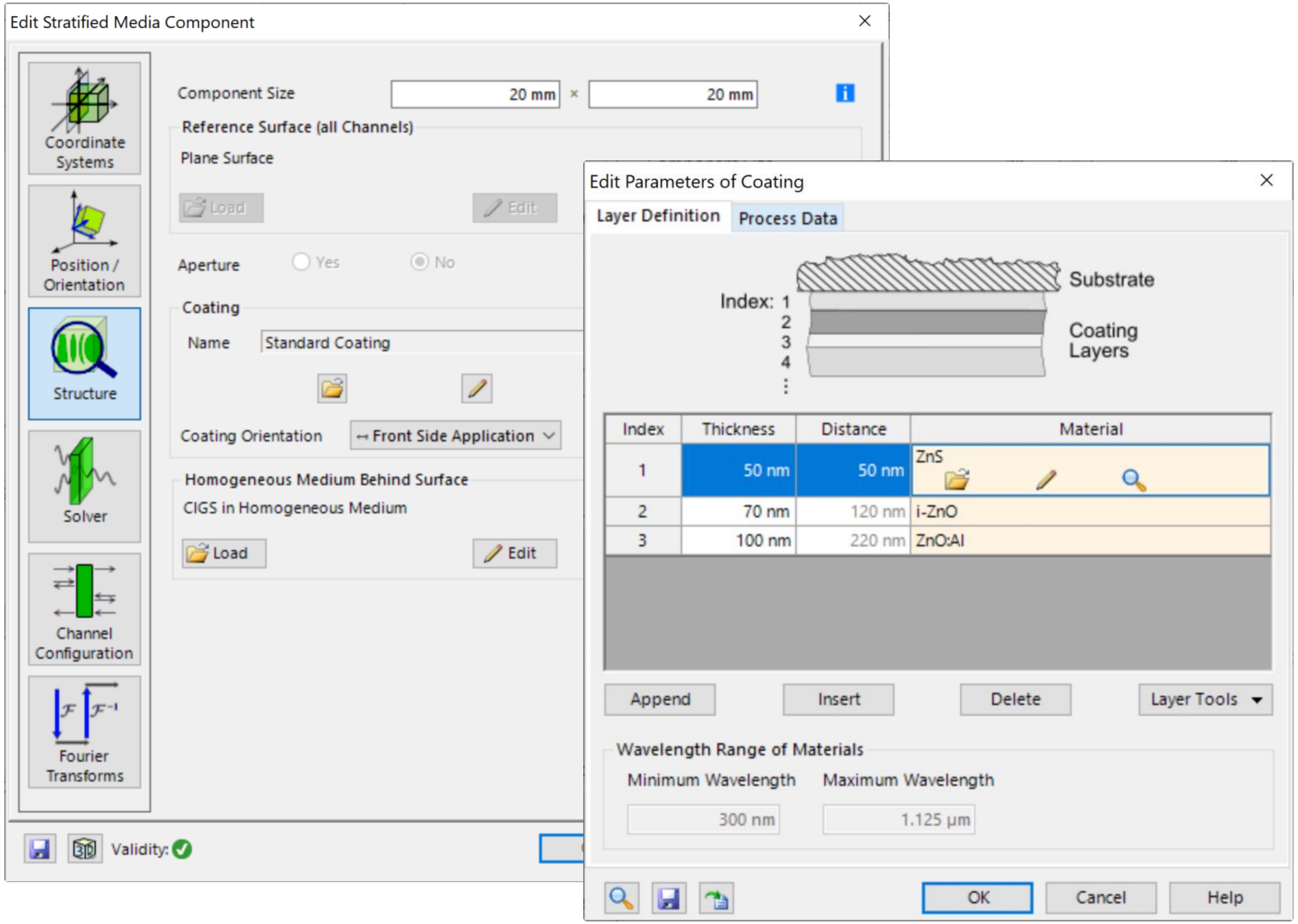
detectors

power (absorbed power will be calculated as the difference between the power readings of both detectors)

System Building Blocks – Stratified Media Component



For the coated mirrors we employ the *Stratified Media Component*, since it provides a fast and rigorous solution for x, y-invariant layer stacks.

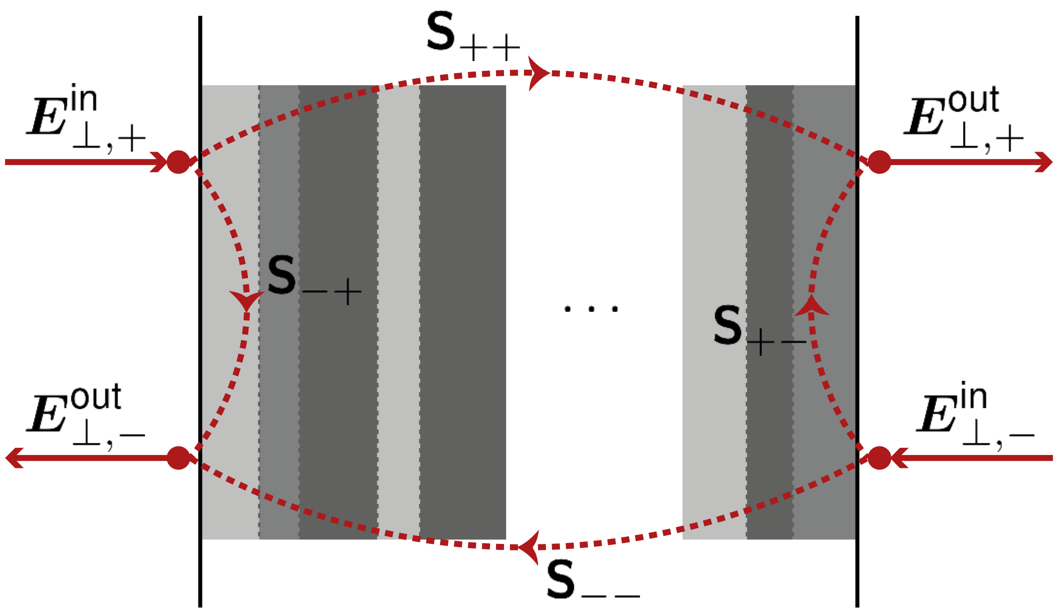


System Building Blocks – Layer Matrix Solver

The *Stratified Media Component* uses the layer matrix electromagnetic field solver. This solver works in the spatial frequency domain (**k-domain**). It consists of

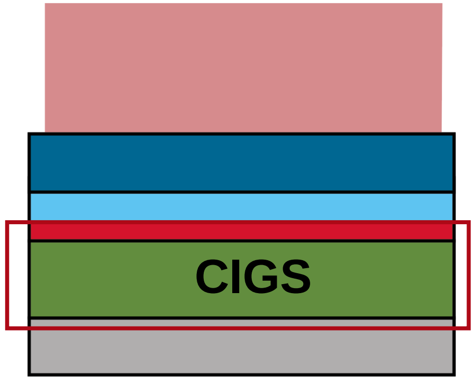
1. an eigenmode solver for each homogeneous layer and
2. an S-matrix for matching the boundary conditions at all the interfaces.

The eigenmode solver computes the field solution in the k-domain for the homogeneous medium in each layer. The S-matrix algorithm calculates the response of the whole layer system by matching the boundary conditions in a recursive manner. This is a method well-known for its unconditional numerical stability since, unlike the traditional transfer matrix, it avoids the exponentially growing functions in the calculation steps.

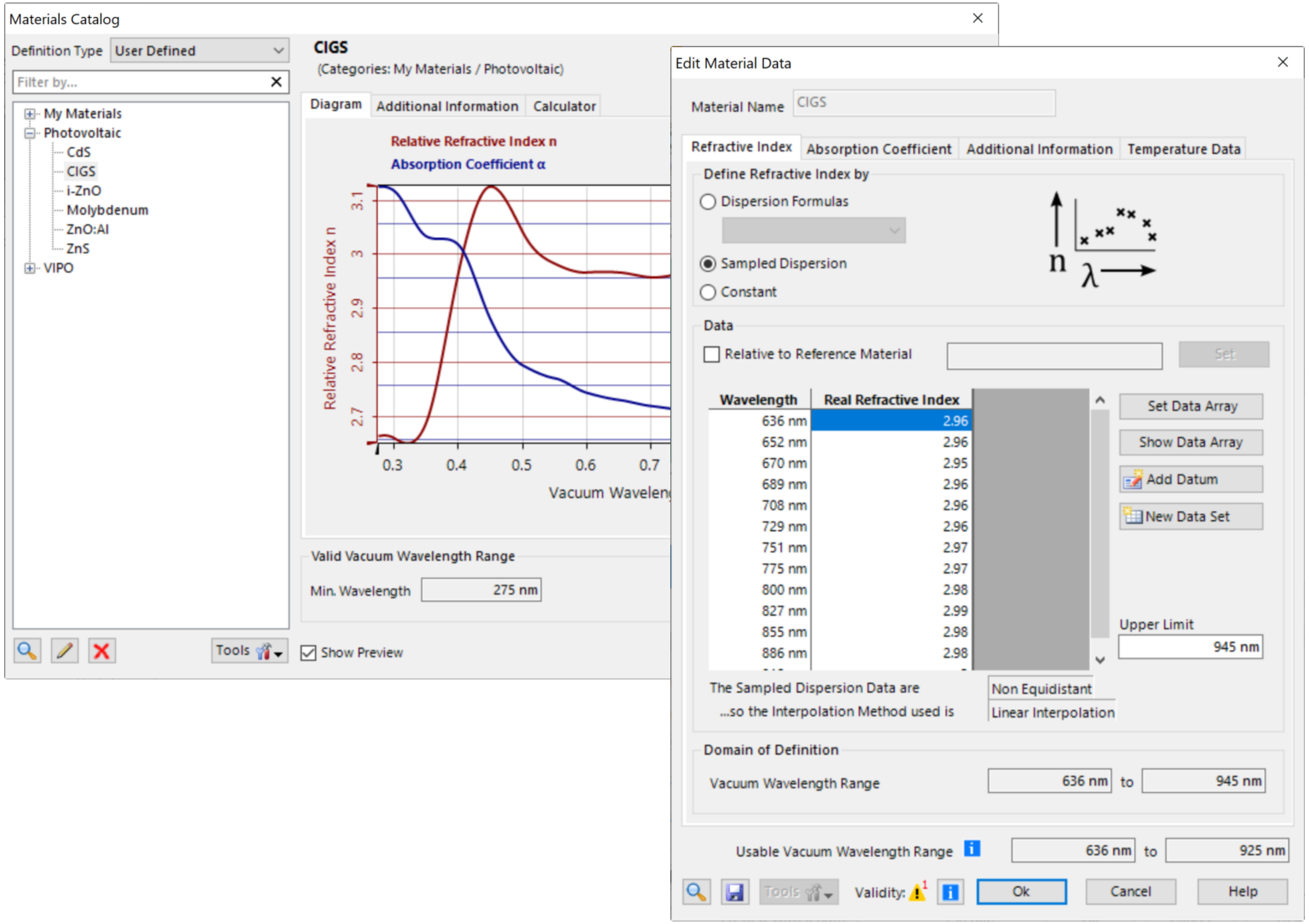


For further information:
[Layer Matrix [S-Matrix]]

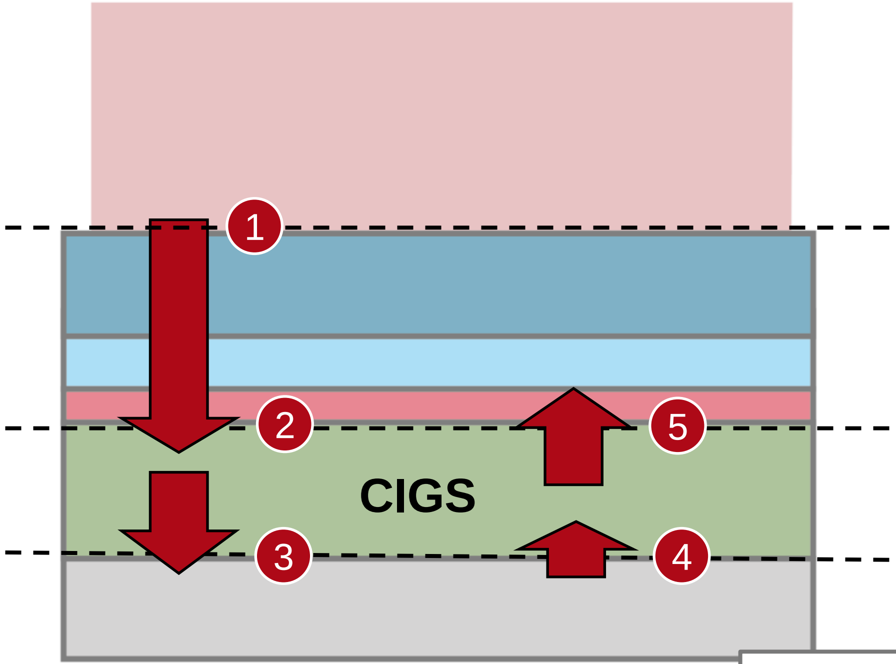
System Building Blocks – Sampled Media

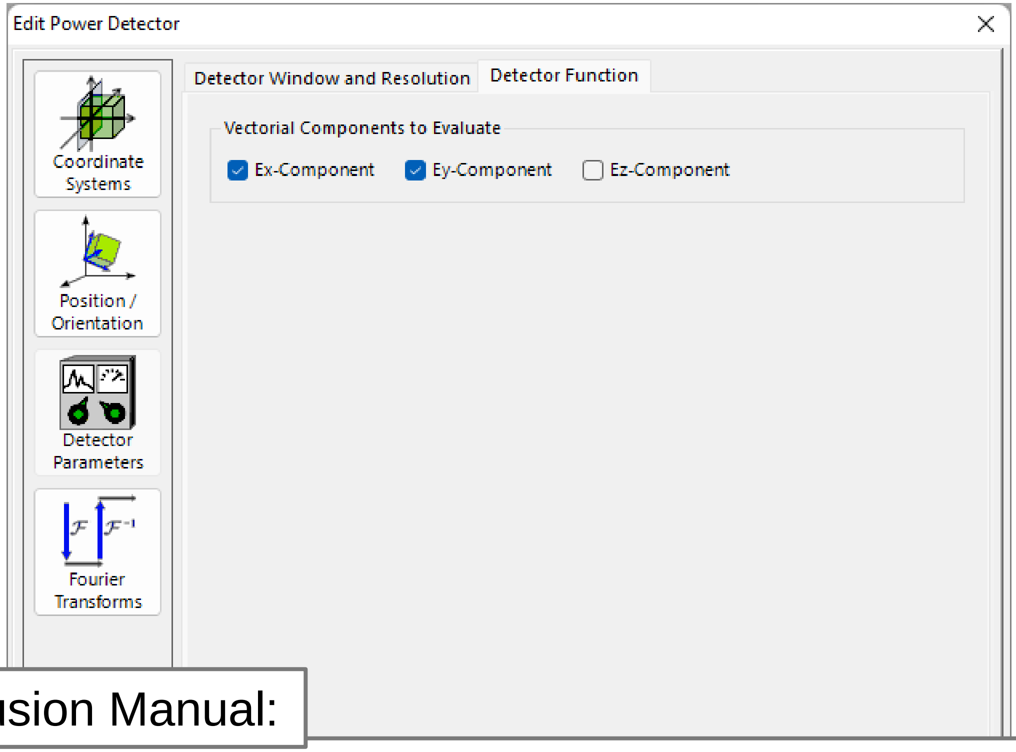


VirtualLab Fusion offers a comprehensive catalogue of different materials that can, among other things, be used for coatings. But it is also possible to import material data from measurements.



System Building Blocks – Detection





$$\text{Abs. Power} = \frac{P_2 - P_3 + P_4 - P_5}{P_1}$$

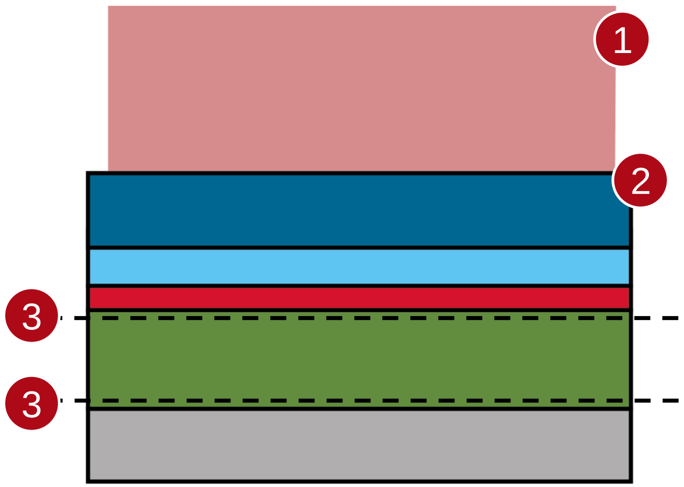
From VirtualLab Fusion Manual:

This detector calculates the power P in watts, either for the complete field in the detector plane or for a region of it. It is calculated via

$$P = n\frac{\epsilon_0}{2}c\sum_i \Delta_i \cdot A_i^2.$$

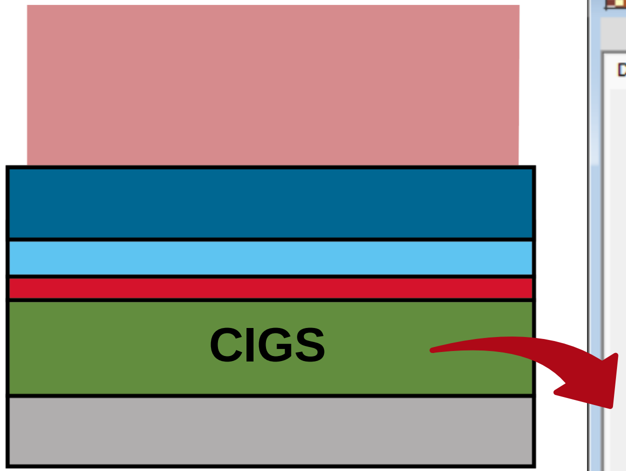
n is the refractive index derived from the embedding medium of the field, ϵ_0 is the dielectric constant and c is the vacuum speed of light. A_i is the squared amplitude of the data point i and Δ_i is the area this data point occupies (sampling distance in x-direction times sampling distance in y-direction for equidistant data).

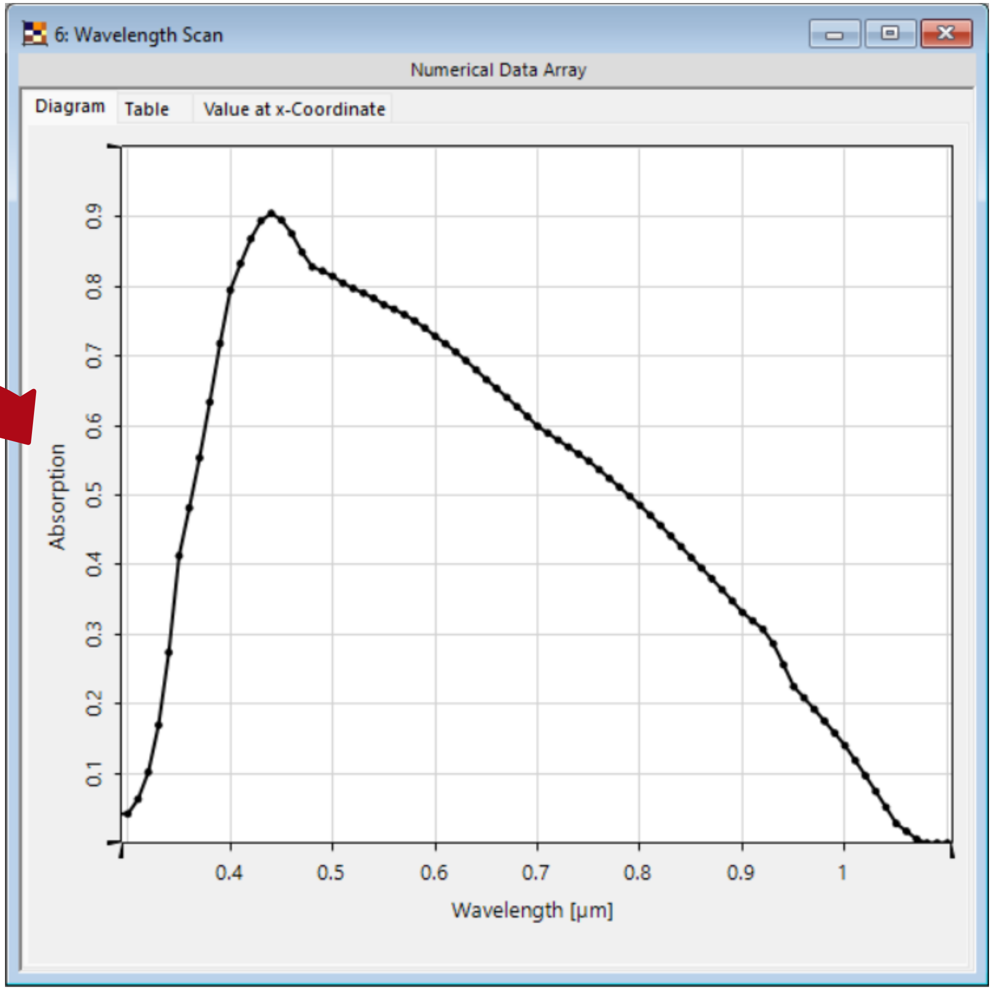
Summary – Components...

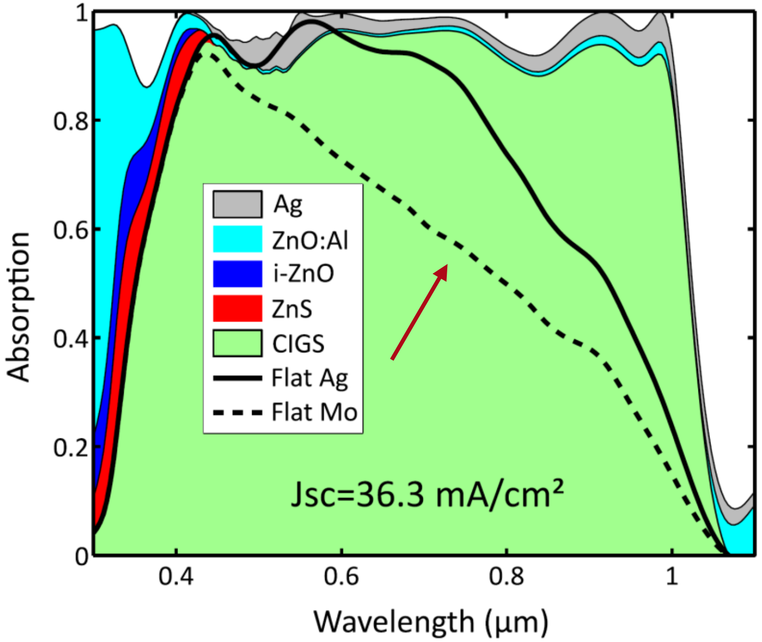


… of Optical System	… in VirtualLab Fusion	Model/Solver/Detected Value
1. source	*Plane Wave* (with *Homogeneous Power Spectrum*)	truncated Ideal Plane Wave (with homogeneous spectrum)
2. solar cell	*Stratified Media Component*	S-Matrix
3. detector	*Power Detector*	energy density integration

Absorption for Different Thicknesses of the CIGS Layer







***Reference:** J. Goffard et al., "Light Trapping in Ultrathin CIGS Solar Cells with Nanostructured Back Mirrors," in IEEE Journal of Photovoltaics, vol. 7, no. 5, pp. 1433-1441, Sept. 2017, doi: 10.1109/JPHOTOV.2017.2726566.*

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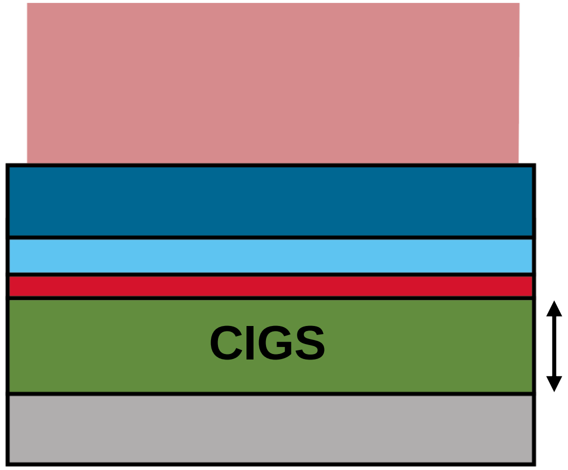
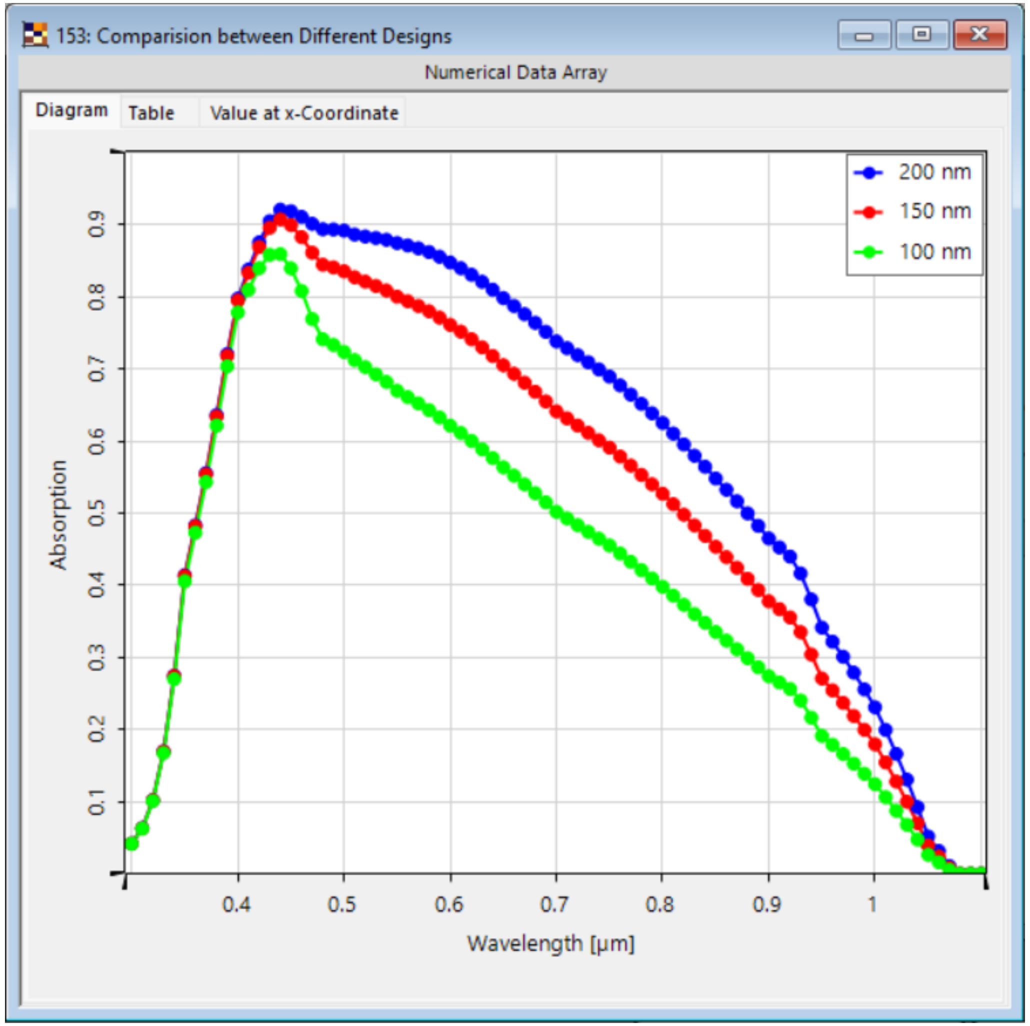


variation of thickness of CIGS layer: 100/150/200 nm

Thickness of the absorbing material is one of the most important factors influencing the overall efficiency of the cell.



Document Information

title	Absorption in a CIGS Solar Cell
document code	MISC.0096
document version	1.0
software edition	VirtualLab Fusion Basic
software version	2021.1 (Build 1.180)
category	Application Use Case
further reading	- Stratified Media Component