Benchmark

by comparison with other tools

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ComPhysics

Symbols and abbreviations used in E2M

Symbol	Meaning
L#	Layer index
T.	Thickness
λ	Wavelength
μ'	Real part of relative permeability
μ''	Imaginary part of relative permeability
ε'	Real part of relative permittivity
ε''	Imaginary part of relative permittivity
$\tilde{k}$	Normalized wave vector
GX#	G: Group index X: separator indicating multiplication #: Repetition count for the group
θ	Azimuthal angle
φ	Polar angle
TE	Transverse Electric
TM	Transverse Magnetic
R	Reflectance
T	Transmittance
A	Absorptance (R + T + A = 1)
α	Period thickness
c	speed of light

- **Introduction**

In this benchmark document, we compare extracted results from E2M and other rigorous tools such as MIT MEEP and MIT MPB for reflectance spectrum and photonic bands.

The comparison demonstrates that E2M delivers highly accurate results, leveraging the well-known precision of the Transfer Matrix Method (TMM) for 1D structures, all while requiring minimal computational resources. While results from MEEP and MPB can converge with E2M's semi-analytical solutions when sufficient computational resources are allocated, E2M provides accurate results instantaneously utilizing semi-analytical solutions.

The following three comparative studies are presented starting on the next page.

1. Reflectance spectrum of a planar interface

2. Reflectance spectrum of two planar interfaces

3. Photonic bands of a 1D structure

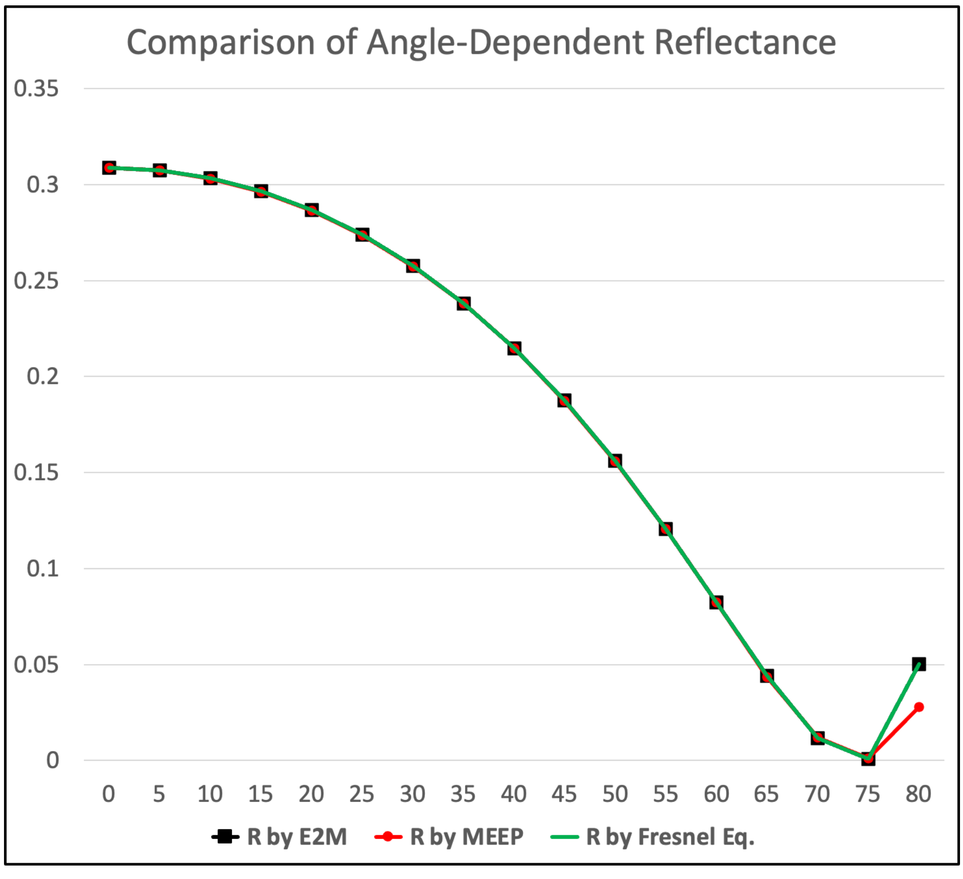
Comparison of the reflectance spectrum of a planar interface

The 1D layer structure used in this comparison is detailed in the table below.

LayerInfo

L#	Name	Thickness [μm]	Wavelength [μm]	Group#	Repetition#
0	n=1	1.0	0.4~0.9939999999999954	0	1
1	n=3.5	1.0	0.4~0.9939999999999954	0	1

A Jupyter notebook containing the Python script for the calculation of the reflectance spectrum within the MEEP environment is available at "https://comphysics.com/index.php/e2m-1d/" for users interested in reproducing the calculations. The comparison results are shown in the figure below.



Here, the x-axis represents the incident angle (degrees), and the y-axis represents the reflectance. From 0 to 75 degrees, the results among E2M, MEEP, and the Fresnel equation are identical. However, at 80 degrees, MEEP's result deviates from the other results, at least within the applied simulation conditions. Theoretically, by allocating sufficient computational resources and time, identical results can be obtained among the three methods.

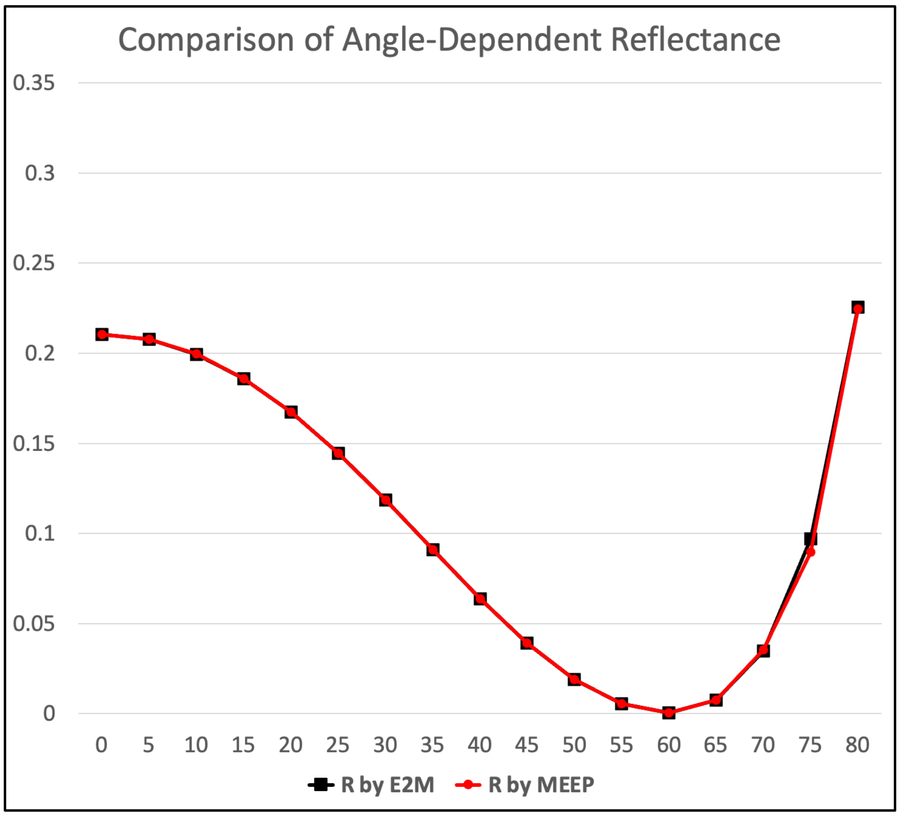
Comparison of the reflectance spectrum for a structure with two planar interfaces

The 1D layer structure used for this comparison is listed in the table below.

LayerInfo

L#	Name	Thickness [μm]	Wavelength [μm]	Group#	Repetition#
0	Vacuum	1.0	0.4~0.9939999999999954	0	1
1	n=2.5	0.6	0.4~0.9939999999999954	0	1
2	n=3.5	1.0	0.4~0.9939999999999954	0	1

A Jupyter notebook file including a Python code for the calculation of the reflectance spectrum within the MEEP environment is uploaded to "https://comphysics.com/index.php/e2m-1d/" as described in the previous section. The comparison results are shown in the figure below.



Here, the x-axis represents the incident angle, and the y-axis corresponds to the reflectance, consistent with the previous section. At the 75-degree point in the result, a significant discrepancy between E2M and MEEP is observed. Since TMM provides exact precision for 1D systems with small computational resources, users will find E2M to be a convenient and precise tool for analyzing 1D structures.

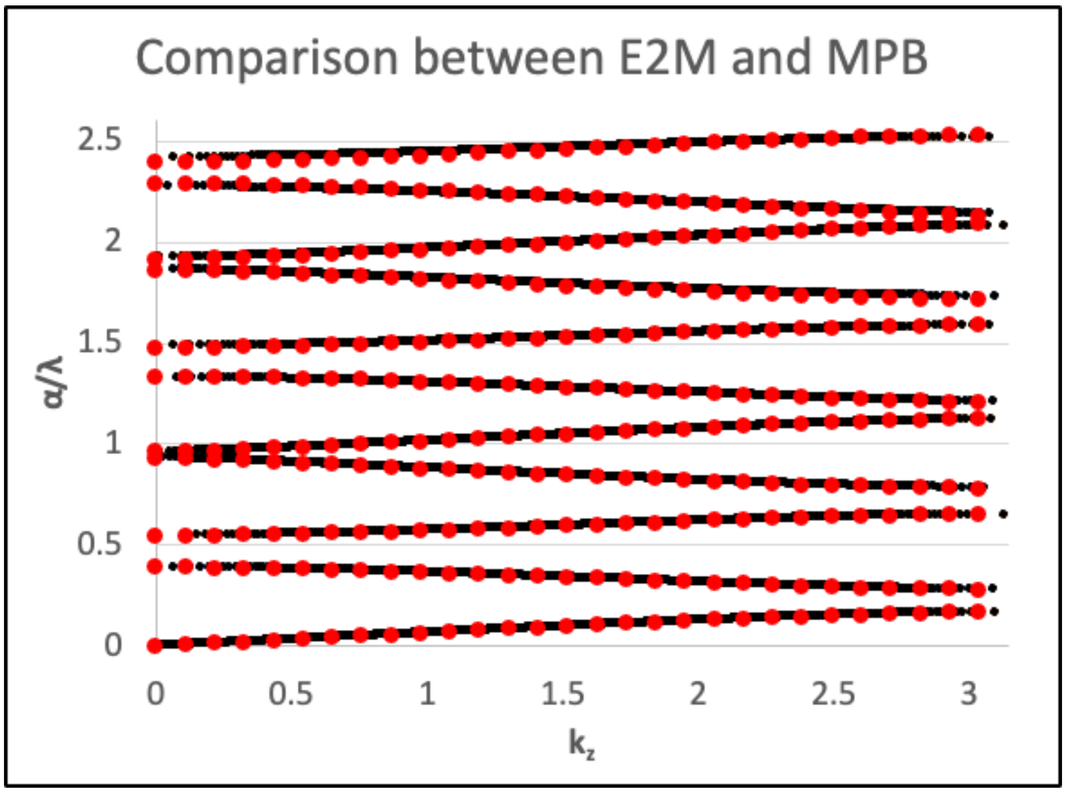
Photonic bands of a 1D structure

The 1D layer structure used for this comparison is listed in the table below.

LayerInfo

L#	Name	Thickness [μm]	Wavelength [μm]	Group#	Repetition#
0	n=1	0.5	0.00001~100000	0	1
1	n=3.25	0.5	0.00001~100000	0	1

A Jupyter notebook containing the Python code for the calculation of band structure is available at "https://comphysics.com/index.php/e2m-1d/" as in the previous sections. The comparison results are shown in the figure below.



The black and red points represent the results from E2M and MPB, respectively.

At longer wavelengths, the results from E2M and MPB show strong agreement in this figure. However, as the wavelength decreases, the deviation between the two results becomes more apparent, at least under the applied simulation conditions.