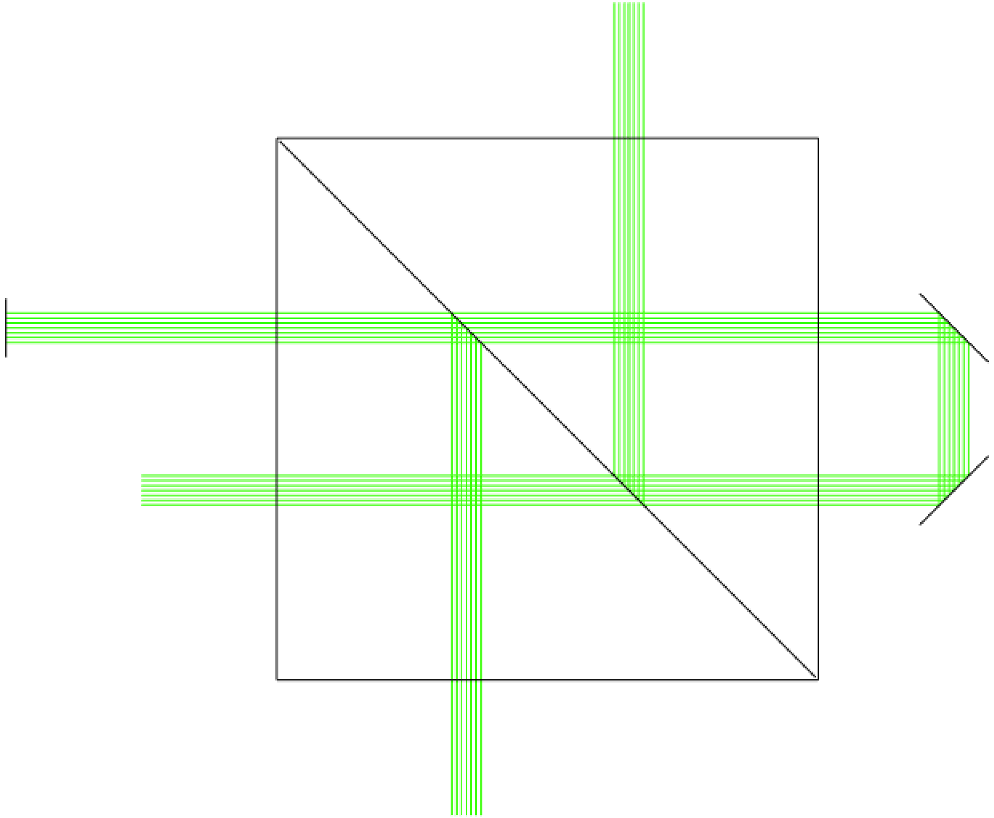
Frustrated Total Internal Reflection (FTIR) in a Cube Beam Splitter

Abstract

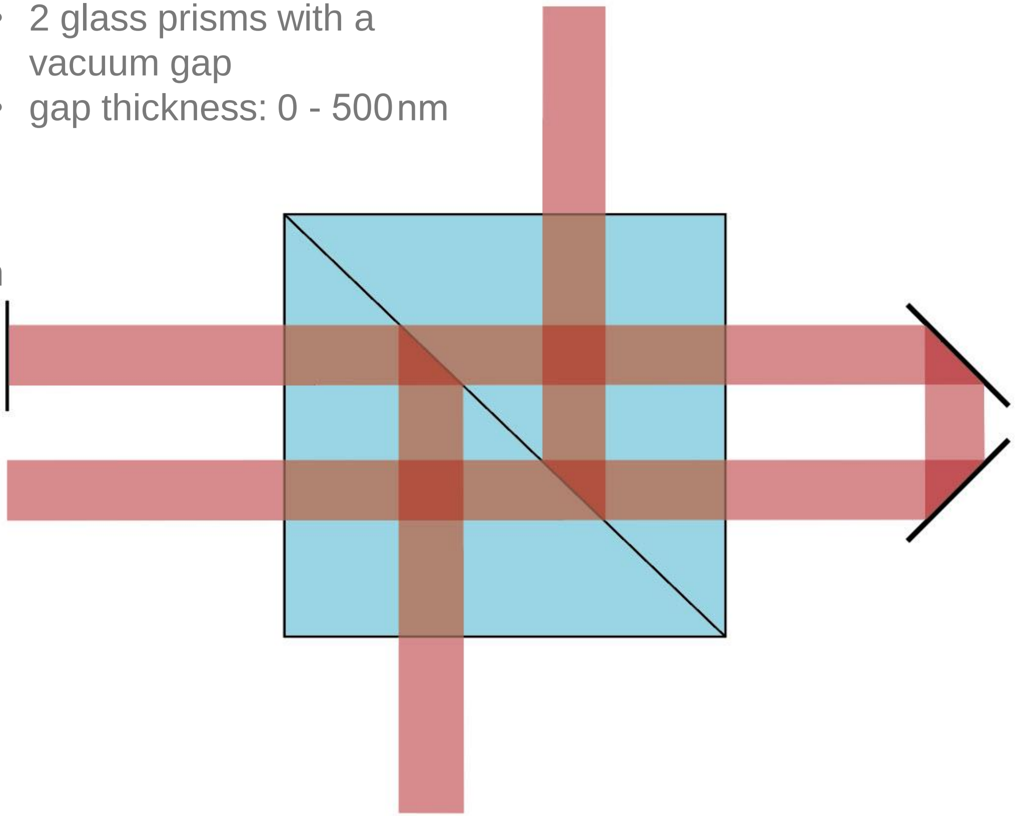


Optical beam splitter devices play a crucial part in many applications in the areas of spectrometry, interferometry and optical communication. A common type of beam splitter is based on the phenomenon of Frustrated Total Internal Reflection (FTIR): a first glass prism is set up so that the incident light impinges on one of its surfaces under conditions of total internal reflection, with a second prism placed directly behind it, so that only a very thin layer of a less dense material (air, for instance) separates the two prisms. If the separation layer is thin enough, the total internal reflection will be at least partially frustrated by the evanescent waves tunneling through the spacing, thus achieving a redistribution of the incident energy between the two outputs of the splitter which can be adjusted through the spacing.

Modeling Task

beam splitter
- 2 glass prisms with a vacuum gap
- gap thickness: 0 - 500 nm

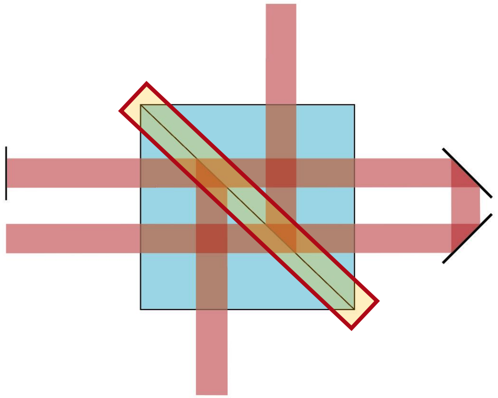
input field
- fundamental Gaussian
- wavelength 500 nm
- TE/TM Polarization



ideal mirrors

detectors
- energy density

Connected Modeling Techniques: Sub-Wavelength Gap

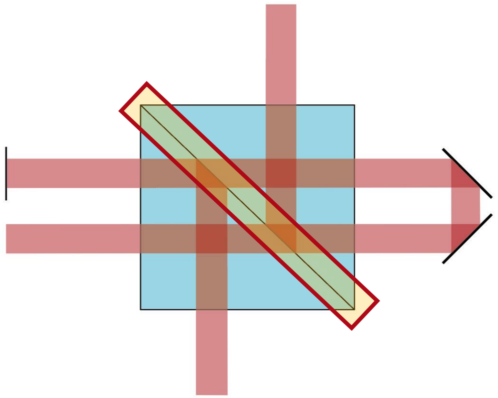


Available modeling techniques for interaction with surfaces:

Methods	Preconditions	Accuracy	Speed	Comments
Functional Approach	-	Low	Very High	No Fresnel Losses
S-matrix	Planar surface	High	High	Rigorous model; includes evanescent waves; k-domain
Local Planar Interface Approximation	Surface not in focal region of beam	High	High	Local application of S-matrix; LPIA; x-domain

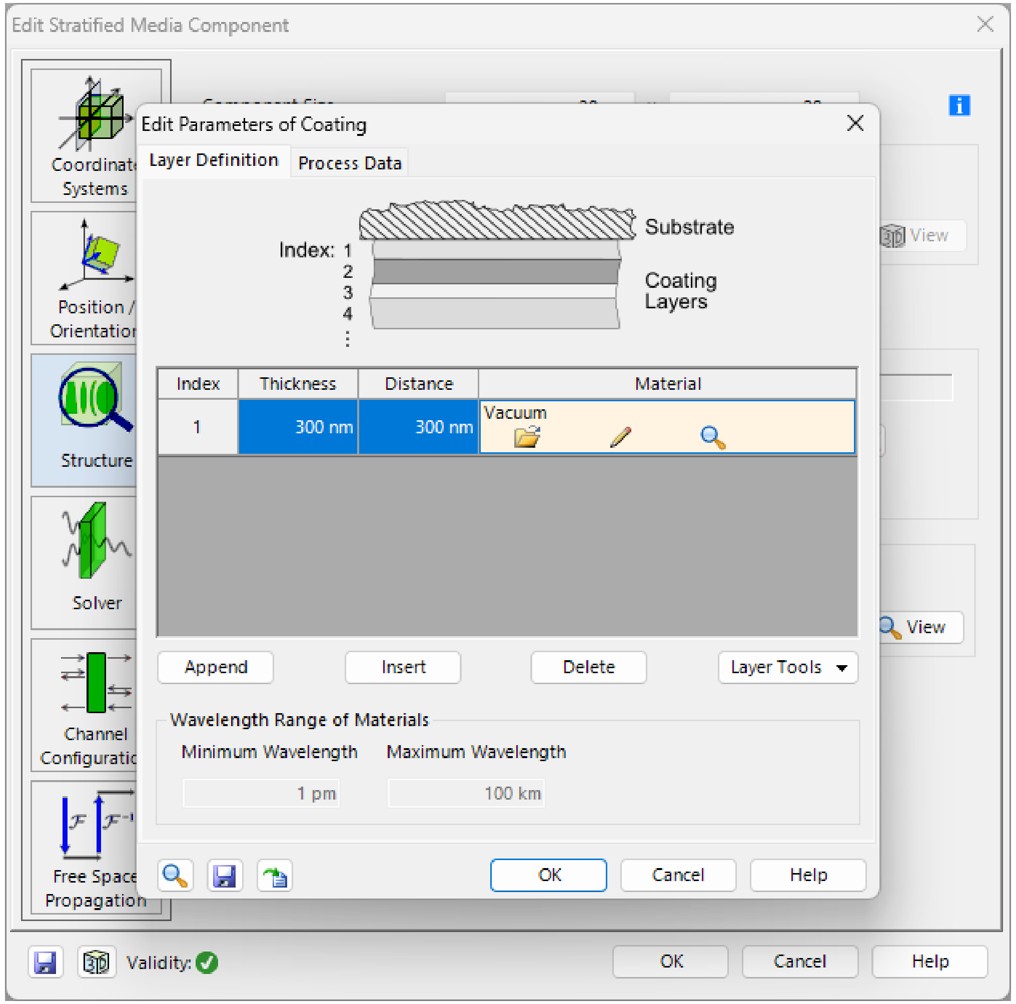
Since evanescent waves tunneling through the gap are the cornerstone of this setup, it is necessary to select a modeling technique that takes them into account. We select the rigorous S-matrix/Layer Matrix algorithm (developed precisely for an x,y-invariant layered structure, which perfectly describes the gap in this system).

Frustrated Total Internal Reflection (FTIR)



The gap between the prisms is modeled by a *Stratified Media Component*. While originally designed to simulate systems with many different layers, the underlying S-Matrix solver is also capable of modeling a single narrow gap rigorously. More information about the *Stratified Media Component* under:

[Stratified Media Component]



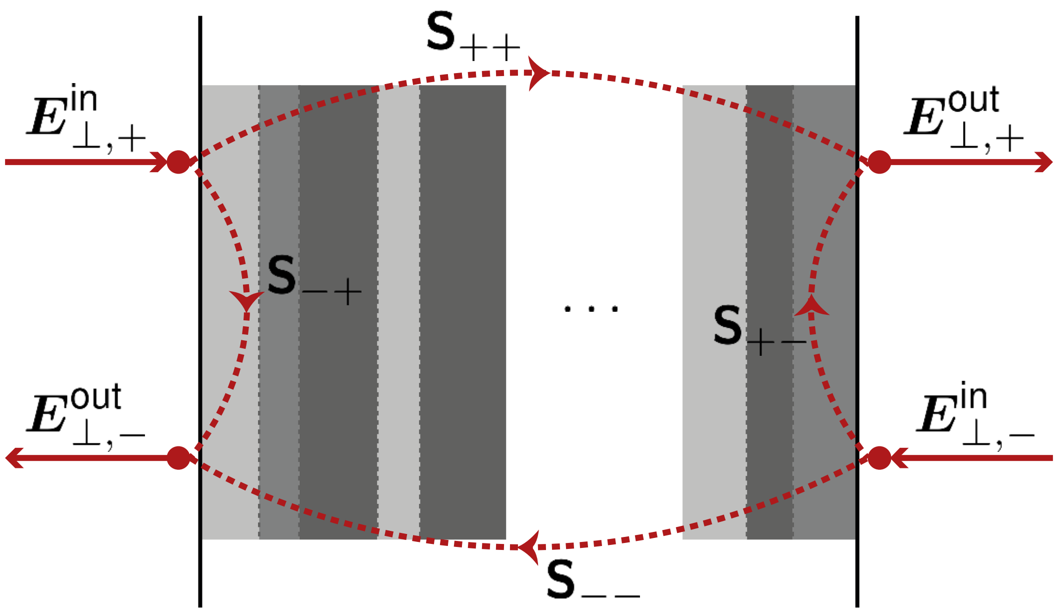
Layer Matrix Solver

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.

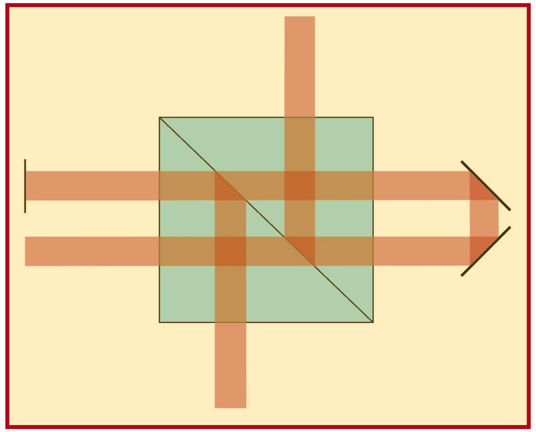
This is a method well-known for its unconditional numerical stability since, unlike the traditional transfer matrix, it avoids the exponentially growing functions in the calculation steps.

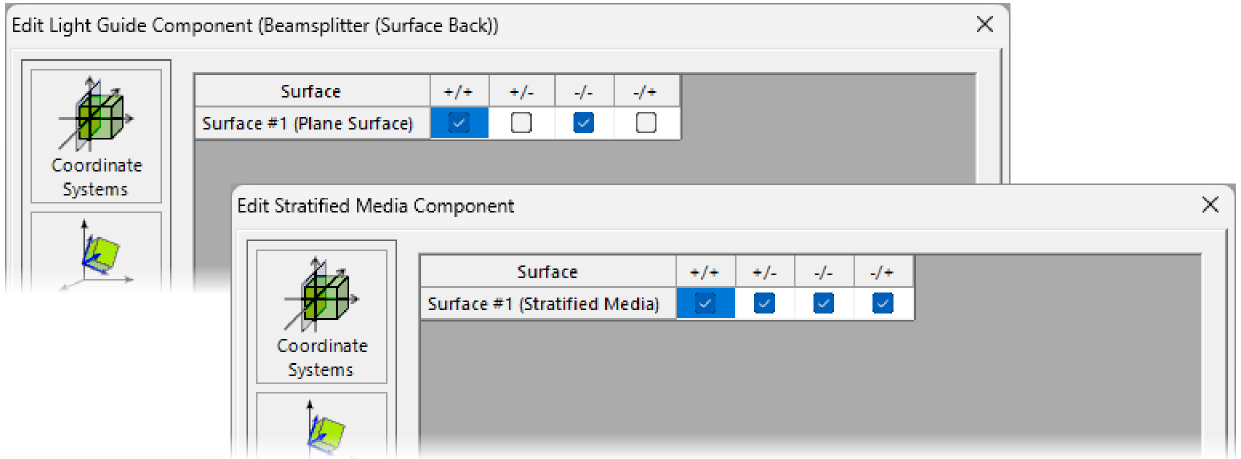


For further information:

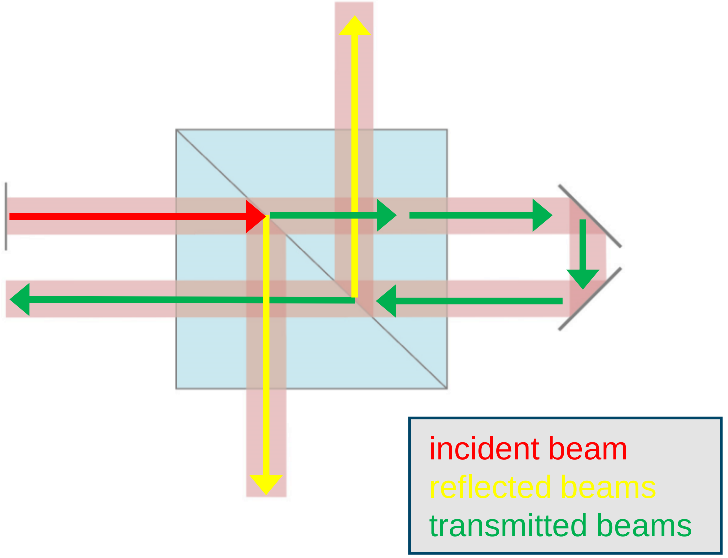
Layer Matrix [S-Matrix]

Non-Sequential Tracing



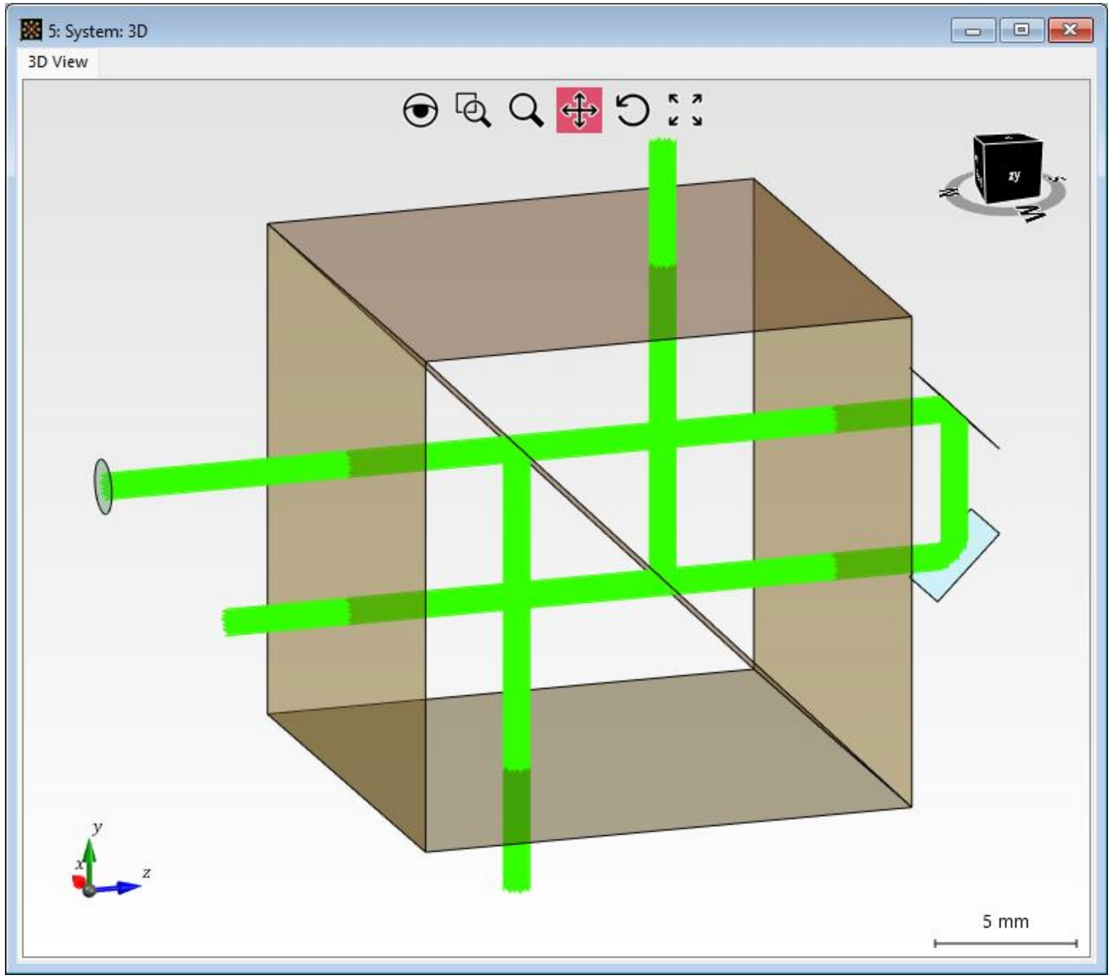


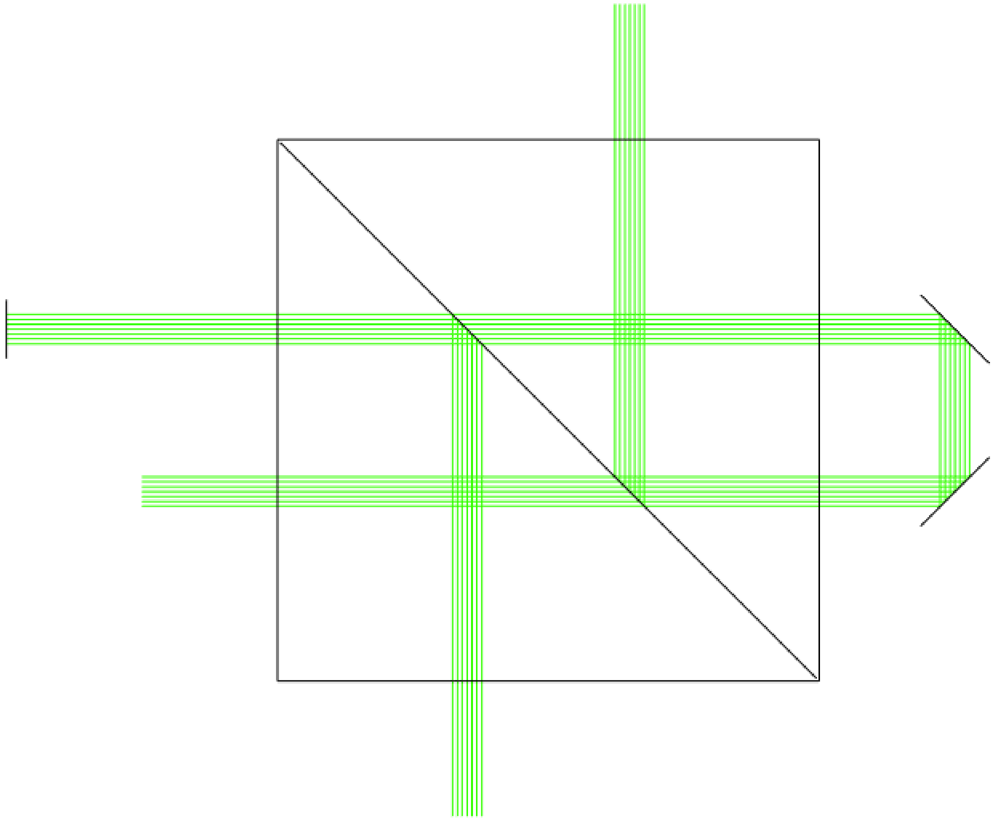
With the channel configuration mode set to *Manual Configuration*, the user can specify which light paths are followed in the simulation, for each surface in the system individually. When the simulation is performed, the available light paths are determined by the so-called *Light Path Finder*. The field is then traced along these paths through the configured setup.



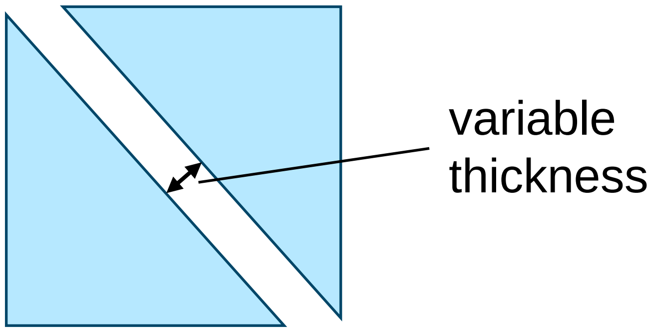
Channel Setting for Non-Sequential Tracing

System Overview (Ray Results Profile: System 3D)





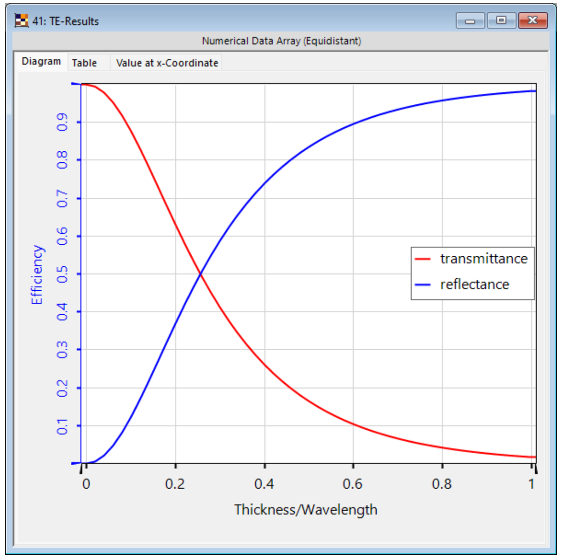
Analysis of Gap Thickness



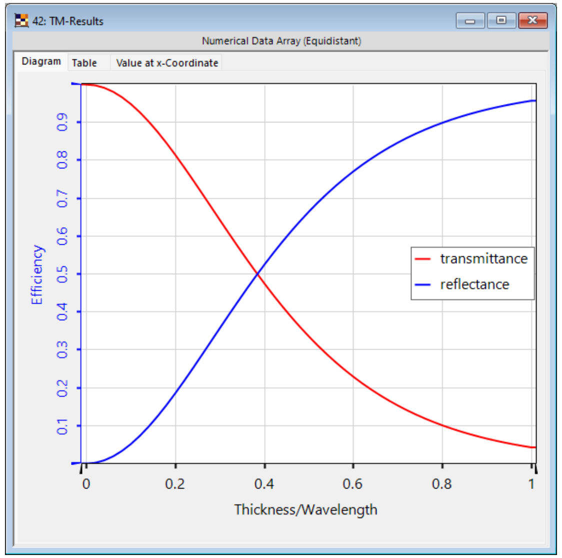
The ratio of reflectance and transmittance in an FTIR-based cube beam splitter strongly dependents on the thickness of the gap between the prisms. In this example, this effect is investigated for a thickness range between 0 nm and 500 nm. We compare the results obtained with VirtualLab Fusion against a published reference:

Reference: Chang Chien et al. "Design Analysis of a Beam Splitter Based on the Frustrated Total Internal Reflection", Prog. Electromagn. Res., Vol. 124, 71-83, 2012.

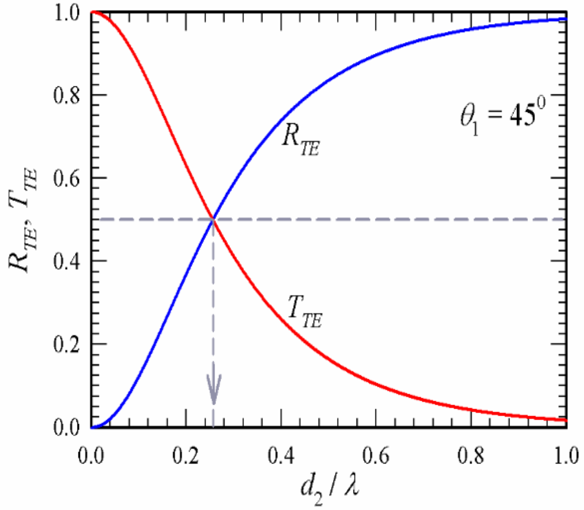
TE:

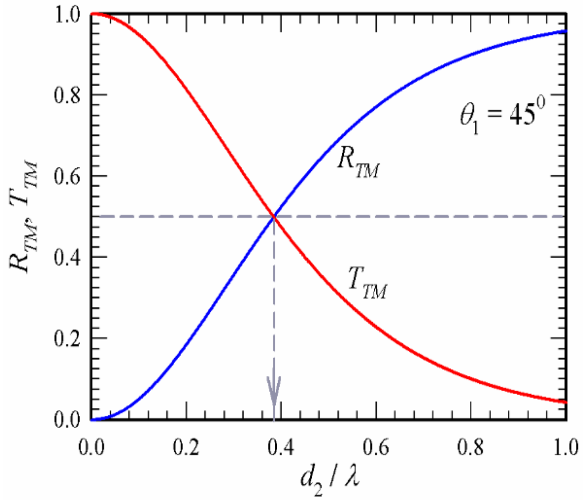


TM:



Results from reference:





Document Information

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