Grating Simulation gallery in OptiFDTD

What kind of grating layout OptiFDTD can simulate?

Grating are basically periodic layout that may contain chirp or Apodization. The wave inside the grating may complex: scattering field, transmission field, diffraction field are all exist, which ask the more advanced simulation tools for high accuracy results. From wave effect, grating layout can be seen as two groups: waveguide grating (See Figure 1a and 1b) and surface grating or volume grating (See figure 1c and 1d). OptiFDTD is suitable for all of these grating simulations. The following are samples for Grating simulation and numerical validation.

1. Metallic surface grating

Figure 1 shows the silver surface grating with plane wave shine in the different angles. The layout extends to y-direction for a relative longer distance compared to the input wavelength, so the simulation can set as 2D simulation. Drude model is used for the silver. The periodic silver surface can be designed by VB scripting or the PBG editor.

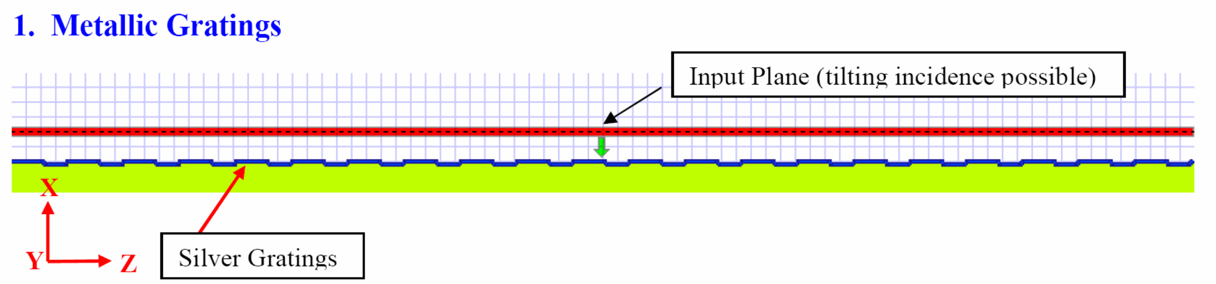
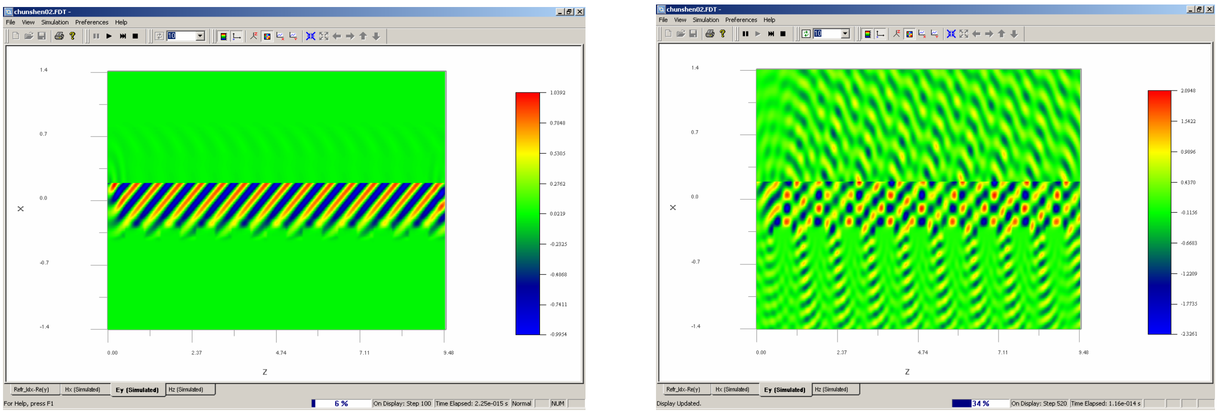


Figure 1, Silver Grating

When tilting plane wave is launched to the layout, the time domain wave propagation can be observed in the simulator. OptiFDTD used the Total-Field/Scattering field (TF/SF) algorithm for the input wave excitation. This TF/SF technical make the pure reflected wave and transmitted wave are obtained in the same simulation. Figure 2(a) is the plane wave response before it accesses the grating surface. Figure 2(b) is the time domain scattering field, diffraction field and transmitted field.



(a) (b)

Figure 2 time domain field response

After the simulation, steady state response can be observed in the analyzer. Using VB script the input angle scan simulation can be done.

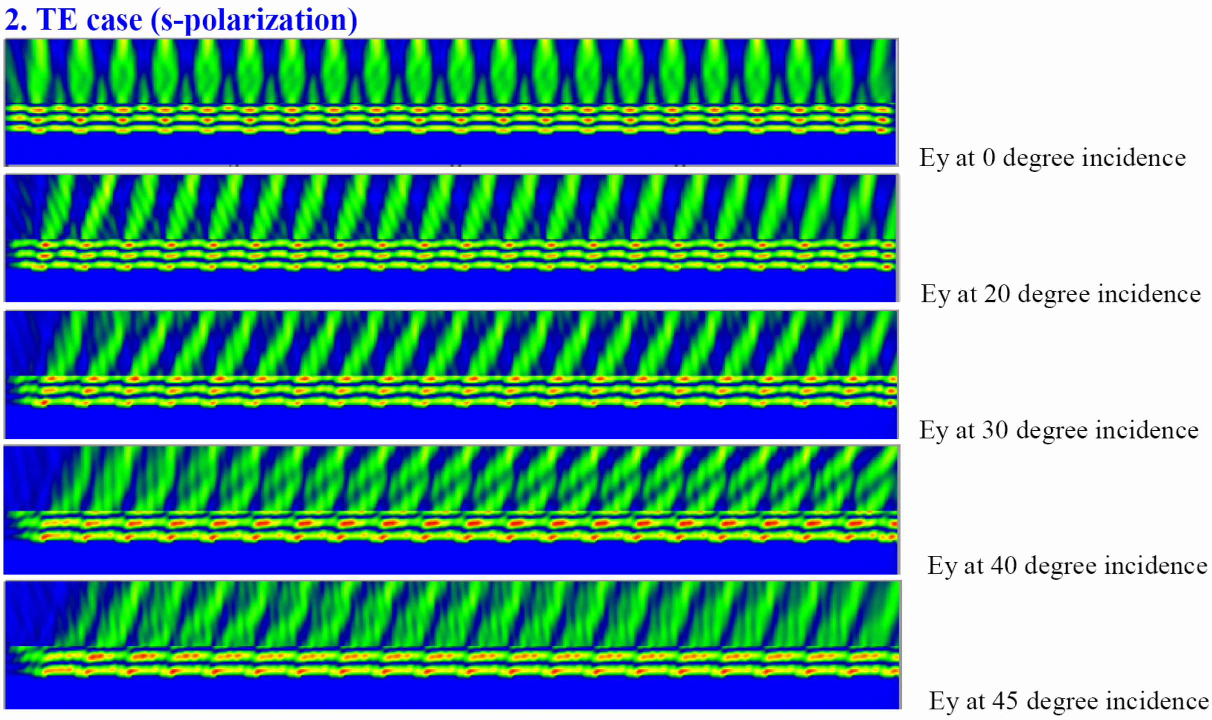


Figure 3 Steady- State field response for different input angle

Slice Viewer in Analyzer allow us to observe the near field in each slice (see figure 4). Then Far-field transform can allow us to find the diffraction field direction and diffraction efficiency (see figure 5).

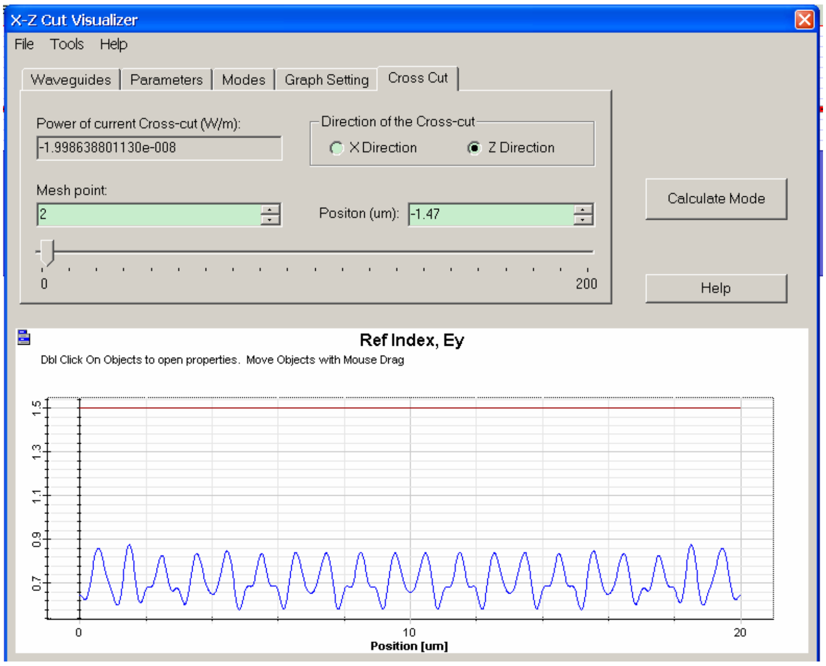
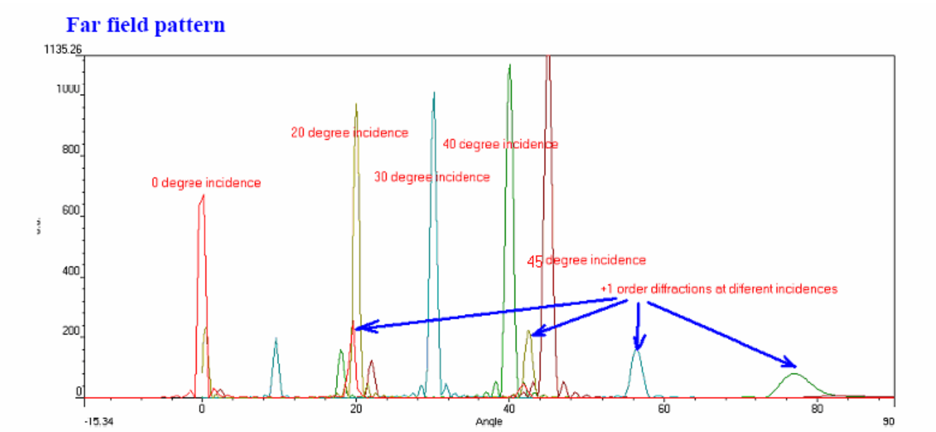


Figure 4 Near field in slice viewer



Diffraction Efficiency Results:

Incident angle (degree)	Incident intensity	+1 order diffraction angle (degree)	+1 order diffraction intensity	Diffraction efficiency (Equation 17.3a)
0	1574	19	255	0.153
20	1574	42	220	0.111
30	1574	57	160	0.064
40	1574	77	81	0.015

Figure 5 Far field pattern and Diffraction efficiency

2. Numerical validation for grating simulation

The first numerical validation for grating simulation is a Directional Grating Coupled Radiation in waveguide Structure as shown in Figure 1. The Original layout was published in IEEE Journal of quantum electronics, Vol. 40, July2004, Curt,A. Flory, " Analysis *of Directional grating-coupled radiation in waveguide structures*",

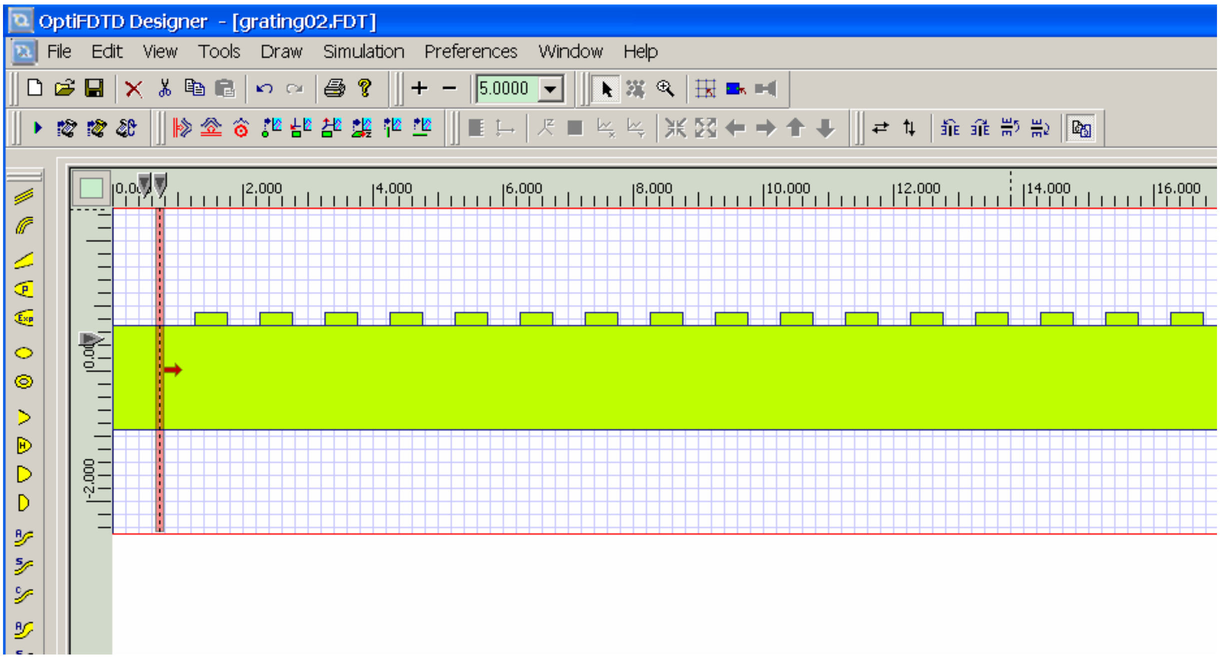


Figure 1 Directional grating Coupled waveguide in OptiFDTD

Results in original reference (the diffraction angle is said at 190.3 and 349.7)

A. Single-Level Rectangular Grating

In order to verify the validity of the VCM technique as applied to grating structures, and highlight the directionality effects induced when a bilevel grating is employed, some results for a simple single-level rectangular grating are shown. The waveguide structure with the rectangular grating has the form and dimensions shown in Fig. 7. For this choice of parameters, (28) of Section III can be used to evaluate the (normalized) angular distribution of diffracted radiation, which is displayed in Fig. 8. The radiation is symmetrically peaked into and out of the substrate at angles of 190.3° and 349.7° respectively, as defined in Fig. 7. This agrees well with published results, which were obtained using Bloch waves and coupled mode analysis in an iterative technique [2].

OptiFDTD results.

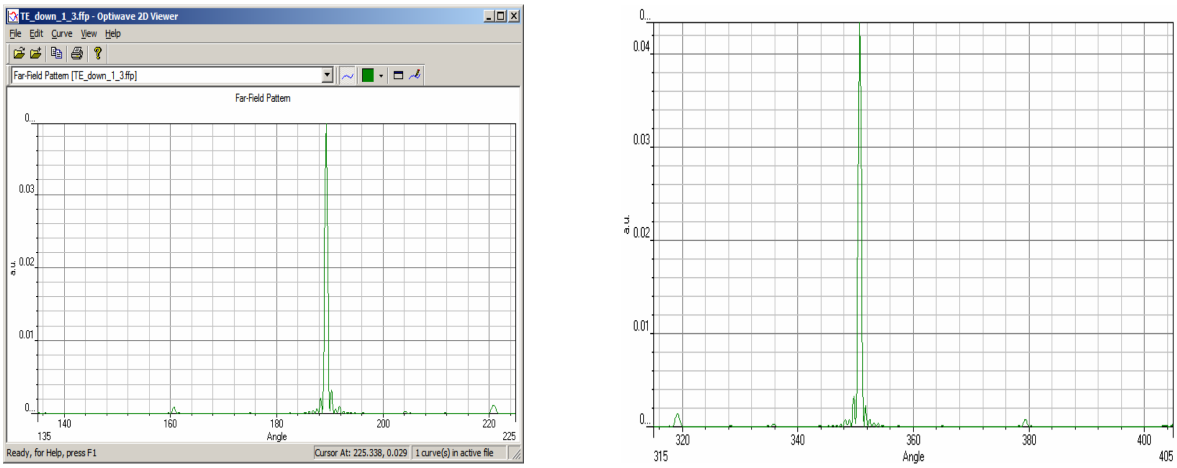


Figure 2 Far field in OptiFDTD θ=189.3, 350.7

The next numerical validation is a surface grating, The diffraction efficiency are comparedwith the published reference.

表 1 耦合波理论与光栅的标量衍射理论比较

衍射效率		0	±1	±2	±3
耦合波理论	Λ = λ	0.7310	0.1230	0	0
	Λ = 2λ	0.0793	0.3600	0.0866	0
	Λ = 3λ	0.0332	0.3810	0.0403	0.0397
	Λ = 4λ	0.0197	0.3850	0.0233	0.0316
	Λ = 5λ	0.0125	0.3820	0.0141	0.0322
	Λ = 10λ	0.0031	0.3880	0.0032	0.0425
标量衍射理论		0	0.4050	0	0.0450

Figure 2 Grating efficiency in reference using couple mode theory)

	0	±1	±2	±2
Ù=λ	**0.7496**	**0.1054**	**0**	**0**
Ù=2λ	**0.1173**	**0.3622**	**0.0600**	**0**
Ù=3λ	**0.0337**	**0.4108**	**0.0322**	**0.0265**
Ù=4λ	**0.0250**	**0.4059**	**0.0245**	**0.0249**
Ù=5λ	**0.0145**	**0.4024**	**0.0159**	**0.0292**
Ù=10λ	**0.0038**	**0.4018**	**0.0045**	**0.0407**

Figure 3   Diffraction efficiency Results in OptiFDTD