PFSS Full Wave Solver: Unit Cell Design via Optimization

1. Create a new **System** by right-clicking **Application** in the **Model Hierarchy** and selecting **New System**.
2. Open a new PFSS simulation by right-clicking the new system and selecting **New Simulation** → **PFSS**.
3. Select the **Spatial Domain** object underneath **pfss** in the **Model Hierarchy** to view its **Property Editor**. In the **Property Editor**, change the **Width** to **2.5 µm** and **Height** to **2.5 µm** (you can enter **um** to specify microns). Set the **Pixels,X** and **Pixels,Y** fields both to **12**.
4. Also in the **Spatial Domain**, change the **Permitivity of Lower Halfspace** to **1.9488**.
5. Next we need to build the **PFEBI Excitation**. To do this, right-click on **Excitations** → **New PFEBI Solver** in the **Model Hierarchy**.
6. In the **Property Editor** for **PFEBI_Excitation1**, change the **Frequency/Wavelength Start** and the **Frequency/Wavelength Stop** fields to **6 µm**. See Figure 1. In addition, set **Frequency/Wavelength Step** to **0.1 µm**.

Name	PFEBI_Excitation1
Frequency/Wavelength Start	6 um
Frequency/Wavelength Stop	6 um
Frequency/Wavelength Step	0.1 um
Step Count	1

Figure 1: PFEBI Settings

7. Import **Lead Telluride (PbTe)** and **Calcium Fluoride (CaF_2)** by right-clicking **Materials** → **Import Materials from Database...** and selecting them from the **Main** category.
8. Right-click on **Patterns** in the **Model Hierarchy** and select **New Binary**. Binary patterns specify a custom pixelated unit cell definition.
9. In the **Property Editor** for **BinaryPattern1**, set **Grid Size** to **12** by **12**. Then, create a pattern with which to seed the optimization by selecting cells on the grid. To select a cell, left-click it on the grid. To clear a cell, right-click it. The seed pattern used in this example can be seen in Figure 2. Once the pattern is created, click the **Assign as Parameters** button.

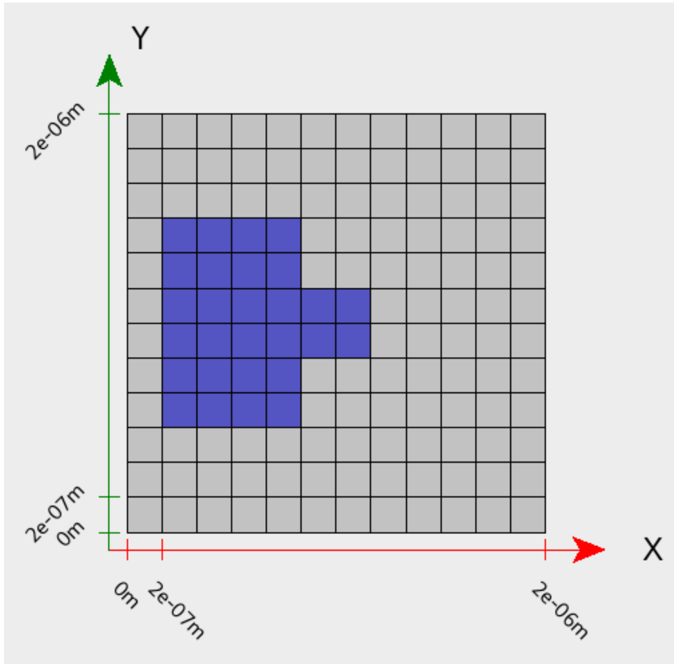

Figure 2: Seed Pattern

10. Now create a material layer by right-clicking on **Layers** in the **Model Hierarchy** and selecting **New Material Layer**.

11. In the created material layer, named **MaterialLayer1** by default, open the **Property Editor** and change the **Thickness** to **0.05 µm**.

12. Next we need to apply our pattern to the material layer in question. To do this, click the **Add** button at the bottom of the **Property Editor** for the material layer. Double-click the **pattern** column of the new table entry and select **BinaryPattern1** from the dropdown. Then double-click the **material** column and select the Calcium Fluoride (**mat__CaF2_**). The end result is shown in Figure 3.

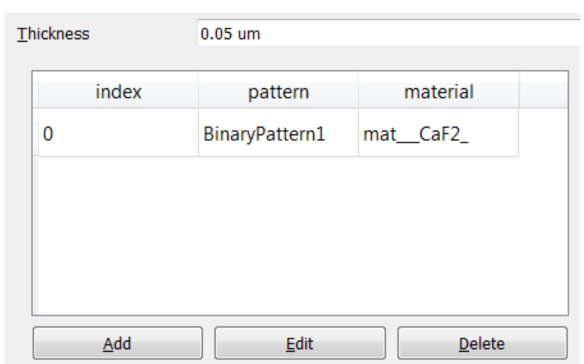

Figure 3: Material Layer Settings

13. Copy the layer you just created in Steps 10–12 either by repeating those steps or by right-clicking on **MaterialLayer1** and selecting **Copy**, then right-clicking on **Layers** in the **Model Hierarchy** and selecting **Paste**. Repeat this process until you have four layers.

14. For **MaterialLayer3** and **MaterialLayer4**, set the material column to Lead Telluride (**mat__PbTe_**).

15. To view the layers you just created, right-click on **Views** in the **Model Hierarchy** and select **New Layer Stackup**. The result should look something like Figure 4.

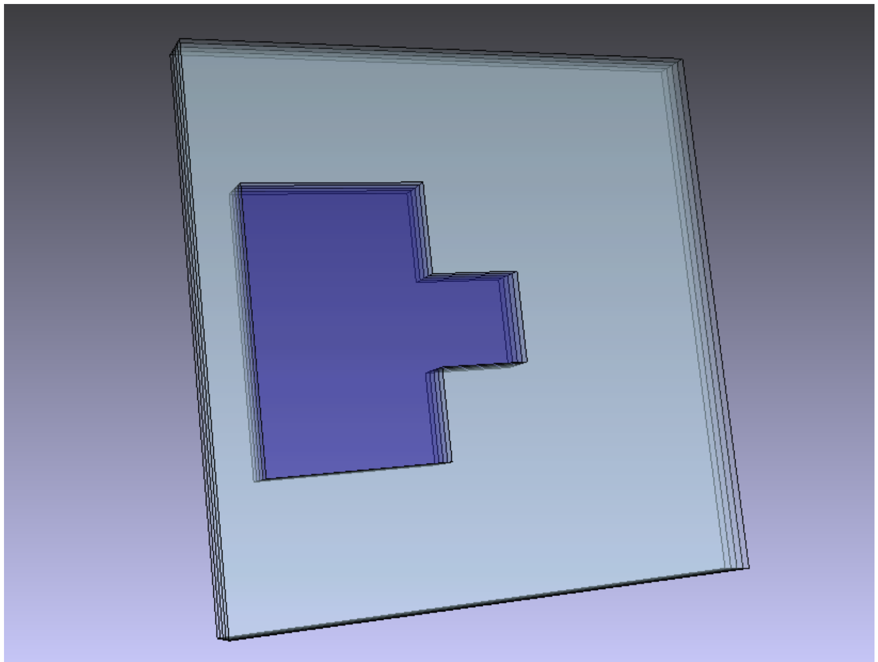

Figure 4: Layer Stackup View before optimization

16. Create a new **Genetic Algorithm** optimizer by right-clicking on **Design Studies** in the **Model Hierarchy** and selecting **New Genetic Algorithm**.

17. In the **Property Editor** for the new **GeneticAlgorithm1** set the **Cost Limit** to **-1**.

18. Underneath the new **GeneticAlgorithm1** object, right-click **Design Goals** and select **New Group**. Underneath the new **GroupGoal1** object, right-click **Design Goals** and select **New Goal** twice to add two **Result Goal** objects.

19. In the **Property Editor** for **ResultGoal1**, click the **Edit** button next to **Data Table Selection** and select **pfss** → **PFEBI_Excitation1_Result** → **TEScatteringData**.

20. Set **ResultGoal1**'s **Data** field to **CoPolTrn**, the **Operation** field to **phase**, and the **Comparison** to **equals (=)**. For this tutorial we set the **Target** field to **-22.5 deg** (approximately $^{15\pi}/_{8}\,\text{rad}$). However, you may set the target to a phase response of your choice.

21. In the **Property Editor** for **ResultGoal2**, click the **Edit** button next to **Data Table Selection** and select **pfss** → **PFEBI_Excitation1_Result** → **TEScatteringData**.

22. Set **ResultGoal2**'s **Data** field to **CoPolTrn**, **Operation** to **mag**, and the **Comparison** to **maximize**. Between the two goals now established, it should be possible to define a unit cell that delivers a specific phase response while maintaining a maximal transmission magnitude.

23. To allow the optimizer to modify the binary unit cell pattern, right-click **Optimization Ranges** underneath **GeneticAlgorithm1** in the **Model Hierarchy**, and select **New Binary Array**.

24. In the **Property Editor** for **ArrayBinaryRange1**, set the **Parameter** field to the array created by your pattern in Step 9. The default name for this array parameter is **BinaryPattern1_binary_pattern**. In addition, set the **Bit Array Length** to **144**.

25. Now that the optimization is ready to run, right-click **GeneticAlgorithm1** in the **Model Hierarchy** and select **Run**. Our run of the optimization produced the unit cell depicted in Figure 5.

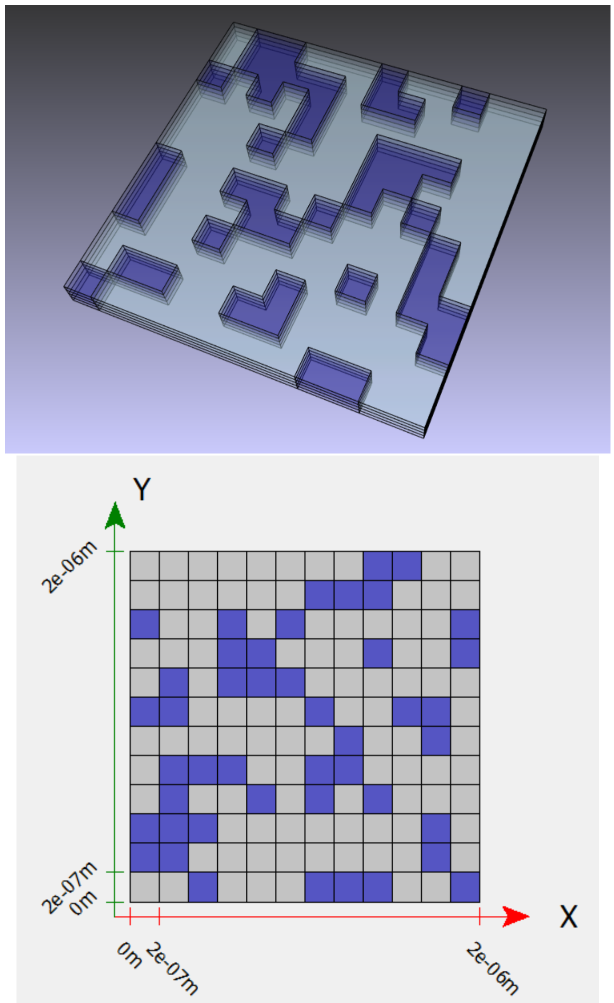

Figure 5: Layer Stackup View After Optimization(top), Pattern View (Bottom)

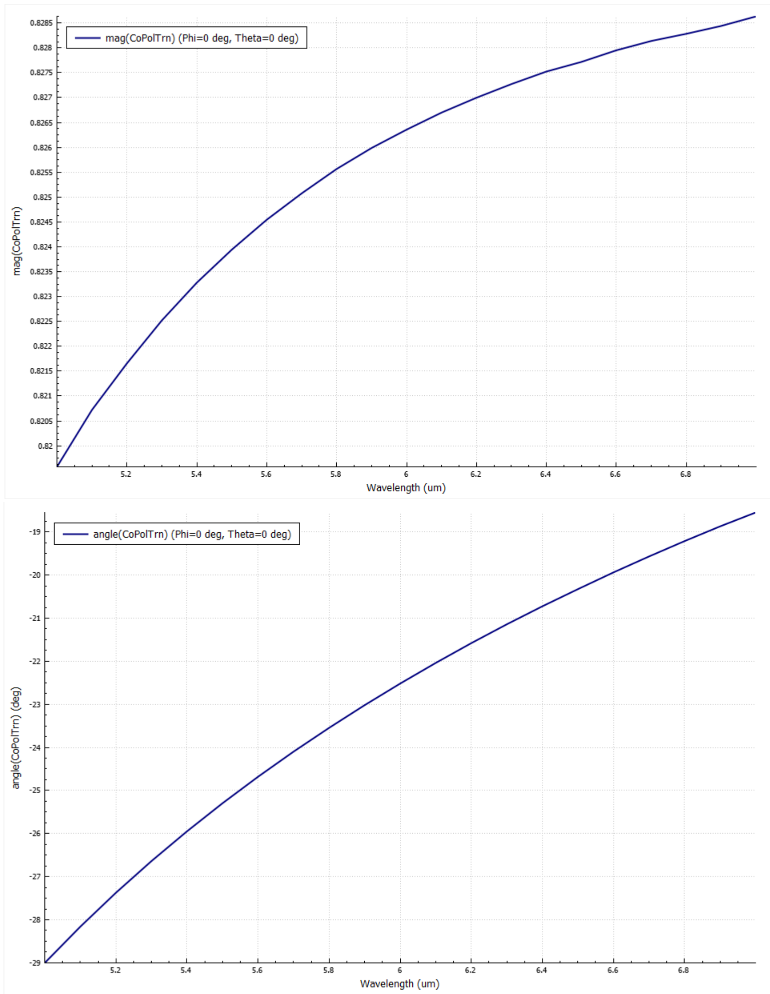

Figure 6: Transmission Magnitude (Top) and Transmission Phase (Bottom)

Select **Excitations** → **PFEBI_Excitation1** and change the **Frequency/Wavelength Start** and **Frequency/Wavelength Stop** fields to encompass the range you wish to plot. These plots range from 5 µm to 7 µm. Then, right-click **Results** → **PFEBI_Excitation1_Result** → **TEScatteringData** and select **Create Plot**. The new plot contains a **Trace** object that can display whatever information you want by changing its **Data Selection** and **Y Data** fields. More traces can be added to the same plot by right-clicking **Traces** and selecting **New Trace**. These plots utilize **Wavelength** as the **X Data**, however options such as **Frequency** are also available. Finally, to obtain the **phase** of a given data output, set the **Y-Operation** field to **Phase**.

