



Model created in COMSOL Multiphysics 6.4

Silicon on Insulator Optical Grating Coupler

Introduction

Silicon photonics combine low-cost and high-performance functionalities into the state-of-the-art optical systems, while maintaining a compact footprint. The high packing density allows for the integration of different photonic components like lasers, waveguides, and detectors on a single chip. However, there is a challenge when interfacing the chip with external systems. This is because the large size mismatch between the on-chip and the off-chip optical modes (that is, a single-mode optical fiber) might cause problems with the coupling efficiency and the overall device footprint. One solution to this problem is the use of optical grating couplers, which offer compact footprints, flexible placement anywhere on the die, relaxed alignment and packaging, and straightforward wafer-level testing. These advantages are especially attractive in large-scale photonic integrated circuits.

This model analyzes the performance of an optical surface grating coupler on a silicon-on-insulator (SOI) platform operating at 1550 nm wavelength. The device consists of a one-dimensional periodic grating patterned on the top of a silicon layer. The coupling efficiency and the radiation losses for different incident angles of a free space laser beam, to couple into the guided mode of the waveguide, is evaluated to characterize the coupler.

Model Definition

Figure 1 shows the schematic of a grating coupler on a SOI platform. A one-dimensional grating is patterned on top of a silicon layer, along the x direction, and the silicon layer is supported by an SiO_2 insulator substrate. A paraxial Gaussian beam is focused on the grating surface. The angle between the beam axis and the normal axis to the grating coupler is θ .

The fundamental operation of a grating coupler is based on the Bragg condition or the phase-matching condition. The gratings create a periodic variation of refractive index of the waveguide that enables to couple external light into the waveguide mode upon satisfying the phase-matching condition. For coupling between the incident light and the fundamental mode of the waveguide, the phase-matching condition is expressed as

$$\beta = kn_{\text{eff}}\sin\theta + m\frac{2\pi}{\Lambda}. \quad (1)$$

In Equation 1, β is the propagation constant of the guided mode, k is the wavenumber in the incident medium, n_{eff} is the effective index of the guided mode, Λ is the periodicity of the gratings, and m is the grating diffraction order.

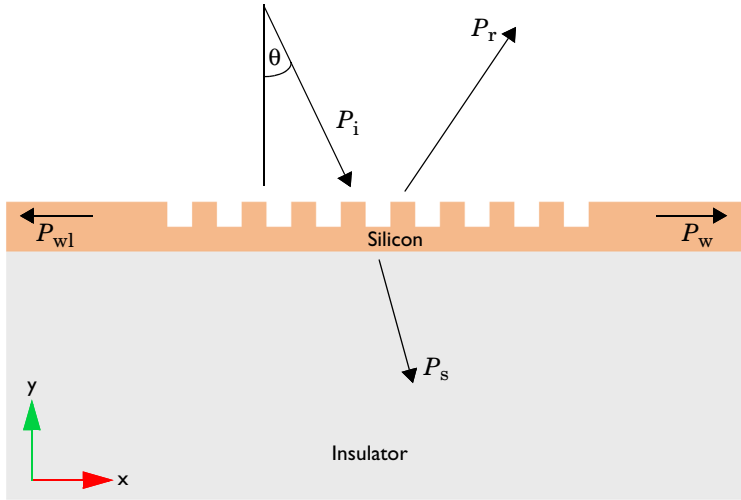


Figure 1: The modeled SOI grating coupler. The model considers a one-dimensional periodic grating patterned on top of a silicon layer that is supported by an SiO₂ insulator.

To estimate the coupling efficiency, the power loss through the major channels should be considered. Firstly, some uncoupled power P_s will propagate downward and leak in to the insulator substrate. Secondly, some portion P_r will be reflected from the grating coupler surface back to the incident medium. Thirdly, some portion P_{wl} is coupled to the waveguide, but propagates in the opposite direction, especially when the incident beam axis is near the normal axis to the grating coupler surface. The final coupled power into the waveguide is expressed as

$$P_w = P_i - (P_s + P_r + P_{wl}) \quad (2)$$

The performance of the grating coupler depends on the incident angle of the beam. This is because the incident angle determines how well the in-plane momentum of the incident wave matches the momentum of the guided mode.

Results and Discussion

Figure 2 shows the electric field norm of the total field for an incident angle $\theta = 12^\circ$. The incident beam is coupled as a fundamental mode into the waveguide through the grating

coupler and propagates dominantly in the +x direction. Some of the incident waves are reflected back from the grating coupler while others are transmitted to the transmission side insulator domain.

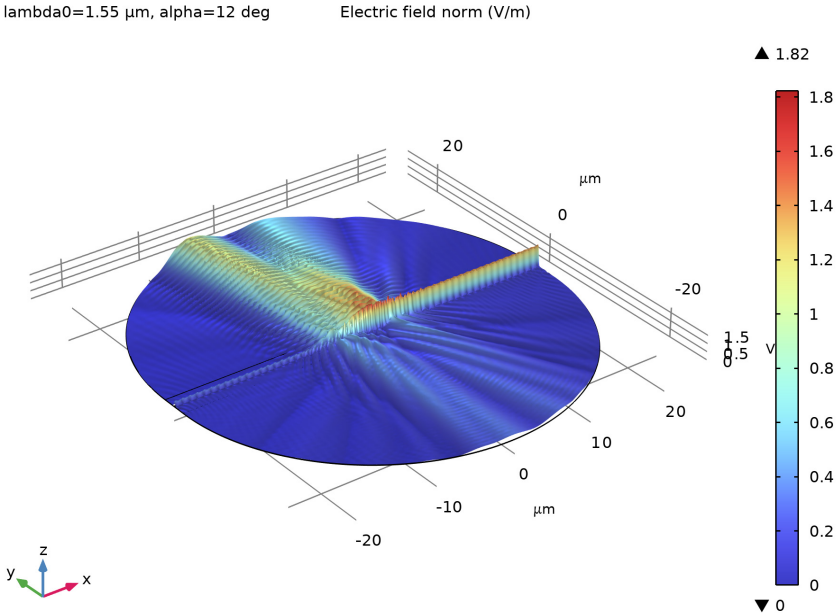


Figure 2: Total electric field norm for incident angle $\theta = \pi/15$.

Figure 3 and Figure 4 show the norm of the electric field of the fundamental guided mode at the cross sections of Port 1 and Port 2, respectively.

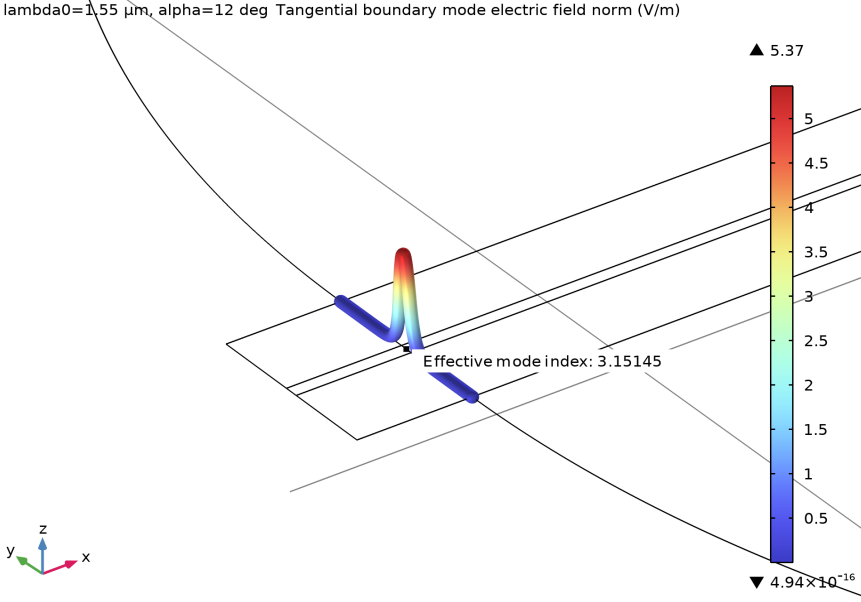


Figure 3: The norm of the electric mode field for Port 1.

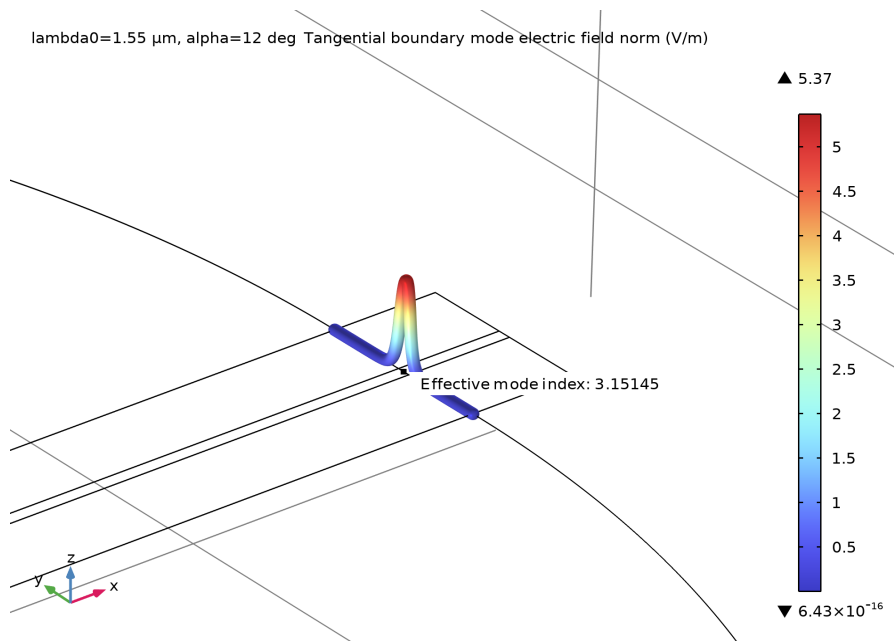


Figure 4: The norm of the electric mode field for Port 2.

Figure 5 shows the calculated reflectance and transmittance for the Gaussian beam, as well as the power of the guided mode flowing through Port 1 and Port 2 versus the incident

angles. Optimal coupling occurs for the incident angle $\theta = 12^\circ$, where the power of the fundamental mode flowing through Port 2 is at its maximum.

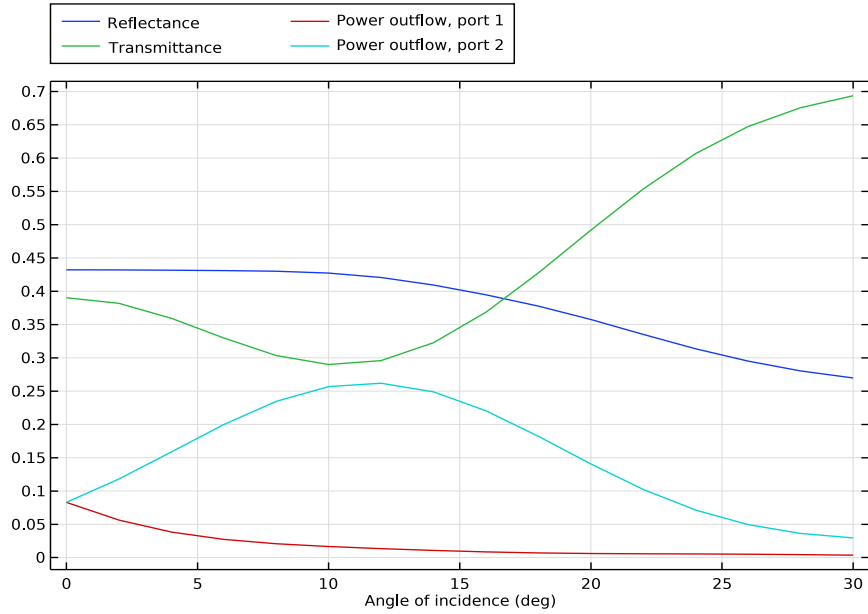


Figure 5: A plot of the reflectance, transmittance, and power outflow of the guided mode through Port 1 and Port 2 versus incident angles.

The radiation loss plot in Figure 6 shows that the loss is minimum for the incident angle $\theta = 12^\circ$, where the coupling efficiency is maximum.

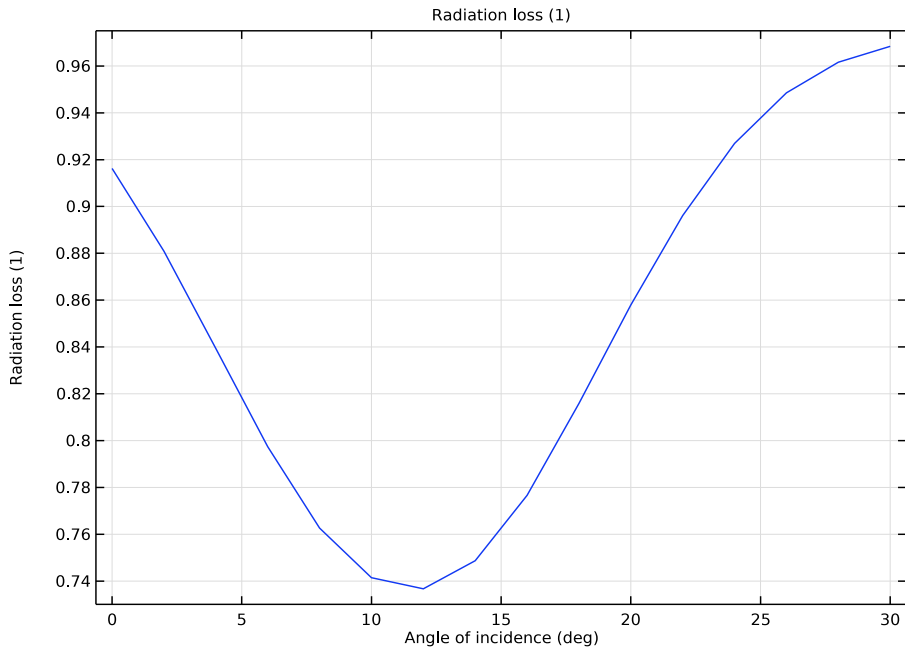


Figure 6: Radiation loss versus incident angles.

Notes About the COMSOL Implementation

The Electromagnetic Waves, Frequency Domain interface is used to perform full-wave simulation at the specified excitation wavelength of 1550 nm. Two Scattering Boundary Condition nodes and two Port nodes are used to handle the free space and the guided modes, and to analyze the coupling efficiency of the incident beam into both sides of the waveguide as well as the general reflection and the transmission characteristics.

The incident wave is an s-polarized free space paraxial Gaussian beam and is defined using a Scattering Boundary Condition (SBC) node. The Reference Point subnode of this SBC is used to ensure that the incident beam is focused on the center of the grating for all incident angles. Another Scattering Boundary Condition is used to absorb the wave transmitted through the waveguide in the transmission side. A numeric-type Port in combination with a Boundary Mode Analysis study step is used to compute the fundamental lowest-order mode of the waveguide. Since modes may exit at both sides of the waveguide, each side has its own numeric Port and associated Boundary Mode Analysis


study steps. To ensure that any higher-order modes in the waveguide are not reflected by the Port conditions, they are backed by Perfectly Matched Layer domains with the slit condition being used. A Wavelength Domain study step with Auxiliary sweep is used to perform a sweep over the incident angle of the beam.

Application Library path: Wave_Optics_Module/Gratings_and_Metamaterials/grating_coupler




Modeling Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click  **Model Wizard**.

MODEL WIZARD

- 1 In the **Model Wizard** window, click  **2D**.
- 2 In the **Select Physics** tree, select **Optics > Wave Optics > Electromagnetic Waves, Frequency Domain (ewfd)**.
- 3 Click **Add**.
- 4 Click  **Study**.
- 5 In the **Select Study** tree, select **Preset Studies for Selected Physics Interfaces > Wavelength Domain**.
- 6 Click  **Done**.

GEOMETRY I

- 1 In the **Model Builder** window, under **Component 1 (comp1)** click **Geometry 1**.
- 2 In the **Settings** window for **Geometry**, locate the **Units** section.
- 3 From the **Length unit** list, choose **μm**.

GLOBAL DEFINITIONS

Create a list of parameters to define the wave properties.

Parameters: Wave Properties

- 1 In the **Model Builder** window, under **Global Definitions** click **Parameters 1**.

2 In the **Settings** window for **Parameters**, type Parameters: Wave Properties in the **Label** text field.

3 Locate the **Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
lda0	1.55[um]	1.55E-6 m	Vacuum wavelength
f0	c_const/lda0	1.9341E14 1/s	Frequency
E0	1[V/m]	1 V/m	Incoming wave field
alpha	30[deg]	0.5236 rad	Angle of incidence
beam_d	8[um]	8E-6 m	Beam waist diameter
P0	$E0^2/Z0_const * beam_d/pi$	6.7594E-9 W/m	Gaussian beam power

Parameters: Geometric Properties

Now, create a list of parameters that will be used to draw the geometry.

1 In the **Home** toolbar, click **Pi Parameters** and choose **Add > Parameters**.

2 In the **Settings** window for **Parameters**, type Parameters: Geometric Properties in the **Label** text field.

3 Locate the **Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
si_d	250[nm]	2.5E-7 m	Si layer thickness
a	600[nm]	6E-7 m	Grating constants
N	9	9	Number of ridges
ridge_d	si_d/2	1.25E-7 m	Ridge depth
ridge_w	a/2	3E-7 m	Ridge width
wg_top	lda0	1.55E-6 m	Waveguide top size
wg_bottom	lda0	1.55E-6 m	Waveguide bottom size
R	3*beam_d	2.4E-5 m	Simulation domain size
t_PML	2[um]	2E-6 m	Thickness PML

Parameters: Material Properties

Finally, create a list of parameters to define the material properties.

1 In the **Home** toolbar, click **Pi Parameters** and choose **Add > Parameters**.



2 In the **Settings** window for **Parameters**, type Parameters: Material Properties in the **Label** text field.

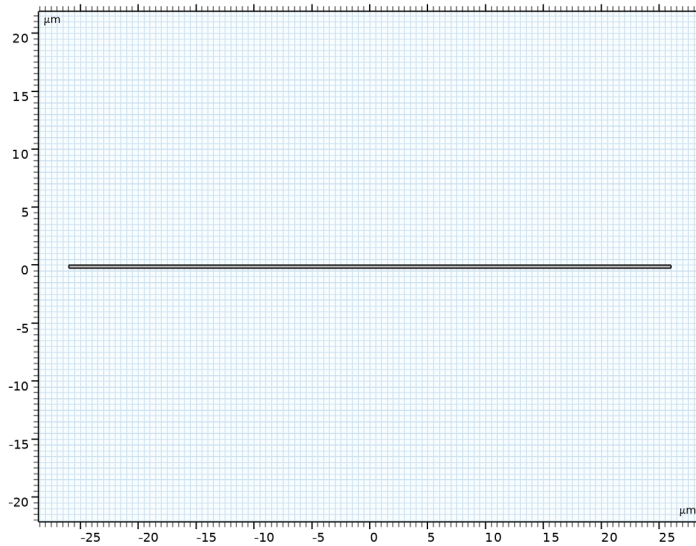
3 Locate the **Parameters** section. In the table, enter the following settings:

Name	Expression	Value	Description
n_Si	3.7	3.7	Si refractive index
n_SiO2	1.4	1.4	SiO2 refractive index

GEOMETRY I

Rectangle 1 (r1)

- 1 In the **Geometry** toolbar, click  **Rectangle**.
- 2 In the **Settings** window for **Rectangle**, locate the **Size and Shape** section.
- 3 In the **Width** text field, type $2*R+2*t_PML$.
- 4 In the **Height** text field, type si_d .
- 5 Locate the **Position** section. In the **x** text field, type $-R-t_PML$.
- 6 In the **y** text field, type $-si_d$.
- 7 Click  **Build Selected**.



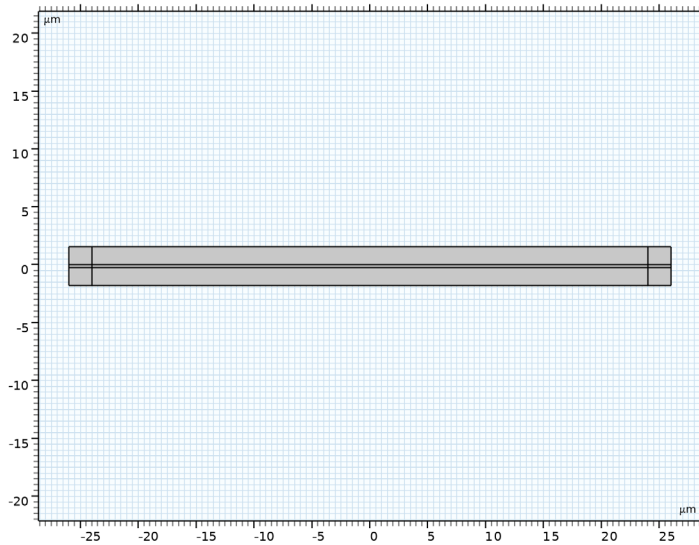
Rectangle 2 (r2)

- 1 Right-click **Rectangle 1 (r1)** and choose **Duplicate**.
- 2 In the **Settings** window for **Rectangle**, locate the **Size and Shape** section.
- 3 In the **Height** text field, type $wg_top+wg_bottom+si_d$.



- 4 Locate the **Position** section. In the **y** text field, type `-wg_bottom-si_d`.
- 5 Click to expand the **Layers** section. Select the **Layers to the left** checkbox.
- 6 Select the **Layers to the right** checkbox.
- 7 Clear the **Layers on bottom** checkbox.
- 8 In the table, enter the following settings:

Layer name	Thickness (μm)
Layer 1	<code>t_PML</code>

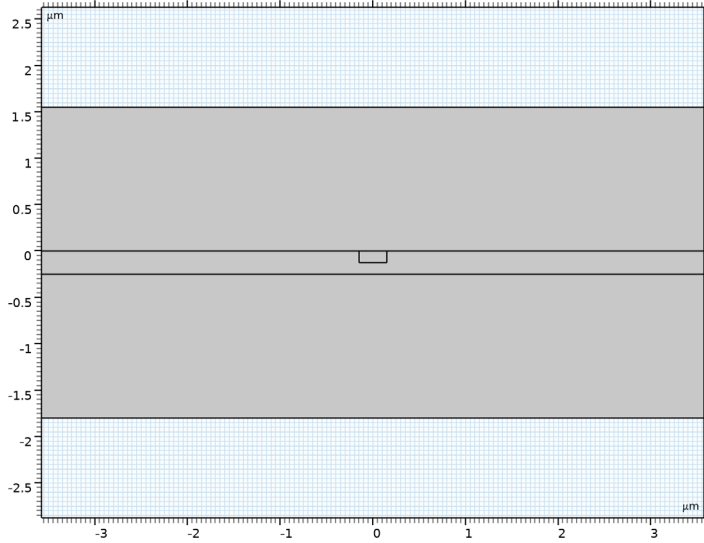
- 9 Click  **Build Selected**.




Rectangle 3 (r3)

- 1 In the **Geometry** toolbar, click  **Rectangle**.
- 2 In the **Settings** window for **Rectangle**, locate the **Size and Shape** section.
- 3 In the **Width** text field, type `ridge_w`.
- 4 In the **Height** text field, type `ridge_d`.
- 5 Locate the **Position** section. In the **x** text field, type `-ridge_w/2`.
- 6 In the **y** text field, type `-ridge_d`.
- 7 Click  **Build Selected**.

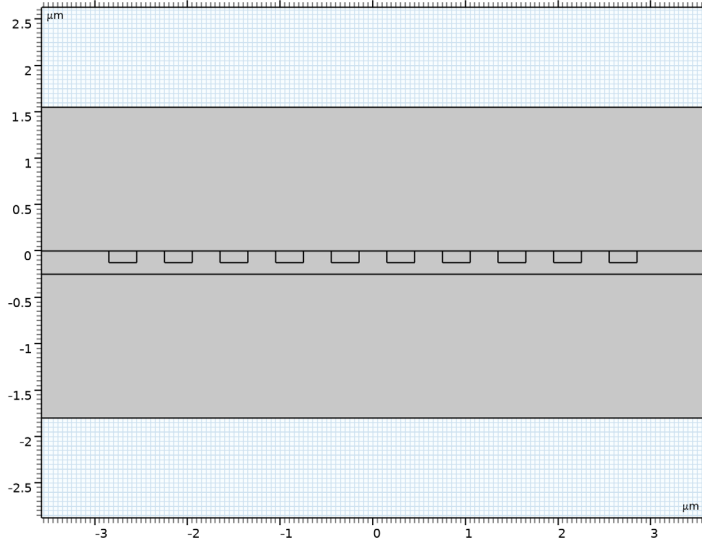
8 Click the  **Zoom In** button in the **Graphics** toolbar, 3 times for better visualization.




Move 1 (mov1)

- 1 In the **Geometry** toolbar, click  **Transforms** and choose **Move**.
- 2 Select the object **r3** only.
- 3 In the **Settings** window for **Move**, locate the **Displacement** section.
- 4 In the **x** text field, type $\text{range}(-N/2, 1, N/2) * a$.



5 Click  **Build Selected**.




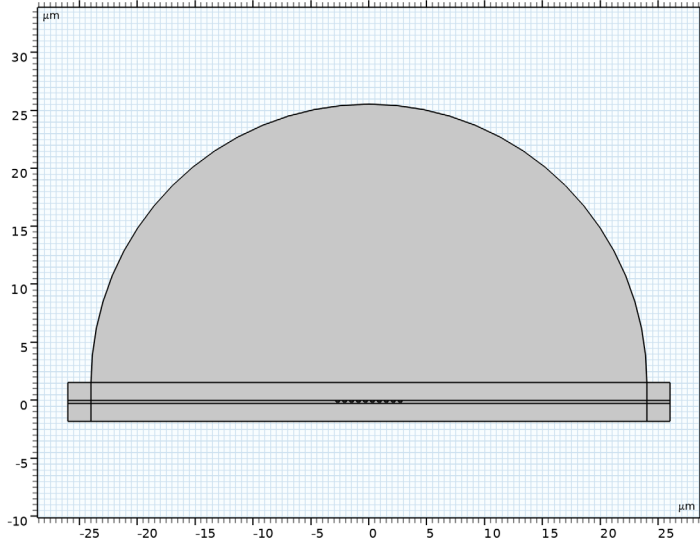
6 Click the  **Zoom Extents** button in the **Graphics** toolbar.

Circle 1 (c1)

Add a circle to draw the top air domain.


- 1 In the **Geometry** toolbar, click  **Circle**.
- 2 In the **Settings** window for **Circle**, locate the **Size and Shape** section.
- 3 In the **Radius** text field, type R.
- 4 In the **Sector angle** text field, type 180.
- 5 Locate the **Position** section. In the **y** text field, type wg_top.
- 6 Click  **Build Selected**.

7 Click the  **Zoom Extends** button in the **Graphics** toolbar.

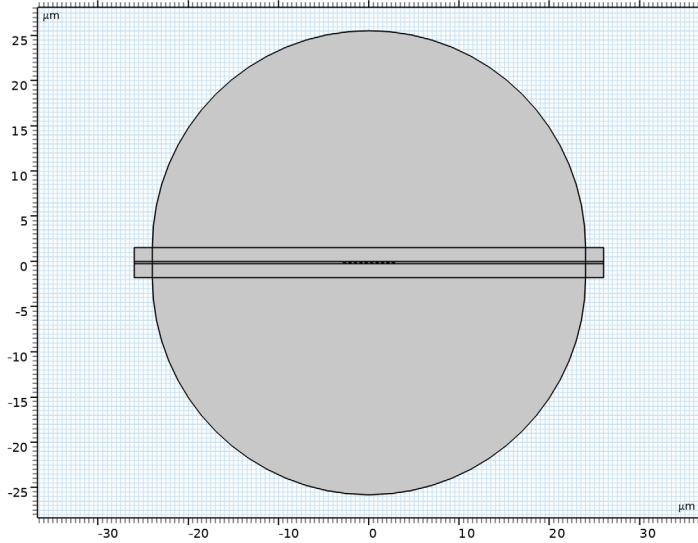



Circle 2 (c2)

Add another circle to draw the bottom insulator domain.

- 1 In the **Geometry** toolbar, click  **Circle**.
- 2 In the **Settings** window for **Circle**, locate the **Size and Shape** section.
- 3 In the **Radius** text field, type R.
- 4 In the **Sector angle** text field, type 180.
- 5 Locate the **Position** section. In the **y** text field, type `-wg_bottom-si_d`.
- 6 Locate the **Rotation Angle** section. In the **Rotation** text field, type 180.

7 Click  **Build Selected.**



8 Click the  **Zoom Extents** button in the **Graphics** toolbar.

MATERIALS

Air

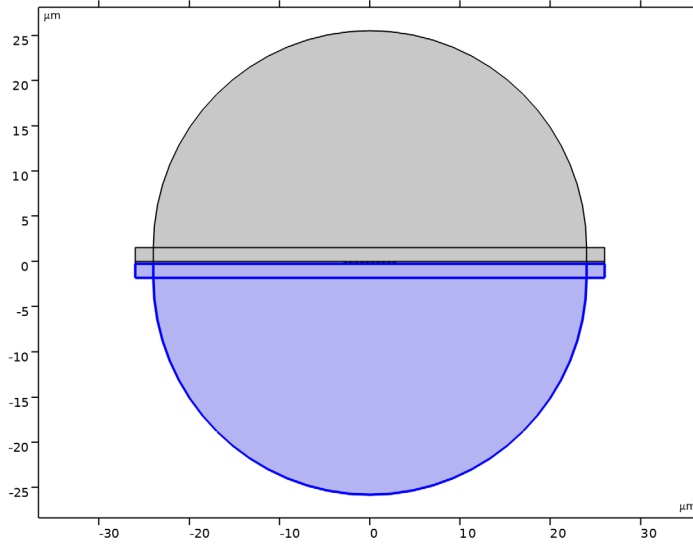
- 1 In the **Model Builder** window, under **Component 1 (comp1)** right-click **Materials** and choose **Blank Material**.
- 2 In the **Settings** window for **Material**, type Air in the **Label** text field.
- 3 Locate the **Material Contents** section. In the table, enter the following settings:

Property	Variable	Value	Unit	Property group
Refractive index, real part	n_{iso} ; $n_{ij} = n_{iso}$, $n_{ij} = 0$	1		Refractive index

SiO2

- 1 Right-click **Materials** and choose **Blank Material**.
- 2 In the **Settings** window for **Material**, type SiO2 in the **Label** text field.

3 Select Domains 1, 4, 5, and 19 only.



4 Locate the **Material Contents** section. In the table, enter the following settings:

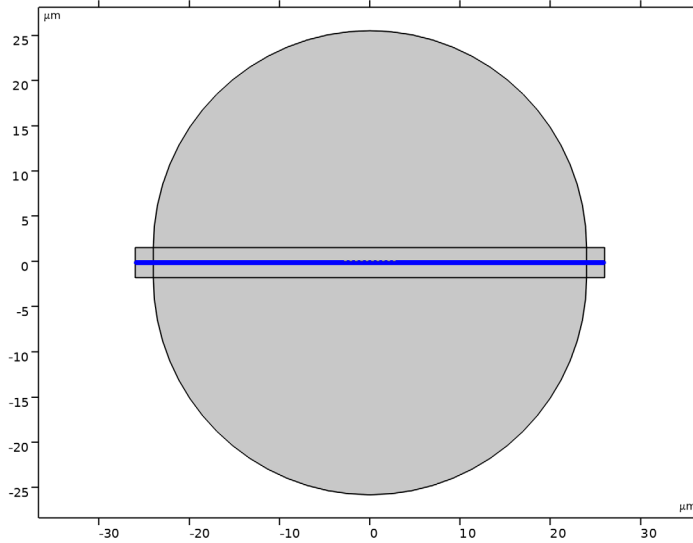
Property	Variable	Value	Unit	Property group
Refractive index, real part	n_{iso} ; $n_{ii} = n_{iso}$, $n_{ij} = 0$	n_{SiO2}	1	Refractive index

Si

1 Right-click **Materials** and choose **Blank Material**.

2 In the **Settings** window for **Material**, type Si in the **Label** text field.

3 Select Domains 2, 6, and 20 only.



4 Locate the **Material Contents** section. In the table, enter the following settings:

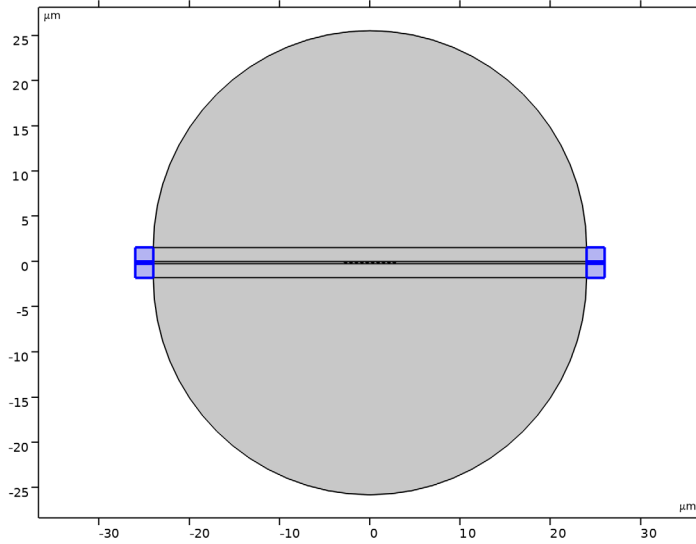
Property	Variable	Value	Unit	Property group
Refractive index, real part	n_{iso} ; $n_{ii} = n_{iso}$, $n_{ij} = 0$	n_{Si}	1	Refractive index

DEFINITIONS

Perfectly Matched Layer 1 (pml1)

1 In the **Definitions** toolbar, click  **Perfectly Matched Layer**.

2 Select Domains 1–3 and 19–21 only.

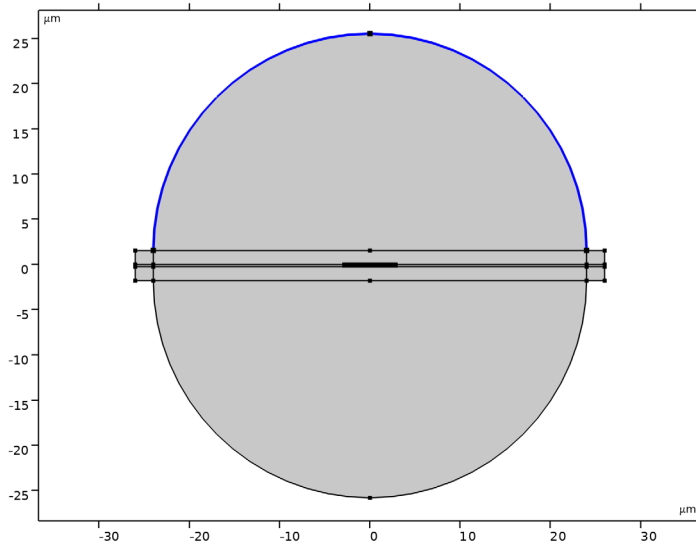


ELECTROMAGNETIC WAVES, FREQUENCY DOMAIN (EWF)

Scattering Boundary Condition 1

1 In the **Physics** toolbar, click  **Boundaries** and choose **Scattering Boundary Condition**.

2 Select Boundaries 78 and 80 only.



3 In the **Settings** window for **Scattering Boundary Condition**, locate the **Scattering Boundary Condition** section.

4 From the **Incident field** list, choose **Gaussian beam**.

5 In the w_0 text field, type beam_d/2.

6 From the **Input quantity** list, choose **Power**.

7 In the P text field, type P0.

8 Specify the \mathbf{E}_{g0} vector as

1	z
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9 Specify the \mathbf{k}_{dir} vector as

sin(alpha)	x
-cos(alpha)	y

10 From the **Scattered wave type** list, choose **Cylindrical wave**.

11 Specify the \mathbf{r}_0 vector as

wg_top	y
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Reference Point 1

1 In the **Physics** toolbar, click  **Attributes** and choose **Reference Point**.

2 In the **Settings** window for **Reference Point**, locate the **Reference Point** section.

3 From the **Definition** list, choose **User defined**.

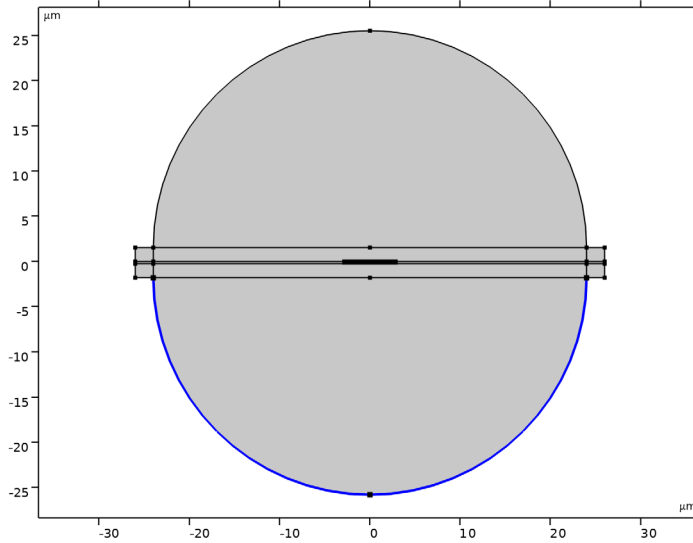
4 Specify the \mathbf{r}_0 vector as

-R*sin(alpha)	x
R*cos(alpha)+wg_top	y

Scattering Boundary Condition 2

1 In the **Physics** toolbar, click  **Boundaries** and choose **Scattering Boundary Condition**.

2 Select Boundaries 77 and 79 only.



3 In the **Settings** window for **Scattering Boundary Condition**, locate the **Scattering Boundary Condition** section.

4 From the **Scattered wave type** list, choose **Cylindrical wave**.

5 Specify the \mathbf{r}_0 vector as

-wg_bottom-si_d | y

Port 1

1 In the **Physics** toolbar, click  **Boundaries** and choose **Port**.

2 Select Boundaries 8, 10, and 12 only.

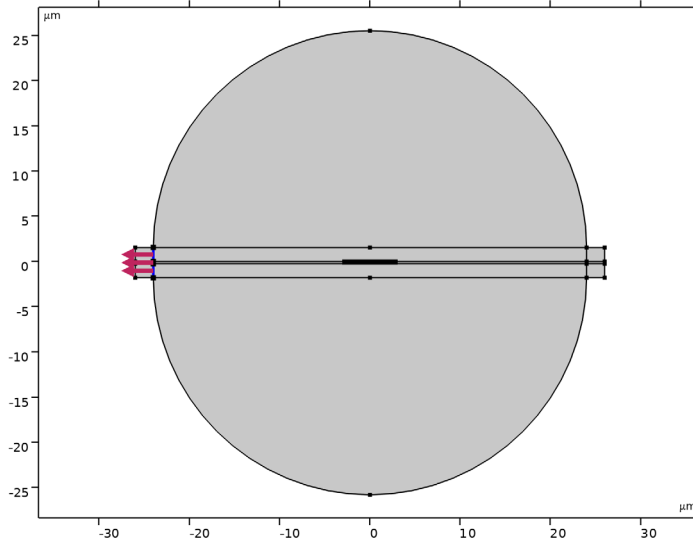
3 In the **Settings** window for **Port**, locate the **Port Properties** section.

4 From the **Type of port** list, choose **Numeric**.


5 From the **Wave excitation at this port** list, choose **Off**.

6 Select the **Activate slit condition on interior port** checkbox.

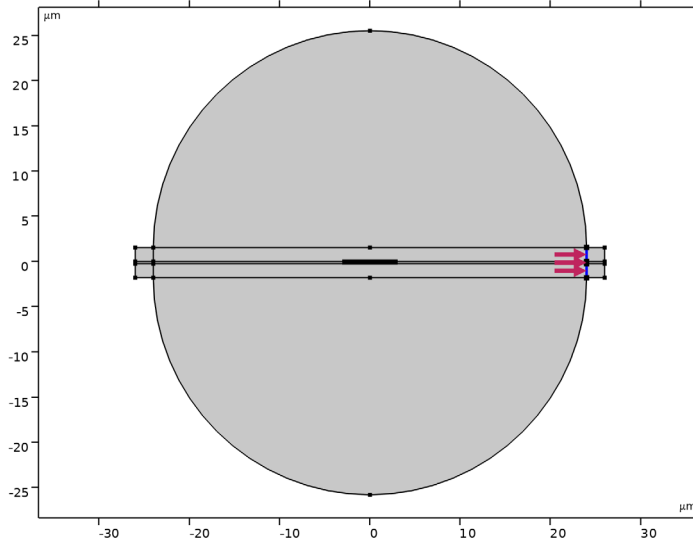
7 Click Toggle Power Flow Direction.



Port 2

- 1** Right-click **Port 1** and choose **Duplicate**.
- 2** In the **Settings** window for **Port**, locate the **Boundary Selection** section.
- 3** Click  **Clear Selection**.
- 4** Select Boundaries 67, 69, and 71 only.

5 Locate the **Port Properties** section. Click **Toggle Power Flow Direction**.




STUDY 1

Step 1: Wavelength Domain

- 1 In the **Model Builder** window, under **Study 1** click **Step 1: Wavelength Domain**.
- 2 In the **Settings** window for **Wavelength Domain**, locate the **Study Settings** section.
- 3 In the **Wavelengths** text field, type $1\text{da}0$.
- 4 Click to expand the **Study Extensions** section. Select the **Auxiliary sweep** checkbox.
- 5 Click **+ Add**.
- 6 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
alpha (Angle of incidence)	range (0, 2, 30)	deg

Step 2: Boundary Mode Analysis

- 1 In the **Study** toolbar, click  **More Study Steps** and choose **Other > Boundary Mode Analysis**.
- 2 In the **Settings** window for **Boundary Mode Analysis**, locate the **Study Settings** section.
- 3 In the **Mode analysis frequency** text field, type $f0$.
- 4 Select the **Desired number of modes** checkbox.

5 In the **Search for modes around shift** text field, type `n_Si`.

Step 3: Boundary Mode Analysis I

1 Right-click **Step 2: Boundary Mode Analysis** and choose **Duplicate**.

2 In the **Settings** window for **Boundary Mode Analysis**, locate the **Study Settings** section.

3 In the **Port name** text field, type 2.

Step 2: Boundary Mode Analysis, Step 3: Boundary Mode Analysis I

In the **Model Builder** window, under **Study 1**, Ctrl-click to select

Step 2: Boundary Mode Analysis and **Step 3: Boundary Mode Analysis I**.

Step 1: Boundary Mode Analysis

1 Drag and drop above **Step 3: Wavelength Domain**.

2 In the **Study** toolbar, click  **Compute**.

RESULTS

Electric Field (ewfd)

1 In the **Settings** window for **2D Plot Group**, locate the **Data** section.

2 From the **Parameter value (alpha (deg))** list, choose **12**, to visualize the field plot at which maximum coupling occurs.

Height Expression I

1 In the **Model Builder** window, expand the **Electric Field (ewfd)** node.

2 Right-click **Surface 1** and choose **Height Expression**.

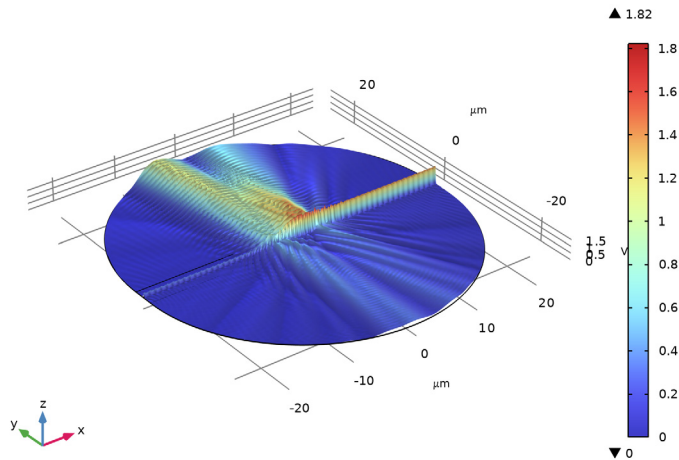
3 In the **Settings** window for **Height Expression**, locate the **Axis** section.


4 Select the **Scale factor** checkbox. In the associated text field, type 2, to better visualize the field plot.

5 In the **Electric Field (ewfd)** toolbar, click  **Plot**.

lambda0=1.55 μm, alpha=12 deg

Electric field norm (V/m)



6 Click the  **Zoom Extents** button in the **Graphics** toolbar.


Electric Mode Field, Port 1 (ewfd)

- 1 In the **Model Builder** window, under **Results** click **Electric Mode Field, Port 1 (ewfd)**.
- 2 In the **Settings** window for **2D Plot Group**, locate the **Data** section.
- 3 From the **Parameter value (alpha (deg))** list, choose **12**.

Line 1


- 1 In the **Model Builder** window, expand the **Electric Mode Field, Port 1 (ewfd)** node, then click **Line 1**.
- 2 In the **Settings** window for **Line**, locate the **Coloring and Style** section.
- 3 Select the **Radius scale factor** checkbox. In the associated text field, type **0.1**.

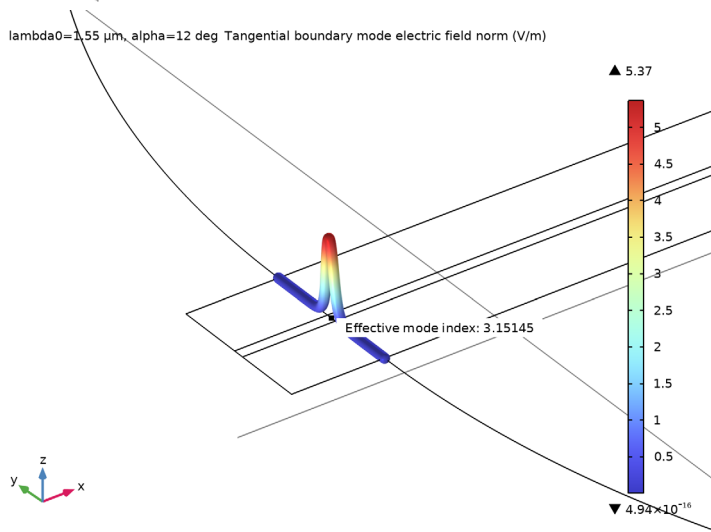
Height Expression 1

- 1 In the **Model Builder** window, expand the **Line 1** node, then click **Height Expression 1**.
- 2 In the **Settings** window for **Height Expression**, click to expand the **View** section.
- 3 Click  **Go to Source**, to adjust the camera settings and properly visualize the field plot.

Camera

- 1 In the **Model Builder** window, expand the **View 3D 3** node, then click **Camera**.

- 2 In the **Settings** window for **Camera**, locate the **Camera** section.
- 3 In the **Zoom angle** text field, type 2.
- 4 Locate the **Center of Rotation** section. In the **x** text field, type -16.
- 5 In the **y** text field, type -0.2.
- 6 In the **z** text field, type 0.
- 7 Locate the **View Offset** section. In the **x** text field, type 1.45.
- 8 In the **y** text field, type 0.77.
- 9 Click  **Update**.




Electric Mode Field, Port 2 (ewfd)

- 1 In the **Model Builder** window, under **Results** click **Electric Mode Field, Port 2 (ewfd)**.
- 2 In the **Settings** window for **2D Plot Group**, locate the **Data** section.
- 3 From the **Parameter value (alpha (deg))** list, choose **12**.


Line 1

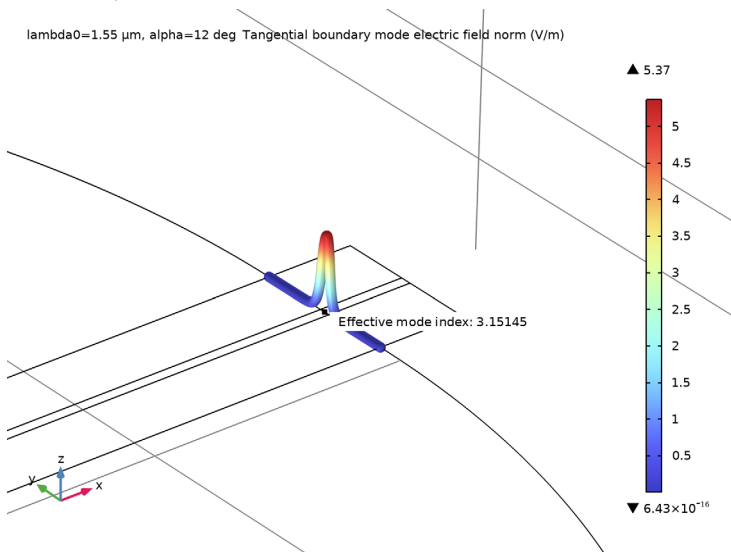
- 1 In the **Model Builder** window, expand the **Electric Mode Field, Port 2 (ewfd)** node, then click **Line 1**.
- 2 In the **Settings** window for **Line**, locate the **Coloring and Style** section.
- 3 Select the **Radius scale factor** checkbox. In the associated text field, type 0.1.

Height Expression 1

- 1 In the **Model Builder** window, expand the **Line 1** node, then click **Height Expression 1**.
- 2 In the **Settings** window for **Height Expression**, click to expand the **View** section.
- 3 Click  **Go to Source**, to adjust the camera settings.


Camera

- 1 In the **Model Builder** window, expand the **View 3D 4** node, then click **Camera**.
- 2 In the **Settings** window for **Camera**, locate the **Camera** section.
- 3 In the **Zoom angle** text field, type 2.
- 4 Locate the **Center of Rotation** section. In the **x** text field, type 22.7.
- 5 In the **y** text field, type -1.8.
- 6 In the **z** text field, type 0.
- 7 Locate the **View Offset** section. In the **x** text field, type -1.45.
- 8 In the **y** text field, type -0.7.
- 9 Click  **Update**.



Coupling Efficiency

Now, plot the reflectance, transmittance, and the power of the guided mode flowing through the ports versus the incident angles to analyze the coupling efficiency.

- 1 In the **Results** toolbar, click  **ID Plot Group**.

- 2 In the **Settings** window for **ID Plot Group**, type **Coupling Efficiency** in the **Label** text field.

Global 1

- 1 Right-click **Coupling Efficiency** and choose **Global**.
- 2 In the **Settings** window for **Global**, click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component 1 (comp1) > Electromagnetic Waves, Frequency Domain > Global > ewfd.sctr1.etaOut - Outcoupling efficiency - 1**.
- 3 Locate the **y-Axis Data** section. In the table, enter the following settings:

Expression	Unit	Description
ewfd.sctr1.etaOut	1	Reflectance

- 4 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component 1 (comp1) > Electromagnetic Waves, Frequency Domain > Global > ewfd.sctr2.etaOut - Outcoupling efficiency - 1**.

- 5 Locate the **y-Axis Data** section. In the table, enter the following settings:

Expression	Unit	Description
ewfd.sctr2.etaOut	1	Transmittance

- 6 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component 1 (comp1) > Electromagnetic Waves, Frequency Domain > Global > ewfd.port1.etaOut - Outcoupling efficiency, port 1 - 1**.

- 7 Locate the **y-Axis Data** section. In the table, enter the following settings:

Expression	Unit	Description
ewfd.port1.etaOut	1	Power outflow, port 1


- 8 Click **Add Expression** in the upper-right corner of the **y-Axis Data** section. From the menu, choose **Component 1 (comp1) > Electromagnetic Waves, Frequency Domain > Global > ewfd.port2.etaOut - Outcoupling efficiency, port 2 - 1**.

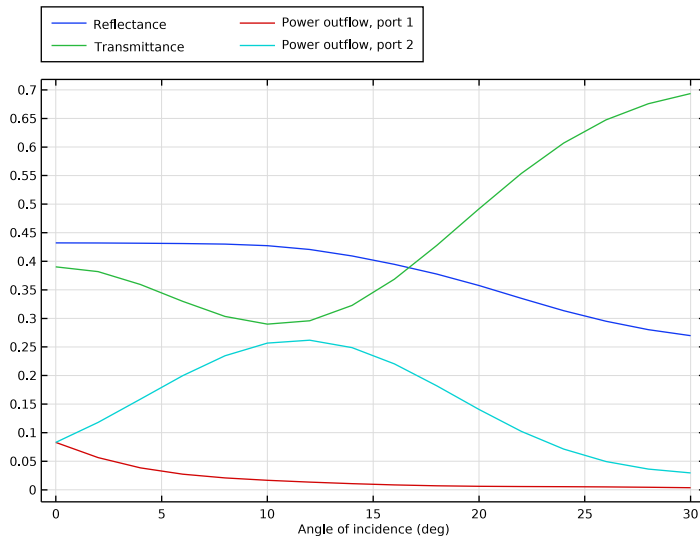
- 9 Locate the **y-Axis Data** section. In the table, enter the following settings:

Expression	Unit	Description
ewfd.port2.etaOut	1	Power outflow, port 2

- 10 Click to expand the **Legends** section. Find the **Include** subsection. Clear the **Solution** checkbox.


Coupling Efficiency

- 1 In the **Model Builder** window, click **Coupling Efficiency**.
- 2 In the **Settings** window for **ID Plot Group**, locate the **Plot Settings** section.
- 3 Select the **x-axis label** checkbox. In the associated text field, type Angle of incidence (deg).
- 4 Locate the **Legend** section. From the **Layout** list, choose **Outside graph axis area**.
- 5 From the **Position** list, choose **Top**.
- 6 In the **Number of rows** text field, type 2.
- 7 In the **Coupling Efficiency** toolbar, click  **Plot**.



Radiation Loss

Finally, plot the radiation loss versus the incident angles.

- 1 In the **Results** toolbar, click  **ID Plot Group**.
- 2 In the **Settings** window for **ID Plot Group**, type Radiation Loss in the **Label** text field.

Global I

- 1 Right-click **Radiation Loss** and choose **Global**.
- 2 In the **Settings** window for **Global**, locate the **y-Axis Data** section.

3 In the table, enter the following settings:

Expression	Unit	Description
$\text{ewfd.sctr1.etaOut} + \text{ewfd.sctr2.etaOut} + \text{ewfd.etaOutPort}_1 + \text{ewfd.LscaPort}_2$	1	Radiation loss


4 Locate the **Legends** section. Clear the **Show legends** checkbox.

Radiation Loss

1 In the **Model Builder** window, click **Radiation Loss**.

2 In the **Settings** window for **ID Plot Group**, locate the **Plot Settings** section.

3 Select the **x-axis label** checkbox. In the associated text field, type Angle of incidence (deg).

4 In the **Radiation Loss** toolbar, click  **Plot**.

