

## Getting Started with AR/MR Lightguide Design

Hands-on, step-by-step tutorial

#### **Getting Started with AR/MR Lightguide Design**

#### Goals

This tutorial provides an introduction to lightguide design for augmented or mixed reality (AR/MR). Its main goal is to help you understand how these lightguides are structured and how they can be simulated using VirtualLab Fusion.

To keep things accessible, the designs and workflows demonstrated here are intentionally simplified.

By the end of this tutorial, you should have a solid foundation that enables you to explore more advanced and realistic lightguide design use cases.



#### Requirements

- VirtualLab Fusion license plus the AR/VR/XR and the Grating Packages (or a valid evaluation license)
- Basic familiarity with VirtualLab Fusion (e.g., completion of *Educational Tutorial #1 & #2*)

## Introduction – AR Light Path

This tutorial demonstrates a lightguide-based AR display using diffraction gratings to couple light in and out of a transparent waveguide.

The waveguide is highlighted in green in the illustration on the right.

Light from a microdisplay enters the waveguide via an input grating and propagates horizontally through total internal reflection. A second grating redirects the light vertically, and an output grating projects it toward the user's eye.

This optical architecture enables the overlay of digital content onto the real-world view, fundamental to augmented reality. The system demonstrated here operates with monochromatic green light at a 532 nm wavelength.



## Introduction – Using Plane Waves in AR Simulations

This tutorial does not cover the microdisplay, nor the beam-shaping optics between the microdisplay and the input coupler. For our purposes, the microdisplay can be considered as a 2D array of green-light-emitting pixels. Each pixel emits spherical waves, which are transformed by the beam-shaping optics into collimated plane waves directed at specific angles toward the input coupler.

At the input coupler, we therefore simulate the light as a set of plane wave beams entering the lightguide at different angles. These beams propagate through the lightguide and are redirected toward the output coupler, where they exit again as collimated plane waves effectively forming a mirror image of the input field.

The eye then focuses these beams onto the retina, forming the augmented image. It's important to note that the lightguide itself does not provide magnification. Any magnification or image positioning must be handled by the optics in front of the microdisplay. In the setup described here, the AR/MR image appears to be located at optical infinity due to perfect collimation. However, if the output is slightly divergent (i.e., not perfectly collimated), the eye would will focus at a finite virtual distance instead.



# Layout Design – Incident Light

The AR/VR/XR package includes a wizard for simplified setup of HoloLens-like waveguides with two 1D beam expanders

- Launch VirtualLab Fusion
- In the *Start* ribbon, select *Layout Design* from the *Light Guides* drop-down menu

	<b>=</b>			
File Start	Sources	Functions	Catalogs	Windows Help
New Open Save	Calculators	Diffractive Gratings Optics • •	[ <b>;</b> ़≓≓] Laser Resonators •	Light Guides - Shaping -
File	Calculators		Setups	Simulation
				🥰 Light Guide Optical Setup
				General Design
				▶ Footprint and Grating Analysis
				Design (Hololens 1 Type Layout)
				🗒 k-Layout Visualization
				🗒 Layout Design
				📐 Grating Design

The wizard's default settings create a valid lightguide but we will adjust them for better insight

- Set Distance Source to Light Guide to 1 mm
- Set Field of View to  $20^{\circ} \times 10^{\circ}$



# Layout Design – Light Guide & Outgoing Light

On the *Light Guide* tab, we will keep the default settings. However, note that this is where you can adjust parameters such as thickness, input coupler period, and the previously discussed internal deflection angle.

📋 16: Layout Design	- • ×
Incident Light Guide Outgoing Light	
Absolute Position10 mm	-5 mm
Position Outcoupling Grating 11 mm	8 mm
Thickness of Light Guide 500 µm	
Design for Reflection	
Light Guide Medium	
S-LAH79_Ohara in Homogeneous Medium	
💕 Load 🥒 Edit	Q View
Grating Parameters	
Orientation Incoupling Grating	0°
Fixed Incoupling Period	
Period Incoupling Grating	380 nm
Deflection Angle of Eye Pupil Expander	90°
Create Result	
Validity: 🖉	Close Help

- In the *Outgoing Light* tab, set *Distance Light Guide to Eye* to 10 mm
- Leave Size of Eye Box at its default settings

Distance Light Guide to Eye	10 mm		
Size of Eye Box	9 mm	×	9 mm

## Layout Design – Eyebox

In *VirtualLab Fusion* the *Size of Eye Box* defines the area in which the eye can move while still seeing the complete image.

The target value is  $9 \text{ mm} \times 9 \text{ mm}$  at a distance of 10 mm from the output coupler.

As illustrated, the eyebox area decreases with increasing lightguide-eye distance.

Additionally, for a given lightguide layout, a larger *Field of View* (FOV) - the angular size of the AR image - also reduces the eyebox size.

The FOV is determined by the microdisplay and the beam-shaping optics placed before the input coupler. In this sense, the FOV itself acts as a target value and is configured under the *Incident Light* tab.

Eye box sizes for different positions



## Layout Design – Create Result

• Click Create Result

1: Layout Design	🔀 🔁 - 📸 🔒 🐯 =	Optical Setup	Wyrowski VirtualLab Fu	sion 2025.1 (Build 1.176)
Incident Light Light Guide Outgoing Light Distance Light Guide to Eye 10 mm	File     Start     Sources     Functions     Catalogs     Windows     Help       Image: Start	Profile Editing & Run Layout Tools	% Speed vs. Accuracy         Fast         New         New Parametric         Gib           % Pointwise vs. Integral         Positioning v         Parameter Run Optimization         System	
Size of Eye Box 9 mm * 9 mm Audity Creste Result Close Help Two more windows appear: • k-Layout Visualization	Execution       Settings       Result Visualization         Indent Light Guide Outgoing Light       Image: Constant C	igitt Path Finder Profile Editing Tools  spoot Vasualization  I Settings View Settings rooment  weiength 532 nm Ught Guide Medium Ught Height	Parameter Variation View	
			Simulation Engine Profile: Ray R	tesults 🗸 🖌 Go!

## **Check the Layout of the Gratings**

- Double-click the *Light Guide* icon
- Select the Surface Layouts tab
- Click *Edit Surface Layout* of *Plane Surface* #1 (the surface facing the eye)

The *Edit Surface Layout* window displays a diagram of the grating regions, with the currently selected region (e.g., the second grating) highlighted in red.

In some design target combinations, the wizard may place overlapping gratings on the same surface, which is physically unfeasible. To prevent this issue, the current design employs a relatively small FOV.

Note: The shadings indicating the grating orientations were added specifically for this tutorial.



# **Explore TIR Conditions with k-Layout Visualization**

The *k-Layout Visualization* tool is an essential resource for rapidly assessing whether light within the lightguide is properly confined via total internal reflection (TIR). In the visualization, the green ring highlights the set of k-vectors that meet the TIR condition.

The present simulations employ plane waves, each defined by a specific k-vector. Although kspace analysis might seem unintuitive at first, it offers the most natural and effective framework for understanding light propagation in this context. The methodology will become clearer as we walk through each step of the process.

The diagram contains four data boxes, but two of them overlap. To improve visibility, set the *Outcoupling Grating: Rotation Angle* to 70°.

Note: K-Layout Visualization is an analysis tool only. Changes made here do not affect the setup



## **Identify Light Paths in k-Layout Visualization**

The graphic shows the distribution of  $k_x$  and  $k_y$  components at different positions in the optical setup. Since monochromatic light is used, the k-vector's magnitude remains constant across all plane waves in the same medium. However,  $k_x$  and  $k_y$  vary with the propagation direction.

The light-blue box represents waves travelling towards the input coupler. A wave originating from the central microdisplay pixel has only a  $k_z$  component and therefore appears at the origin of the k-space plot. The box size reflects the range of input angles defining the FOV. Adjusting the FOV changes the box dimensions accordingly.

The diagram includes four such boxes, each corresponding to one of the four light path intervals in the setup, as indicated by the numbering in the illustrations on the right.



## **Explore How Gratings Manipulate Light Paths in k-Space**

The gratings redirect the k vector by redistributing its  $k_x$ ,  $k_y$  and  $k_z$  components. Diffraction into the desired orders appears as translations of the boxes in the diagram. With three gratings, there are three corresponding translations, as shown on the right.

The green ring indicates the condition for total internal reflection. The medium and dark blue boxes must stay within this ring. In the current setup, they do. But if the input coupler grating period is changed to 480 nm, the box moves outside the ring. (Tip: the translation equals the grating vector whose magnitude is  $2\pi$  divided by the grating period.)

Total internal reflection does not affect  $k_x$  or  $k_y$  and therefore does not appear as a translation. The expansion grating is oriented at 45°, so the magnitude of the corresponding translation must increase by a factor of  $\sqrt{2}$  in order to remain within the green ring. Consequently, the grating period must be smaller than that of the input coupler by the same factor.



Finally, the outcoupling grating should redirect the FOV back toward the center, or close to it.

To learn more about this powerful tool, see the use case <u>k-Domain Layout Visualization ("The Magic Circle")</u>

This tutorial will not use the tool further, so you may close it now.

## **Beam Expansion – Setting Up**

The beams entering the input coupler have diameters of only 1 mm. Transferring these beams to the output coupler without modification results in a very small eye box. To overcome this, the second and third gratings are used to expand the eye box. Ray tracing illustrates how this expansion is achieved.

- Close the Edit Light Guide dialog
- Close the Layout Design wizard
- Select Ray Results Profile
- Click the *cogwheel* icon next to System: 3D



• Set *Number of Sampling Points* to  $1 \times 1$ This initializes the simulation with a single ray.

Edit Parameters for 3D System Visualization	X
Ray Selection View Settings	
Sampling Positions Ox-y-Grid OHex	apolar 🔿 Random
Number of Sampling Points	1
Info: For regular x-y sampling position 1 points will b	e used.
✓ Unselect Points with an Associated Energy Smaller than	0.1 %
Use Color Table for Different Modes	
Opy From	OK Cancel Help

Tip: Use the *View Settings* tab to customize the appearance of the *Ray Results* plots. For the plots on the following pages *Background Color Gradient*, *Global Coordinate System*, *Tool Bar* and *View Cube* were deselected. Furthermore *Ray Thickness* was set to 2.

## **Beam Expansion – Follow the Rays**

- Click the cogwheel icon in the *Light Path Finder*
- Set Maximum Level to 8
- Uncheck Show Only Paths that Hit a Detector ...



- Run Ray Results Profile/System: 3D
- Repeat for *Maximum Levels* 20, 30 and 60
- Reset to default level 100



Note: The detector (in red) matches the eyebox size and is smaller than the output coupler.

The four simulations demonstrate how the beam expansion works. The polygon-shaped grating has a low diffraction efficiency, redirecting only a small fraction of the beam upward at each interaction. Most of the beam continues along its original path (zeroth order), allowing for repeated partial redirections. This process creates multiple adjacent copies of the beam along the horizontal axis. The output coupler uses the same principle along the vertical axis.

As a result, the eyebox is filled with closely spaced beam copies, ensuring that from any position within it, one or more beams will enter the eye.

While the polygon-shaped grating is typically referred to as the *expansion grating*, it's important to note that the output coupler contributes equally to the overall beam expansion. Both elements are essential in forming the 2D array of beam copies that fill the eyebox. So far, we have illustrated the beam expansion using a beam at 0°, which corresponds to a pixel located at the center of the field of view (FOV). To better understand the full shape and function of the expansion grating, it is helpful to consider beams corresponding to pixels near the corners of the FOV. This requires adjusting the input beam angle accordingly. It's important to remember that the FOV is defined as a total angular range – for example, a FOV of 20° spans from –10° to +10°. Selecting a pixel at the edge of the FOV means launching a beam at an angle near these extremes



## **Understand the Grating Region Dimensions**

- Double-click the Plane Wave source
- Set Alpha to -10°
- Set *Beta* to -5° and click *OK*

Basic Paramet	ters	Spectral Paran	neters
Spatial Parameters	Polarization	Mode Selection	Sampling
Direction Define by		Cartesian Angle	ac V
Direction Define by Alpha		Cartesian Angle	es ∽ -10°

- Re-enable Tool Bar and View Cube (cogwheel next to System: 3D, then View Settings)
- Run the simulation
- Select the <sup>(5)</sup> tool and drag the mouse across the image to view the ray paths from various angles

Tip: Click directly on a face of the black cube to switch to a standard planar view.



For further understanding, you may want to repeat this analysis with other values of *Alpha* and *Beta*.

Conclusion: the four-sided polygon shape results from minimizing the expansion grating region while meeting design requirements. Likewise, the input and output couplers are the smallest possible rectangles.

### **General Profile**

Let us now move beyond ray tracing:

- Close all result windows
- Select the General Profile
- Set *Alpha* and *Beta* both to 0°
- Run the simulation

Image: Close All Sources Functions Catalogs Windows Help   Image: Close All Image: Close Al	Image: Start Sources Functions Catalogs   Image: Start Sources Functions Catalogs   Image: Start Sources Cascade   Image: Close All Image: Start   All But Current Start   Vindows Image: Start   Close Document Windows Image: Start   Image: Start Sources   Image: Start <	-
File       Start       Sources       Functions       Catalogs       Windows       Help         Image: Close All Close All But Current Windows       Image: Close All Close All But Current Windows       Image: Close All Close All But Current Windows       Image: Close Close All Close All But Current Windows       Image: Close Close All Close All But Current Windows       Image: Close Close All Close All But Current Windows       Image: Close Close All Close All But Current Windows       Image: Close Close All Windows       Image: Close All Windows <t< th=""><th>File       Start       Sources       Functions       Catalogs       Windows         Close       Close All All But Current       Image: Close All Result Windows       Image: Close</th><th></th></t<>	File       Start       Sources       Functions       Catalogs       Windows         Close       Close All All But Current       Image: Close All Result Windows       Image: Close	
Image: Close All But Current Windows       Image: Close All Result Windows       Image: Close All Result Windows       Image: Close All Result Windows       Image: Close Close All Result Windows	Image: Cose All Cose All All But Current Windows       Image: Cose All Result Windows         Close Document Windows       Image: Cose Document Windows         Image: Cose Document Windows       Image: Cose Document Windows	Hel
Close Document Windows	Close Document Windows       Arrange Document Windows         Image: Close Document Windows       Image: Close Documen	6:
File       Start       Sources       Functions       Cataloc         Image: Start       Start       Start       Start         Image: Start       Start       Start <t< td=""><td>Image: Start       Sources       Functions       Catal         File       Start       Sources       Functions       Catal         Image: Start       Image: Start       Sources       Functions       Catal         Image: Start       Image: Start       Image: Start       Start       Start         Image: Start       Image: Start       Image: Start       Image: Start       Start         Image: Start       Image: Start       Image: Start       Image: Start       Start         Image: Start       Image: Start       Image: Start       Image: Start       Image: Start         Image: Start       Image: Start       Image: Start       Image: Start       Image:</td><td></td></t<>	Image: Start       Sources       Functions       Catal         File       Start       Sources       Functions       Catal         Image: Start       Image: Start       Sources       Functions       Catal         Image: Start       Image: Start       Image: Start       Start       Start         Image: Start       Image: Start       Image: Start       Image: Start       Start         Image: Start       Image: Start       Image: Start       Image: Start       Start         Image: Start       Image: Start       Image: Start       Image: Start       Image: Start         Image: Start       Image: Start       Image: Start       Image: Start       Image:	
Execution     Settings       Edit Plane Wave     ×       Basic Parameters     Spectral Parameters       Spatial Parameters     Polarization       Mode Selection     Sampling       Generate Cross Section     Direction       Define by     Cartesian Angles       Alpha     0°       Beta     0°	Edit Plane Wave	oç
Edit Plane Wave       ×         Basic Parameters       Spectral Parameters         Spatial Parameters       Polarization         Mode Selection       Sampling         Generate Cross Section          Direction          Define by       Cartesian Angles          Alpha       0°         Beta       0°	Edit Plane Wave	
Basic Parameters       Spectral Parameters         Spatial Parameters       Polarization       Mode Selection         Generate Cross Section       Direction         Direction       Cartesian Angles         Alpha       0°         Beta       0°		×
Generate Cross Section   Direction   Define by   Cartesian Angles   Alpha   Beta	Basic Parameters Spectral Parameters Spatial Parameters Polarization Mode Selection Sampling	
Define by Cartesian Angles Alpha 0° Beta 0°	Generate Cross Section	
Alpha 0° Beta 0°	Define by Cartesian Angles	
Beta	Alpha 0°	
	Beta O°	

### **General Profile**

The detector is currently limited to the eyebox, as defined in the setup wizard. To gain more insight, we'll enlarge the detector and switch to false color mode to better visualize brightness variations. 

- Double-click the Camera object
- Set Window Size to 15 mm × 15 mm
- Change to False Color: Midnight Sun
- Run the simulation again

The simulation indicates that the beam copies decrease in brightness with increasing distance from the lower-right corner of the eyebox.



## **Brightness Variation Across the Eyebox**

Let's examine the properties of the expansion grating:

- Open the *Edit Surface Layout* of the *Light Guide* component
- Select the *Expansion Grating*, then click *Edit*

Edit	Surface Layout			×
				10 mm
#	Name of Region	Region Type	Period	🥖 Edit
1	Incoupling Grating	Rectangular Region	380 nm	
2	Expansion Grating	Simple Polygon Region	268.7005769 nm	_E Add
3	Outcoupling Grating	Rectangular Region	380 nm	
				X Remove
				Duplicate

- Click the *Grating* tab, then navigate to *Efficiencies*
- Review the values in the *Efficiency* table

lit Grating Region				
Shape Region Channels Grating				
• 1D-Periodic (Lamellar)		O 2D-Periodic		
Grating Period	268.7005769 nm			
Orientation (Rotation about z-Axis)	-45°			
Order Selection Efficiencies				
O Constant	O Programmab	ble		From Real Gratings
Overall Transmission	0 %		Overall Reflection	100 %
From Front Side		From Back Sid	de	
Order Efficiency		Order	Efficiency	
		R-1		10 %
		0.0		00.0/

We note that the diffraction efficiencies are constant. The same applies to the output coupler. The beams farther from the lower-right corner follow paths that interact more frequently with the gratings, and as a result, they become progressively weaker.

# **Beam Clipping**

The boundaries of the regions cause partial beam clipping. When a beam partially overlaps a boundary, the portion outside the region undergoes 100% reflection due to total internal reflection (TIR), while the portion within the region experiences only partial reflection, since the grating's  $R_0$  is less than 100%.

The outer edge of the current light distribution is defined by the size of the output coupler. The vertical edges arise from the beam partially hitting the inner side of the input coupler ( $R_0 = 50\%$ ) after its initial zigzag pass.

This can be verified by slightly adjusting the input coupler dimensions, which alters (or even removes) the dark edge. However, these dimensions are necessary to maintain the intended field of view (FOV) and the source-to-light-guide distance.

The expansion grating introduces two edges at slanted angles. The horizontal edge caused by the output coupler is barely visible in this plot.

Clipping severity changes with input angle, and while it does not create visible edges in the AR image, it can lead to gradual brightness variations across the FOV.



## **Switch to Real Gratings**

Our goal is to achieve more uniform brightness across the eyebox. A straightforward approach is to use expansion and output gratings with higher zeroth-order efficiencies (e.g.  $R_0 = 95\%$ ). However, this reduces overall brightness, lowering the efficiency of the lightguide system. A more effective strategy involves varying grating efficiencies across the region. The use case *Optimization of Lightguide with Continuously Modulated Grating Regions* demonstrates how to apply the uniformity detector and automated optimization to determine optimal grating parameters.

In this tutorial, we will also work with real gratings, but manually adjust their design to deepen understanding and better prepare for advanced use cases.





- Edit the Expansion Grating
- Under Efficiencies Select From Real Gratings
- Click on Load

## Load and Edit a Rectangular Grating

• Select *Rectangular Grating* and click *OK* 

Stacks Catalog					×
Definition Type LightTrans Defined  Filter by  Single Gratings Hetagrating Pillar Grating Rectangular Grating Rectangular Grating	× 7				
- Sawtooth Grating - Sinusoidal Grating - Slanted Grating - Slanted Grating With Rounded Edg - Transition Point List Grating - Triangular Grating - Volume Grating		dex z-Distance 1 0 mm	2-Position 0 mm	Surface Rectangular Grating Surface	Subsequent Medium Standard Air in Homogeneous Medium
	Periodic	Stack; Stack Perio Preview	od	2 µm ×	2 µm

• Click on Edit

order Selection	Efficiencies		
🔵 Constant		O Programmable	From Real Gratings
Use Modul	lated Grating Parameter	s within Region	
Grating Stac	k		
Sawtooth G	rating		🎽 Load 🥒 Edit 🔍 View
On Front	Side of Base Surface	On Back Side of Base Surface	1

• Click the *pencil* symbol



- Switch to Relative Slit Width: 50%
- Set the *Grating Period* to 268.7 nm and the *Modulation Depth* to 100 nm



Click OK

# **Change the Modulation Depth of the Grating**

• Select Stack Period is Dependent on the Period of Surface



- Close all dialogs by clicking OK in each
- Run the simulation



**Note:** The rapid brightness drop-off in the horizontal direction. This suggests excessive diffraction at the expansion grating and a too-low  $R_0$ . Reducing the *modulation depth* can improve this.

• Open the Profile Editor



- Select Components & Solvers
- Start typing *modulation* note that *mod* is sufficient.
- Set the Value to 20 nm



## **Divide the Expansion Grating into Segments**

Run the simulation and observe that the brightness drops by about 50% in the horizontal direction, indicating a high  $R_0$ , likely around 90%.

However, compared to the initial design with an ideal grating, the overall efficiency has decreased by roughly 50%.

This suggests that  $R_{-1}$  is not approximately 10% as intended, but closer to 5%, with the remaining light lost to unwanted diffraction orders.



## **Divide the Expansion Grating into Segments**

Next, divide the *Expansion Grating* into multiple smaller segments and gradually vary the modulation depth.

- Select the Expansion Grating
- Click Gridded Segmentation

dit S	urface Layout	-			10 mm
#	Name of Region	Region Type	Period		/ Edit
1	Incoupling Grating	Rectangular Region	380 nm		
2	Expansion Grating	Simple Polygon Region	268.7 nm		E Add
3	Outcoupling Grating	Rectangular Region	380 nm		X Remove
					×
					Duplicate
					Gridded Segmentation
) A	pply Absorption Outsid	e of Region on Surface	ОК	Cance	l Help

- Set Number of Tiles: Horizontal to 7
- Enter a descriptive segment name
- Click OK



# Vary the Modulation Depth Across the Expansion Grating

		- 4			10 mm
ŧ	Name of Region	Region Type	Period		🖉 Edit
1	Incoupling Grating	Rectangular Region	380 nm		
3	Outcoupling Grating	Rectangular Region	380 nm		<mark></mark> ⊢ Add
4	Expander Segm. #4	Simple Polygon Region	268.7 nm		
5	Expander Segm. #5	Simple Polygon Region	268.7 nm		X Remove
6	Expander Segm. #6	Simple Polygon Region	268.7 nm		Duplicate
7	Expander Segm. #7	Simple Polygon Region	268.7 nm		Capicate
8	Expander Segm. #8	Simple Polygon Region	268.7 nm		Gridded
9	Expander Segm. #9	Simple Polygon Region	268.7 nm		Segmentation
10	Expander Segm. #10	Simple Polygon Region	268.7 nm	J	
					Edit Vertex Couplings

Observe the segmentation of the expansion grating.

- Keep the first segment's modulation depth at 20 nm
- Increase by 10 nm for each following segment
- Click OK

-19	mod X Hide N	Iodeling Paramet
Sources	1 2 * Parameter	Value
	😑 "Light Guide (After Surface Layout)" (# 1)	
1	🛄 📮 Surface #1 (Plane Surface)	
	Surface Region #4 (Expander Segm. #4)   Grating Stack (Rectangular Grating)   Surface #1 (Rectangu	lar G 20 nm
omponents	Surface Region #5 (Expander Segm. #5)   Grating Stack (Rectangular Grating)   Surface #1 (Rectangu	lar G 30 nm
& Solvers	Surface Region #6 (Expander Segm. #6)   Grating Stack (Rectangular Grating)   Surface #1 (Rectangu	lar G 40 nm
white	Surface Region #7 (Expander Segm. #7)   Grating Stack (Rectangular Grating)   Surface #1 (Rectangu	lar G 50 nm
	Surface Region #8 (Expander Segm. #8)   Grating Stack (Rectangular Grating)   Surface #1 (Rectangu	lar G 60 nm
d 0	Surface Region #9 (Expander Segm. #9)   Grating Stack (Rectangular Grating)   Surface #1 (Rectangu	lar G 70 nm
Detectors	Surface Region #10 (Expander Segm. #10)   Grating Stack (Rectangular Grating)   Surface #1 (Rectan	gular 80 nm
\$ <u>\$</u>		
ner Settings		

- Close all dialogs by clicking *OK* in each
- Open the Profile Editor

# **Final Design of the Expansion Grating**

Run the simulation and observe that the brightness in the horizontal direction initially increases, then decreases. Using smaller steps and a slightly higher starting value may result in a more even distribution.

- Start at 22 nm
- Use increments of 3 nm
- Run the simulation



# **Final Design of the Expansion Grating**

Let us accept this result and move on to the output coupler:

- Select the output coupler and click *Edit*
- For the grating efficiences, choose *From Real Gratings* and load a rectangular grating
- Edit the rectangular grating:
  - o Set Relative Slit Width to 50%
  - Set Grating Period to 380 nm
  - o Set Modulation Depth to 22 nm
  - o Click OK
- Select Stack Period is Dependent on the Period of Surface
- Click OK twice



ructure	Height Discontinuities	Scaling of Elem	entary Surface	Periodization	
Special R	ectangular Grating Valu	ies	-		
Relative	e Slit Width 🗸	50 %			
	Crating Values				
Evtensi	ion				
Casti	an Desired	380 pm	Madulatian De		22 pm
Grati	ng Period	500 mm	Modulation De	pth	22 1111
Positio	n				
Later	al Shift	0 mm	Rotation Angle	e	0°

Validity: 🕑	Add		Insert		Delete
Periodicity & Aper	ture () Non-Periodic		_		
Stack Period is	Dependent on the Period of Surface	~	with Index	1	<b></b>
Stack Period	380 nm		-		

## **Divide the Output Coupler into Segments**

- Go to Gridded Segmentation
- Set Number of Tiles: Vertical to 7
- Rename to *Output Segment*

Parameters for Equidistant Segr	nentation	×
Equidistant Segmentation		
Number of Tiles	Segmentation Angle	
Horizontal Vertical	0° 🜩	
	Alian With Sides	
Prefix for the Segment Names	Output Segment	
Preview		
	#17	
	#16	
LO -	#15	
Ē	#14	
>	#13	
0	#12	
	#11	
-		
	-5 0 5	
	x [mm]	

- Open the *Profile Editor* and enter: *mod outp* in the search bar
- Set the Values to 22 nm, 25 nm, etc.

nod outp X Vide Modeli	ng Paramet
2 * Parameter	Value
"Light Guide (After Surface Layout)" (# 1)	
📮 Surface #1 (Plane Surface)	
Surface Region #11 (Output Segment #11)   Grating Stack (Rectangular Grating)   Surface #1 (Rectangula	22 nm
Surface Region #12 (Output Segment #12)   Grating Stack (Rectangular Grating)   Surface #1 (Rectangula	25 nm
Surface Region #13 (Output Segment #13)   Grating Stack (Rectangular Grating)   Surface #1 (Rectangula	28 nm
Surface Region #14 (Output Segment #14)   Grating Stack (Rectangular Grating)   Surface #1 (Rectangula	31 nm
Surface Region #15 (Output Segment #15)   Grating Stack (Rectangular Grating)   Surface #1 (Rectangula	34 nm
Surface Region #16 (Output Segment #16)   Grating Stack (Rectangular Grating)   Surface #1 (Rectangula	37 nm
Surface Region #17 (Output Segment #17)   Grating Stack (Rectangular Grating)   Surface #1	40 nm

• Run the simulation

## **Divide the Output Coupler into Segments**

Run the simulation and observe the brightness distribution, which suggests the need for higher modulation depths.

Since the period has increased by a factor of  $\sqrt{2}$ , scale the modulation depths accordingly to maintain the aspect ratio.

 Set the values according to the table below and run the simulation

Now display the result again,

but limited to the 9 mm  $\times$  9 mm eyebox and place it side by side with the result from the original design to allow direct comparison.





## Final vs. Original Design

The light distribution across the eyebox is now significantly more uniform.

However, using real gratings has reduced overall efficiency. The original design assumed ideal gratings with a reflectivity of  $R_0$  = 90% and 10% of the light directed into the desired diffraction order.

In practice, rectangular gratings scatter a notable portion of light into unwanted diffraction orders.

For example, if 5% is lost this way, efficiency in the desired order could drop from 10% to 5%, a twofold reduction per grating.

This highlights the potential for improvement by refining the grating design, such as exploring non-rectangular profiles or optimizing the relative slit width.





## Next Steps in AR/VR Lightguide Design

Designing an effective light guide is a complex task that involves balancing multiple optimization goals. For each angle, we aim to:

- Minimize diffraction into undesired orders
- Maximize total efficiency
- Ensure uniform brightness across the eyebox

When considering the entire field of view (FOV), additional goals include:

- Achieve uniform brightness across the FOV
- Maximize the field of view
- Preserve the clarity of the real-world scene

While balancing these factors requires careful tradeoffs, VirtualLab Fusion supports this process with powerful numerical tools for grating analysis and flexible optimization capabilities.

As an example, diffraction efficiency lookup tables can be precomputed for a defined parameter space, reducing computational cost in iterative design processes and enabling integration into automated workflows.

Further tutorials and advanced use cases are available via the <u>Diffractive Lightguides</u> section on our website.

## Conclusion

Our goal was to introduce the fundamentals of lightguide design for AR/MR glasses.

We examined the structure and function of three key grating regions: the input coupler, the expansion grating, and the output coupler. The expansion grating replicates the beam horizontally, while the output coupler does so vertically - positioning multiple beam copies to fill the entire eyebox, thus ensuring the AR image remains visible across a range of eye positions.

To achieve uniform brightness, we tuned the efficiency of rectangular gratings through modulation depth adjustments. While effective, further refinements - like non-rectangular profiles or narrower slits - hold promise for even greater performance.

AR/MR technologies illustrate the transition of state-ofthe art optical systems from niche applications to broader consumer markets. Addressing the design challenges in this domain requires advanced modeling capabilities. VirtualLab Fusion provides the simulation environment necessary to meet these technical requirements.

We hope you found this tutorial valuable and invite your feedback, which helps us refine future materials and better address the needs of the optics community.

info@lighttrans.com

title	Getting Started with AR/MR Lightguide Design
document code	TUT.0450
document version	1.0
required packages	AR/VR/XR Package / Grating Package
software version	2025.1 (Build 1.176)
category	Tutorial
further reading	- <u>Diffractive Lightguides</u>