

Tolerancing with Random Distributions using the Programmable Mode of the Parameter Run

Abstract



When investigating the effect of manufacturing deviations on an optimized system in VirtualLab Fusion, randomly varied Parameter Runs can be used. Depending on the kind of manufacturing process, it may be that the deviations for the different parameters follow different random distribution rules. While the default Random mode of the Parameter Run assumes a uniform distribution, in this use case we want to show how to use a programmable Parameter Run to apply different random distributions to each of the parameters involved in the tolerancing. As illustration we have selected the example of a sawtooth grating, for which we investigate the minimal efficiency of the minus first transmission order.

Task Description

Task: According to the allowed tolerances what is the minimal efficiency of the minus first transmitted order? How is the overall efficiency distributed among the different emanating orders in that case?



Source: Ideal Plane Wave

• 532 nm wavelength

Sawtooth Grating (fixed parameters):

- 2 µm period
- fused silica
- 1 mm thickness

Sawtooth Grating (parameters for tolerancing):

- blaze angle ζ: 30° (2° tolerance, normal distribution)
- rotation angle θ: normal distribution between -5° and 5°
- rotation angle φ: uniform distribution between -5° and 5°
- modulation depth h: 1 µm (0.25 µm tolerance, evenly distributed)

The System in VirtualLab Fusion – Components



🔞 🛃 Tools 🌾 🗸

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The grating is modeled using a Sawtooth Grating Interface. In the configuration dialog of the surface, the period, blaze angle and modulation depth can be adjusted.

The System in VirtualLab Fusion – Analyzer

lit Grating Order Analyzer >	C Edit Grating Order Analyzer X
General Single Orders	General Single Orders
Calculated Orders Transmission Output Order Collections Single Order Output	Order Selection Strategy Selection Strategy Above Efficiency Threshold Efficiency Threshold 1E-08 %
Summed Transmission, Absorption, and Reflection	Coordinates Spherical Angles Wave Vector Components Positions
	Efficiencies Rayleigh Coefficients Ex Ey Ez TE TE TM
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In a Grating Optical Setup the Grating Order Analyzer enables an easy analysis of the grating. It provides different output formats that allow the user to determine how overall energy is distributed among the different emanating orders. In addition, the fully vectorial field information in the form of the Rayleigh coefficients per order is also accessible.



Programmable Parameter Run

Go! Use Already Calculated R	esults for Next Run							
				It	teration Step		Source Code	Editor — —
etector	Subdetector	Combined Output	1 584	1 585	1 586	1 587	Source coue	
	Modulation Depth ("Sawto	Data Array	6589034 µm	1.092440115 µm	750.0807982 nm	1.143349523 µm	Source Code	Global Parameters Snippet Help Advanced Settings
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	Efficiency T[+1; 0]	Data Array	52142822 %	3.539101006 %	7.261497136 %	2.951357697 %	11	
						>	12	<pre>for (int i = 0; i < NumberOfIterations; i++) {</pre>
Create Output from Selec	tion						13	<pre>for (int parameterIndex = 0; parameterIndex < Number</pre>
							14	parameters[parameterIndex, i] = randomNumber
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							16	}
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combinations. Through a parameter in the programmable Parameter Run, it is possible to assign to each parameter either a normal or a uniform distribution, as illustrated in the next page.

Options of the Programmable Parameter Run

1: C:\Temp\\3071 - Parameter Run with Different Random Distributi	ons.ru 🗖 🗖 💌
Parameter Specification	
Set up a snippet which generates a two dimensional array, which is used as Parameter Run.	parameter set for the
Definition Image: Constraint of the second secon	
Parameters	
UseSeed	
Seed	0
SigmasInHalfInterval	2
Distributions	/ Edit
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Parameter Extraction	
Make Entries Available for Parameter Extraction	
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1 2	k
2 0	Next > Show •
Renet Table	
OK Cancel Help	

Use Seed

Allows for reproducible results

Seed

• Define a specific seed to recreate a particular distribution of the randomly generated Parameter Run

SigmasInHalfInterval

 Determine the width of the distribution, more information can be found in the "Help" document

Distributions

- Choose either a "Uniform", "Normal" or "Cutoff-Normal" Distribution for each individual varied parameter
- The distribution type is coded with numbers: 0 uniform, 1 – normal, 2 – cutoff-normal; more information can be found in the "Help" document

Note: In the "Help" document you can find a short explanation of all used parameters and the function of the component.

Distribution Types



uniform distribution







cutoff-normal distribution

In the case of a uniform distribution, the number of points will be evenly distributed over the allowed range. The normal and cutoff normal distributions both assume a Gaussian profile for the probability of a point being taken. The difference between the standard normal distribution and the cutoff normal distribution is that in the case of the cutoff distribution the values outside of the parameter range will not be taken, but a new number inside the range is generated instead.

Statistical Distribution of the Efficiency

Go!							
Use Already Calculated R	esults for Next Run						
				It	eration Step		
etector	Subdetector	Combined Output	1 584	1 585	1 586	1 587	
Varied Parameters	Modulation Depth ("Sawto	Data Array	6589034 µm	1.092440115 µm	750.0807982 nm	1.143349523 µm	
	Rotation #1 (about X-Axis)	Data Array	.503275514°	-1.196948991°	-3.043554858°	-2.994923633°	
	Rotation #2 (about Y-Axis)	Data Array	;893143299°	3.870853468°	3.487450092°	-1.124331136°	
	Rotation Angle ("Sawtooth	Data Array	30.1193587°	30.5270092°	27.99470706°	29.30117893°	
Grating Order Analyzer" (#	Transmission Result	Animation 🗸 🥖	er Collection	Order Collection	Order Collection	Order Collection	
"Grating Order Analyzer" (#800) (Results for Individual Orders)	Efficiency T[-6; 0]	Data Array	22049219 %	0.001513942357 %		0.0002329068886 %	
	Efficiency T[-5; 0]	Data Array	41490561 %	0.01242901447 %	0.007943152103 %	0.002657151786 %	
	Efficiency T[-4; 0]	Data Array	99259131 %	0.07460787438 %	0.04338002262 %	0.1151399559 %	
	Efficiency T[-3; 0]	Data Array	09475967 %	0.3108249199 %	0.02733774357 %	0.4361768419 %	
	Efficiency T[-2; 0]	Data Array	01320884 %	0.2406861452 %	1.25302212 %	0.5634374119 %	
	Efficiency T[-1; 0]	Data Array	20105301 %	71.06530728 %	46.20124392 %	75.10256396 %	
	Efficiency T[0; 0]	Data Array	66578527 %	5.022484567 %	28.96273187 %	2.460893894 %	
	Efficiency T[+1; 0]	Data Array	52142822 %	3.539101006 %	7.261497136 %	2.951357697 %	
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From the Parameter Run result it is possible to get an overview of the statistical distribution and range in which the efficiency of the order lies with the Histogram Detector (under Detectors in the Main Window).



Tolerancing of the Grating



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be determined and the results further investigated. You can use the detectors in the main window (under Detectors) to find the minimum.

Order Efficiencies for Minimal Efficiency

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Go!							
Use Already Calculated R	esults for Next Run						
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etector	Subdetector	Combined Output	1 584	1 585	1 586	1 587	
Varied Parameters	Modulation Depth ("Sawto	Data Array	6589034 µm	1.092440115 µm	750.0807982 nm	1.143349523 µm	
	Rotation #1 (about X-Axis)	Data Array	.503275514°	-1.196948991°	-3.043554858°	-2.994923633°	
	Rotation #2 (about Y-Axis)	Data Array	;893143299°	3.870853468°	3.487450092°	-1.124331136°	
	Rotation Angle ("Sawtooth	Data Array	30.1193587°	30.5270092°	27.99470706°	29.30117893°	
Grating Order Analyzer" (#	Transmission Result	Animation 🗸 🥖	er Collection	Order Collection	Order Collection	Order Collection	
	Efficiency T[-6; 0]	Data Array	22049219 %	0.001513942357 %		0.0002329068886 %	
	Efficiency T[-5; 0]	Data Array	41490561 %	0.01242901447 %	0.007943152103 %	0.002657151786 %	
	Efficiency T[-4; 0]	Data Array	99259131 %	0.07460787438 %	0.04338002262 %	0.1151399559 %	
Grating Order	Efficiency T[-3; 0]	Data Array	09475967 %	0.3108249199 %	0.02733774357 %	0.4361768419 %	
Results for Individual	Efficiency T[-2; 0]	Data Array	01320884 %	0.2406861452 %	1.25302212 %	0.5634374119 %	
rders)	Efficiency T[-1; 0]	Data Array	20105301 %	71.06530728 %	46.20124392 %	75.10256396 %	
	Efficiency T[0; 0]	Data Array	66578527 %	5.022484567 %	28.96273187 %	2.460893894 %	
	Efficiency T[+1; 0]	Data Array	52142822 %	3.539101006 %	7.261497136 %	2.951357697 %	
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Additional information and the results of any individual iteration can be directly accessed in the Parameter Run document.



Random Distribution Types

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Subdetector	Combined Outp	out 1584	1 585	1 586	1 587	
Modulation Depth ("Sawto	Data Array	6589034 µm	1.092440115 µm	750.0807982 nm	1.143349523 μm	
Rotation #1 (about X-Axis)	Data Array	.503275514°	-1.196948991°	-3.043554858°	-2.994923633°	
Rotation #2 (about Y-Axis)	Data Array	3893143299°	3.870853468°	3.487450092°	-1.124331136°	
Rotation Angle ("Sawtooth	Data Array	30.1193587°	30.5270092°	27.99470706°	29.30117893°	
Transmission Result	Animation ~	🥖 er Collection	Order Collection	Order Collection	Order Collection	
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Efficiency T[-5; 0]	Data Array	41490561 %	0.01242901447 %	0.007943152103 %	0.002657151786 %	
Efficiency T[-4; 0]	Data Array	99259131 %	0.07460787438 %	0.04338002262 %	0.1151399559 %	
Efficiency T[-3; 0]	Data Array	09475967 %	0.3108249199 %	0.02733774357 %	0.4361768419 %	
Efficiency T[-2; 0]	Data Array	01320884 %	0.2406861452 %	1.25302212 %	0.5634374119 %	
Efficiency T[-1; 0]	Data Array	20105301 %	71.06530728 %	46.20124392 %	75.10256396 %	
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For maximum flexibility it is possible to use different random distributions for different parameters in the same Parameter Run document.



Document Information

title	Tolerancing with Random Distributions using the Programmable Mode of the Parameter Run
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version	1.0
edition	VirtualLab Fusion Advanced
software version	2020.2 (Build 2.22)
category	Application Use Case
further reading	 <u>Usage of the Parameter Run Document</u> <u>Grating Order Analyzer</u>