

# Free Space Propagation Settings

# Abstract

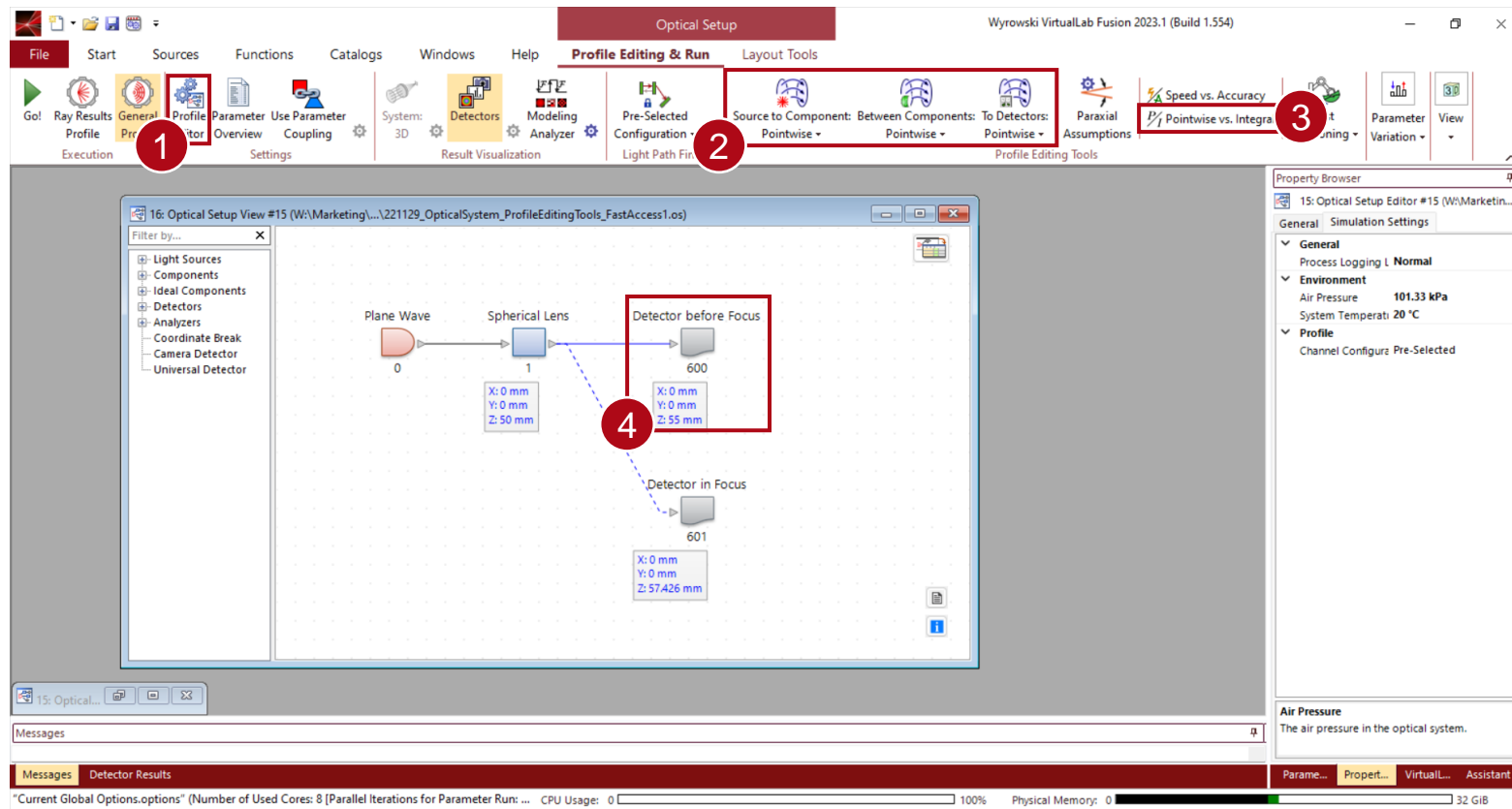


The free space propagation operator – connecting elements and surfaces which each other – is one of the most essential mathematical operations in the context of optical modeling and design. Performing the calculation of these operators as fast as possible becomes then crucial for a fast simulation of the system. For precisely this reason VirtualLab Fusion offers a catalog of different algorithms to calculate the Fourier transform – the mathematical foundation of the free space propagation operator - with varying levels of accuracy and sampling requirements, from which to select the most appropriate at each plane in the system where a Fourier transform operation is necessary.

It is a powerful, but complex, topic. This is why VirtualLab Fusion offers different options to configure how the choice between these algorithms is made, ranging from some pre-defined “configuration packages” that rely on an automatic decision-making process performed by the software in the background, all the way to full pinpointed control of which Fourier transform algorithm must be used where. In this use case we provide an overview of the different ways of controlling the selection of Fourier transform algorithms.

# Settings for Free Space Propagation

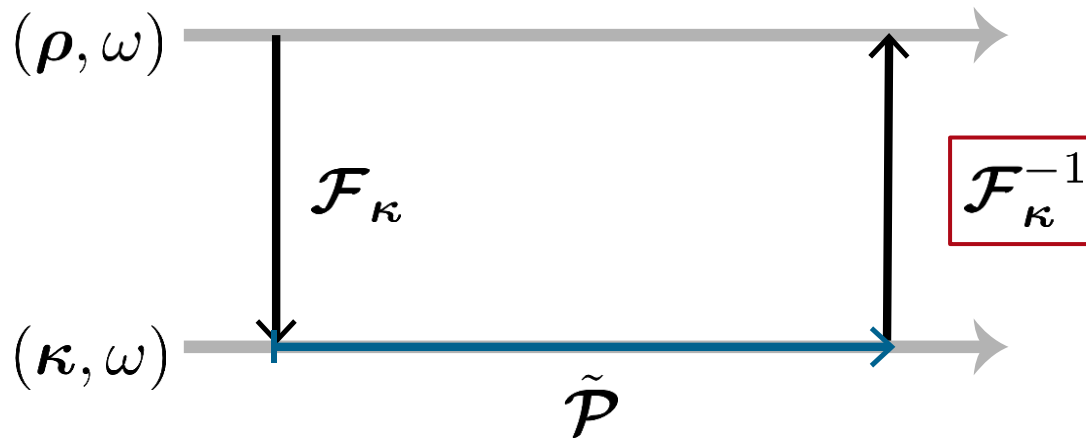
The settings regarding free space propagation can be adjusted in multiple places in VirtualLab Fusion, in a more general or more pinpointed way. The options are:



- 1 The *Profile Editor* offers a summary of all parameters of a system, including the settings for the free space propagation.
- 2 Fast access tools in the *Profile Editing & Run* ribbon allow you to choose from “configuration packages” with only a few clicks.
- 3 The *Pointwise vs Integral* tool presents the configuration in a double-entry matrix which also allows you to configure the selection criteria for the Fourier transform algorithms more flexibly.
- 4 Finally, if only the configuration of an individual element have to be adjusted, this can be done in the edit dialog of the corresponding element.

*Note: If adjusted with one control, the settings will be updated everywhere.*

# Fourier Transform

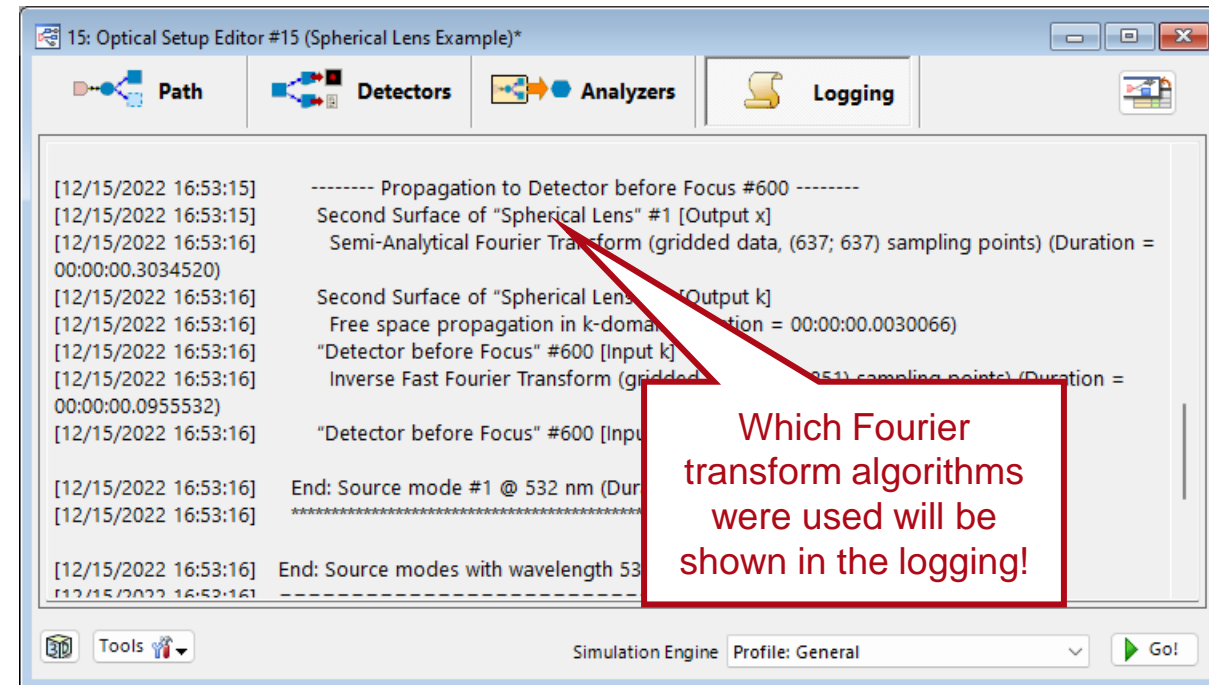


- $\mathcal{F}_\kappa^{-1}$ : inverse fast Fourier transform (IFFT)
- $\mathcal{F}_\kappa^{-1, \text{semi}}$ : inverse semi-analytical Fourier transform (ISFT)
- $\mathcal{F}_\kappa^{-1, \text{p}}$ : inverse Pointwise Fourier transform (IPFT)

(\*) in some cases, such as when the element in front of or behind the propagation step is implemented in the k-domain, one or both Fourier transform operations in the modeling sequence may not be required.

The standard modeling sequence\* of a free space propagation step is an initial Fourier transform into the k-domain, followed by the application of the propagation operator, and finally an inverse Fourier transform. The main goal of the settings is to determine which algorithm will be used for the calculation of the Fourier transform.


More information about the different Fourier transform algorithms here: [Fourier Transforms in VirtualLab Fusion](#)

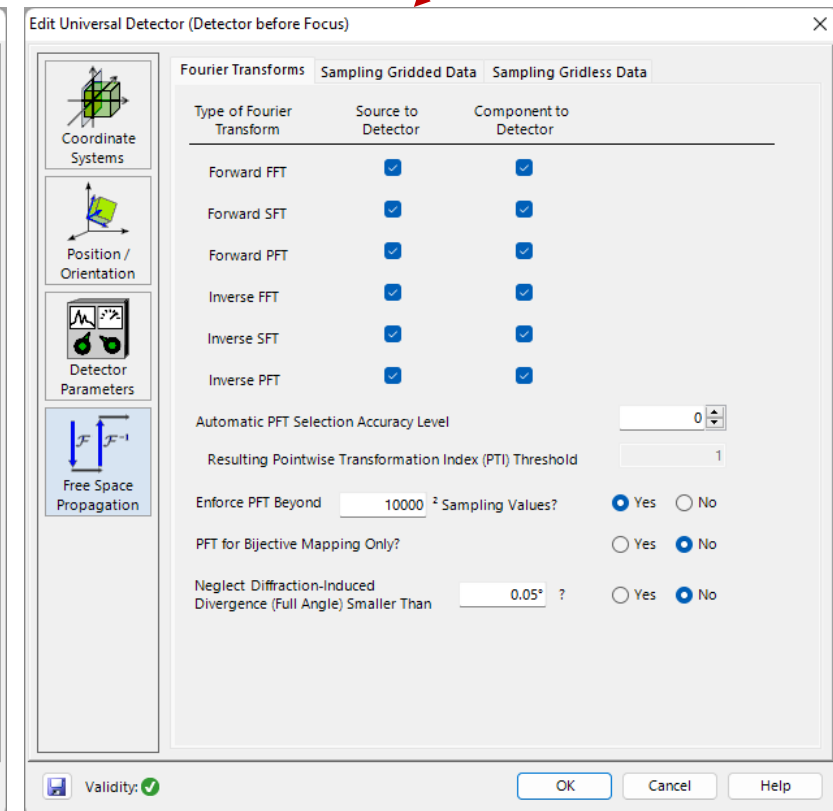
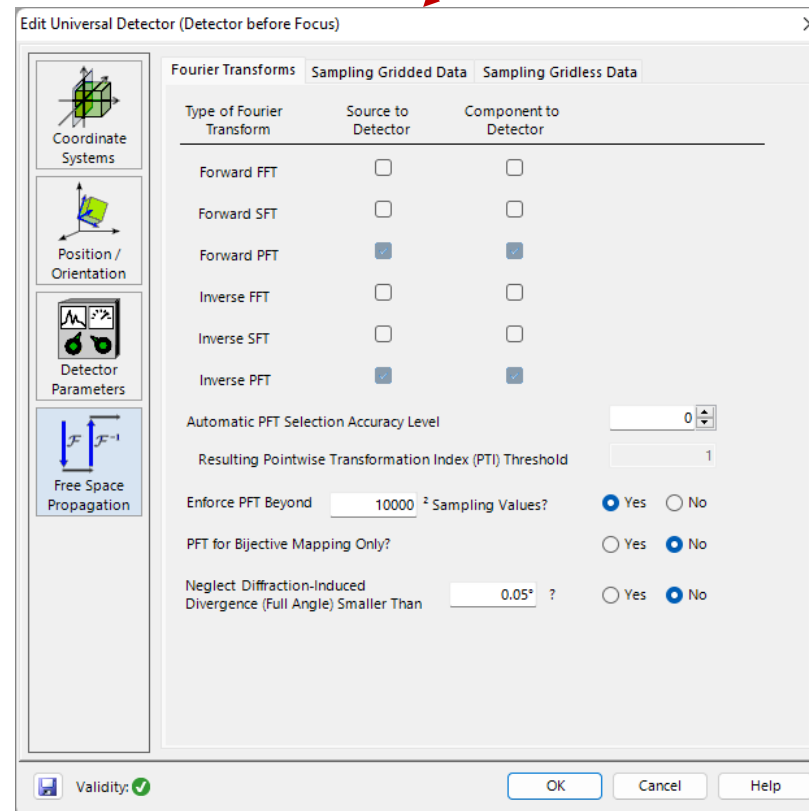
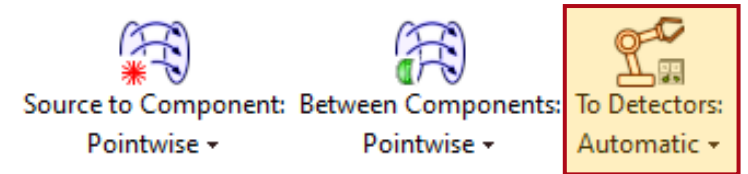
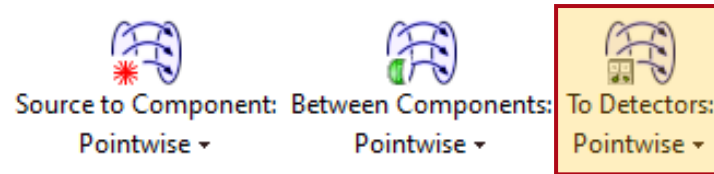


# Tools in the Main Menu

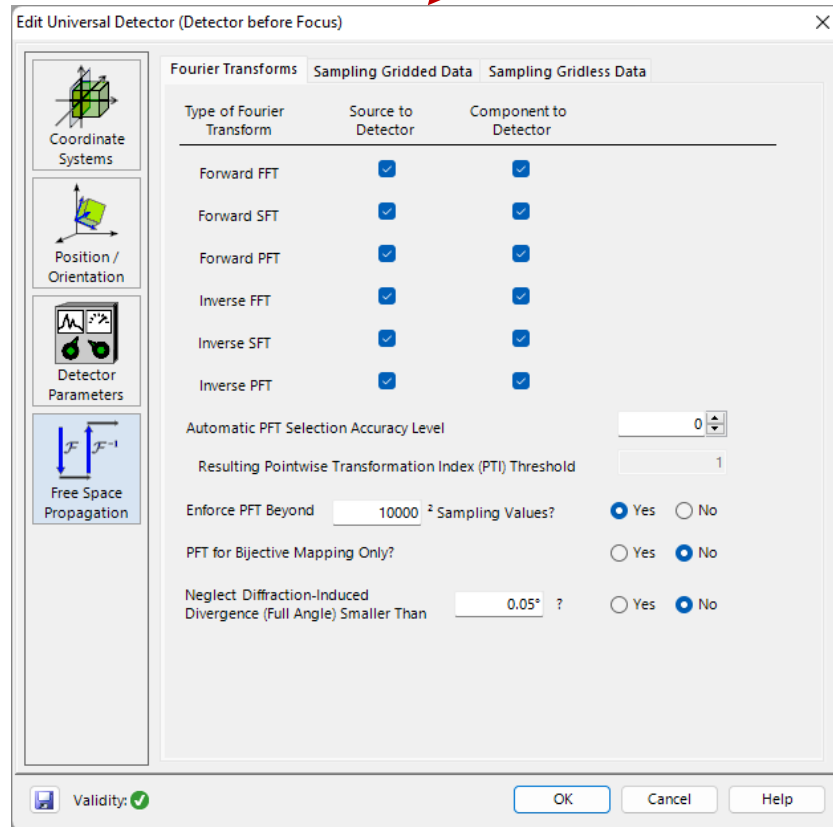
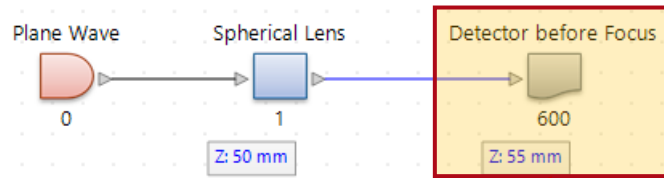
To quickly preconfigure the entire system (or to see the current configuration at a glance) there are three toggles in the main menu to switch between restricting to pointwise operators only or allowing the software to choose the Fourier transform algorithm automatically.

There is also a third state, which cannot be actively set through this tool. This state will appear if there are e.g. two detectors, where one is configured to operate pointwise and the other one automatic.

  
To Detectors:  
State = N/A ▾



# Settings in Individual Elements



Each component or detector has an entire page dedicated to Fourier transform settings. This includes one section that determines which Fourier Transform algorithms are allowed for automatic selection as well as various other advanced settings.

## Automatic PFT Selection Accuracy Level

When using the automatic selection, VirtualLab Fusion will compare the accuracy of the various Fourier transform algorithms available based on the pointwise transformation index (PTI), which is calculated by taking 1D cuts of the field and comparing field sizes after the application of pointwise and integral Fourier transform algorithms. With a higher accuracy level, VirtualLab Fusion will more often choose the integral Fourier transform algorithms.

## Enforce PFT Beyond $XXXX^2$ Sampling Values

This option allows the user to enforce the pointwise operation if the numerical effort would be too high with an integral one. The threshold of the number of sampling points necessary for this fallback option to take action can be specified; it is also possible to turn it off completely.

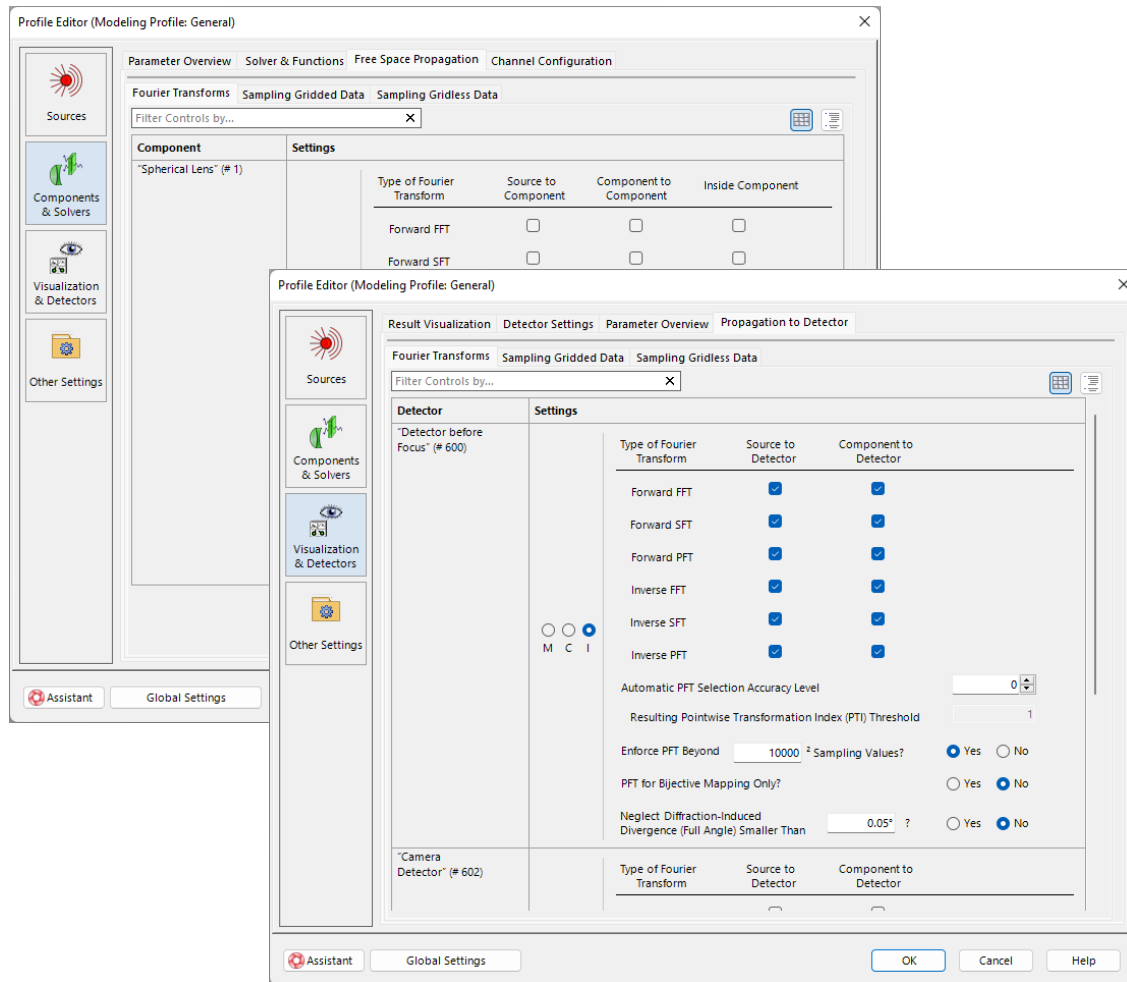
## PFT for Bijective Mapping Only?

The pointwise operator is normally only valid for bijective cases. In some cases, the pointwise operator may provide good results in non-bijective cases. This parameter allows the user to allow or forbid the use of the pointwise operator in non-bijective cases.

## Neglect Diffraction-Induced Divergence Smaller Than $XXXX$ ?

With this parameter the user can enforce the use of the pointwise algorithm if the divergence generated by diffraction is small. For more information, see: [Paraxial Assumptions Tool](#)

# The Profile Editor



In the *Profile Editor*, the sections *Components & Solvers/Free Space Propagation* and *Visualization & Detectors/Propagation to Detector* offers the same controls as in the options of the individual component or detector.

Should there be multiple components or detectors in the system, the *Profile Editor* offers functionalities to adjust all of them with a few clicks. More information on the *Profile Editor* through the following link:

[Profile Editor](#)

As mentioned earlier, all the settings are linked to each other, meaning that changing something in one place will automatically update it everywhere.



# The Pointwise vs Integral Tool

The screenshot shows a dialog box titled "Profile Editing Tool: Pointwise vs. Integral". At the top, there is a "Selection Mode" section with four radio buttons: "Individual" (selected), "All Pointwise", "All Automatic", and "All Integral". Below this is a table with three rows and two columns. The columns are "To Component" and "To Detector". The rows are "From Source", "From Component", and "Inside Component". Each cell in the table contains three radio buttons: "Pointwise" (selected in all), "Integral", and "Automatic Selection". At the bottom of the dialog, there are five buttons: "Assistant" (with a red circle icon), "Apply", "OK", "Cancel", and "Help".

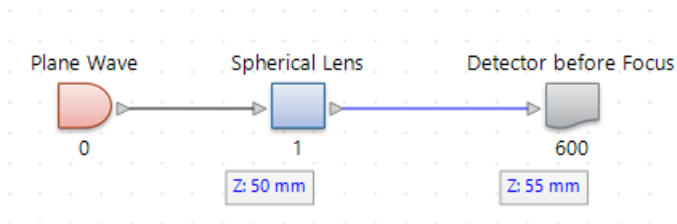
	To Component	To Detector
From Source	<input checked="" type="radio"/> Pointwise <input type="radio"/> Integral <input type="radio"/> Automatic Selection	<input checked="" type="radio"/> Pointwise <input type="radio"/> Integral <input type="radio"/> Automatic Selection
From Component	<input checked="" type="radio"/> Pointwise <input type="radio"/> Integral <input type="radio"/> Automatic Selection	<input checked="" type="radio"/> Pointwise <input type="radio"/> Integral <input type="radio"/> Automatic Selection
Inside Component	<input checked="" type="radio"/> Pointwise <input type="radio"/> Integral <input type="radio"/> Automatic Selection	

Finally, with the *Pointwise vs Integral* tool the user can specify what kind Fourier Transform algorithm shall be used under various circumstances, through a double-entry matrix. Here it is also possible to enforce the use of an integral Fourier transform algorithm.



# Example System

To demonstrate the differences between the various configurations, we have prepared a simple example of a Plane Wave that is focused by a spherical lens. The detector is positioned shortly before the actual focal plane.



## Parameters:

### input field

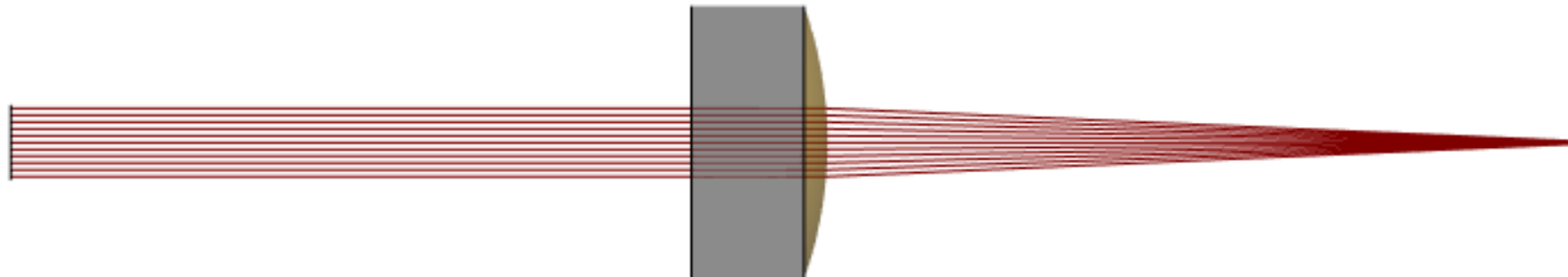
- wavelength: 632.8nm
- plane wave
- diameter: 5mm

### spherical lens

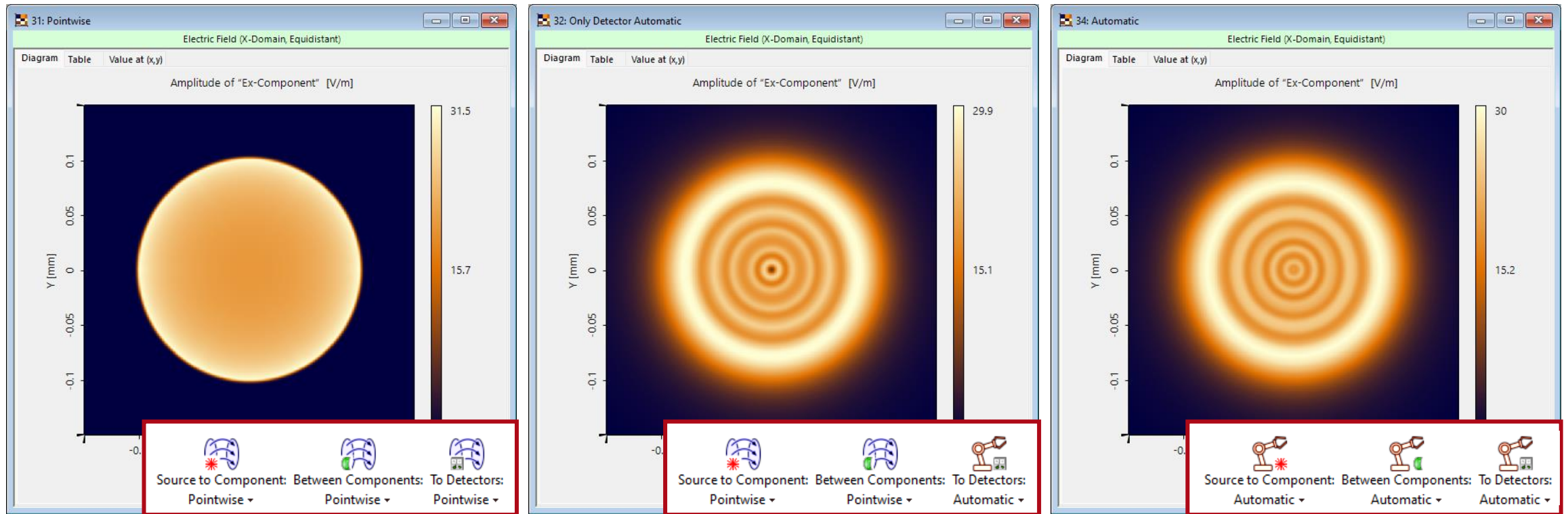
- plano-convex
- material: NBK-7
- radius of curvature: 30mm
- effective focal length: 57.75mm

### detector

- electromagnetic field
- positioned 2.75mm before focal plane



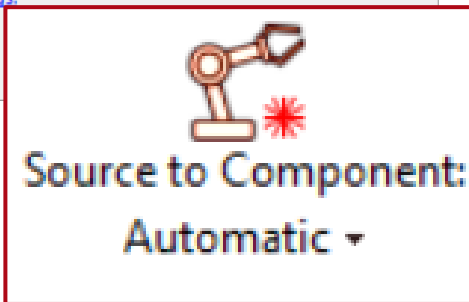
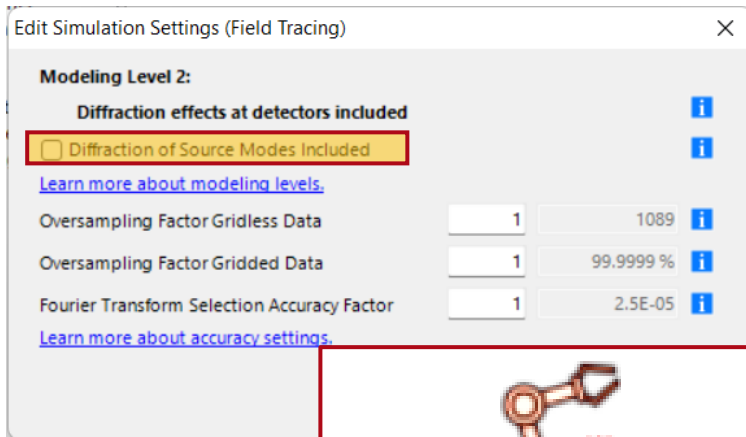
# Results



Setting all Fourier Transform algorithms to pointwise will grant you an overview of the expected spot size, but will not include diffraction fringes, as the pointwise operation neglects all diffraction effects. Using *Automatic Selection* for the propagation to the detector will provide a quite accurate result in this case as we expect most diffraction to happen between the lens and the focal region. But to include all effects, all three toggles must be set to *Automatic Selection*, revealing that the diffraction before the lens has a small but noticeable influence on the overall result.

# Translation of the Modeling Levels from Version 2021.1

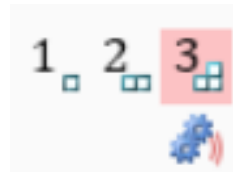
In VirtualLab Fusion 2021.1 the selection of the Fourier Transform algorithms was controlled through the Modeling Level. On the right we depict how they correspond to the options available in the latest version, 2023.1.



Source to Component: Pointwise ▾  
Between Components: Pointwise ▾  
To Detectors: Pointwise ▾



Source to Component: Pointwise ▾  
Between Components: Pointwise ▾  
To Detectors: Automatic ▾



Source to Component: Automatic ▾  
Between Components: Automatic ▾  
To Detectors: Automatic ▾

VirtualLab Fusion 2021.1, regardless of the *Modeling Level*, also had the option to include diffraction of the source modes in addition. Activating this toggle in 2021.1 is equivalent to setting the Fourier Transform *Source to Component* to *Automatic* in version 2023.1.

# Document Information

title	Free Space Propagation Settings
document code	SWF.0011
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software edition	VirtualLab Fusion Basic
software version	2022.1 (Build 1.554)
category	Feature Use Case
further reading	<ul style="list-style-type: none"><li>• <a href="#"><u>Configuring Your Simulation in VirtualLab Fusion</u></a></li><li>• <a href="#"><u>Speed vs Accuracy Tool</u></a></li><li>• <a href="#"><u>Fourier Transform Settings –Discussion at Examples</u></a></li></ul>