SAR – PHY – Optique – B: Fourier Optics and DOEs

Practical Class 1 – VirtualLab Fusion – Fourier Optics

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1. Introduction

In this practical class we will use the software package VirtualLab Fusion to simulate light propagation and diffraction by various objects in the Fresnel and Fraunhöfer diffraction regimes. The aim of the practical class is for you to gain a better understanding of the concepts presented in the introductory lecture and to test this understanding by checking and quantifying the shape and size of the diffracted light patterns and their dependence on object size, wavelength, diffraction distance etc.

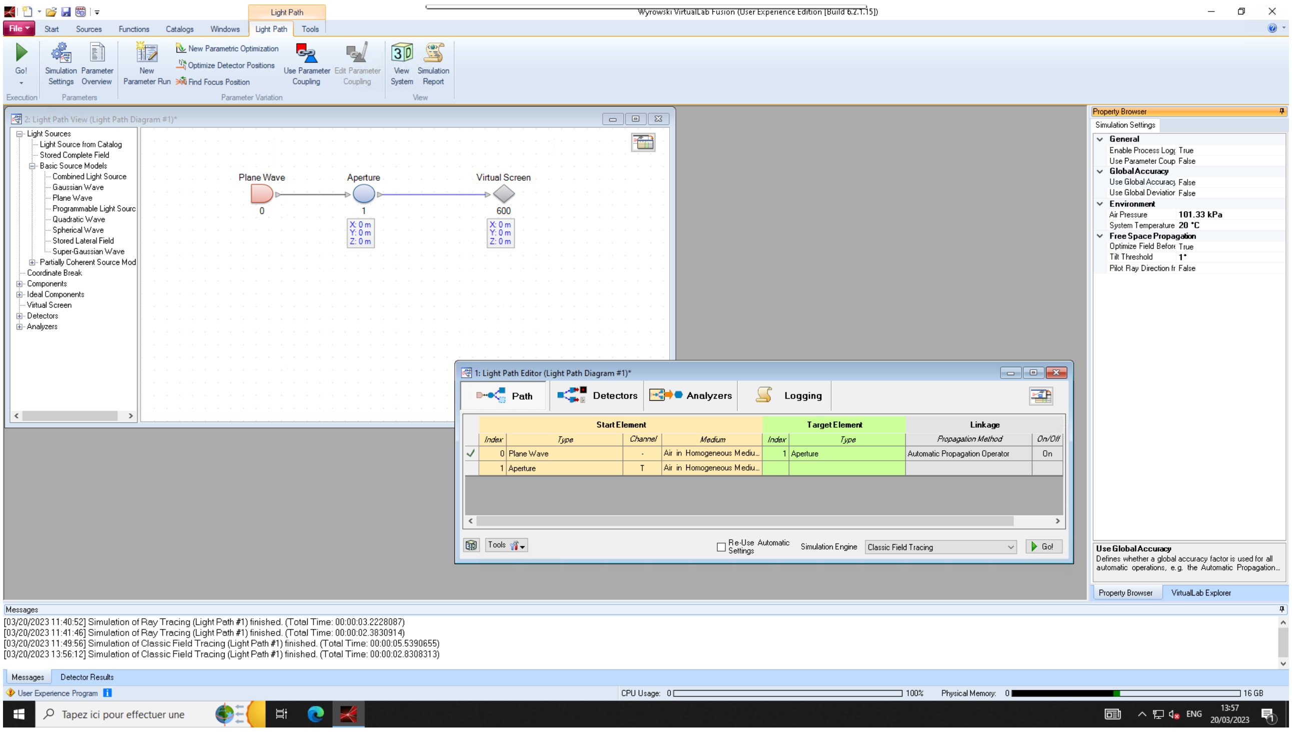
The software uses 2D Fourier Transforms to simulate the propagation of the light field from the source through various optical components (apertures, diffraction gratings …) and on to an output screen. The user can choose and position the components as required and observe and measure the diffracted pattern on the output screen. Please note that for complex or high resolution (large numbers of sampling points) systems the simulation time can become long … so keep them as simple as possible.

While progressing, save representative output view results for inclusion in your practical class report file which will be used to evaluate and mark your work.

2. VirtualLab Fusion basic operation

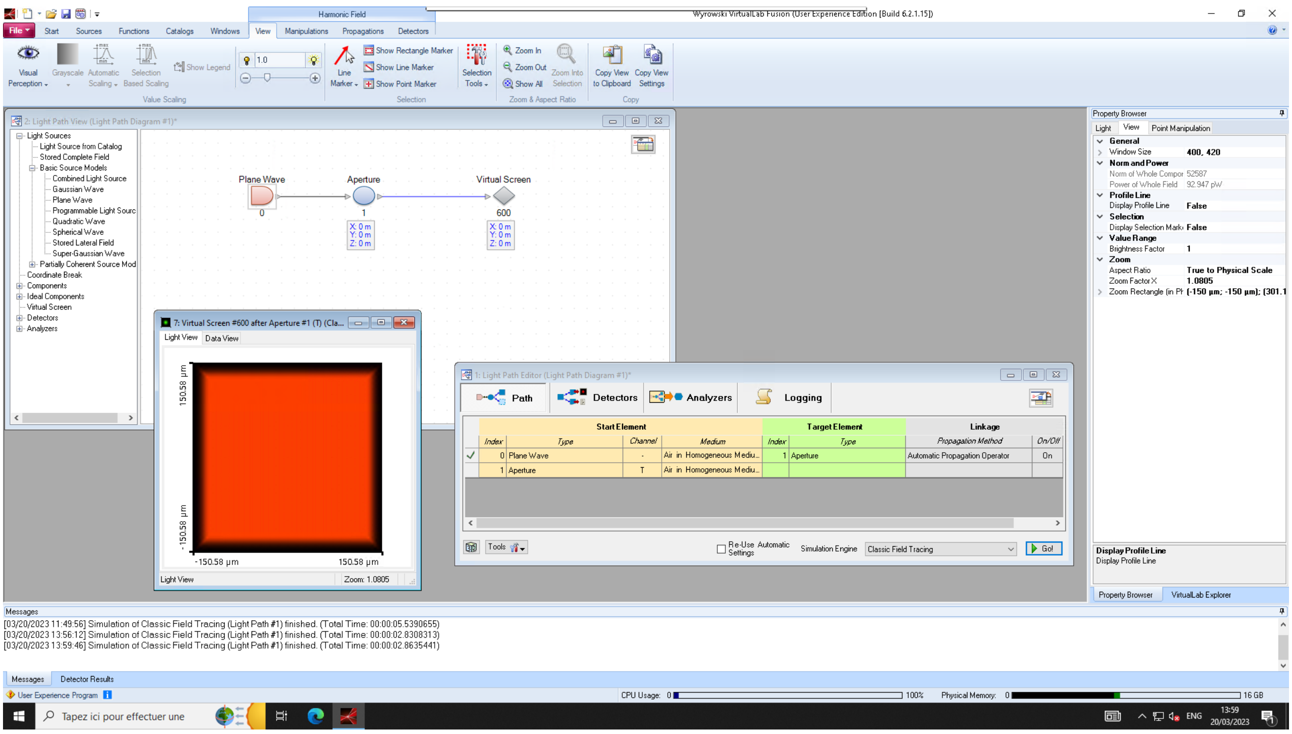
To use VirtualLab fusion, the user must construct a “Light Path Diagram” by clicking and dragging various optical components from the catalogue, connect them together to construct the optical path and finally run the simulation. The parameters of each component (e.g. wavelength for a source, size and shape for an aperture) can be chosen or modified by double clicking on an object to “open” it. To get started, please follow the steps indicted below:

1. Launch **VirtualLab Fusion** (Desktop icon or Windows menu)
2. Click on the **“Starter”** toolbox in the icon bar near the top of the VirtualLab window
3. In the “Light Path **View”** window (leave the Light Path Editor window in the background for the moment) select the Plane Wave (Basic Light Source) from the menus on the left and add it to the Light Path Diagram (LPD)
4. Do the same for an “**Aperture**” component (Ideal components → Apertures and Lenses menu)
5. Do the same for a “**Virtual Screen**” component
6. Connect the components together by clicking and dragging on the arrows on the sides of the components to produce an LPD like the one shown below.
7. Delete the unneeded Ray Tracing System Analyser component if it is present
8. Double click on the Plan Wave component to open it and set the wavelength (Spectral Parameters) to 633nm, the wavelength of the red laser that will be used in the laboratory experiments.
9. Similarly set the Aperture to a 200µm square aperture (Physical Parameters). For the moment use the default settings for the other parameters.

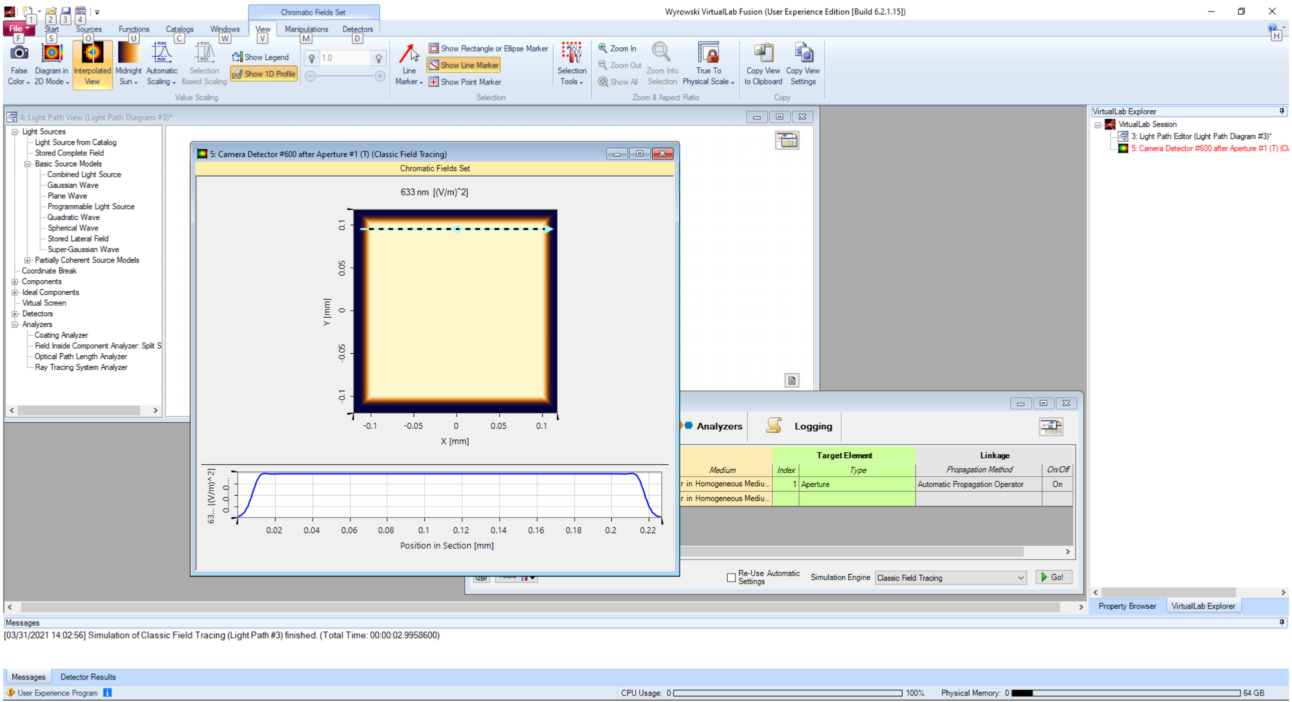


At present all the components are placed in the same Z plane along the optical propagation direction (Z coordinate shown under each component). This allows us to check that the system is properly set up because if we run a simulation we should simply see the shape of the square aperture on the Virtual Screen in the output field.

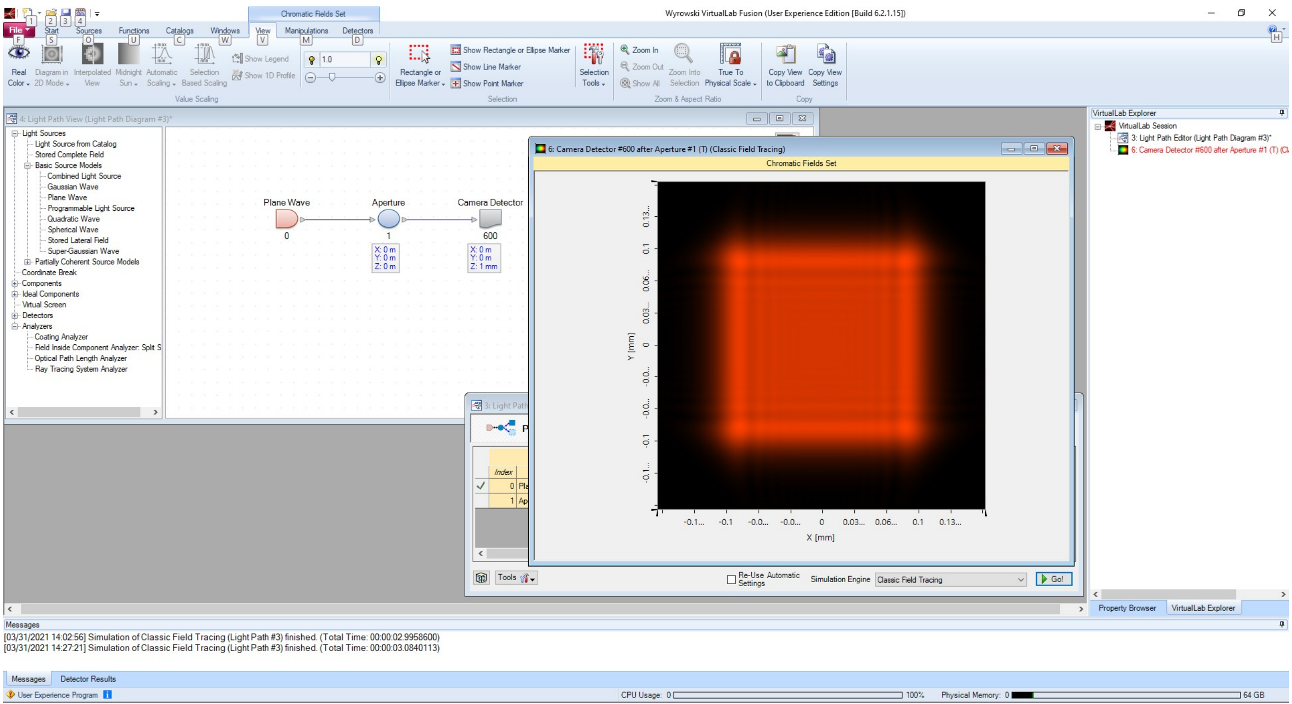
10. In the Light Path **Editor** window select the **Classic Field Tracing** Simulation Engine (it is the simulation engine we will use for all simulations) then run the simulation by clicking on the green arrow "Go" button. After a few seconds this should open a Virtual Screen Window similar to the one below. The aperture should be square and of the correct size (200x200µm) and colour (red)



11. We can change the output view by changing the controls (top icon bar) and make measurements on the output field by changing to **False Colour** mode (“Colour by LUT” to the top left of the icon bar) and then selecting “Show 1D Profile” and “Line Marker” (in the “Rectangle or Ellipse Marker” drop down menu.). This should give an output view like the one below. Experiment to familiarise yourself with the various controls and possibilities offered by the software for the analysis of the output pattern.



12. Close the Virtual Screen window and in the Light Path Diagram change the position of the Virtual Screen by clicking on the coordinates box below the icon to move it to 1mm behind the aperture (set z=1mm). Rerun the simulation (“Go”) and observe the new output pattern which should be similar to that shown below.



We can clearly see, as to be expected, a “classic” Fresnel diffraction pattern for a square aperture. Repeat with various diffraction distances to try to identify the Fresnel and Fraunhöfer diffraction ranges.

For the rest of the practical class, only general instructions are given, you must apply and adapt what you have learnt in the above examples to construct the appropriate systems (Light Path Diagrams) and the output field view parameters to produce and analyse the results as necessary.

Include representative output view results in your practical class report file which will be used to evaluate and mark your work.

3. Fresnel/Fraunhöfer diffraction by a square aperture

a) Identify the approximate limit of the Fresnel Diffraction regime

b) How does this vary for aperture size and wavelength?

4. Diffraction by a rectangular aperture

a) Change one of the aperture dimensions (make sure it is still smaller than the plane wave dimensions to be sure that it is completely illuminated)

b) Explain the output pattern shape ?

c) In the Fraunhöfer (Fourier) regime, measure the output pattern size and check that it corresponds to the size predicted by the theory presented in the lectures (e.g. width of central lobe)

d) Check and quantify the variations with diffraction distance, wavelength and aperture size.

5. Diffraction by a circular aperture (Fraunöfer)

Repeat the observations and measurements for a circular aperture (Airy Disc Pattern)

6. Diffraction by a double rectangular aperture (Fraunöfer)

Construct a double slit aperture with two 100μm wide slits separated by 500μm (centre to centre) – slit height isn’t important but 2mm is OK (check the plane wave is big enough to illuminate the whole aperture). There are various ways of doing this but probably the simplest is to construct a 600μmX2mm aperture and place an opaque 400μmx2mm “stop” object centred in the middle and in the same Z plane.

a) Describe and explain the diffraction pattern observed

b) How and why does the pattern change with a variation in the separation of the two slits. Try to give a concise explanation in terms of Fourier Optics rather than long mathematical demonstrations.

7. Diffraction by a multiple slit aperture

Extend the double slit aperture to create a multiple slit grating with 3 or 4 slits. Explain the output pattern in terms of Fourier Optics

<u>Supplementary exercises</u>

If time permits you can continue to investigate and explain the following setups.

8. Diffraction by a many slit grating

Extend the multiple slit aperture to create a many slit grating (N > 10).
One way to do this is to edit the aperture function :

Basic Parameters → Single Function → Periodic Function

This can also be done (perhaps more simply) by using the Rectangular Grating component (Ideal Components → Grating Transmissions)
Explain the output pattern in terms of Fourier Optics

9. Diffraction by a 2D array of small square apertures

Explain the output pattern in terms of Fourier Optics

10. Diffraction by a 2D array of small circular apertures

Explain the output pattern in terms of Fourier Optics

11. Using a lens to form the diffraction pattern

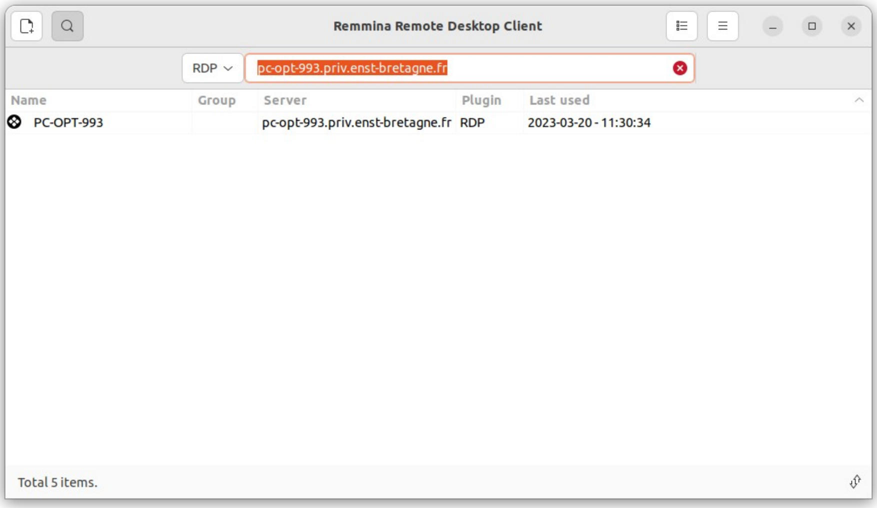
Place an ideal lens behind a chosen object and observe the light pattern at various distances behind the lens and in particular in the focal plane.
Do we see the Fraunhöfer diffraction pattern ?
Relate the pattern dimensions to the lens focal length.

12. Fourier filtering system

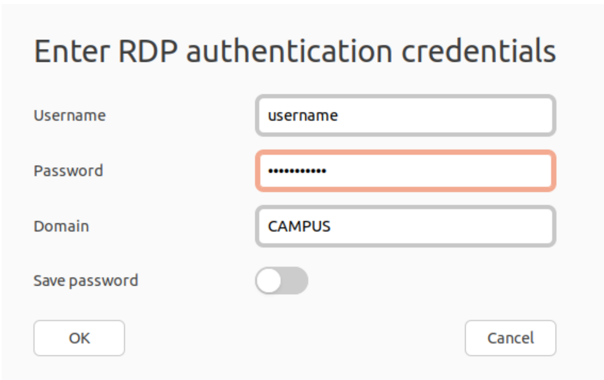
Use two ideal lenses to construct a 4f setup
Place apertures and stops in the Fourier plane between the lenses to filter the input pattern
Observe the light pattern in the output plane for different types of filter

Connection to VirtualLab Fusion from a CAMPUX (Linux version IMT Atlantique) PC

1. Login to the CAMPUX PC using your usual IMT Atlantique username and password
2. Open the "Remmina" Remote desktop viewer (available in the "Applications → Internet" menu for example
3. Select the RDP protocol and one of the three available simulation distance PCs running Windows :
   - pc-opt-993.priv.enst-bretagne.fr
   - pc-opt-995.priv.enst-bretagne.fr
   - pc-opt-998.priv.enst-bretagne.fr



4. Login to the distant windows machine with your usual IMT Atlantique username and password and selecting the "CAMPUS" domain:



5. Once the Windows session opens (this may take some time – please be patient) select and open the VirtualLab Fusion software … then follow the Practical Class description.