OTOM Ray tracer

GUIDE DOCUMENT
Ver. 1.24.1

Works with Nvidia driver

Dec 2023

OTOM Ray- tracer

The OTOM Ray-tracer software is a sophisticated optical/electromagnetic path tracer tool designed for analyzing the interaction of light with objects. It provides a robust platform for conducting high-fidelity ray-tracing analyses on both opaque and transparent objects. This tool excels in precisely determining ray intersection points and accurately assessing energy transfer within optical systems and objects.

🚀 Key Features:

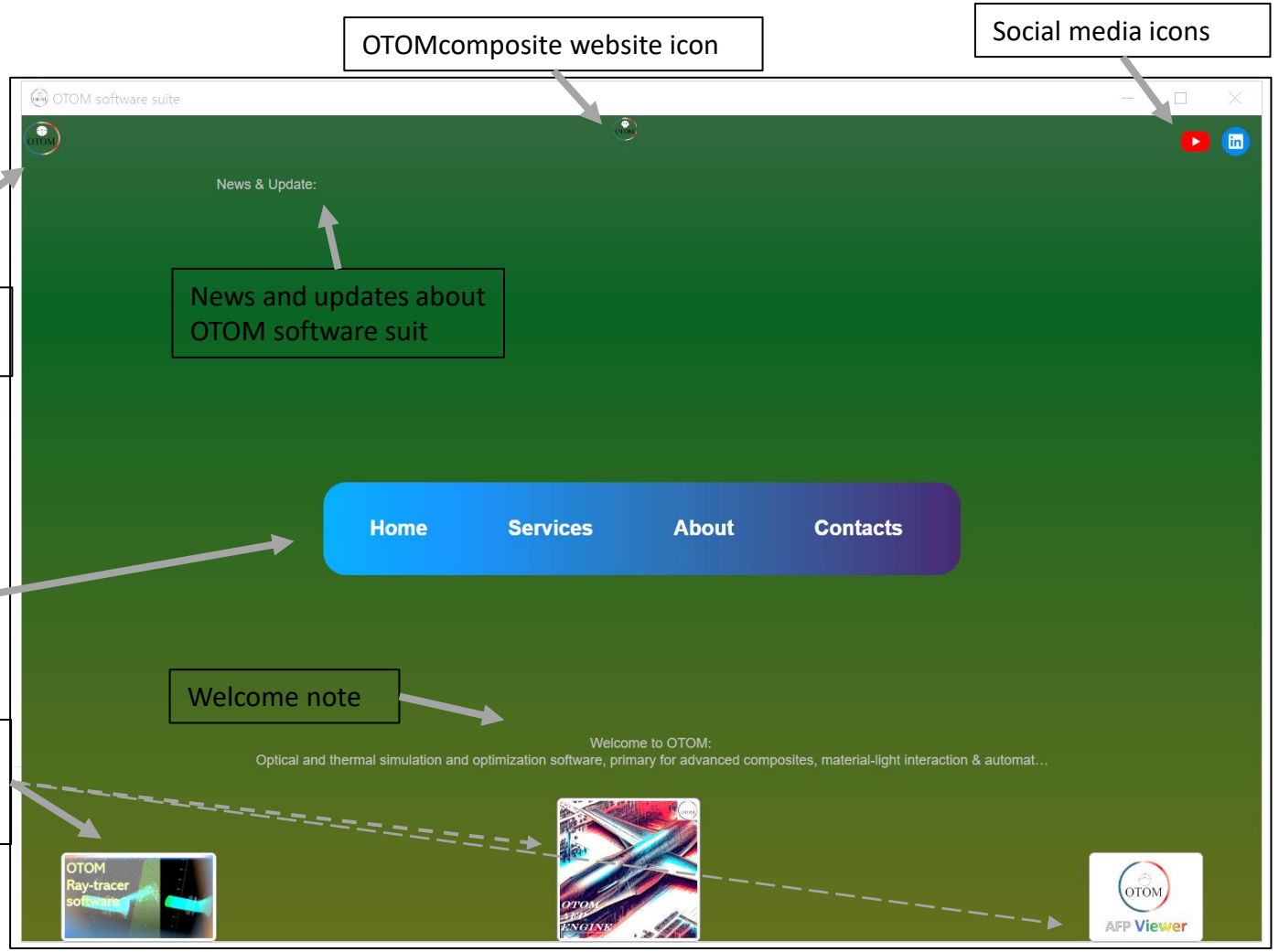
✅ **Versatility**: ADD as many objects into the scene for Optical characterizing, and light energy interactions with any surface - from metals to composites.

✅ **Microscopy Integration**: Enhancing surface characterization by importing microscopy data directly into the system. We can seamlessly incorporate surface roughness from microscopy, providing an unprecedented level of detail.

✅ **Precision Engineering**: Achieve unparalleled precision in surface modification. OTOM allows you to tailor interventions based on real-world microscopic data, optimizing outcomes in surface engineering projects.

OTOM suit start page

You can initiate the OTOM Ray Tracer software from the OTOM Suit start page. On the welcome page, various menus are available, allowing you to manage your license access, engage with the company's social media, or access news and updates. To launch the OTOM Ray Tracer software, simply click on its respective option.

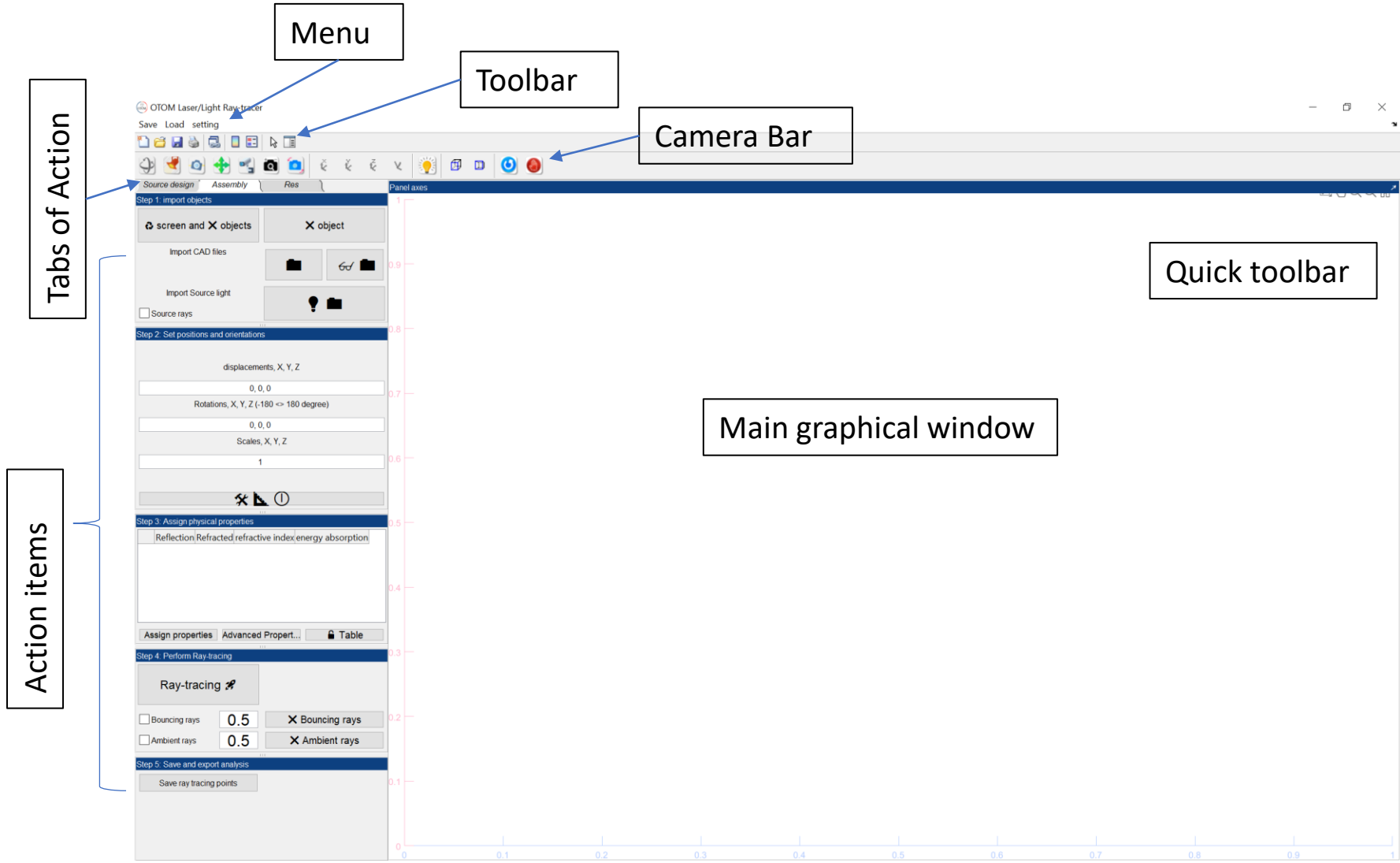


- Software to launch: (left to right) OTOM ray tracer
- OTOM AFP Engine
- OTOM AFP Viewer

Main window

The main window of the Ray Tracer software comprises several elements, namely: menu, toolbar, camera bar, quick bar, main graph, window tabs, actions menu, and action items.

You have the option to modify the general settings through the menu. Utilize the camera bar to rotate the view within the main graphical window. It is crucial to assign optical objects and configure settings for the rendering process in the tabs designated for actions.



Menu and Camera toolbar

The list of actions for the menu and camera bar are listed below:

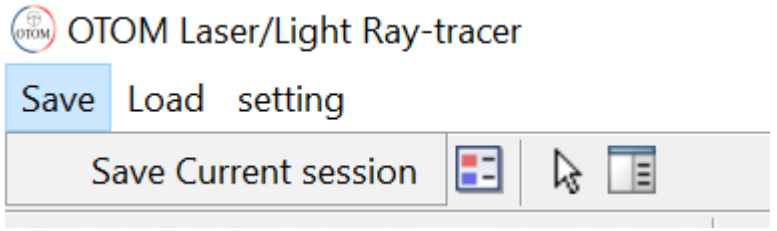
- Orbit camera
- move camera
- Move camera height
- Roll camera
- scene light
- Zoom camera
- tilt camera
- light bulb icon
- Reset camera
- Perspective/ isotropic view
- Toggle scene light
- Stop moving camera

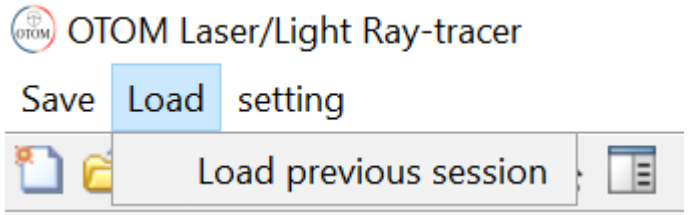
Standard Matlab/ Java swing toolbar:
You can change some of the properties with mouse icon and change the properties

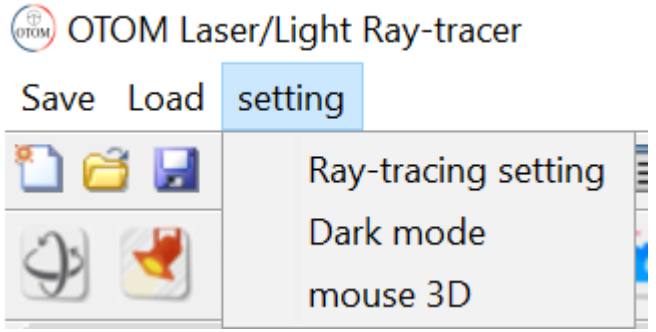
Camera toolbar

Menu

When conducting optical analysis using ray tracing, it is possible to save the session. Subsequently, you have the option to reload the saved sessions and import both the objects and results. Additionally, post-ray tracing, you can modify settings, including memory management and level of detail for analyzers. Furthermore, you can adjust the scene's ambiance through the dark scene settings, and manipulate the 3D view by instructing the software to perform window rotations, zoom in, or zoom out using the mouse.



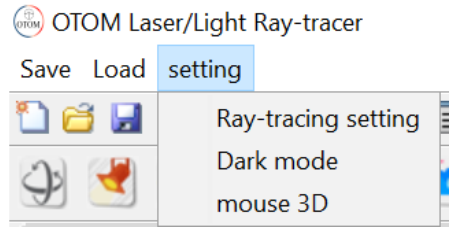


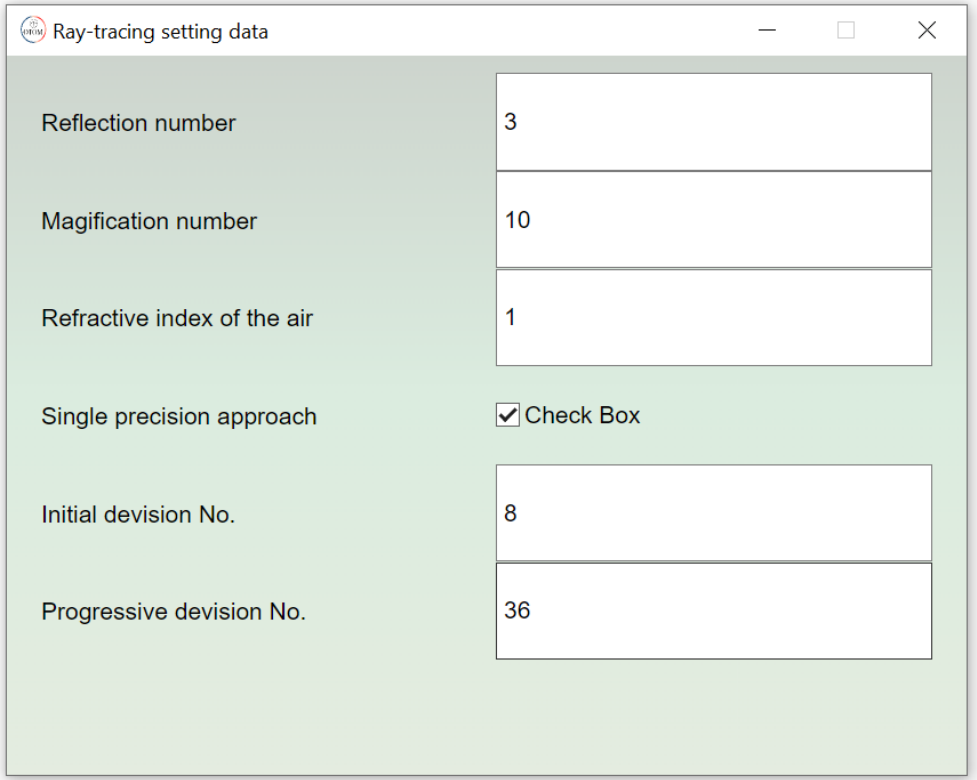


Ray tracing setting

Conducting a thorough ray tracing analysis allows for a high level of detail, but it can also be executed with a more generalized approach. The degree of detail can be adjusted through ray tracing settings, wherein various parameters can be modified:

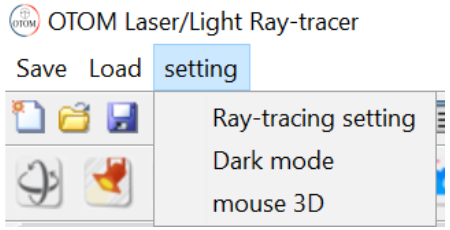
1. **Reflection Number:** This parameter dictates the quantity of reflections to be calculated.
2. **Magnification Number:** Adjusting this parameter influences the graphical representation in the window.
3. **Refractive Index of Air:** It is possible to alter the refractive index of the air.
4. **Precision of Numbers:** The precision of numerical calculations for ray interactions can be customized. The default is double precision, but for faster results, it can be changed to single precision.
5. **Initial Division Number:** This pertains to the memory management during the first interaction of the rays with objects.
6. **Progressive Division Number:** As the number of reflections increases, this parameter enhances the divisions of scenes and rays in memory. Consequently, a higher number of steps for reflections, such as the 5th or 6th, can be achieved.

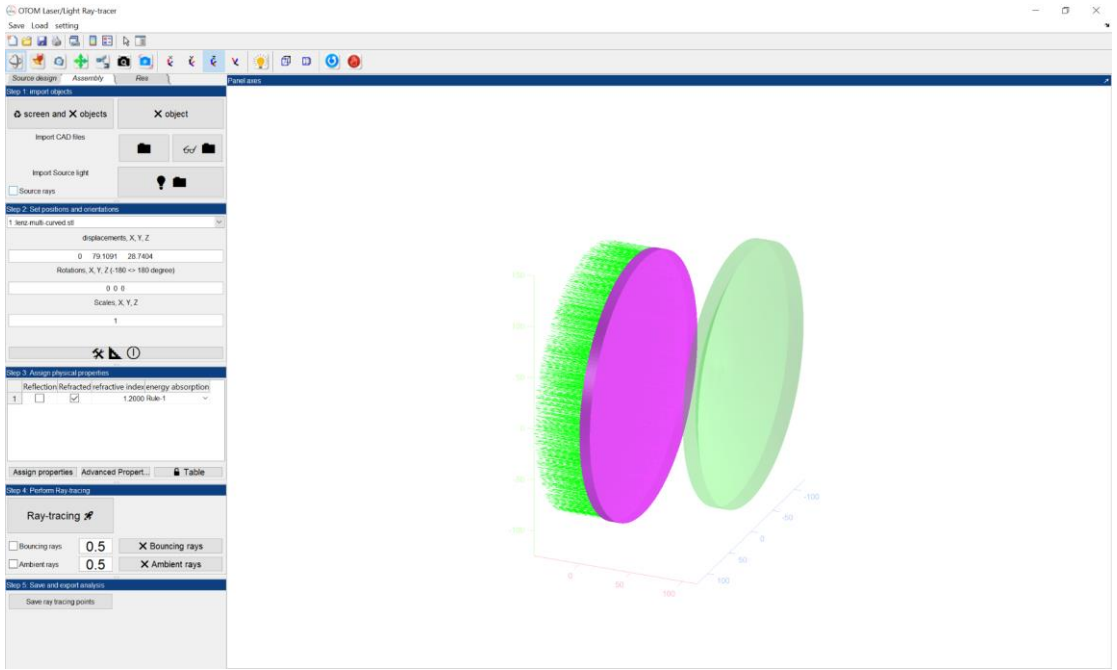


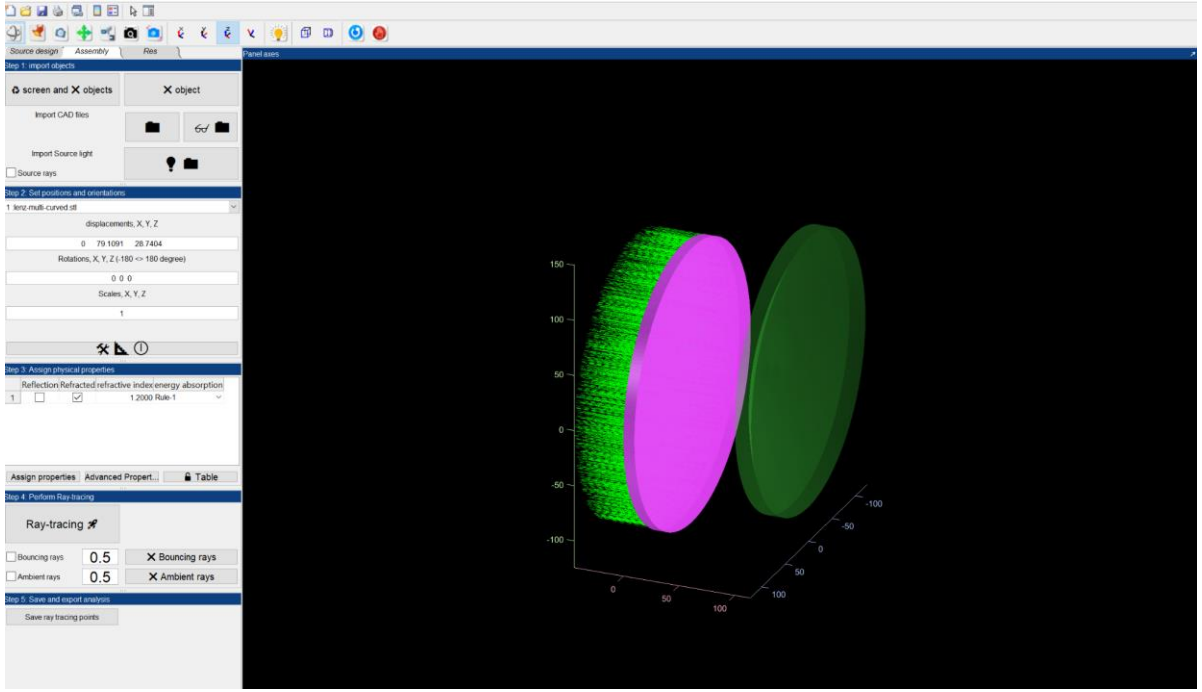


Ray tracing setting

if you click on the dark mode the graphical window will change the color to the black theme

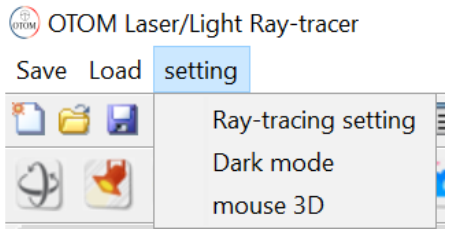




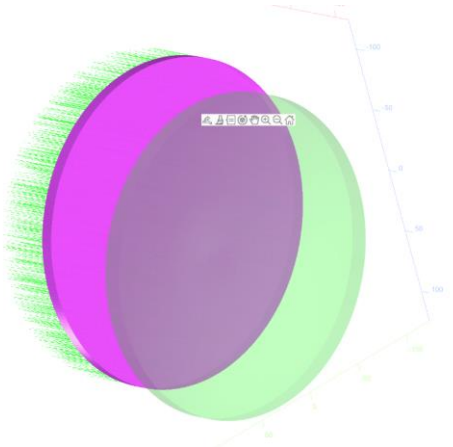


Ray tracing setting

To employ the mouse for concurrent rotation, zooming in, and zooming out, access the settings and select "Mouse 3D." Upon clicking "Mouse 3D," you will observe highlighted features that enable specific actions. Additionally, you have the option to utilize keyboard directions, such as arrows for corresponding rotations, and the plus or minus keys for zooming in or out. Various keyboard buttons can be employed to control the 3D scene, and deactivation can be accomplished by clicking the same option or by using the camera toolbar to disable these functionalities.



Shortcuts with keyboards and mouse:
◇ Rotate with Directions ← → ↑ ↓
◇ Use Shift to Yaw, use Ctrl to pan + Directions
◇ Use i letter for initial position
◇ Use right and middle mouse buttons to zoom and pan
◇ Use + and - to Zoom in and Zoom out
◇ P: compass
◇ Use H to Hold/Pause



Creating Laser/Light/Signal broadcast source step 1

To conduct the analysis, it is necessary to establish a light, laser, or signal broadcast source. This involves importing a 3D object, typically in STL format. The process can be executed in the "Source Design" tab, which comprises five sequential steps. Here is an overview of the steps within this tab:

1.Import CAD File: Initiate the process by clicking on "Import CAD File" to select and import your STL file.

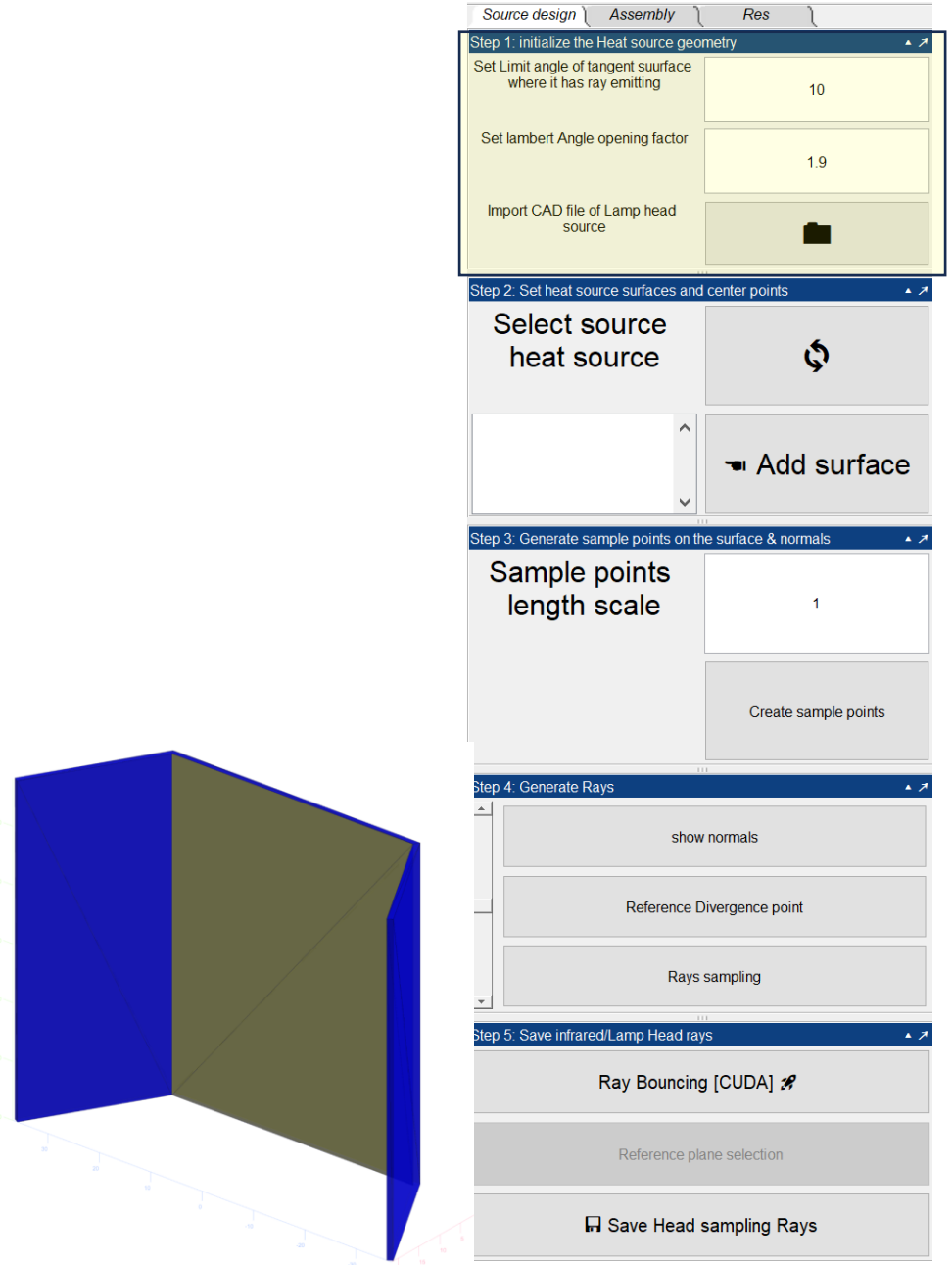
2.Define Emission Phases: After importing the file, select the phases from which the rays will emit by clicking on the corresponding file.

3.Surface Tangent Conditions: Adjust the conditions of the two adjacent surfaces using the "Limit Tangent Angle" in the first edit box. This angle limit determines the continuity condition between the surfaces. A higher limit allows for more surface selection, while a lower limit restricts the number of surfaces.

It's crucial to experiment with the tangent limit to gain a better understanding of its impact on surface selection.

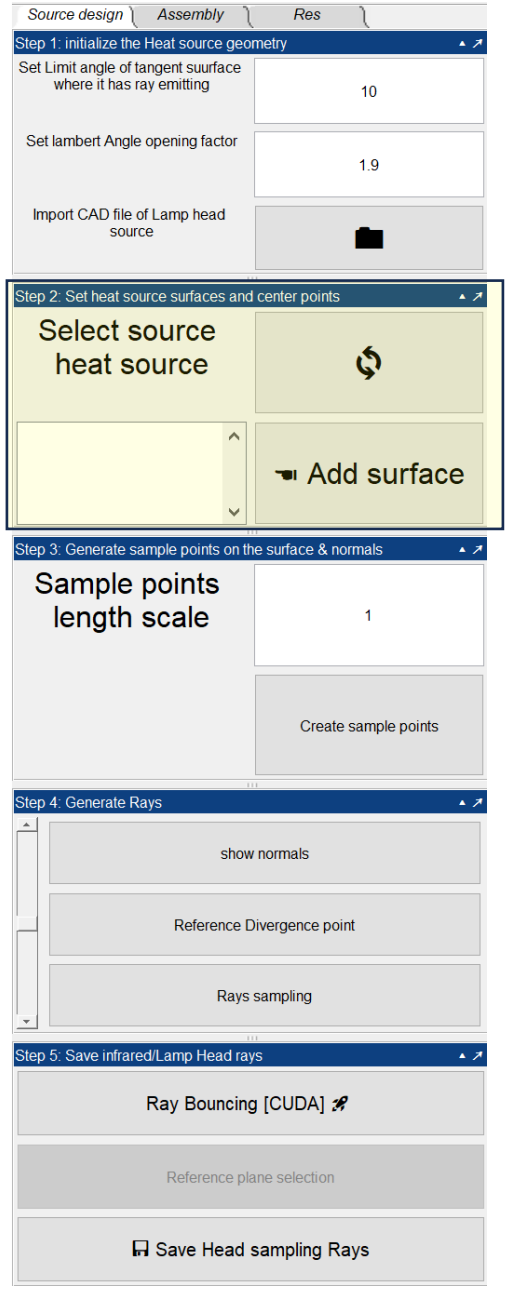
The **Lambert Angle Opening Factor** influences the divergence of the rays. When set to 0, all emitting rays are parallel. Increasing this value results in a higher level of divergence. This factor represents the magnitude of the vector from the reference source to the specific emission location. A higher opening factor leads to a greater magnitude of the divergence vector.

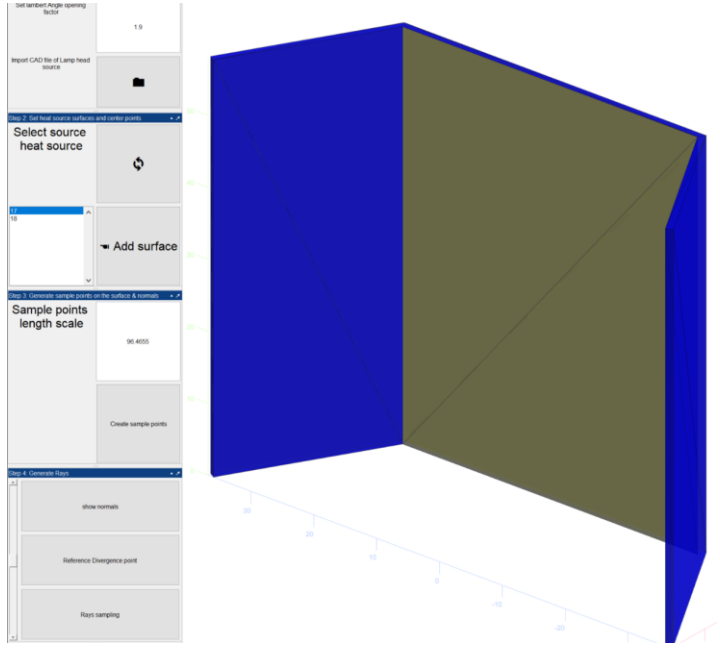
It's advisable to experiment with the Lambert Angle Opening Factor to grasp its influence on the divergence of rays.



Creating Laser/Light/Signal broadcast source, step 2

After selecting specific phases, the next step involves adding surfaces in the second stage. These added surfaces are then recognized as emitting surfaces. If needed, you can clear the selected surfaces by using the recycle icon. By clicking on a particular surface ID in the left list box, the corresponding phase will be highlighted, providing clarity and focus on the selected surfaces for further manipulation.

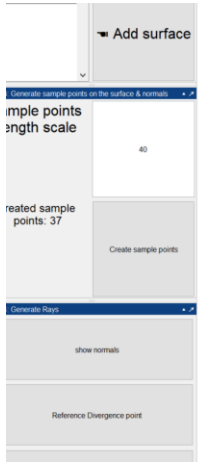


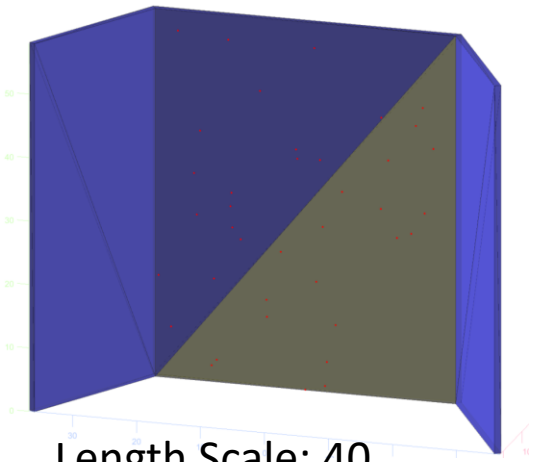


Creating Laser/Light/Signal broadcast source step 3

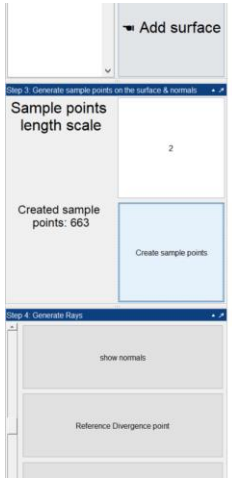
In the third step, you have the option to generate sample points for the rays' intersections. The lens scale parameter determines the average distance between these sample points. A higher lens scale corresponds to fewer sample points, while a lower lens scale results in more sample points.

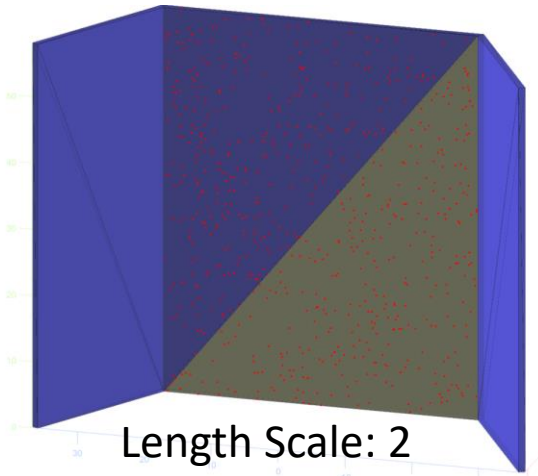
To illustrate this, consider the comparison between sample points for a lens scale of 40 and a lens scale of 2. The difference is significant, with the smaller lens scale of 2 having approximately 25 times more sample points compared to the larger lens scale of 40, as depicted in the images below.



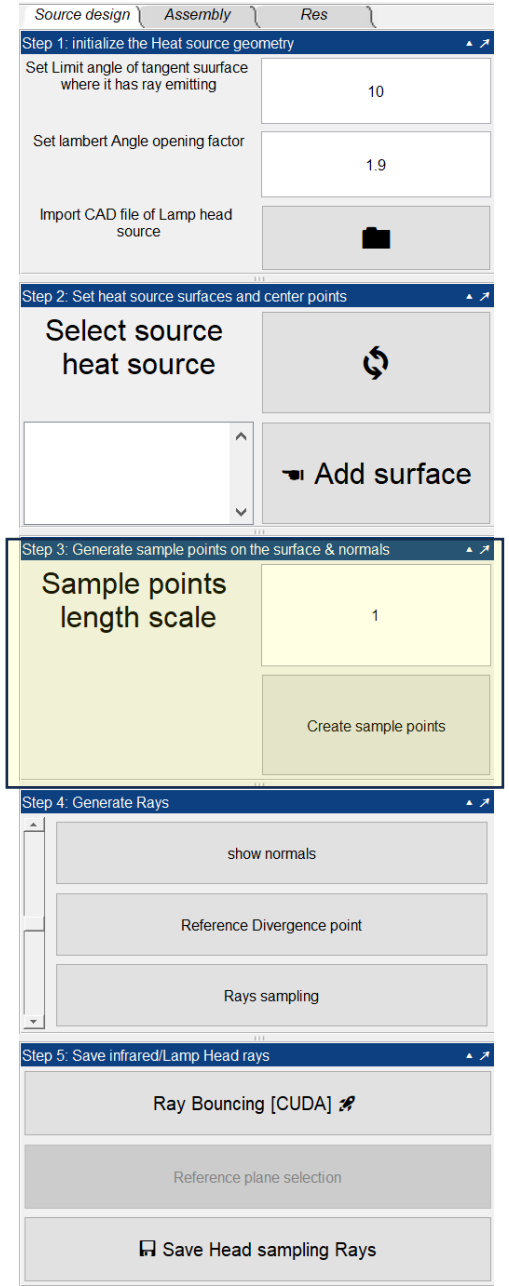


Length Scale: 40





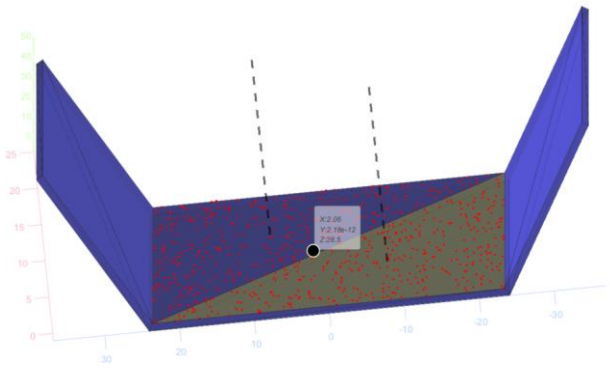
Length Scale: 2

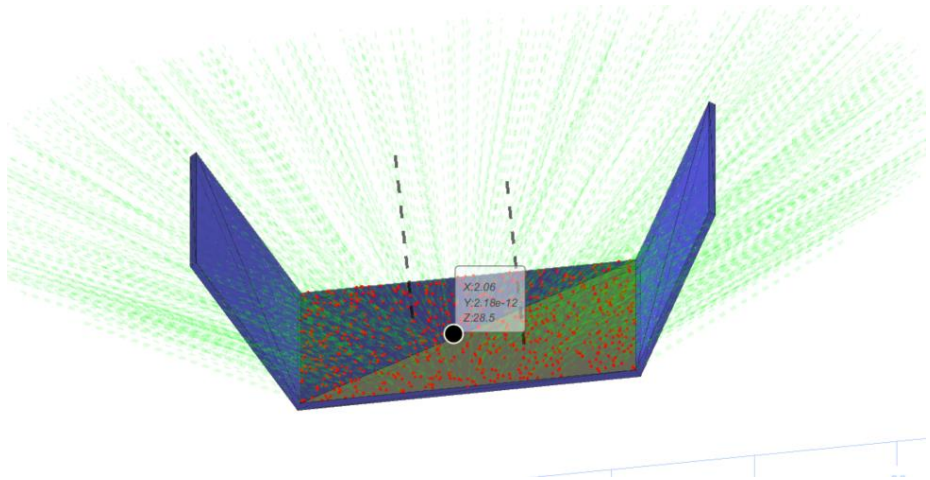


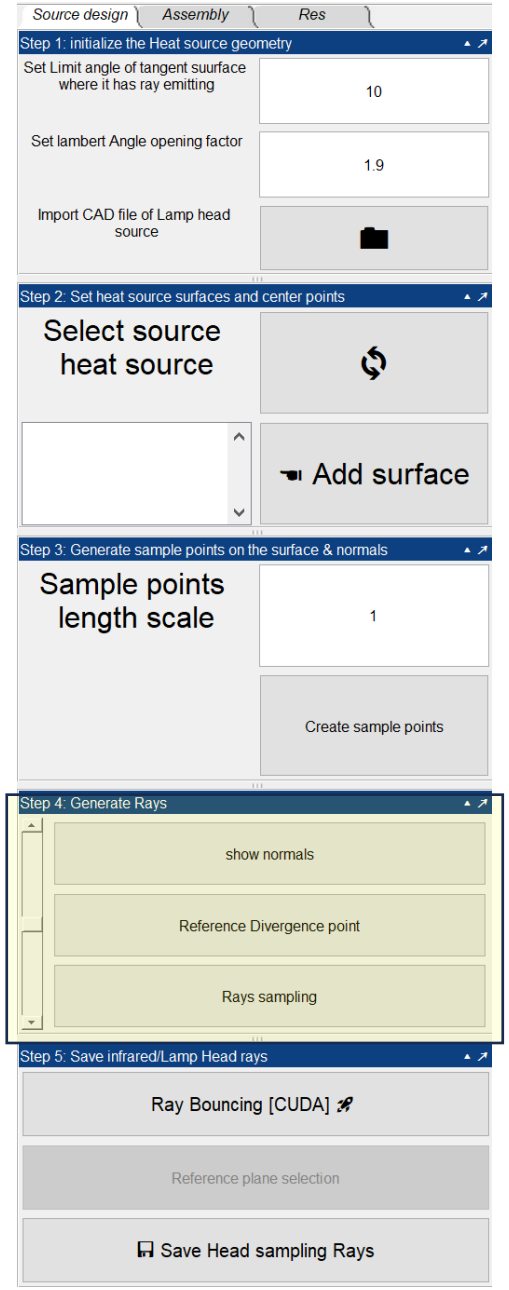
Creating Laser/Light/Signal broadcast source step 4

In the fourth step, after defining the normal surface, setting the reference divergent point, and creating ray samples, you can review the setup. The magnitude of the slider can be adjusted to represent the rays and their normals using the left slider bar. By changing the location of the reference divergent point, the divergence is measured from the sample points with respect to this reference point. This implies that sample points farther away will exhibit a higher level of divergence.

When you click on "Ray Sampling," the rays will be displayed, showcasing the calculated initial directions. It is important to note that this step is purely a visual representation and does not perform any actual ray tracing; it serves as an initial depiction of the outgoing rays from the sample points.





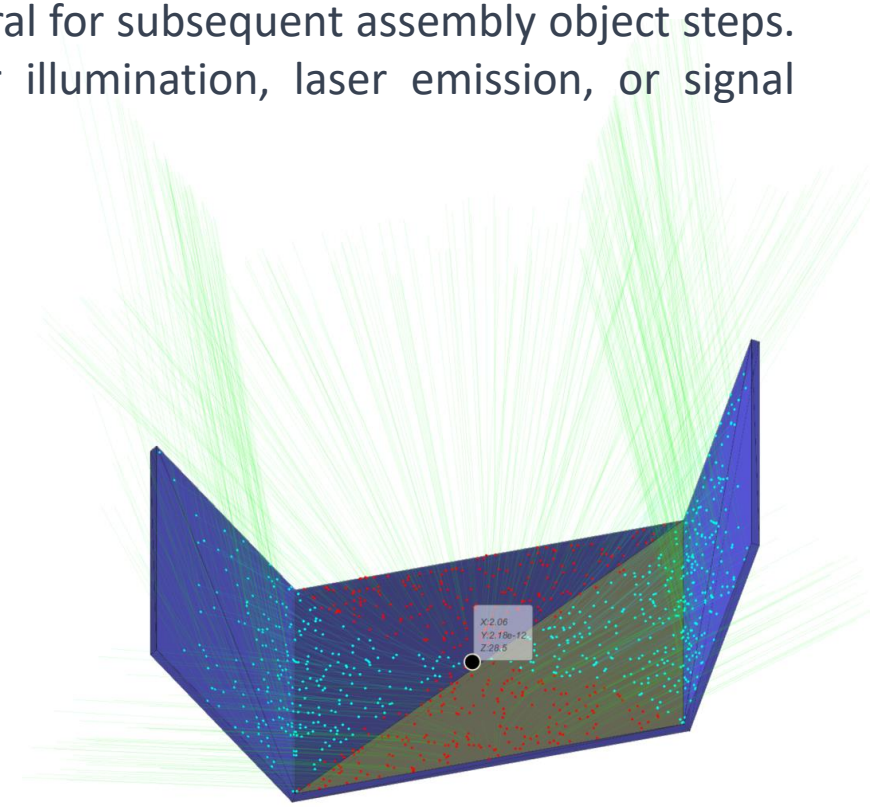


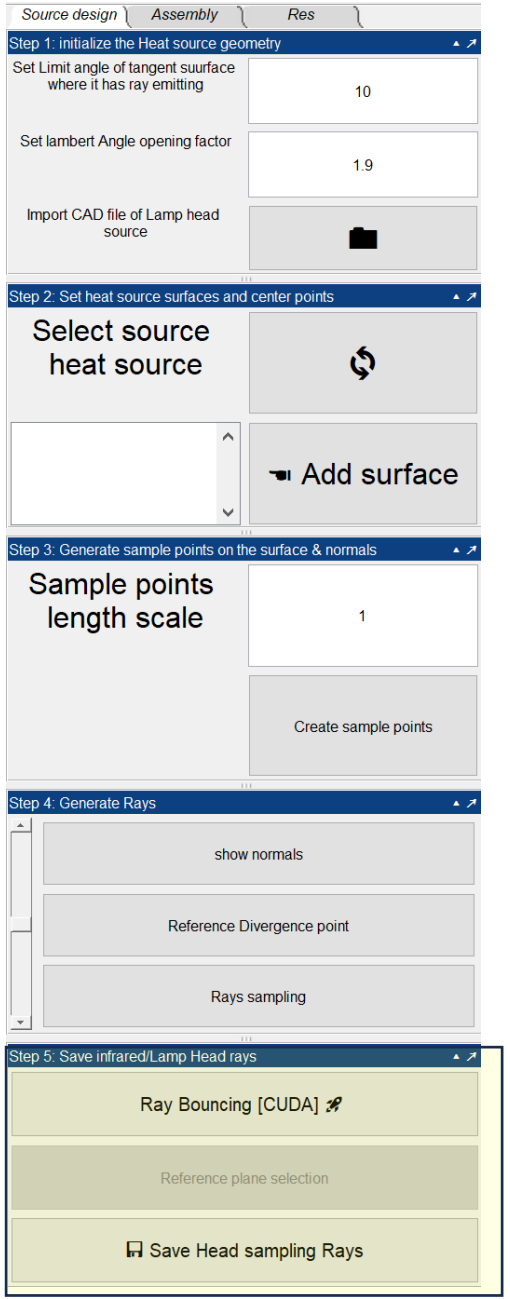
Creating Laser/Light/Signal broadcast source

step 5

In the final step, actual ray tracing is executed. When you click on "Ray Tracing," the software prompts you to confirm whether you intend to perform new ray tracing or remove previous data. If you choose to proceed with new ray tracing by selecting "Yes," the calculations will be initiated. The output will include the paths of the rays, including those bouncing within the source and intersection points represented as points.

Distinctively, points are displayed when rays do not intersect with object surfaces. Following this step, you have the option to save the head sampling rays. This action saves the head source as a new source object, which becomes integral for subsequent assembly object steps. These saved rays serve as the primary source for illumination, laser emission, or signal broadcast in the analysis.





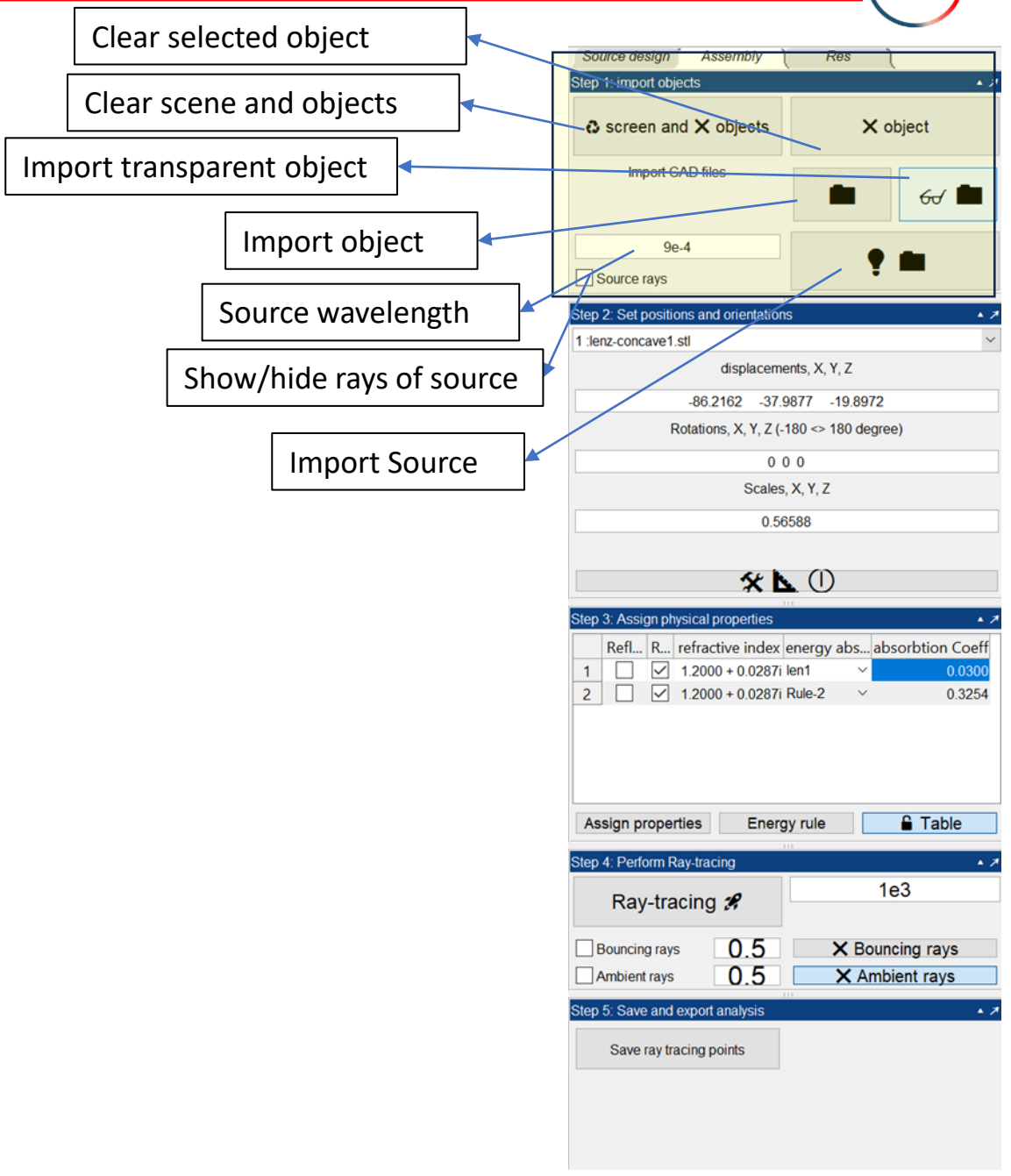
Assembly of the objects step 1

In the second tab, the "Assembly" tab, you can import and assemble the object lenses, lights, or laser sources. The process involves several key steps:

1. **Import Objects:** Begin by importing the objects you wish to analyze.
2. **Position and Orientation:** Set the appropriate positions and orientations for each imported object.
3. **Refractive Index:** Select the refractive index for the objects as part of the configuration.
4. **Output Configuration:** Define the desired output, whether it be reflections, refracted calculations, or a combination of both.
5. **Save Output:** After configuring the parameters, you have the option to save the output of the ray tracing analyzers as an Excel file.

By following these steps in the "Assembly" tab, you can effectively manage and analyze the interactions of the imported objects, ensuring accurate and detailed results based on the specified configurations.

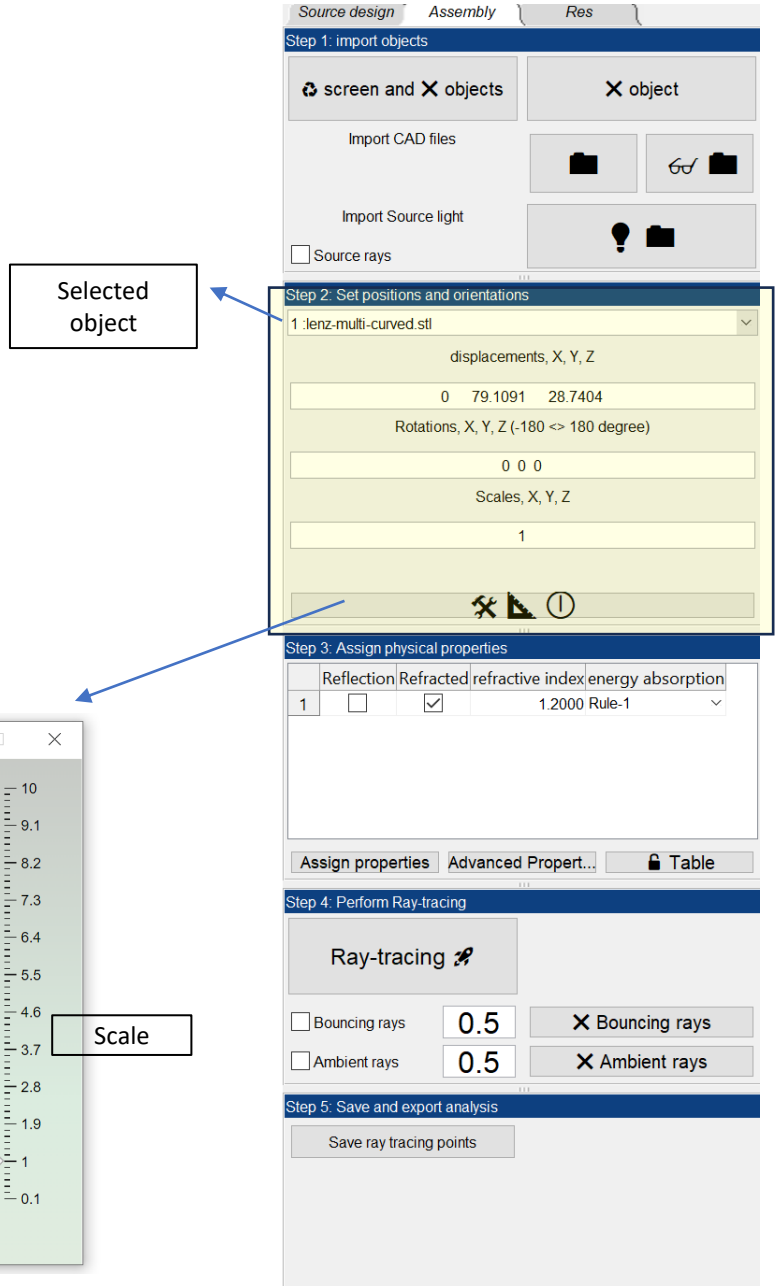
** Source wavelength is only used for the calculation of energy loss/absorption if the calculations are determined by an imaginary part of the refractive index.



Assembly of the objects step 2

In the second step of the assembly process, you have the capability to select an object and adjust its position, orientation, or scale. This can be achieved through either the edit boxes or the graphical tools. Upon selecting the graphical tools option, a window will appear, providing sliders that facilitate the modification of the object's position, orientation, and scale.

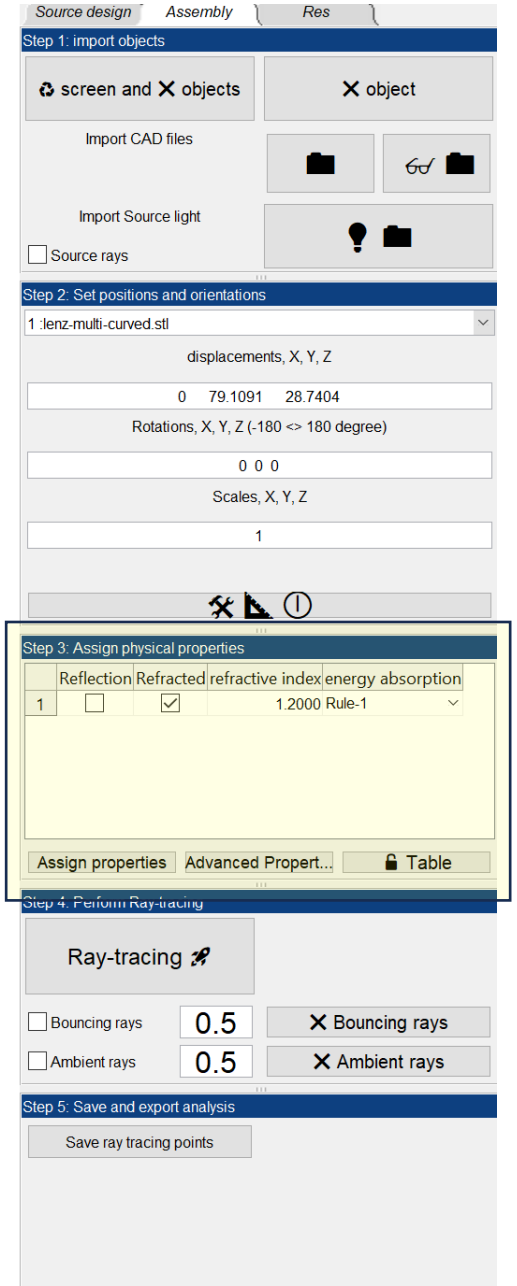
If the desired adjustments extend beyond the limits of the slider boundaries, you have the option to first input the values into the corresponding edit boxes. After entering the values, apply the changes, and then reopen the graphical slider window for further adjustments. This dual approach ensures flexibility in making precise modifications to the object's properties.



Assembly of the objects step 3

In the third step, you have the opportunity to assign the physical properties to each object, focusing specifically on objects that interact with the source. This involves specifying which objects exhibit reflections or refractive characteristics. Additionally, you can assign the refractive index and establish rules for energy absorption. These rules dictate the proportion of energy reflected from the surface and the amount transmitted within the object.

Once the settings for the interacting objects are configured, click on "Assign Properties" to implement your desired specifications. It's important to note that the table will be locked after assignment. If you need to make further adjustments, you can unlock the table by clicking on the corresponding option.



Assembly of the objects

step 3: Energy dispersion/ absorption

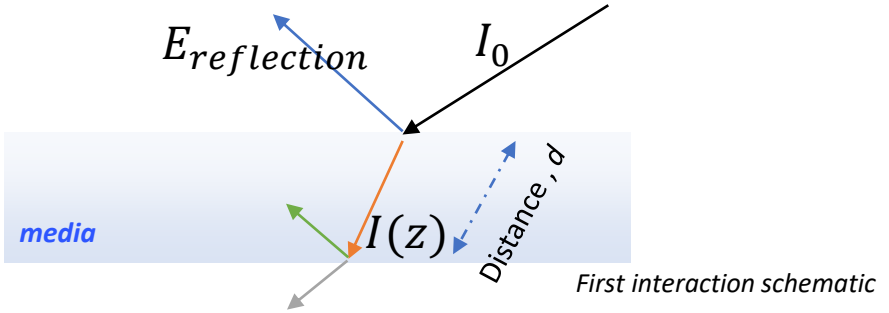
Energy absorption is calculated by Beer-lambert law. The extinction coefficient, often denoted by the symbol κ, is part of the complex refractive index and represents the imaginary component. It accounts for the absorption of light in a material. The second Energy E2 can be calculated based on the initial E0 energy and the attenuation.

It works based on :

1- the attenuation constant or absorption coefficient

2- the imaginary part of the refractive index

$$I(z) = I_0 * (\exp(-\mu * d))$$



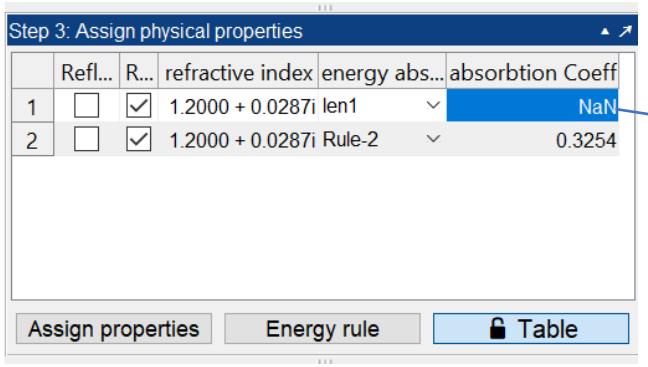
First interaction schematic

μ: is the absorption coefficient (attenuation factor) which can be obtained by the user or calculated via the imaginary part of the refractive index k and the source wavelength, see below for more details:

https://en.wikipedia.org/wiki/Beer%E2%80%93Lambert_law

https://www.pveducation.org/pvcdrom/pn-junctions/absorption-coefficient

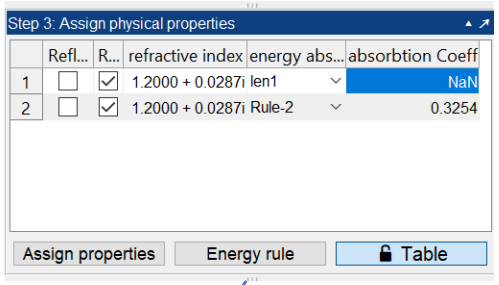
https://www.quora.com/What-is-the-relation-between-the-imaginary-part-of-the-refractive-index-and-the-attenuation

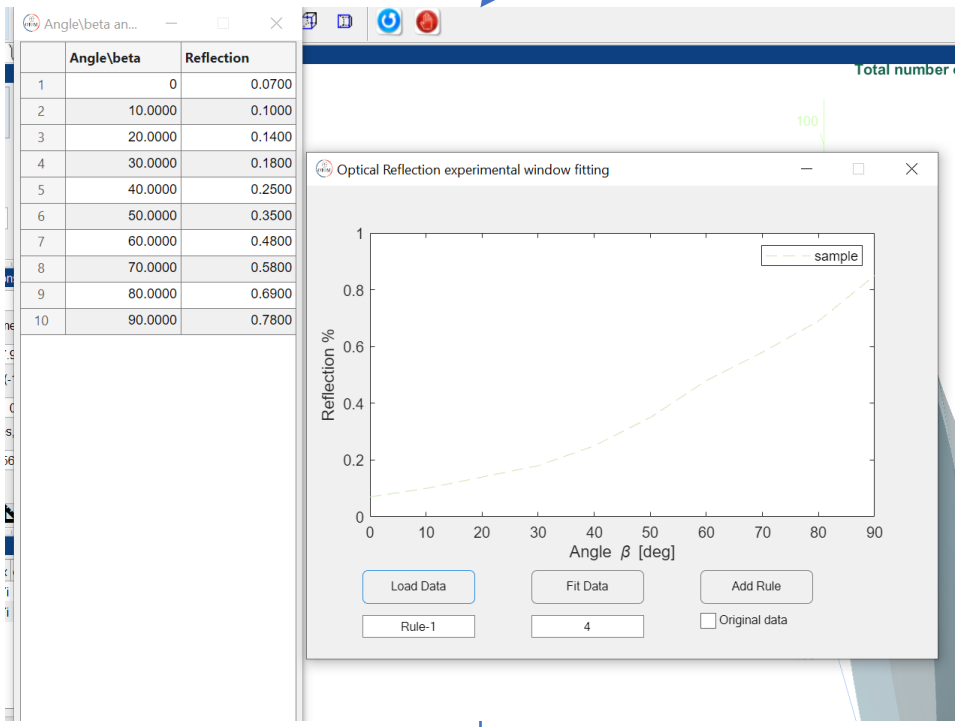


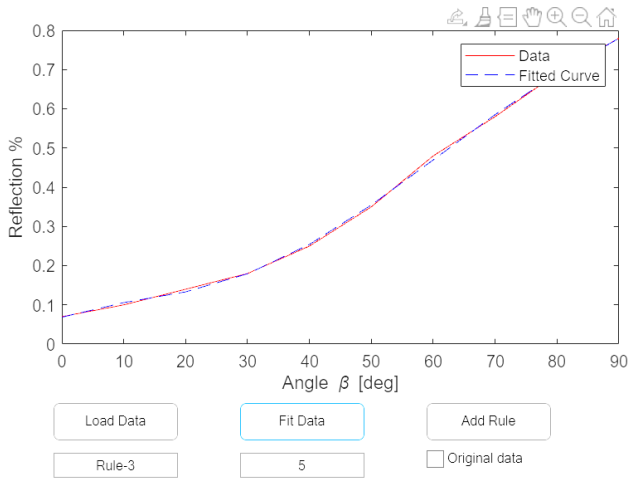
If the *absorption Coeff* is Nan, μ is calculated based on $\mu = \frac{4\pi k}{\lambda_0}$, where λ_0 is the wavelength μ is directly the value from the user.
After setting the details, you should click on "Assign properties"

Assembly of the objects
step 3: Set Energy Rule

With the ***Energy Rule***, you give the Reflection % vs incident angle. Click on *Load Data*. After loading data and modification, if needed, click on *Fit data* based on the polynomial order. Then click on the *Add rule* with a specific name. The Rule is added to the main window.
Please note: The software does not calculation these reflection percentages based on only the refractive index since in reality surfaces can have a coating or other surface preparation where the reflections do not always follow the reflective index Fresnel law.



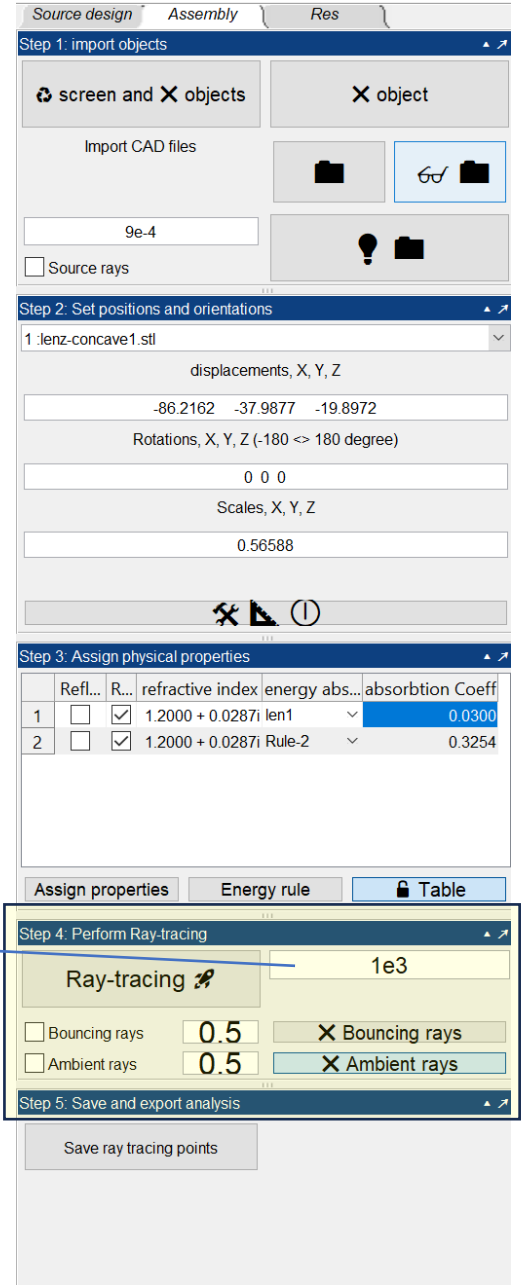




Assembly of the objects step 4

In the fourth step, you can execute ray tracing for the assembly of the objects by clicking on the ray tracing icon, and the simulation will commence. During this process, you have the option to display or conceal the bouncing rays and ambient rays. Moreover, you can adjust their transparency using the edit box.

It's worth noting that you also can delete bouncing or ambient rays. However, when you delete these rays, they are permanently removed from the scene. Consequently, you won't be able to display them again without restarting the ray tracing simulation. Exercise caution when deleting rays to ensure that the simulation results align with your analytical objectives.



Total Energy/ signal power

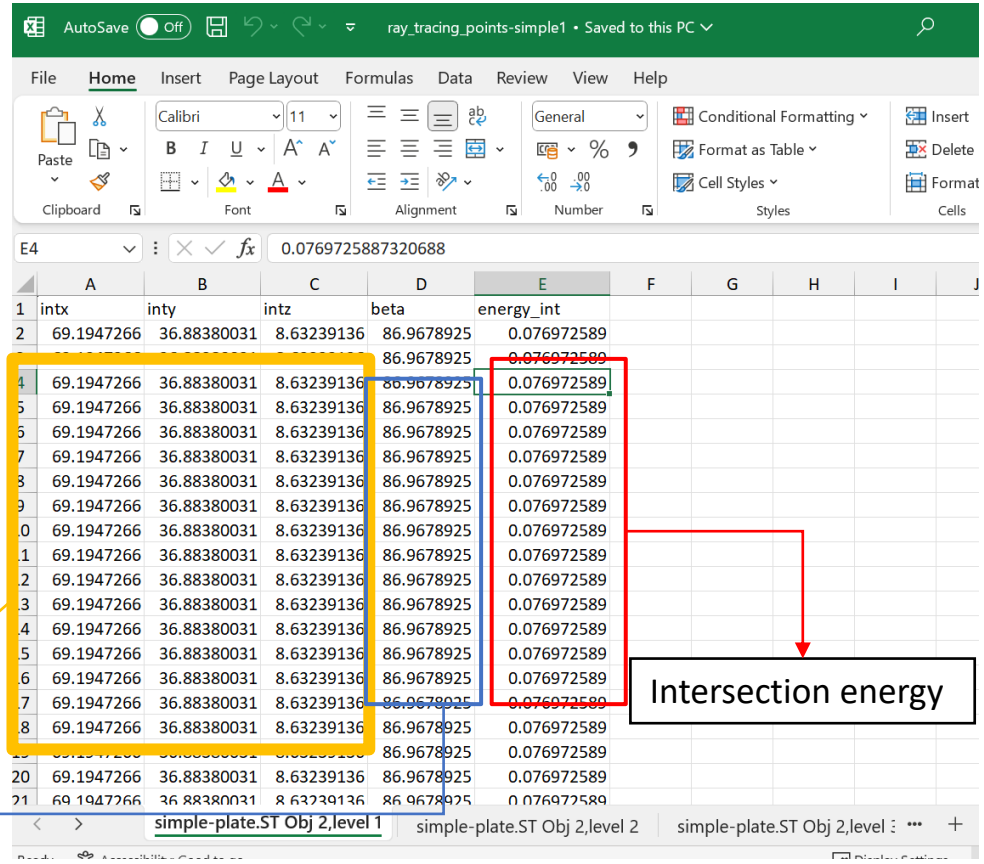
Assembly of the objects step 5

In the fifth step of assembling objects, after completing the ray tracing simulations, you can save the data generated during the simulation. To do this, follow these steps:

1.Perform Simulations: Execute the ray tracing simulations for the assembled objects.

2.Save Ray Tracing Data: If you wish to save the simulation data, click on "Save Ray Tracing Points." Assign a name to the file and choose the desired location. This action will create an Excel file containing information about all intersection points and angles of incidence from the simulation.

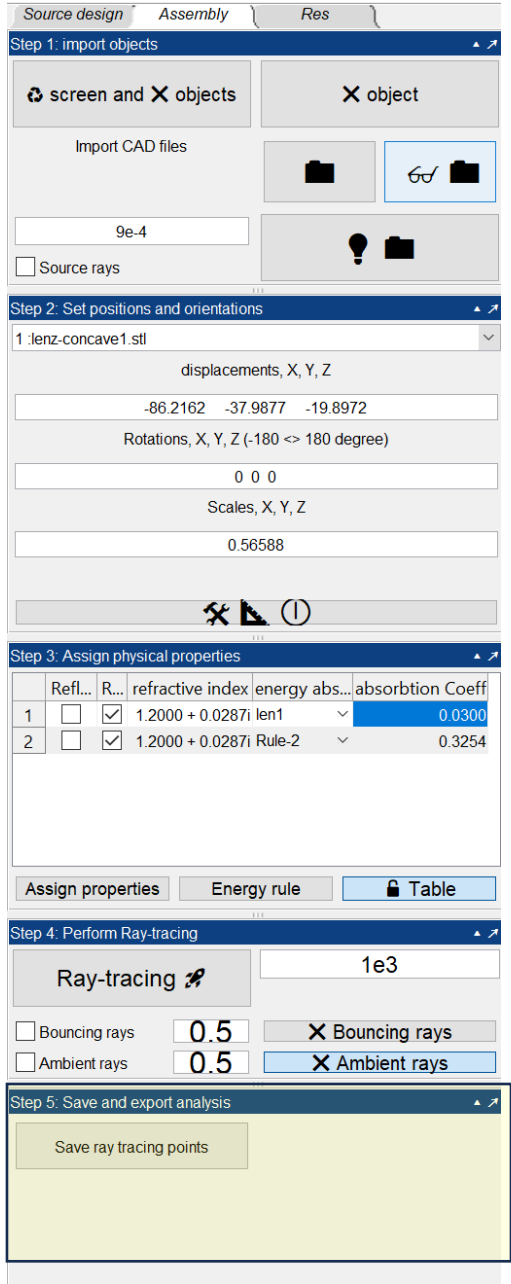
For each level of intersection with the objects, the naming convention of the tabs includes the interacting object and the level of interaction. For instance, "Level 1" indicates the first interaction of the rays with the object, "Level 2" signifies the second level, and so forth. If you have set the number of reflections to be 10 in the scene, and there are reflecting points between the objects, you can anticipate having 10 levels of interaction points in the file. Each tab in the Excel file will correspond to a specific level of interaction, providing a comprehensive representation of the ray tracing results.



Intersection points

Intersection angles

Intersection energy

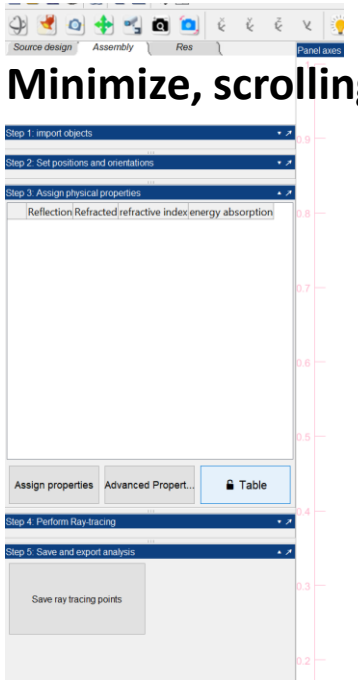


General interaction:

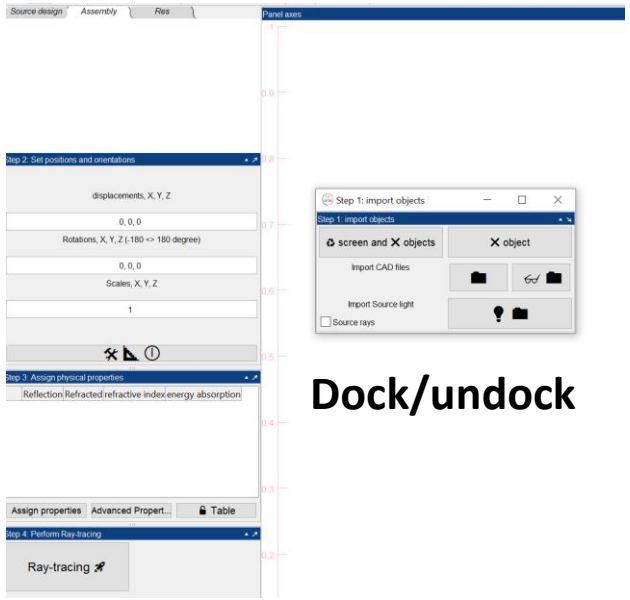
Dock/Undock: You have the option to dock or undock each panel on either the left or right side of the graphical window.

Minimize: To minimize or maximize each panel, click on the triangle point located on the right side of the panel.

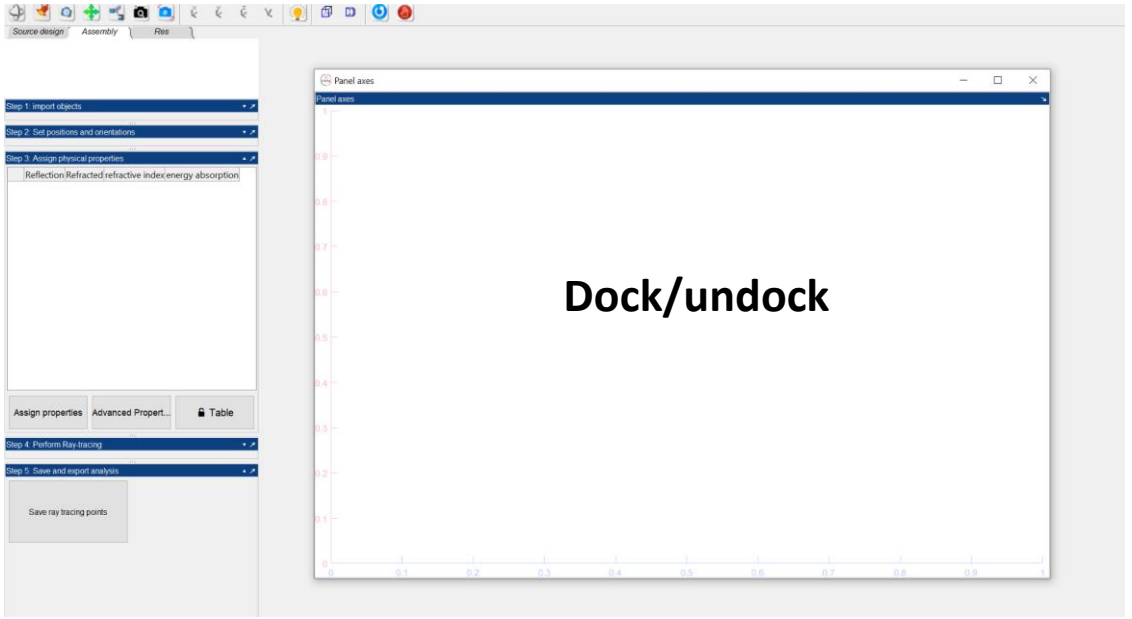
Mouse Scrolling on the Left Panels: While on the left panel, you can use the mouse scroll to navigate up or down, moving along the content within the panel.



Minimize, scrolling



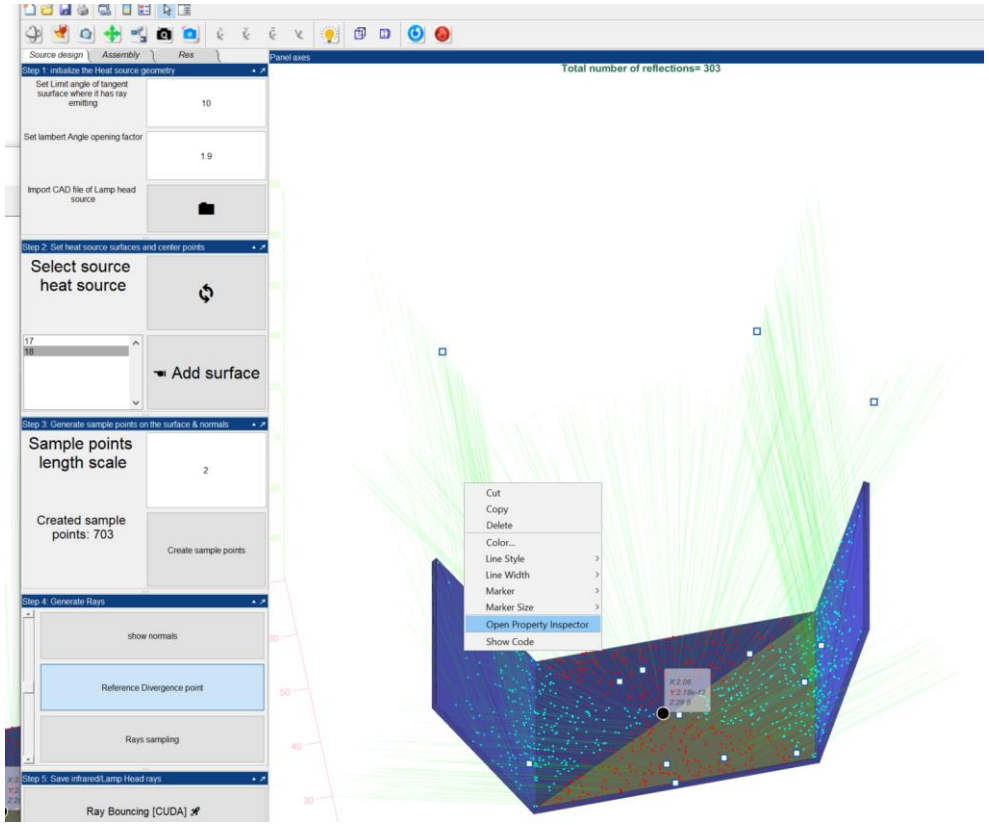
Dock/undock

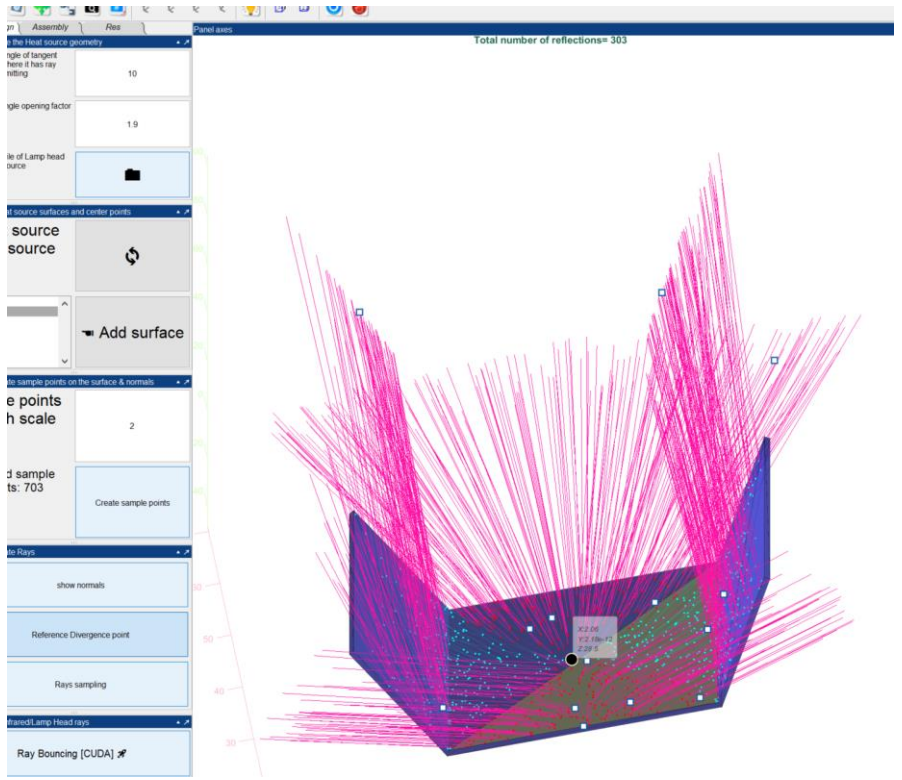


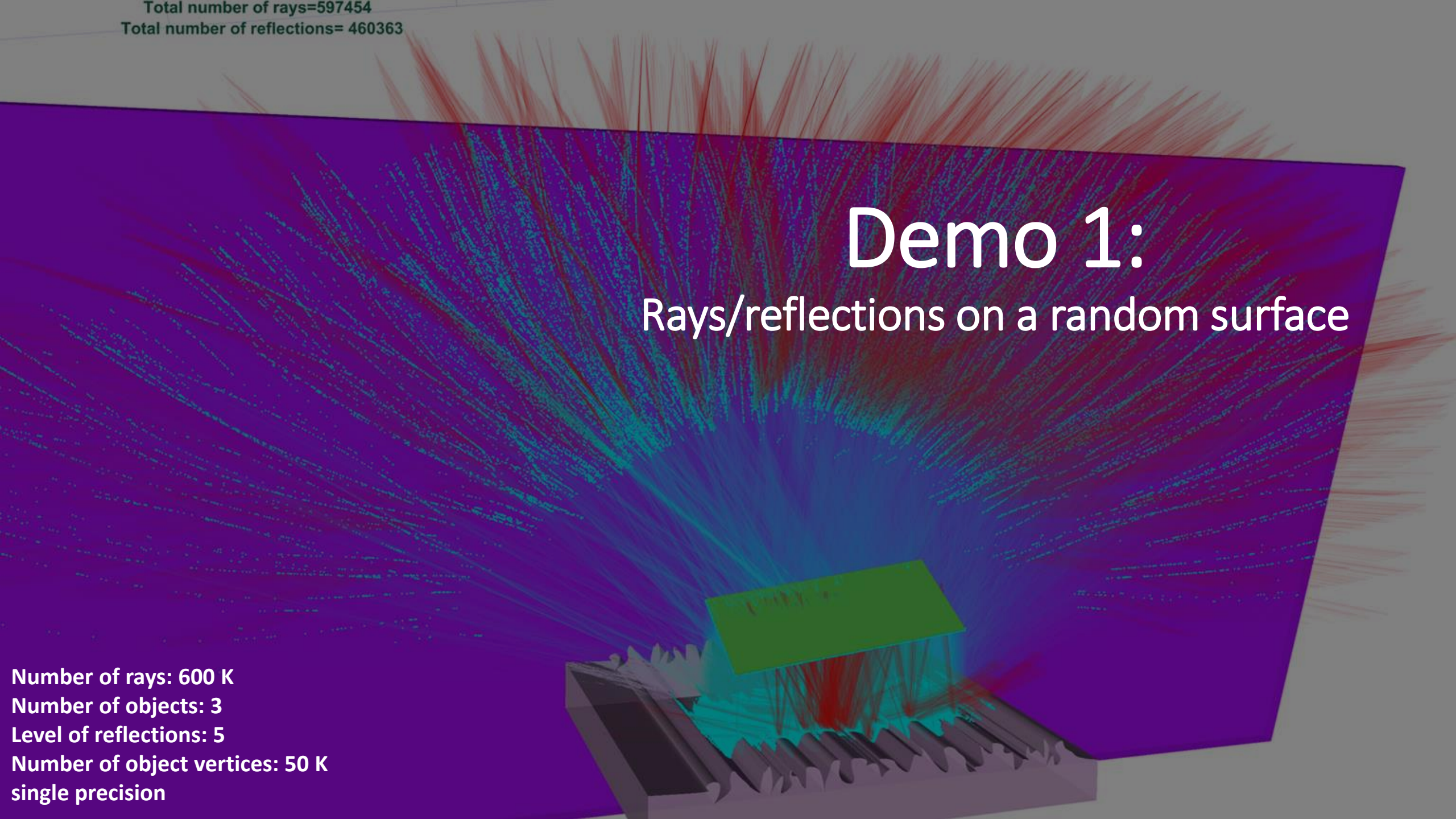
Dock/undock

Open property editor

This is the property editor, where you can modify standard details such as color, line representation, and other visual attributes.







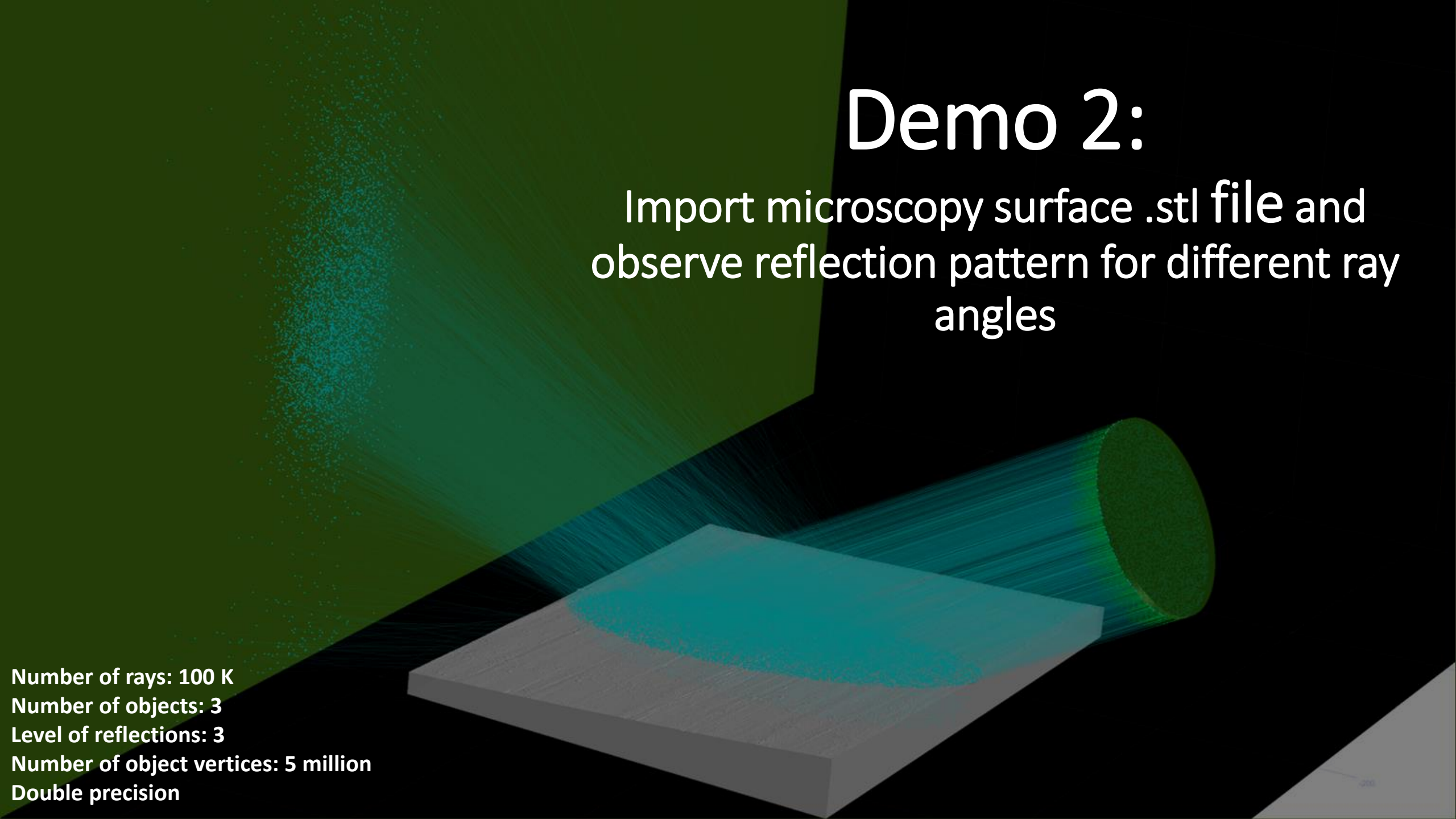
Demo 1:

Rays/reflections on a random surface

Number of rays: 600 K
Number of objects: 3
Level of reflections: 5
Number of object vertices: 50 K
single precision

Demo 2:

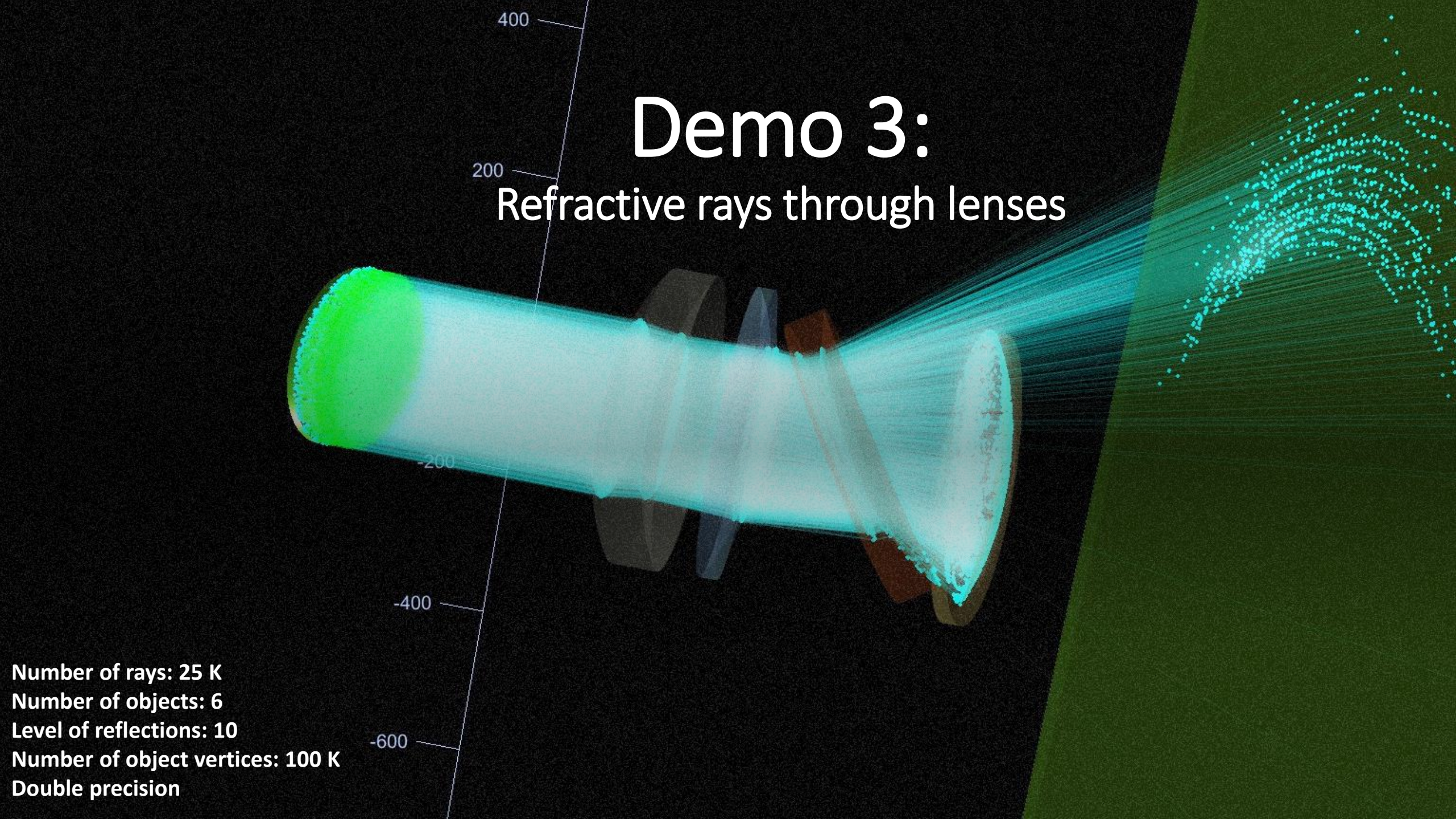
Import microscopy surface .stl file and observe reflection pattern for different ray angles



Number of rays: 100 K
Number of objects: 3
Level of reflections: 3
Number of object vertices: 5 million
Double precision

Demo 3:

Refractive rays through lenses



Number of rays: 25 K
Number of objects: 6
Level of reflections: 10
Number of object vertices: 100 K
Double precision

END

For suggestions and feedback please contact:

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