

Hinds MicroImager

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System Overview

The Exicor MicroImager is a highly sensitive polarization imaging system that measures different features of a sample such as intensity, optical retardation, and angle fast axis. The samples need to be flat and transparent to the wavelength being used. This MicroImager comes with a LED light source having four different wavelengths: Blue 475 nm, Green 535 nm, Orange Red 615 nm, Dark Red 655 nm, and three different objectives 5X, 10X, and 20X. To use the 20X objective, **mount an additional** plano-convex lens ON TOP of the already mounted lens above the light source.

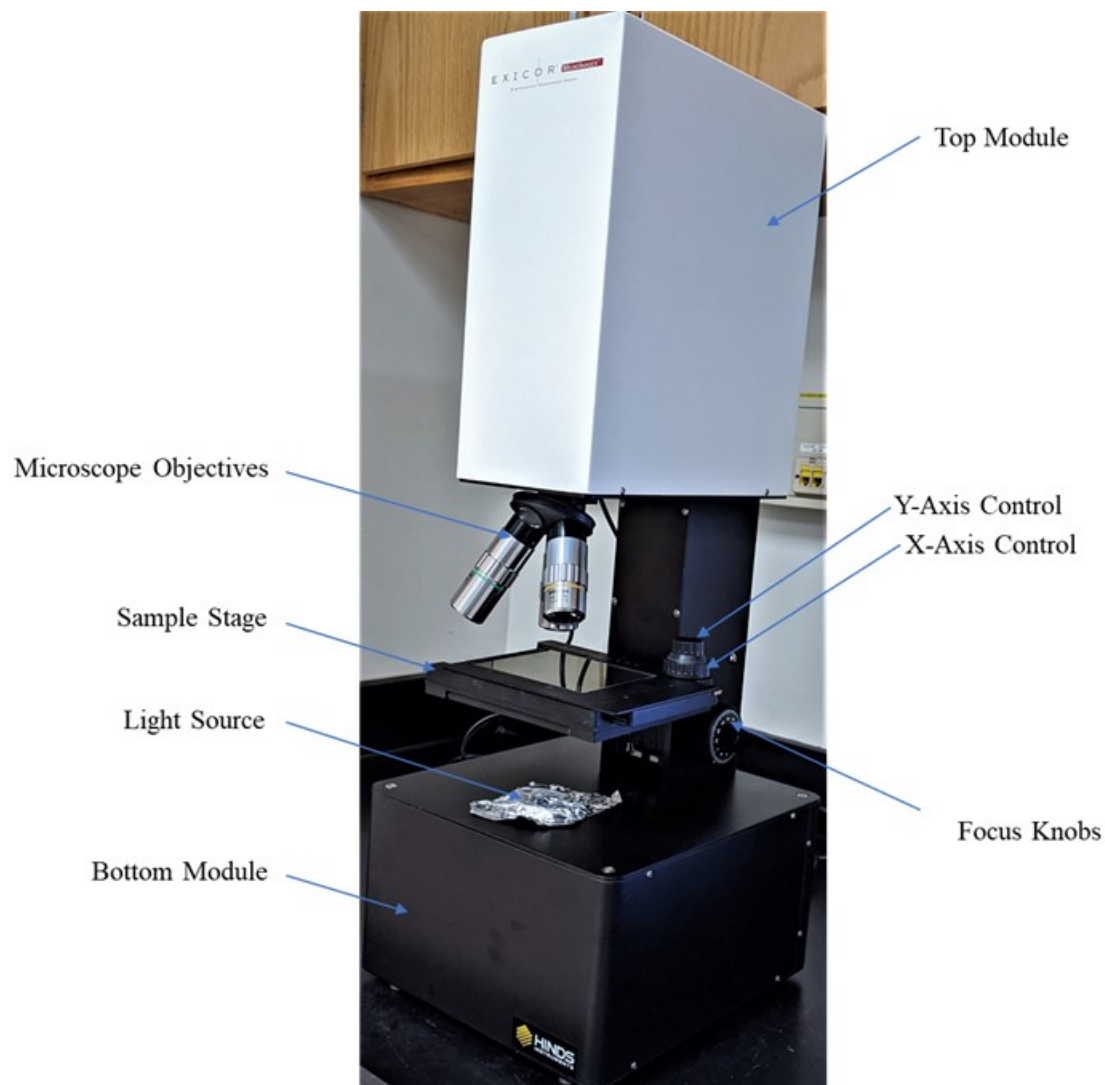


Fig. 1. MicroImager main components

Note: The MicroImager uses a fan to keep internal electrical components located in the base of the system cool. Therefore, the airflow from its rear panel should not be restricted by any items.

System Initialization and Placing the Sample

1. Turn the power switch **ON** (located on the backside of the Bottom Module) and wait for 10-15 minutes for the light source to warm up → Open the software “**Hinds MicroImager**”, then the main window will come up as shown in Fig. 2 with **Live** menu.

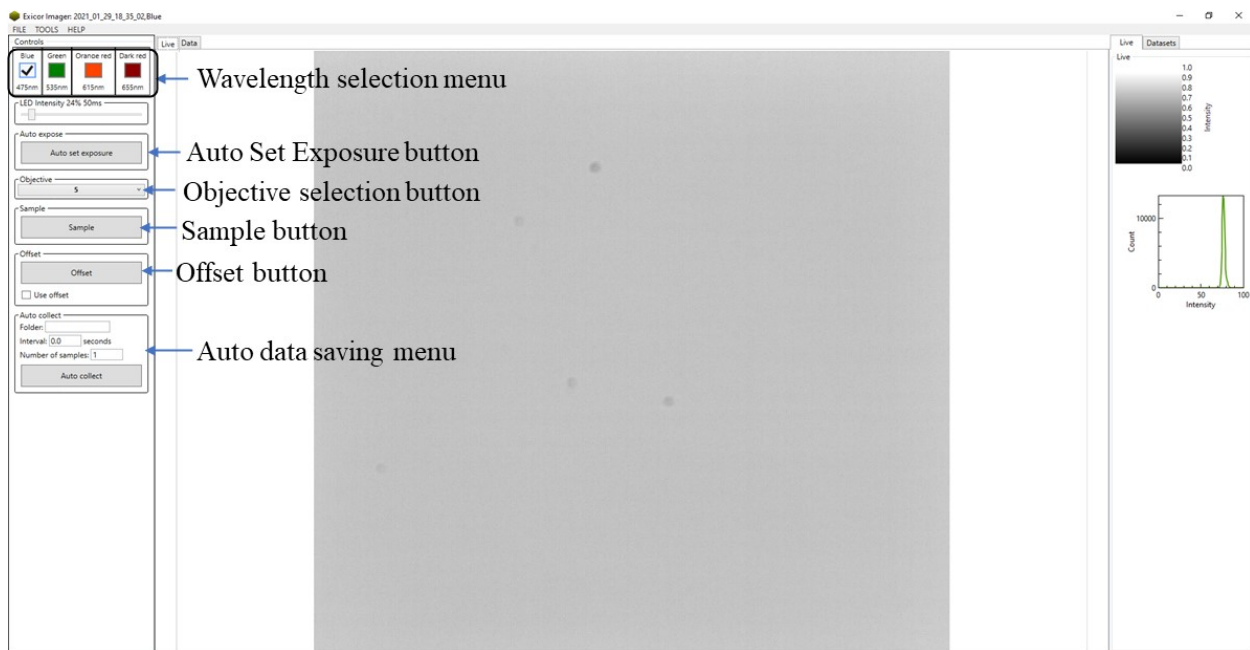


Fig. 2. Main Window

2. Select one of the wavelengths → choose the objective's magnification → set the Light Level/Exposure by clicking the **Auto Set Exposure** button. Repeat for all other remaining wavelengths.

3. Place the sample on the **Sample Stage** → focus on the sample as shown in Fig. 3 → click the **Auto Set Exposure** button again.

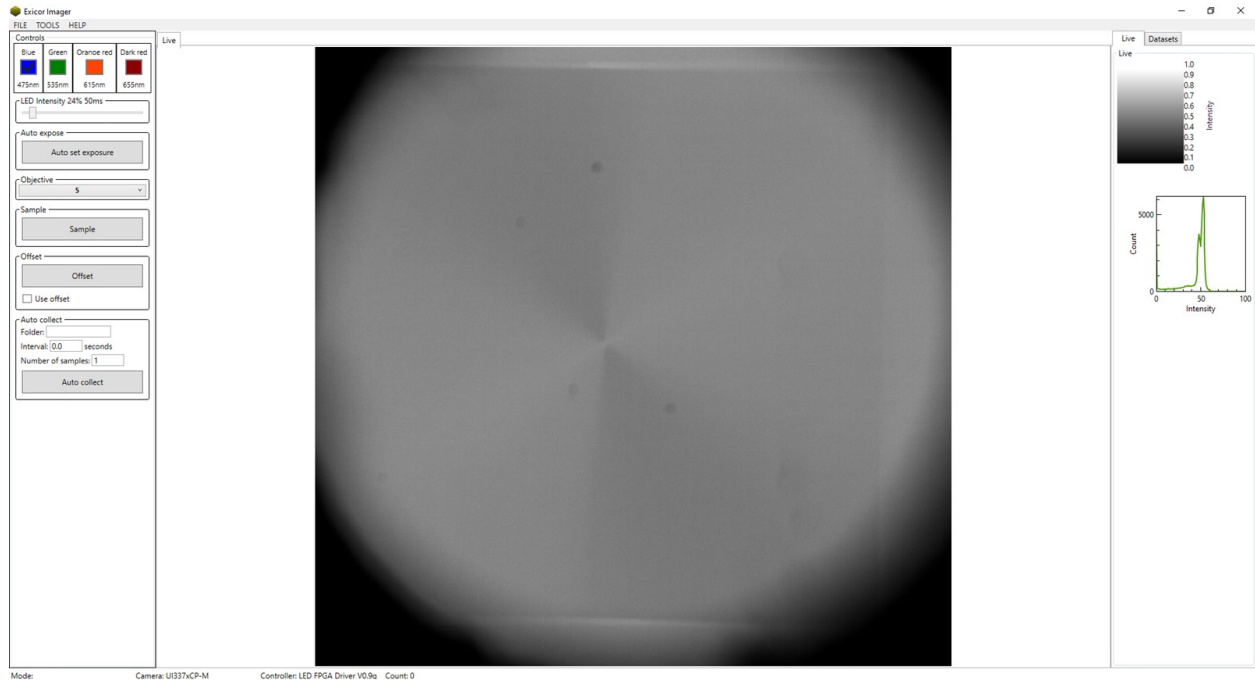


Fig. 3. Focused sample with +1 radial defect (CCN-47, 2.4 μm , 45 $^{\circ}\text{C}$) using 5X objective

Note: For the room temperature measurements, it is recommended to wait at least 10 minutes before measuring samples in order for the sample to reach thermal equilibrium. Handling of the sample can change its temperature temporarily, which may affect measured values.

Measuring a Sample

4. By default, the software considers **clockwise rotation** as a positive measurement of angle. To choose the counterclockwise rotation for the angle, go to **Tools** menu \rightarrow **Angle** \rightarrow mark “**Invert**”.

5. By default the software displays the **fast axis**. To display the orientation of the **slow axis**, again go to **Tools** menu \rightarrow **Angle** \rightarrow insert “**90 $^{\circ}$** ” offset (or type “**0 $^{\circ}$** ” to display **fast axis**)

As shown in Fig. 4.

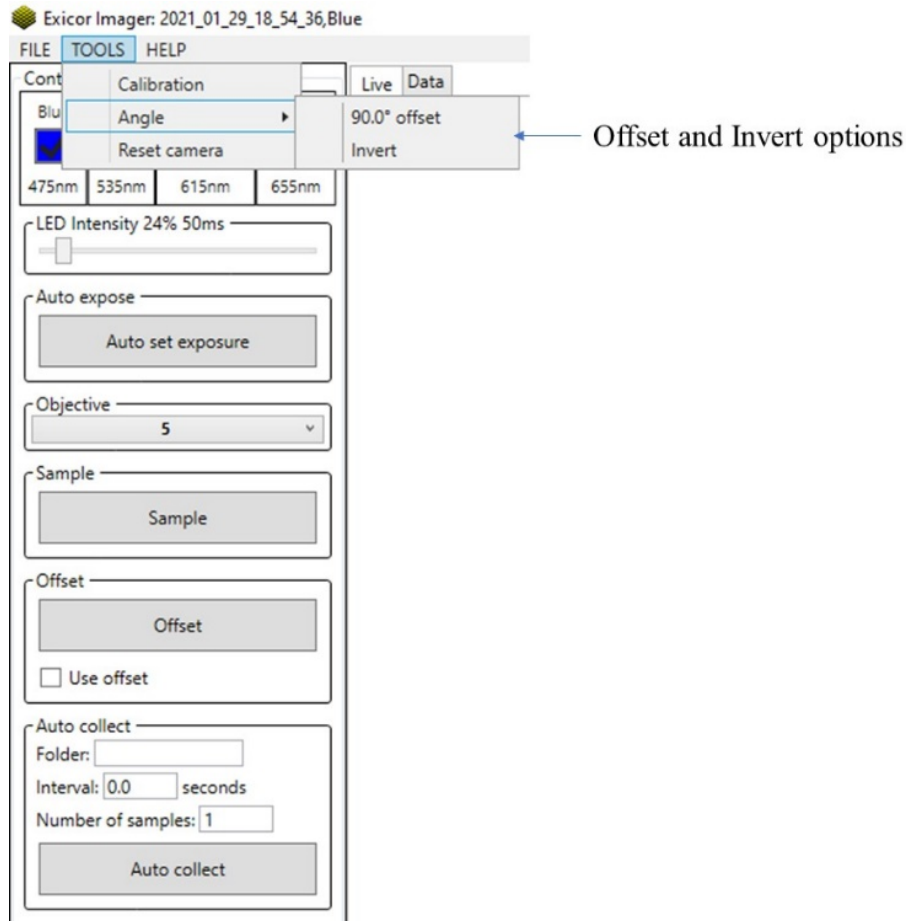


Fig. 4. offset and invert options selection menu

6. To start collecting the data at the chosen wavelength → press **Sample** button.

When the scan complete, the **Live** window will switch to the **Data** tab. The **Data** tab has the results displayed as the colored images in the **Display** tab with 7 different formats: **Intensity**, **Retardance**, **Angle of the fast axis** (After inserting 90 ° offset, shows slow axis), **Retardance and Intensity**, **Angle and Intensity**, **Retardance and Angle**, **Retardance, Angle and Intensity** and **Analysis** tab on the right as shown in Fig. 5.

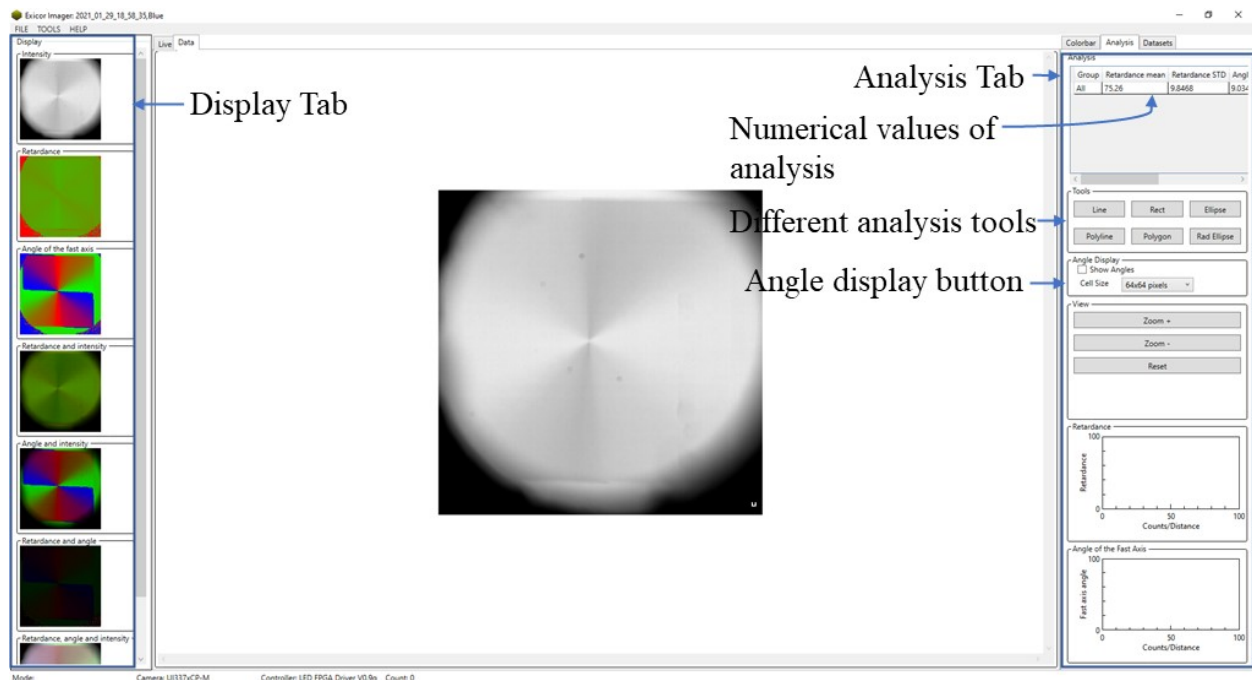


Fig. 5 Displaying results in **Data** tab

7. To see the director field, go to the **Analysis** tab → mark **Show angles** inside the **Angle display** button (Shown in Fig. 5).

8. In the **Data** tab, choose the image → place the cursor on the image to see **Intensity** in the arbitrary units (UA), **Retardance (R)** in nm's, **Angle (A)** in degrees ($^{\circ}$) for a given coordinate displayed in terms of pixels as shown in Fig. 6. Recall, angles are measured counterclockwise due to **step 4**.

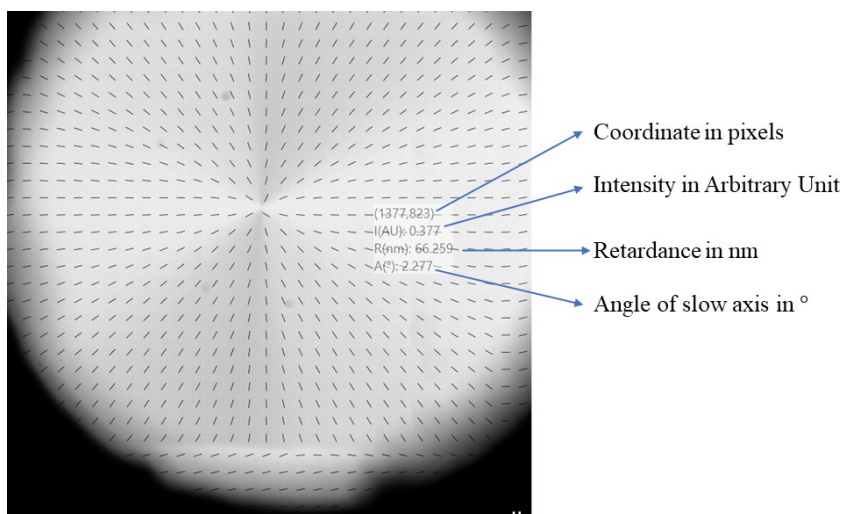


Fig. 6 Coordinate in pixels, intensity, retardance, and angle of the slow axis at the position of the mouse cursor

Analysis

9. The numerical values of analysis for the current image are found in the upper part of the [Analysis](#) tab. The first row will always have the mean and standard deviation of the retardation, mean angle, and mean intensity of the entire image (as shown in Fig. 5).

10. Several shape tools for drawing out data from specific parts of the image are available in the [Tools](#) menu of the [Analysis](#) tab (as shown in Fig. 5). To access these tools, click the tool → draw this tool in the interested region of the image. The analysis of the selected region will appear as the additional rows in the upper part of the [Analysis](#) tab. A variety of functions available for each tool can be accessed by right-clicking on the shape (e.g., as shown in Fig. 7 for the [Line](#) tool).

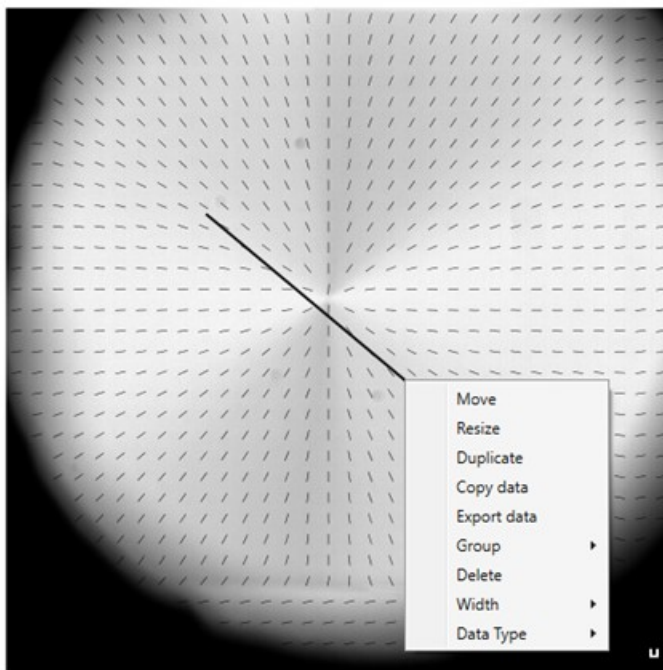


Fig. 7. Varieties of functions available for the [Line](#) analysis tool

Colorbar

11. To see the [Colorbar](#) corresponding to different images, select an image → click the [Colorbar](#) tab on the right. For example, a colormap for intensity is shown in Fig. 8 below.

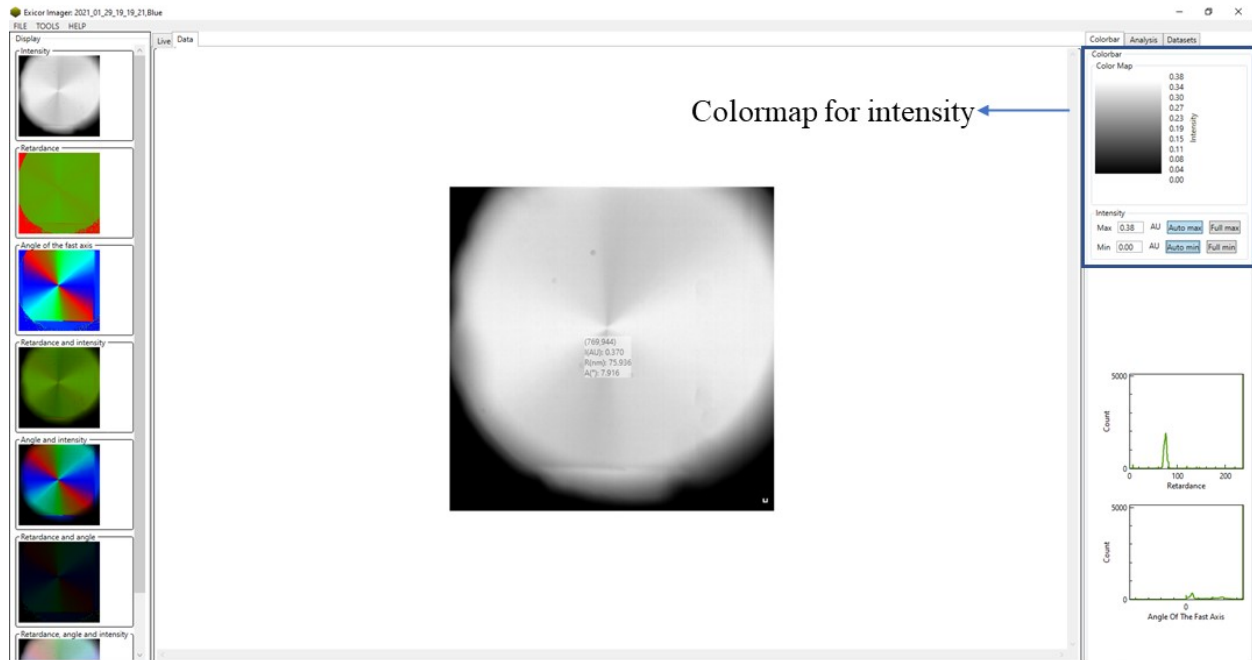


Fig. 8 Colormap for intensity

Optical retardations with a single wavelength

While working with a **single wavelength**, the following points need to be considered.

12. Optical retardation (R) = $\Delta n * \text{cell thickness } (t)$, Δn is the function of **wavelength** and **temperature**.
13. For $0 < R < \lambda/2 \rightarrow 1^{\text{st}}$ order retardation, For $\lambda/2 < R < \lambda \rightarrow 2^{\text{nd}}$ order retardation and so on. Therefore, if we **know** an approximate value of retardation for our sample, we can approximate the order of retardation for a given wavelength and hence can calculate the actual value of retardation at any order.
14. The MicroImager **always** gives the value of retardation in between 0 to $\frac{\lambda}{2}$ (Unless it is unwrapped, will explain later) for any order of retardations. However, in the 1^{st} order, $R < \lambda/2$, the displayed value of the retardation represents its actual value as shown in Fig. 9.

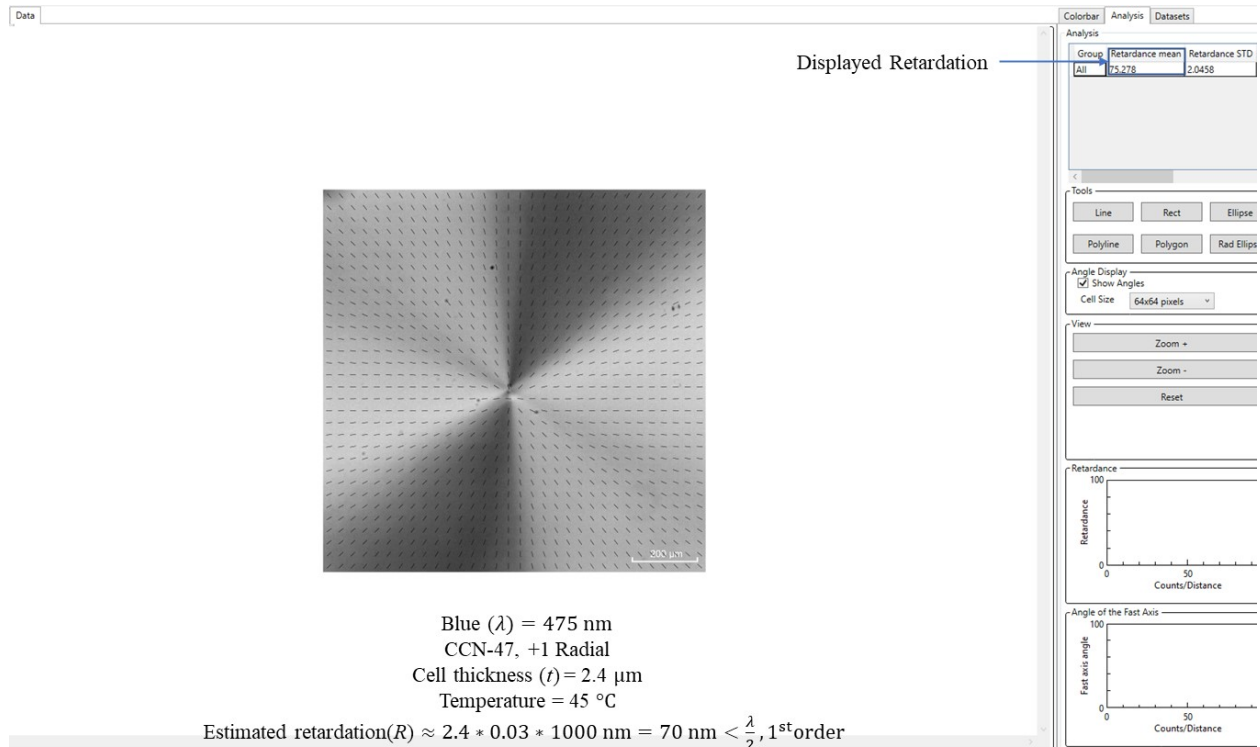
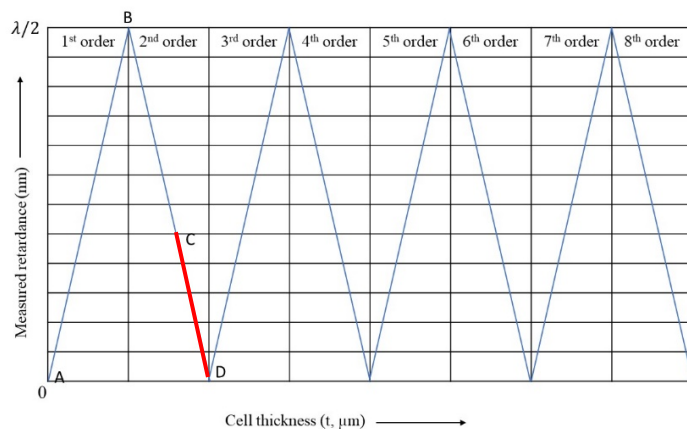


Fig. 9. Retardation in the 1st order.

15. For the higher-order retardations (2nd, 3rd, 4th, ...), the MicroImager does not give its actual value. Use the following method to calculate the actual value in any higher order. Example:

2nd order



$$\text{Actual retardation (R)} = AB + BC = AB + (BD - CD) = \lambda/2 + \lambda/2 - \text{Displayed retardation (CD)}.$$

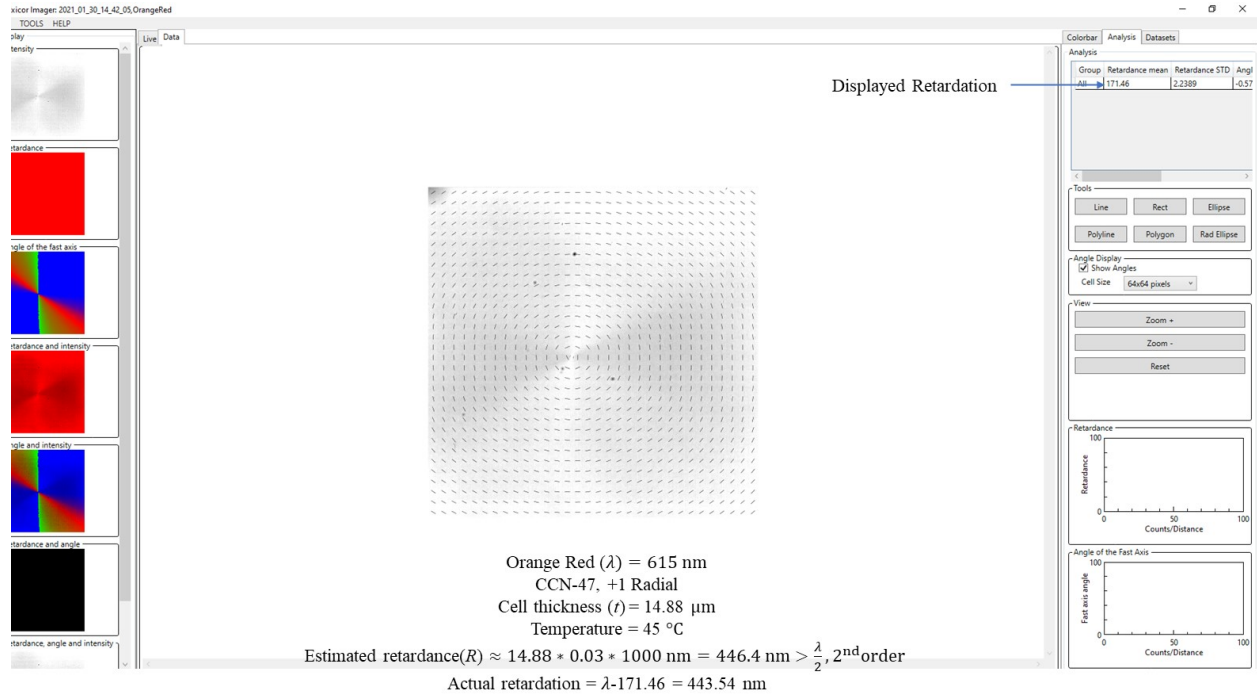
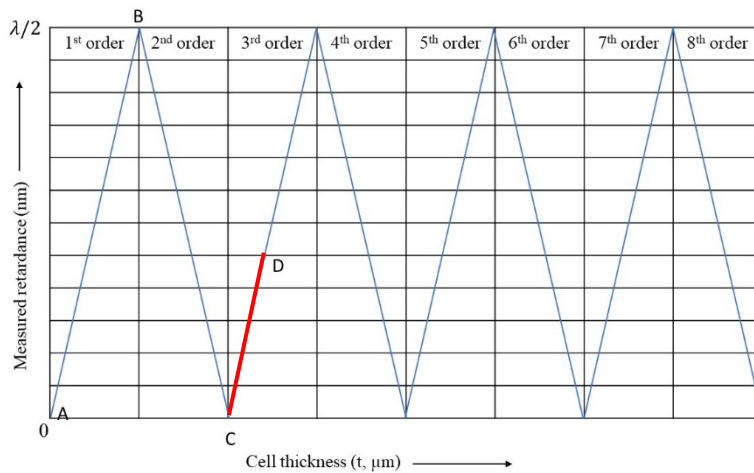


Fig. 10. Calculation of Actual retardation in the 3rd order retardation for the Orange Red.

3rd order:



$$\text{Actual retardation (R)} = AB + BC + CD = \lambda/2 + \lambda/2 + \text{Displayed retardation (CD)}.$$

16. For retardation in the odd orders (e.g., 1st, 3rd, 5th,), the MicroImager shows the actual director profile, whereas in the even-order retardation (e.g., 2nd, 4th,), the MicroImager does not show the actual director profile, but shows the director profile with the slow axis rotated by 90°. This is illustrated in Fig. 11.

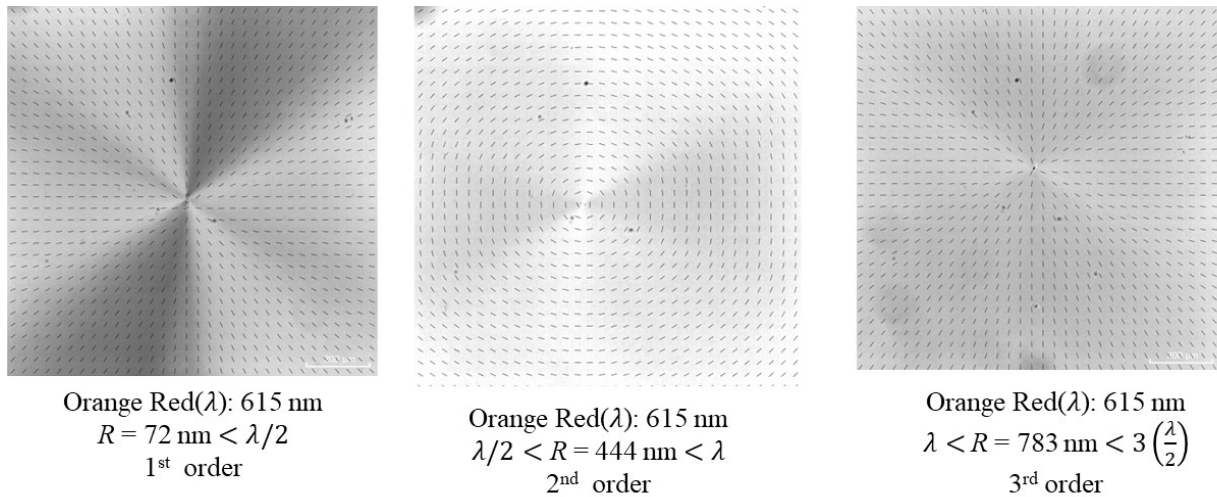


Fig. 11. A +1 radial defect in three different cells having different values of retardations which corresponds to different orders of retardation for Orange Red.

Higher-Order Retardations and Phase unwrapping

To find the absolute value of the retardation (In case you do not know the approximate value of retardation of your sample) and the correct director profile in any order of retardation multiple wavelengths need to be measured and **Unwrapped**. For this,

17. Measure the exact same area of the sample with all four wavelengths (Blue, Green, Orange Red, Dark Red). For this, go back to the **Live** tab → mark the desired wavelength → press the **Auto Set Exposure** button → press **Sample** button. Then new images will be displayed as in Fig. 5 in the **Data** tab. All these datasets (including other previous datasets) will appear in the **Datasets** tab with the corresponding **recorded date, time, and wavelength**.

18. Click the Datasets tab → Although you will see all the previous datasets, click and drag only the datasets that you want to include in the higher-order analysis to the “**Datasets to Process**” area → enter the minimum and maximum expected retardation. The maximum limit of retardation is 4000 nm. This **Phase Unwrapped** dataset will appear in the **Datasets** tab (as shown in Fig. 12) with analyzed numerical values in the **Analysis** tab.

19. To process other **Datasets**, press **Clear** → repeat step 18.

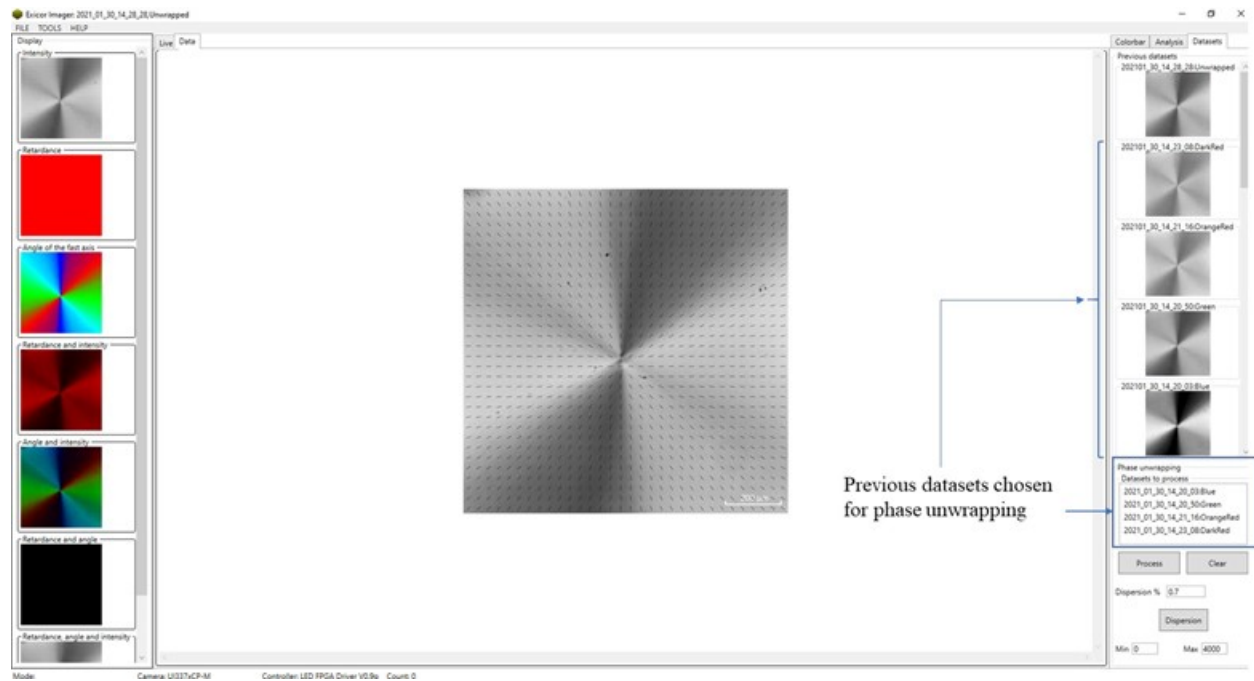


Fig. 12 Datasets window

Saving Data

Data can be saved in the following ways.

20. **Whole dataset**: The saved data will be saved in “.mic” format, MicroImager readable. For this go to **File** tab → **Save** → choose the folder and write file name → press **Save**. To open the saved .mic file, go to **File** → **Open** → choose the .mic file → click **Open**.

21. **Export Rad Data**: The data will be saved in the 7 different “.csv” format files (Microsoft Excel readable) numbered from 0-6 corresponding to 7 different images of a dataset. For this go to the **File** tab → **Export Raw Data** → if needed choose the File Prefix and browse the directory → press **Export** as shown in Fig. 13.

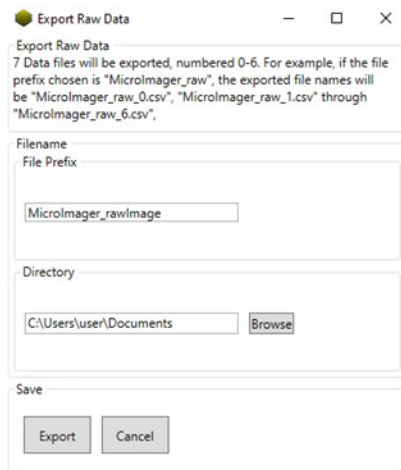


Fig. 13. Exporting Raw Data as 7 different “.csv” format files

22. **Export Images**: It allows us to save the 7 different images of a dataset. For this, go to **File** → **Export Images** → mark the **Images** (e.g., **Intensity**, **Retardance**, **Angle of the fast axis**, etc.) → select image format → if needed, choose **File Prefix** → choose the **Directory** → press **Export** as shown in Fig. 14.

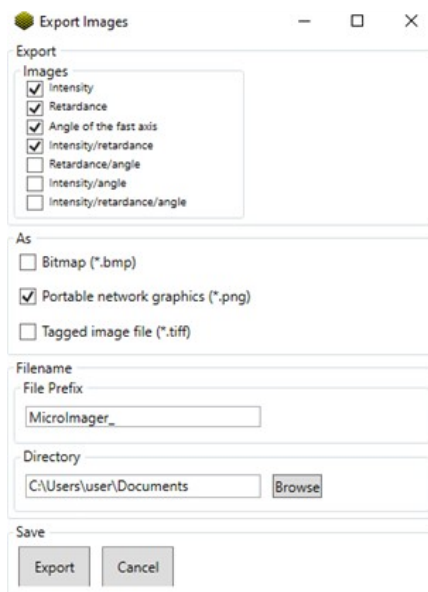


Fig. 14. Exporting Images

23. **Export Data**: It saves the Raw data corresponding to Intensity, Retardance, Angle of the fast axis (in our case Angle of the slow axis after 90° offset) as “.txt” format or “.csv” format if “Export as csv” is **marked**. For this, go to **File** → **Export Data** → mark data type (e.g., **Intensity**, **Retardance**, **Angle of the fast axis**) → choose the **File Prefix** if needed → choose the **Directory** → press **Export** as shown in Fig. 15.

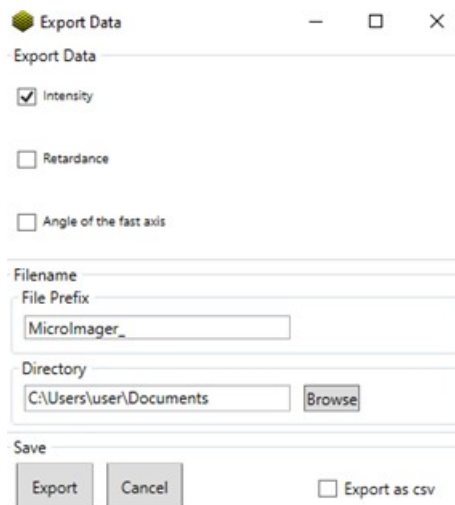


Fig. 15. Exporting Data as .txt file or .CSV format.

24. **Auto Collect:** The **Auto Collect** feature as shown in the bottom left corner of Fig. 16, allows us to collect a number of samples with some repeatable amount of time between them.

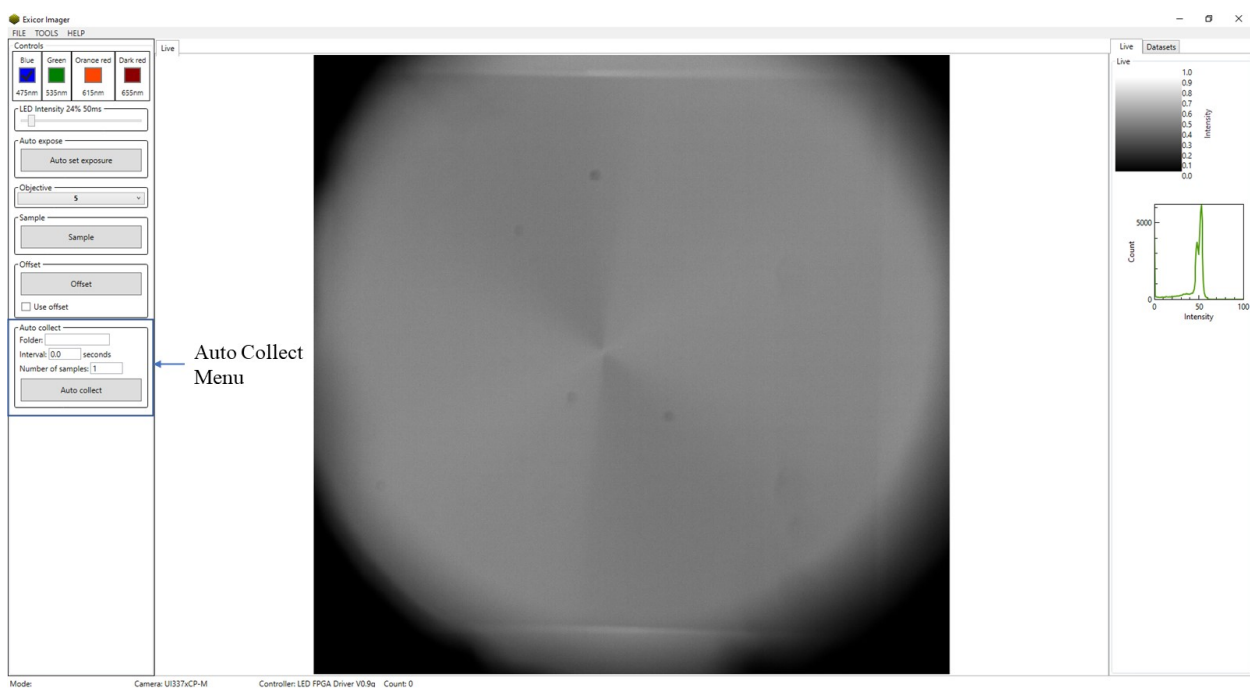


Fig. 16. Auto Collect Main Window

25. Select the folder → enter the time interval between each scan and the number of samples → click “**Auto Collect**” button. A window similar to Fig. 17 will appear. Click “**Start**” when ready.

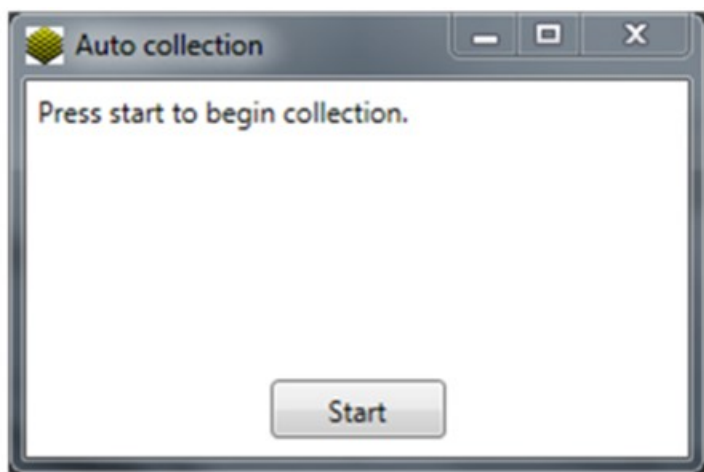


Fig. 17. Auto Collect Start Window

26. While the **Auto Saving** is running, you will see a window similar to Fig. 18. When the recording is finished, you will see the window similar to Fig. 17. If you are finished, simply close out the window.

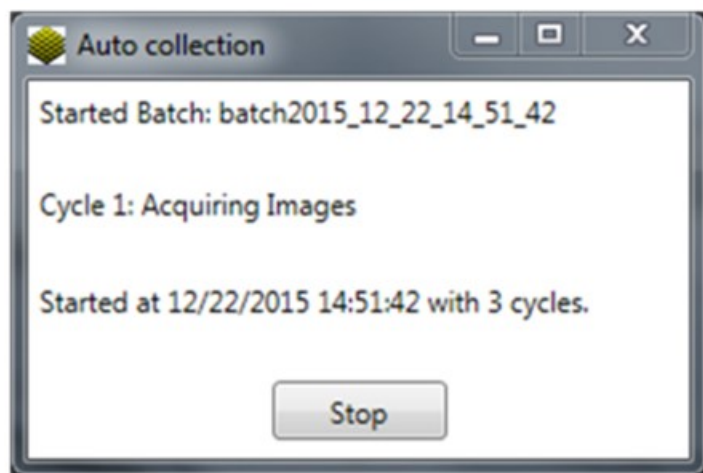


Fig. 18. Auto Collect Status Window