Tutorial for Extraction of Photonic Band Structures

with step-by-step instructions

Ver: 1.0 (July 17, 2025)

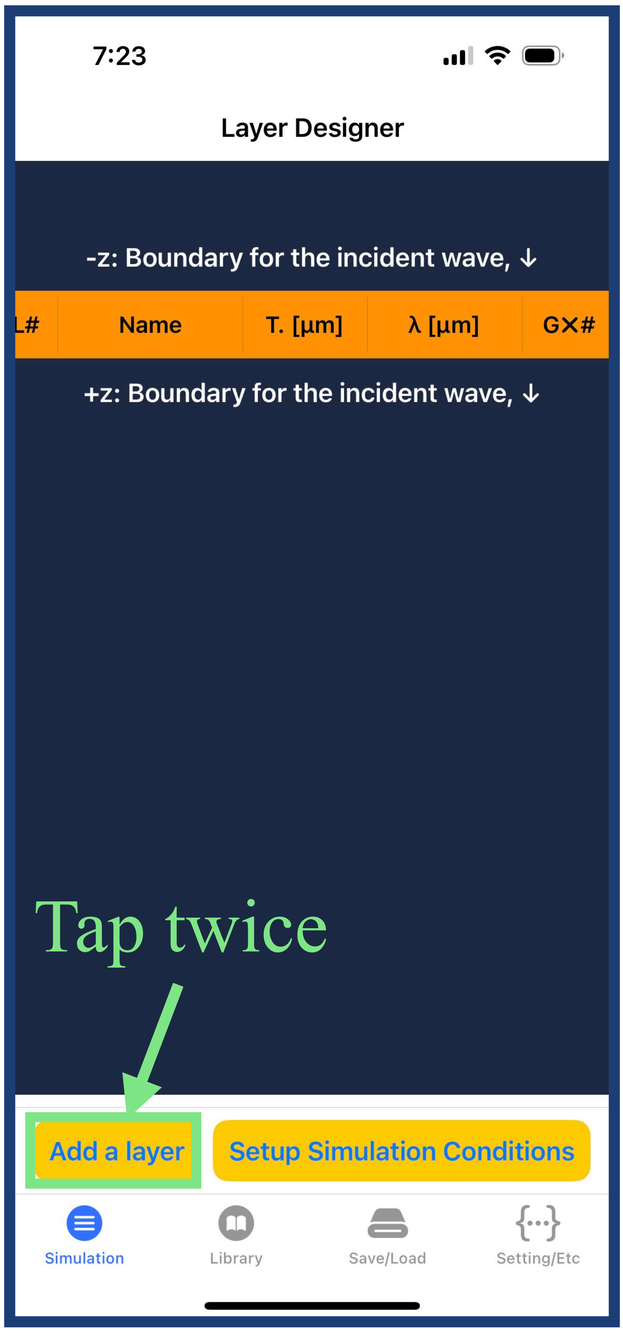
ComPhysics

Symbols and abbreviations used in E2M

Symbol	Meaning
L#	Layer index
T.	Thickness
λ	Wavelength
μ’	Real part of relative permeability
μ’’	Imaginary part of relative permeability
ε’	Real part of relative permittivity
ε’’	Imaginary part of relative permittivity
$\tilde{k}$	Normalized wave vector
GX#	G: Group index X: seperator meaning times #: Repetition num. for the group
θ	The azimuthal angle
φ	The polar angle
TE	Transverse Electric
TM	Transverse Magnetic
R	Reflectance
T	Transmittance
A	Absorptance (R + T + A = 1)
α	Thickness of a period
c	speed of light

In this tutorial, step-by-step instructions for recalculating Fig. 2 of reference 1) below are offered. By performing these steps, you will learn how to calculate photonic band structures by utilizing E2M.

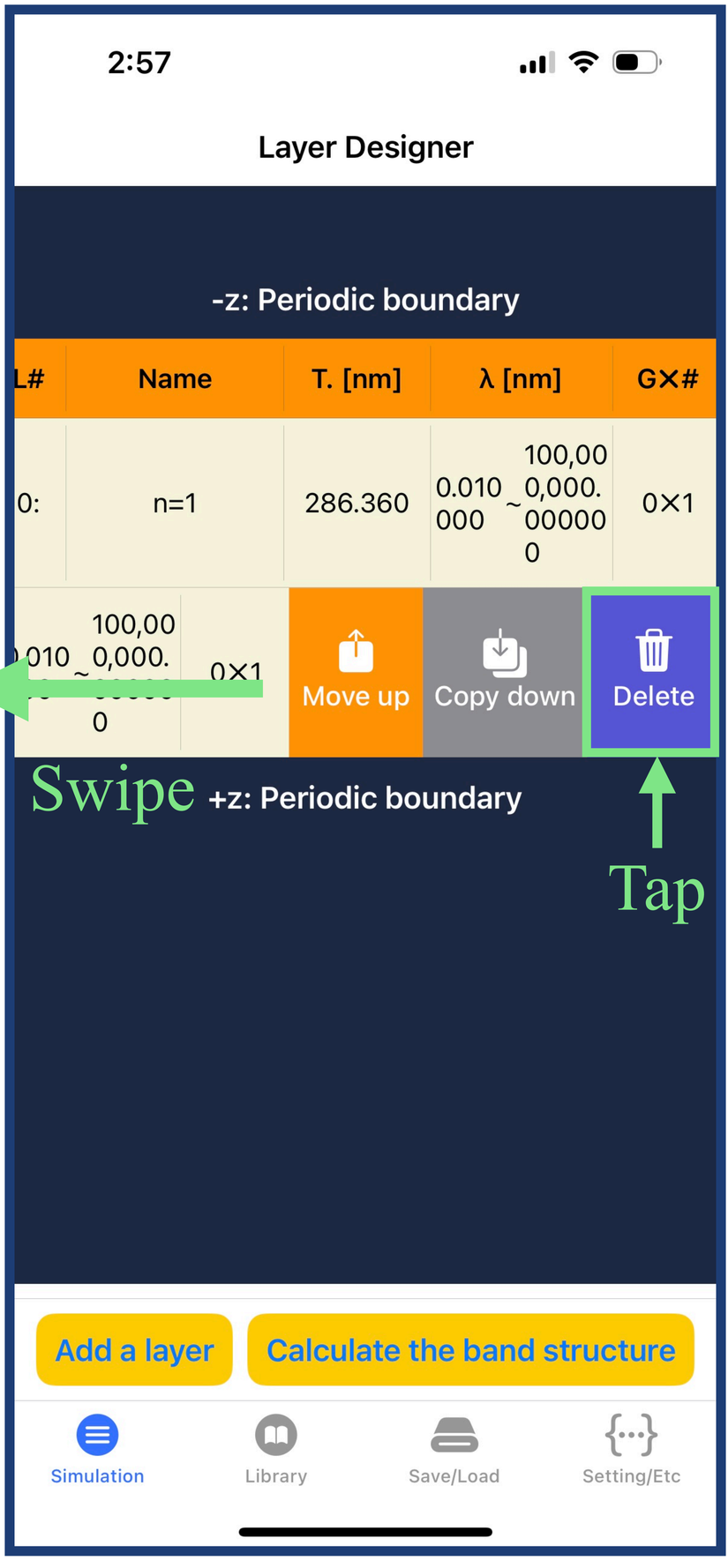
1. Tap “Add a layer” button twice to create two layers.



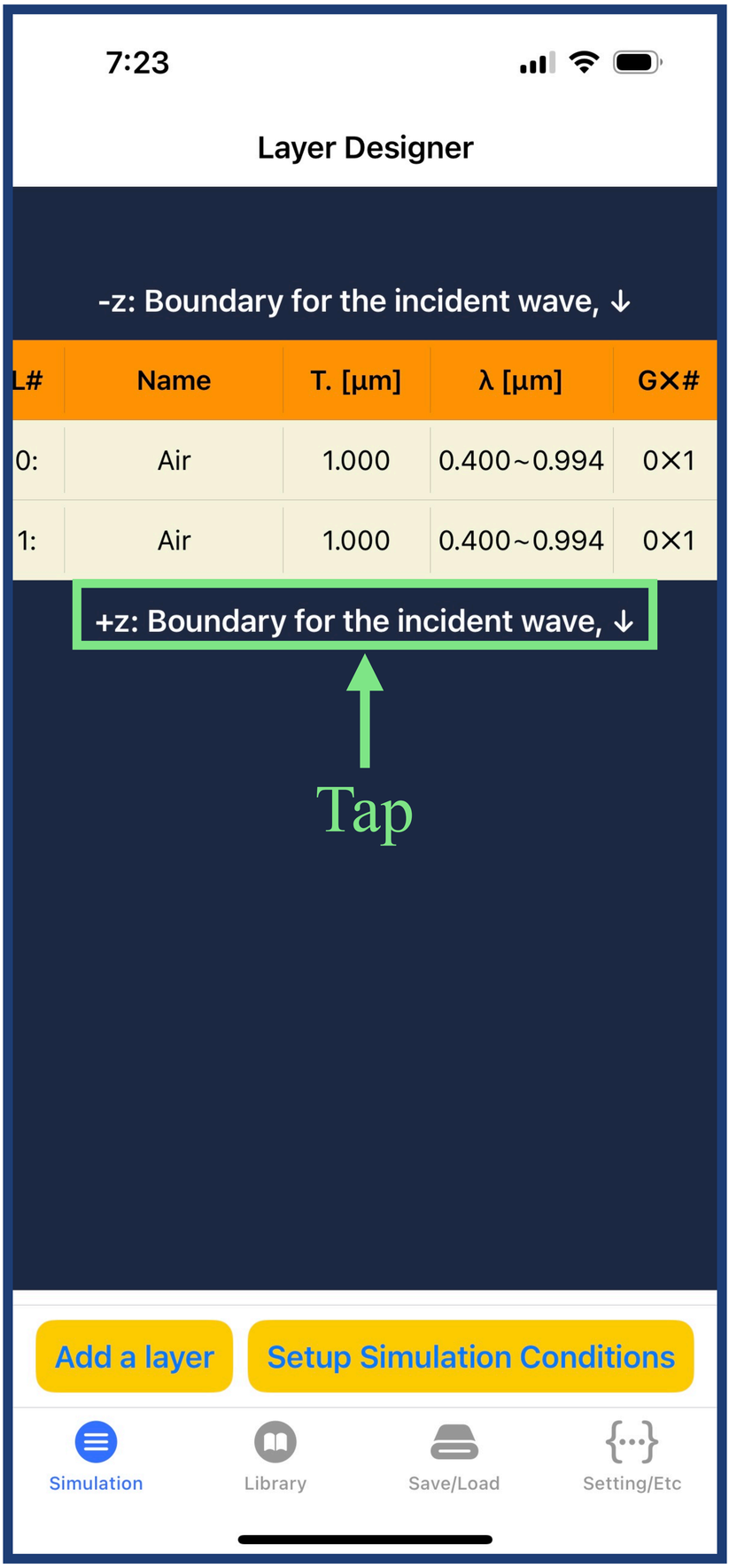
1) Li, P., Guo, Y., Xi, Y. *et al.* Controlling the TE-TM splitting of topological photonic interface states by precise incident angle adjustment. *Commun Phys* **7**, 201 (2024). https://doi.org/10.1038/s42005-024-01695-6

(Optional)

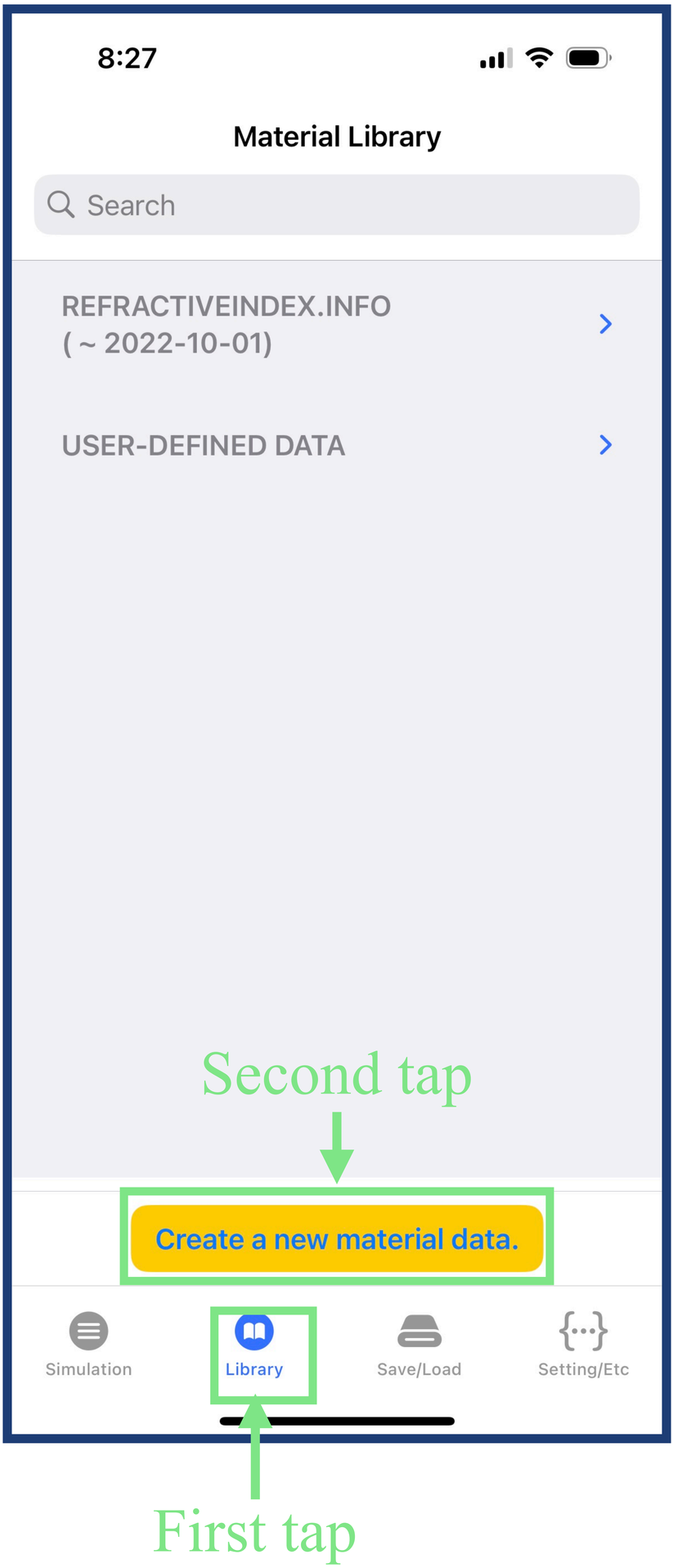
- If you already created some layers before step 1. Delete those layers by swiping from right to left for each layer and then tapping a trash can icon.



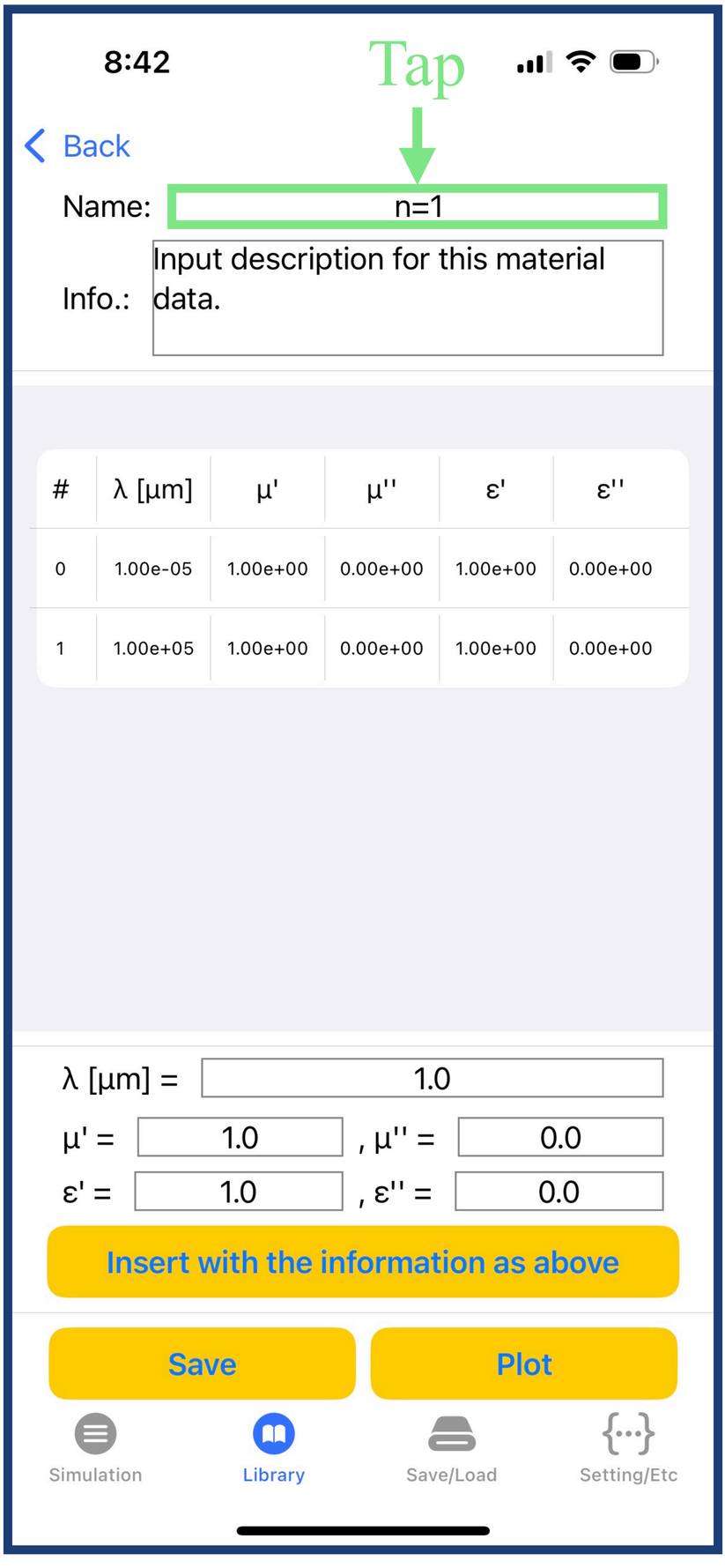
2. Tap “-z: Boundary for the incident wave, ↓” or “+z: Boundary for the incident wave, ↓” to toggle to the periodic boundary condition.



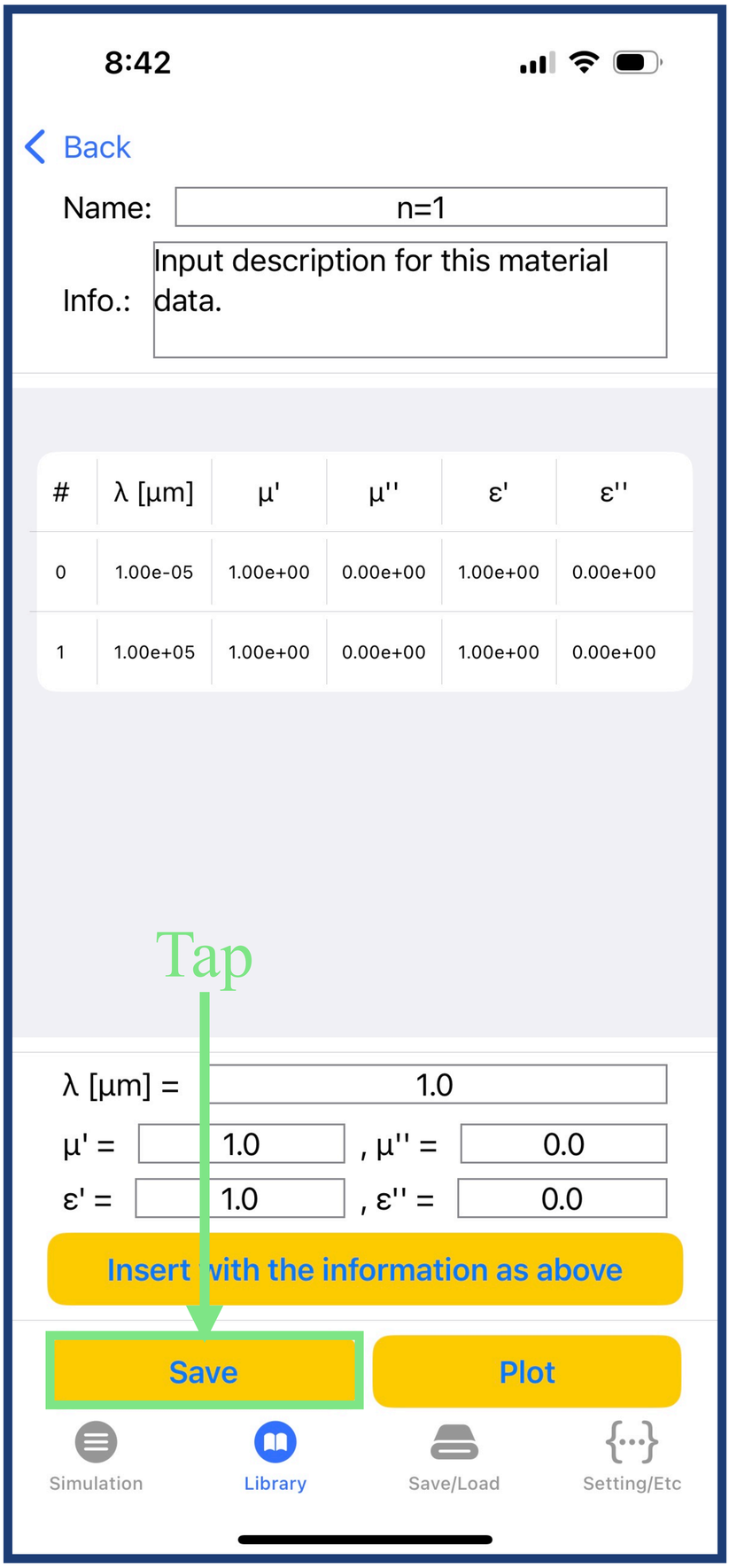
3. Tap “Library” icon below, then tap “Create a new material data” button



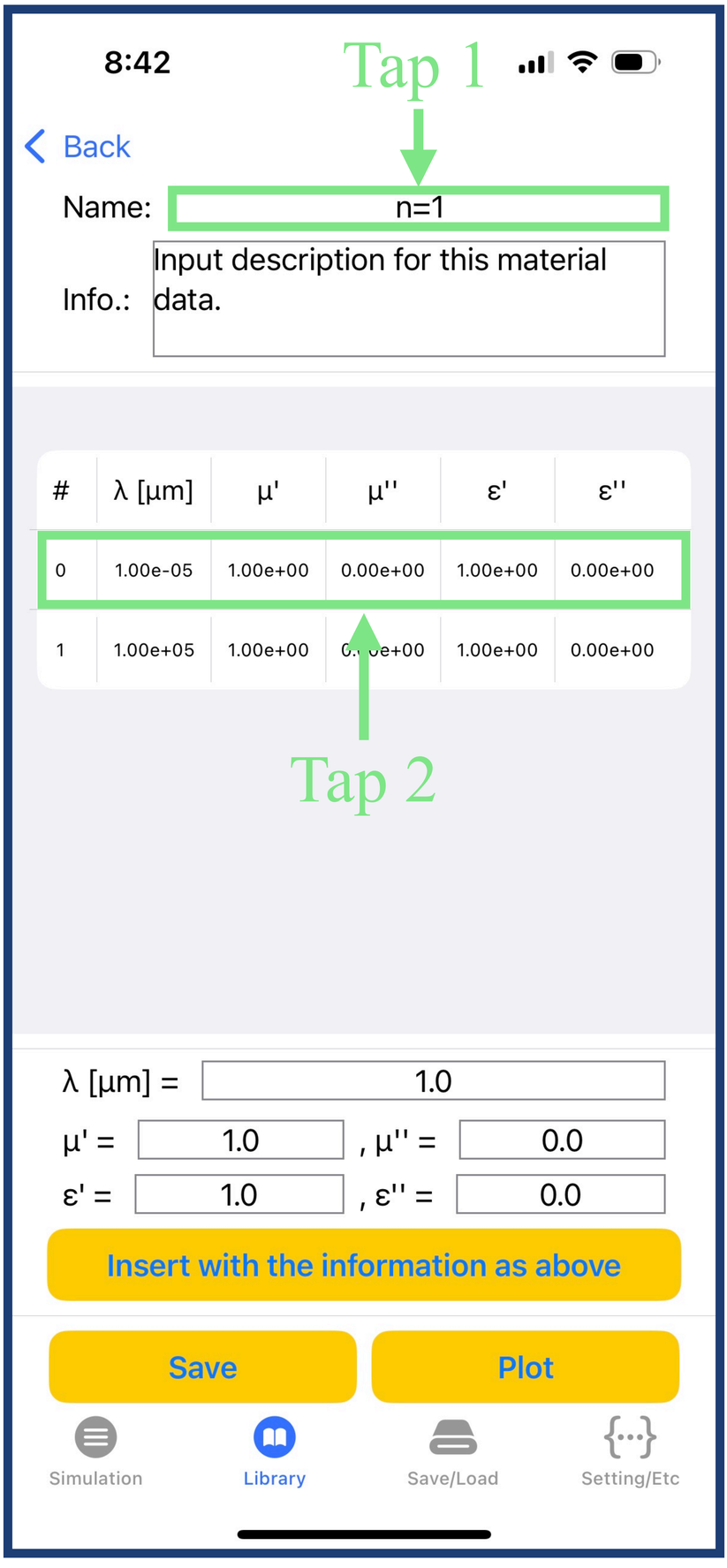
4. Tap “Name” field, then input the name you want. In this tutorial, I name the first user-defined material as “n=1” since we need a refractive index value of 1 for the first layer.



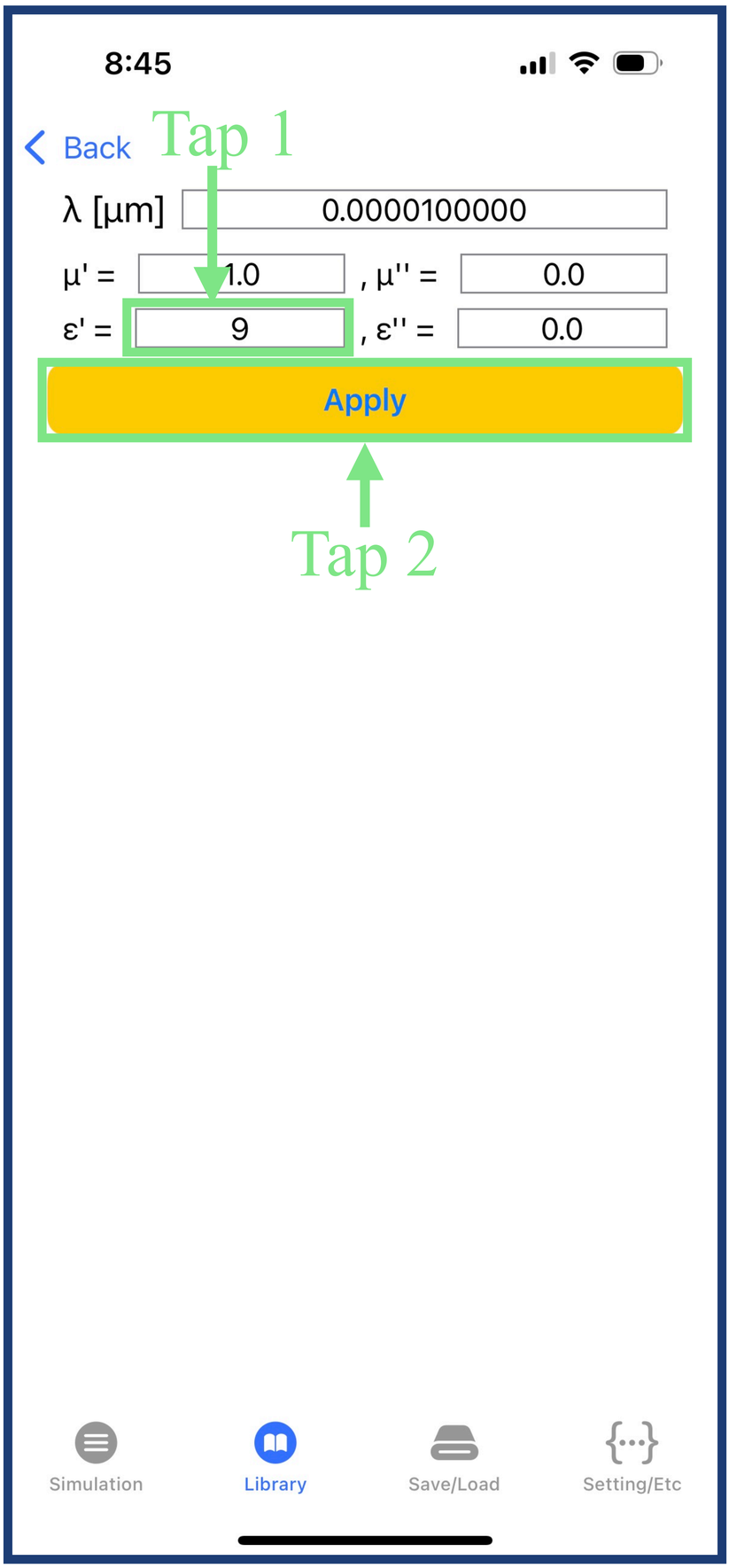
5. The table's initial values are $\varepsilon' = 1$ and $\mu' = 0$. We do not change those values since those are already the values that we want for the first layer. Tap the "Save" button. Thereafter, the first necessary material is created.



6. To make the second required material, click the name field again and type “n=3”. Next, tap the #0 row of the table to input the wavelength, complex relative permittivity, and complex relative permeability.

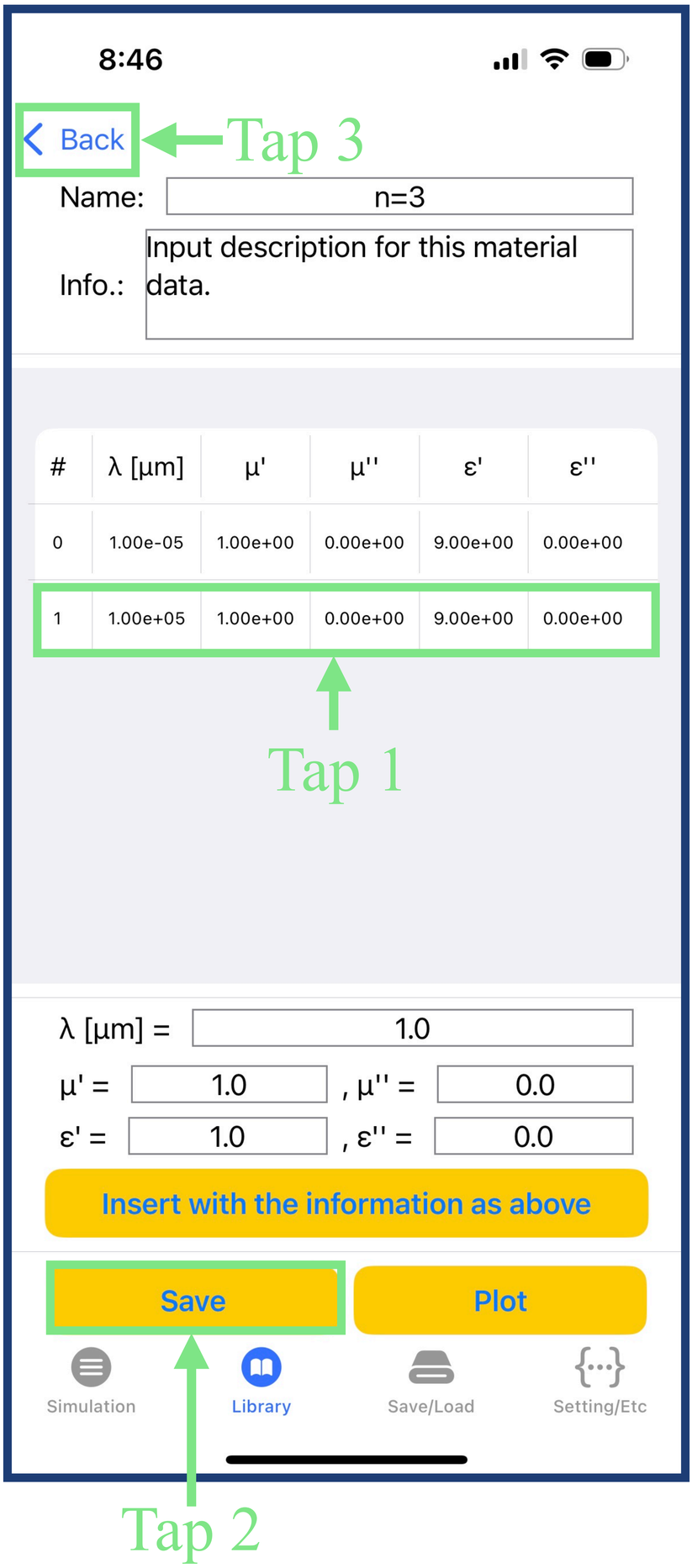


7. Change the ε' value to 9.0. Then, tap “Apply” button.

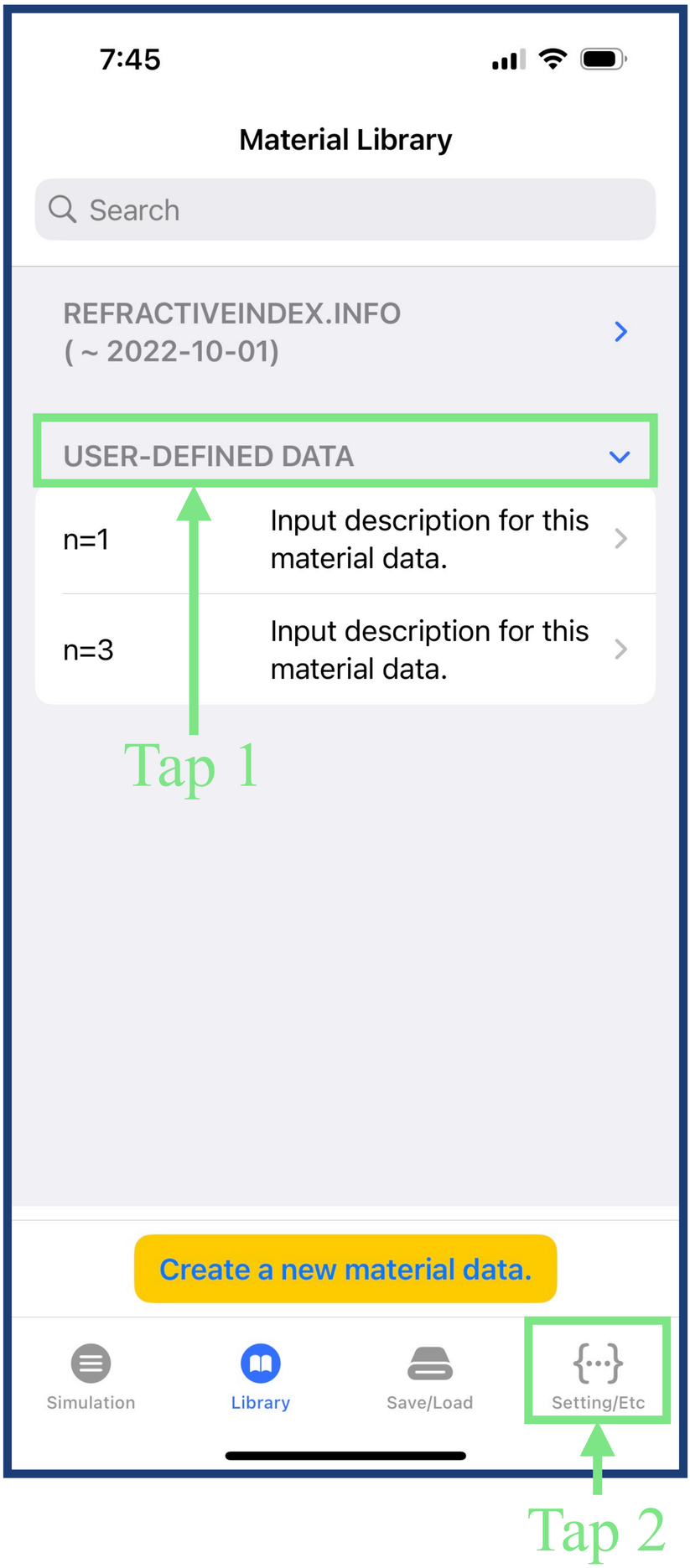


- Piecewise linear interpolation is performed among recorded wavelengths to extract permittivity and permeability of non-explicitly recorded wavelengths in E2M

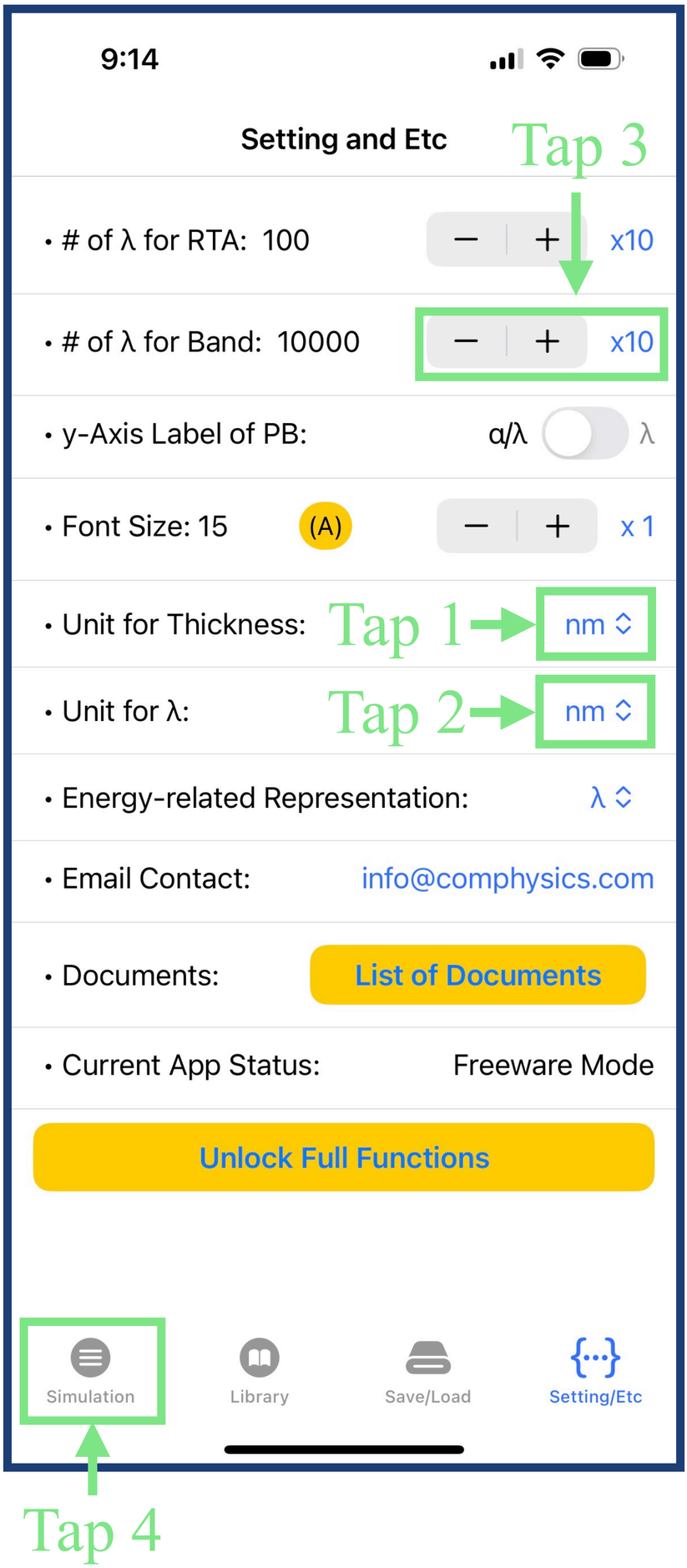
8. Tap #1 row of the table. Then, repeat step 7. After that, tap “Save” button. Then, the second material “n=3” is created. Finally, tap “Back” button.



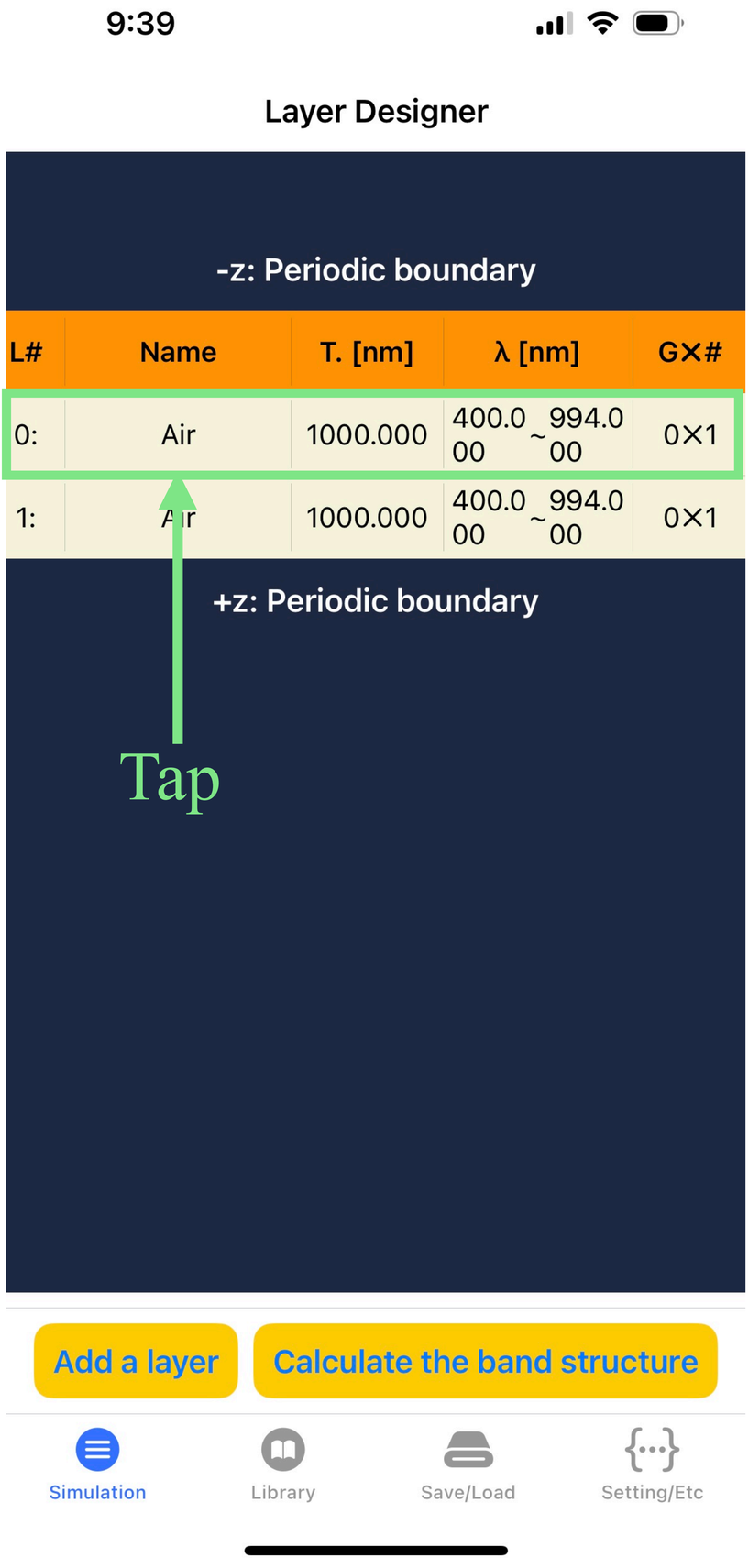
9. Expand USER-DEFINED DATA section by tapping. You can find the newly created two materials. Finally, tap “Setting/Etc” icon below.



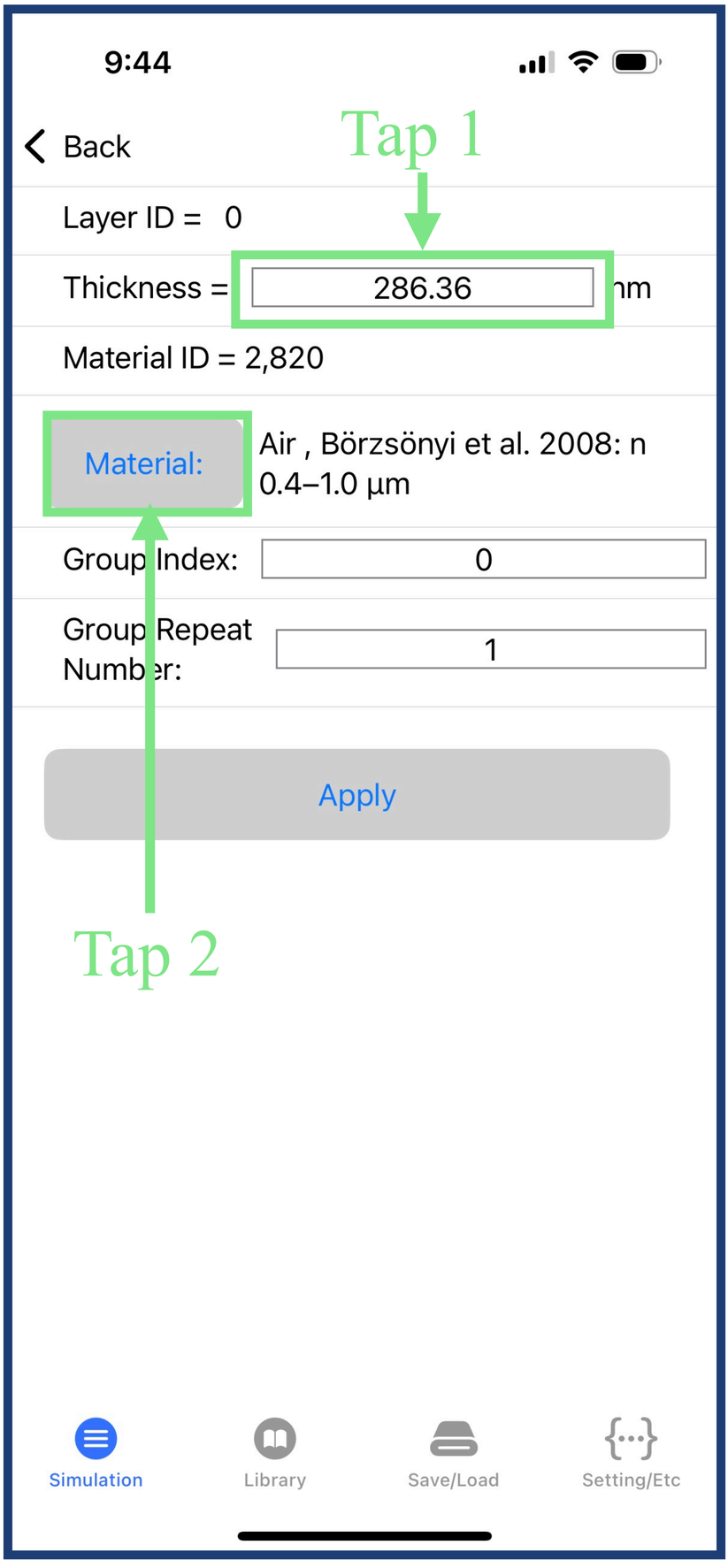
10. Change “Unit for Thickness” and “Unit for λ” to “nm”. Also, change the “# of λ for Band” to 10000. Then, tap the “Simulation” icon.



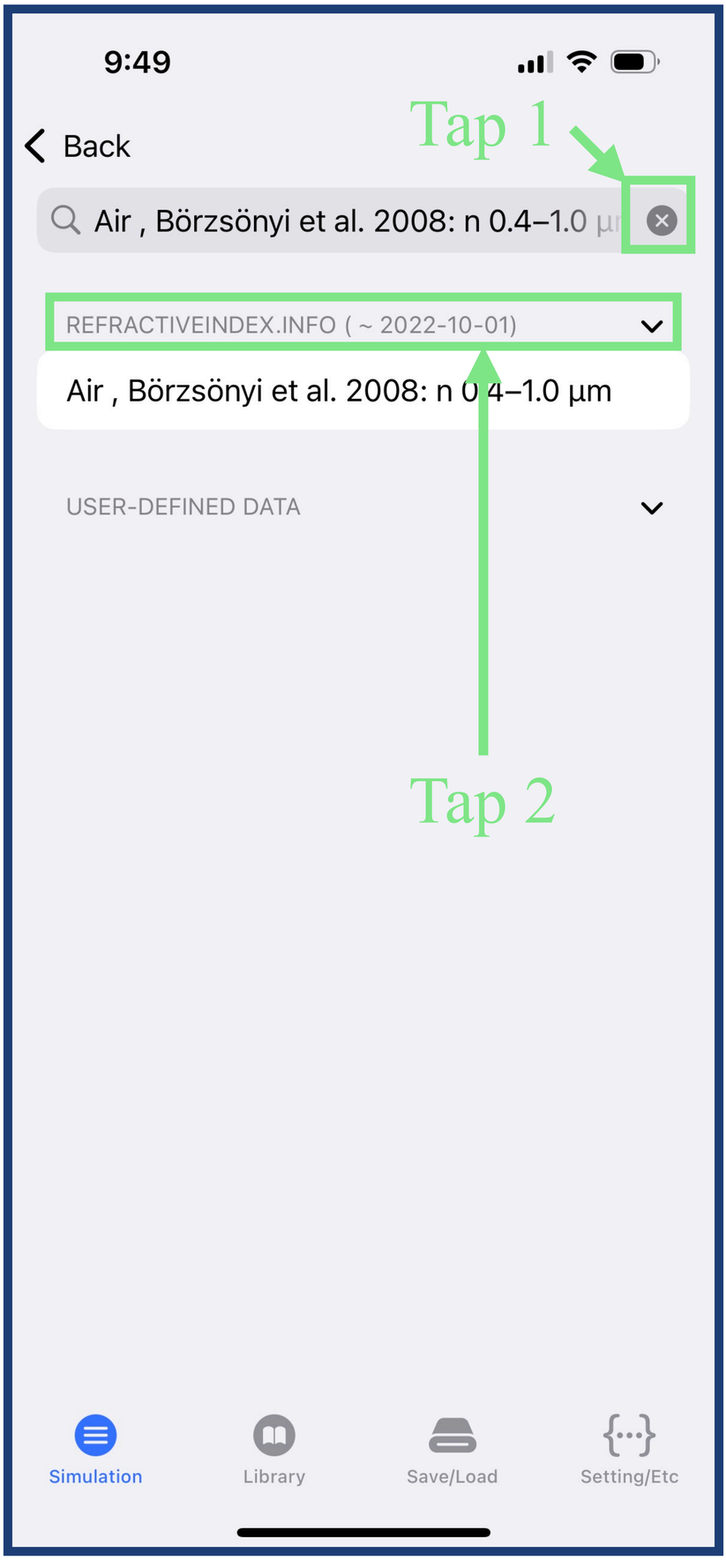
11.Tap L#0 row as below.



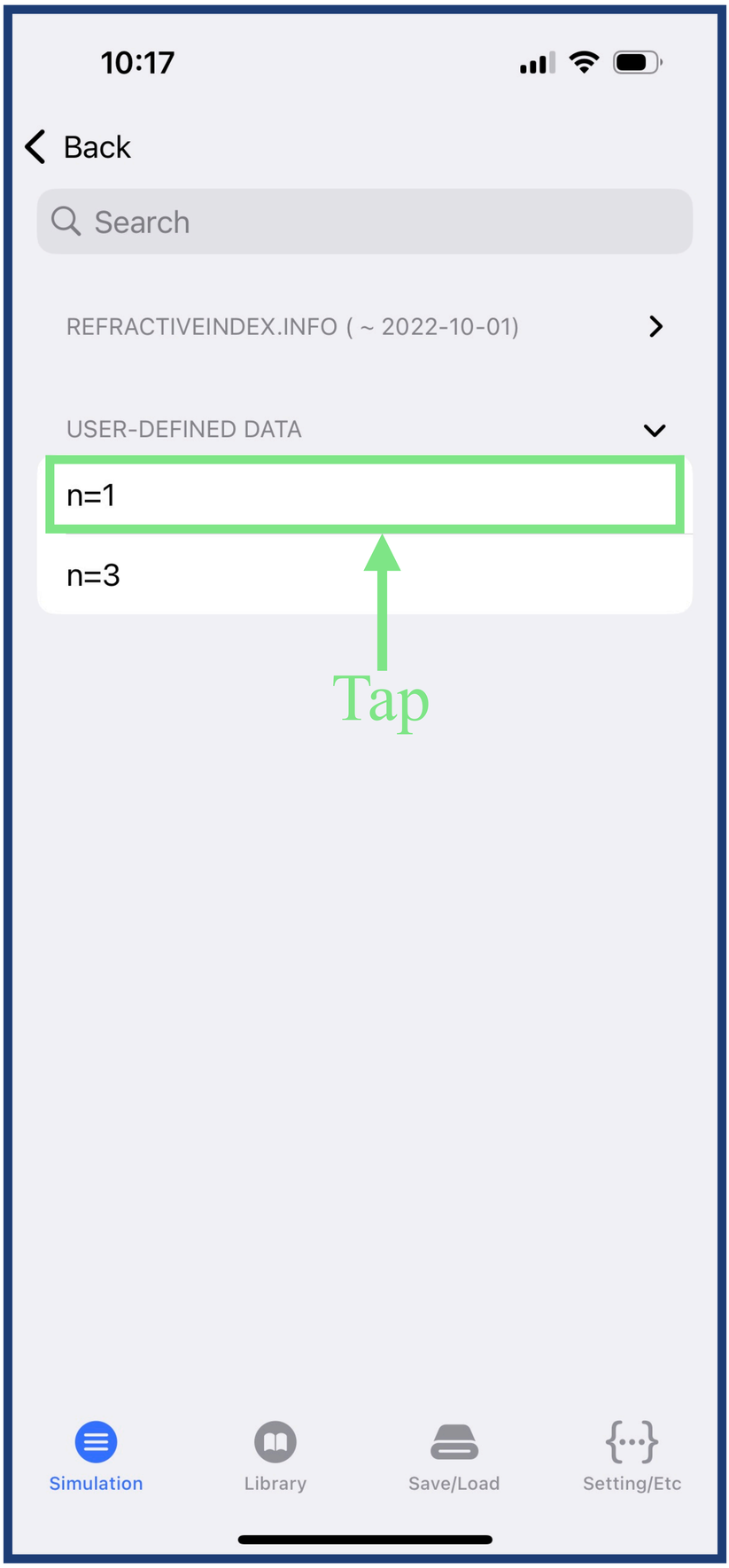
12. Change thickness to 286.36 nm by tapping the “Thickness” field. Then, tap the “Material” button.



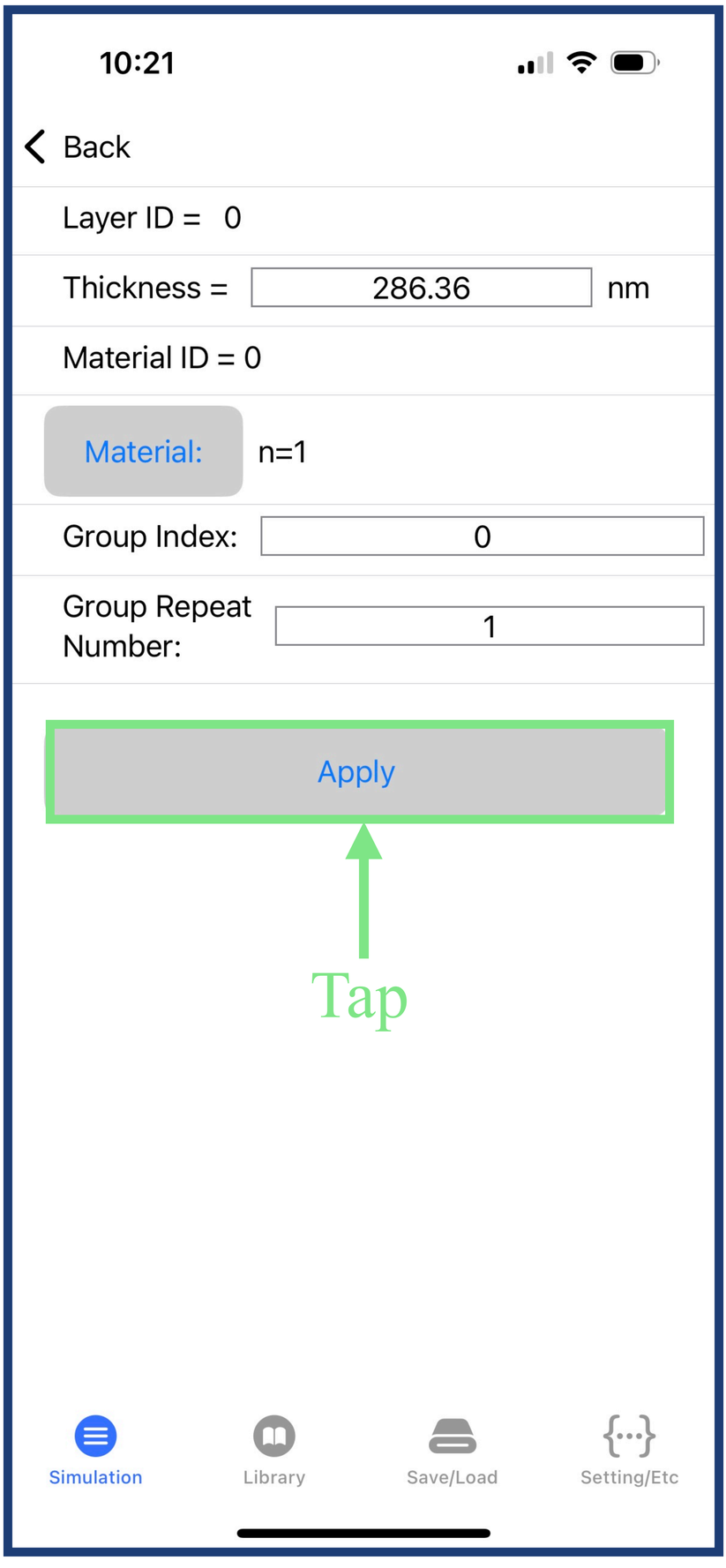
13. Tap ⓧ button to clear the filtering text. Then, tap “REFRACTIVEINDEX.INFO(~2022-10-01)” to shrink the material list.



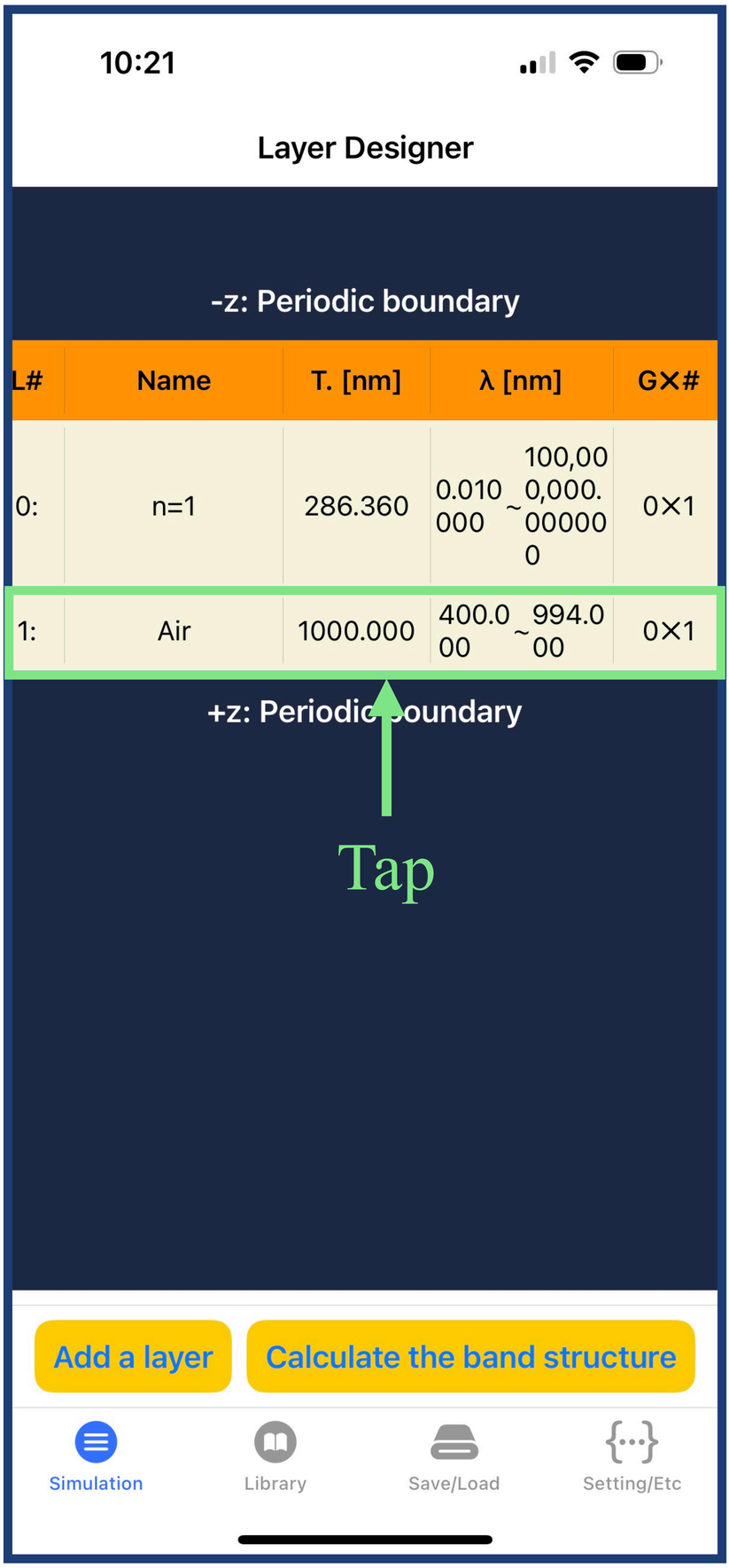
14. Tap “n=1”, user-defined material.



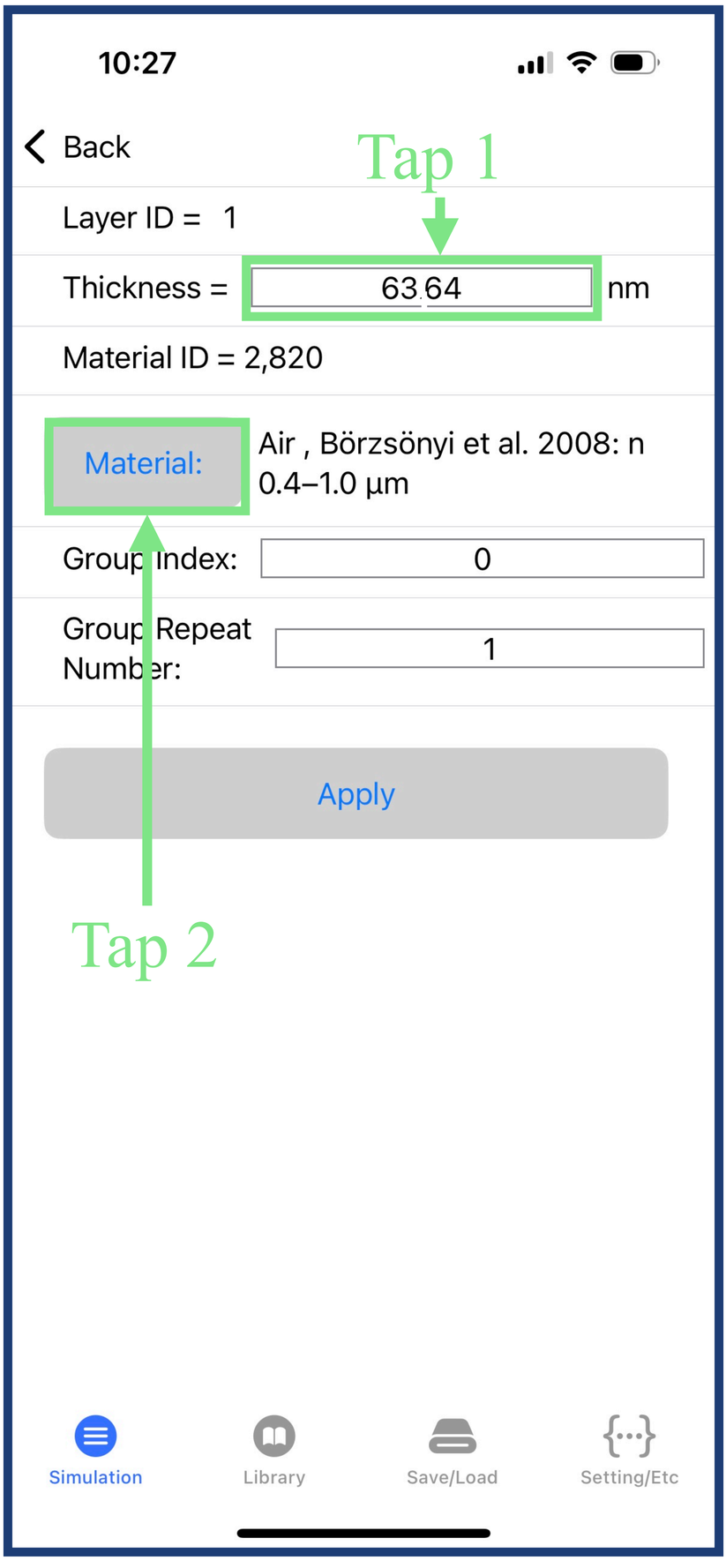
15. After confirming the validity of the input, tap the “Apply” button.



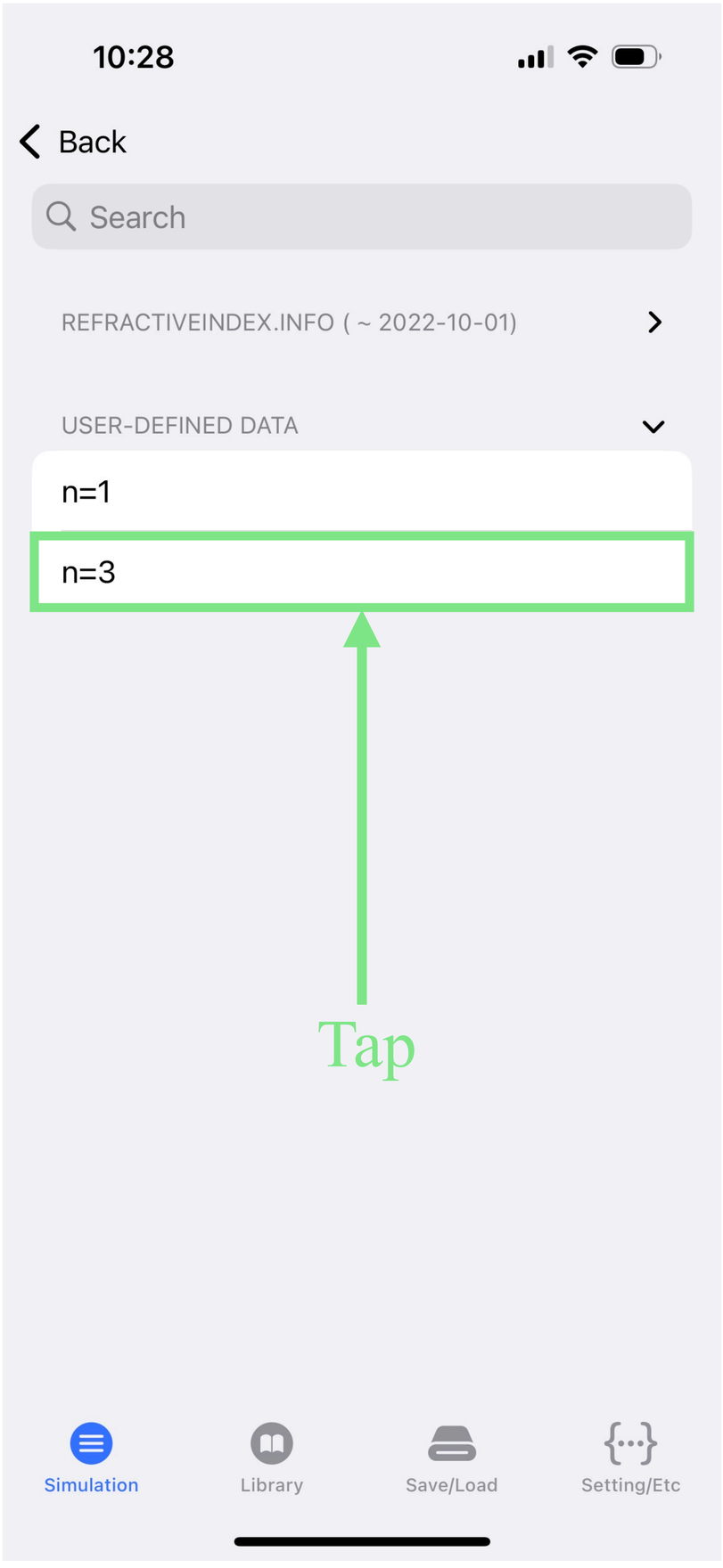
16. To change the second layer's thickness and material, tap L#1.



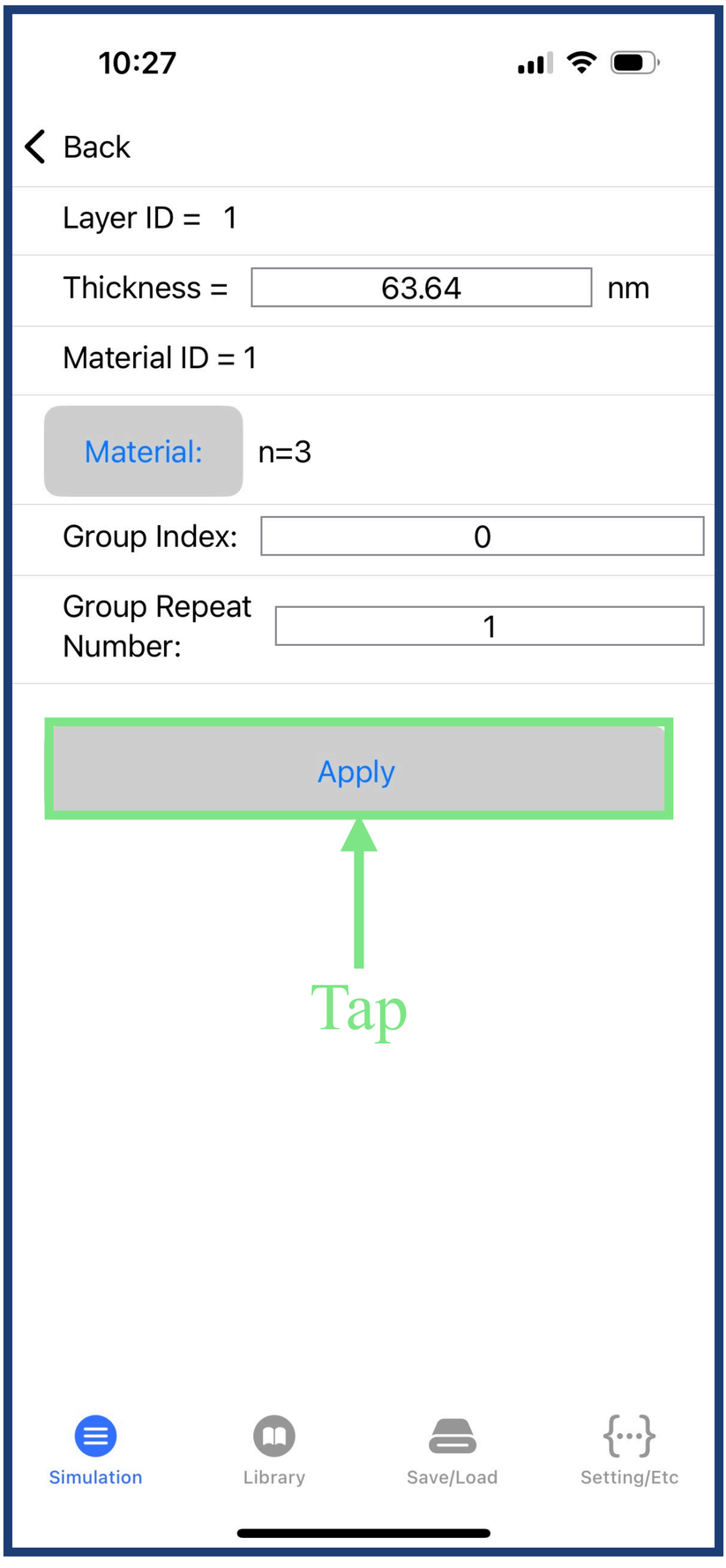
17. Tap “Thickness” field to change the value to 63.64 nm. Then, tap “Material” button.



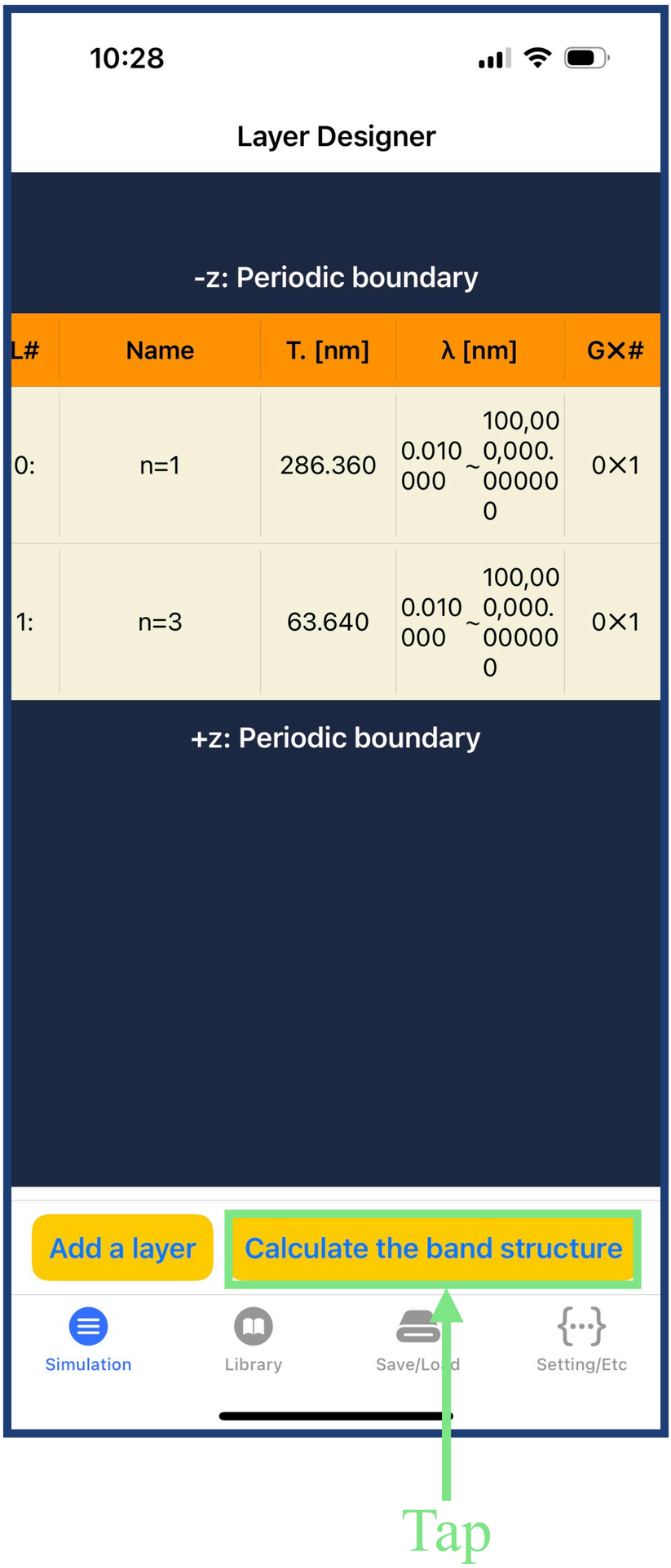
18. Select “n=3” material in the USER-DEFINED DATA section.



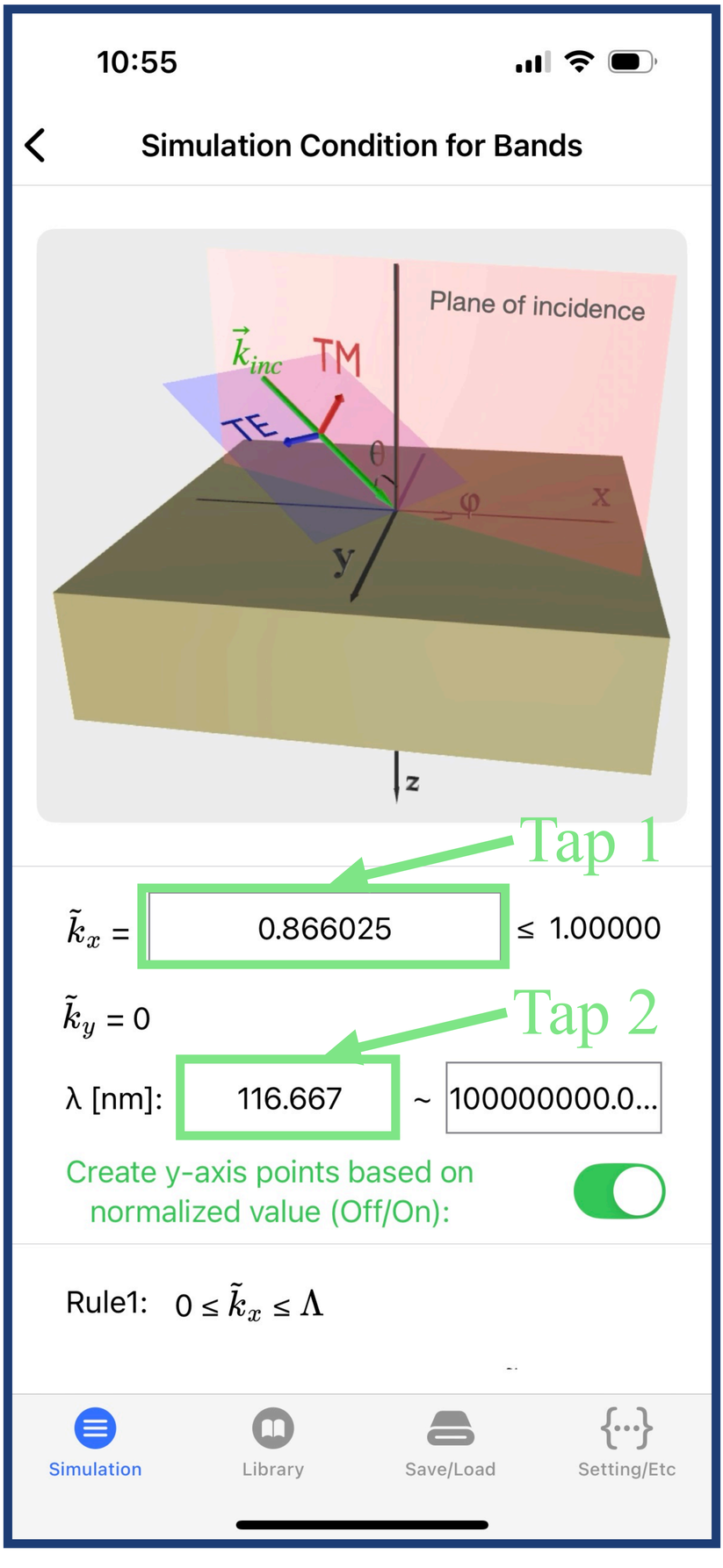
19. After confirming the validity of the input, tap the “Apply” button.



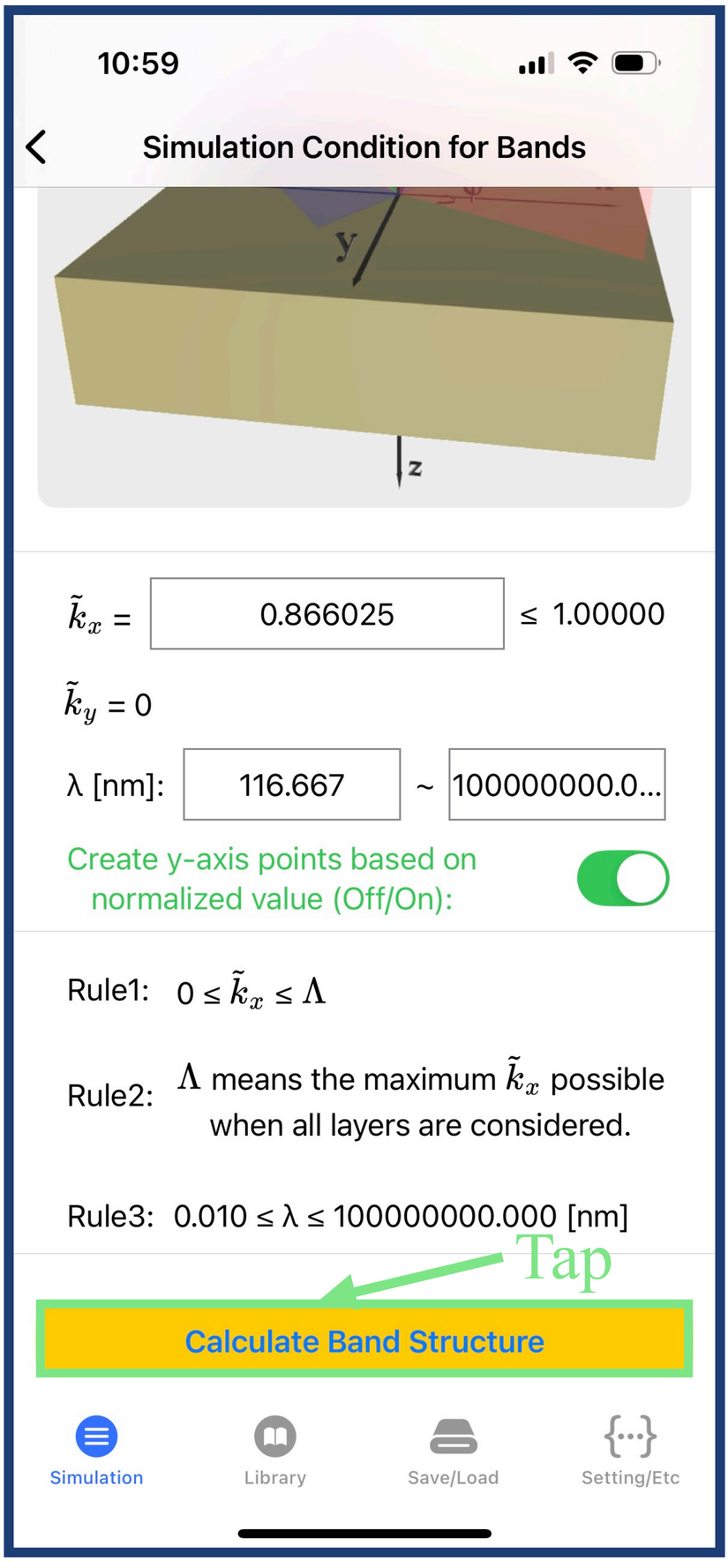
20. Layer design is completed. Tab “Calculate the band structure” button as below.



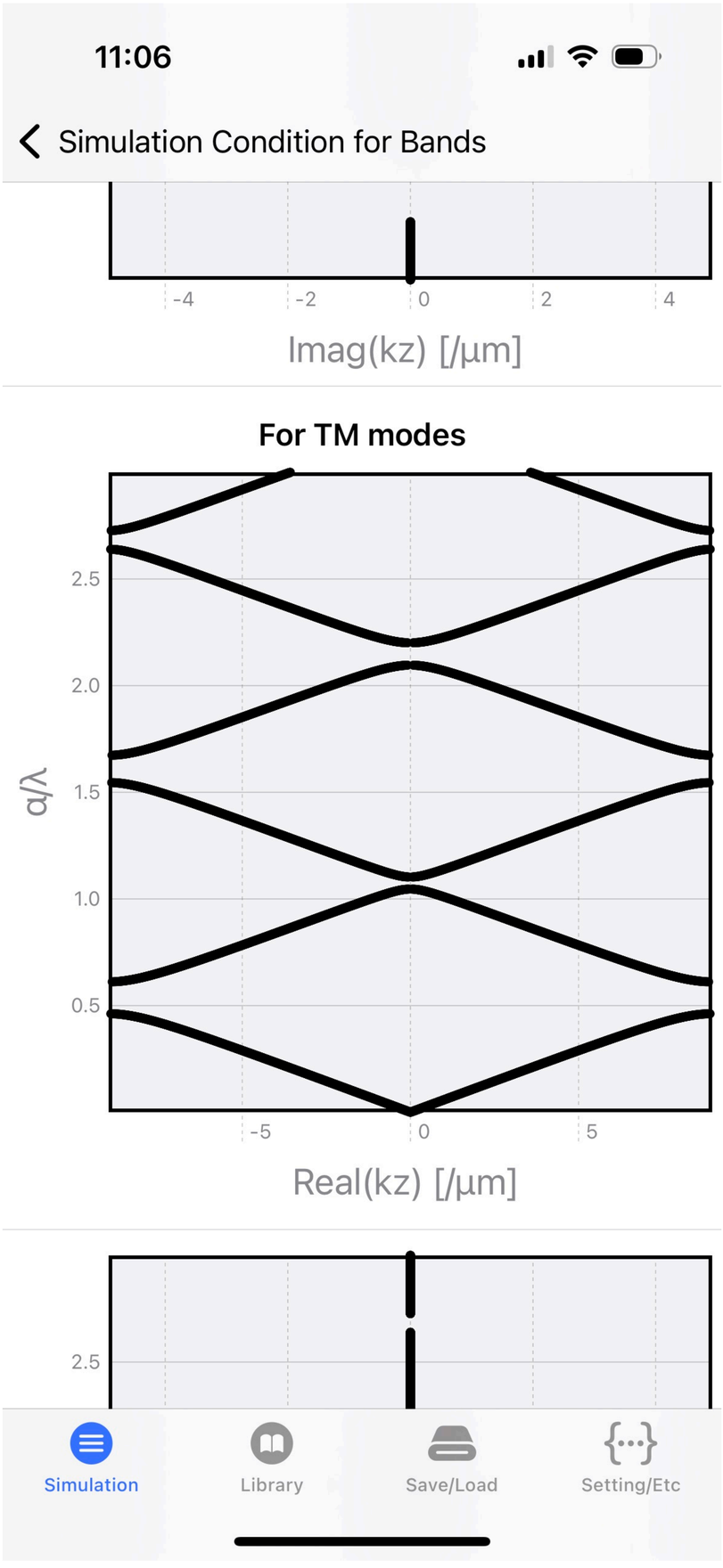
21. Input $\tilde{k}_x$ field as 0.866025 and λ = 116.667 [nm] ~. Here, $\tilde{k}_x$ is the normalized wave vector for the x-axis and $\tilde{k}_x = sin(\theta)cos(\phi)$. ϕ is fixed at 0 in the current E2M version, 1.0. θ is the angle of incidence.



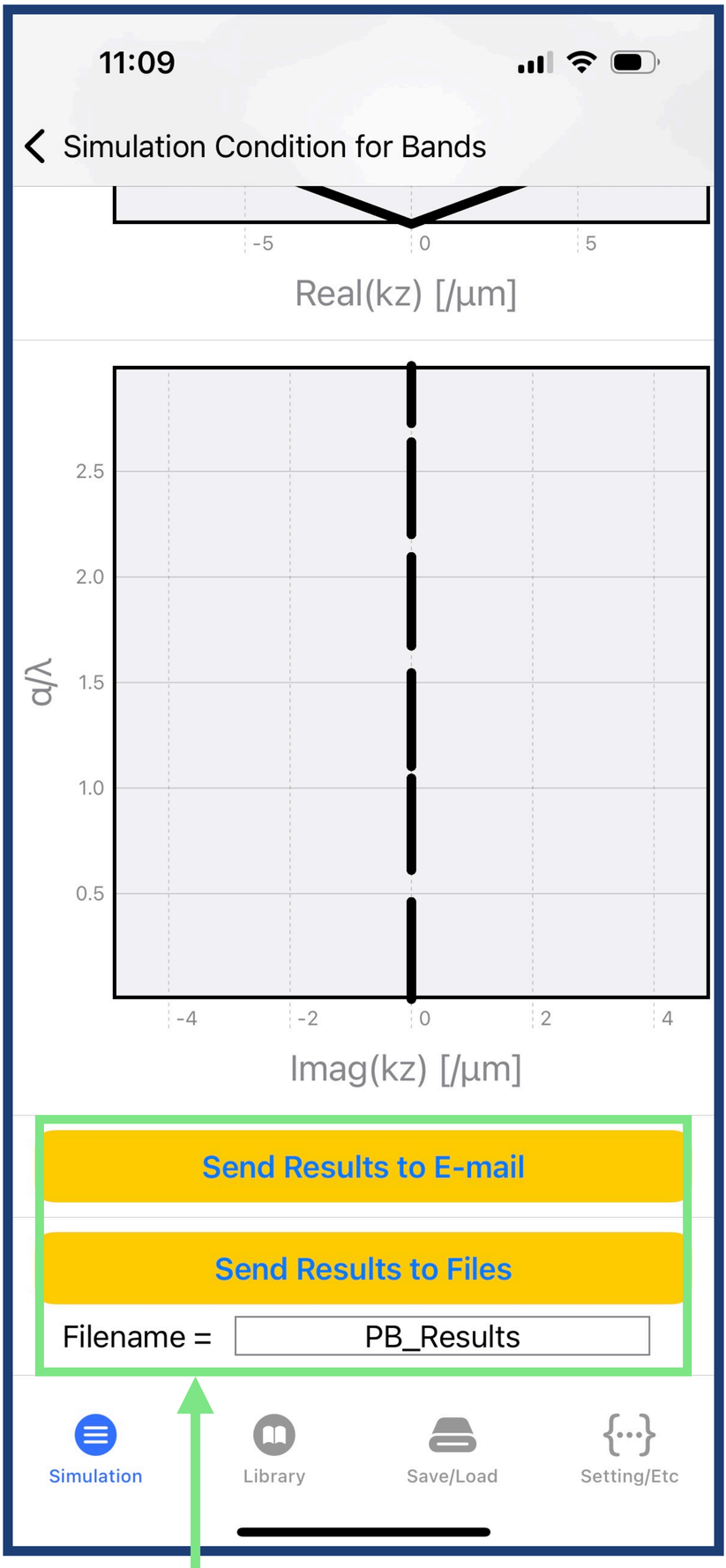
22. Scroll down the screen. Then, tap “Calculate Band Structure” button.



23. After scrolling down, we can confirm the photonic band for TM modes that can be compared with Fig. 2 of the target reference.

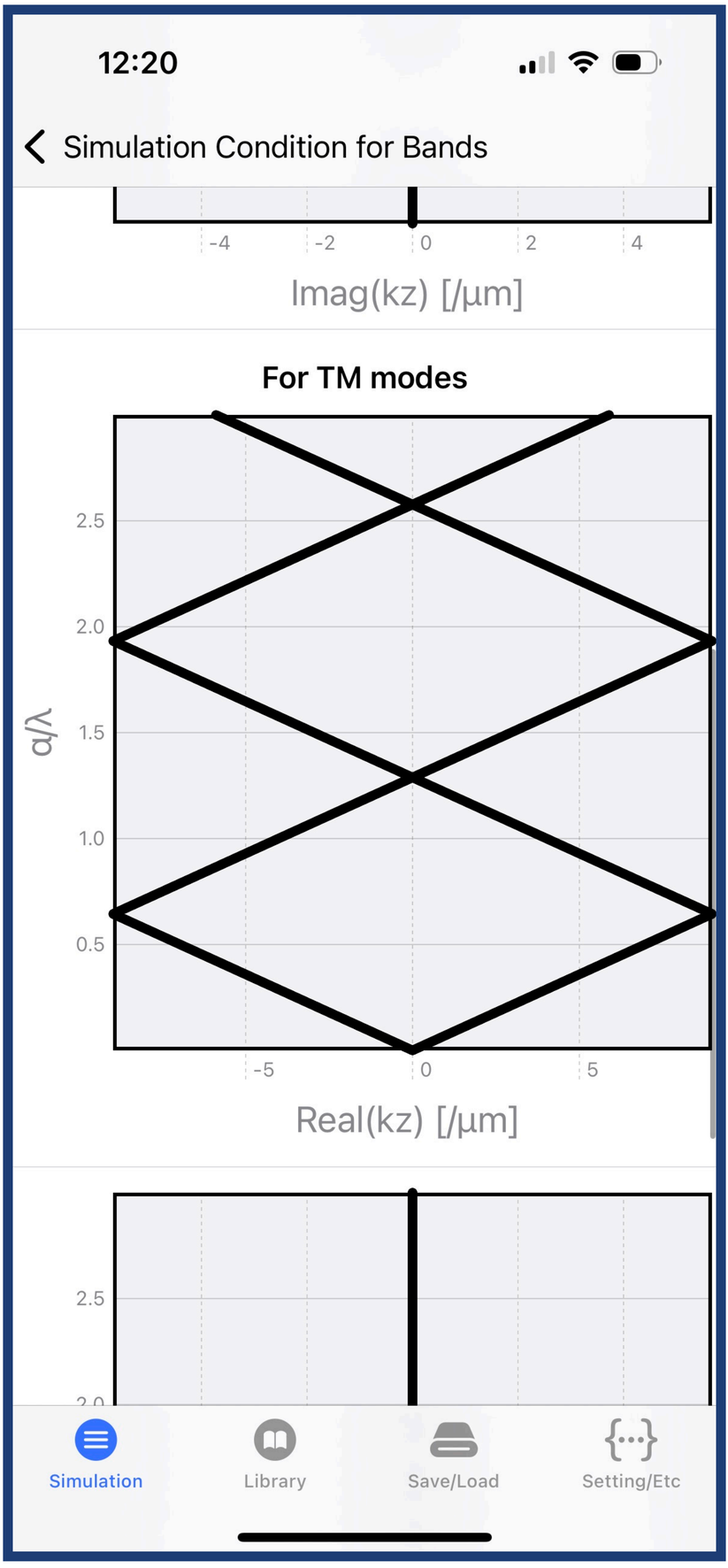


24. By scrolling down more, the options for export of results are shown. The results include both raw data files and figure files.

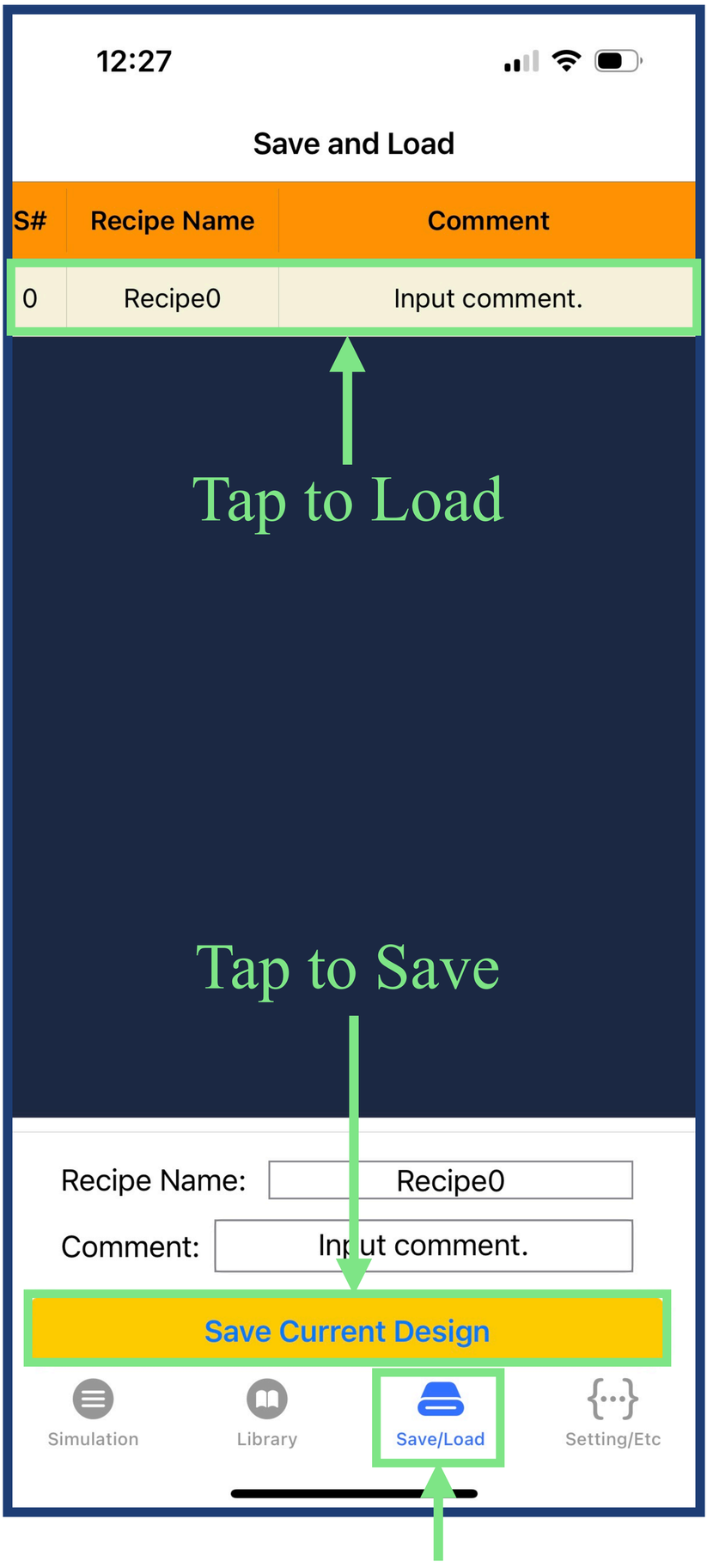


Options for the export of results

25. After the Brewster angle of $\theta = 71.57^{\circ}$ ($\tilde{k}_x = 0.948711$) is applied, the photonic bands for TM modes can be extracted as below. Detail progress steps for this is omitted since it is like the previous steps.



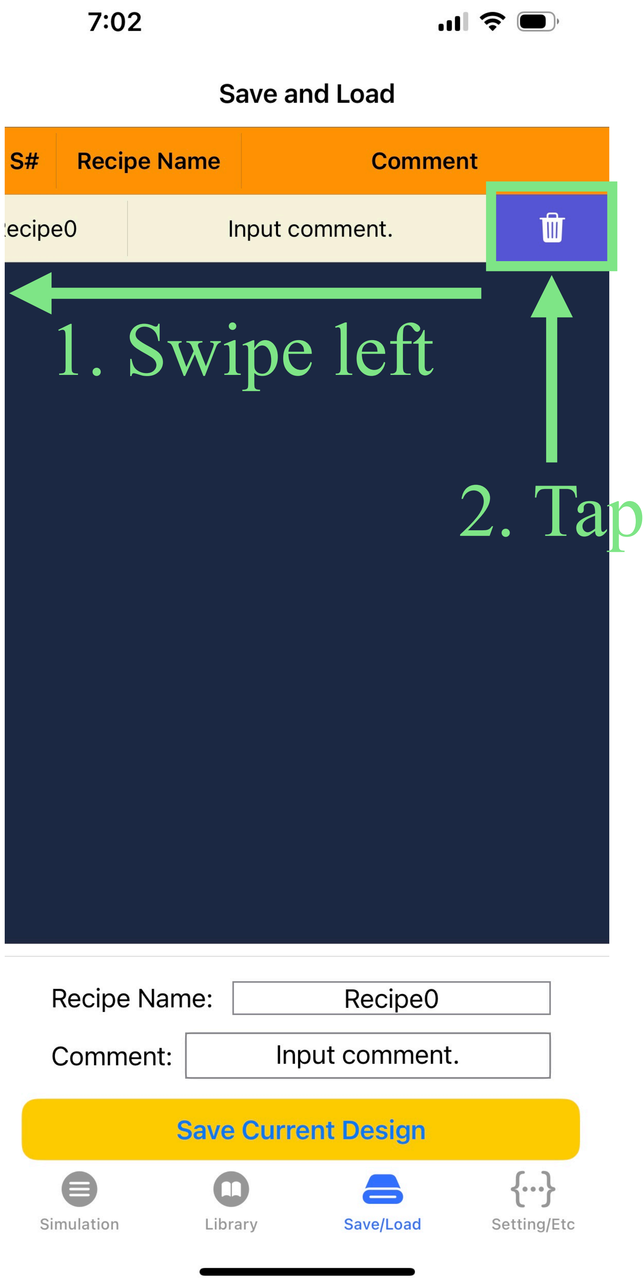
26. Current simulation conditions, including layer design, can be saved by tapping the Save/Load icon and “Save Current Design” button sequentially.



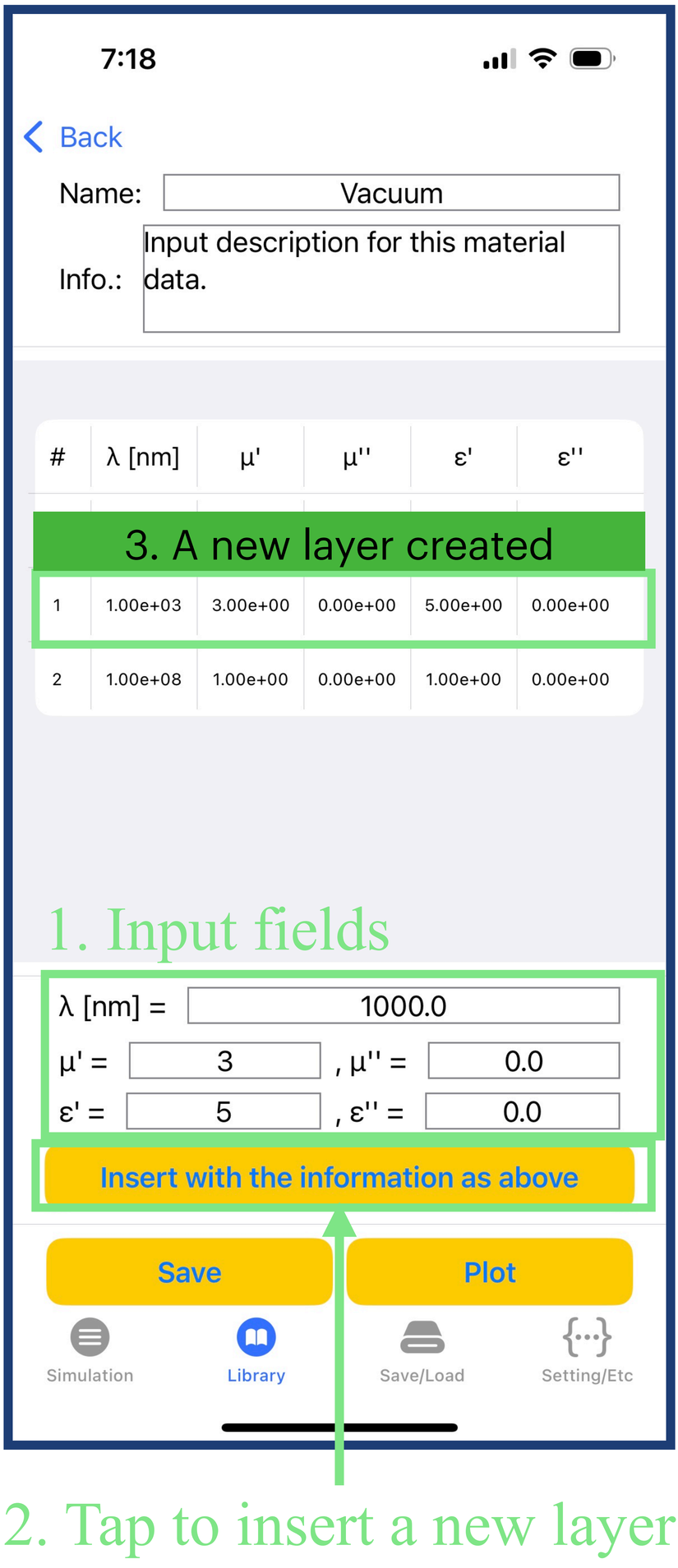
Additional Functions of E2M

From now on, additional functions that may be useful for the design and analysis with E2M will be introduced.

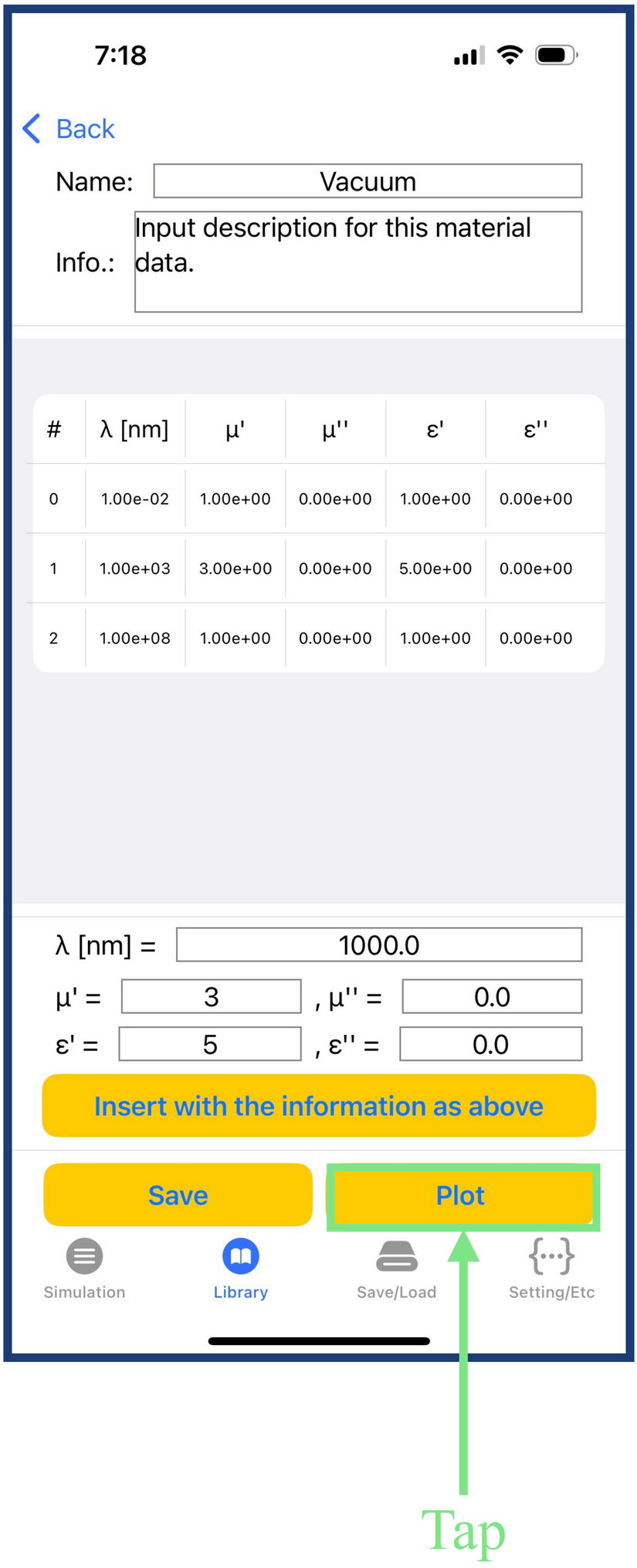
A) Delete save files: On “Save and Load” page, you can easily remove the saved recipe by swiping and tapping the trash as below



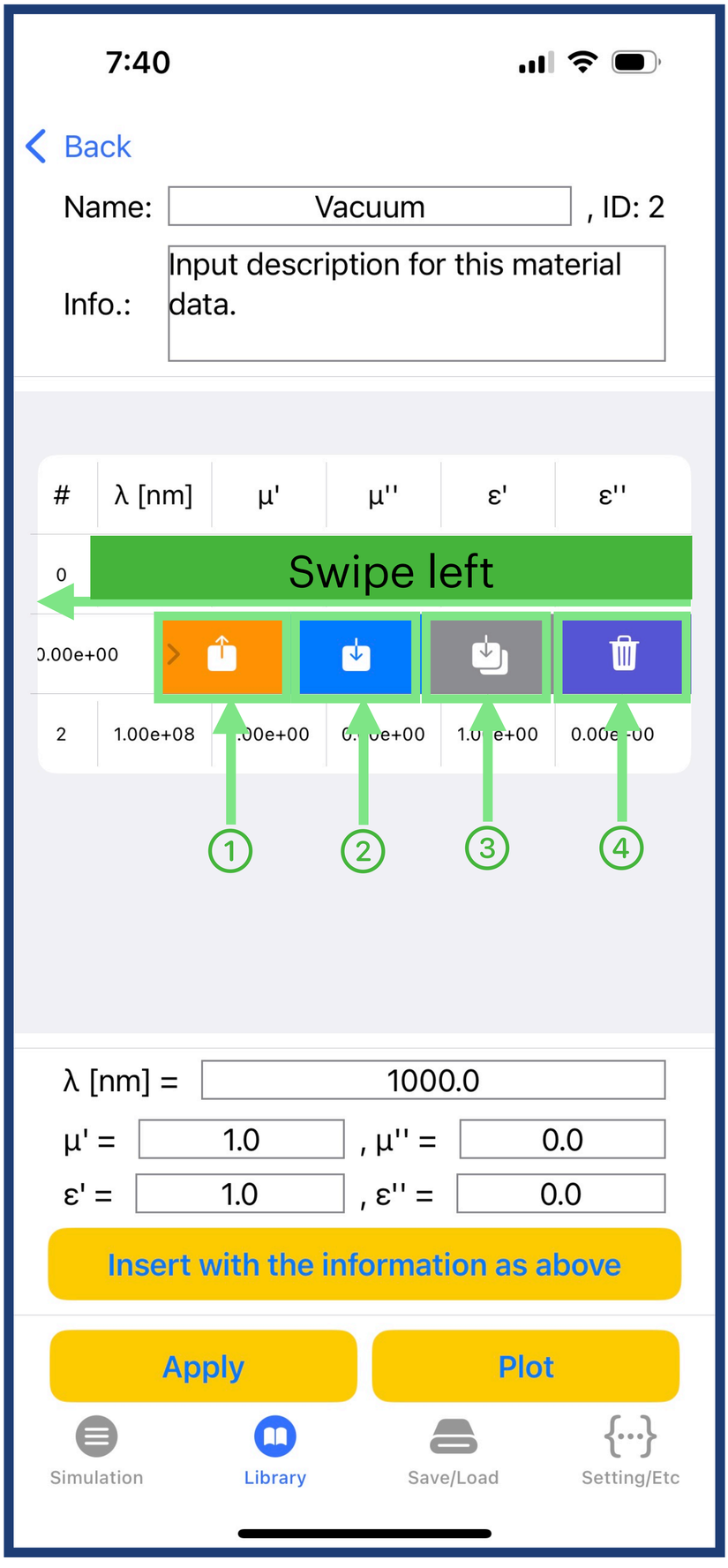
B) Create or edit user-defined material data with several points as you want



To confirm the modification graphically, tap the “Plot” button.

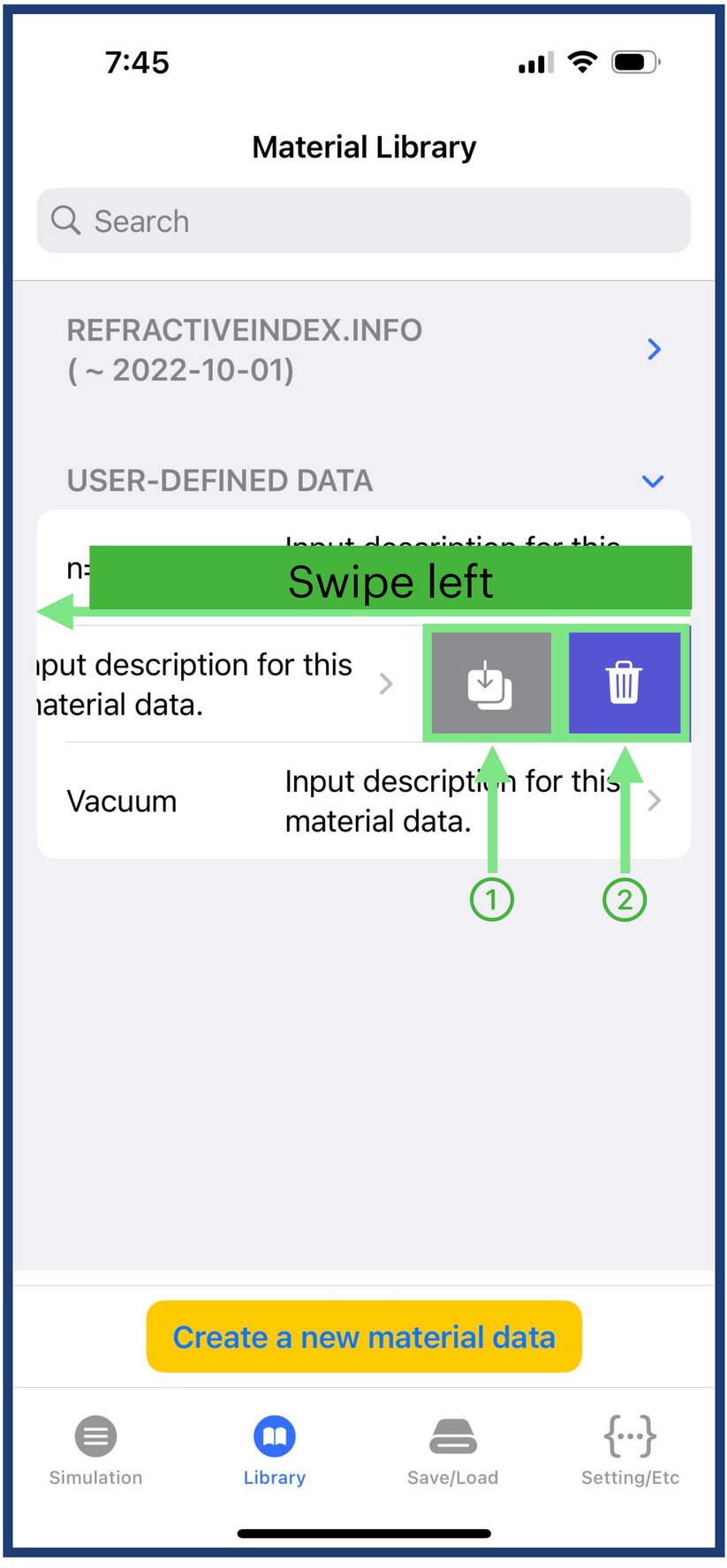


Design the user-defined material using swipe action and tap actions as described below



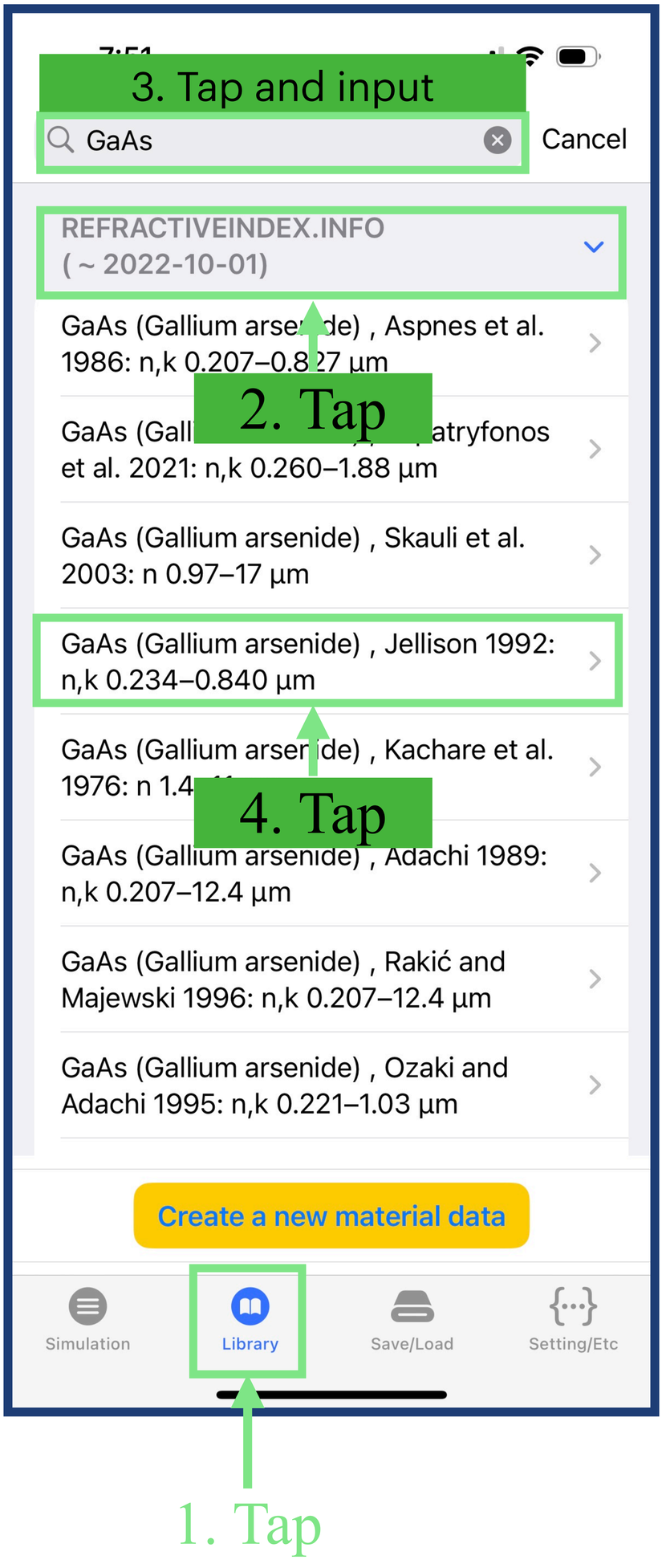
①: Exchange with the layer right above
②: Exchange with the layer right below
③: Copy the current layer and paste to right below
④: Delete the selected layer

C) Delete or copy the user-defined material by swiping and tapping on “Material Library” page

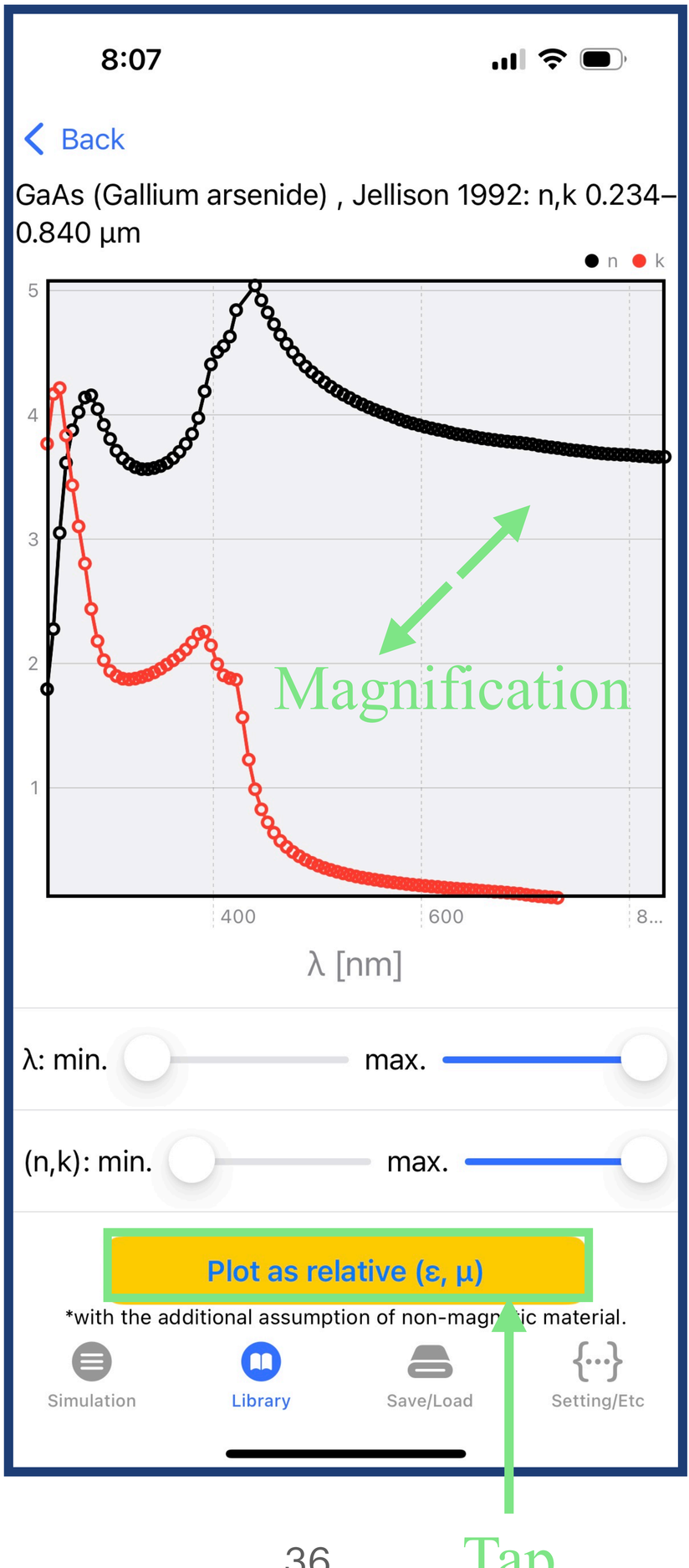


①: Copy and paste right below
②: Delete the selected user-defined material

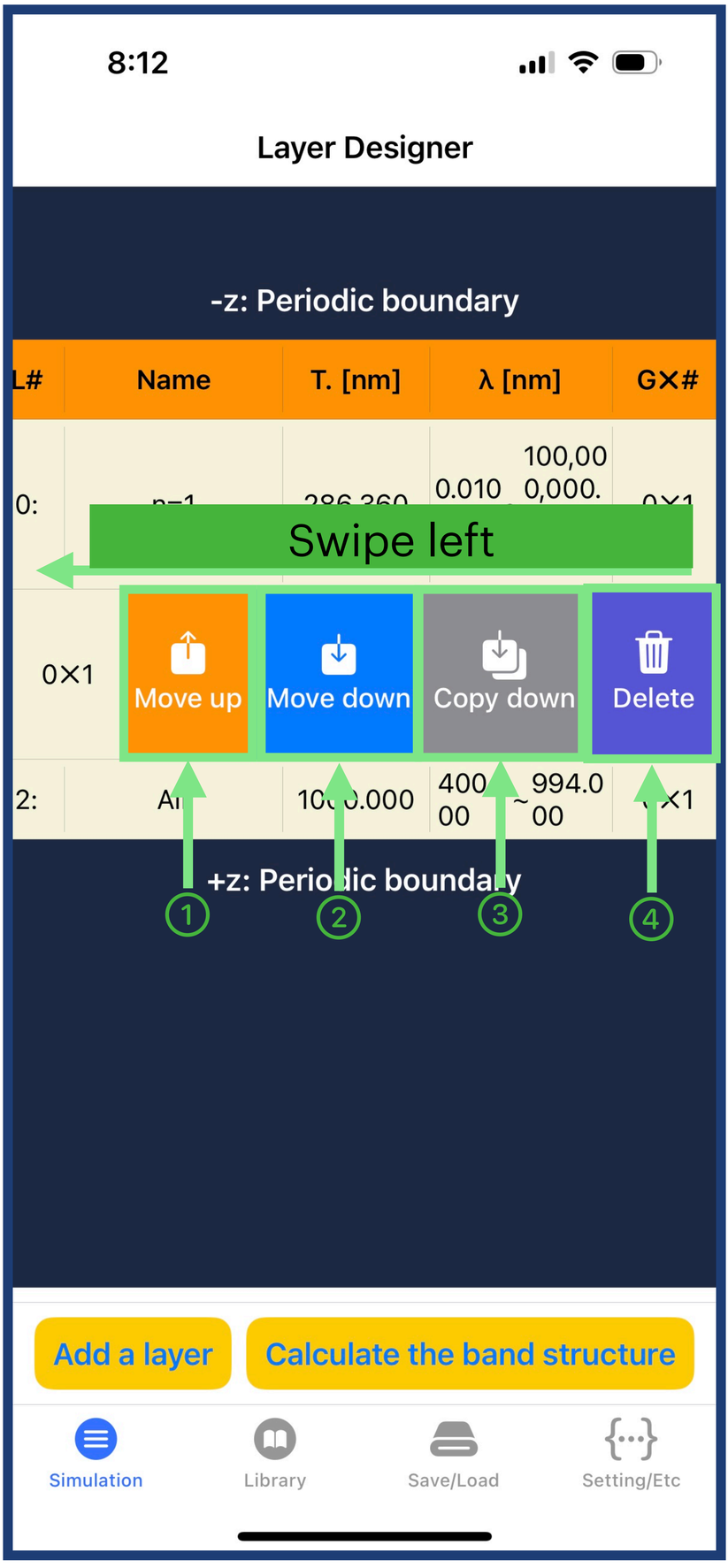
D) Search the refractiveindex.info material database by tapping the section and entering search words as an example below



You can confirm the graphical data of complex refractive index as below. Gestures for magnification and drag are allowed in the chart. Tap the only button to convert the (n,k) plot into the (ε,μ).

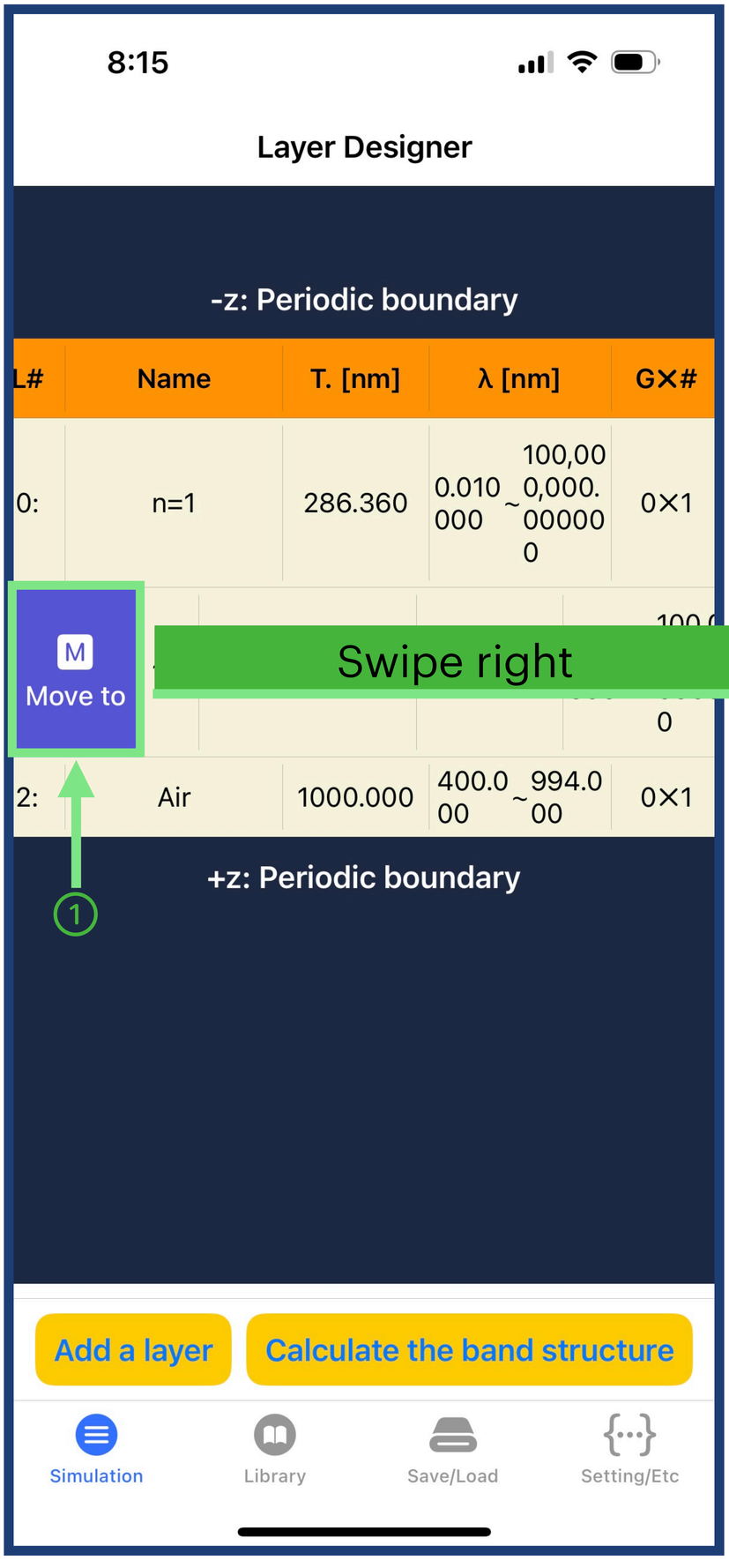


E) On “Layer Designer” page, you can use the additional functional buttons as below after swiping left.



①: Exchange with the layer right above
②: Exchange with the layer right below
③: Copy the current layer and paste to right below
④: Delete the selected layer

After swiping right, “Move to” button is shown as in the figure below. After tapping this, you can input a layer number. Then, your selected layer is exchanged with the input layer number.



①: Move to a designated layer number

F) If you select “refractiveindex.info" database in the layer design process, you can see the (n, k) or the (ε, μ) graph of the material by swiping and tapping as in the figure below.