

# Tutorial for Extraction of Photonic Band Structures

***with step-by-step instructions***

Ver: 1.0 (July 17, 2025)



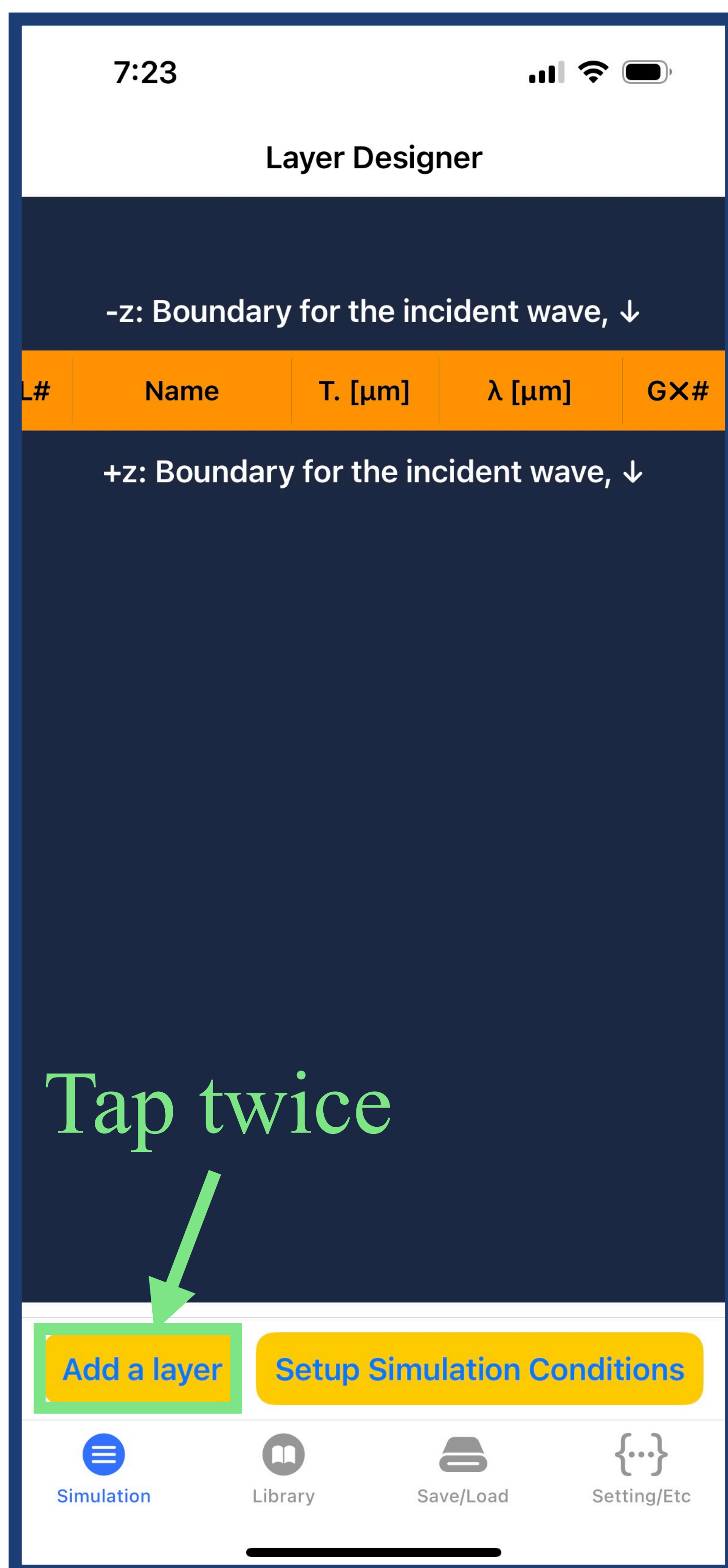
ComPhysics

# Symbols and abbreviations used in E2M

Symbol	Meaning
$L\#$	Layer index
T.	Thickness
$\lambda$	Wavelength
$\mu'$	Real part of relative permeability
$\mu''$	Imaginary part of relative permeability
$\varepsilon'$	Real part of relative permittivity
$\varepsilon''$	Imaginary part of relative permittivity
$\tilde{k}$	Normalized wave vector
GX#	G: Group index X: seperator meaning times #: Repetition num. for the group
$\theta$	The azimuthal angle
$\varphi$	The polar angle
TE	Transverse Electric
TM	Transverse Magnetic
R	Reflectance
T	Transmittance
A	Absorptance ( $R + T + A = 1$ )
$\alpha$	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.

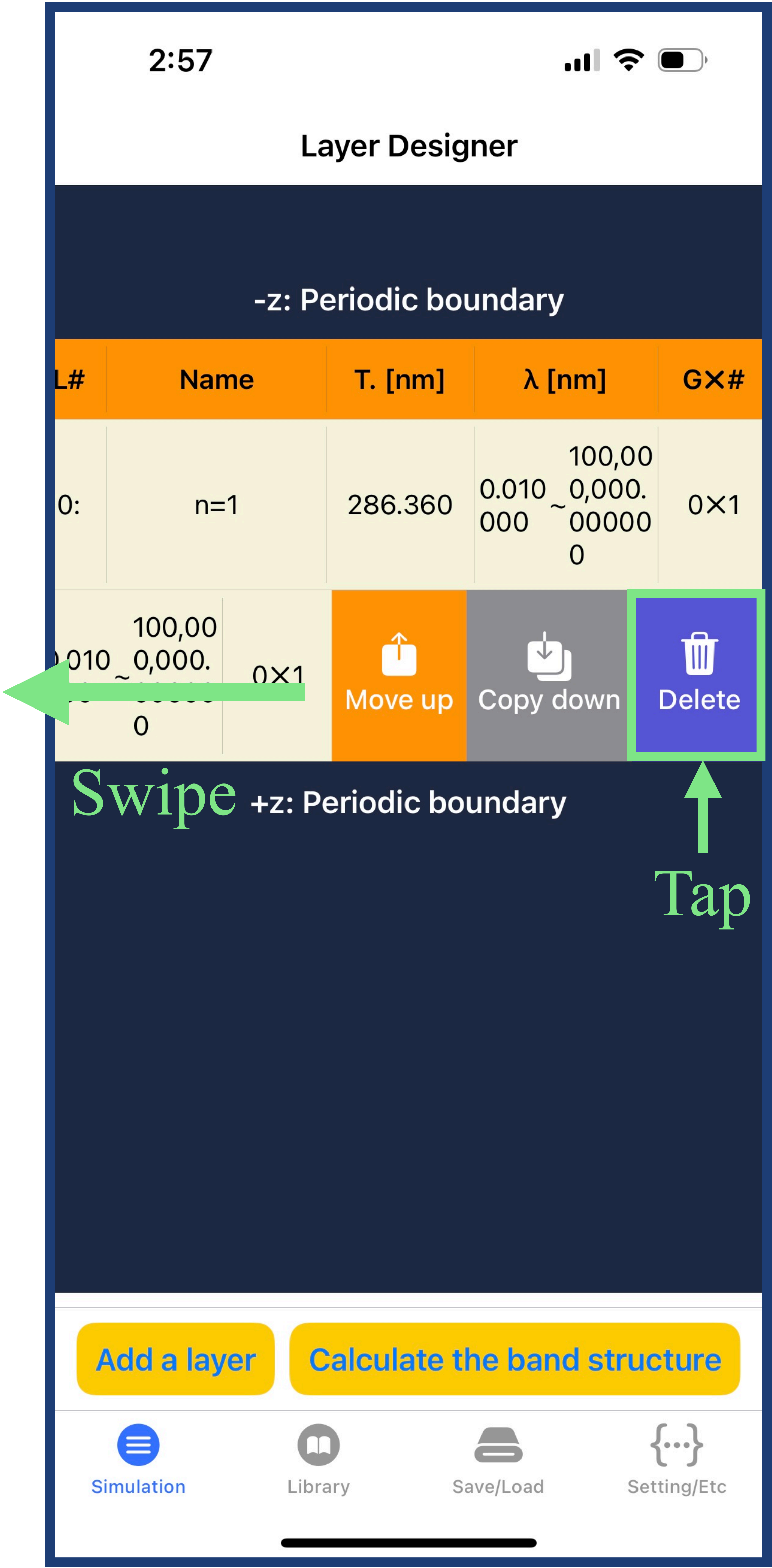
1. Tap “Add a layer” button twice to create two layers.



- 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>

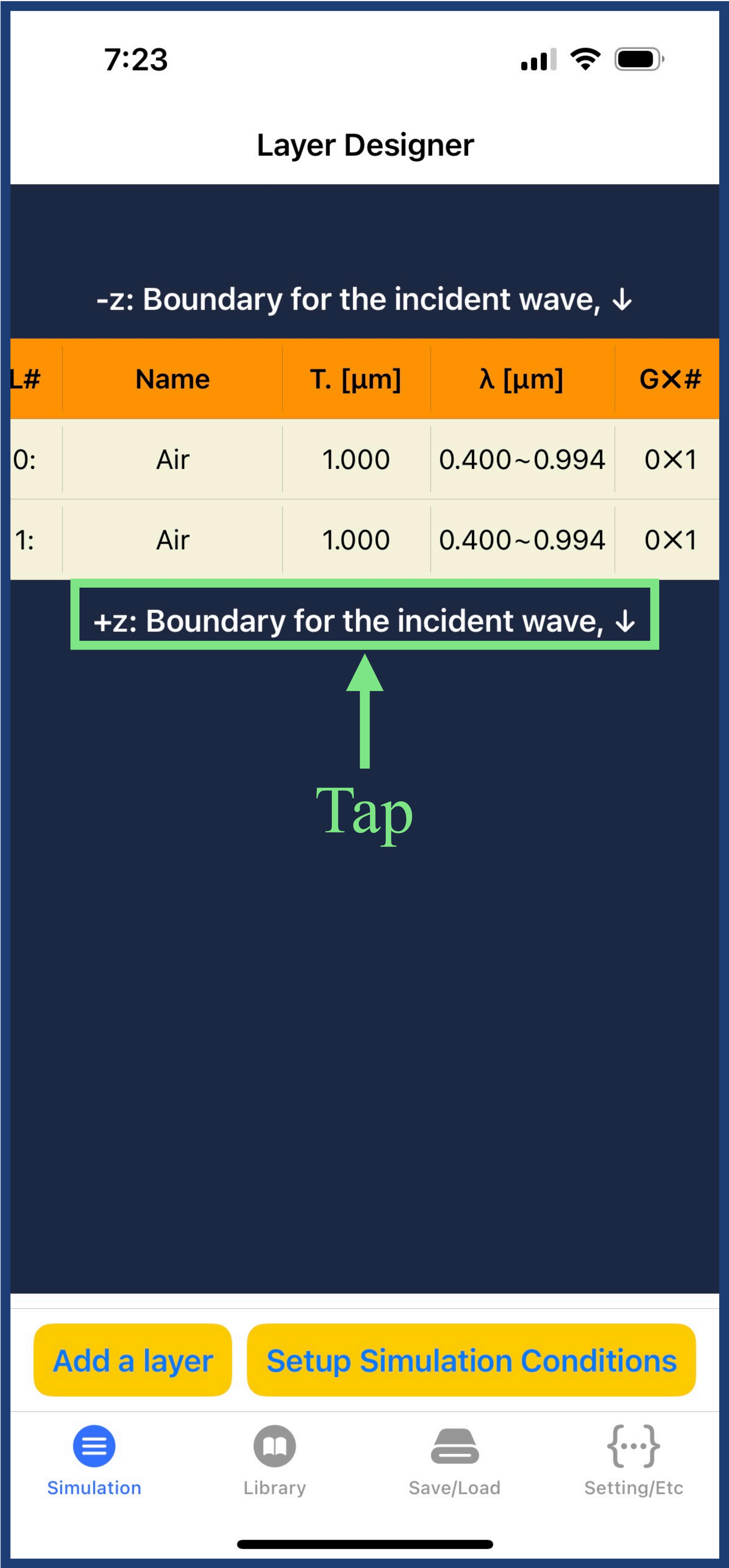
(Optional)

- 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.

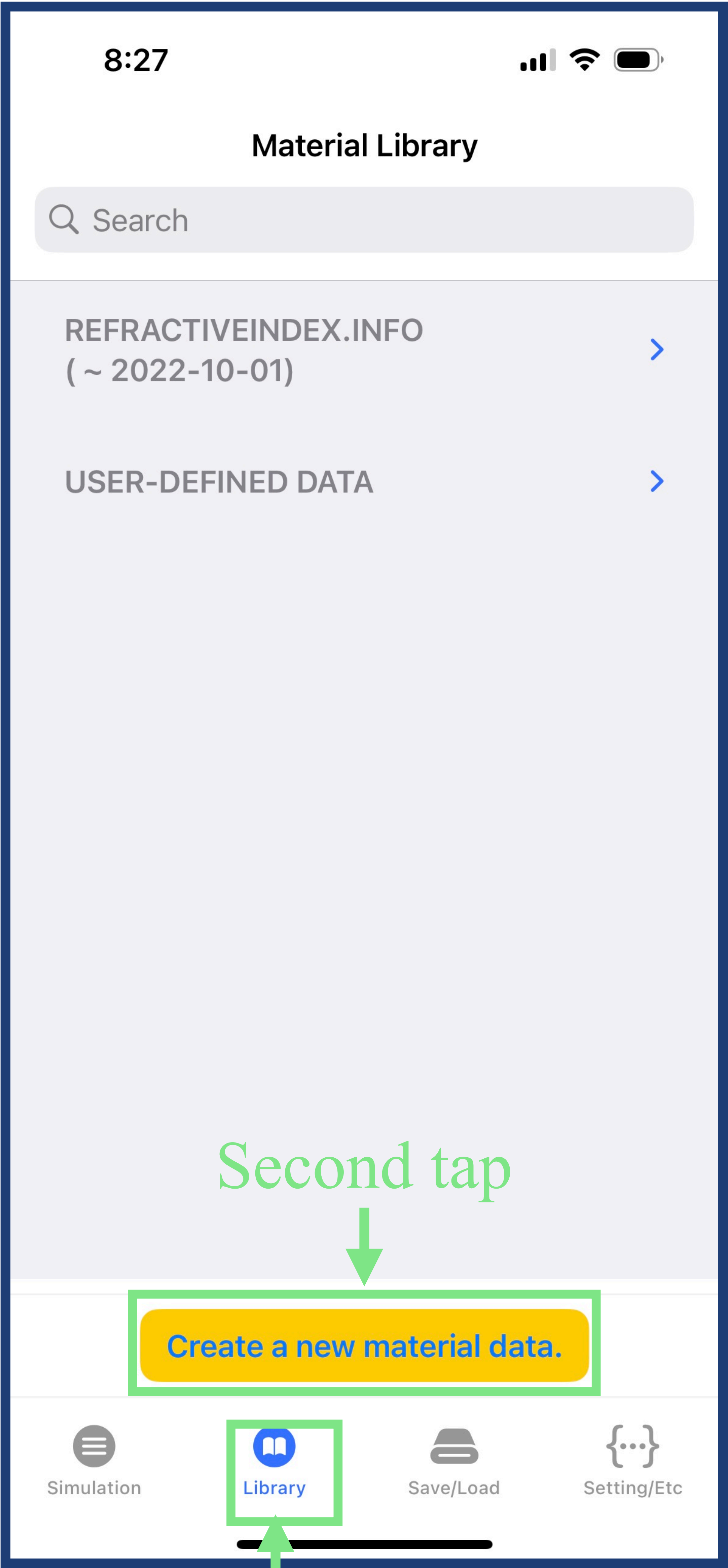




2. Tap “-z: Boundary for the incident wave, ↓” or “+z: Boundary for the incident wave, ↓” to toggle to the periodic boundary condition.



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.

8:42

Tap

Back

Name: n=1

Info.: Input description for this material data.

#	$\lambda$ [ $\mu\text{m}$ ]	$\mu'$	$\mu''$	$\epsilon'$	$\epsilon''$
0	1.00e-05	1.00e+00	0.00e+00	1.00e+00	0.00e+00
1	1.00e+05	1.00e+00	0.00e+00	1.00e+00	0.00e+00

$\lambda$  [ $\mu\text{m}$ ] = 1.0

$\mu' = 1.0$  ,  $\mu'' = 0.0$

$\epsilon' = 1.0$  ,  $\epsilon'' = 0.0$

Insert with the information as above

SavePlot

Simulation

Library

Save/Load

Setting/Etc



5. The table's initial values are  $\epsilon' = 1$  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.

8:42

< Back

Name: n=1

Info.: Input description for this material data.

#	$\lambda$ [ $\mu\text{m}$ ]	$\mu'$	$\mu''$	$\epsilon'$	$\epsilon''$
0	1.00e-05	1.00e+00	0.00e+00	1.00e+00	0.00e+00
1	1.00e+05	1.00e+00	0.00e+00	1.00e+00	0.00e+00

Tap

$\lambda$  [ $\mu\text{m}$ ] = 1.0

$\mu' = 1.0$  ,  $\mu'' = 0.0$

$\epsilon' = 1.0$  ,  $\epsilon'' = 0.0$

Insert with the information as above

Save

Plot

Simulation

Library

Save/Load

Setting/Etc

8



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.

8:42

Tap 1

Back

Name: n=1

Info.: Input description for this material data.

#	$\lambda$ [ $\mu\text{m}$ ]	$\mu'$	$\mu''$	$\epsilon'$	$\epsilon''$
0	1.00e-05	1.00e+00	0.00e+00	1.00e+00	0.00e+00
1	1.00e+05	1.00e+00	0.00e+00	1.00e+00	0.00e+00

Tap 2

$\lambda$  [ $\mu\text{m}$ ] = 1.0

$\mu' = 1.0$  ,  $\mu'' = 0.0$

$\epsilon' = 1.0$  ,  $\epsilon'' = 0.0$

Insert with the information as above

SavePlot

SimulationLibrarySave/LoadSetting/Etc

7. Change the  $\varepsilon'$  value to 9.0. Then, tap “Apply” button.

The screenshot shows a mobile application interface with a status bar at the top displaying the time 8:45 and signal/battery icons. The main content area has a blue header bar with a back arrow and the text "Back". Below the header, there are input fields for material properties:  $\lambda$  [ $\mu\text{m}$ ] with the value 0.0000100000,  $\mu' =$  with the value 1.0,  $\mu'' =$  with the value 0.0,  $\varepsilon' =$  with the value 9, and  $\varepsilon'' =$  with the value 0.0. A green arrow labeled "Tap 1" points to the  $\varepsilon' = 9$  input field. Below the input fields is a yellow button labeled "Apply" with a green border. A green arrow labeled "Tap 2" points to the "Apply" button. At the bottom of the screen is a navigation bar with four icons: a hamburger menu icon labeled "Simulation", a book icon labeled "Library", a floppy disk icon labeled "Save/Load", and a settings icon labeled "Setting/Etc".

8:45

< Back

Tap 1

$\lambda$  [ $\mu\text{m}$ ] 0.0000100000

$\mu' =$  1.0 ,  $\mu'' =$  0.0

$\varepsilon' =$  9 ,  $\varepsilon'' =$  0.0

Apply

Tap 2

Simulation Library Save/Load Setting/Etc

- 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.

8:46

< Back

← Tap 3

Name:

n=3

Info.:

Input description for this material data.

#	$\lambda$ [ $\mu\text{m}$ ]	$\mu'$	$\mu''$	$\epsilon'$	$\epsilon''$
0	1.00e-05	1.00e+00	0.00e+00	9.00e+00	0.00e+00
1	1.00e+05	1.00e+00	0.00e+00	9.00e+00	0.00e+00

↑ Tap 1

$\lambda$  [ $\mu\text{m}$ ] =

1.0

$\mu' =$

1.0

,  $\mu'' =$

0.0

$\epsilon' =$

1.0

,  $\epsilon'' =$

0.0

Insert with the information as above

Save

Plot

≡

Library

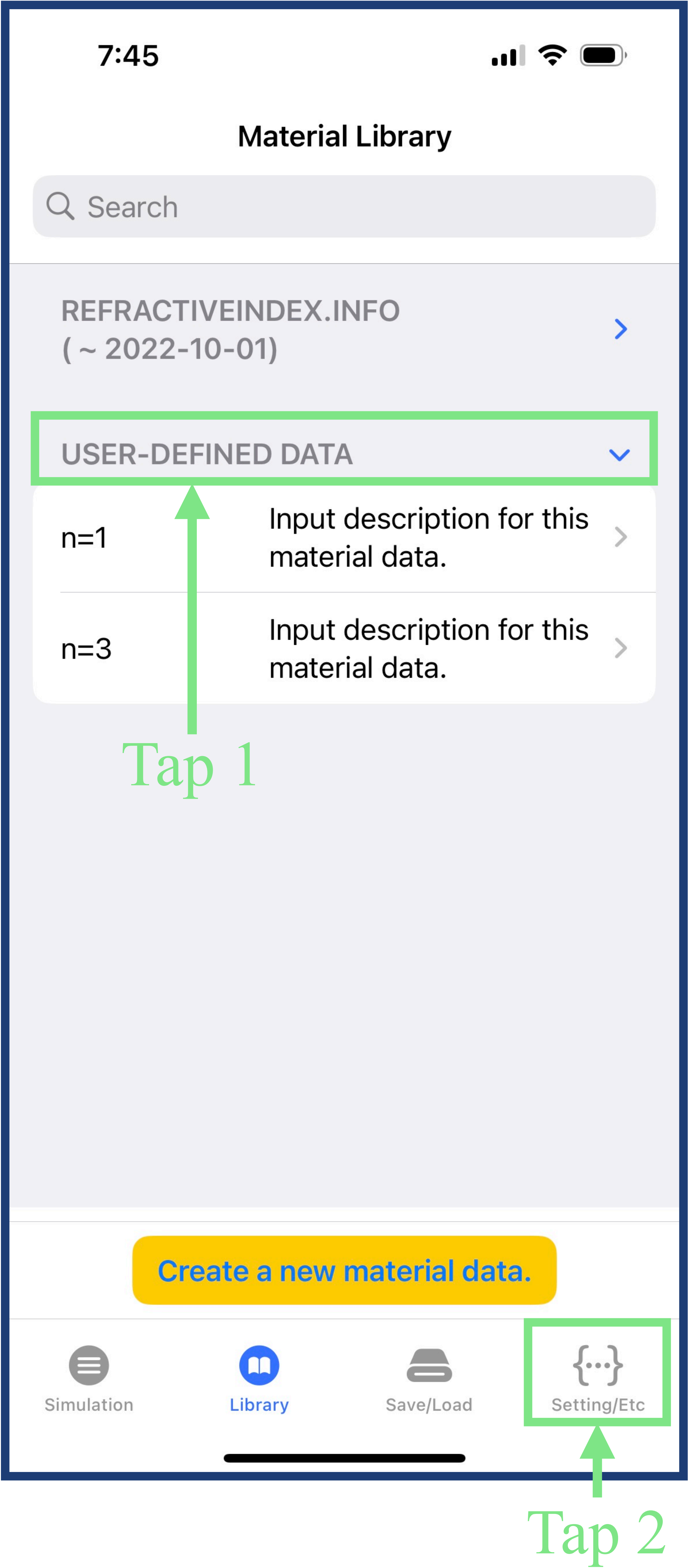
Save/Load

Setting/Etc

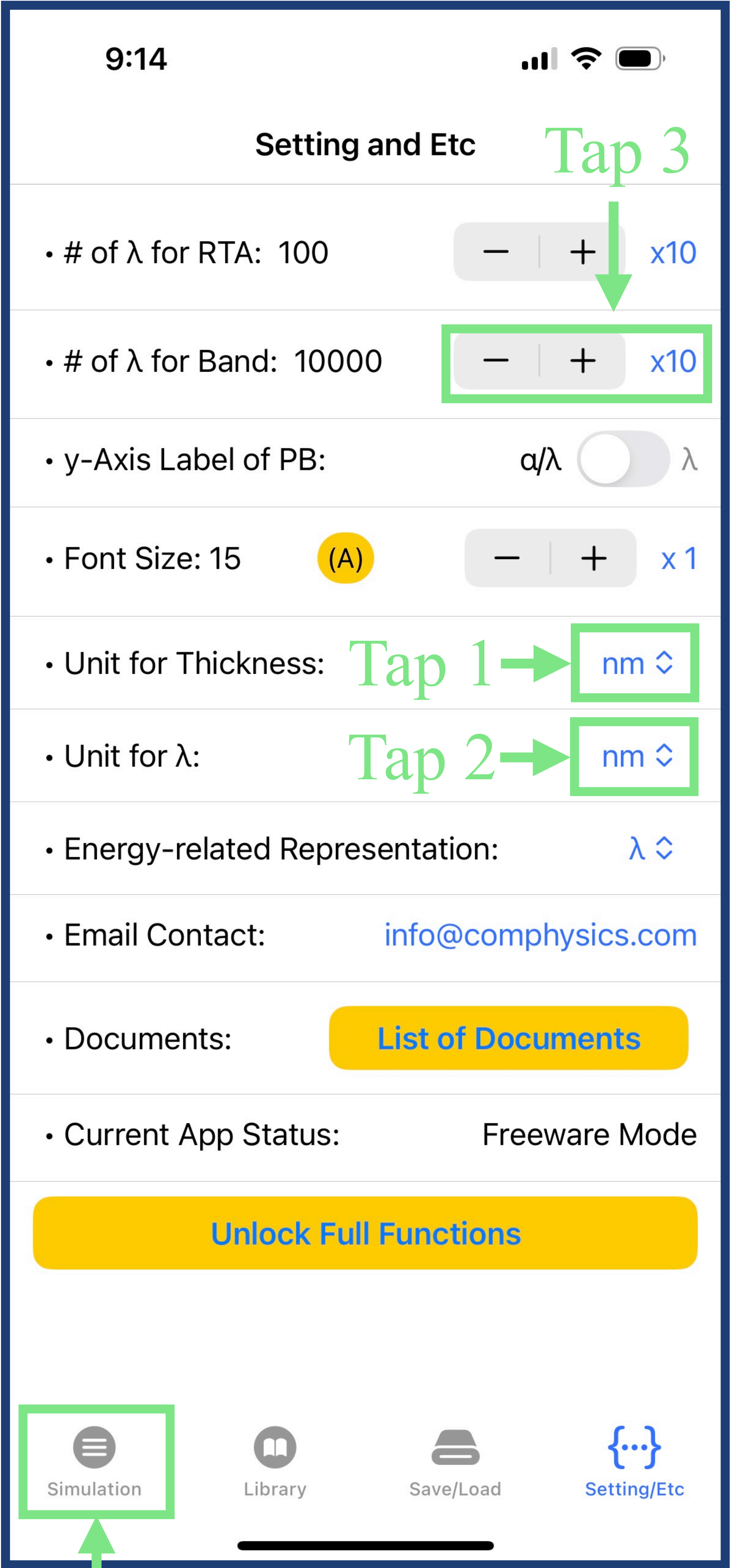
Tap 2



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  $\lambda$ ” to “nm”. Also, change the “# of  $\lambda$  for Band” to 10000. Then, tap the “Simulation” icon.



11. Tap L#0 row as below.

9:39

Layer Designer

-z: Periodic boundary

L#	Name	T. [nm]	$\lambda$ [nm]	GX#
0:	Air	1000.000	400.000 ~ 994.000	0X1
1:	Air	1000.000	400.000 ~ 994.000	0X1

+z: Periodic boundary

Tap

Add a layer

Calculate the band structure

Simulation

Library

Save/Load

Setting/Etc



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

9:44

< Back

Layer ID = 0

Thickness =

286.36

nm

Material ID = 2,820

Material:

Air , Börzsönyi et al. 2008: n  
0.4–1.0  $\mu\text{m}$

Group Index:

0

Group Repeat  
Number:

1

Apply

Simulation

Library

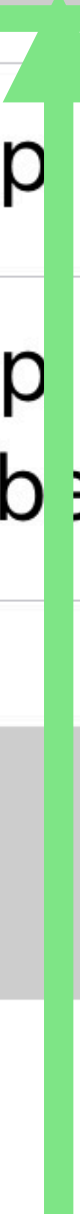
Save/Load


Setting/Etc

Tap 1



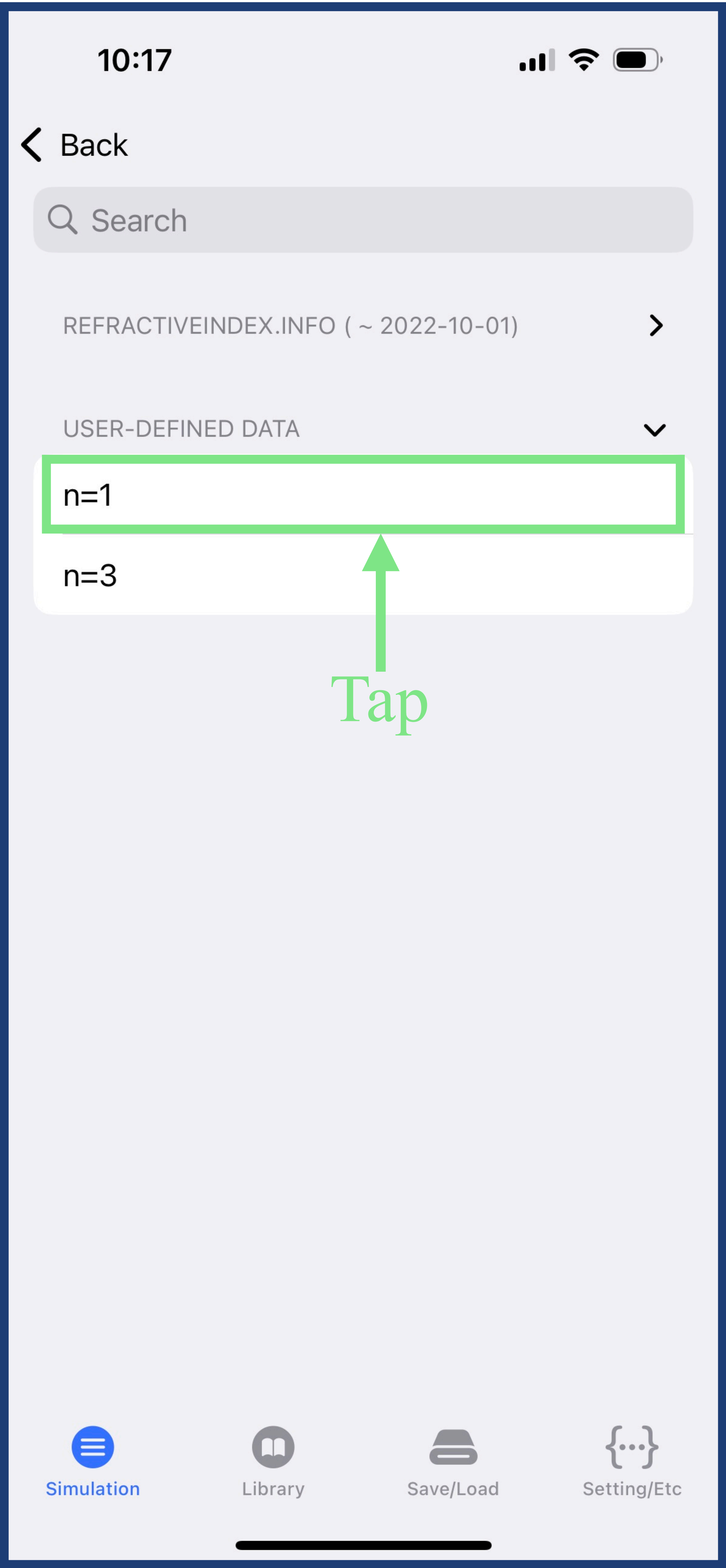
Tap 2



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.

10:21

< Back

Layer ID = 0

Thickness =

286.36

nm

Material ID = 0

Material:

n=1

Group Index:

0

Group Repeat Number:

1

Apply

Tap

Simulation

Library

Save/Load

Setting/Etc

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

10:21

Layer Designer

-z: Periodic boundary

L#	Name	T. [nm]	$\lambda$ [nm]	GX#
0:	n=1	286.360	100,00 0.010 0,000. 000 ~ 00000 0	0×1
1:	Air	1000.000	400.0 994.0 00 ~ 00	0×1

+z: Periodic boundary

Tap

Add a layer

Calculate the band structure

Simulation

Library

Save/Load

Setting/Etc

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

10:27

< Back

Tap 1

Layer ID = 1

Thickness =

63.64

nm

Material ID = 2,820

Material:

Air , Börzsönyi et al. 2008: n  
0.4–1.0  $\mu\text{m}$

Group Index:

0

Group Repeat  
Number:

1

Apply

Tap 2

Simulation

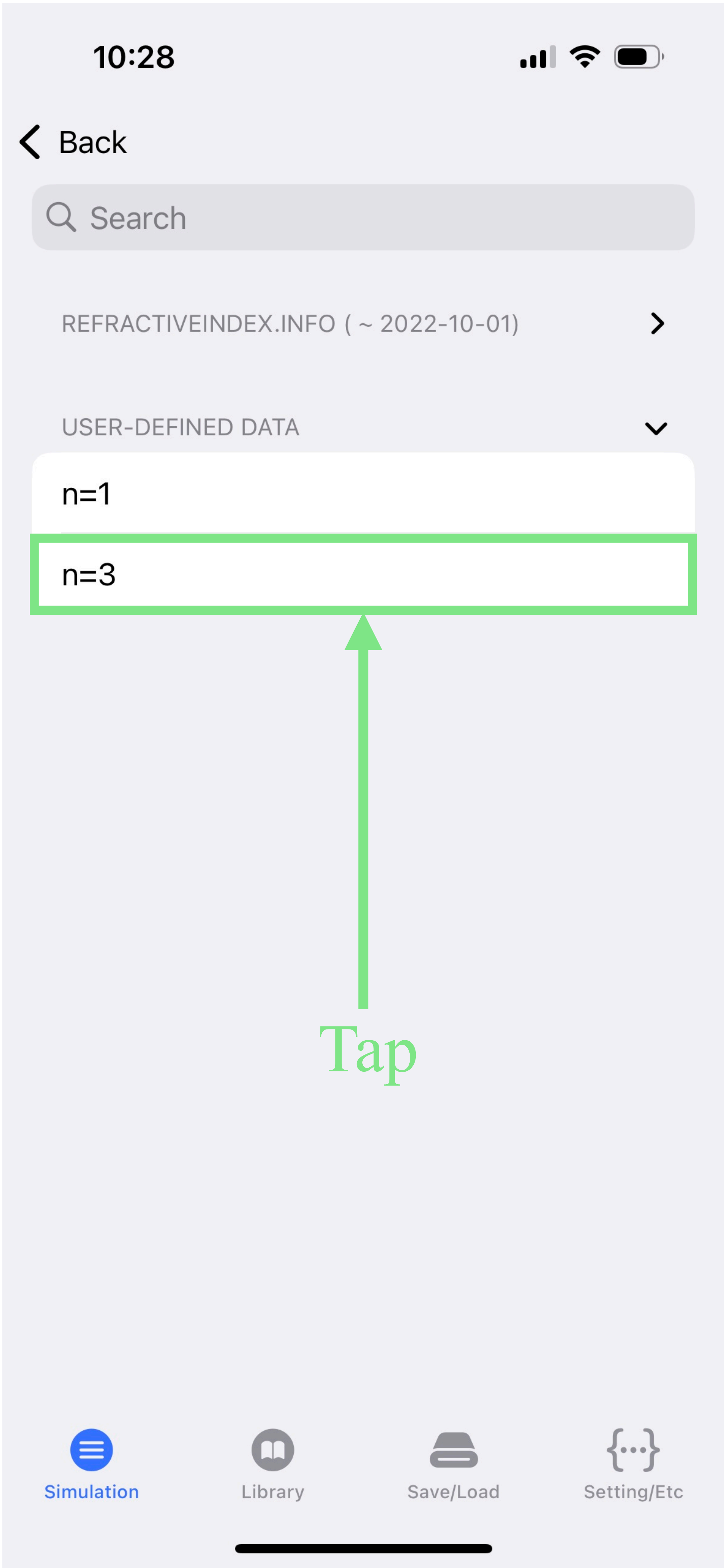
Library

Save/Load

Setting/Etc



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



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

10:27

< Back

Layer ID = 1

Thickness =

63.64

nm

Material ID = 1

Material:

n=3

Group Index:

0

Group Repeat Number:

1

Apply

Tap

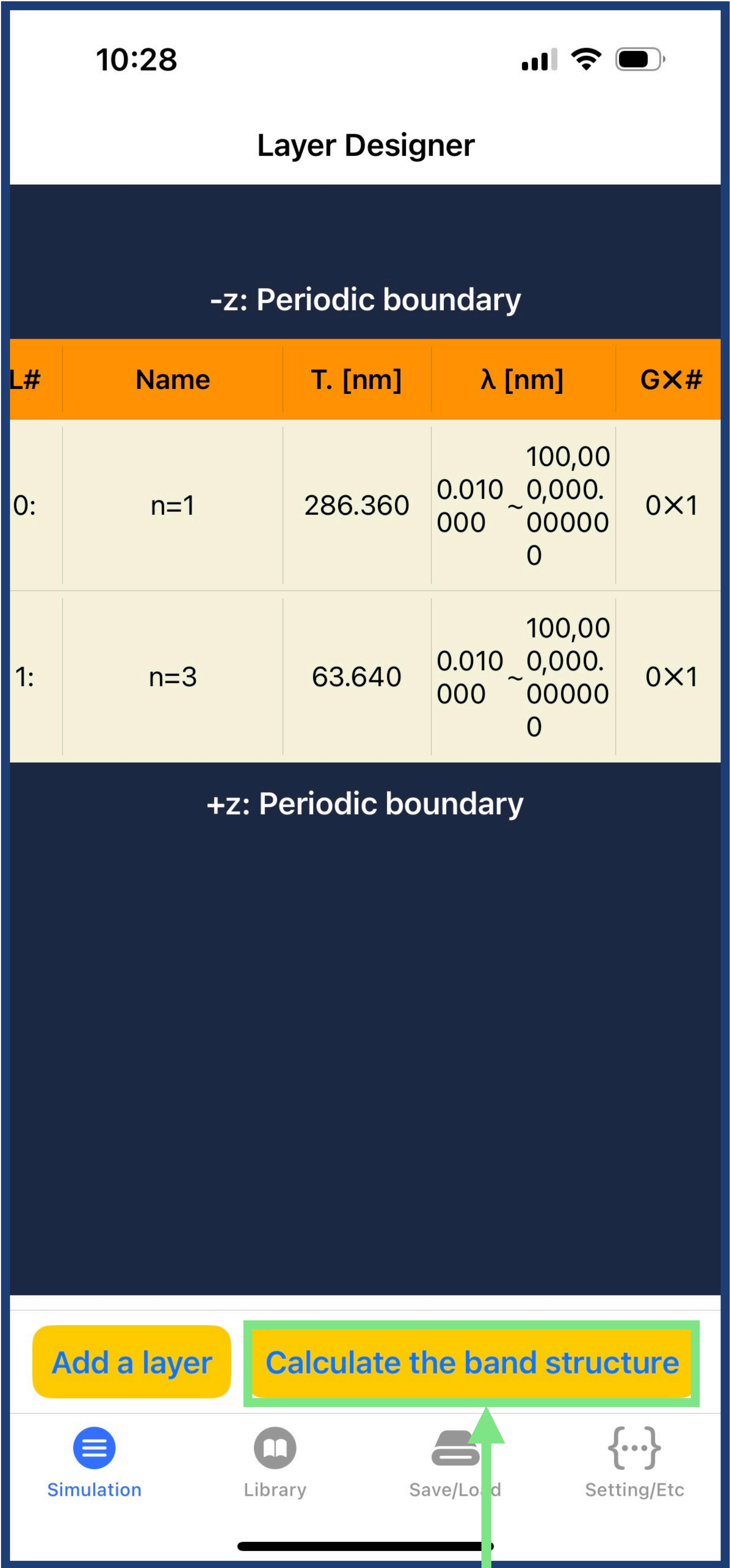
Simulation

Library

Save/Load

Setting/Etc

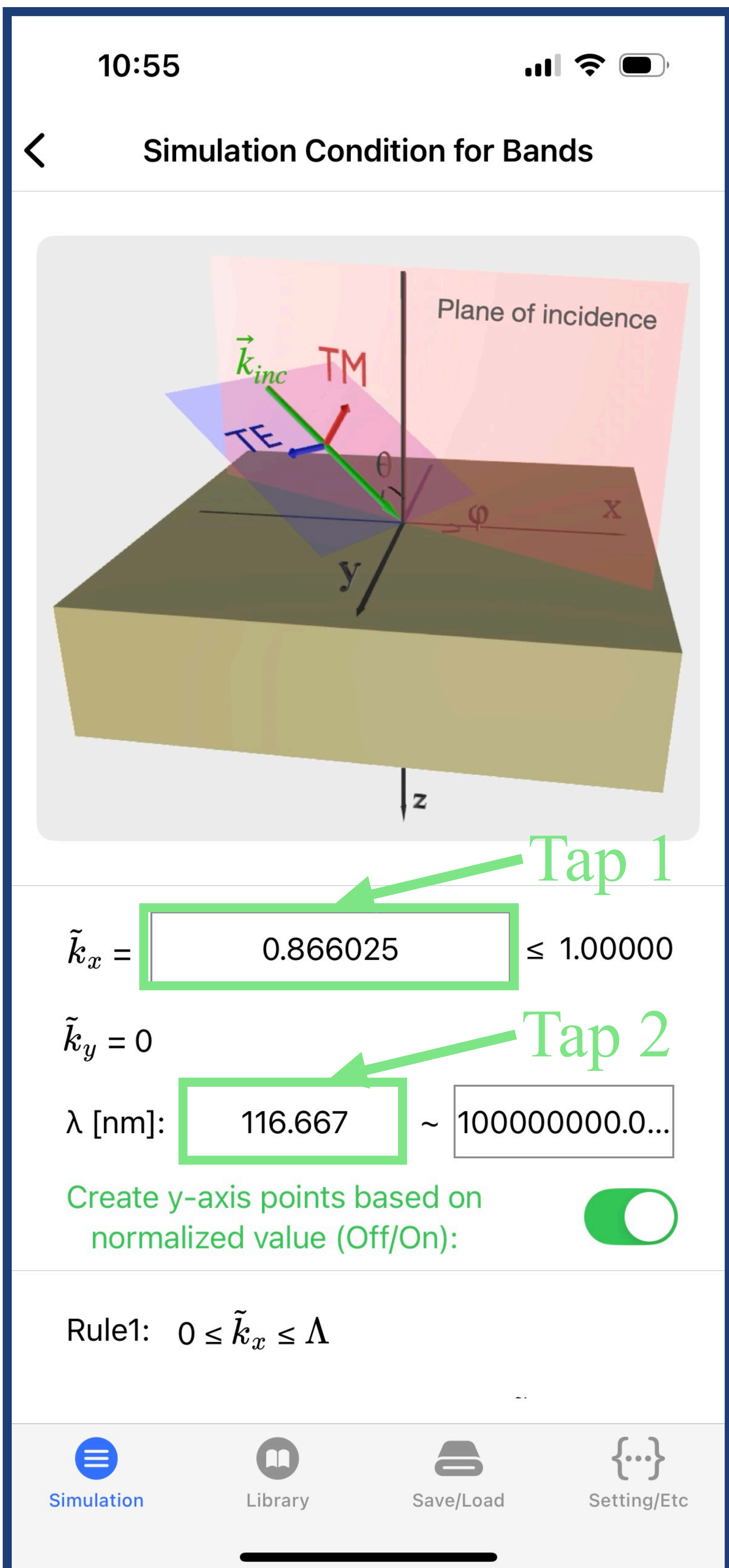
20.Layer design is completed. Tab “Calculate the band structure” button as below.



Tap

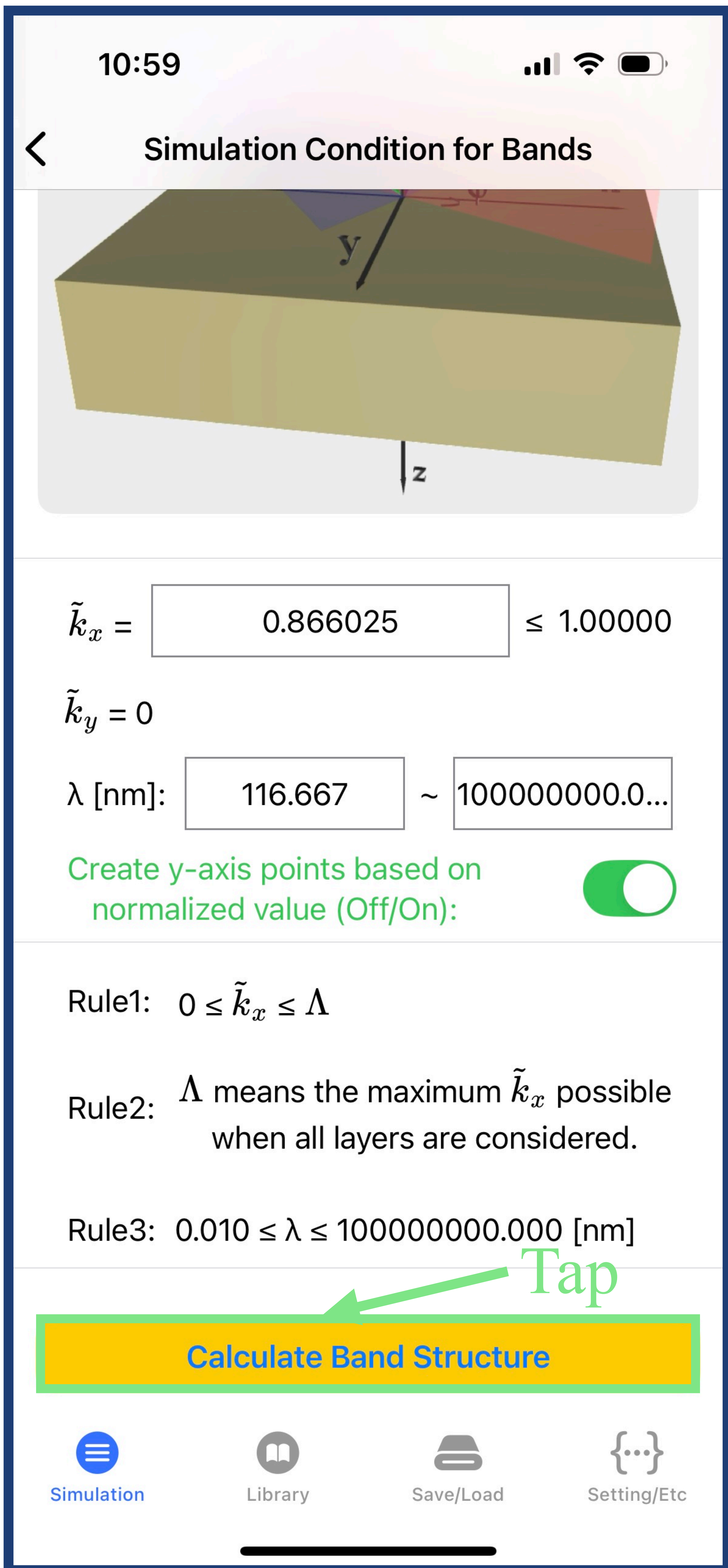


21. Input  $\tilde{k}_x$  field as 0.866025 and  $\lambda = 116.667$  [nm]  $\sim$ . Here,  $\tilde{k}_x$  is the normalized wave vector for the x-axis and  $\tilde{k}_x = \sin(\theta)\cos(\phi)$ .  $\phi$  is fixed at 0 in the current E2M version, 1.0.  $\theta$  is the angle of incidence.

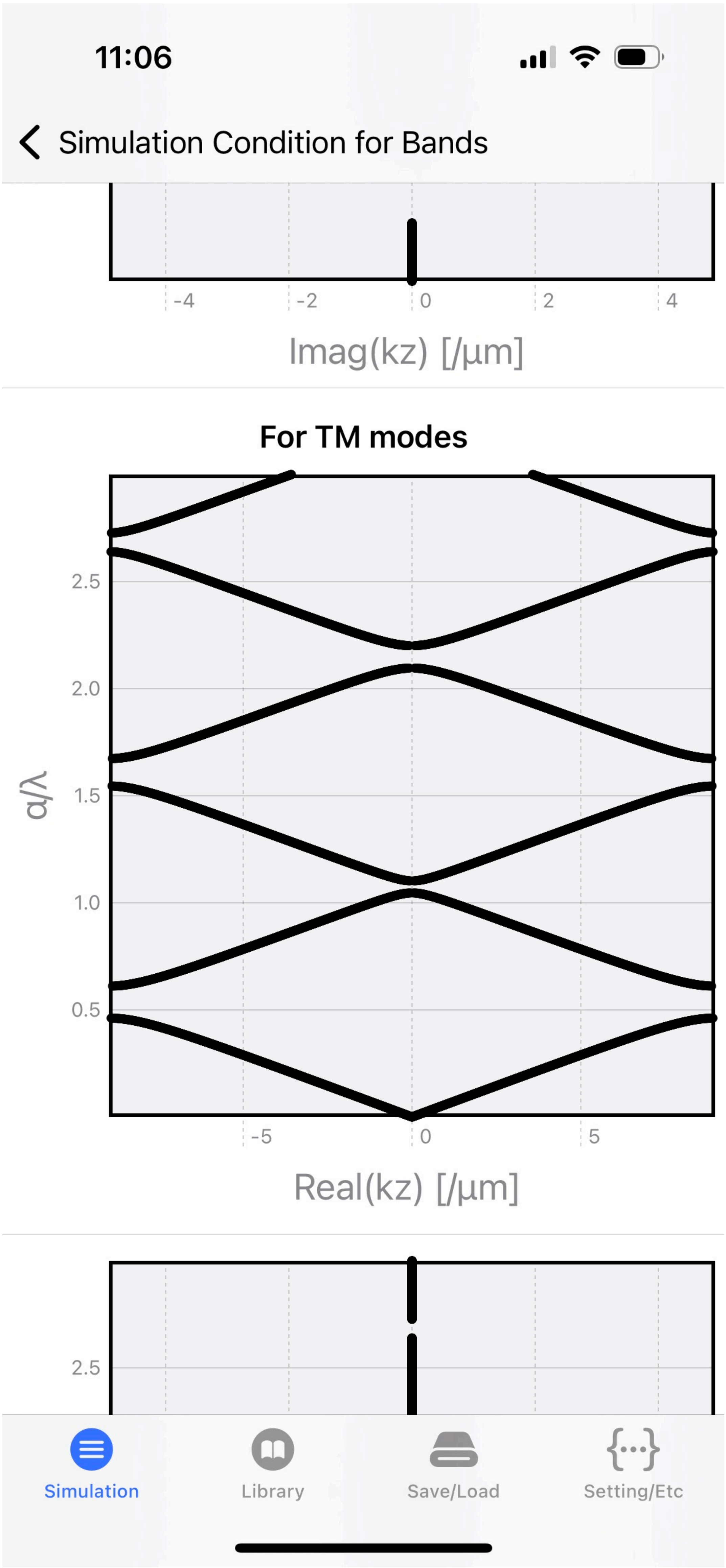




22. Scroll down the screen. Then, tap “Calculate Band Structure” button.

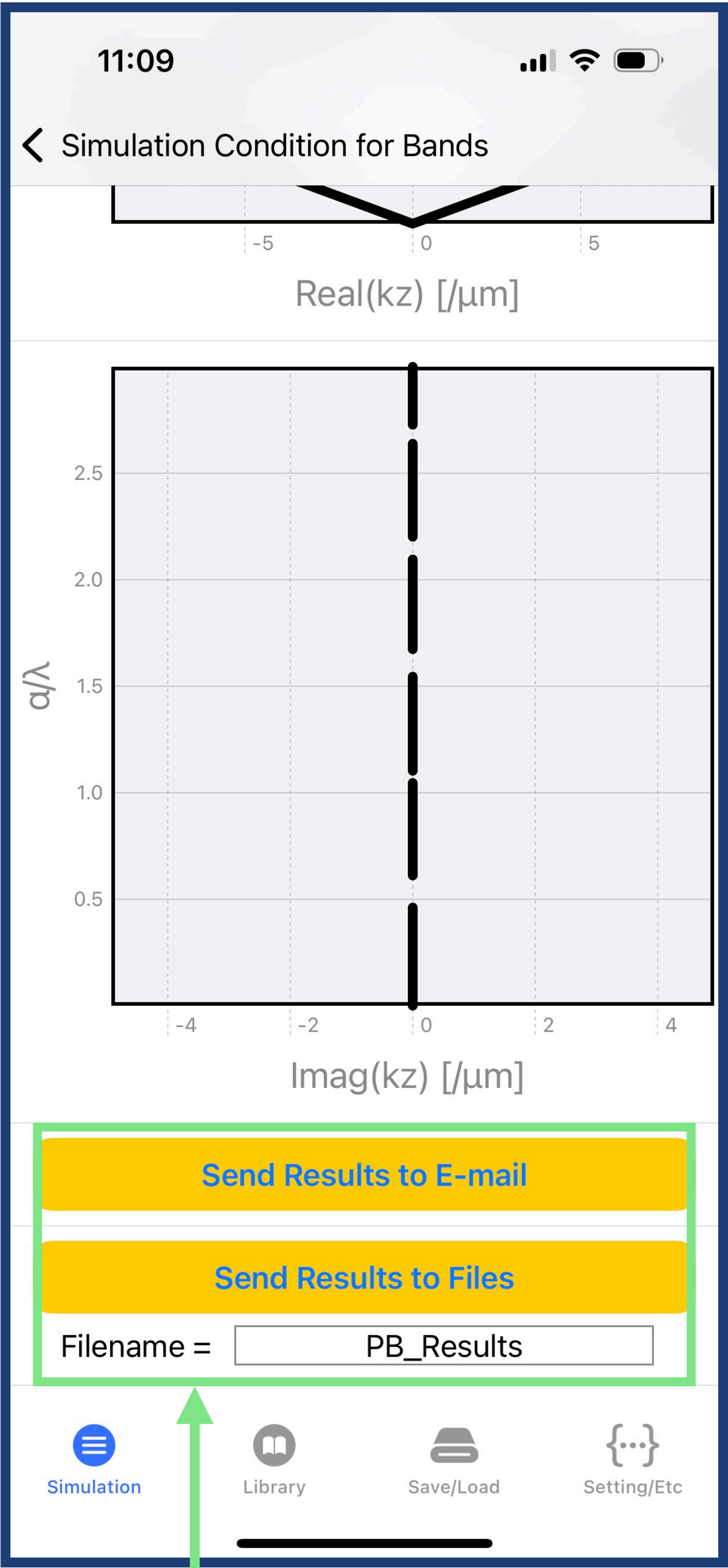


23. After scrolling down, we can confirm the photonic band for TM modes that can be compared with Fig. 2 of the target reference.





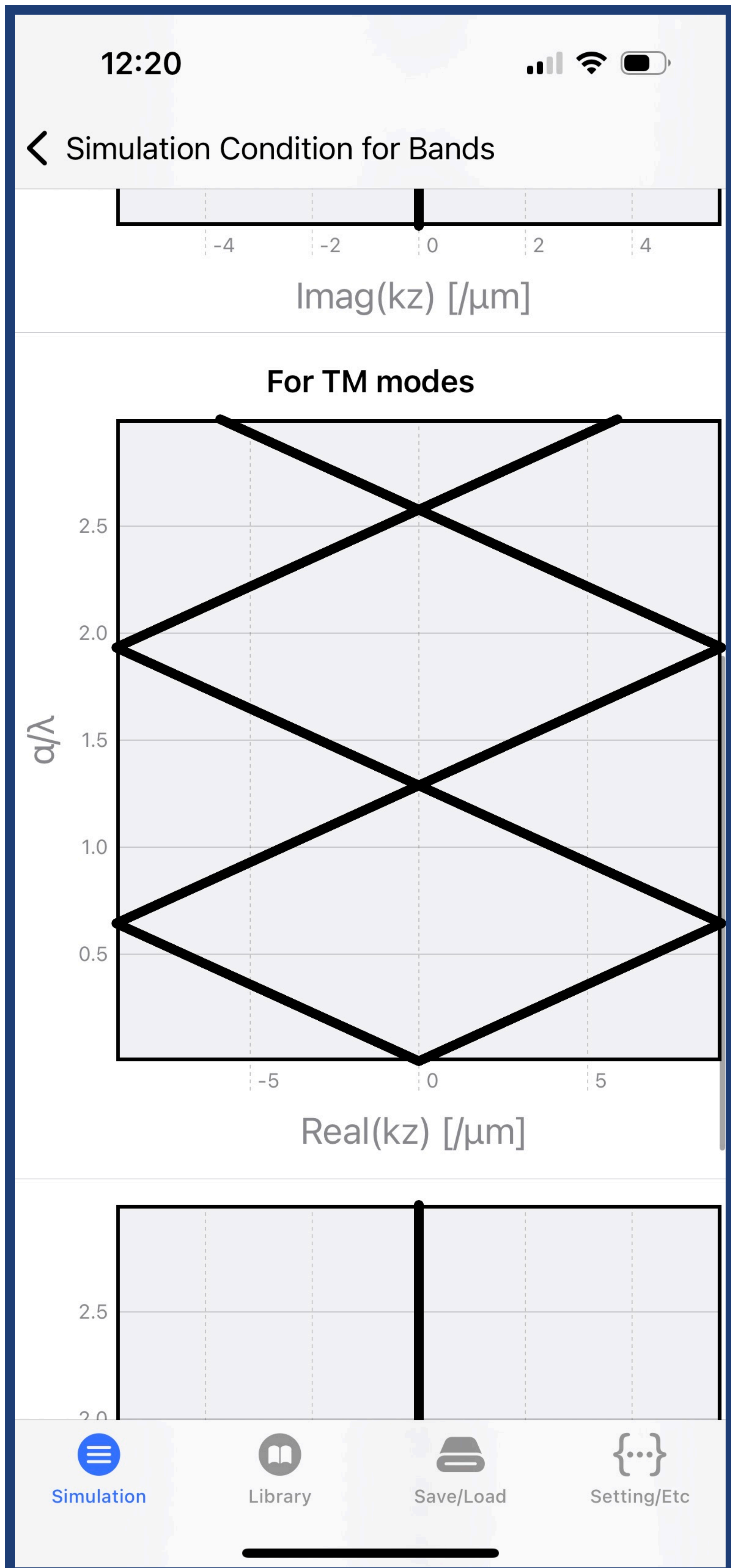
24. By scrolling down more, the options for export of results are shown. The results include both raw data files and figure files.



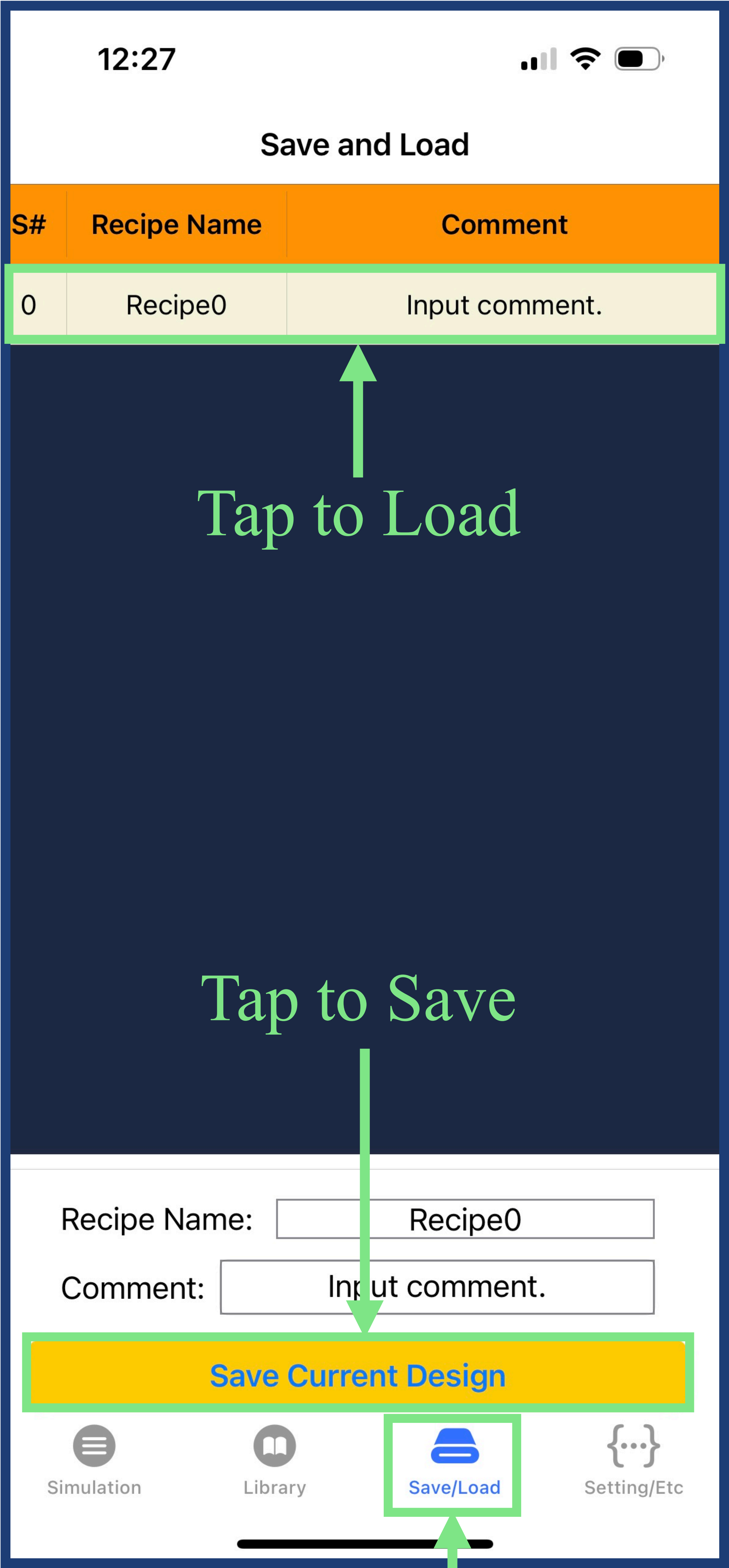
Options for the export of results



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.

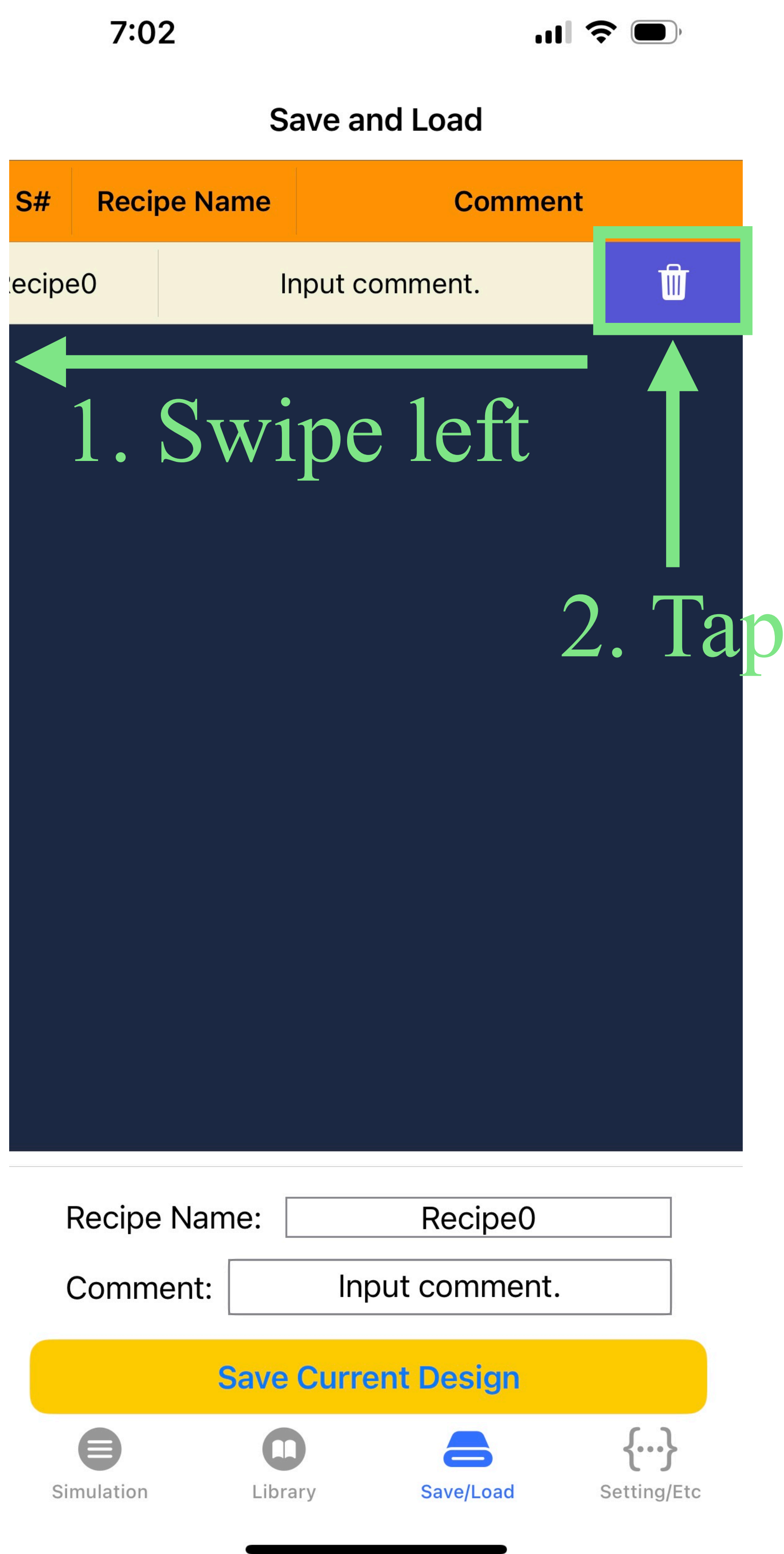


Tap to show Save/Load View

# 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

7:18

Signal strength

Wi-Fi

Battery

< Back

Name: Vacuum

Info.: Input description for this material data.

#	$\lambda$ [nm]	$\mu'$	$\mu''$	$\epsilon'$	$\epsilon''$
3. A new layer created					
1	1.00e+03	3.00e+00	0.00e+00	5.00e+00	0.00e+00
2	1.00e+08	1.00e+00	0.00e+00	1.00e+00	0.00e+00

1. Input fields

$\lambda$  [nm] = 1000.0

$\mu' = 3$  ,  $\mu'' = 0.0$

$\epsilon' = 5$  ,  $\epsilon'' = 0.0$

Insert with the information as above

SavePlot

SimulationLibrarySave/LoadSetting/Etc

2. Tap to insert a new layer

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

7:18

< Back

Name: Vacuum

Info.: Input description for this material data.

#	$\lambda$ [nm]	$\mu'$	$\mu''$	$\epsilon'$	$\epsilon''$
0	1.00e-02	1.00e+00	0.00e+00	1.00e+00	0.00e+00
1	1.00e+03	3.00e+00	0.00e+00	5.00e+00	0.00e+00
2	1.00e+08	1.00e+00	0.00e+00	1.00e+00	0.00e+00

$\lambda$  [nm] = 1000.0

$\mu' = 3$  ,  $\mu'' = 0.0$

$\epsilon' = 5$  ,  $\epsilon'' = 0.0$

Insert with the information as above

Save

Plot

Simulation

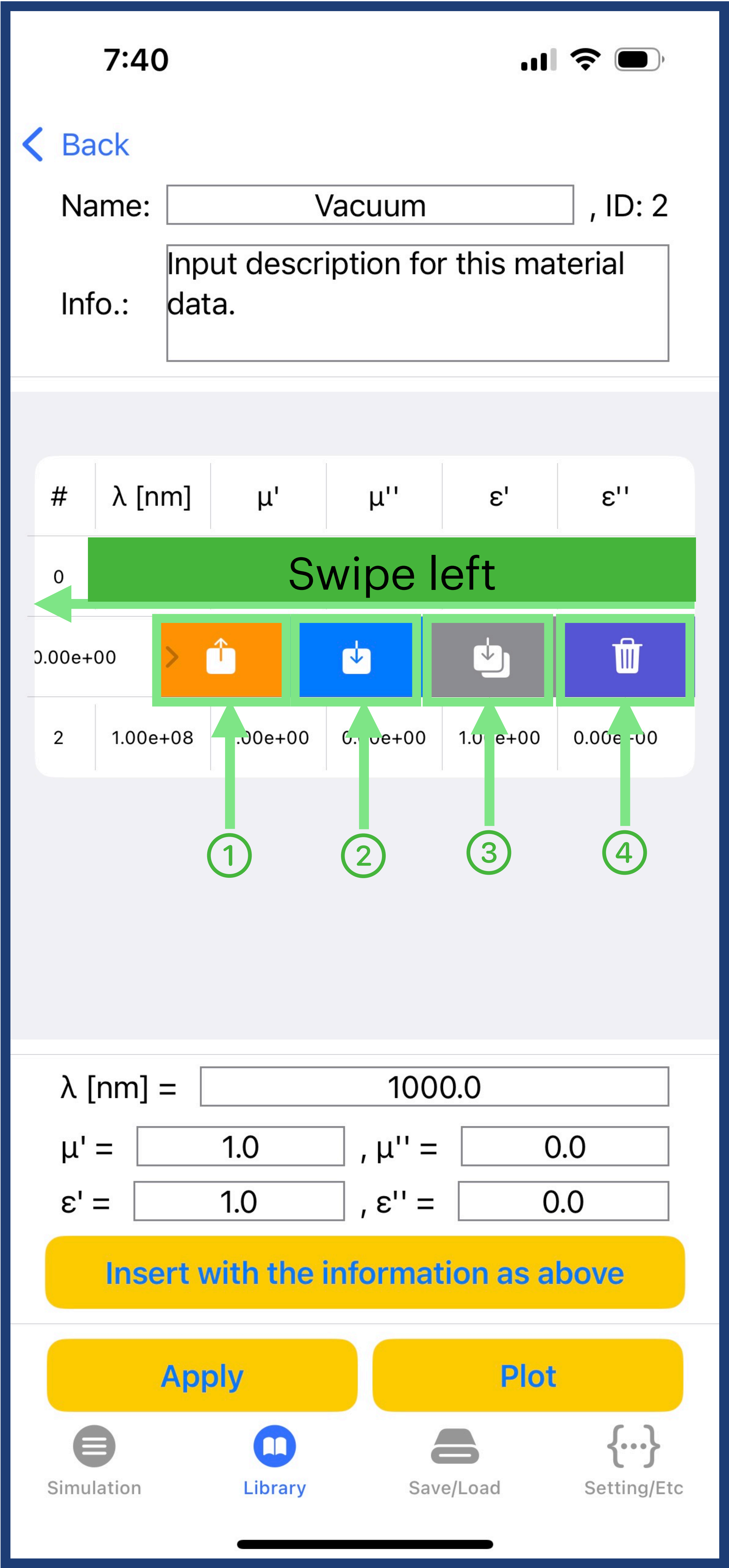
Library

Save/Load

Setting/Etc

Tap

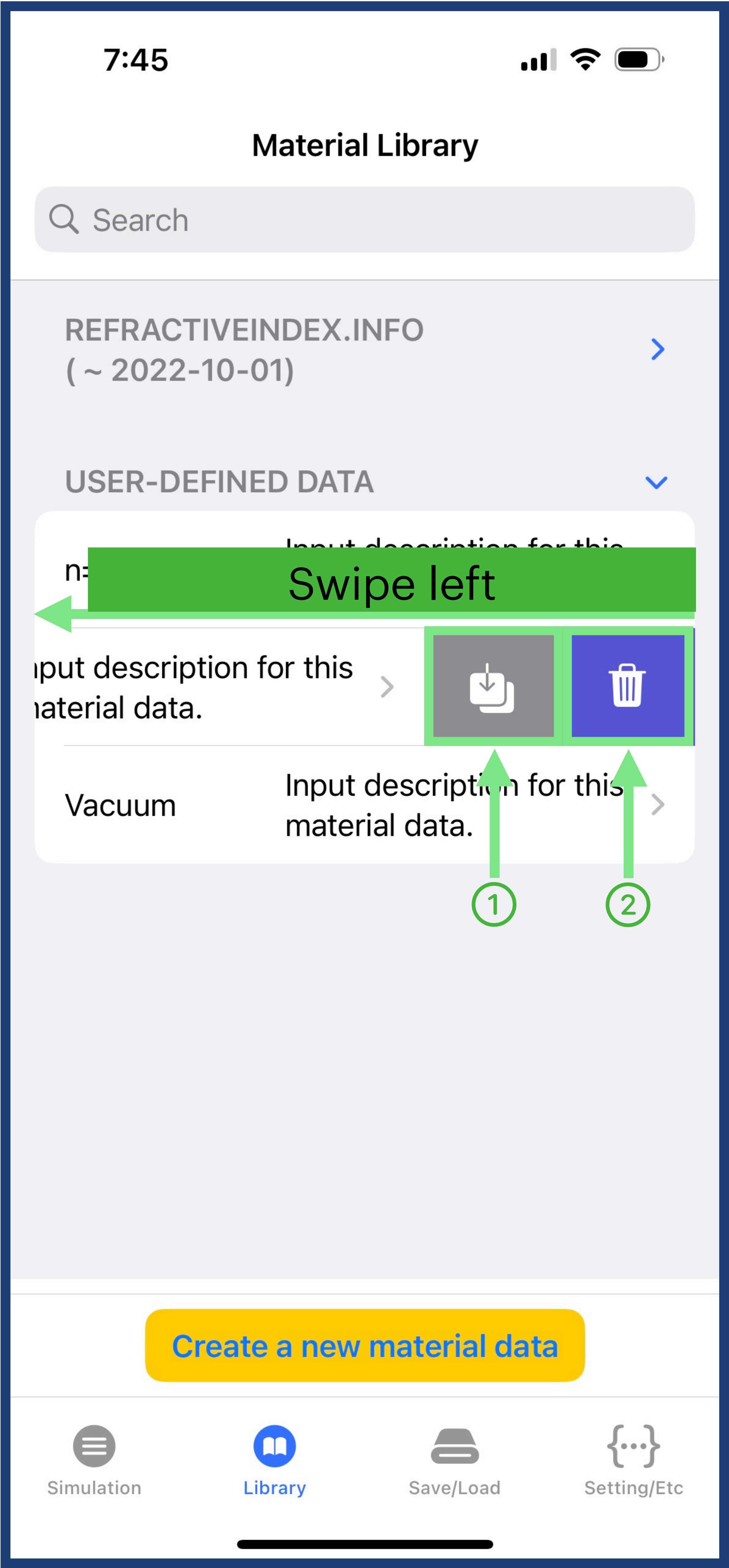
# Design the user-defined material using swipe action and tap actions as described below



- 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

The screenshot shows the RefractiveIndex.INFO app interface. At the top, a green box labeled "3. Tap and input" highlights the search bar containing "GaAs". Below the search bar, a list of search results for "GaAs (Gallium arsenide)" is shown. A green box labeled "2. Tap" highlights the first result: "GaAs (Gallium arsenide) , Aspnes et al. 1986: n,k 0.207–0.827 μm". Below this, another green box labeled "4. Tap" highlights the fourth result: "GaAs (Gallium arsenide) , Jellison 1992: n,k 0.234–0.840 μm". At the bottom of the screen, a yellow button labeled "Create a new material data" is visible. Below the button, a green box labeled "1. Tap" highlights the "Library" icon in the bottom navigation bar. The bottom navigation bar also includes icons for "Simulation", "Save/Load", and "Setting/Etc".

3. Tap and input

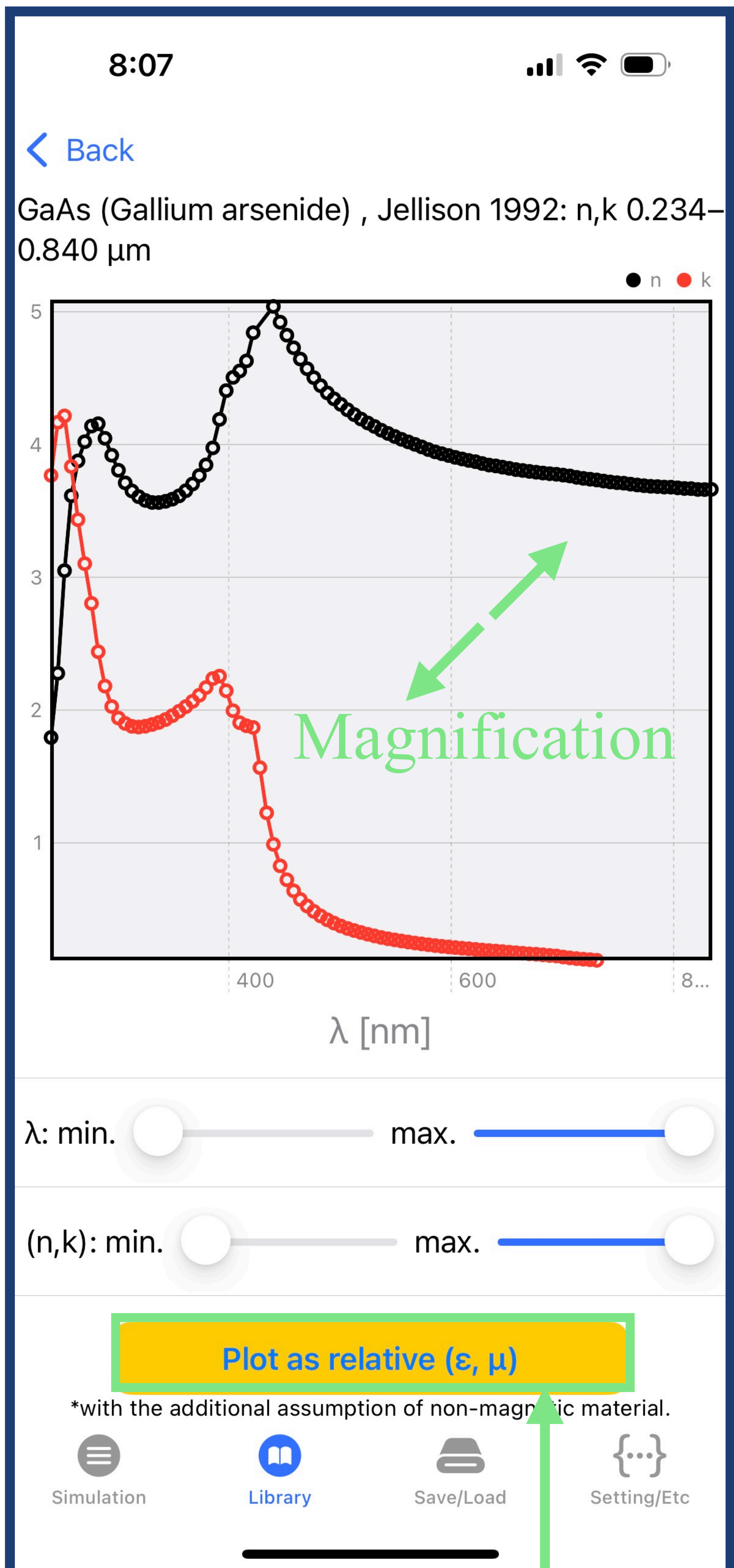
2. Tap

4. Tap

1. Tap

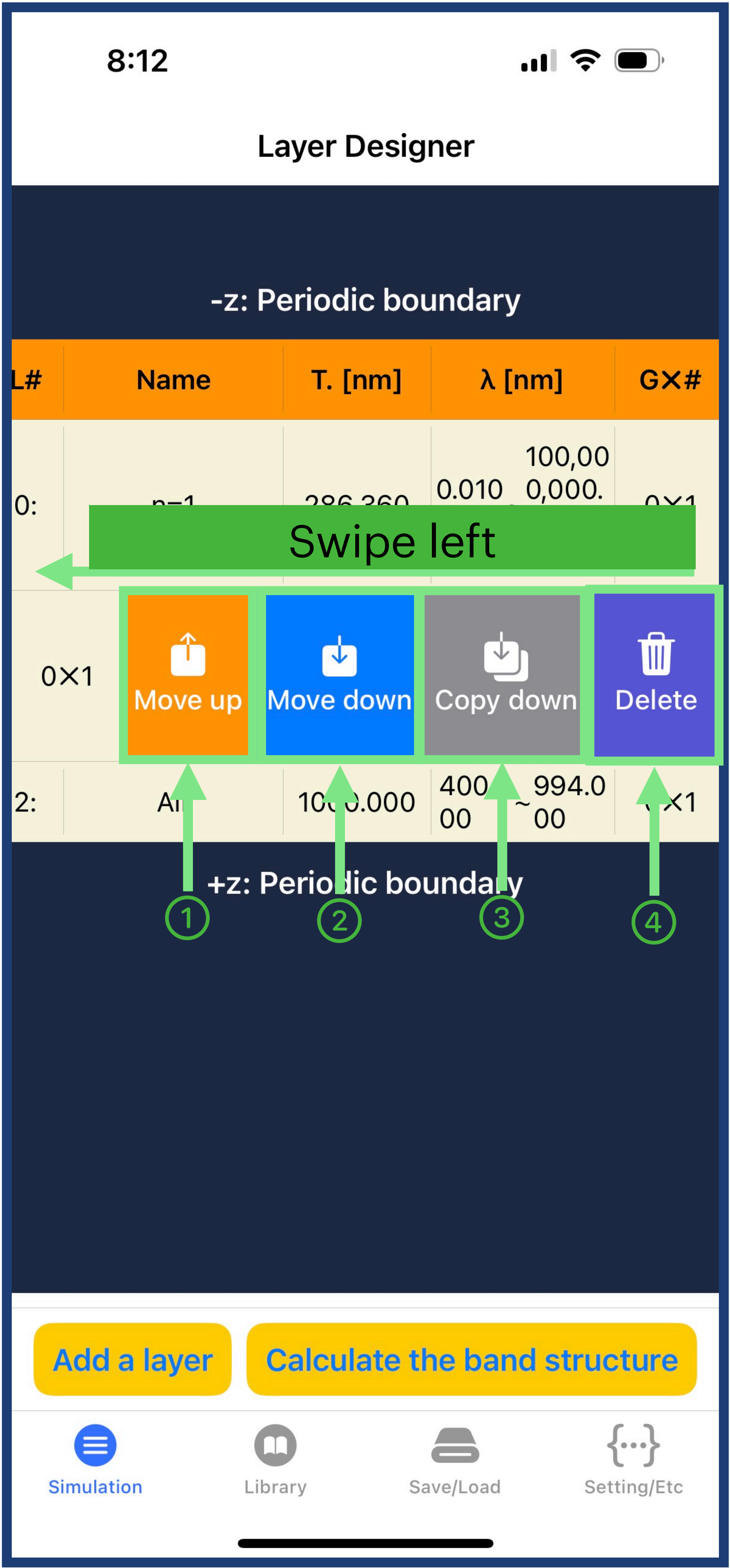


You can confirm the graphical data of complex refractive index as below. Gestures for magnification and drag are allowed in the chart. Tap the only button to convert the  $(n,k)$  plot into the  $(\epsilon,\mu)$ .



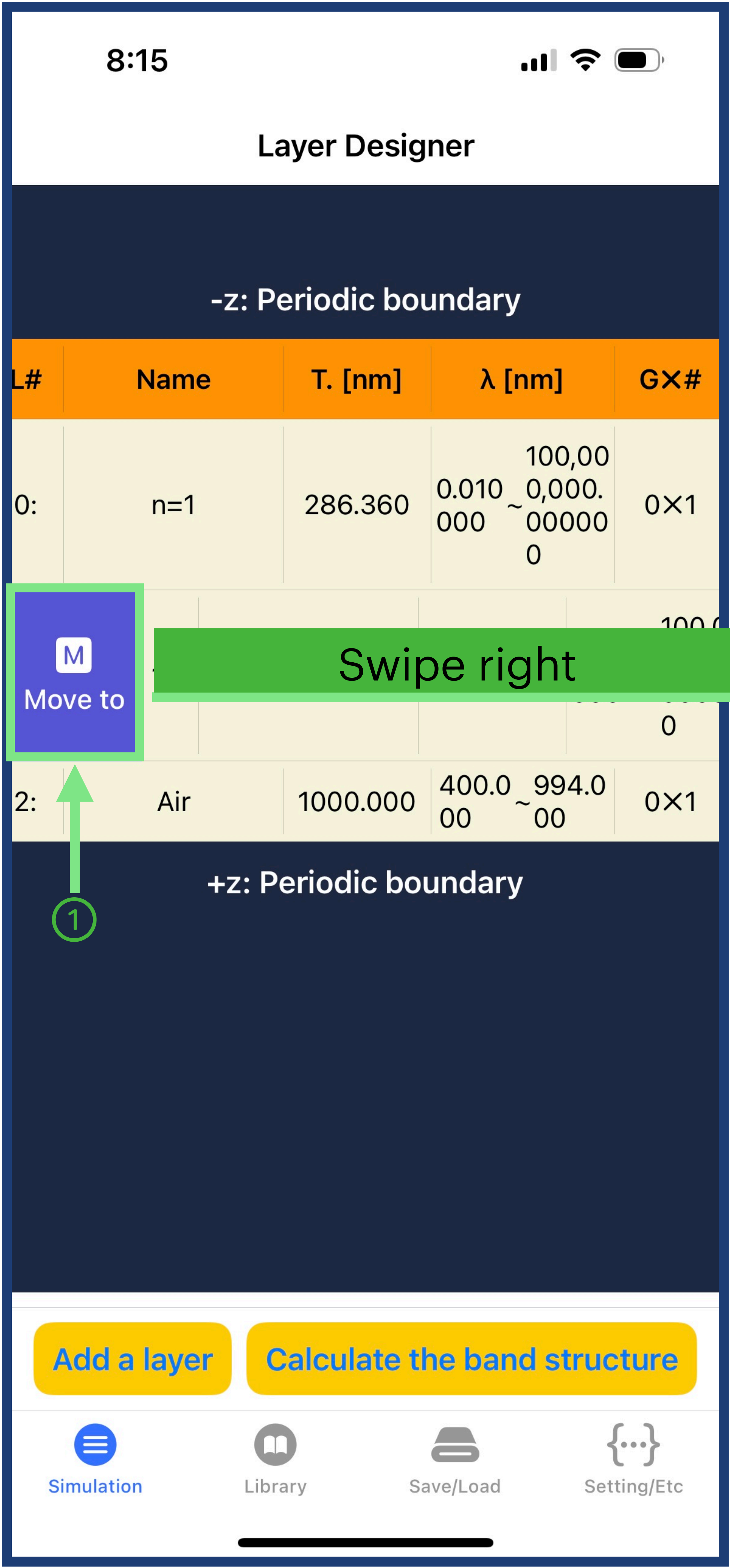


E) On “Layer Designer” page, you can use the additional functional buttons as below after swiping left.



- 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  $(\epsilon, \mu)$  graph of the material by swiping and tapping as in the figure below.

