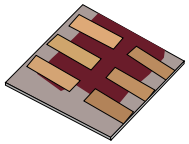


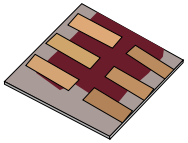
An introduction to simulating optoelectronic devices with *gpvdm*.

Covering: Organic solar cells, perovskites solar cells, OFETs and OLEDs. Both time domain and steady state.

Dr. Roderick MacKenzie
roderick.mackenzie@nottingham.ac.uk
Autumn 2019

https://www.gpvdm.com

Overview



- **What is gpvdm/theoretical overview?**
- Installing gpvdm
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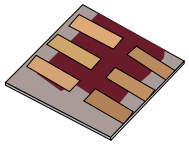
  - Changing electrical parameters
- Optical simulations and the materials database
- Perovskite solar cells and time domain simulations
- OFET simulations and finite difference meshing.
- Editing the device structure using the layer editor
- Meshing and dumping
- OLEDs
- Closing remarks

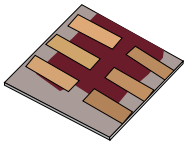
What is gpvdm?



- gpvdm is a 1D/2D opto-electronic device model, which can be used to simulate ***solar cells***, ***LEDs***, ***diodes***, ***FETs*** etc..
  - Solves the **drift diffusion** equations using the **finite difference** method.
  - Solves the optical equations, using **ray tracing** or **the transfer matrix method**.
  - Cross platform/open source

Very quick theoretical overview…...

Simulating charge transport:



Gauss's Law

$$\nabla \epsilon_o \epsilon_r \cdot \nabla \phi = q \cdot (n - p)$$

Electron driving terms

$$J_n = q \mu_e n \nabla E_c + q D_n \nabla n$$

Hole driving terms

$$J_p = q \mu_h p \nabla E_v - q D_p \nabla p$$

Electron continuity

$$\nabla \cdot \boldsymbol{J}_n = q \left(R_n + T_n + \frac{\partial n_{free}}{\partial t} \right)$$

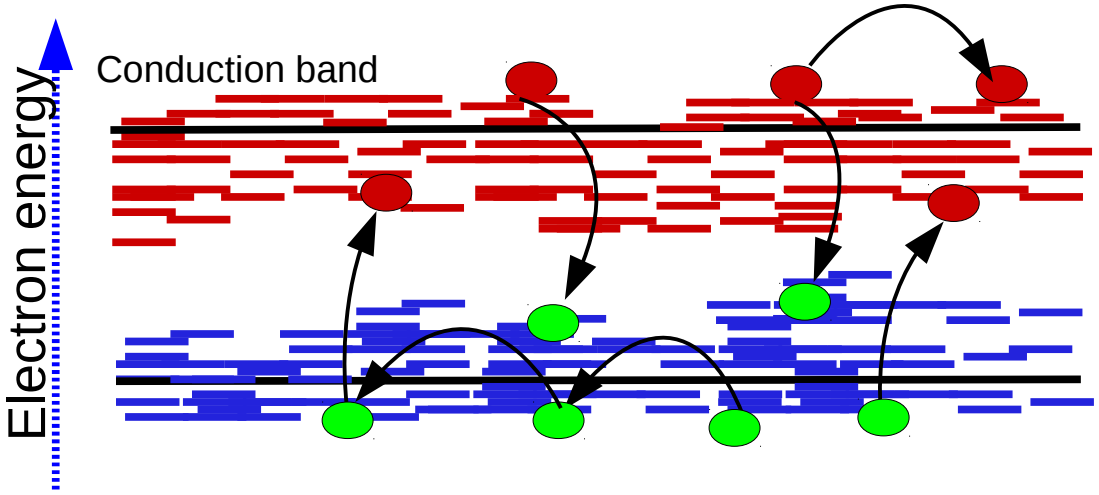
Hole continuity

$$\nabla \cdot \boldsymbol{J}_p = -q \left(R_p + T_p + \frac{\partial p_{free}}{\partial t} \right)$$

- In this respect gpvdm is similar to many other device models.

MacKenzie , Shuttle, Adv. Energy Mater. 2012, 2 (6), 662-669

However to simulate disordered materials you need to include trapping/recombination via trap sates...

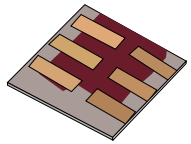


$$R_T = \frac{np - n_i^2}{\tau_{p0}\left[n + n_i \exp\left(\frac{E_t - E_i}{kT}\right)\right] + \tau_{n0}\left[p + n_i \exp\left(\frac{E_i - E_t}{kT}\right)\right]}$$

- This is often done using the following ***SRH*** equation, which assumes a ***steady state distribution*** of trapped charge carries in the trap states.

- This form of the SRH equation is therefore ***not suitable for time domain*** simulations where trapping/recombination via trap states dominate charge dynamics. As the charge carriers can not go out of equilibrium

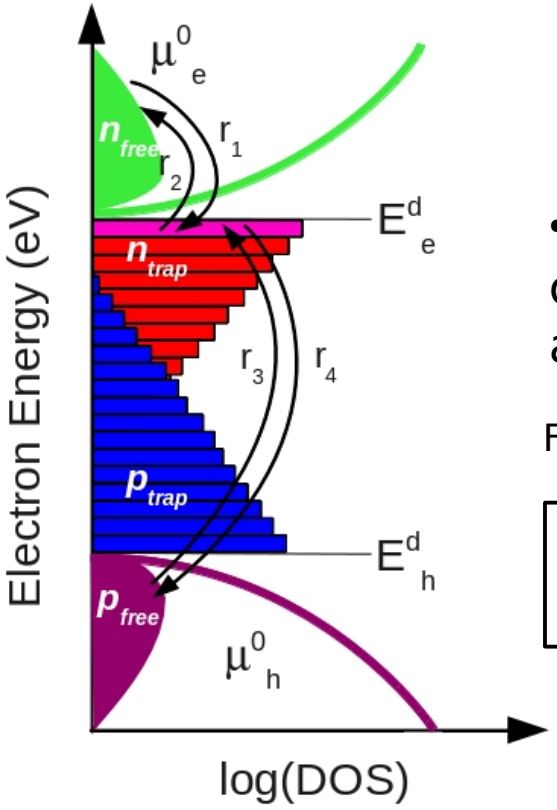
We therefore need to solve for the charge density of each trap state explicitly.



- We split energy space up into energy slices.
- And use the SRH equations but don't assume steady state, so solve the SRH equations explicitly in time domain.
- Each trap state gets its own rate equation:

$$\frac{\partial n}{\partial t} = r_1 - r_2 - r_3 + r_4$$

Process	
electron capture	r_1
electron emission	r_2
hole capture	r_3
hole emission	r_4



- Recombination can be calculated as:

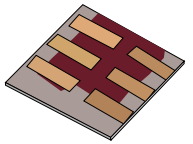
Free carrier recombination

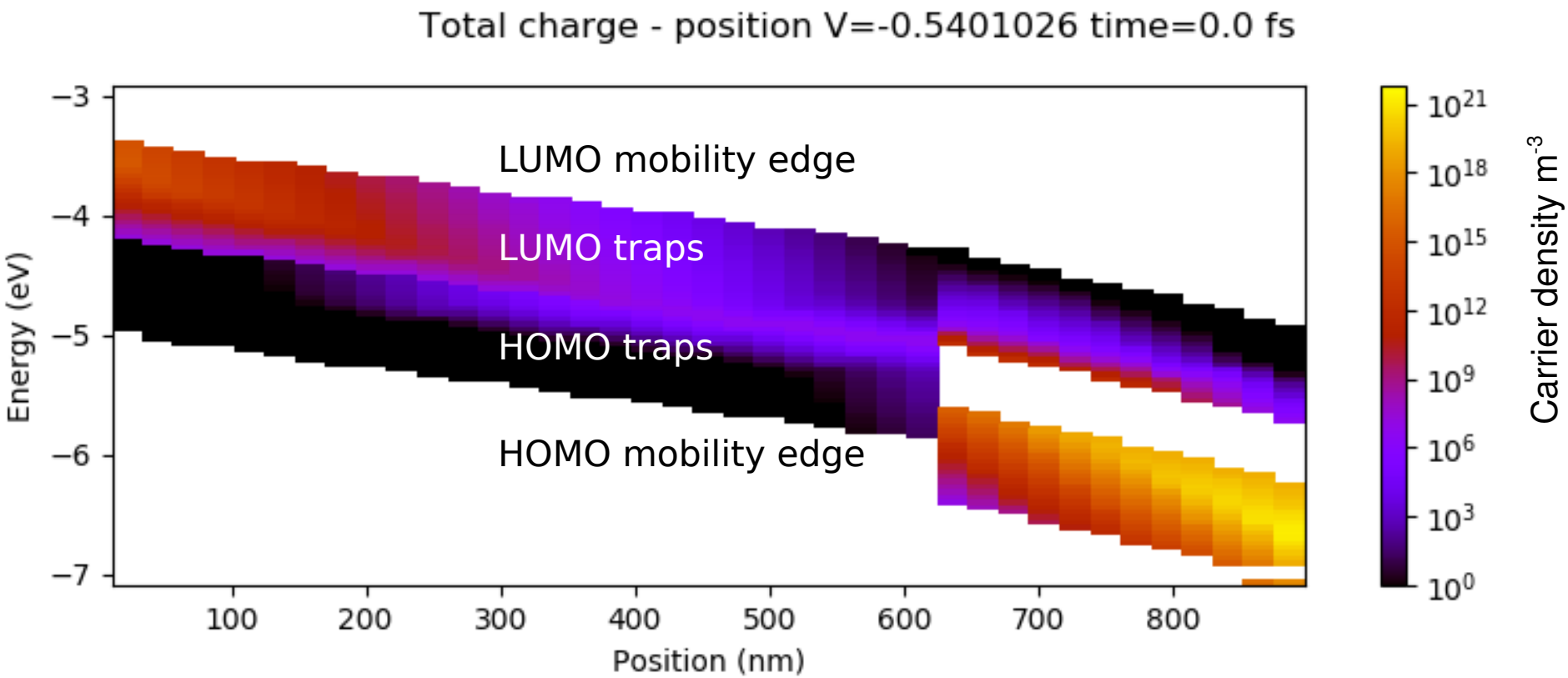
$$R_n = \sum_{0}^{n_{band}} \left(r_1^e - r_2^e \right)$$

Detailed balance is maintained.

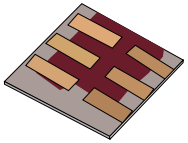
- **Other models do not do this….**

This enables us to know where the charge carriers are in position/energy space.





Overview



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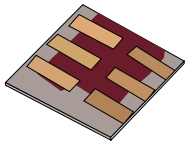
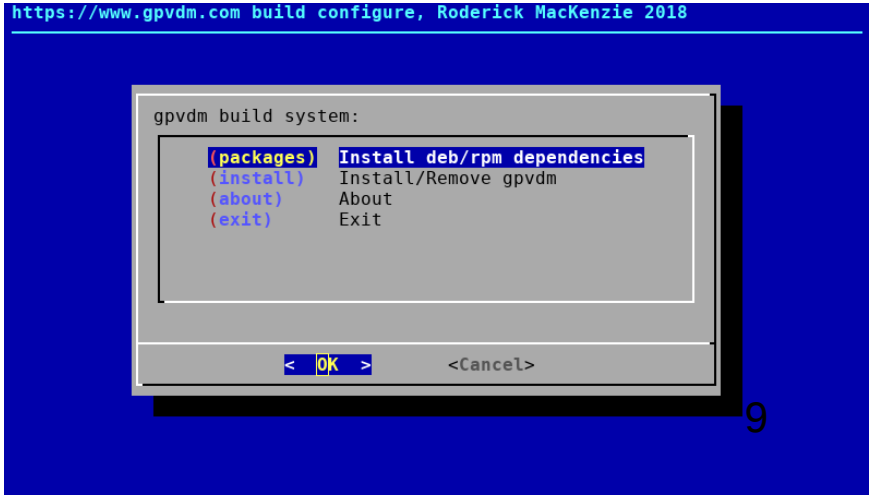
Downloading and installing



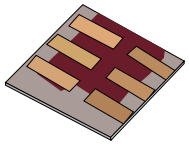
- The easiest way (*and recommended way*) to use gpvdm is to download gpvdm for Windows (https://www.gpvdm.com/download.php), double click on the installer, and follow the instructions. I keep this version up-to-date.

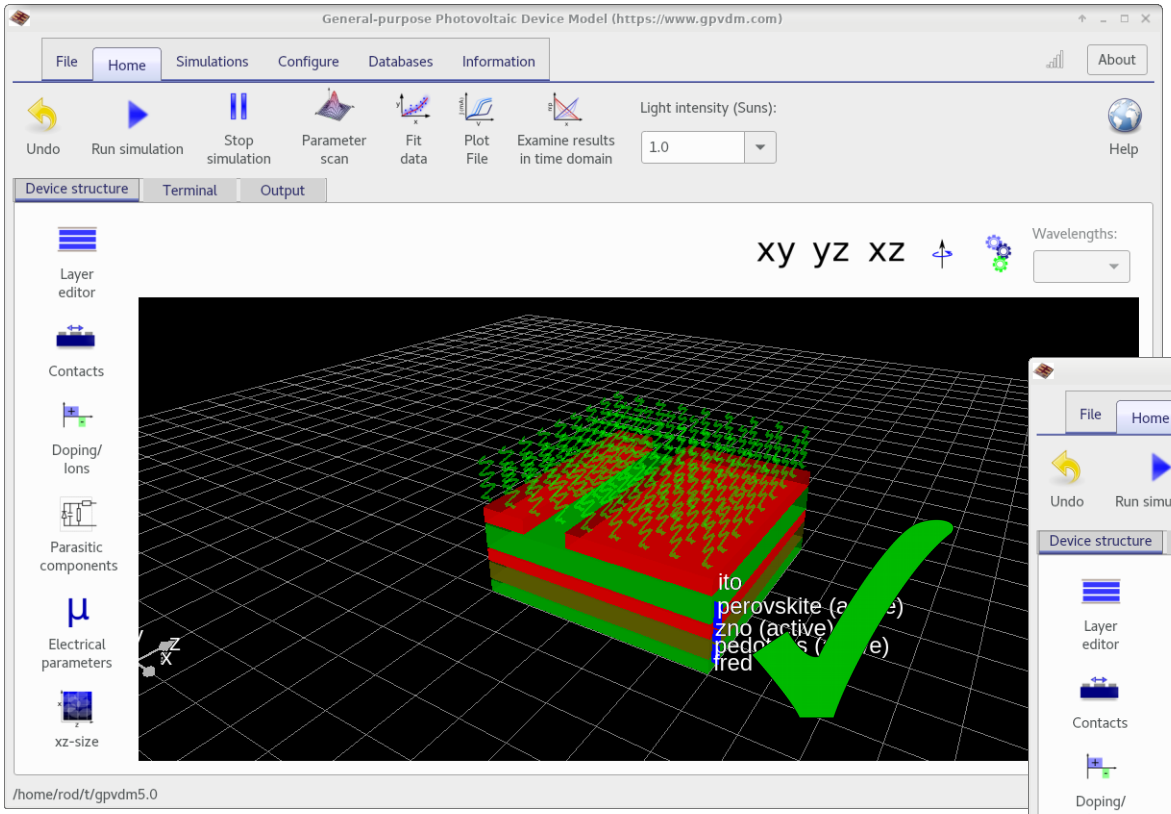
- Alternatively If you are on Linux, you can compile from source. You can find instructions on how to do this here:
  - https://www.gpvdm.com/code.php

- On Linux, I highly recommend using the ***./build*** as it will take care of a lot of the hard work for you.



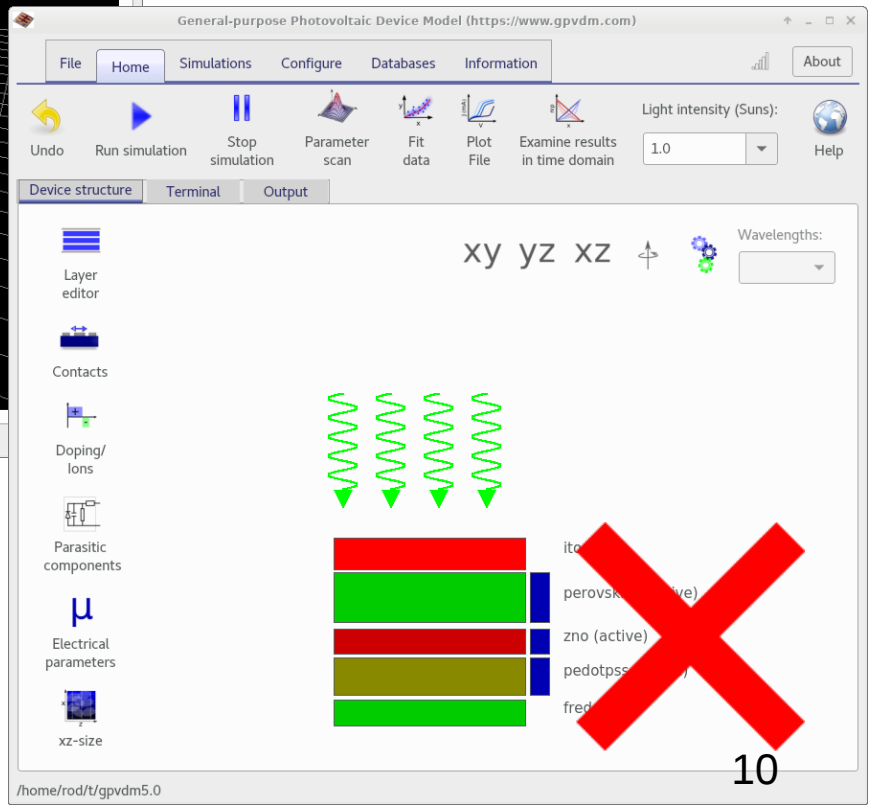
If you don't get a nice 3D interface it means your graphics drivers for you computer are not configured.



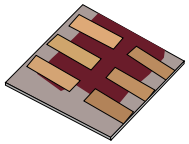


•OpenGL working :)

•OpenGL not working :/



Overview



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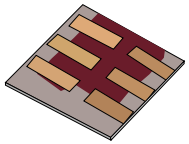
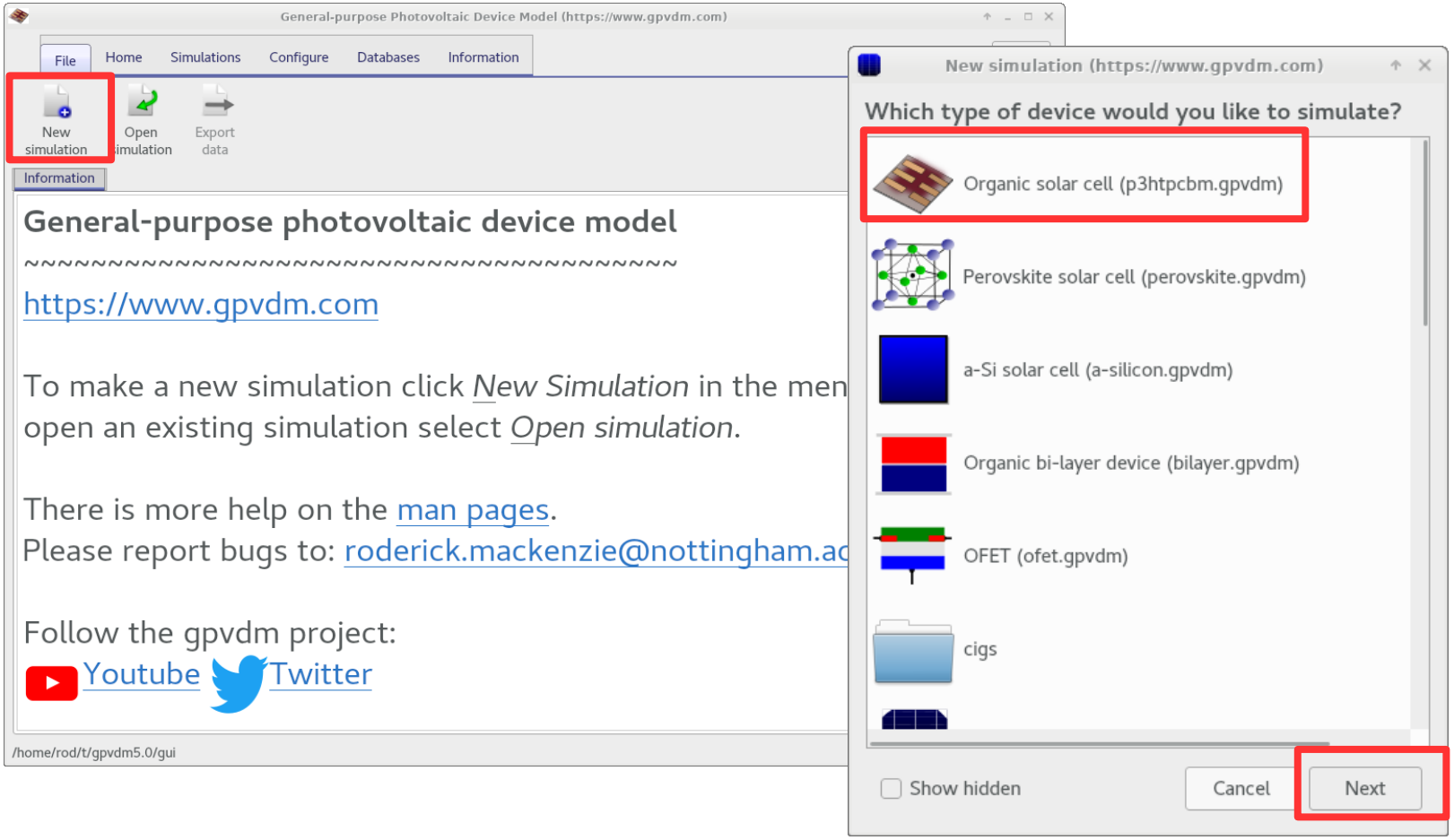
Your first gpvdm simulation

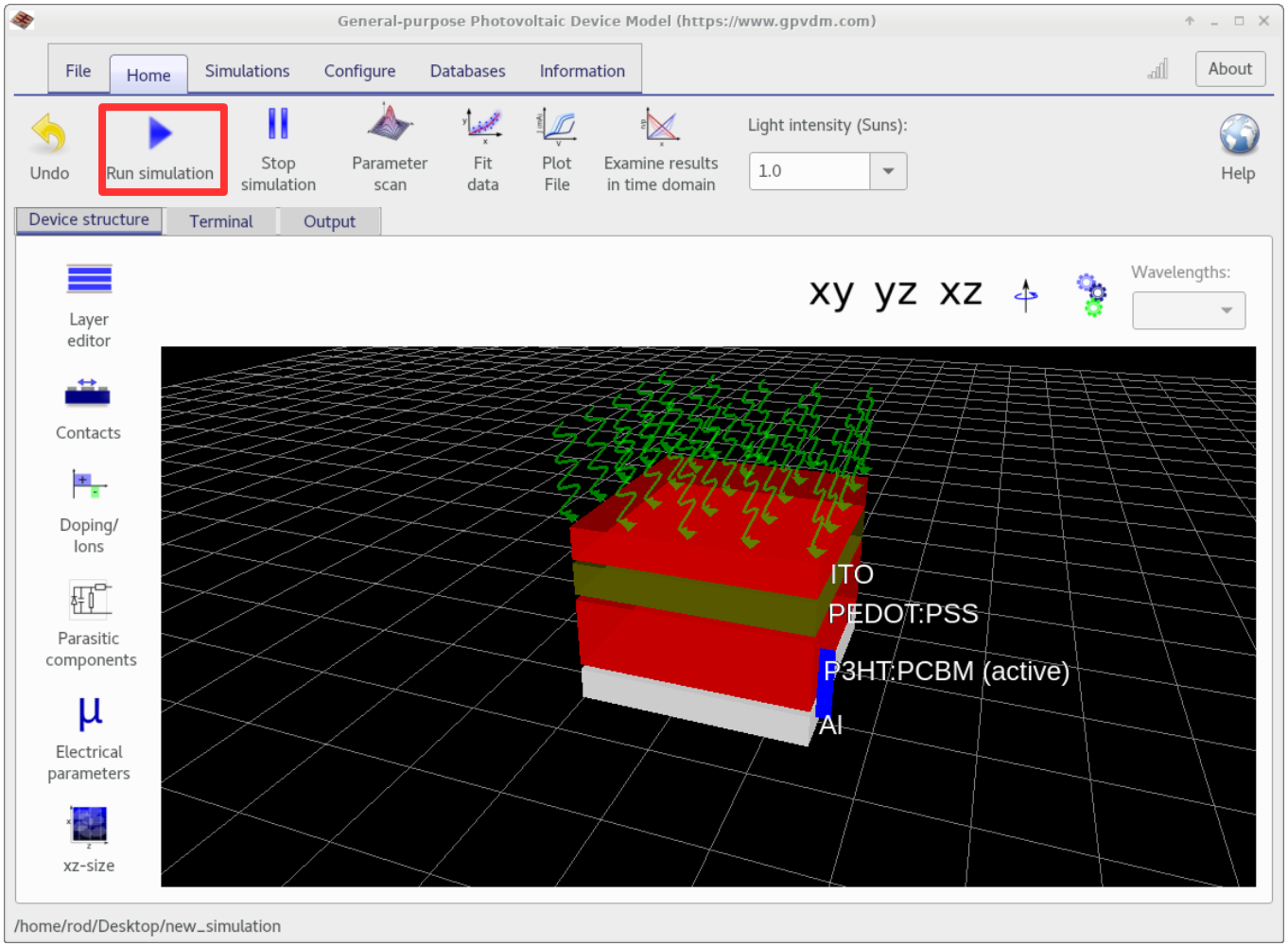


- Click on *New simulation*, in the file menu.



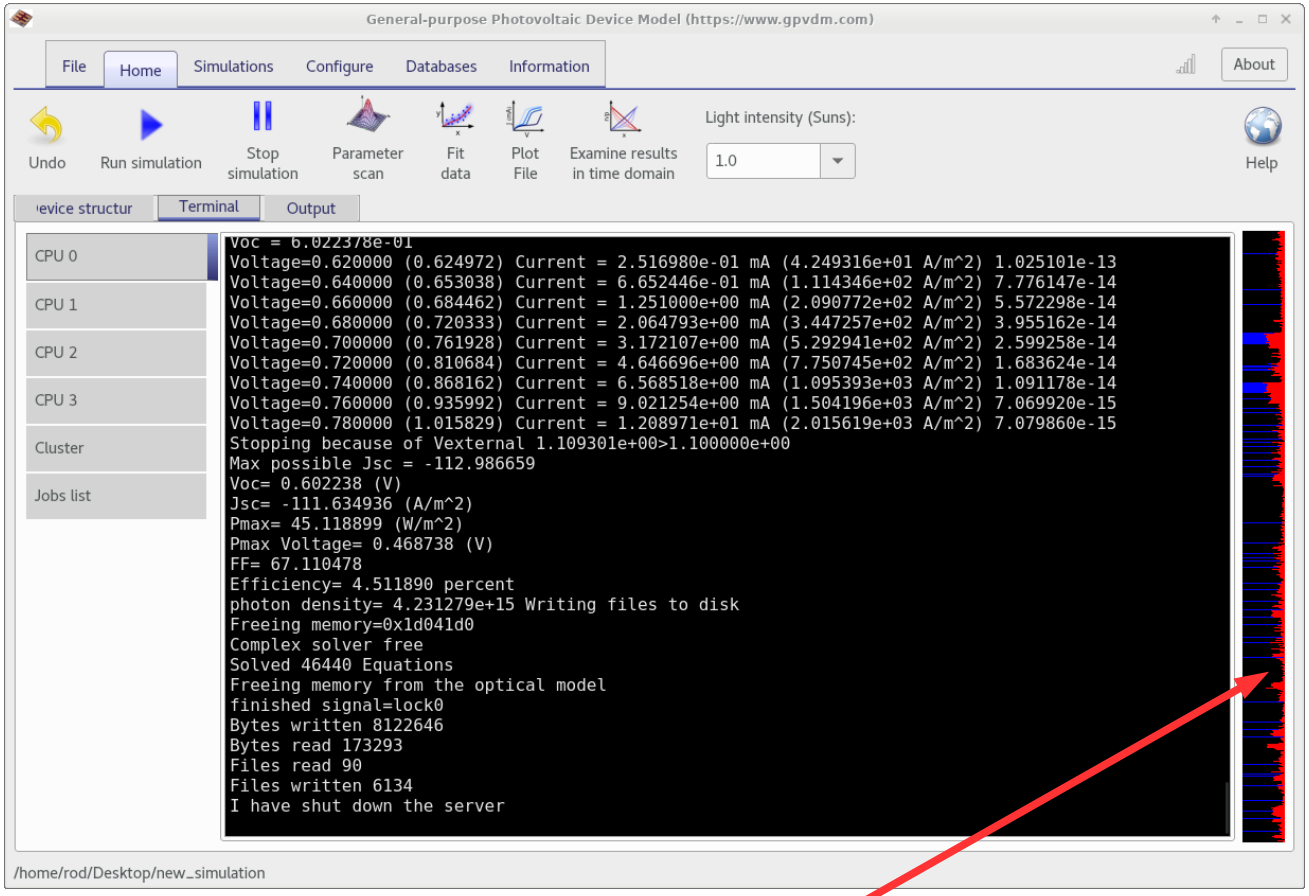
- Save it somewhere but ***not*** in the install directory.

You should get this window.



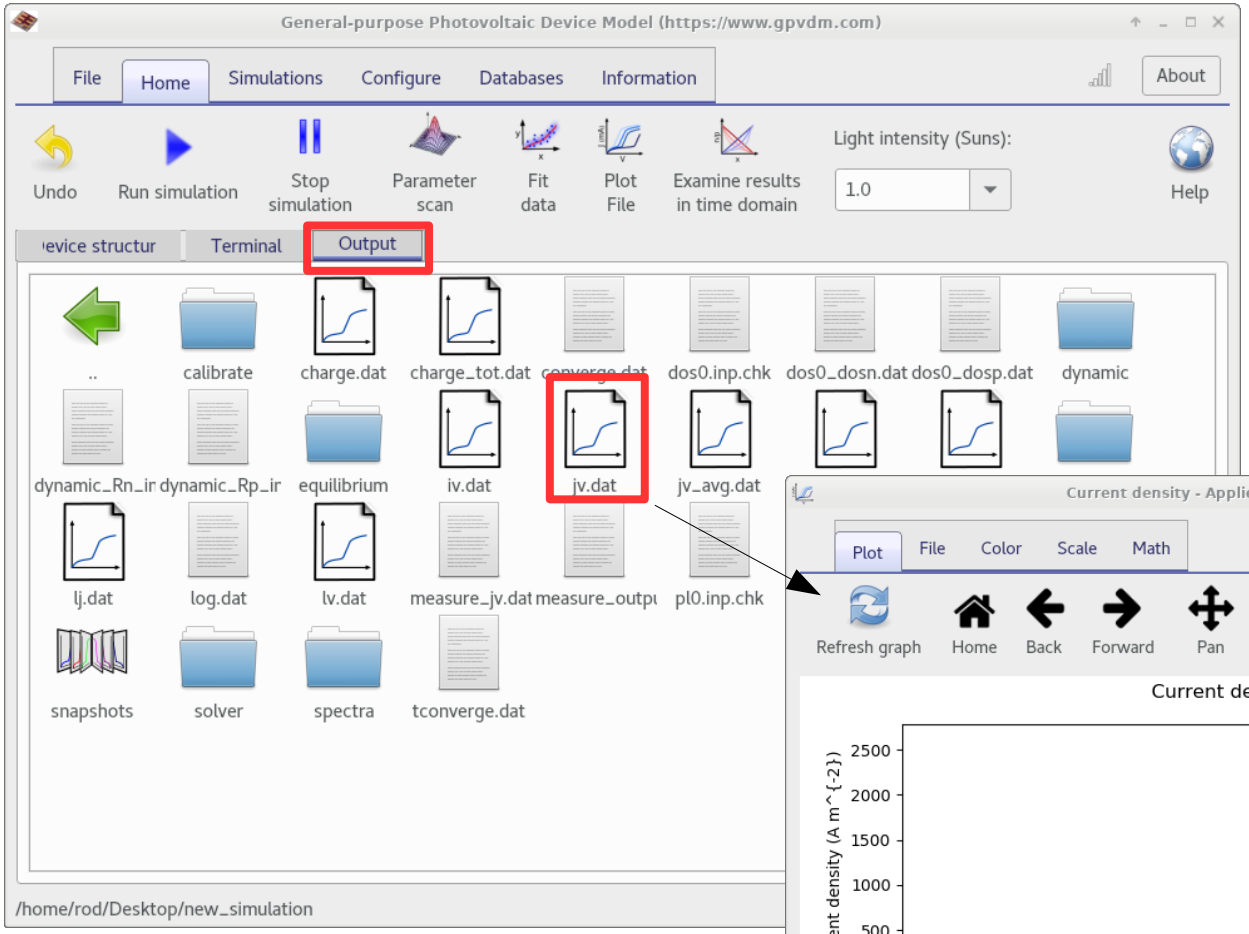
Click the play button

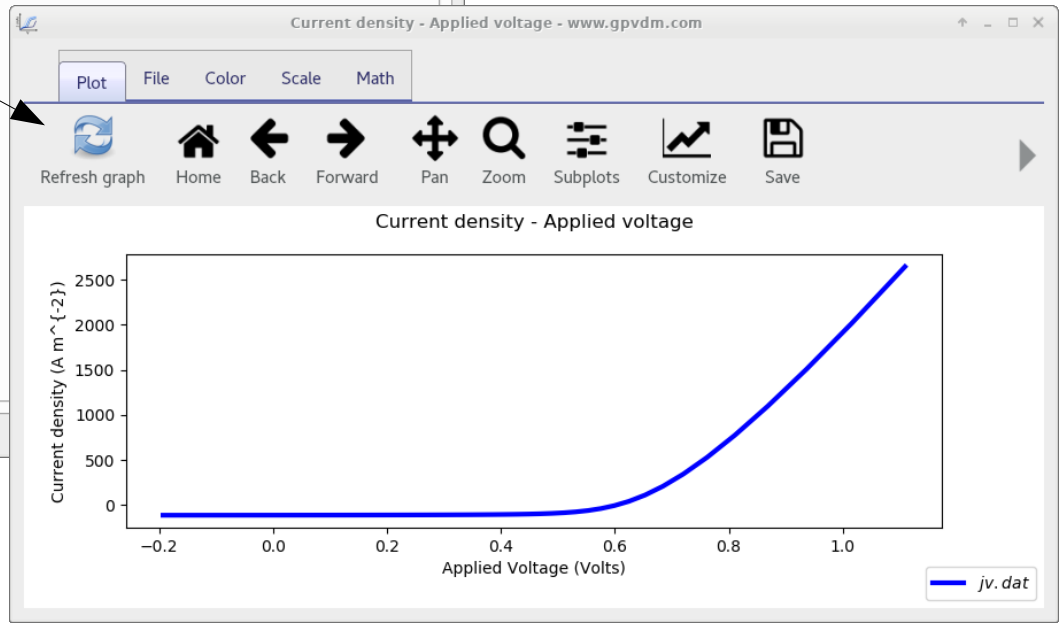
The core solver will be run on CPU 0



- Blue is CPU usage, red is disk usage, if you simulation is running slowly, writing to the HDD is ***always*** the bottleneck, SSDs highly recommended.

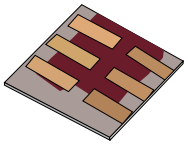
Examining the results.

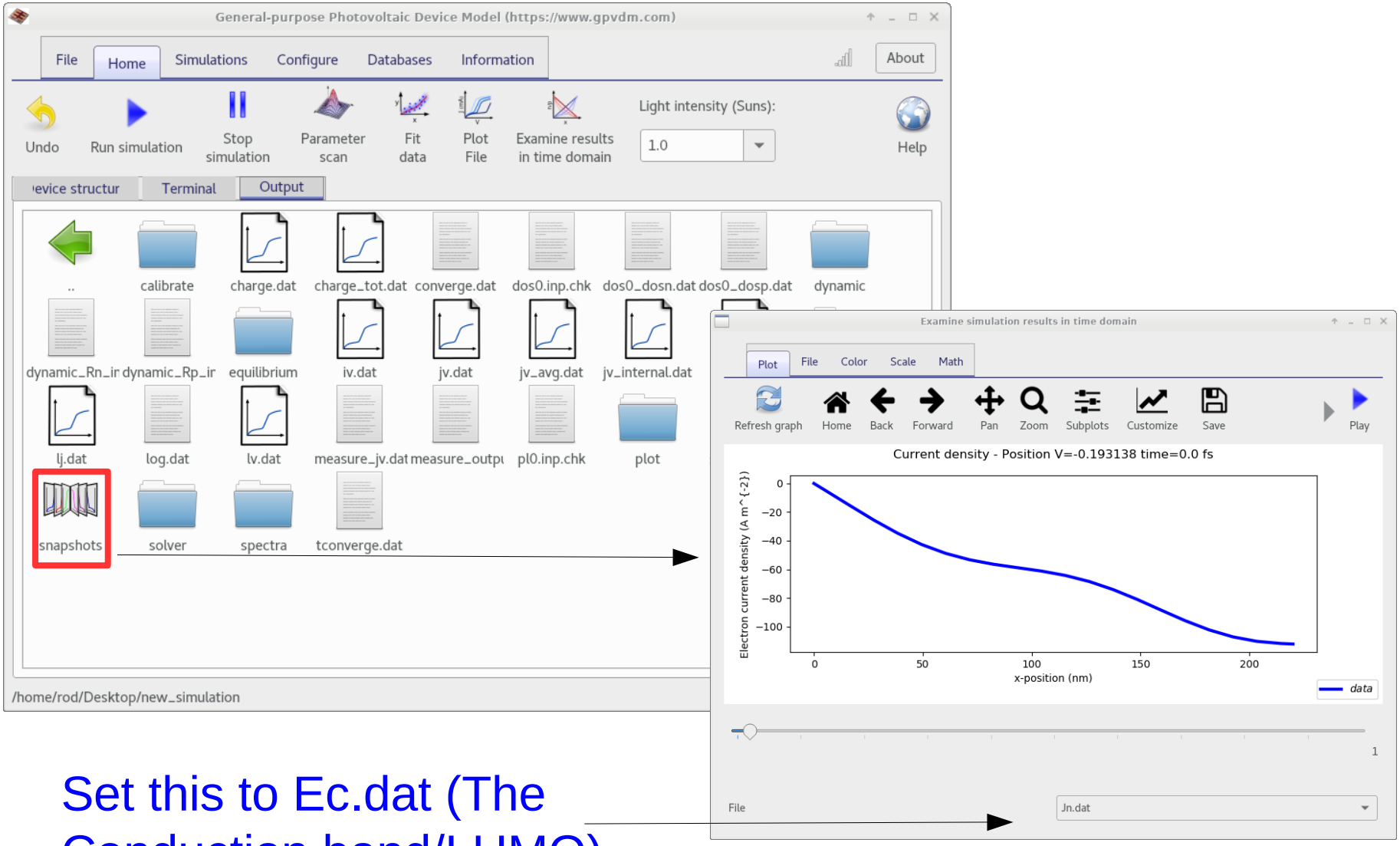




Double click on jv.dat to view J-V curve generated by the model.

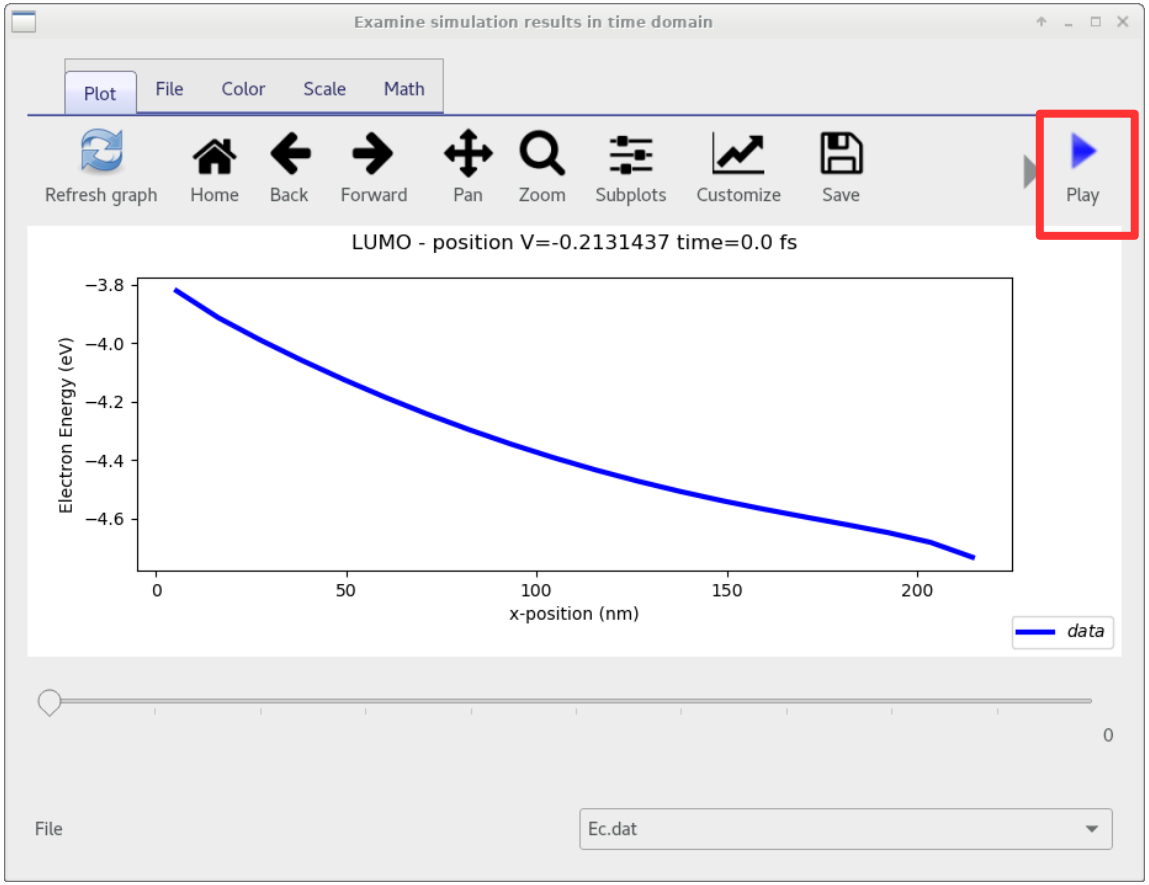
The snapshots window, this is used to show changes in the device as a function of voltage and time.





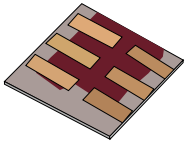
Set this to Ec.dat (The Conduction band/LUMO)

Using the snapshots window



- Click play and the simulation will iterate through each voltage step. If you were doing a time domain simulation it would do the same.

Overview



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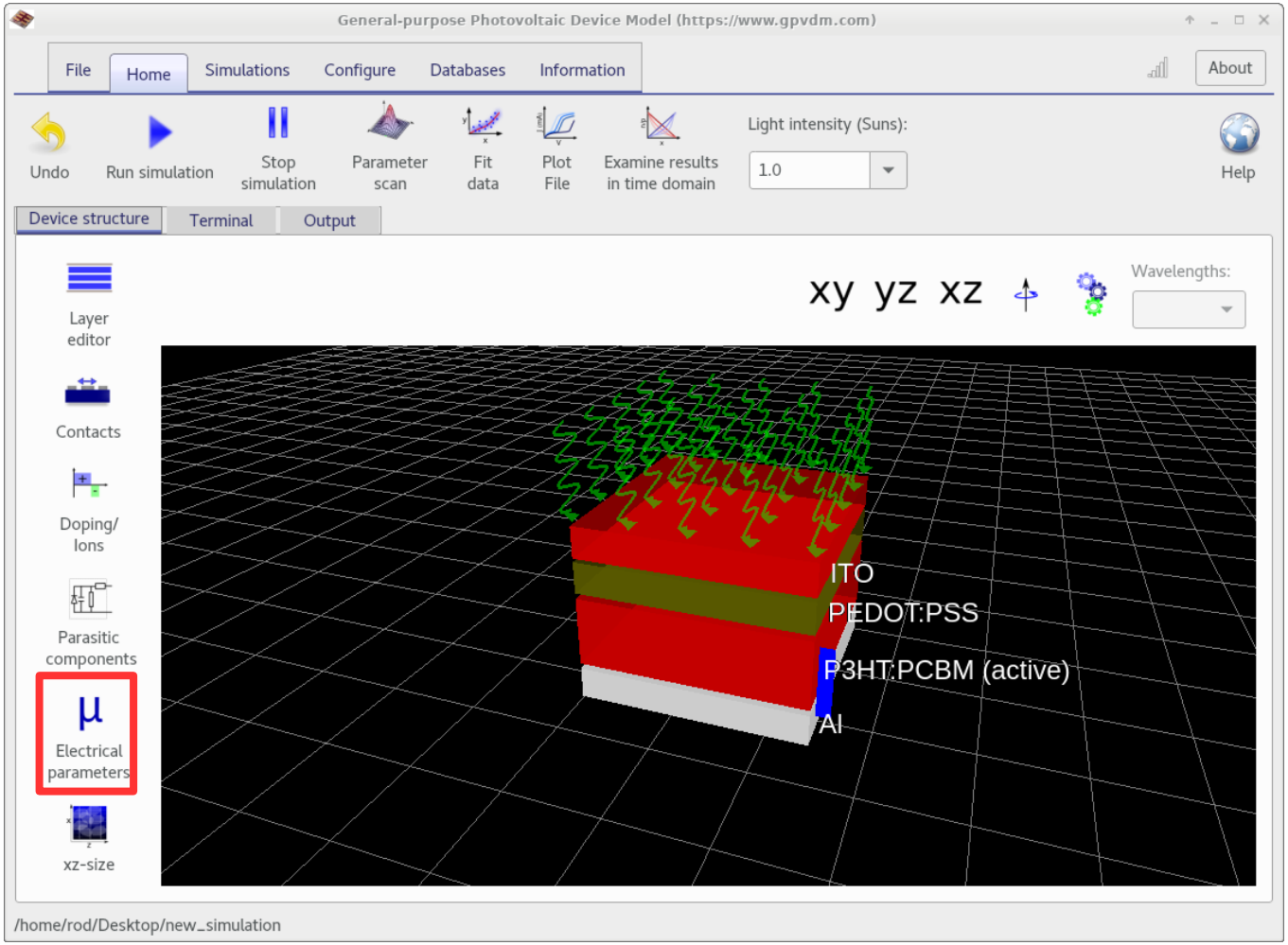
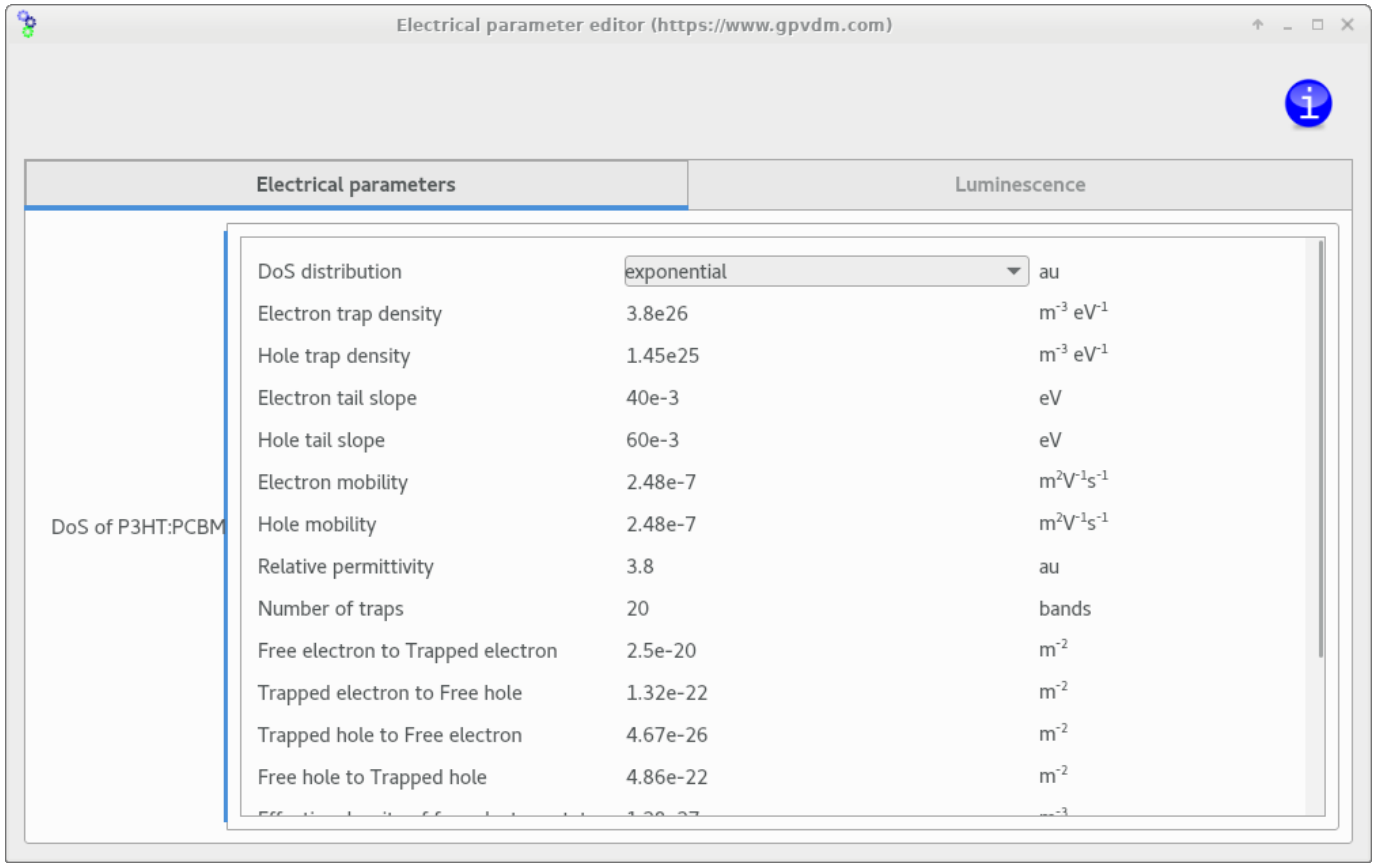
Editing the electrical parameters of a material



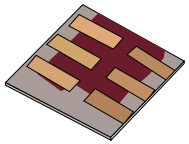
- Click on the Electrical parameter editor, under the device structure tab.

This is the electrical parameter window



•Here you can edit the electrical parameters of the electrically active layers. Each ***electrically active*** layer will get a new tab here.

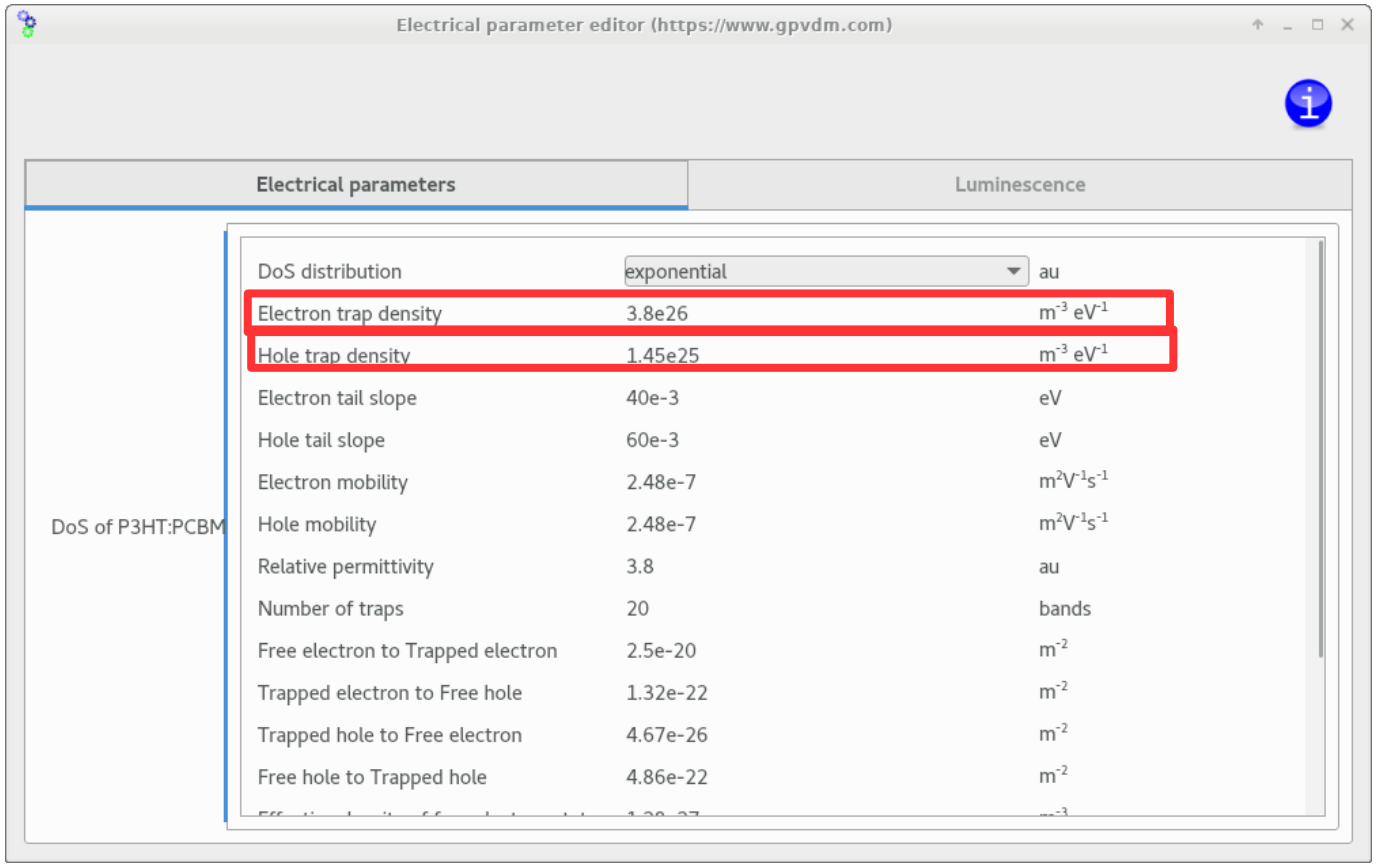
Types of layers in gpvdm:



Layer type	Description	Electrical Equations solved	Optical Equations solved.
active	The electrical model is solved over these layers, each layer gets it's own set of electrical parameters.	Yes	Yes
other	No electrical equations are solved in these layers.	No	Yes
contact	These layers are used to define the electrical contacts, no electrical equations are solved in the layers.	No	Yes

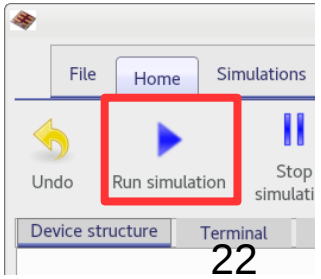
- The layer type can be changed using the layer editor…. more on this later.

Editing an electrical parameter...the trap density….

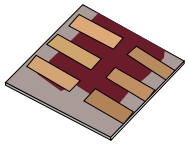


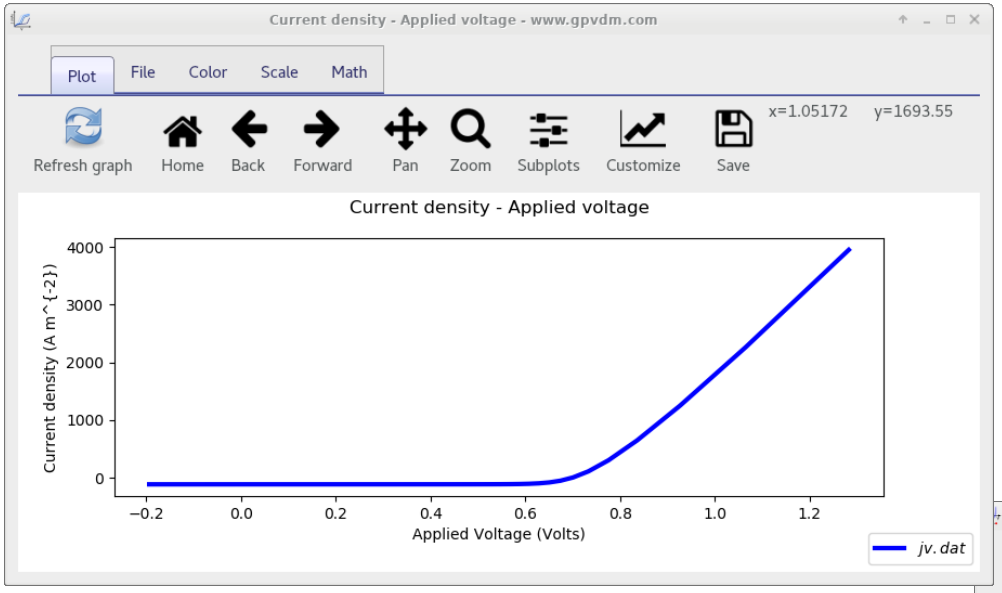
a) Make the density of trap state symetric at $1x10^{24}$ m^{-3}, and rerun the simulation.

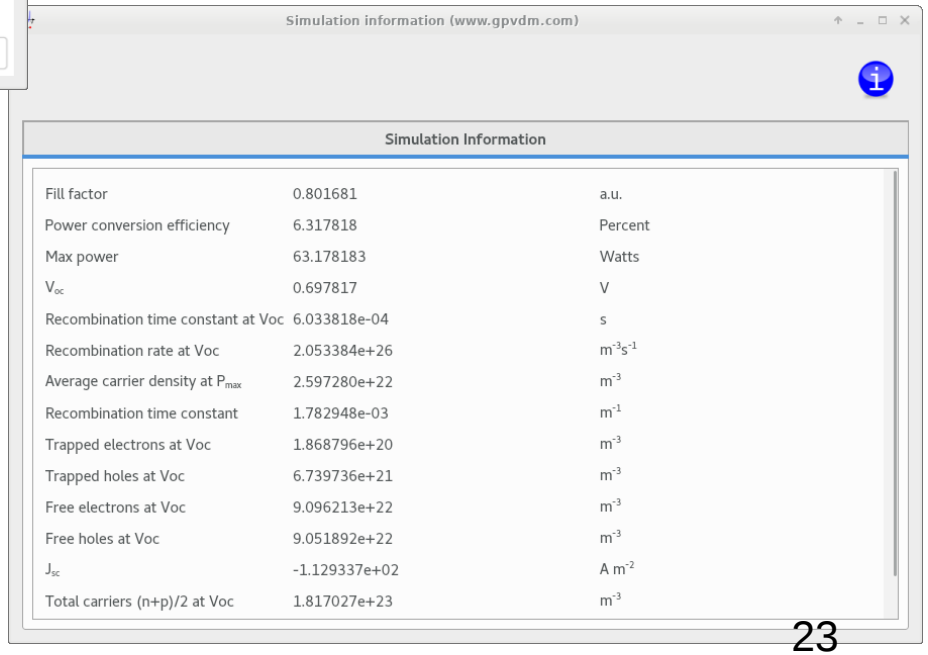
b) Now re-plot the JV curve (**jv.dat**), also find the (**sim_info.dat)** file, double click on it and find the power conversion efficiency.



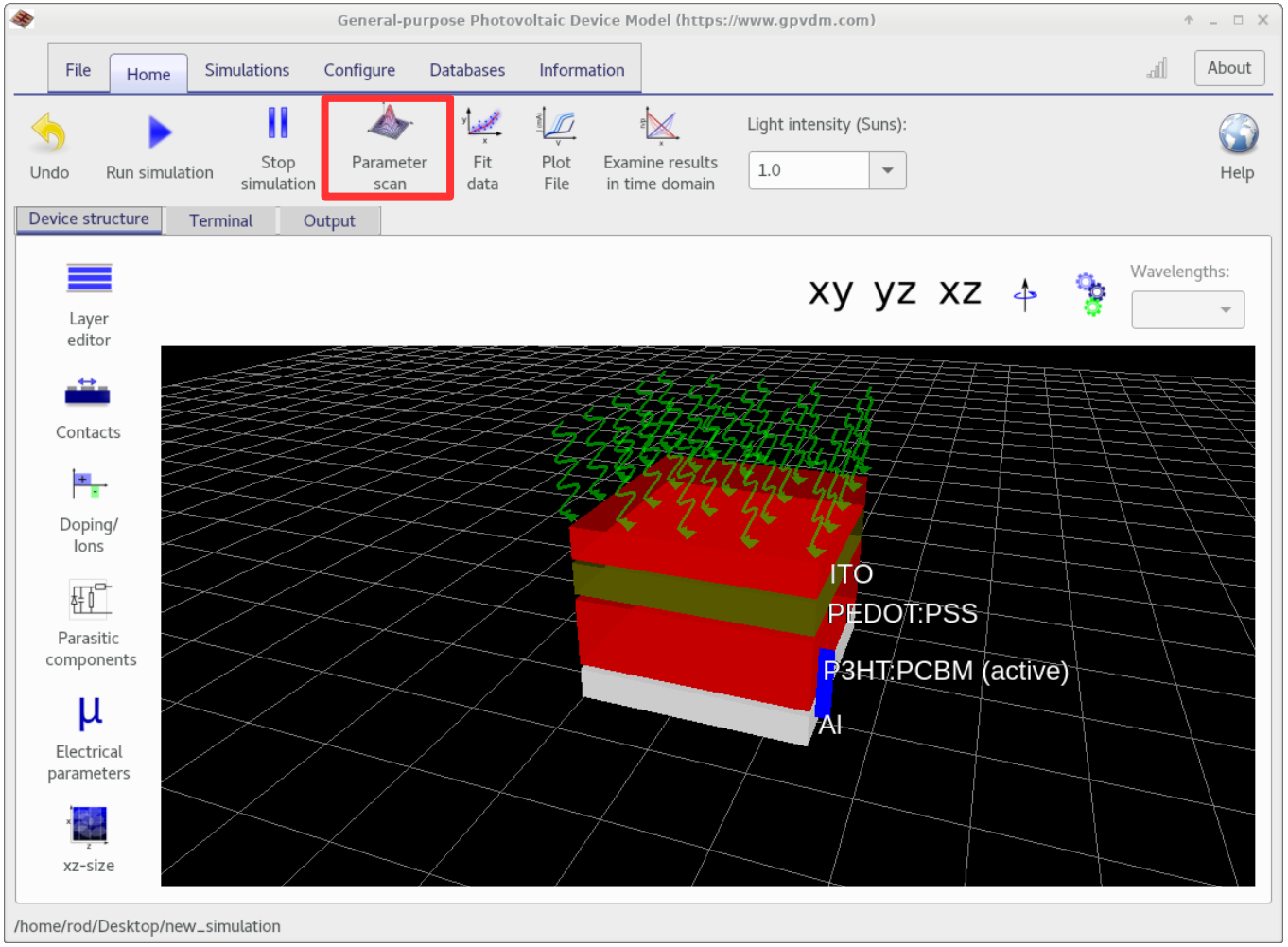
You should have results which look a bit like this:







Varying a parameter many times using the Parameter Scan, window.

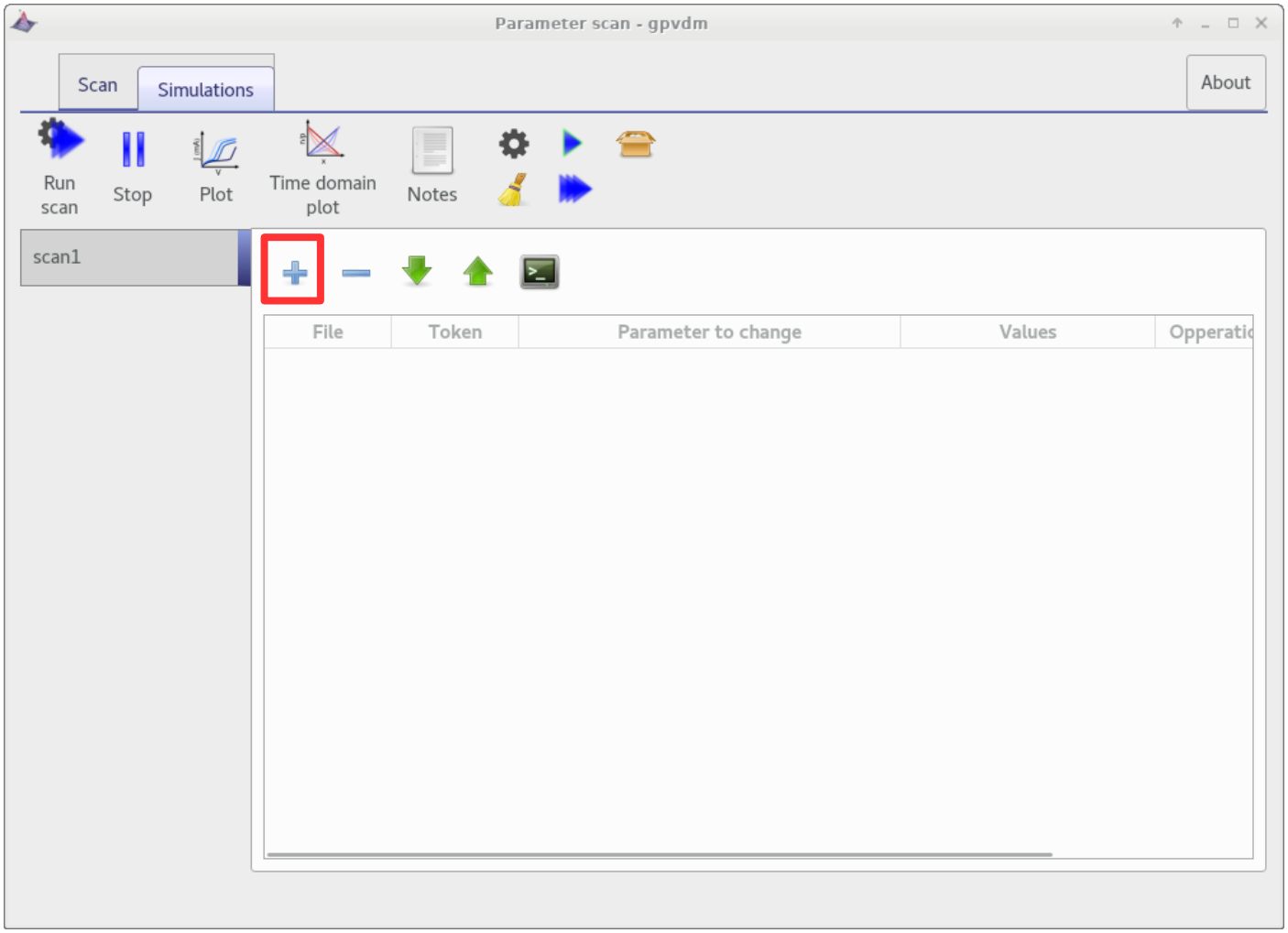


- Often we want to change a simulation parameter several times to understand how a parameter affects a device.

- To do this, use the ***Parameter Scan*** *tool*

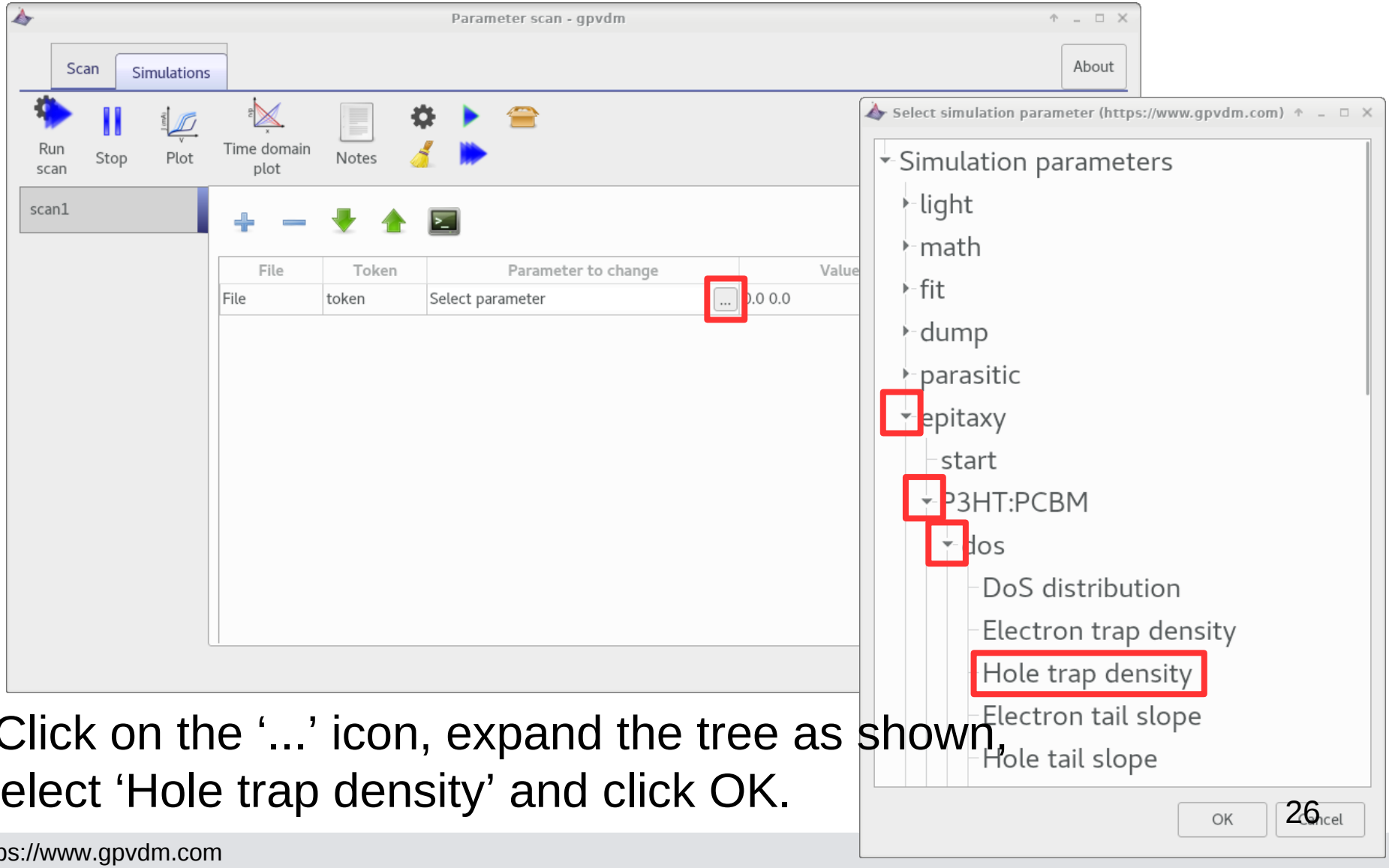
- **Click on the parameter scan tool**

The parameter scan window



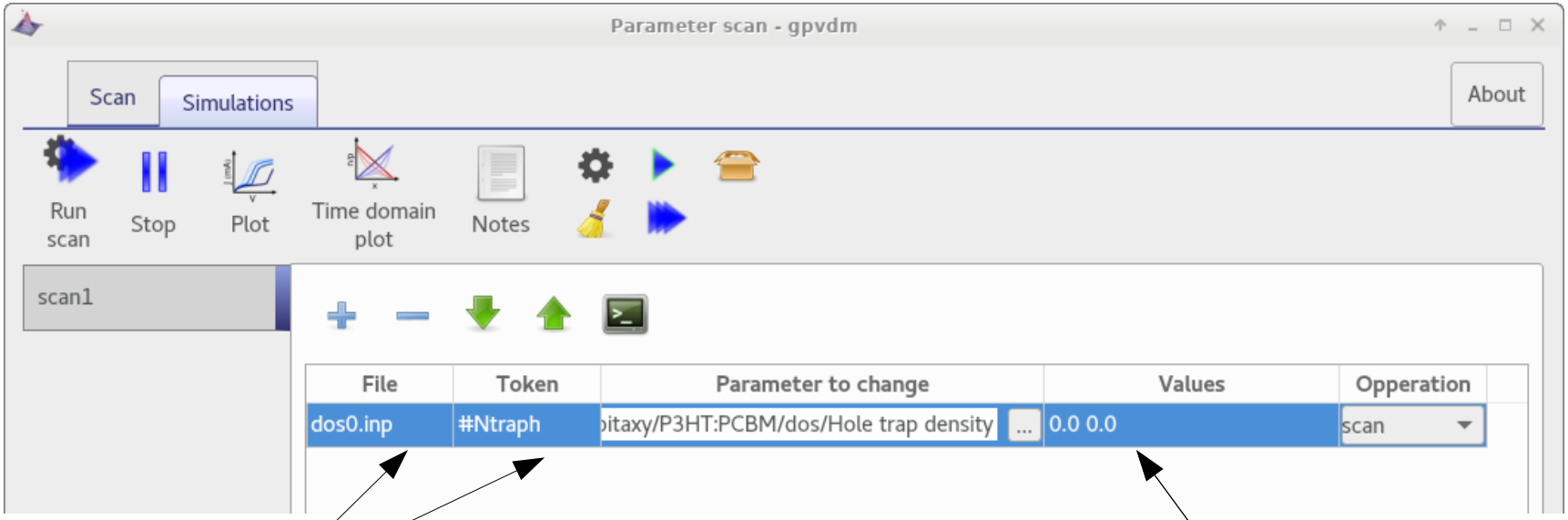
•Click on the + to add a new line to the scan.

A new line should appear...



•Click on the '...' icon, expand the tree as shown, select 'Hole trap density' and click OK.

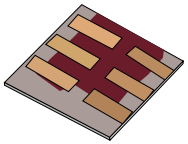
The parameter scan window...

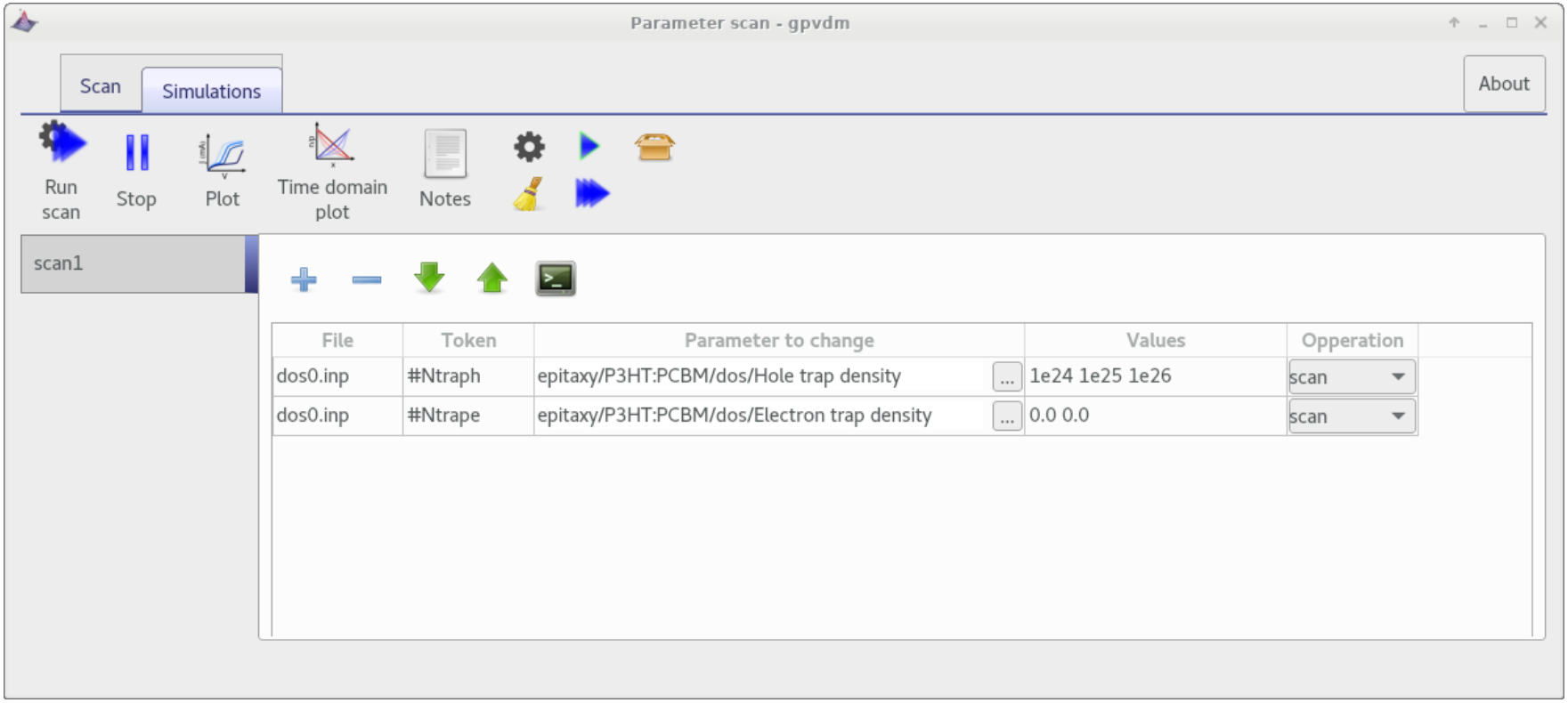


This shows the file/section of the file which will be edited (generated automatically).

Enter these (1e24 1e25 1e26) values in here. They are the trap densities we are going to scan over (units are m^{-3} eV^{-1})

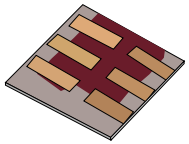
But we want to simulate a symmetric device (where Ntraph=Ntrape)...

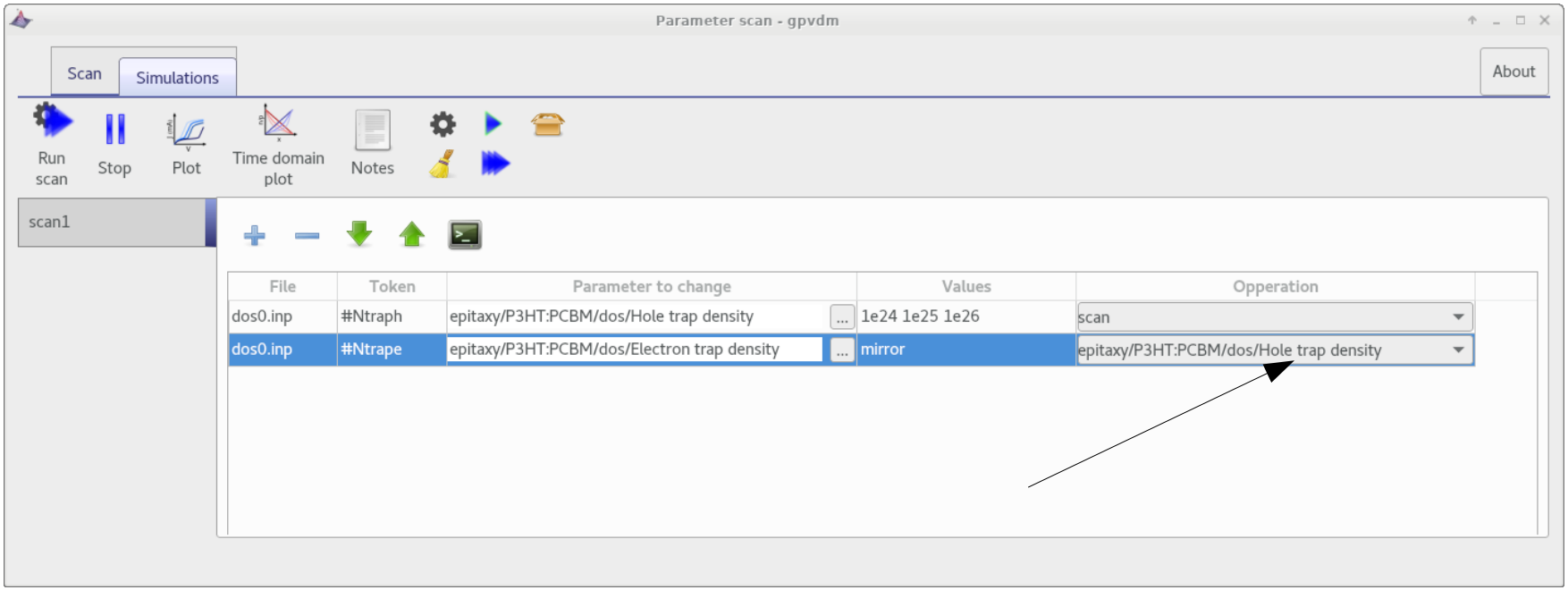




So using the '+' button add another row and then using the '...' buttons make it look like the above..

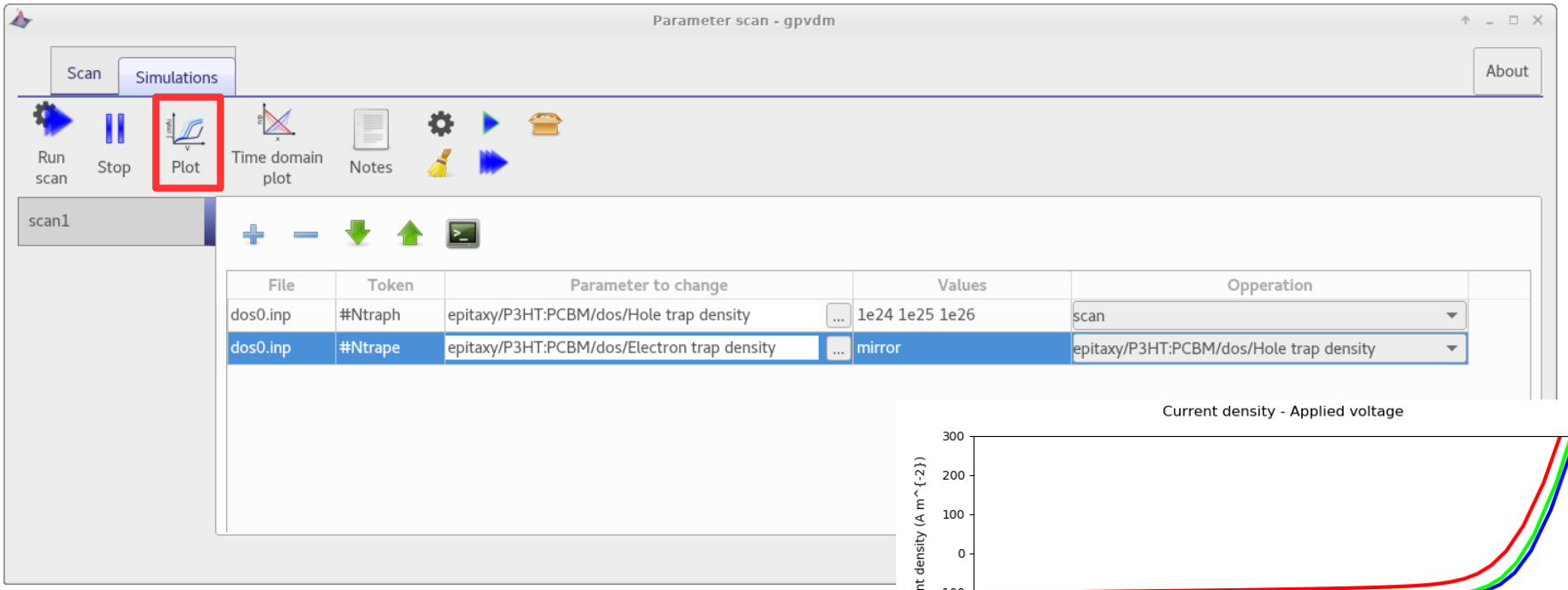
But we want to simulate a symmetric device (where Ntraph=Ntrape)...





- Then from this menu select, ‘epitaxy/P3HT:PCBM/dos/Hole trap density’.
- The words ‘mirror’ will appear in the values column. This means that the values for Electron trap density will follow that of the Hole trap density.
- Now click ‘Run scan’…., it will run the simulations in parallel across all cores of your CPU.

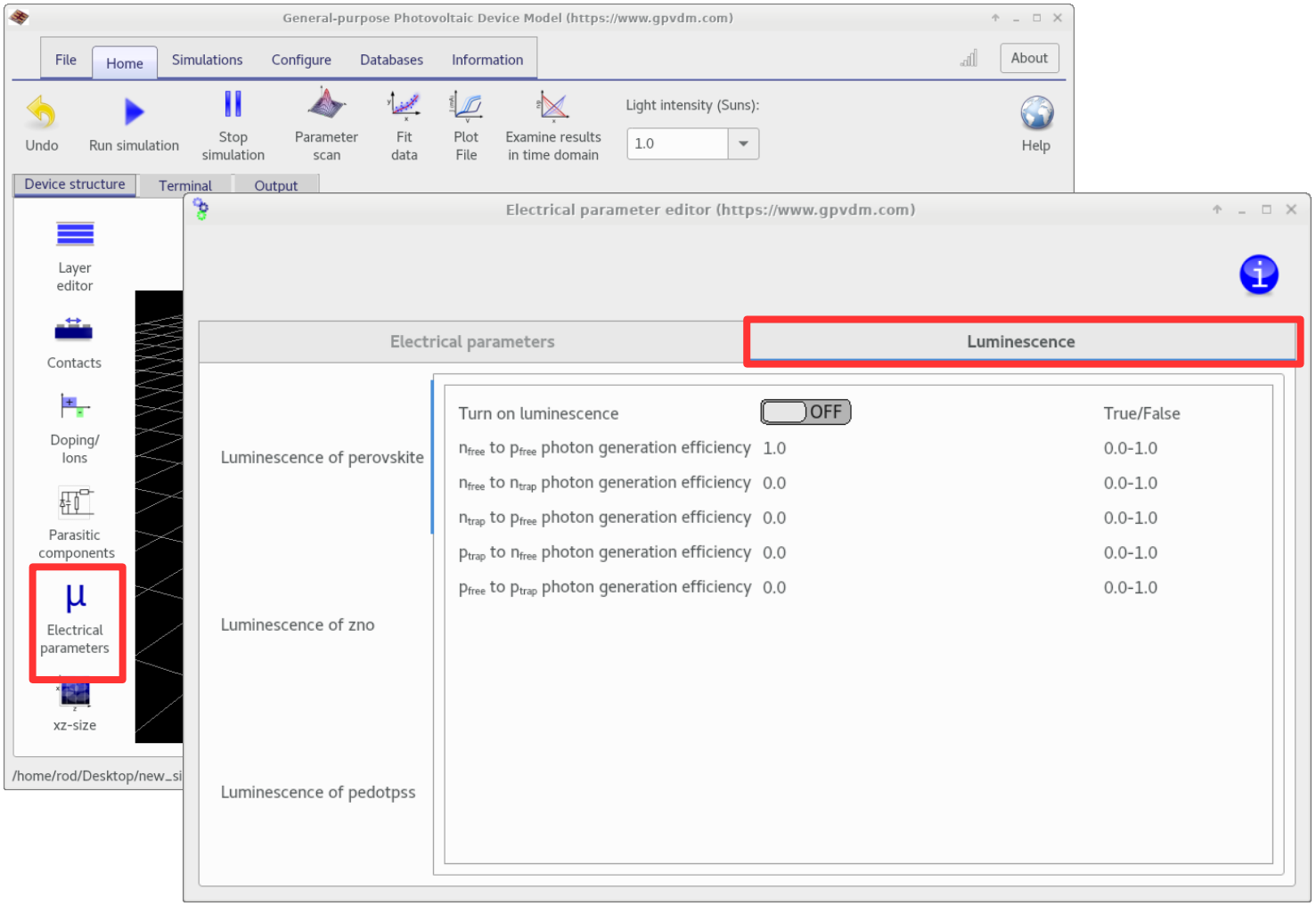
Plotting the results.



- Click plot, and plot the file scan1/1e24/jv.dat.

- All jv.dat curves will be plotted from the simulation tree.

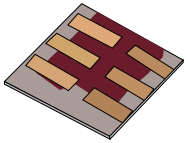
A final note on the electrical parameter window...



- We can assign a photon generation efficiency to each recombination process, so we an get a predicted PL/EL spectrum…

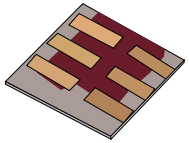
- We can only do this because we know where the carriers are in energy space across the device.

Overview



- What is gpvdm/theoretical overview?
- Installing gpvdm
- Running simple simulations
  - Your first gpvdm simulation
  - Changing electrical parameters
- **Optical simulations and the materials database**
- Perovskite solar cells and time domain simulations
- OFET simulations and finite difference meshing.
- Editing the device structure using the layer editor
- Meshing and dumping
- OLEDs

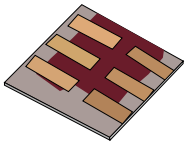
Optical simulations

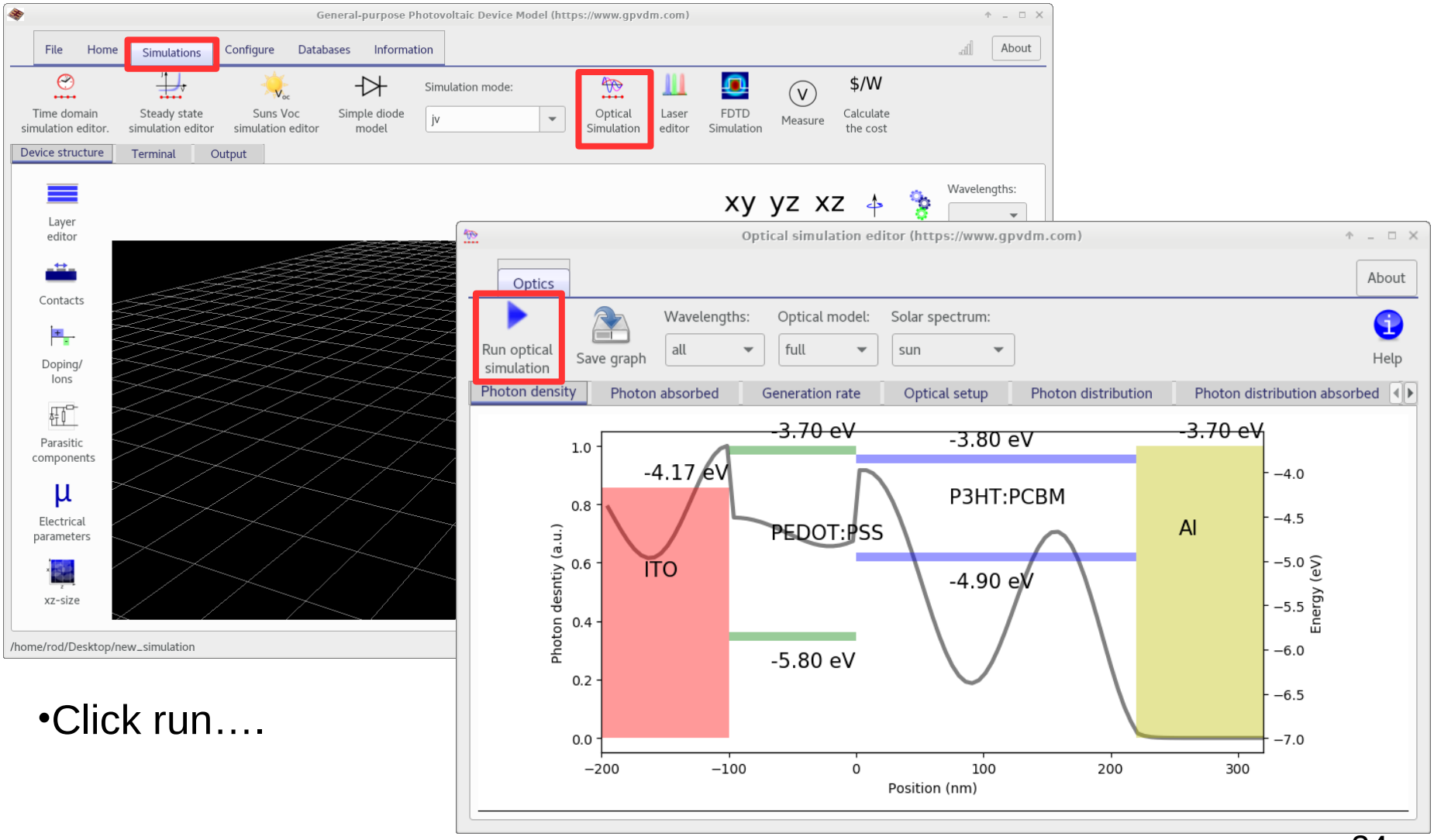


•gpvdm will always perform an optical simulation if the light intensity is not set to zero, but it will not dump all the information it calculates to disk as this is too slow.

•Therefore there is an optical simulation window to explore the optical performance of the device in more detail…..

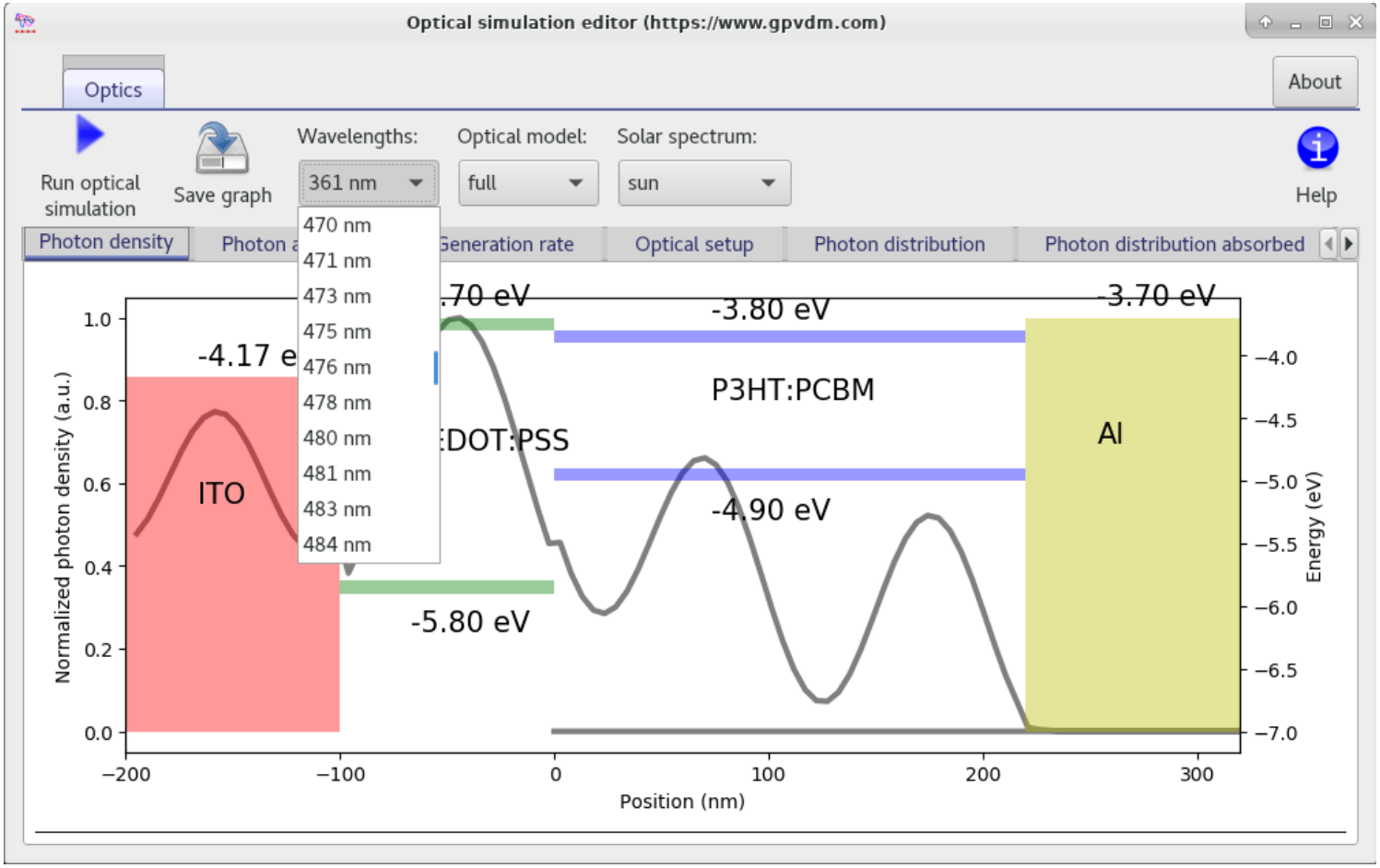
Running the full optical simulation...





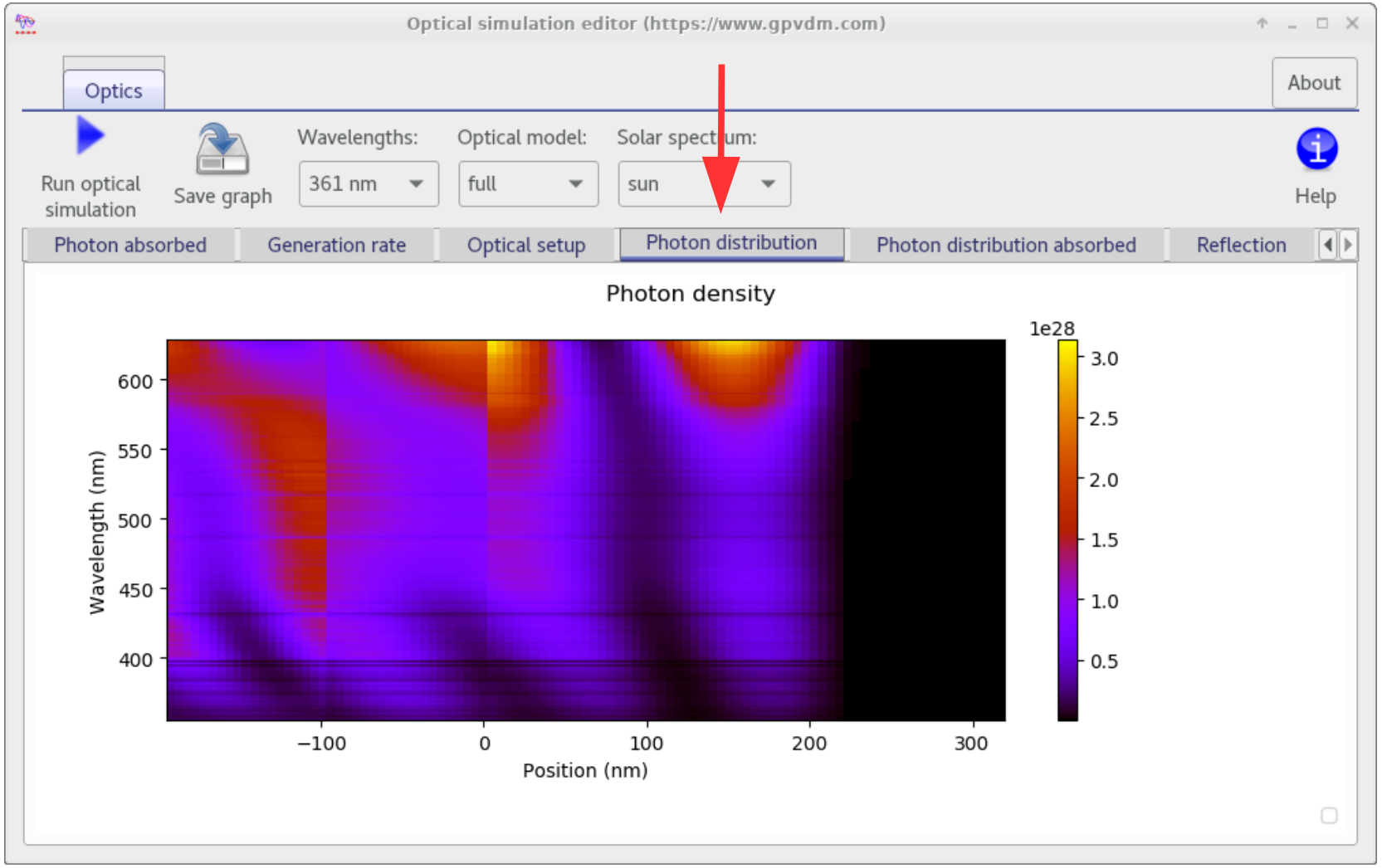
- Click run….

Looking at the photon distribution.

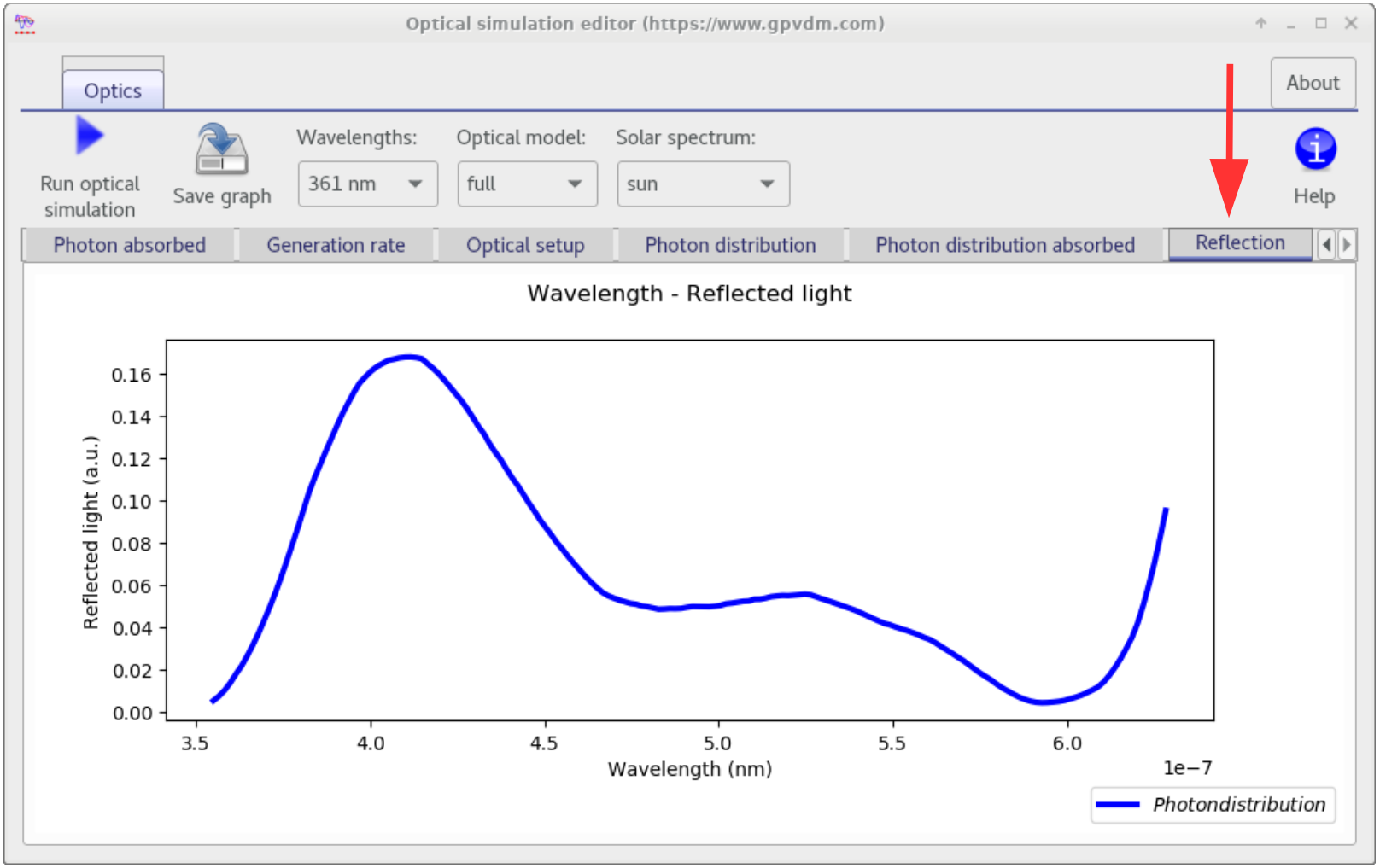


•Normally the model shows the sum of all optical modes, but you can select which mode you would like to look at. Using the above menu.

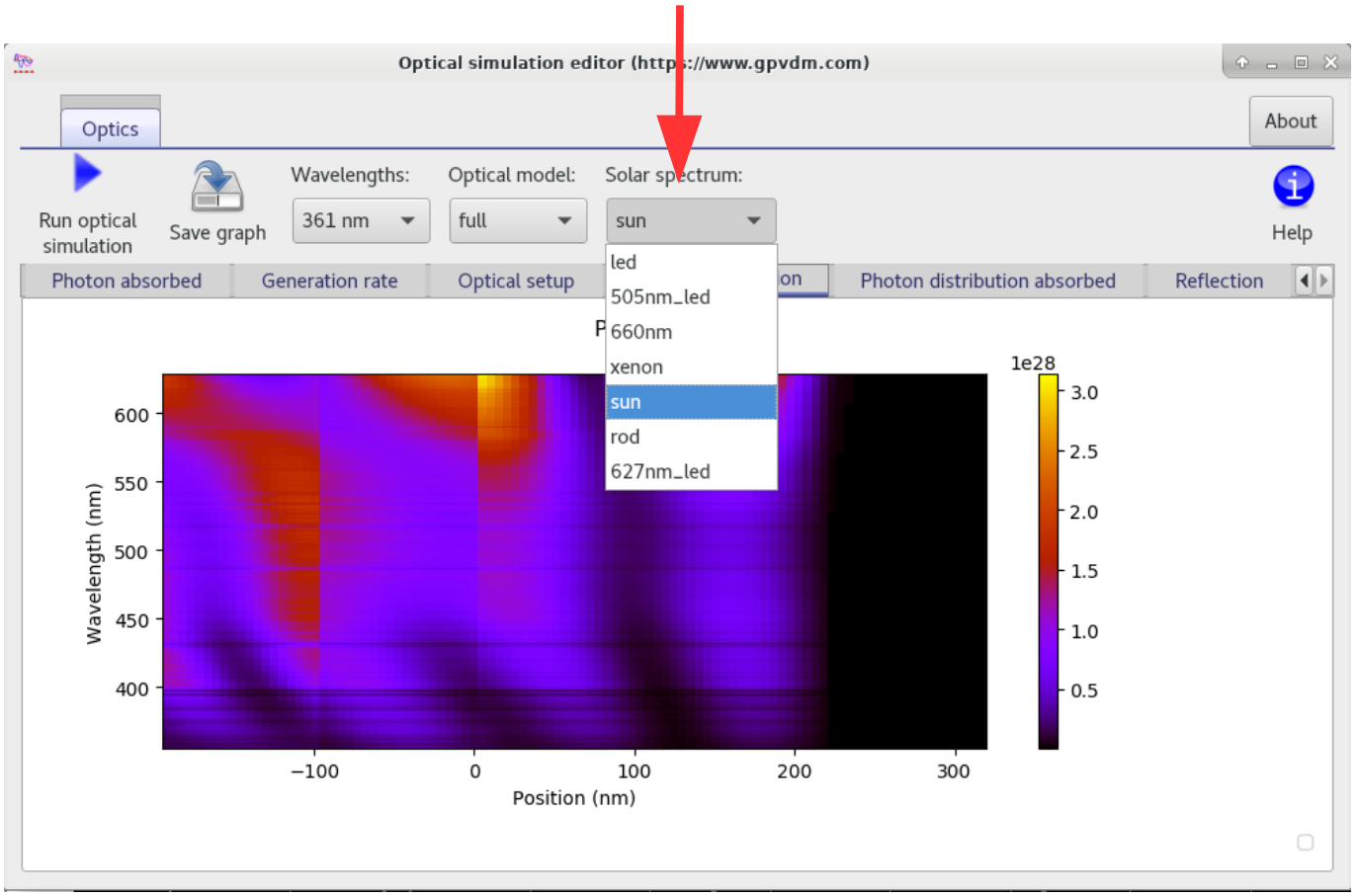
Plot the photon density as a function of wavelength/position



And also reflected light from the cell



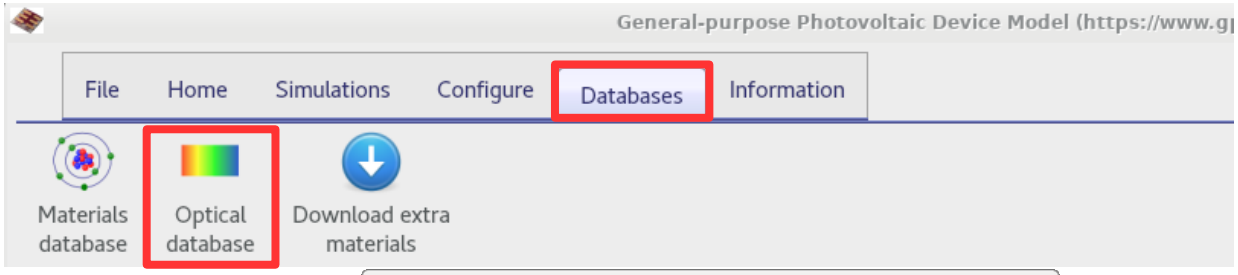
You can also vary the light source.



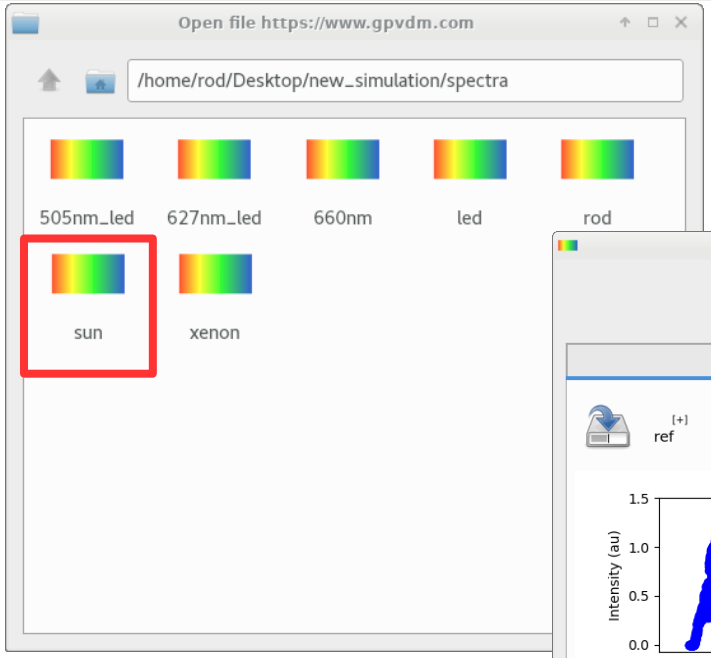
- Try rerunning the simulation with the xenon lamp.

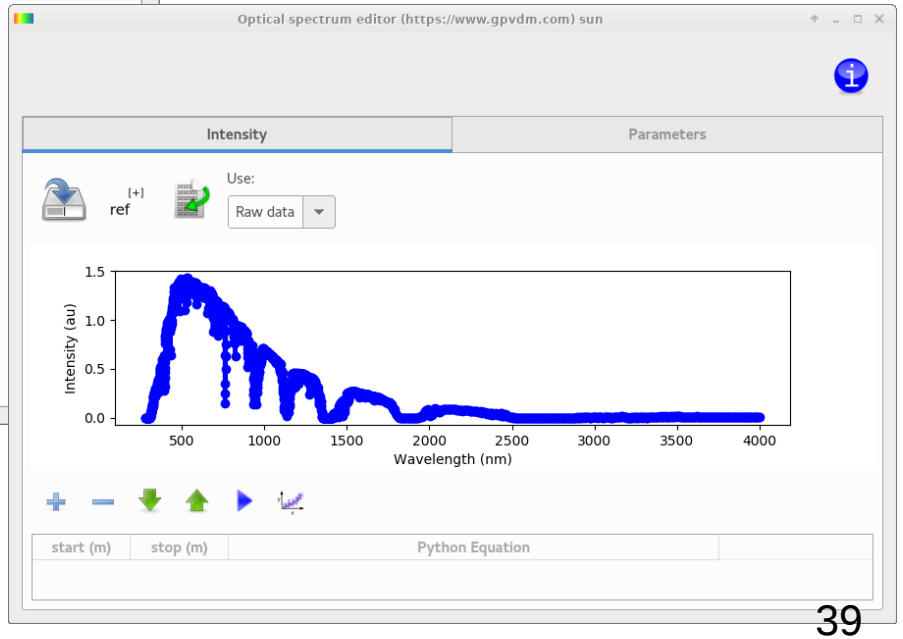
- How does the Photon distribution change?

There is a database of light sources, you can edit it, it is far from exhaustive….

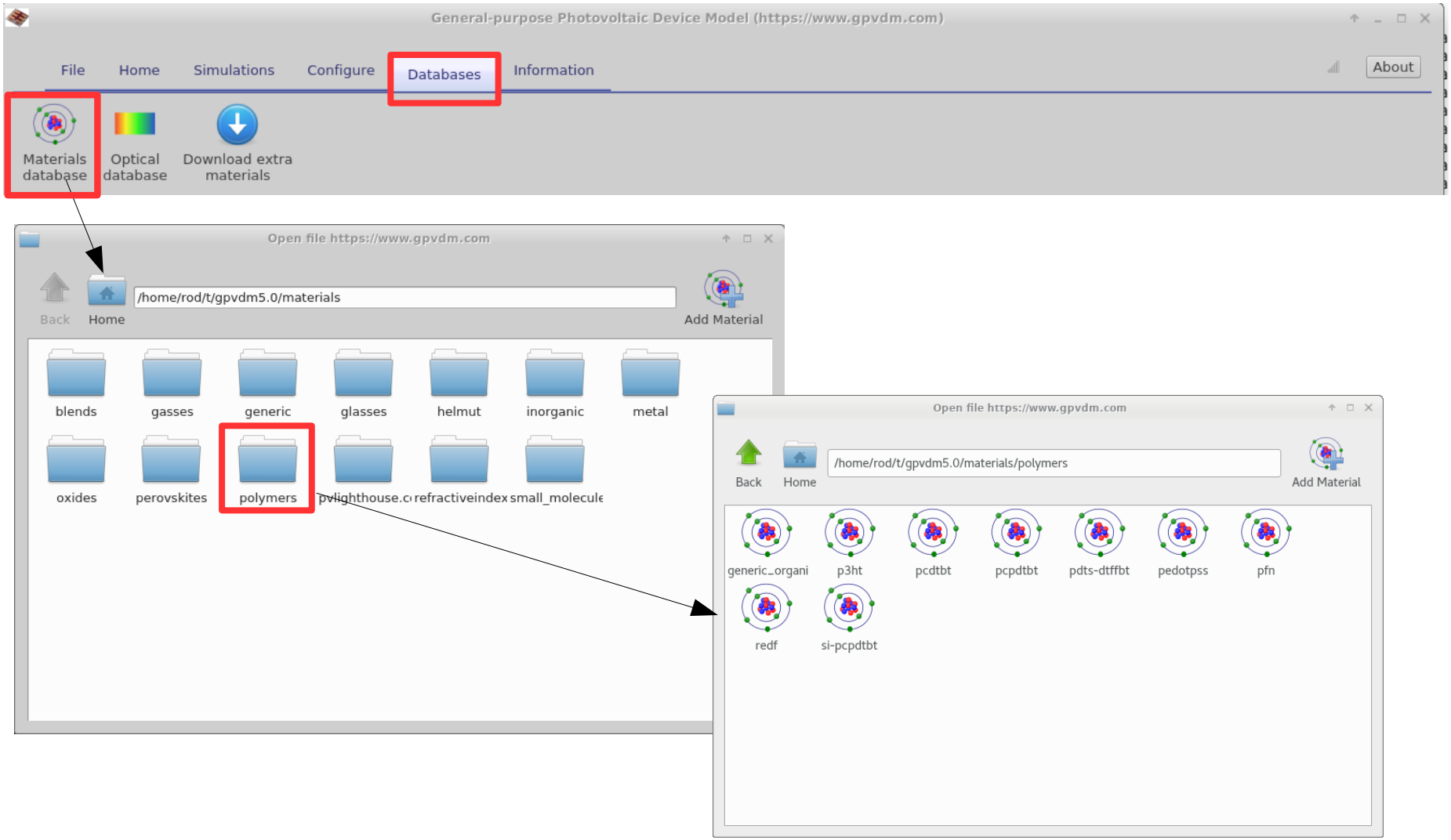


- But you can add your own light sources if you want to...

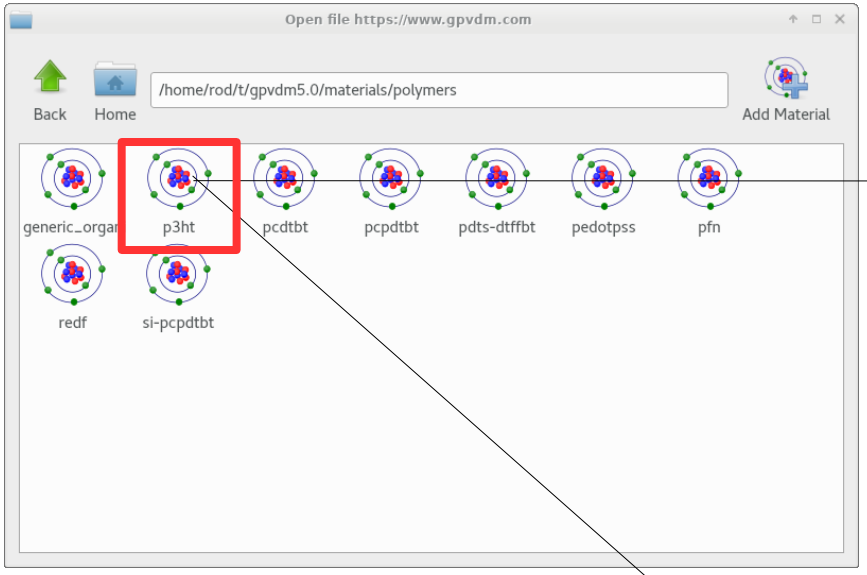


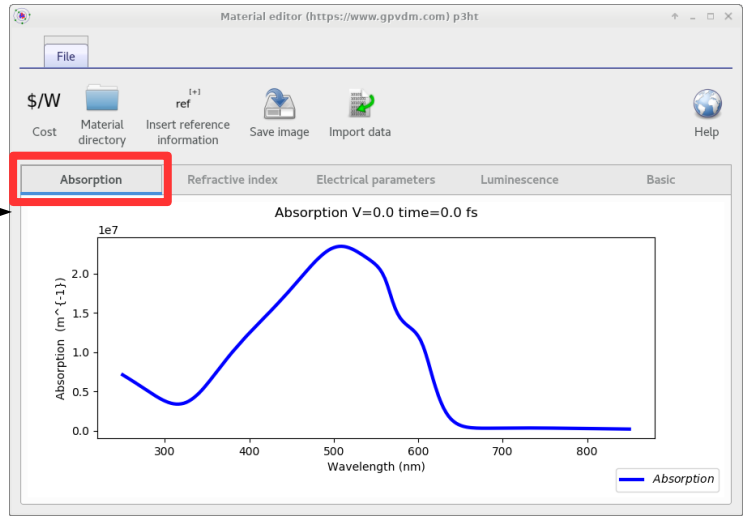


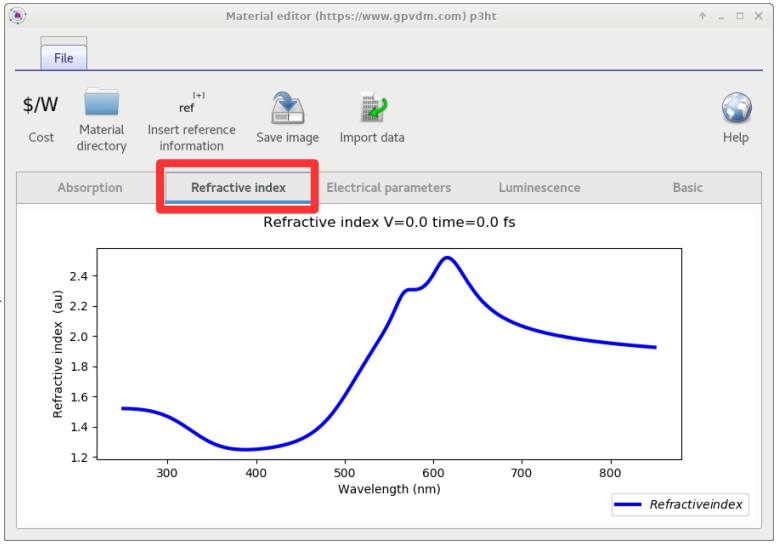
There is also a materials database..



The materials database



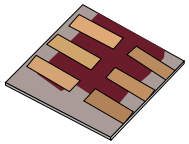




- Each material has n/alpha data stored for it.

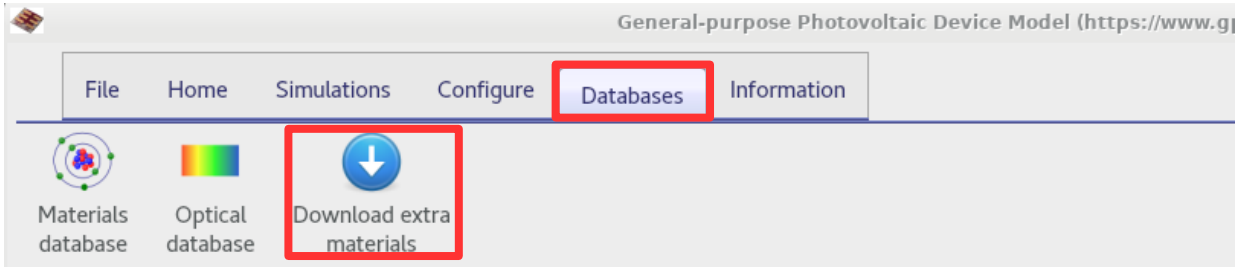
- By default I have included a small subset of materials I use for my simulaions.

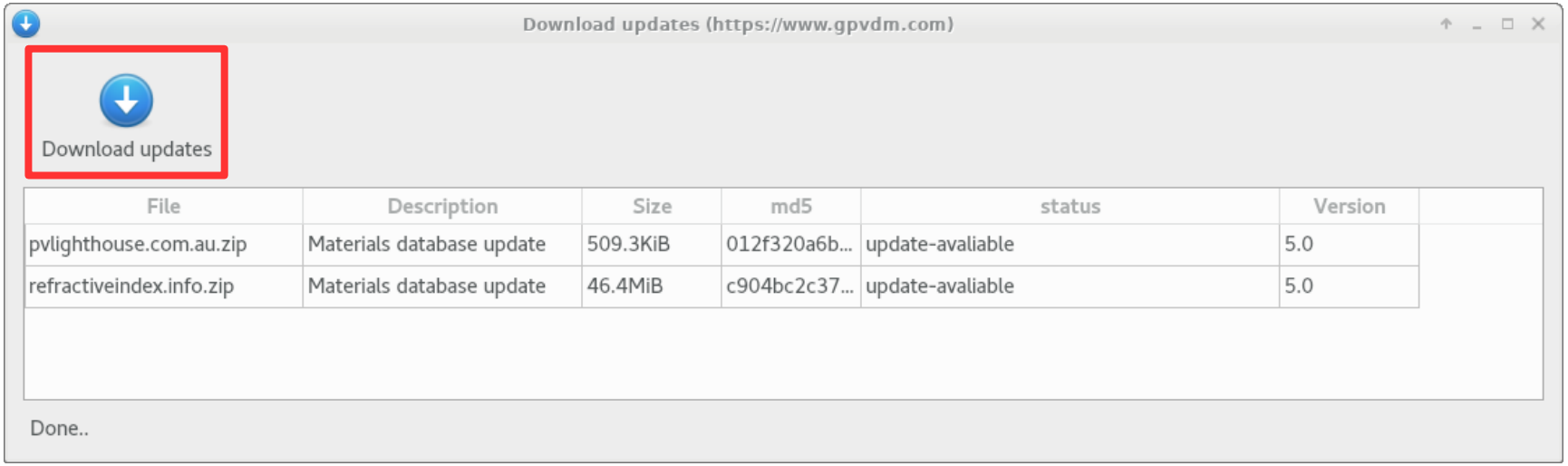
Getting (lots) more materials



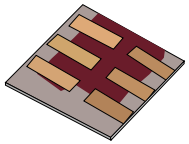
- There is also data from https://www.pvlighthouse.com.au (Keith McIntosh) and refractiveindex.info (Mikhail N. Polyanskiy).

- I've included this as an add on pack.





Making a new material, the hard way...



•If you want to add new material, just copy the a directory containing an old material to a new one i.e.:

```
cp c:\gpvdm\materials\polymers\p3ht c:\gpvdm\materials\polymers\new_material -rf
```

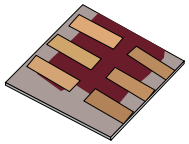
•Each material contains about 10 files, the only ones you really need to care about are ***alpha.omat***, and ***n.omat***

```
[rod@rodlinuxbox p3ht]$ ls -all
total 60
drwxr-xr-x.  2 rod rod 4096 Feb 28 13:05 .
drwxrwxr-x. 11 rod rod 4096 Oct 16 21:37 ..
-rw-r--r--   1 rod rod 6232 Oct 16 21:37 alpha.omat
-rw-------   1 rod rod  308 Oct 16 21:37 alpha.ref
-rw-rw-r--   1 rod rod 4856 Oct 16 21:37 cost.xlsx
-rw-------   1 rod rod  714 Oct 16 21:37 dos.inp
-rw-r--r--   1 rod rod  144 Oct 16 21:37 fit.inp
-rw-r--r--   1 rod rod  186 Oct 16 21:37 mat.inp
-rw-r--r--   1 rod rod 6256 Oct 16 21:37 n.omat
-rw-r--r--   1 rod rod  475 Oct 16 21:37 n.oplot
-rw-------   1 rod rod  308 Oct 16 21:37 n.ref
-rw-------   1 rod rod  100 Oct 16 21:37 pl.inp
[rod@rodlinuxbox p3ht]$
```

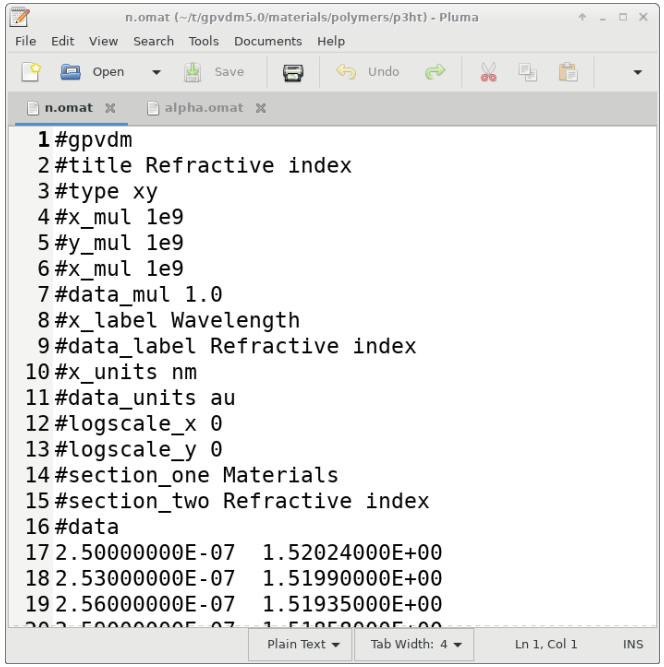
•****.ref*** files tell you where the data in the file came from

•***dos.inp*/*pl.inp*** files contain the the default electrical parameters for, realistically you are going to have to tune these through fitting anyway… so ignore the files during materials creation.

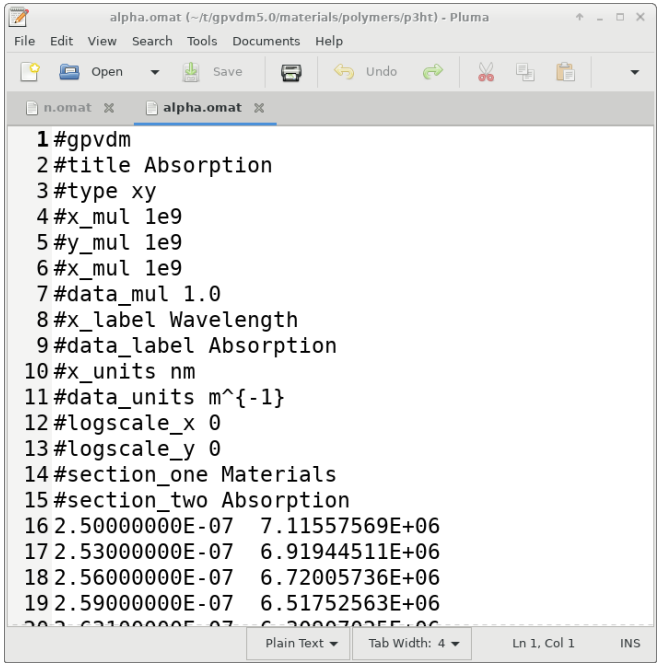
n.omat and alpha.omat files look like this...



- n.omat



- alpha.omat



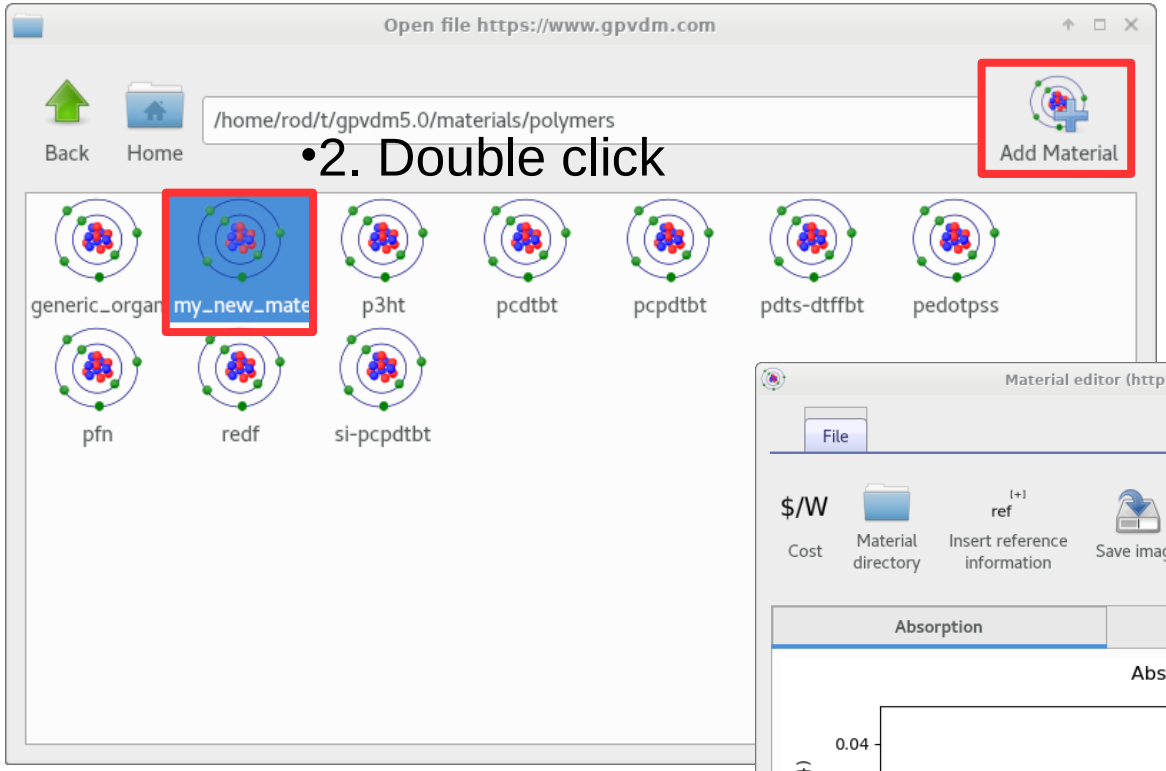
There is a header which you can leave alone, then there are two columns:

n.omat: wavelength (meters) refractive index

alpha.omat: wavelength (meters) Absorption in (m^{-1})

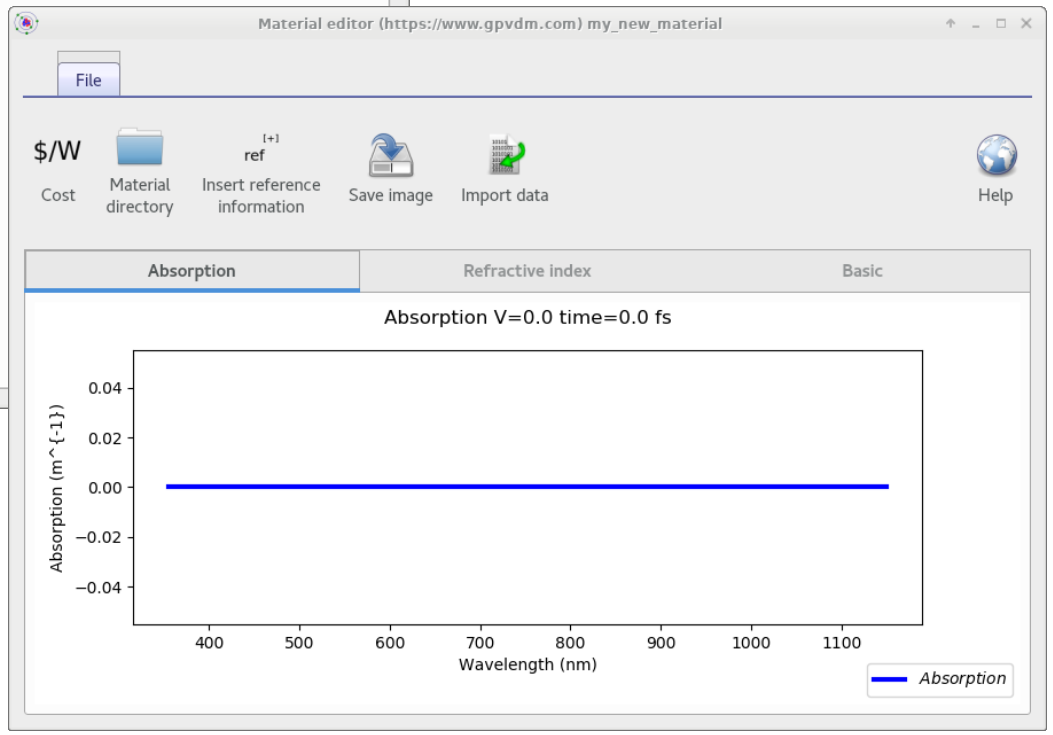
Replace the data with your new data.

Making a new material the easy way...



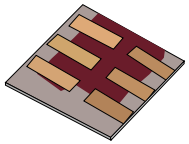
•1. Click

•2. Double click



•The material file has no data….

Let's get hold of some data to import…, usually you would get this from experiment.



- Download this zip archive https://gpvdm.com/demo/materials.zip and UNZIP it.

- You should have two files….

k.dat (~/t/gpvdm5.0/materials/blends/ptb7pc70bn

File Edit View Search Tools Documents Help

Open Save

k.dat n.dat

```
 1 #wavelength k
 2 251.35  0.61614
 3 252.94  0.61523
 4 254.54  0.61951
 5 256.13  0.6179
 6 257.73  0.61311
 7 259.32  0.60845
 8 260.92  0.60482
 9 262.51  0.59722
10 264.11  0.59348
11 265.7   0.58948
12 267.3   0.5807
13 268.89  0.58519
```

Plain Text Tab Width: 4 Ln 1, Col 1 INS

n.dat (~/t/gpvdm5.0/materials/blends/ptb7pc70bn

File Edit View Search Tools Documents Help

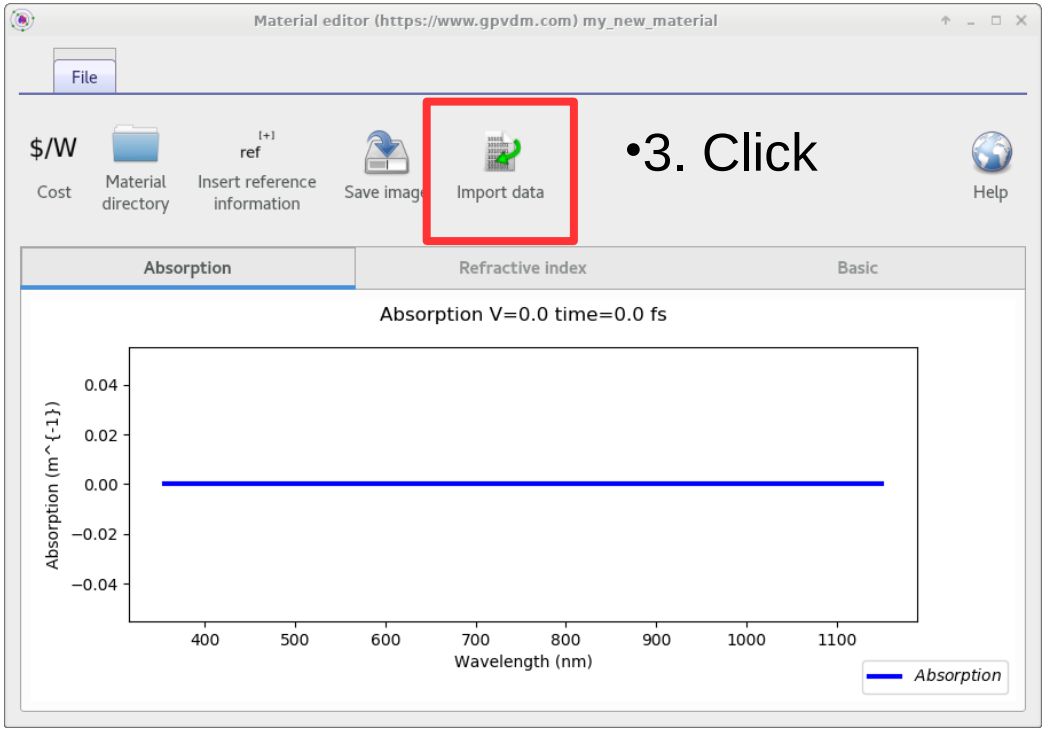
Open Save

k.dat n.dat

```
 1 251.35  1.73515
 2 252.94  1.73988
 3 254.54  1.74155
 4 256.13  1.74679
 5 257.73  1.76971
 6 259.32  1.77795
 7 260.92  1.79008
 8 262.51  1.80517
 9 264.11  1.80383
10 265.7   1.81409
11 267.3   1.83196
12 268.89  1.84133
13 270.49  1.84207
```

Plain Text Tab Width: 4 Ln 1, Col 1 INS

Let’s import k.dat

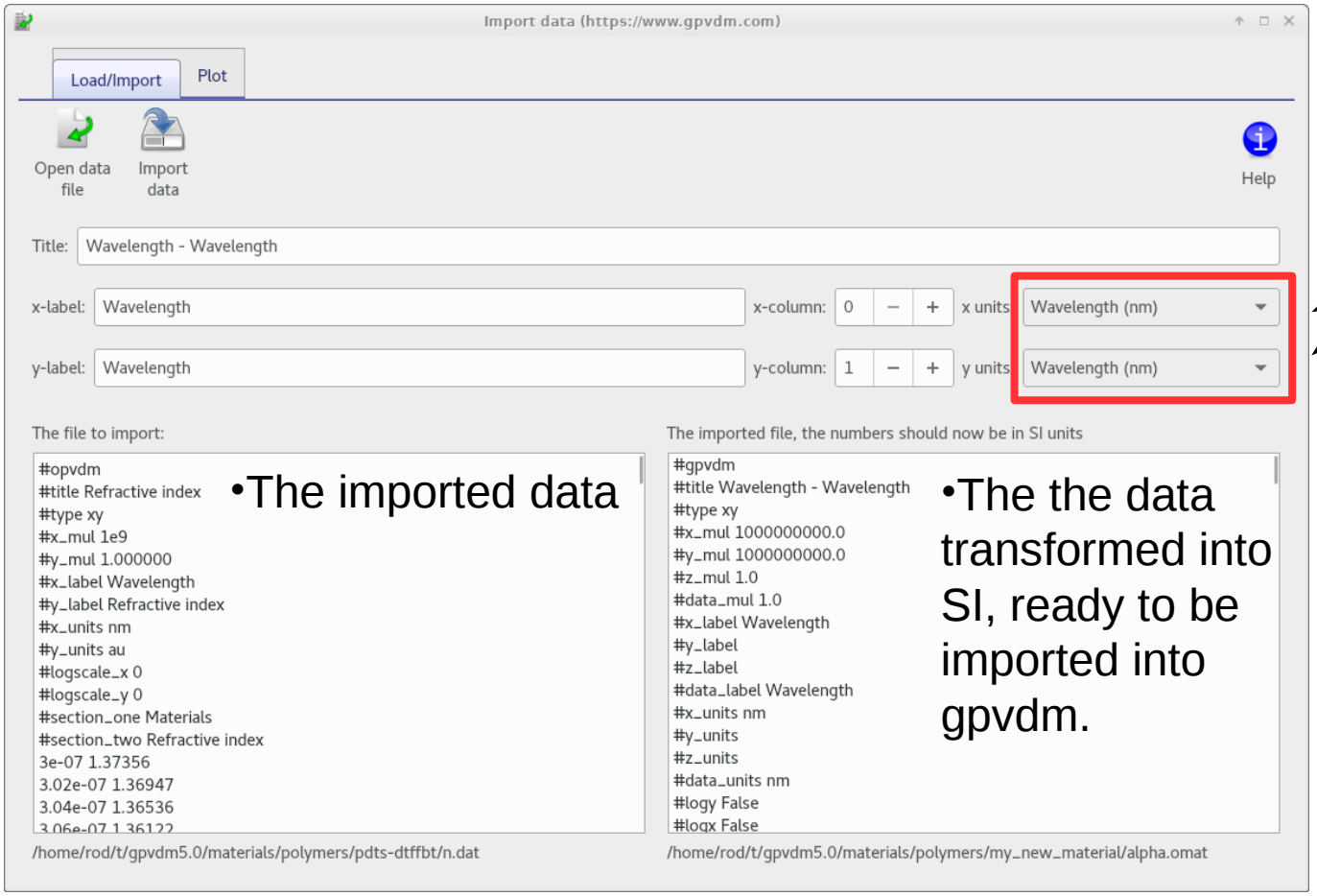


- Note from the previous slide the data is not in SI, so we can’t import is straight into gpvdm.

- **gpvdm can only deal with SI data.**

- Select k.dat to import…, from where ever you extracted n/k.dat

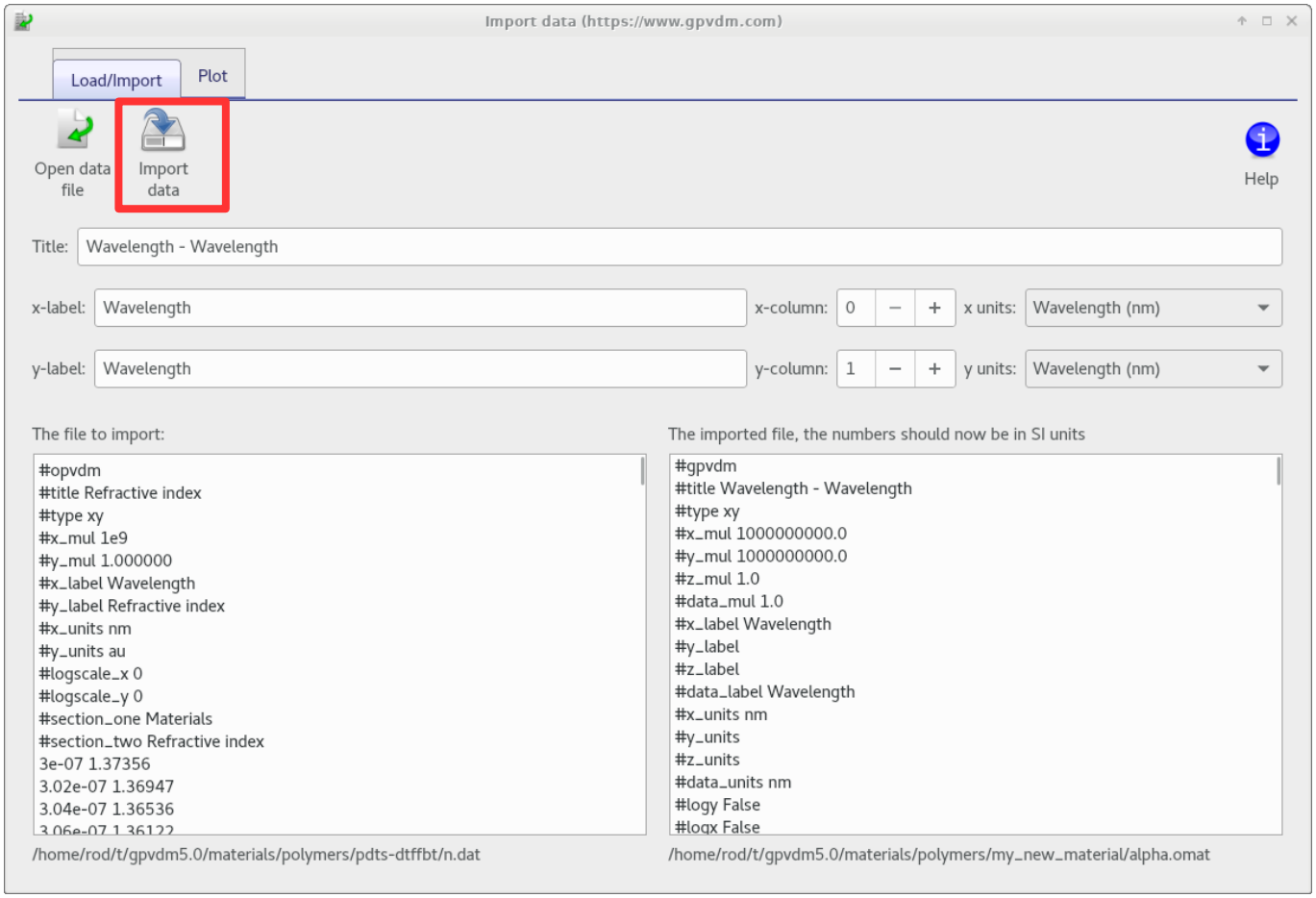
The import window used to convert data to SI



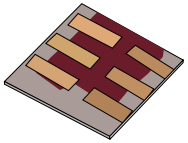
•Set these to the units of the **input file**.

•Set the values to **Wavelength (nm)**, and **Attenuation coefficient (au)**, the RHS will then be in SI, scroll down to inspect the file. Make sure it has been imported correctly

Then click import data and the data will be imported into the new material..



Overview



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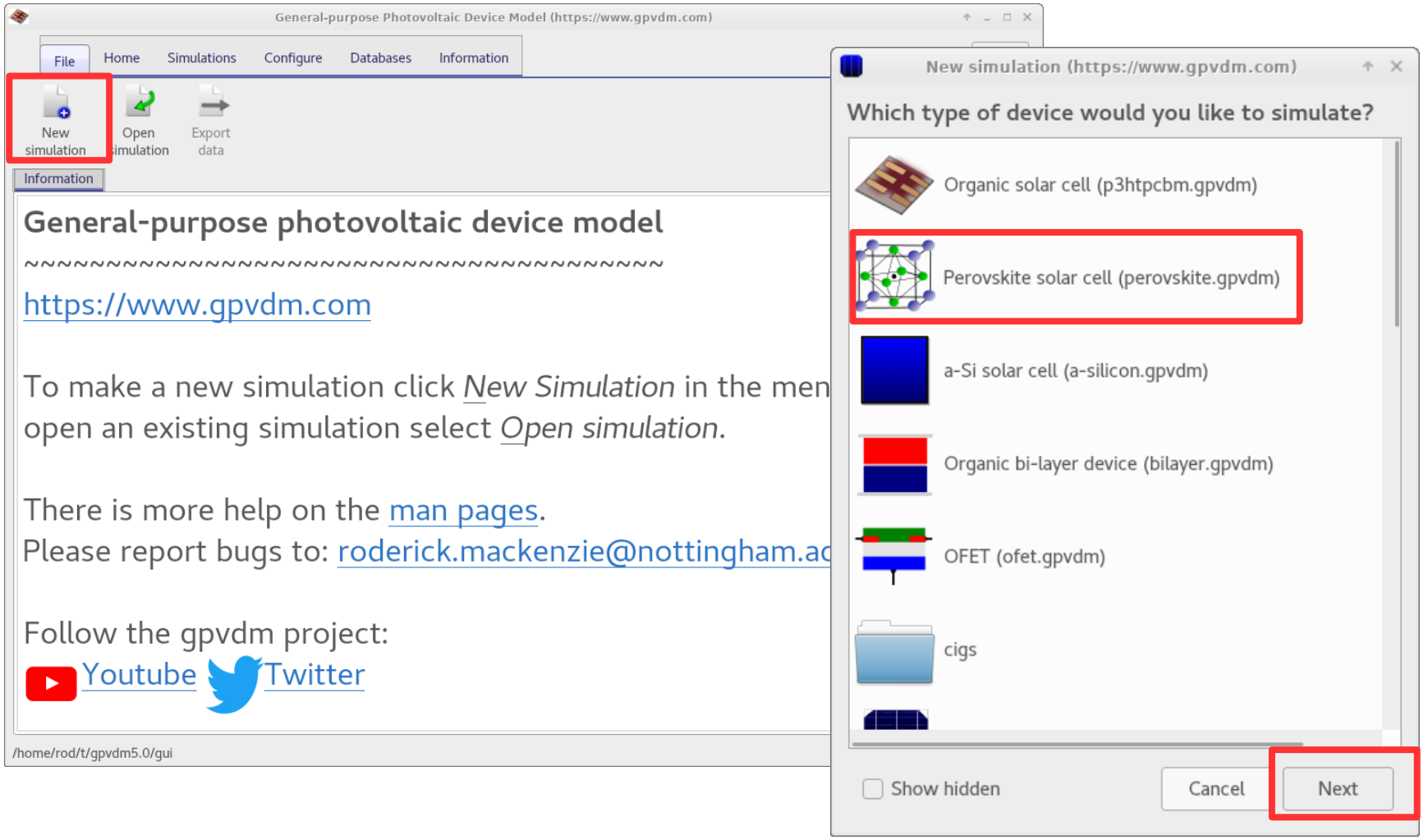
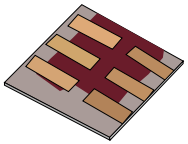
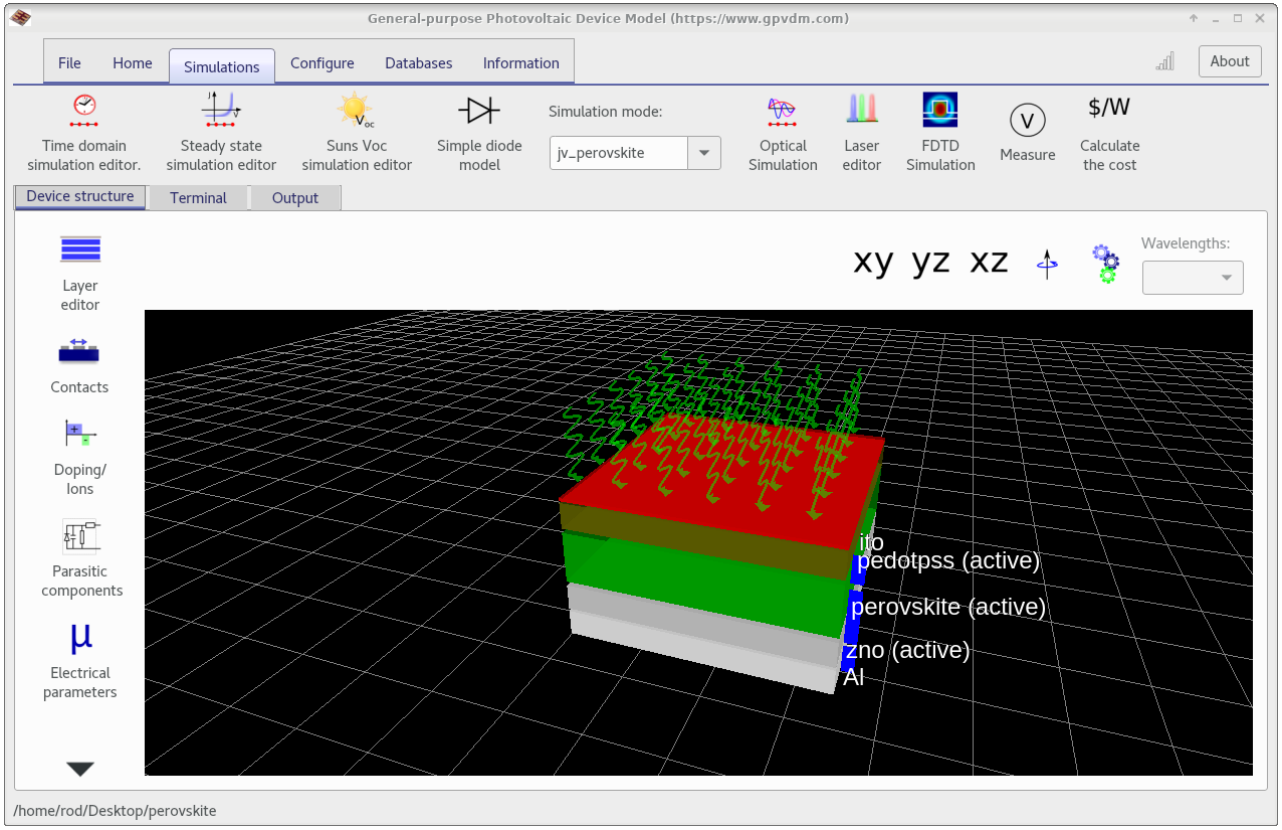
Make a new perovskite simulation



Perovskite solar cells/time domain simulations.

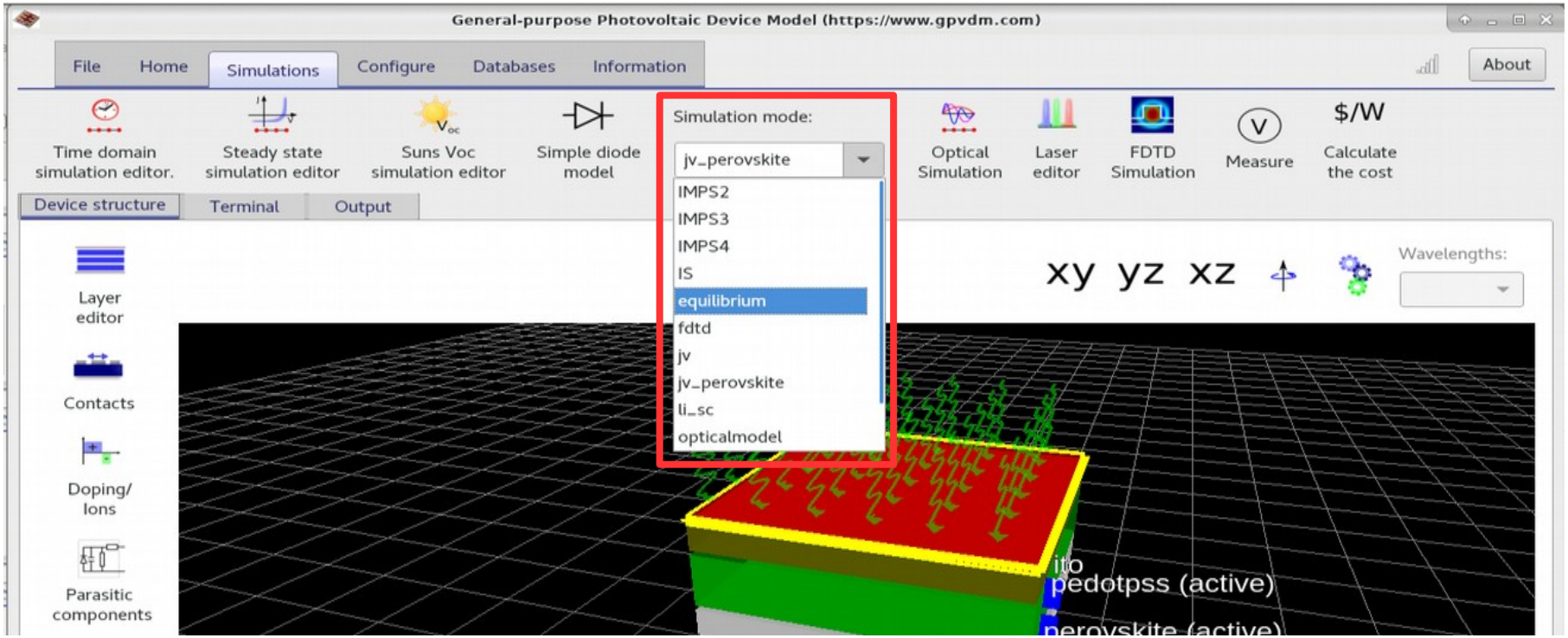




- A JV curve on a Perovskite device is really a time domain simulation due to the movement of ions.

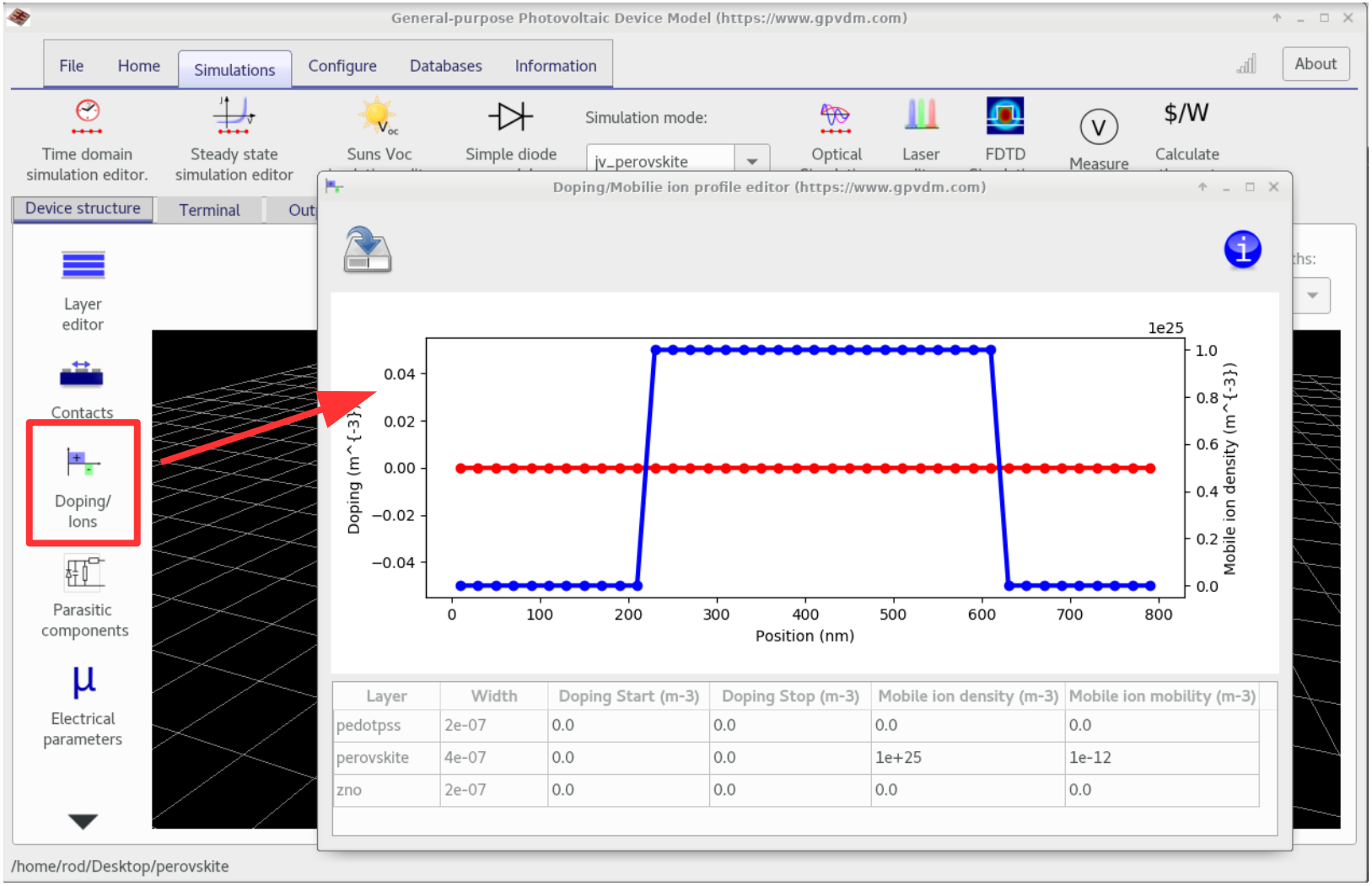
- We will therefore use Perovskite simulations to learn about time domain simulation in gpvdm.

The simulation mode menu

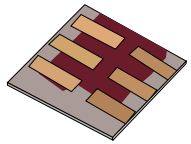


- This menu is used to select the simulation mode.
- The simulations we have performed until now were in ***jv*** mode, this is a purely steady-state simulation.
- Set the value to ***jv_perovskite,*** this is a time domain simulation including perovskite ions.

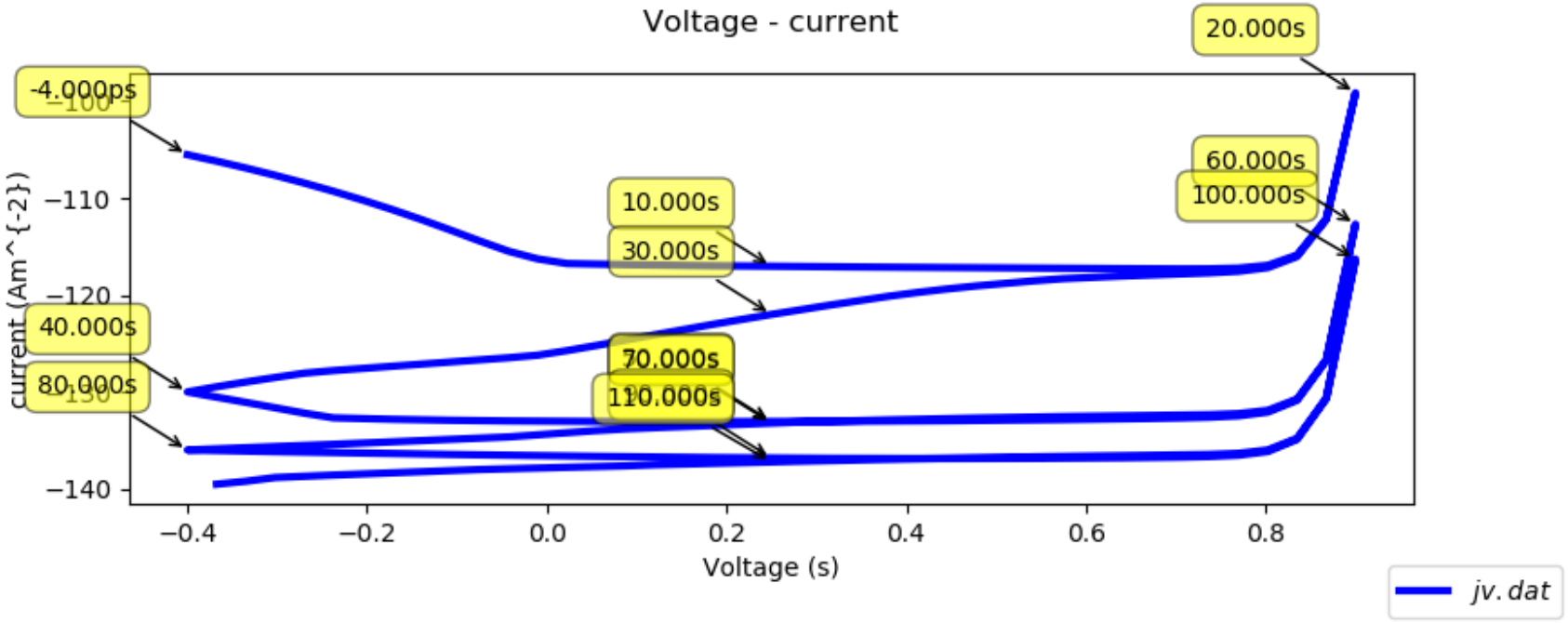
You can edit the density of ions using the ion/doping editor.



Running the simulation...

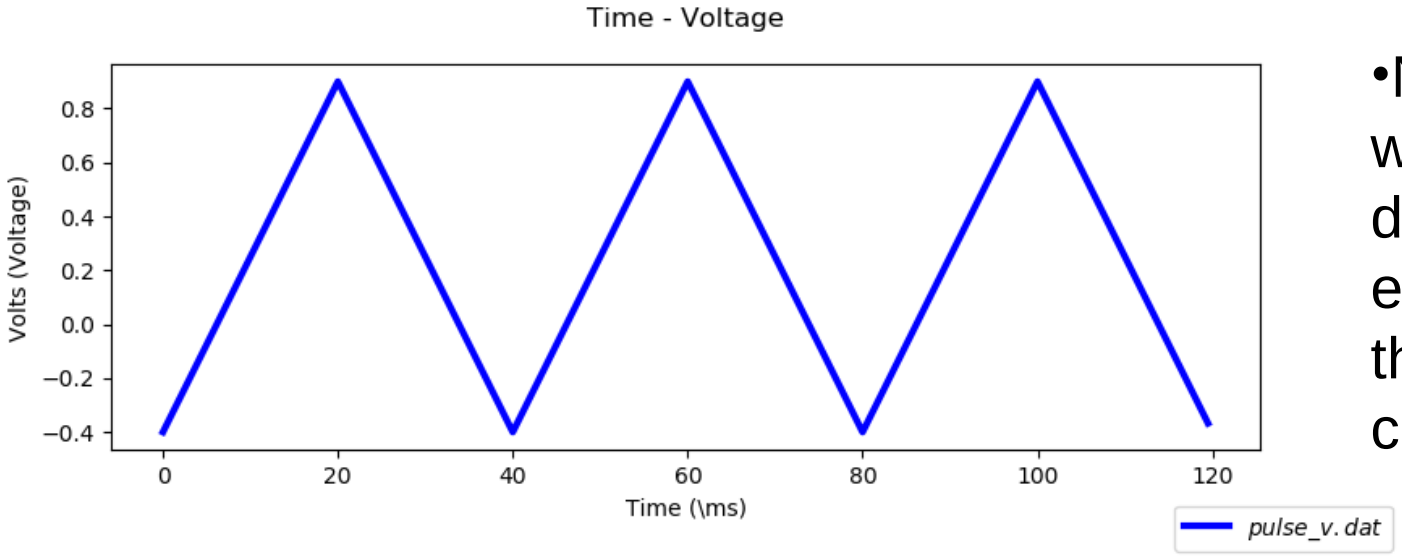


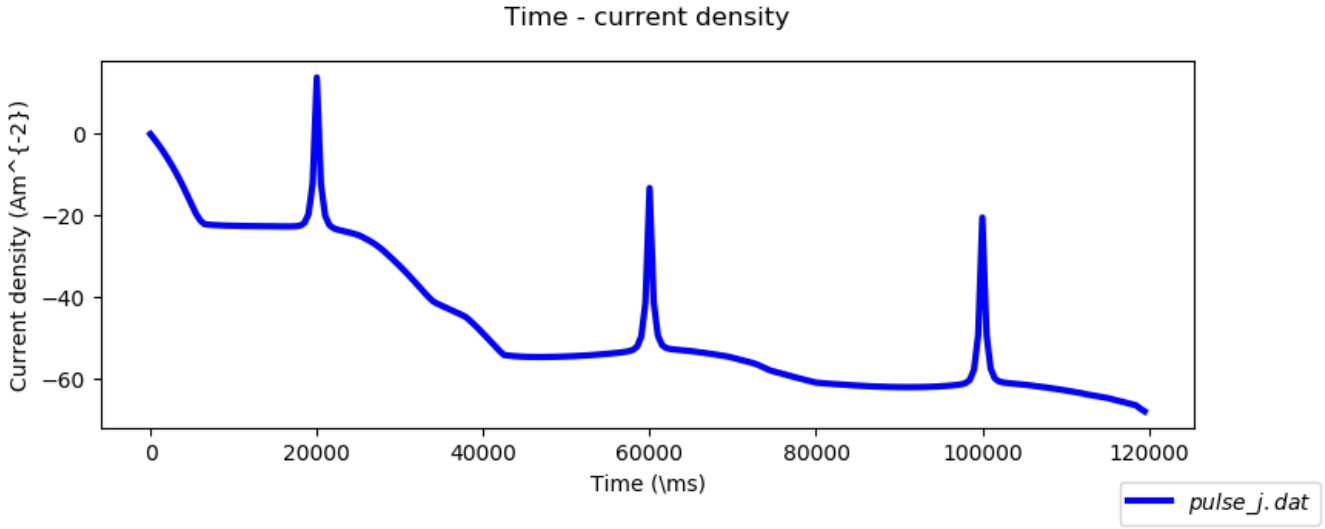
- Run the simulation (blue play button) then open the file ***jv.dat***



- Notice it's a jv curve but it changes as a function of time
- Plot ***pulse_v.dat*** and ***pulse_j.dat***, these plot voltage and current against time.

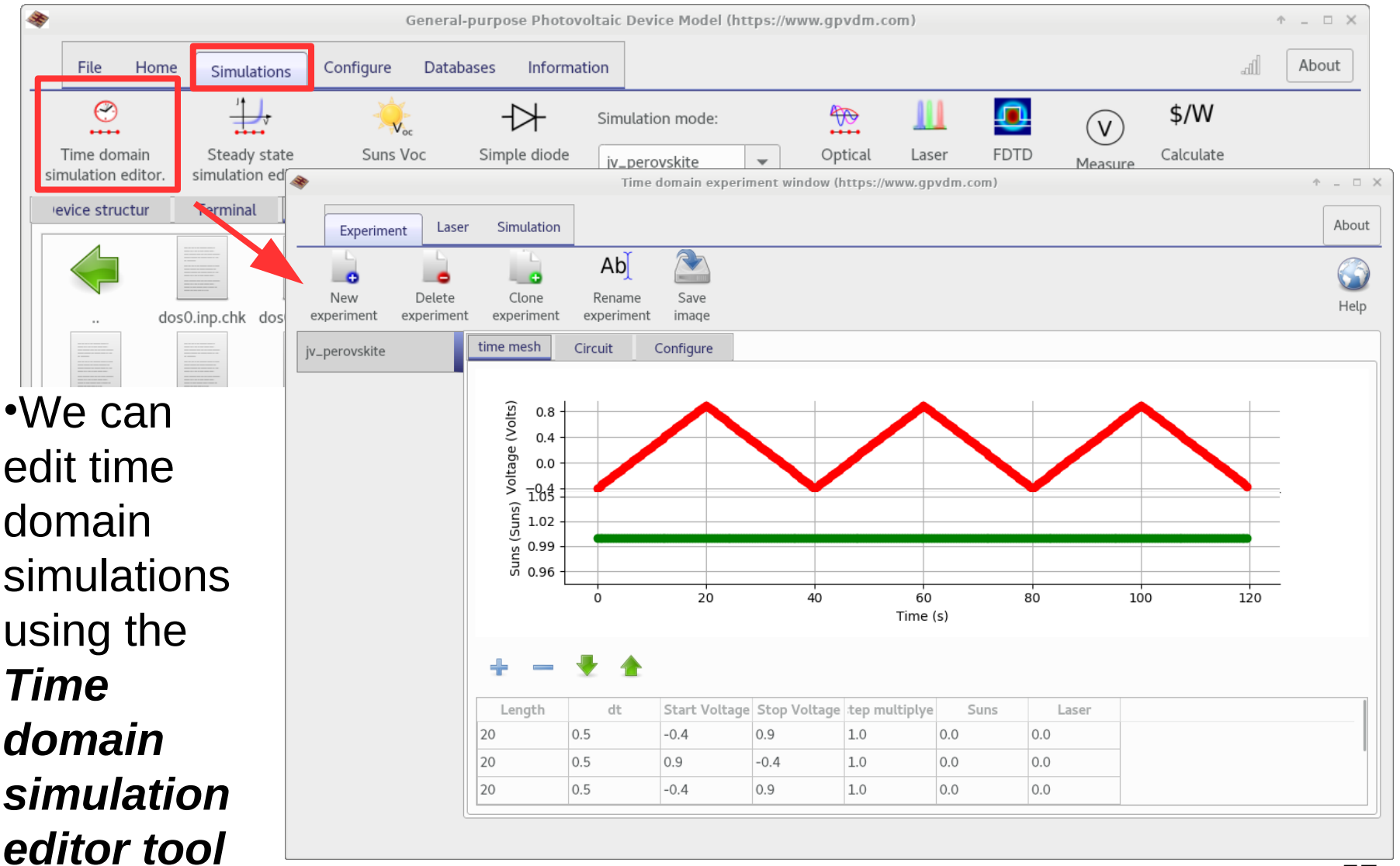
pulse_v.dat, pulse_j.dat Current/voltage against time…..





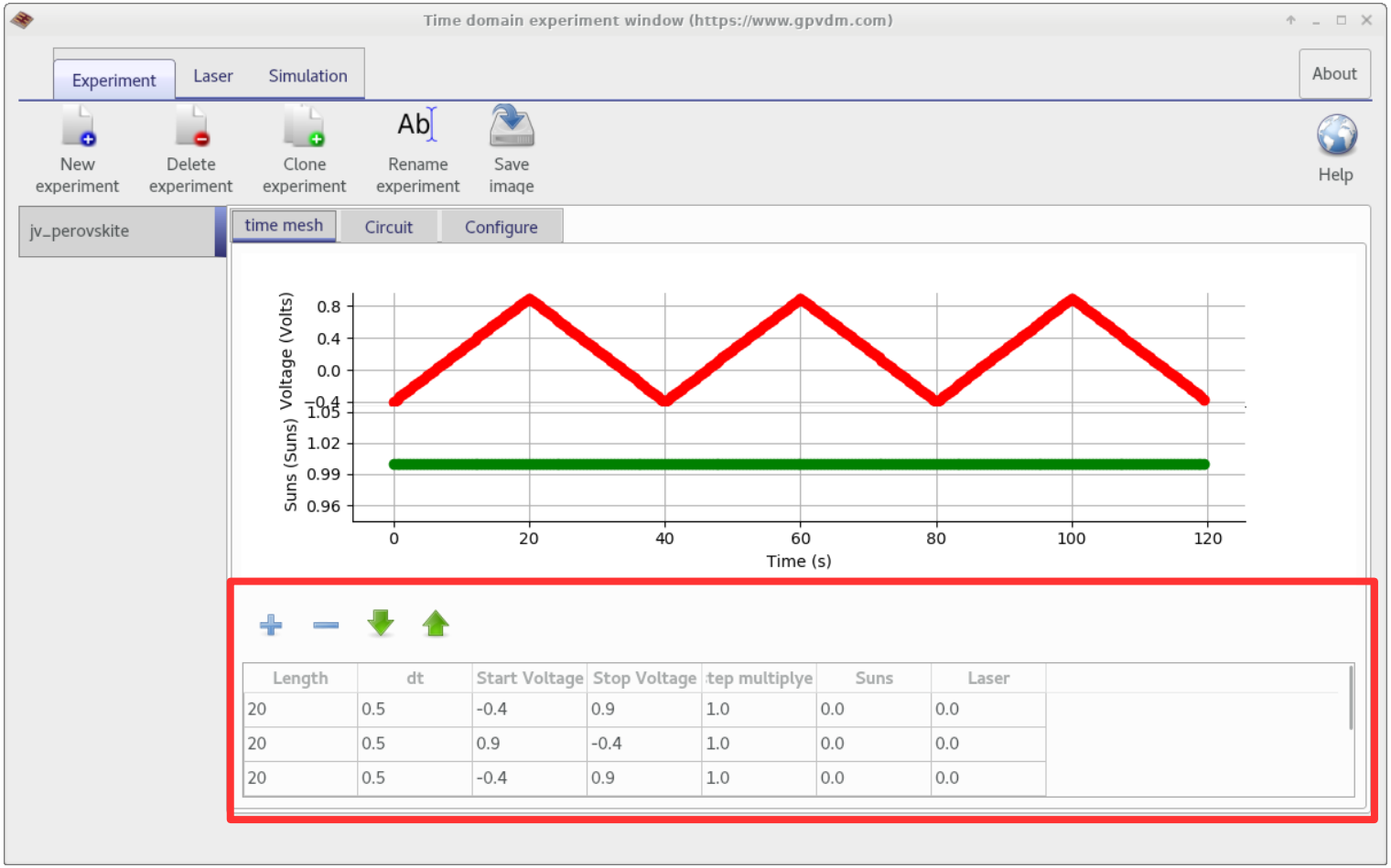
- Notice the saw wave of the time domain JV experiment and the resulting current transient.

Editing time domain simulations

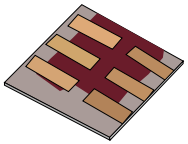


- We can edit time domain simulations using the ***Time domain simulation editor tool***

Edit the applied voltage/light intensity

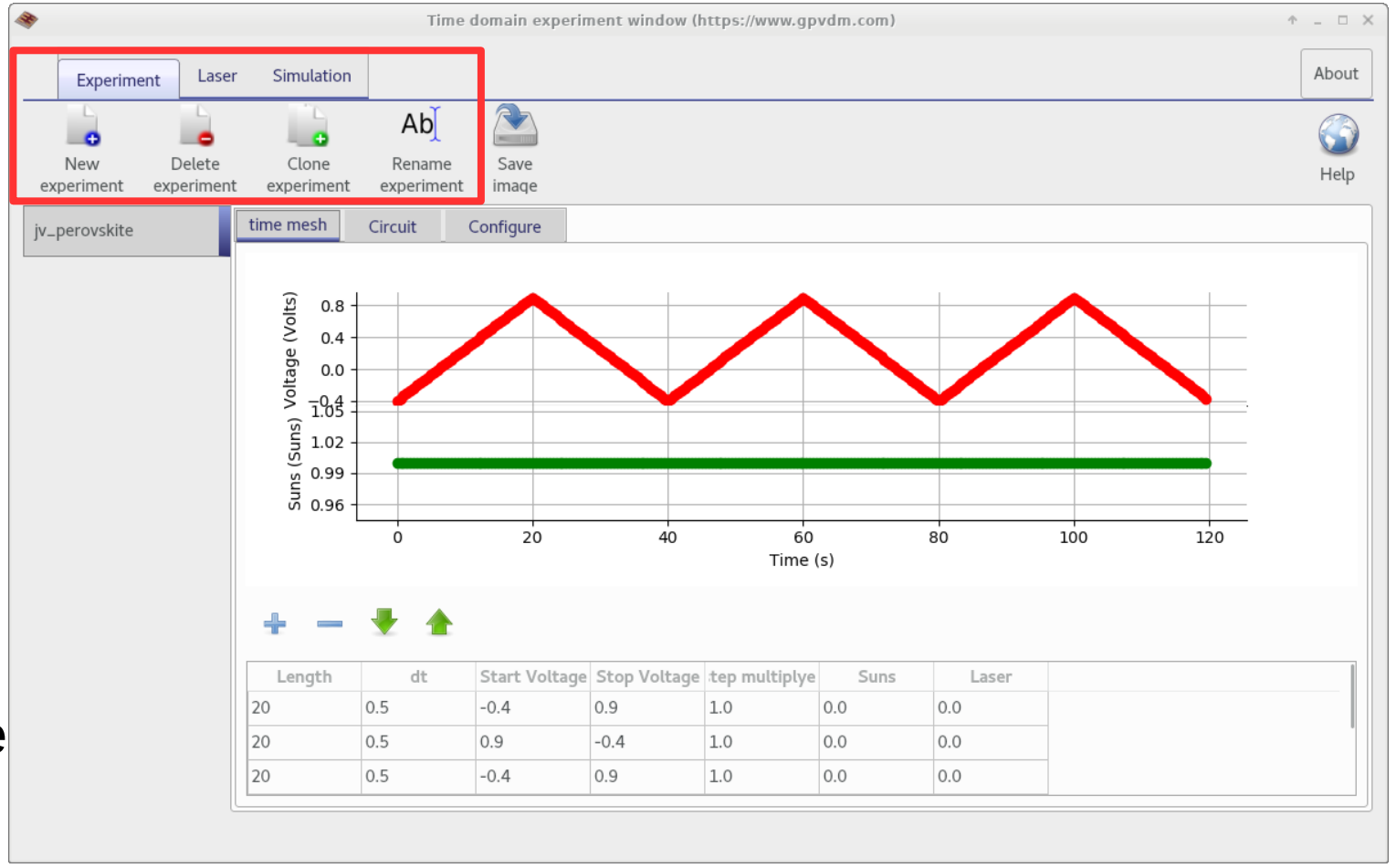


Making new simulations

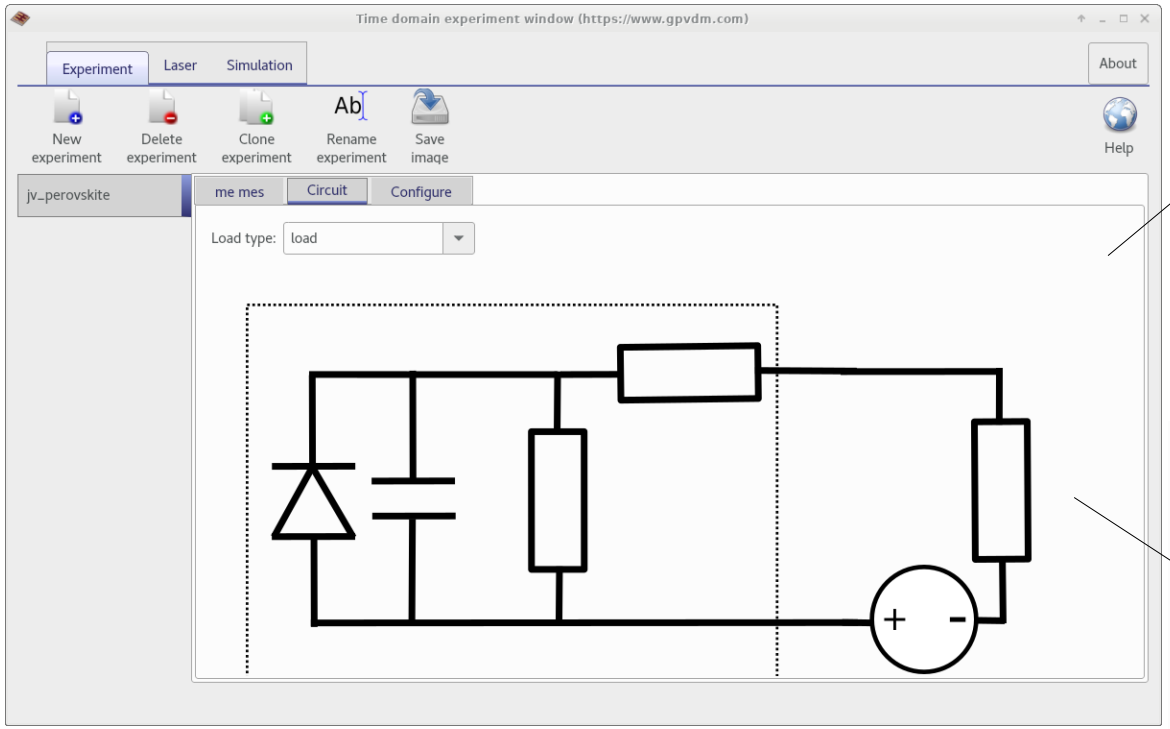


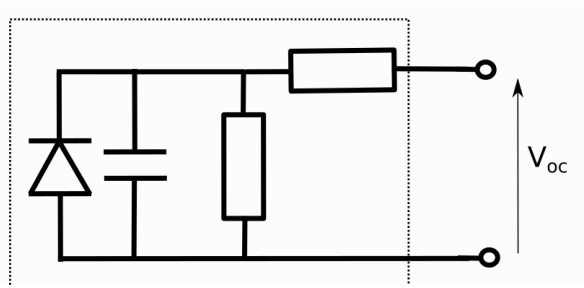
- Use these tools to create new transient simulations

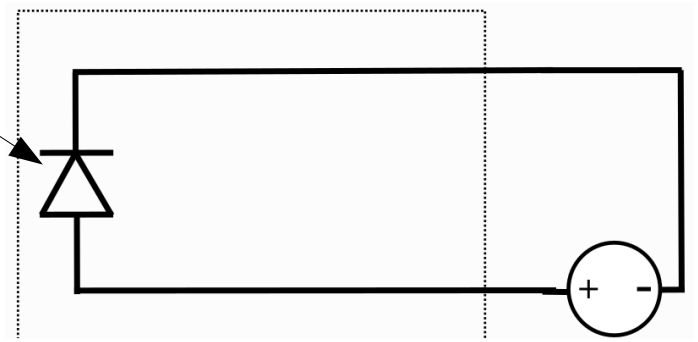
- These new simulations will appear in the ***simulation menu*** in the main interface.



You can change the external circuit conditions using the ***Circuit*** tab

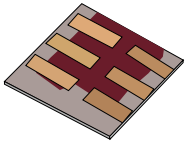






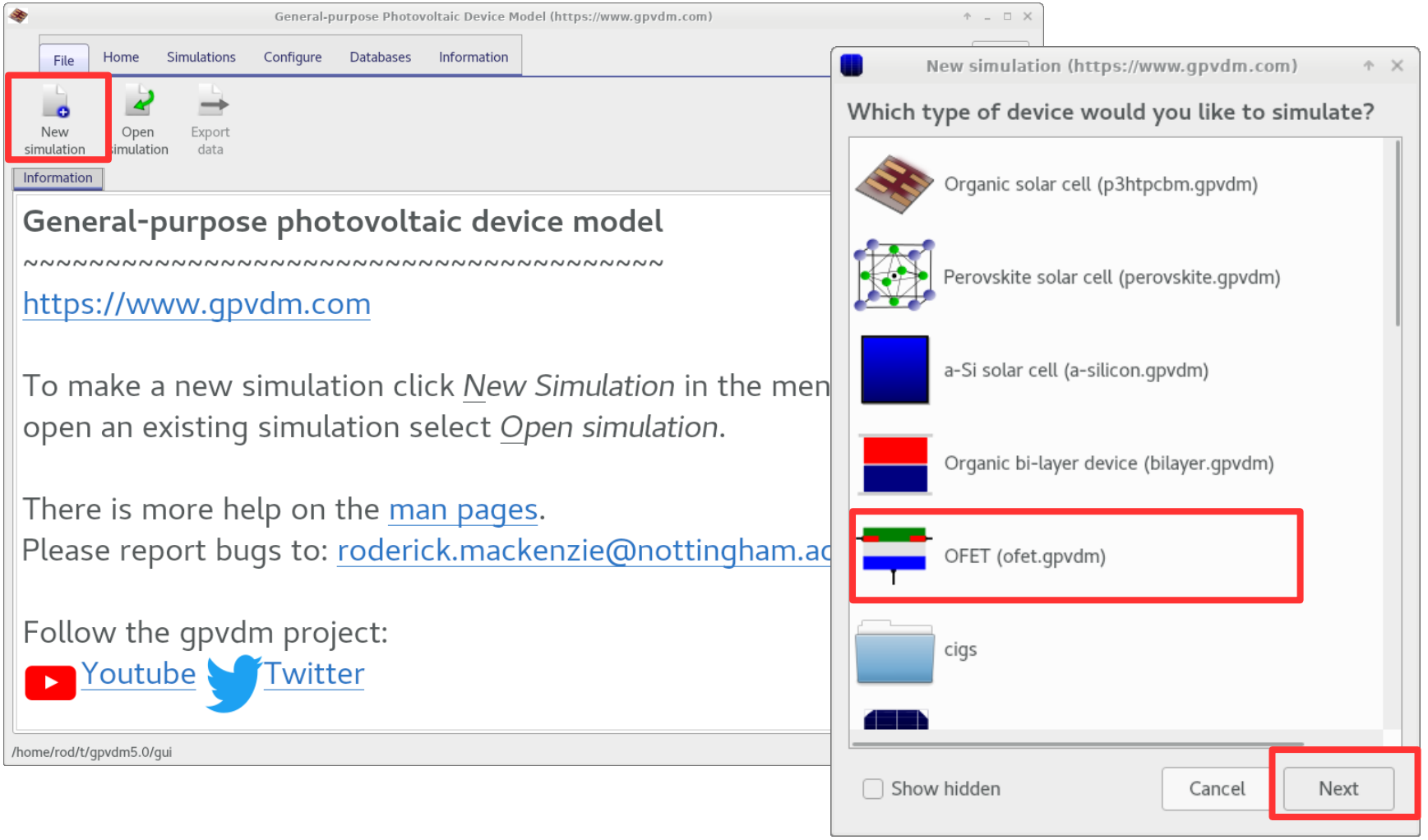
- You could use this to do things like TPC/TPV, where you need short circuit/open circuit conditions.

Overview



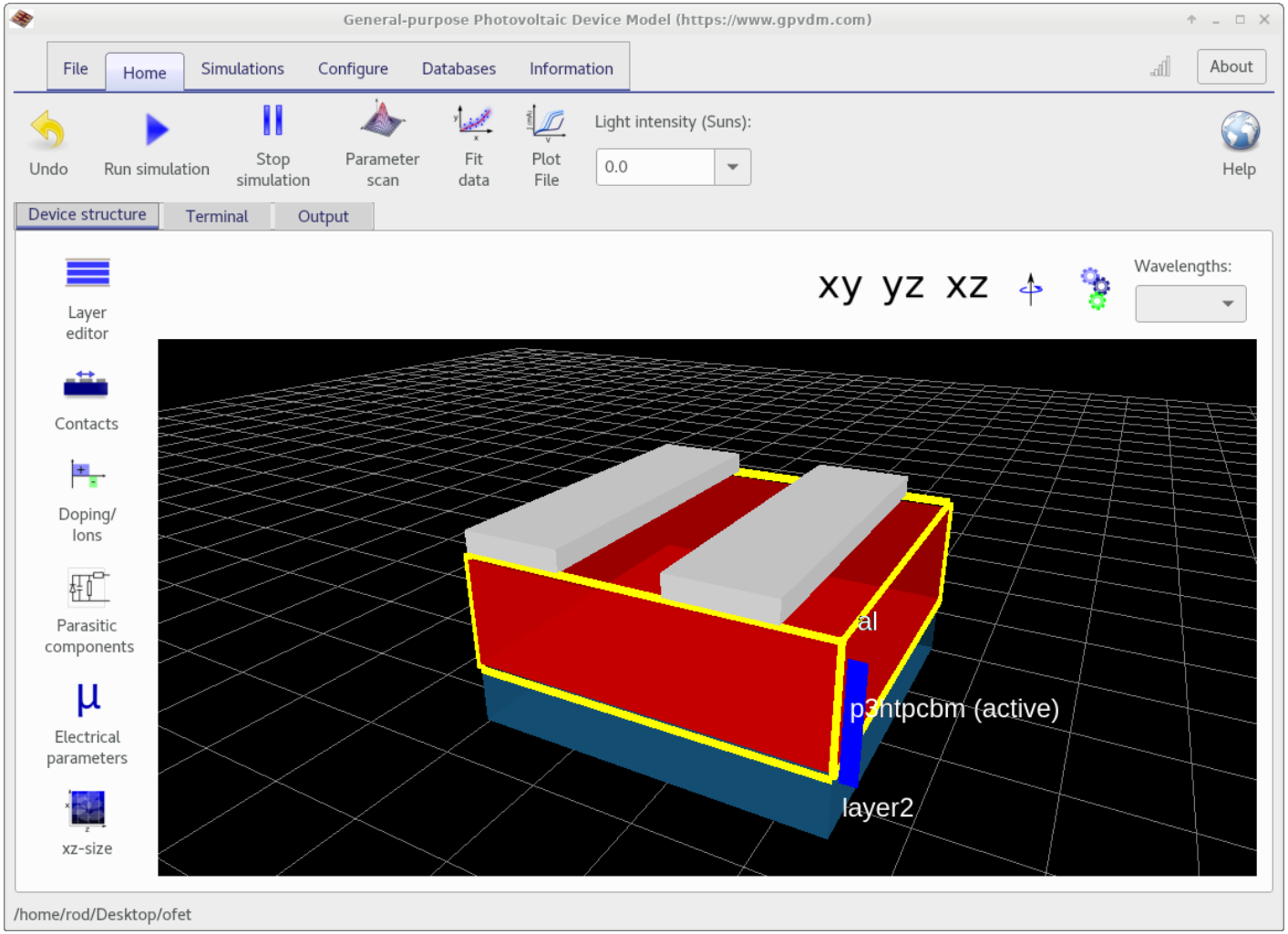
- What is gpvdm/theoretical overview?
- Installing gpvdm
- Running simple simulations
  - Your first gpvdm simulation
  - Changing electrical parameters
- Optical simulations and the materials database
- Perovskite solar cells and time domain simulations
- **OFET simulations and finite difference meshing.**
- Editing the device structure using the layer editor
- Meshing and dumping

Make a new OFET simulation



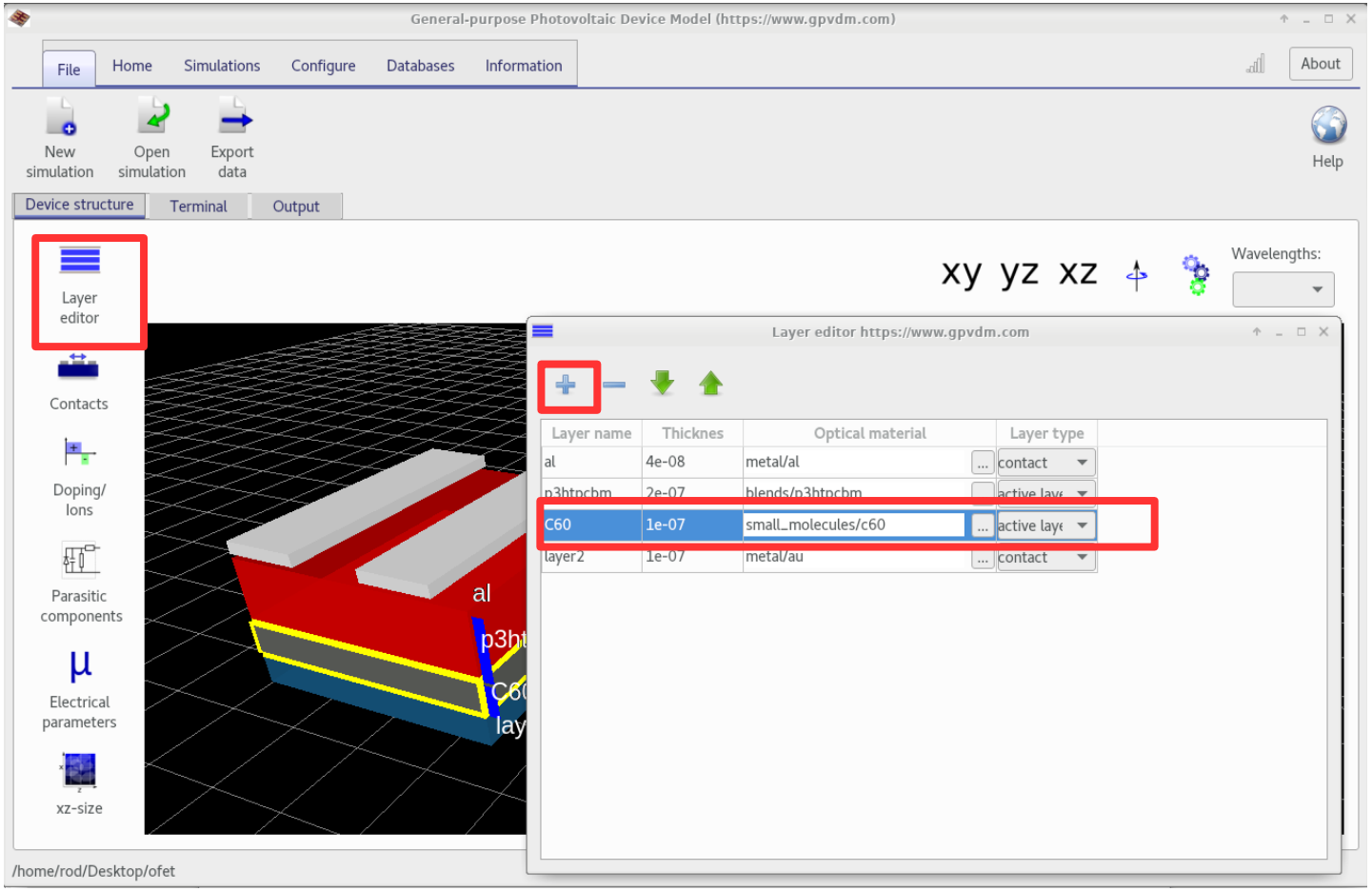
- This will use a 2D solver instead of the 1D solver.

This will create a new 2D simulation



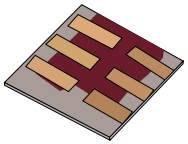
- Notice the contacts which are 2D structures.

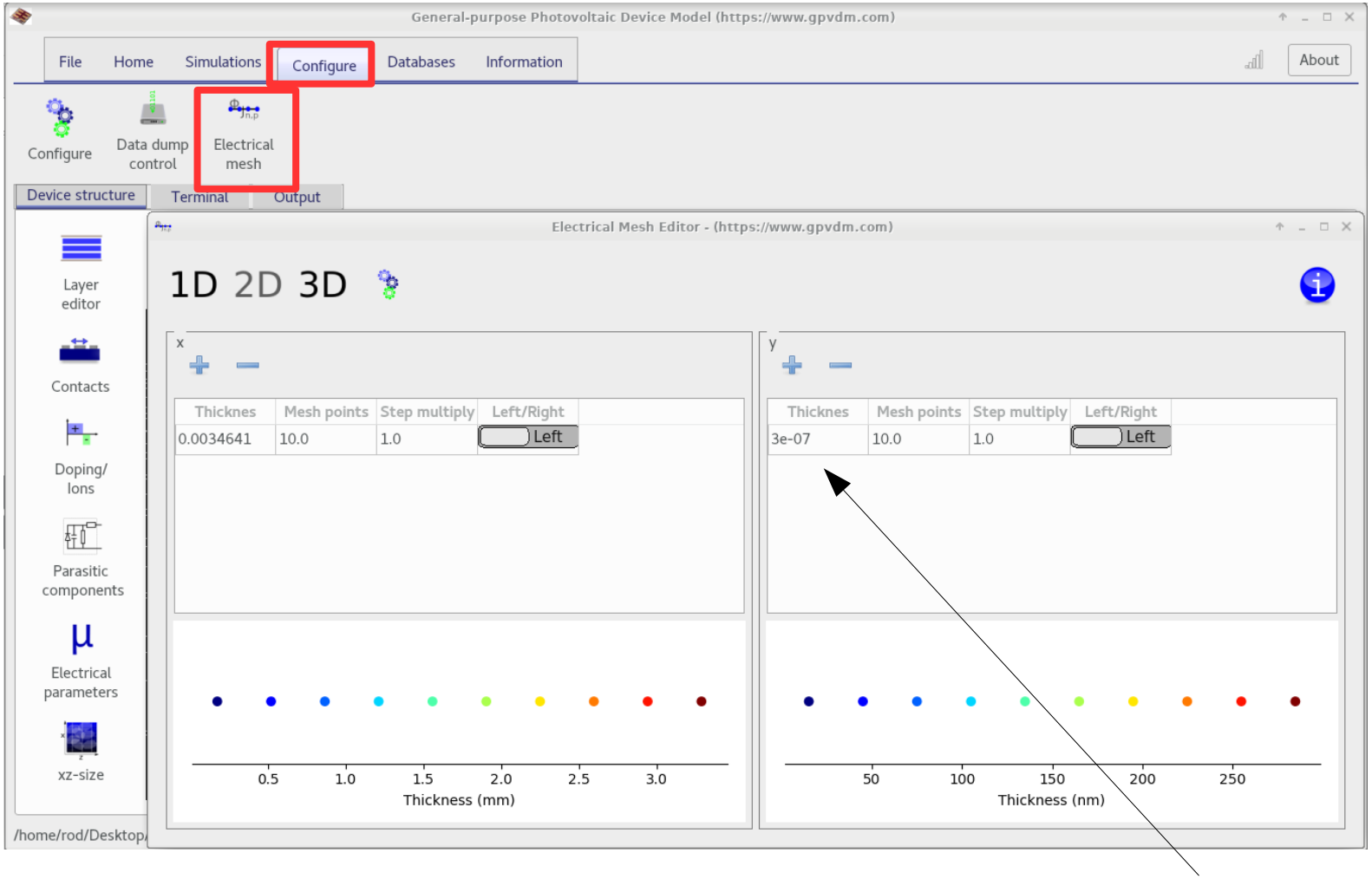
Adding another electrically active layer



- Click on the layer editor and then the +.
- Use the up and down arrows to move the layer to the correct place.

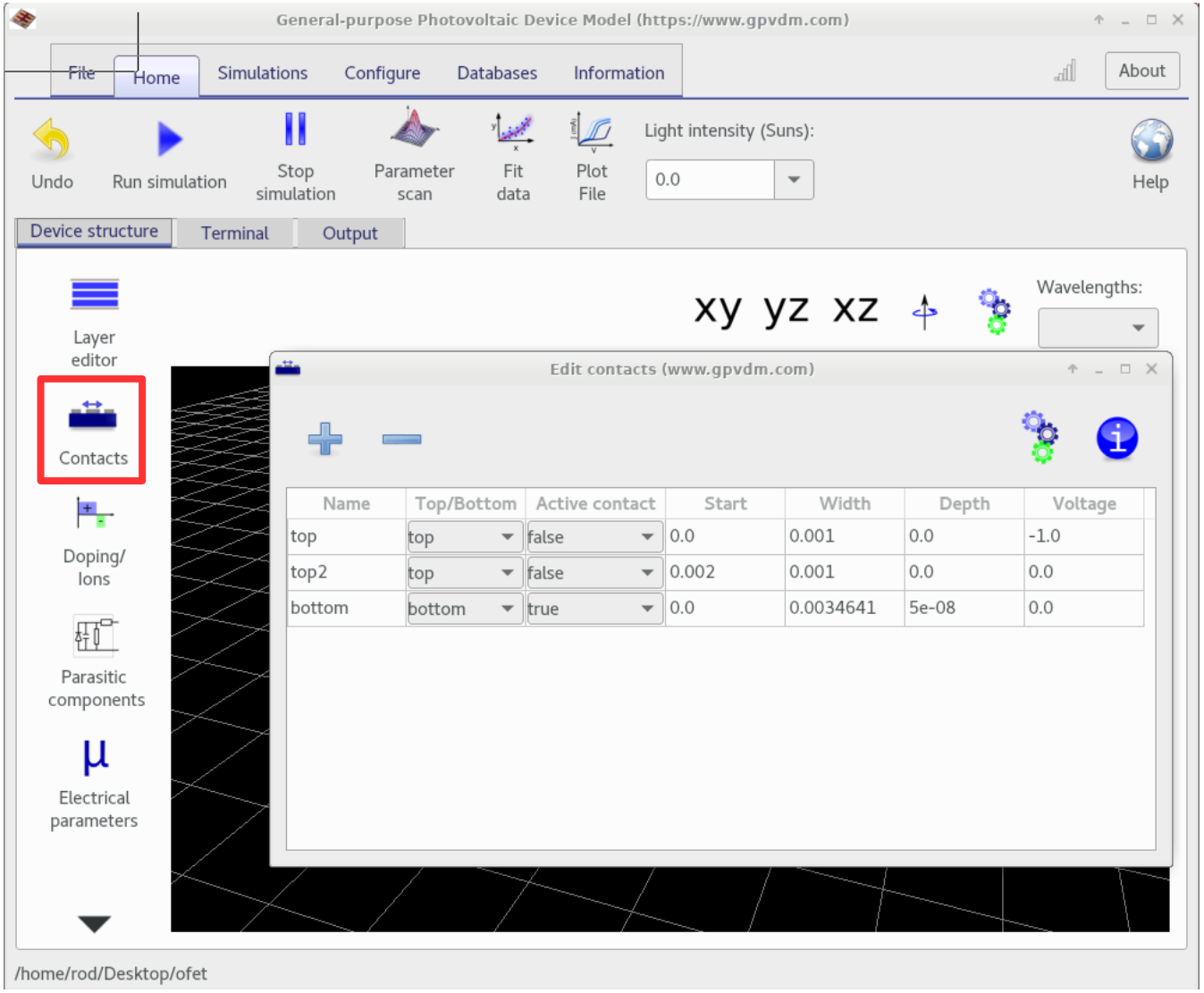
Take a look at the electrical mesh to make sure it adds up to the width/height.



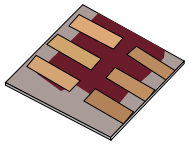


- This values should have updated so that the mesh matches the width of the active layers.

Let’s now look at the contacts

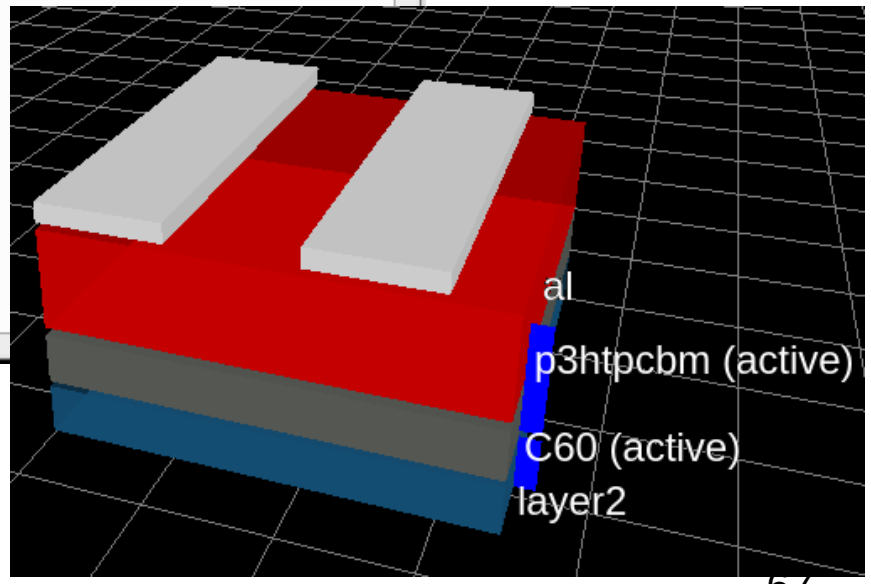


The human readable name of the contact, you can call them what you want.

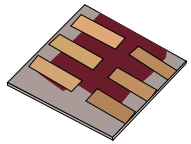


Edit contacts (www.gpvdm.com)

Name	Top/Bottom	Active contact	Start	Width	Depth	Voltage
top	top	false	0.0	0.001	0.0	-1.0
top2	top	false	0.002	0.001	0.0	0.0
bottom	bottom	true	0.0	0.0034641	5e-08	0.0



Is the contact at the top or bottom of the device.



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top	top	false	0.0	0.001	0.0	-1.0
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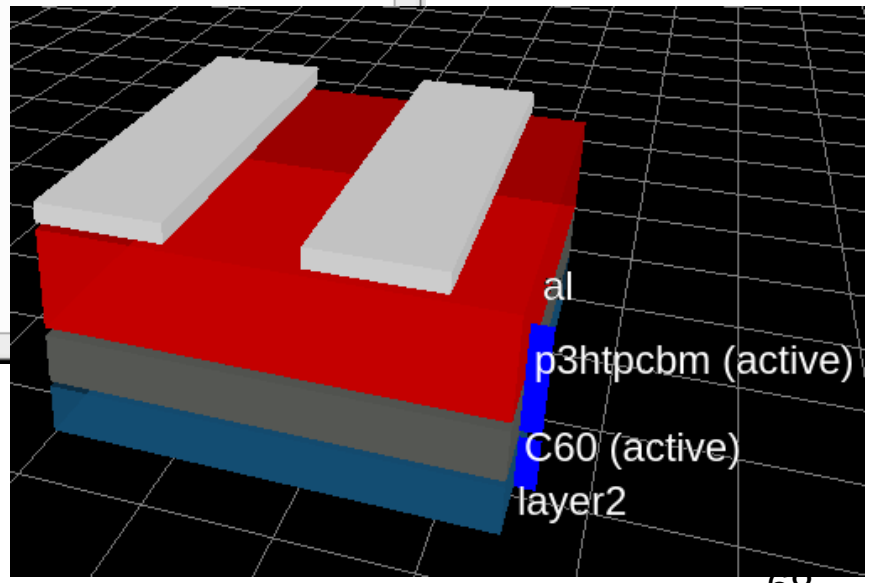
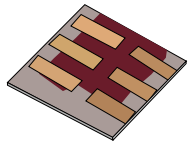


The contact to which the voltage ramp/transient/frequency pulse is applied.



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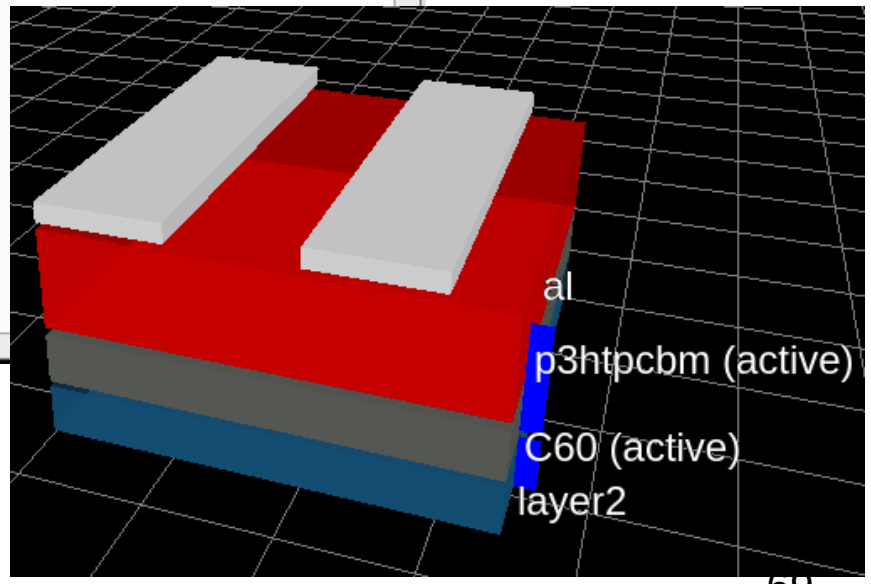
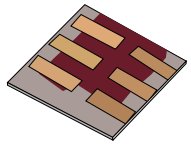


Start of the contact from the left of the device in meters.



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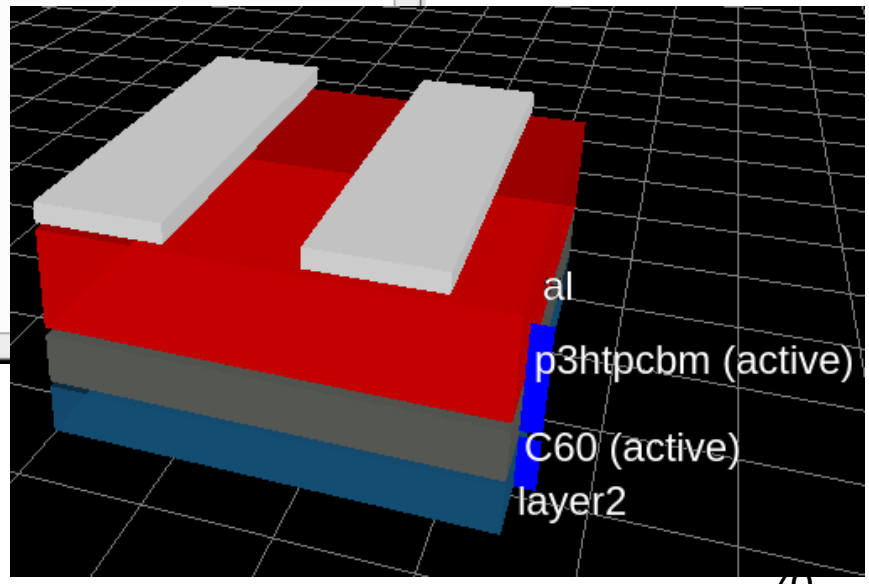
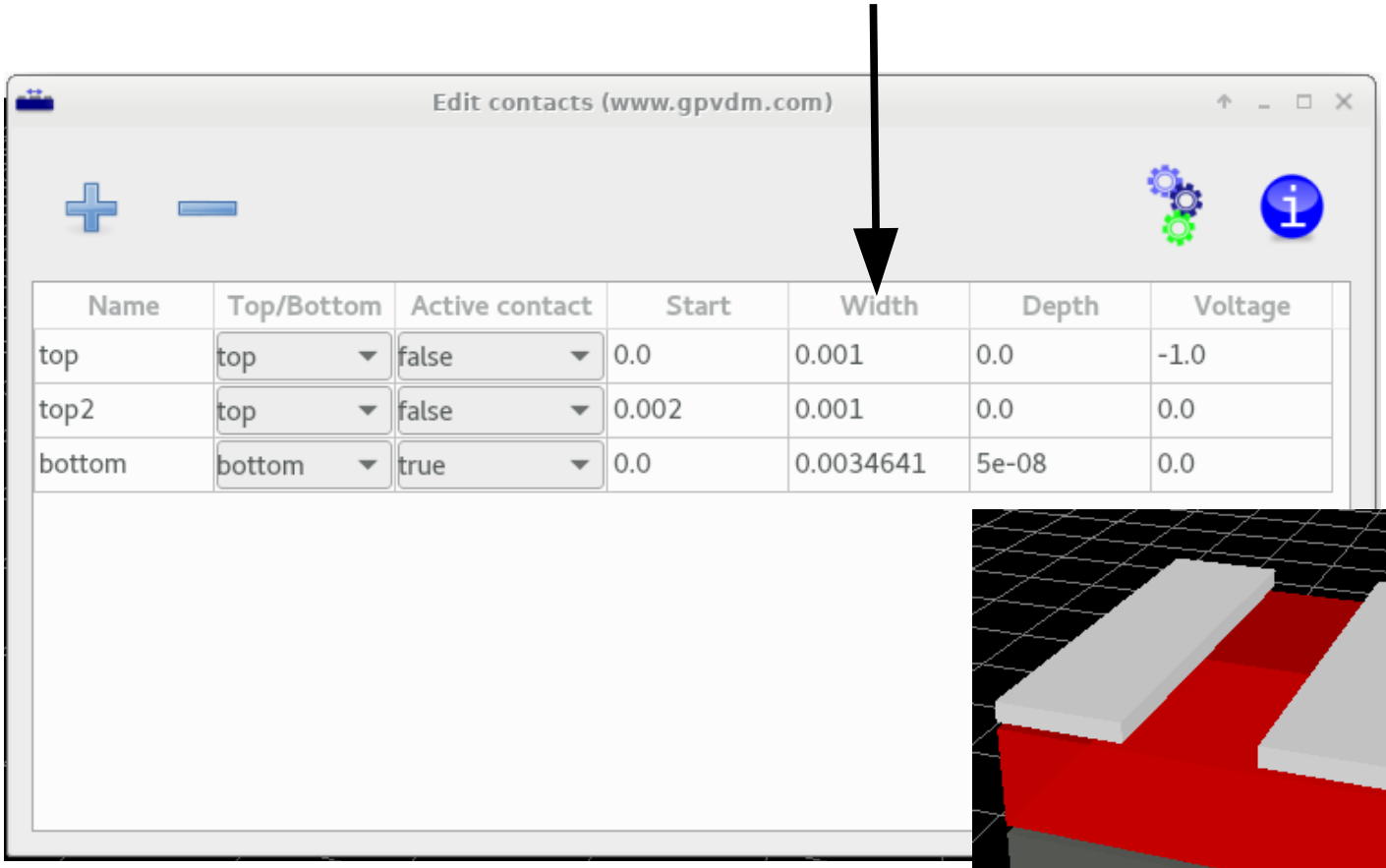
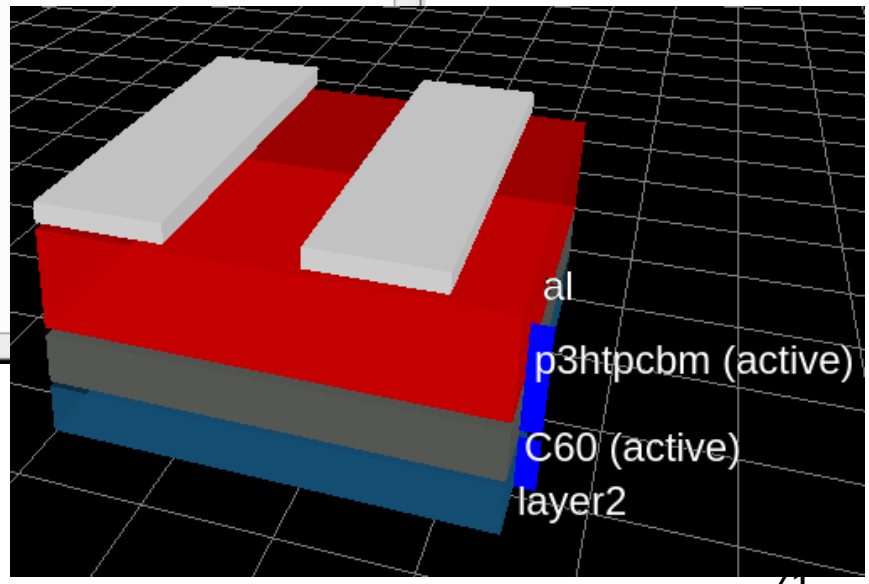
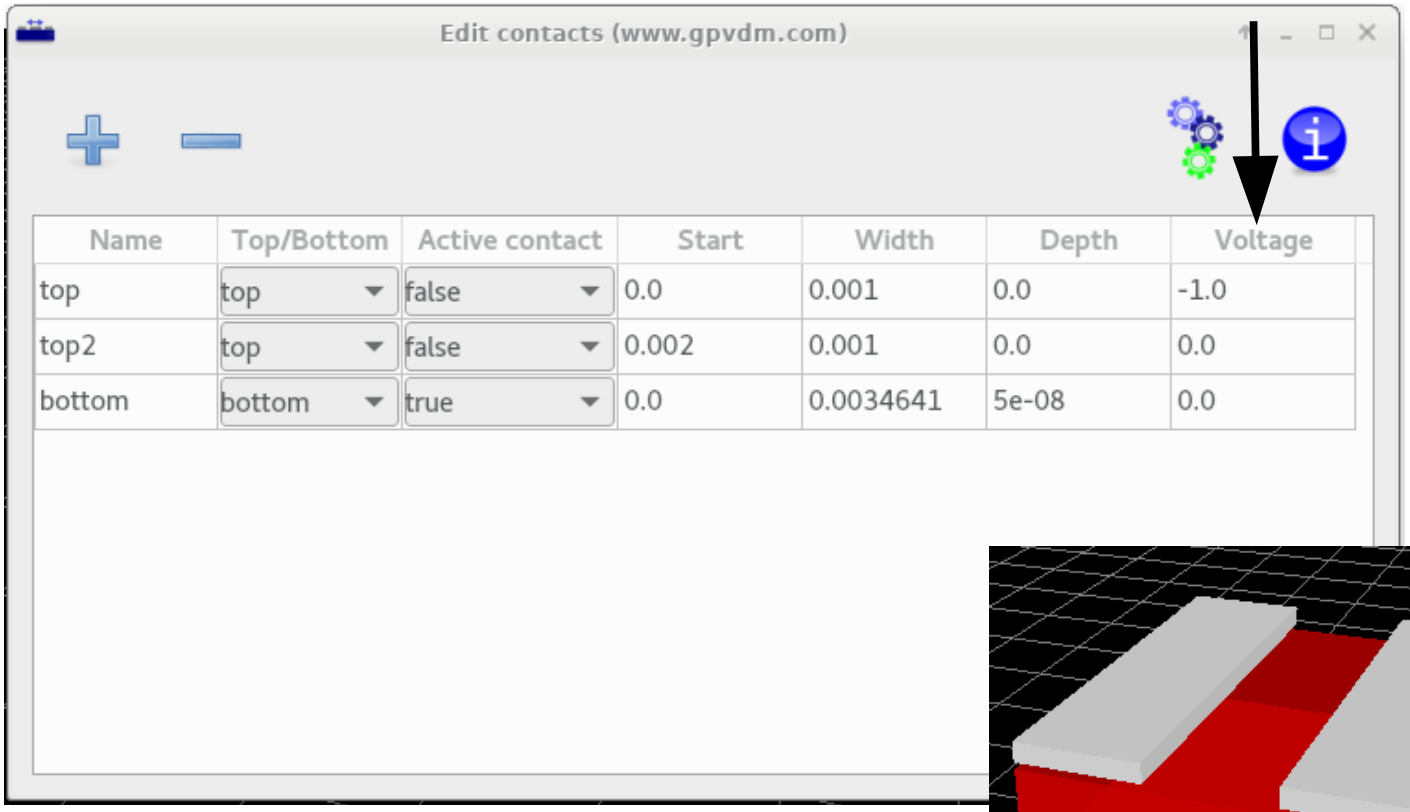


Width of the contact in meters





The voltage applied to the contact.



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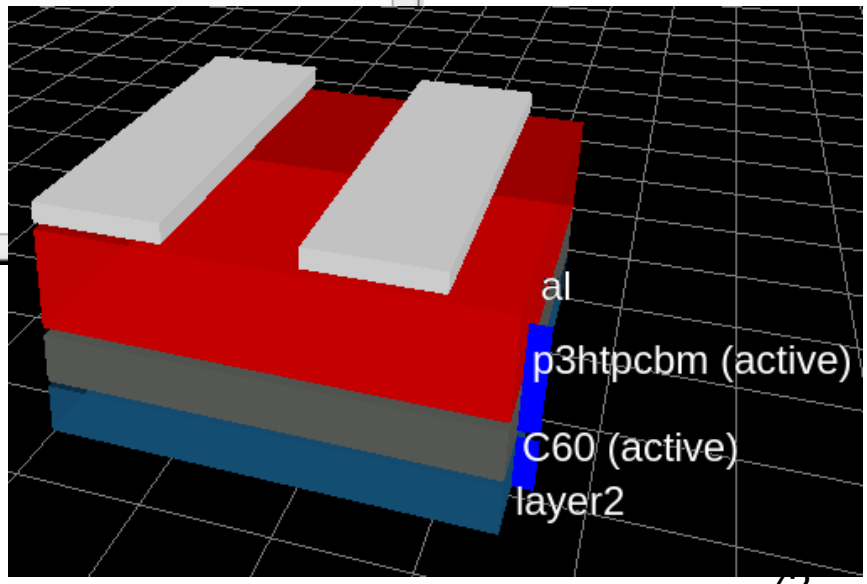
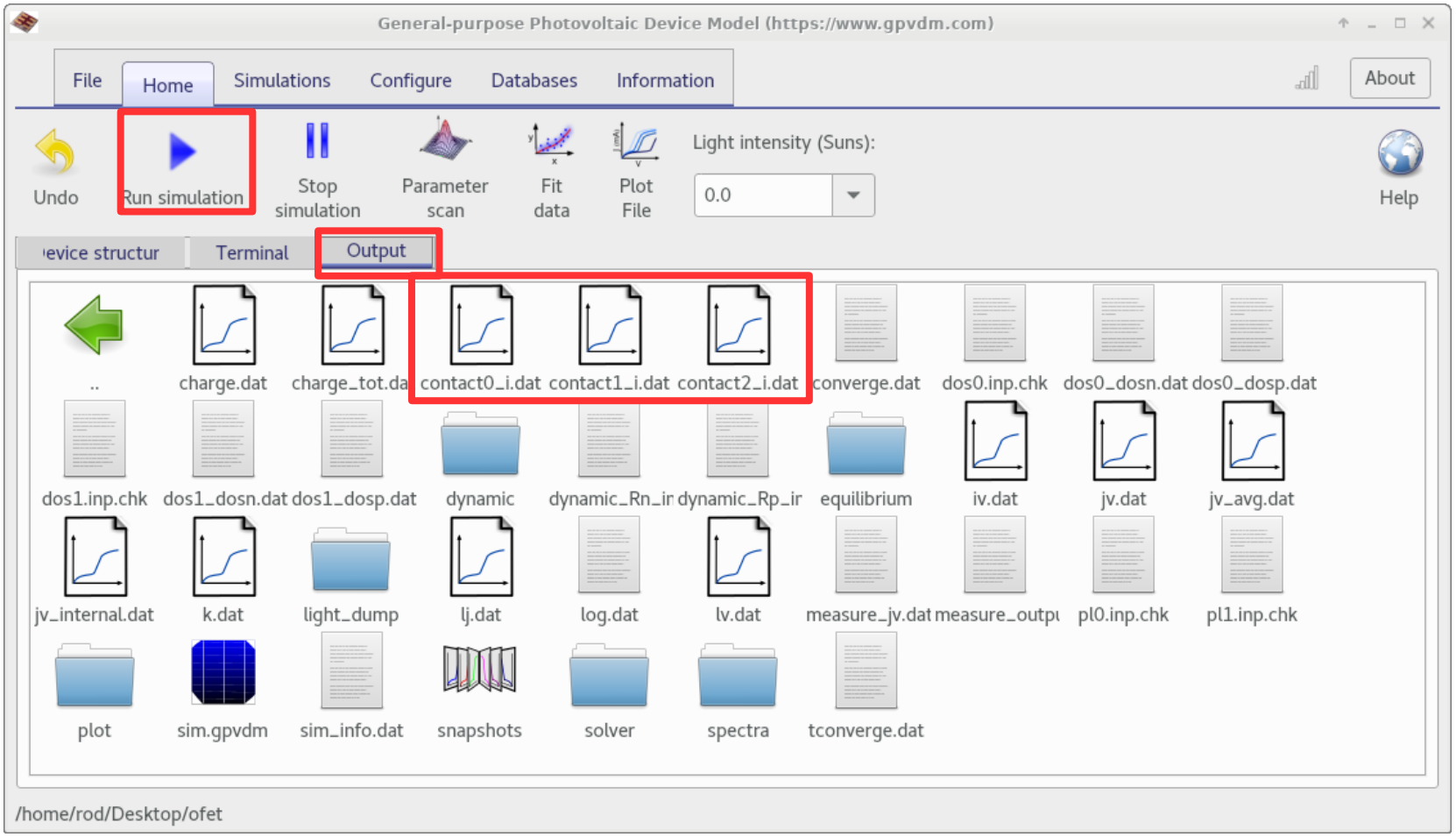
bottom	bottom	true	0.0	0.0034641	5e-08	0.0



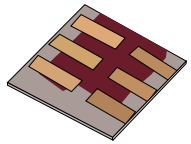
•So in this case we are applying -1V to ***top***, 0V to ***top2*** and applying a voltage ramp to ***bottom*** – *as we are in JV simulation mode.*

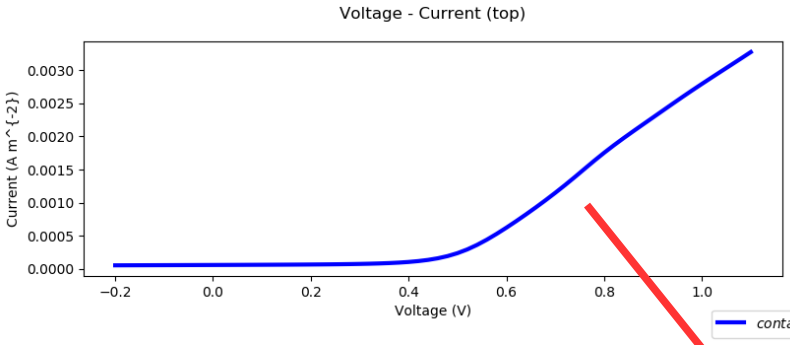
Run the simulation…, by clicking on the play button.

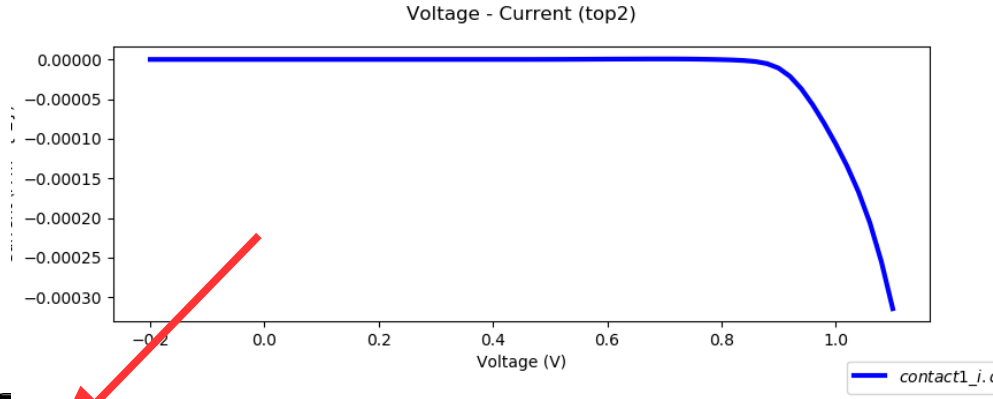


- Then let's look at the output.

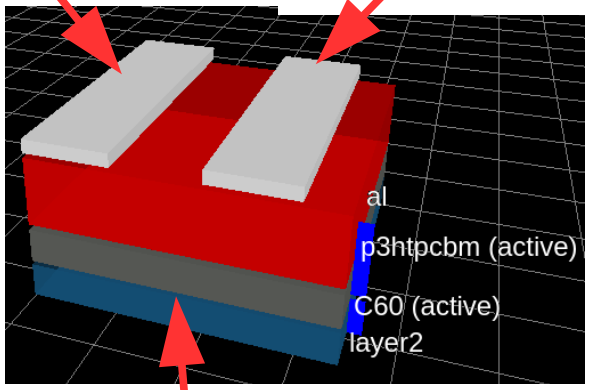
Current in/out of the contacts and the gate current..



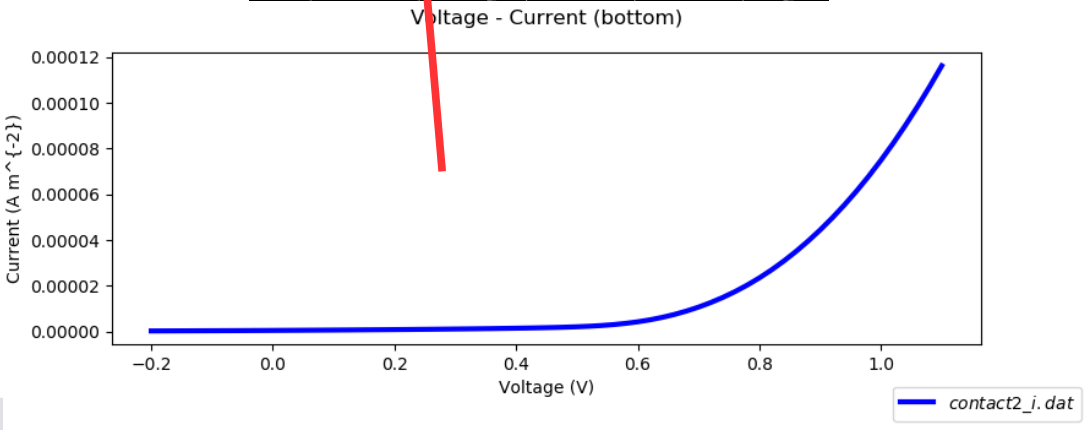




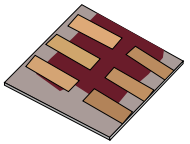
- Current going into left contact (+), current coming out of the right contact(-).

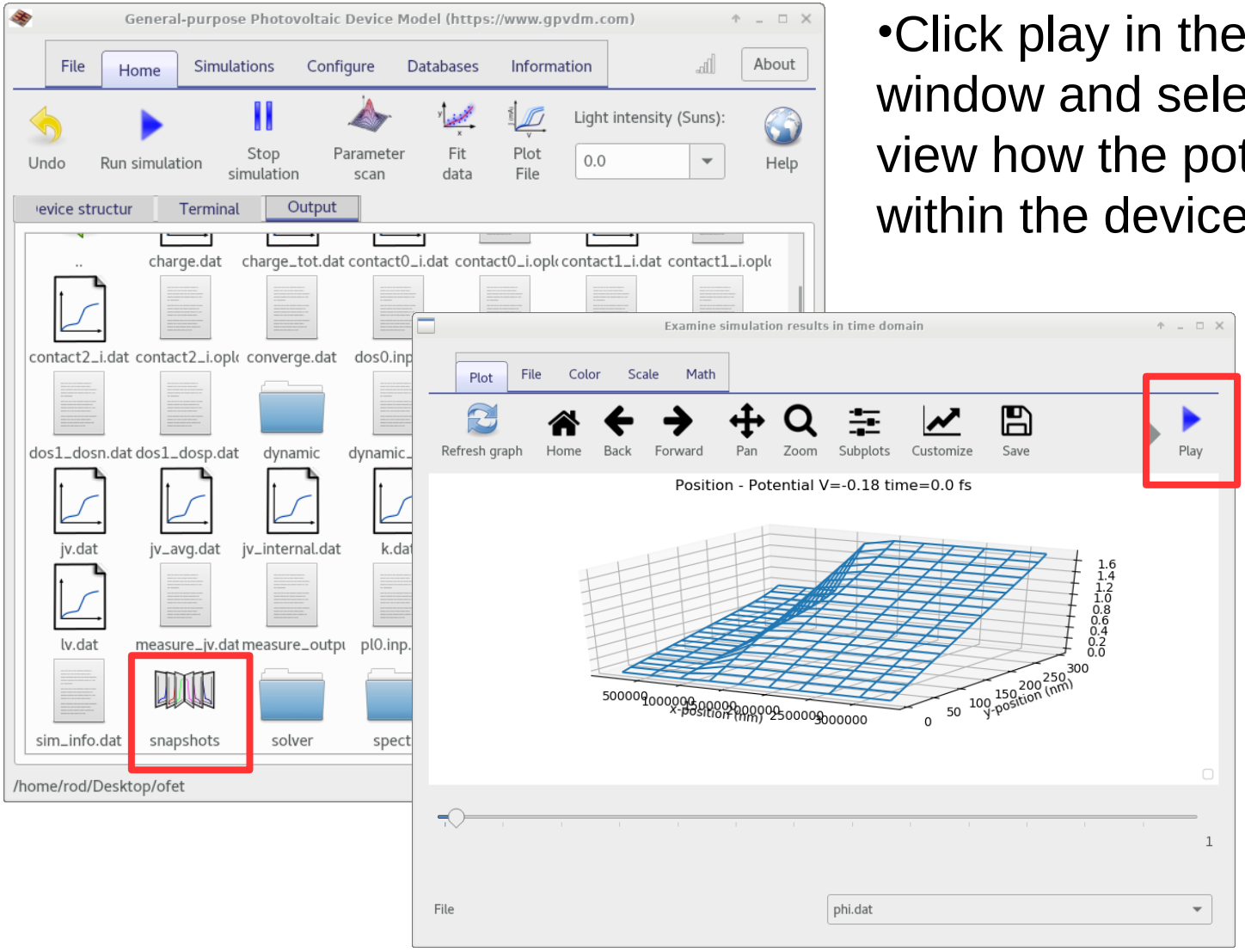


- Gate current much smaller than source/drain therefore amplification.



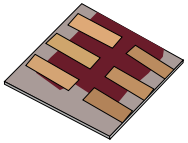
Using the snapshot tool to view what is going on in 2D during the simulation.





- Click play in the snapshot window and select phi.dat, to view how the potential changes within the device.

Overview



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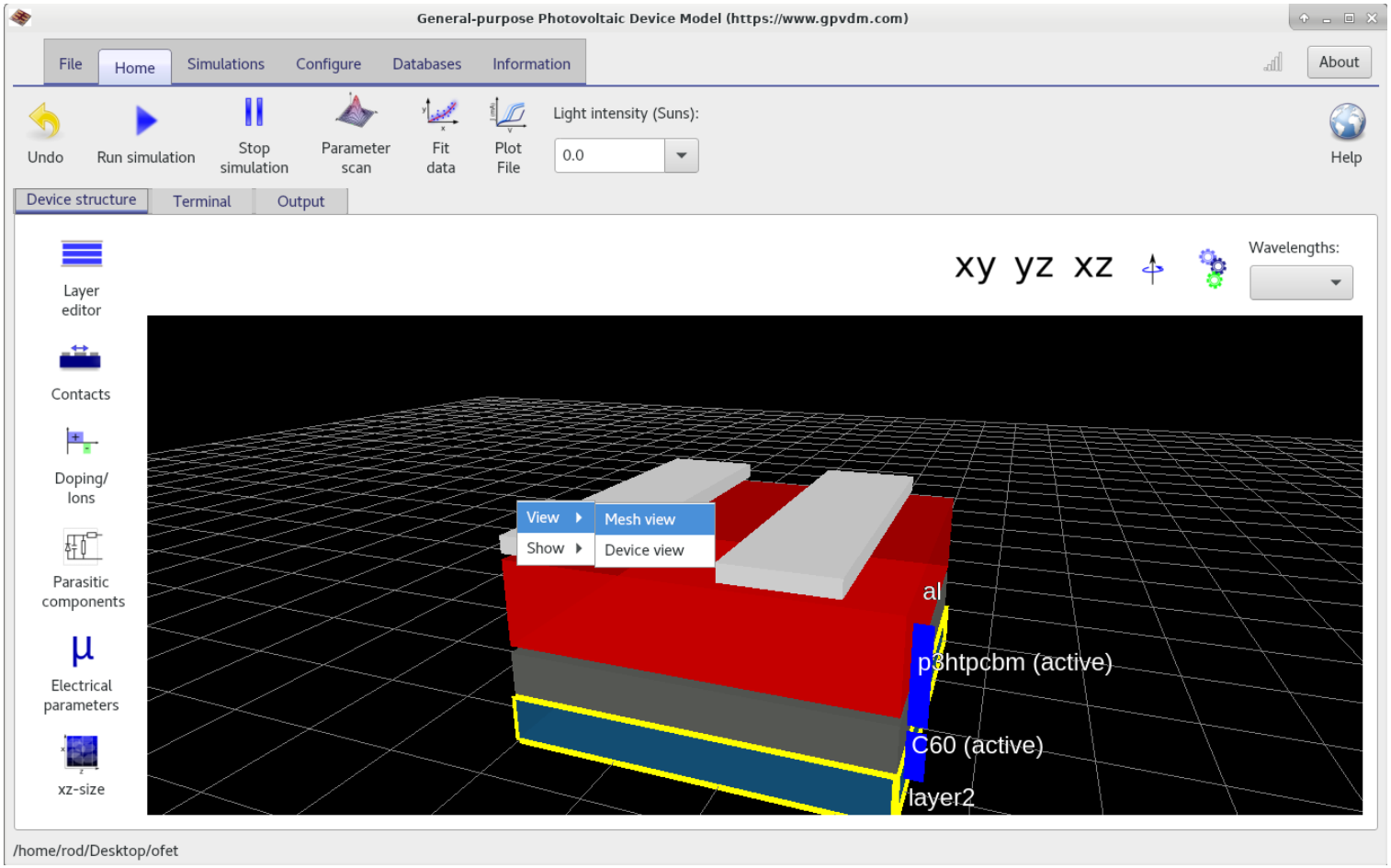
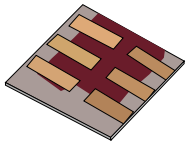
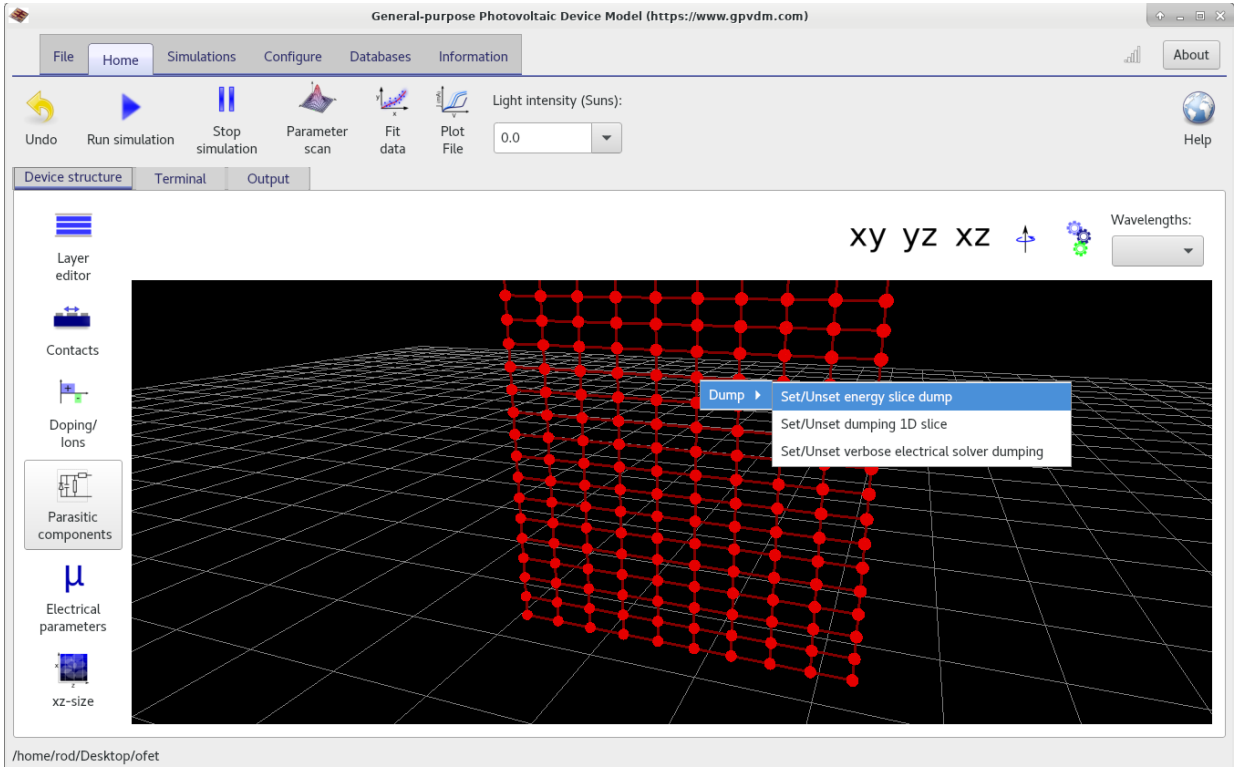
- Meshing and dumping

Meshing and dumping



Now you should be able to see the electrical finite difference mesh



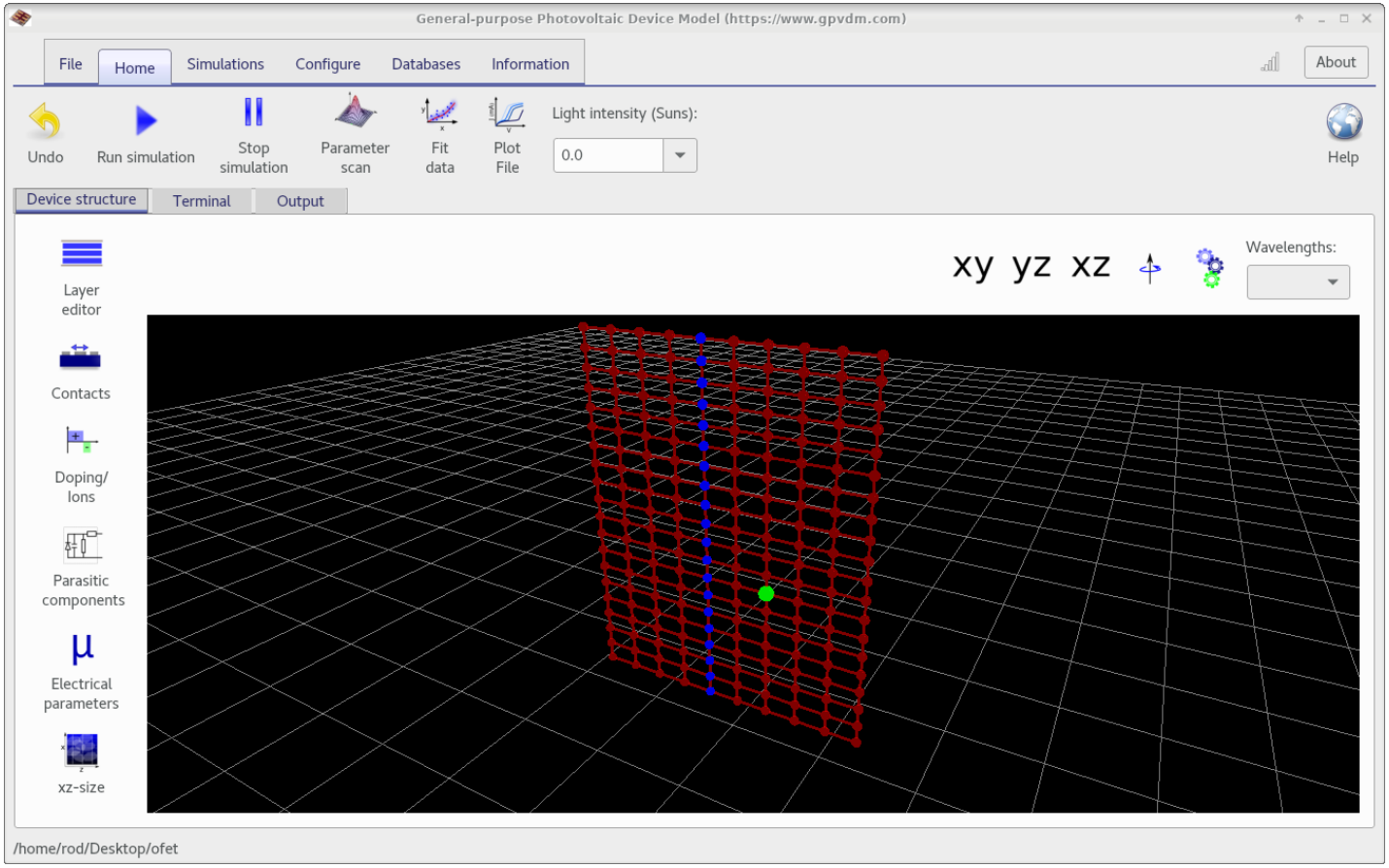


•***On*** a mesh point click ***'Set/Unset energy slice dump'*** this will turn on dumping of the trap population at a given mesh point.

•Click '**Set/Unset verbose electrical solver dumping**', this will ***turn off*** the outputting files like Ec.dat, Ev.dat, Fn.dat etc…

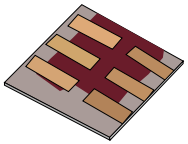
•Click on another mesh point and select '**Set/Unset dumping 1D slice**', this will turn on the dumping of the trap population across the device.

Your window should now look like this..

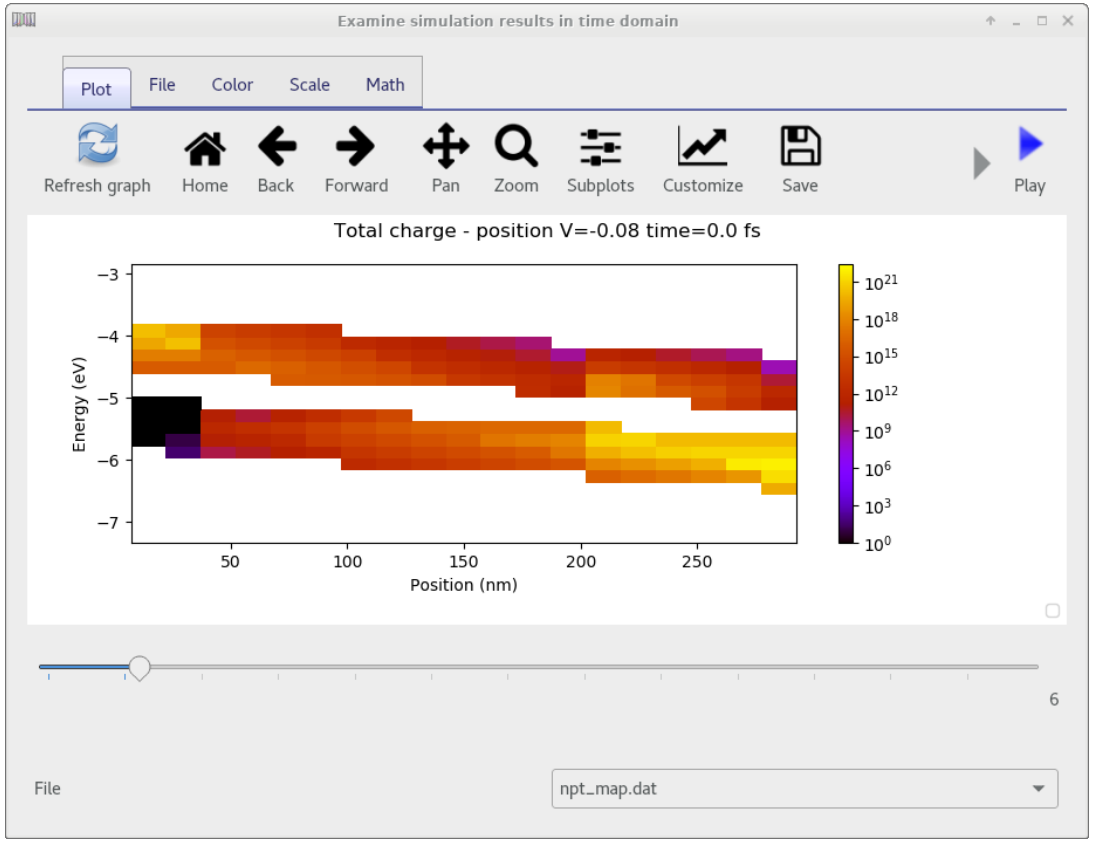


•We have turned off dumping of Ec.dat, Ev.dat etc…., and are going to be dumping the distribution of trap states along the blue line, and at the green point.

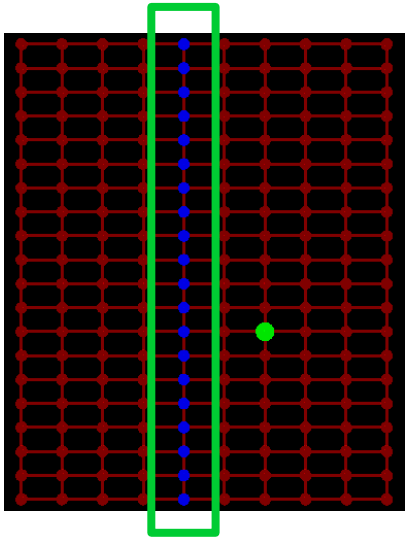
Now run the simulation...



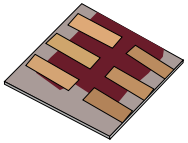
- From the ***output tab*** open the snapshot window.

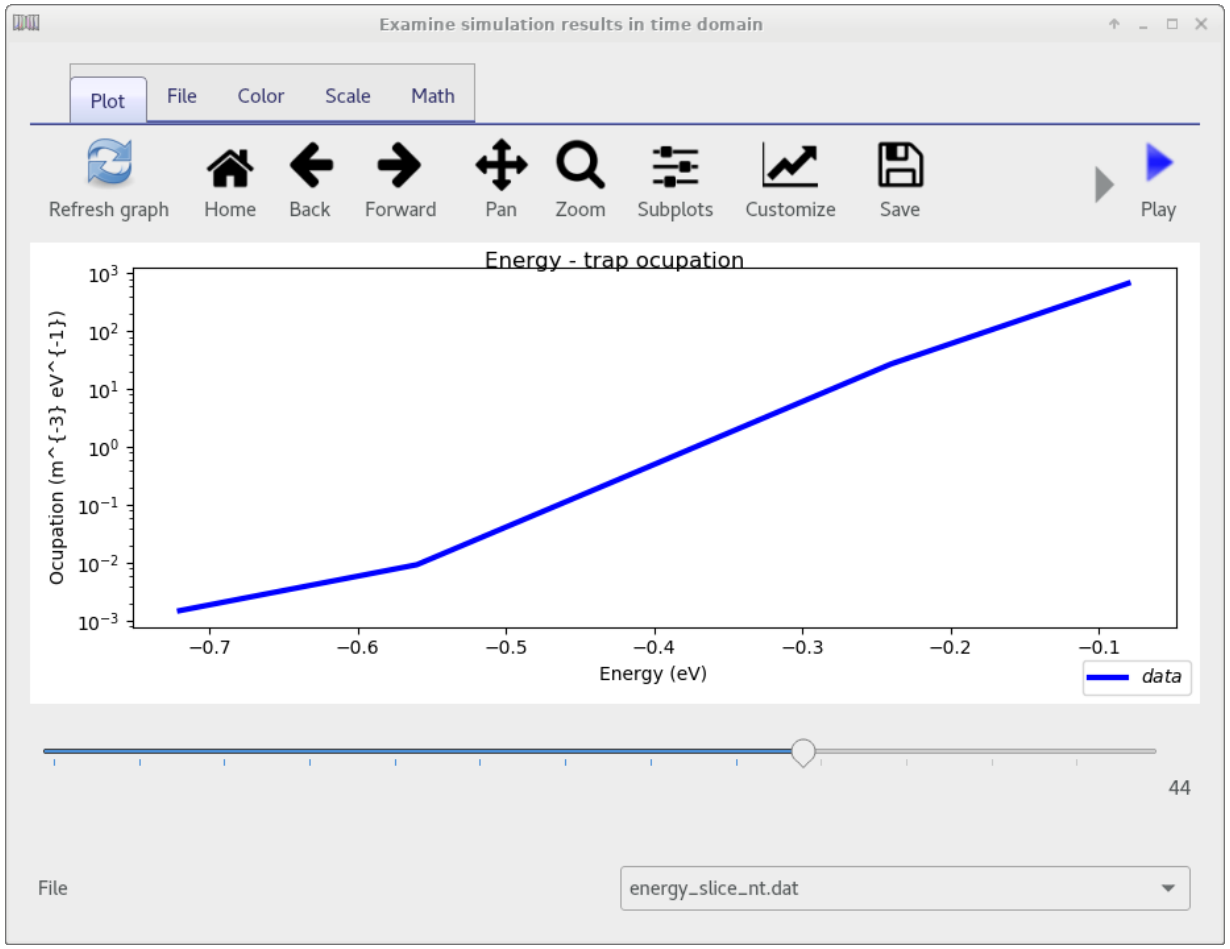


- Then make sure npt_map.dat is selected this is a slice through the device in position/energy space. Along the blue dots below.

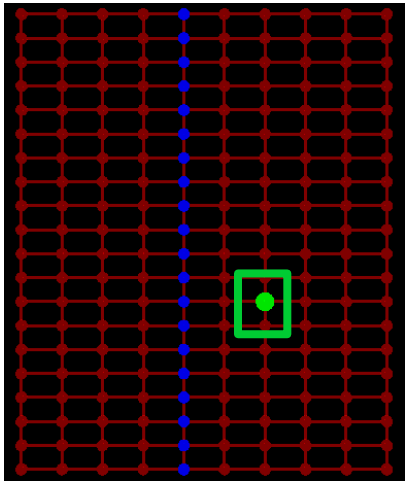


Select energy_slice_nt.dat, to show the trap population at a given point.

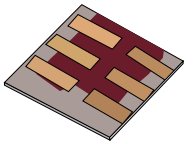


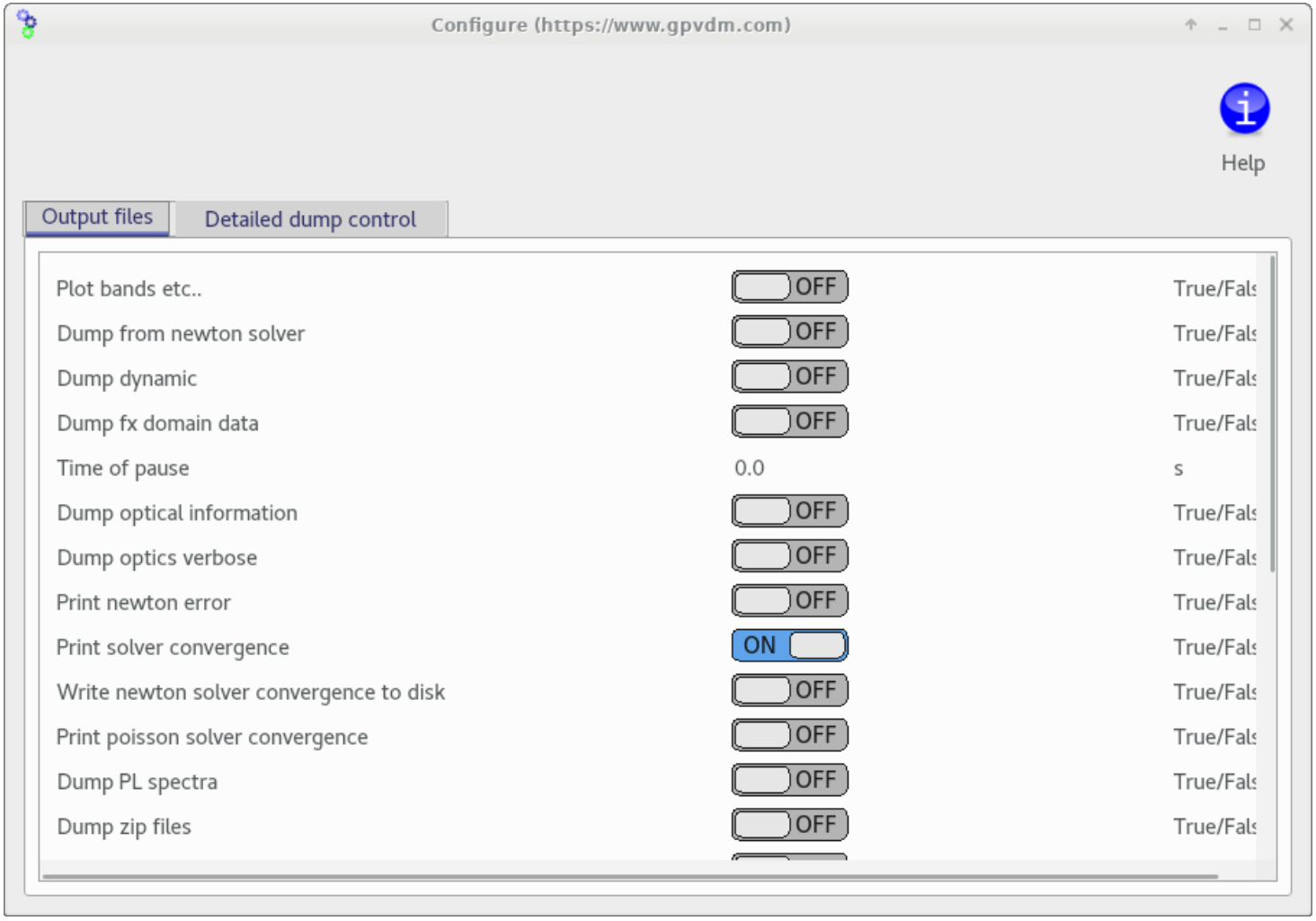


- You can step through the simulation as a function of time/voltage.

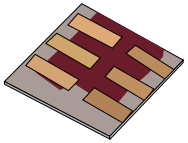


You can turn on/off other output files through configure→configure→output files





Overview



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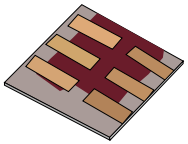
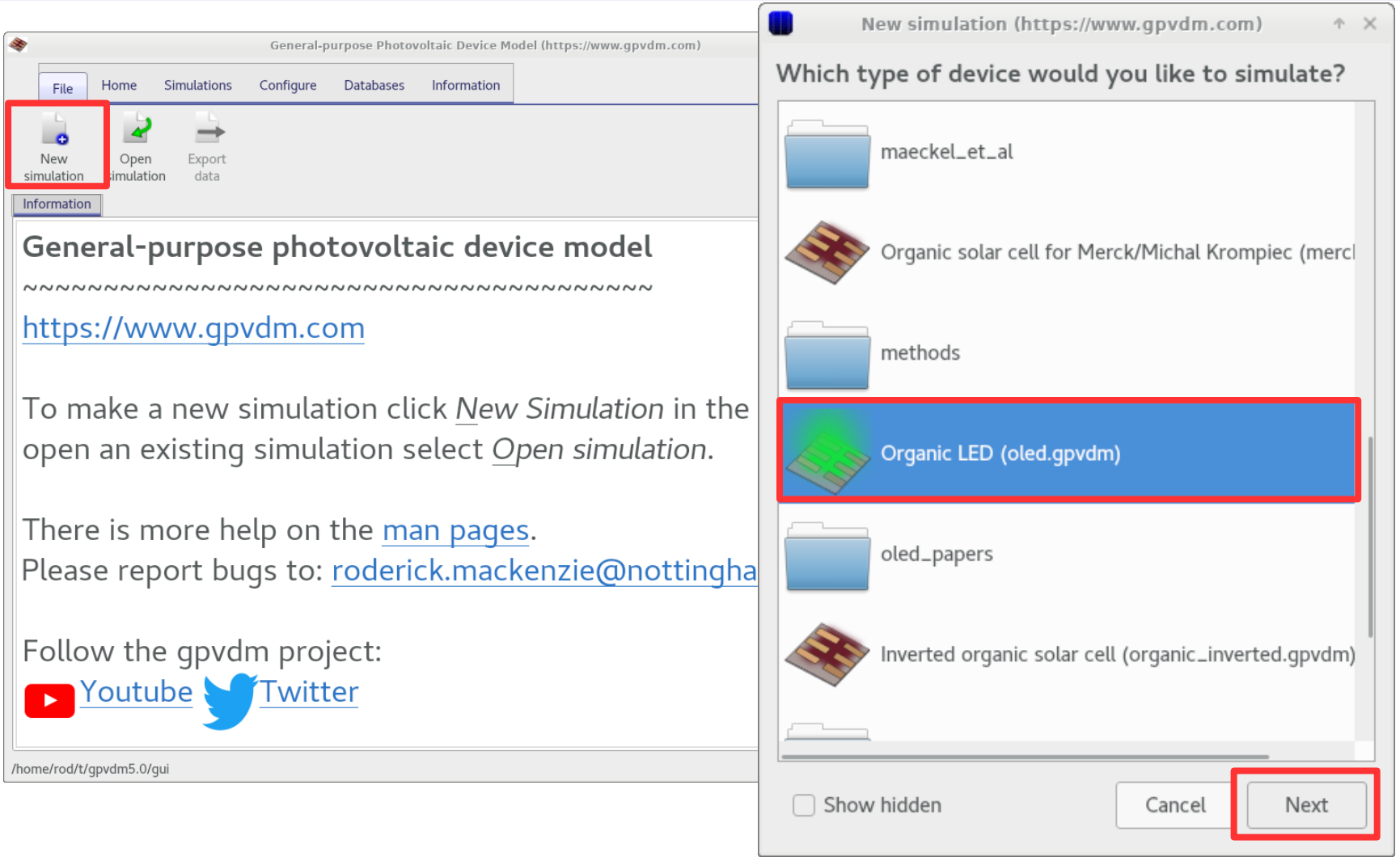
- **Simulation OLEDs with gpvdm**

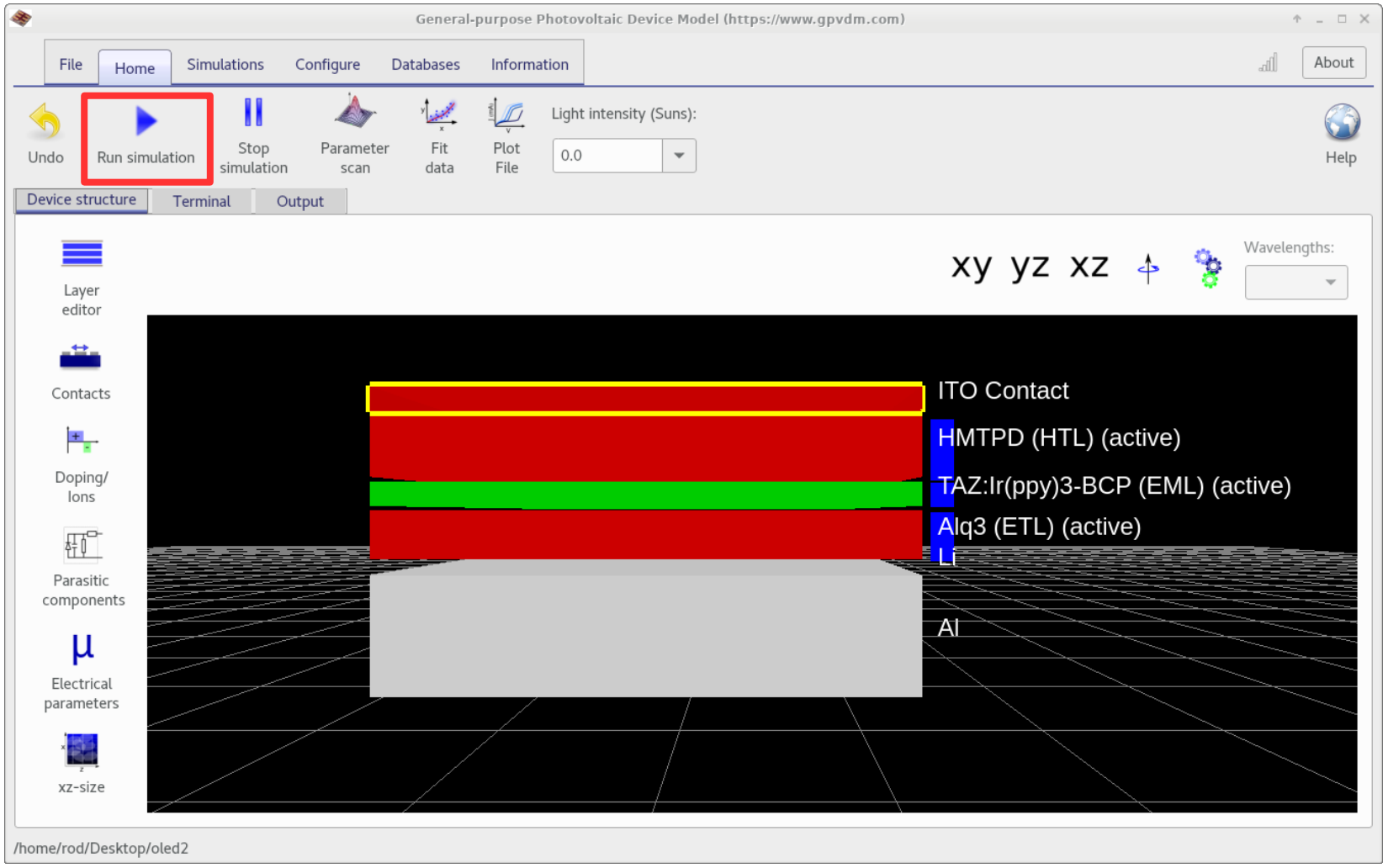
OLED simulation





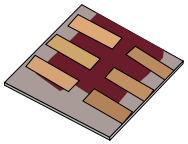
- This will setup an OLED simulation.

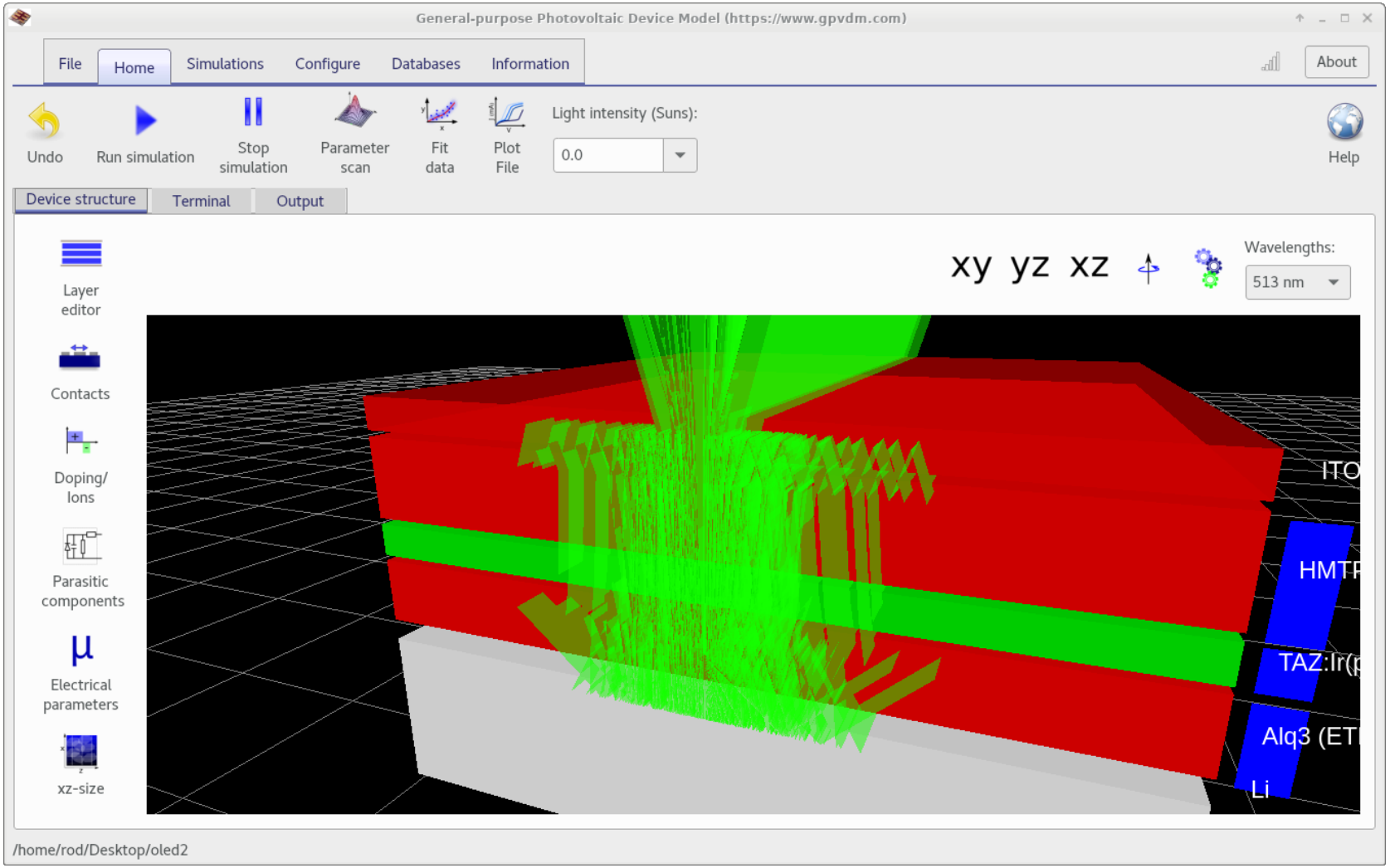
You should get a window looking like this..



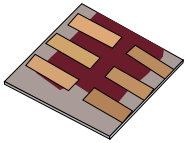
- Run the simulation...

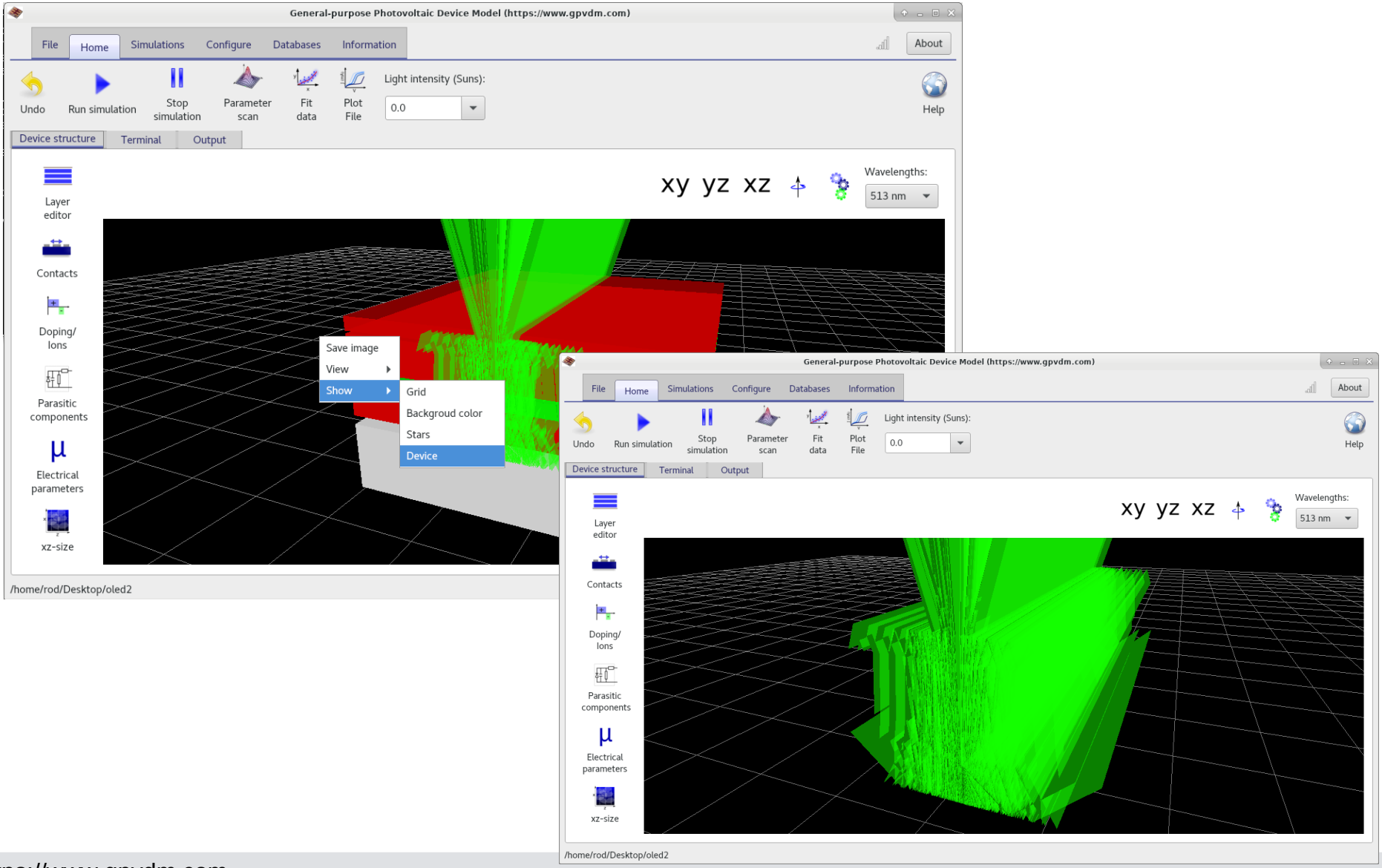
You will be able to see the rays emitted from the active layer.



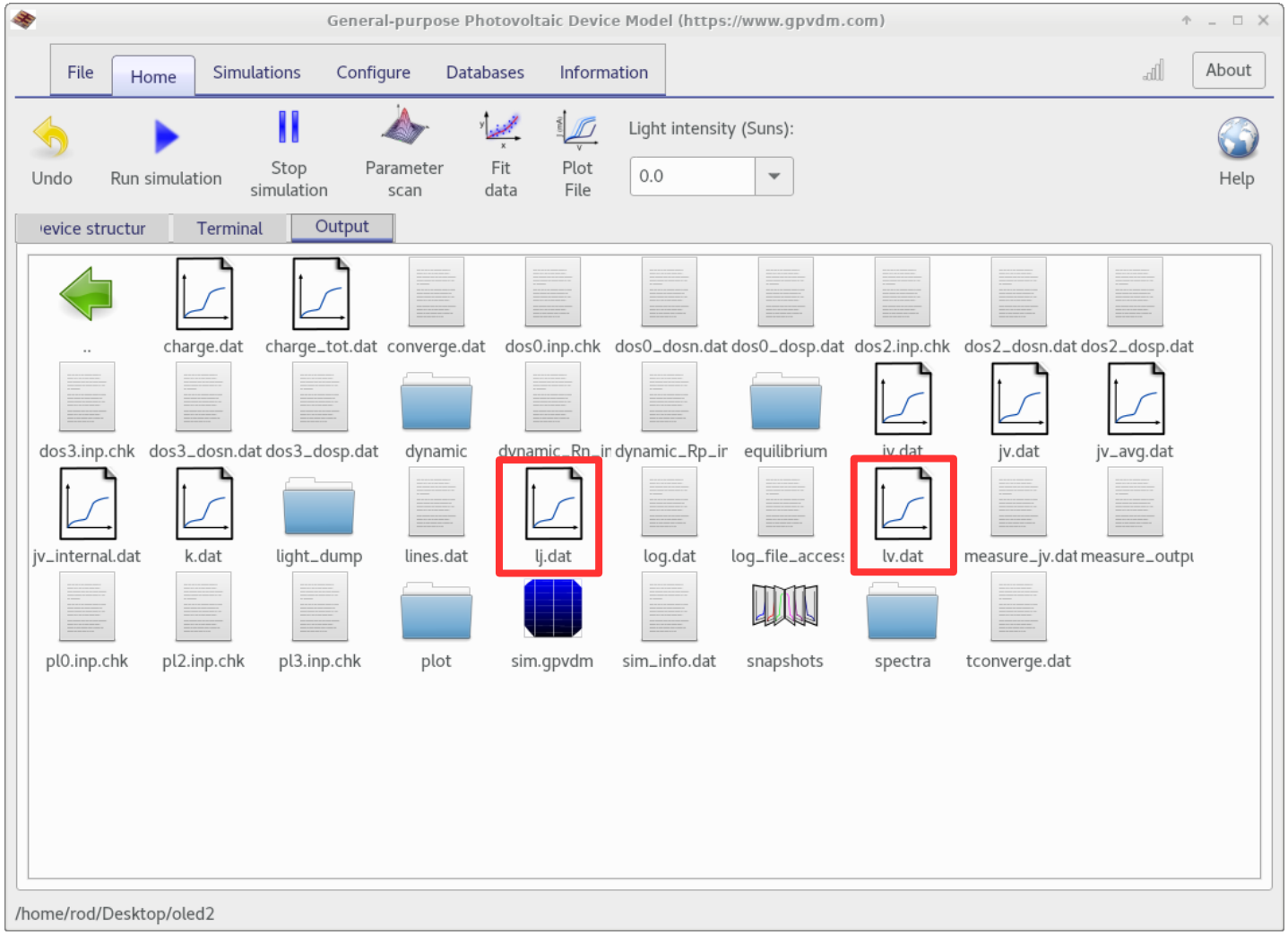


Hide the device





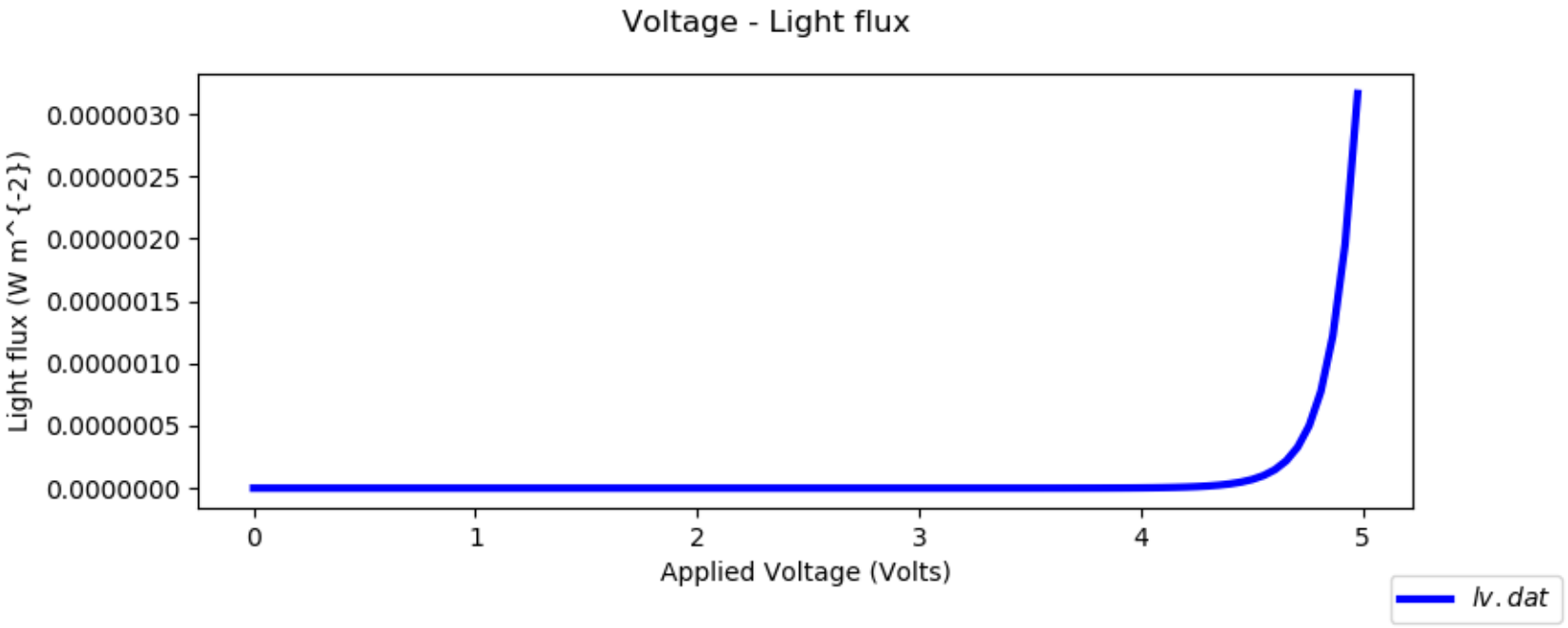
In the output you will see two new files



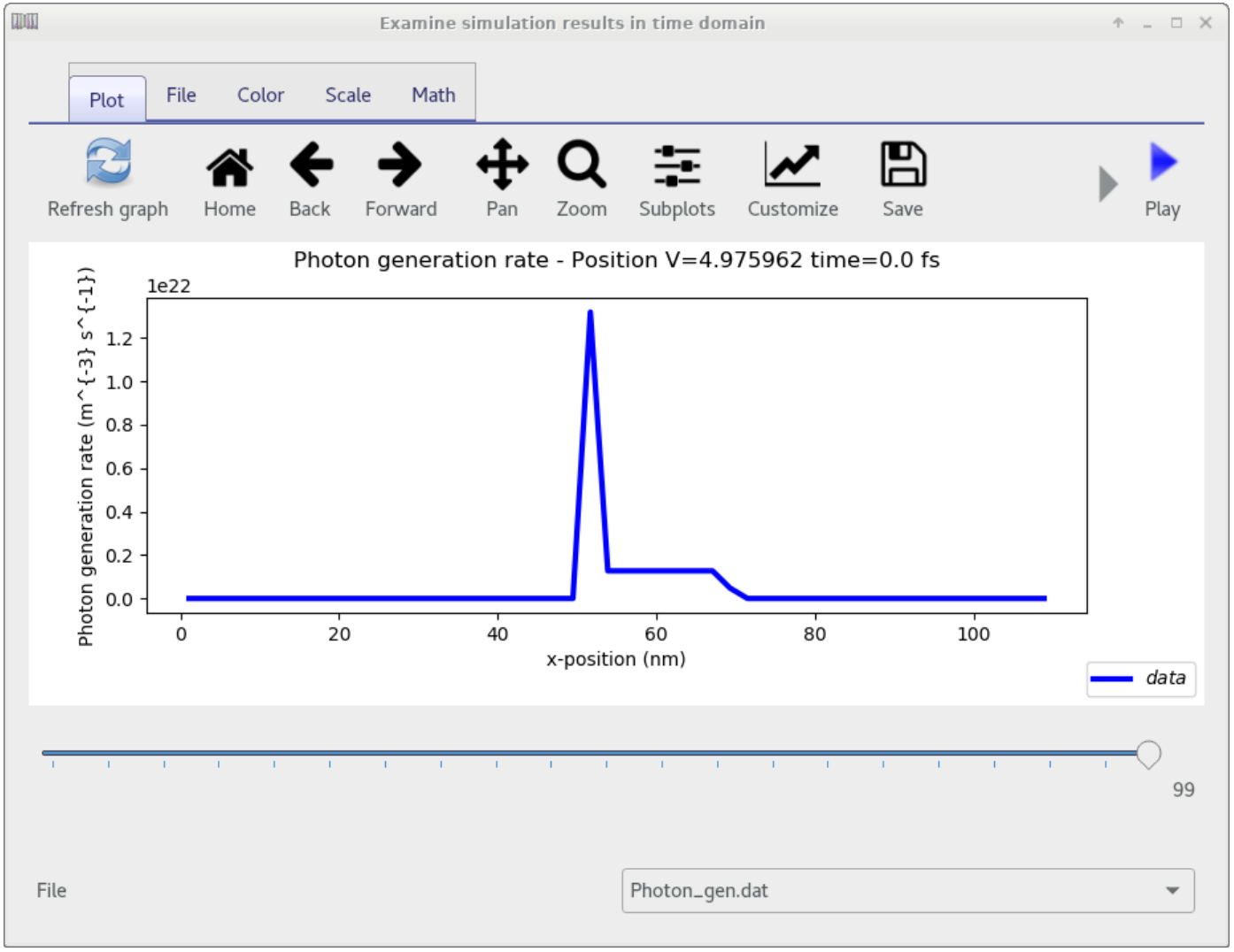
- lj.dat and lv.dat.

- These are light intensity against voltage and current.

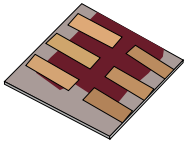
Light emission.



Where are the photons emitted?

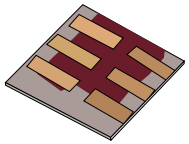


Overview



- What is gpvdm/theoretical overview?
- Installing gpvdm
- Running simple simulations
  - Your first gpvdm simulation
  - Changing electrical parameters
- Optical simulations and the materials database
- Perovskite solar cells and time domain simulations
- OFET simulations and finite difference meshing.
- The position of carriers in energy space and dumping to disk.
- Simulation OLEDs with gpvdm
- **Closing remarks**

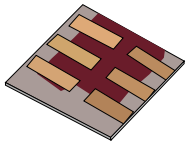
Things I’ve not covered/ working together...



•gpvdm can do quite a few other things like simulate PL/EL spectra, IS, IMPS, import FDTD data etc.. but I’ve either not had time to cover this in this tutorial or the features are not robust enough to release.

•gpvmd is a work in progress if you want a feature added it does not have let me know….. and please include me in your paper/collaboration ;). I am always after new experimental partners/collaborations

Fitting to experiment..



•Fitting complex data sets to experiment is a pain due to high CPU demand/number of parameters So I have built quite a lot of code to do the fitting on a cluster of 100 CPUs.

•I’ve released the code but it is a pain to use, **SO: If you want to fit the model to data sets, I recommend you talk to me and see if I can do it for you.**

number	type	name	ip	cpus	max_cpus	sock	load	load0	last_seen
0	slave	node001	10.0.0.1	8	8	5	8	0.790000	1
1	slave	node008	10.0.0.8	12	12	7	12	1.030000	0
2	slave	node005	10.0.0.5	8	8	6	8	0.560000	0
3	slave	node002	10.0.0.2	8	8	10	8	1.080000	1
4	master	gpvdm_master	10.154.55.33	0	0	8	0	0.350000	1543332532

n	name	done	status	target	ip	copystate	start	force_stop	stop	cpus	pid
0	job0	0	1	/home/rod/t/data_sets/merck_new_fit/non_symetric1/0.1/200			10.0.0.1	0	2018/11/27-15:28:43		
1	job1	0	1	/home/rod/t/data_sets/merck_new_fit/non_symetric1/0.1/400			10.0.0.1	0	2018/11/27-15:28:43		
2	job2	0	1	/home/rod/t/data_sets/merck_new_fit/non_symetric1/0.1/600			10.0.0.1	0	2018/11/27-15:28:43		
3	job3	0	1	/home/rod/t/data_sets/merck_new_fit/non_symetric1/0.1/800			10.0.0.1	0	2018/11/27-15:28:43		
4	job4	0	1	/home/rod/t/data_sets/merck_new_fit/non_symetric1/0.1/1000			10.0.0.8	0	2018/11/27-15:28:43		
5	job5	0	1	/home/rod/t/data_sets/merck_new_fit/non_symetric1/0.2/200			10.0.0.8	0	2018/11/27-15:28:43		
6	job6	0	1	/home/rod/t/data_sets/merck_new_fit/non_symetric1/0.2/400			10.0.0.8	0	2018/11/27-15:28:43		
7	job7	0	1	/home/rod/t/data_sets/merck_new_fit/non_symetric1/0.2/600			10.0.0.8	0	2018/11/27-15:28:43		
8	job8	0	1	/home/rod/t/data_sets/merck_new_fit/non_symetric1/0.2/800			10.0.0.8	0	2018/11/27-15:28:43		
9	job9	0	1	/home/rod/t/data_sets/merck_new_fit/non_symetric1/0.2/1000			10.0.0.8	0	2018/11/27-15:28:43		
10	job10	0	1	/home/rod/t/data_sets/merck_new_fit/non_symetric1/0.4/200			10.0.0.5	0	2018/11/27-15:28:43		
11	job11	0	1	/home/rod/t/data_sets/merck_new_fit/non_symetric1/0.4/400			10.0.0.5	0	2018/11/27-15:28:43		
12	job12	0	1	/home/rod/t/data_sets/merck_new_fit/non_symetric1/0.4/600			10.0.0.5	0	2018/11/27-15:28:43		
13	job13	0	1	/home/rod/t/data_sets/merck_new_fit/non_symetric1/0.4/800			10.0.0.5	0	2018/11/27-15:28:43		
14	job14	0	1	/home/rod/t/data_sets/merck_new_fit/non_symetric1/0.4/1000			10.0.0.2	0	2018/11/27-15:28:43		
15	job15	0	1	/home/rod/t/data_sets/merck_new_fit/non_symetric1/0.8/200			10.0.0.2	0	2018/11/27-15:28:43		
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21	job21	0	0	/home/rod/t/data_sets/merck_new_fit/non_symetric1/1.0/400			-	0	-	-	2
22	job22	0	0	/home/rod/t/data_sets/merck_new_fit/non_symetric1/1.0/600			-	0	-	-	2
23	job23	0	0	/home/rod/t/data_sets/merck_new_fit/non_symetric1/1.0/800			-	0	-	-	2
24	job24	0	0	/home/rod/t/data_sets/merck_new_fit/non_symetric1/1.0/1000			-	0	-	-	2

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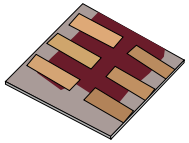
Road map...



- Two immediate things I’m working on:
  - Ray tracing of complex surfaces
  - Better FDTD

Fitting