TCAD for electronic devices part 4

Microelectronics devices, sensors and MEMS

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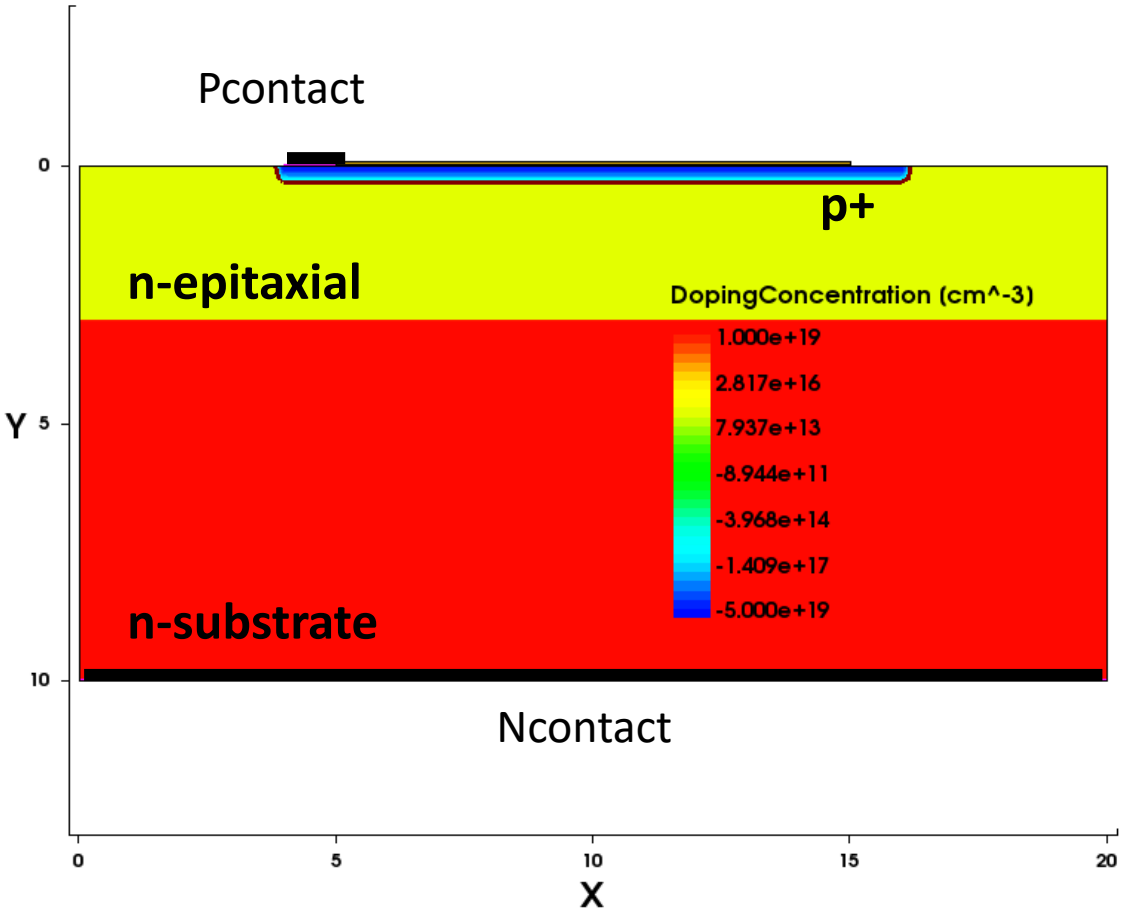
Example 1. Photodiode

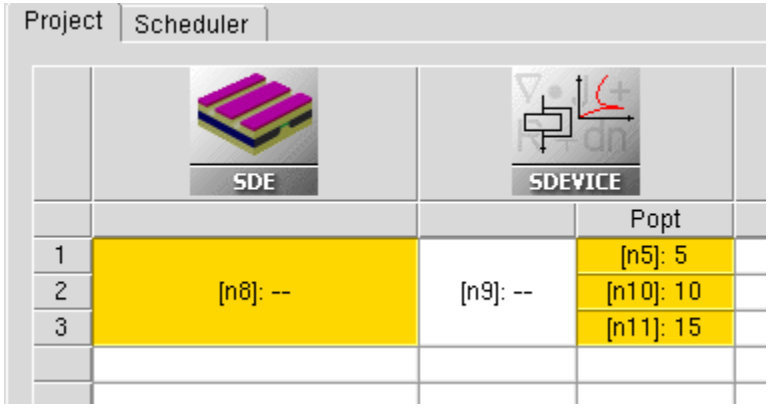


Optical window with Antireflective Coating (ARC) (x1 = 5 : x2 = 15)

30nm Silicon Oxide
60nm Silicon Nitride

File: **`P4EX1_Photodiode_sde.txt`**

Example 1a. Forward bias



Simulate I-V curves with:
V(Ncontact) = 0
V(Pcontact) = 0 → 0.75V

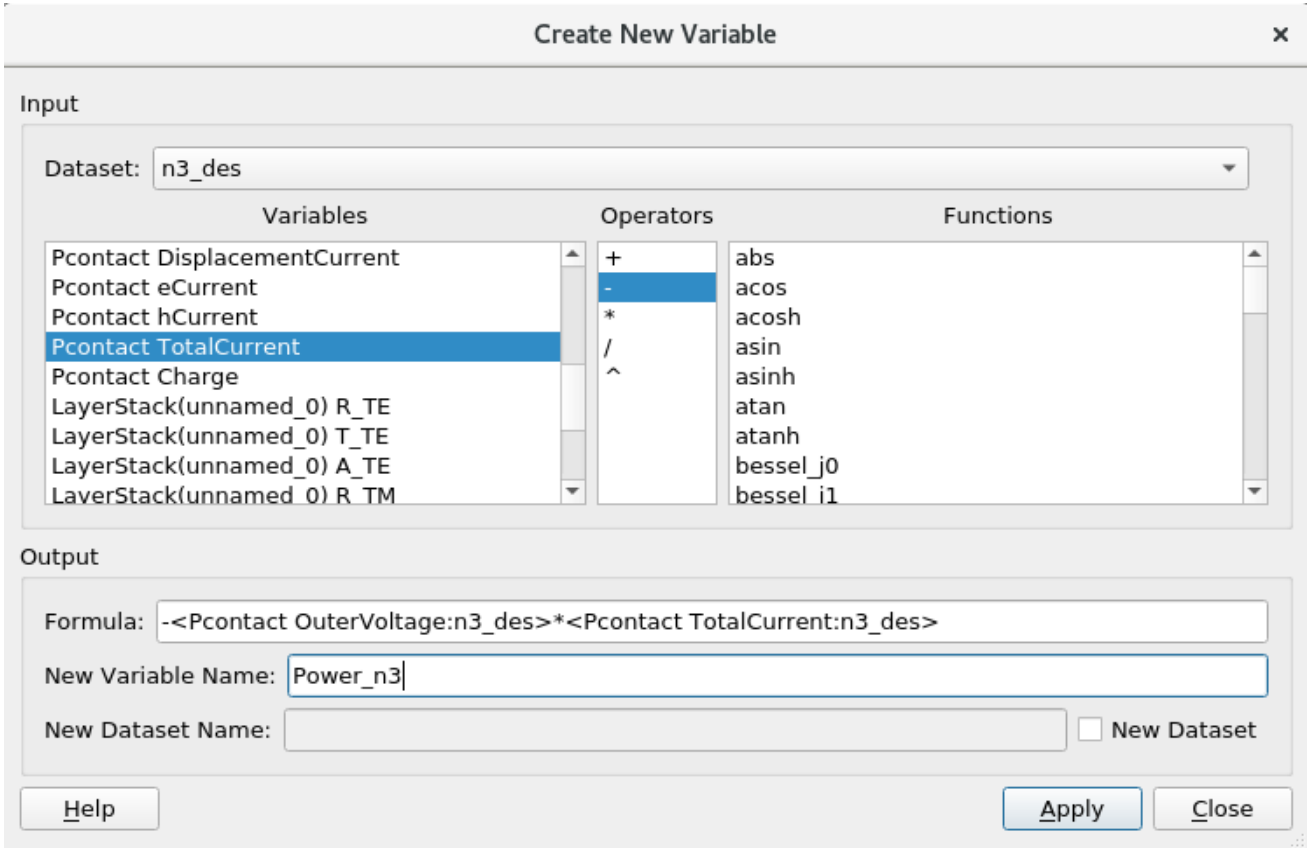
Plot the I-V curves for the 3 different optical power densities

Report the maximum electrical power generated at Popt = 15 W/cm^2 in the shared spreadsheet:
https://docs.google.com/spreadsheets/d/1lVVuYz--40sHPwWE4pYOevZ1eQrdjCjwVpUHHLtRXj4/edit?usp=sharing

File: **`P4EX1_Photodiode_sdevice1.txt`**

Example 1a. Maximum power calculation

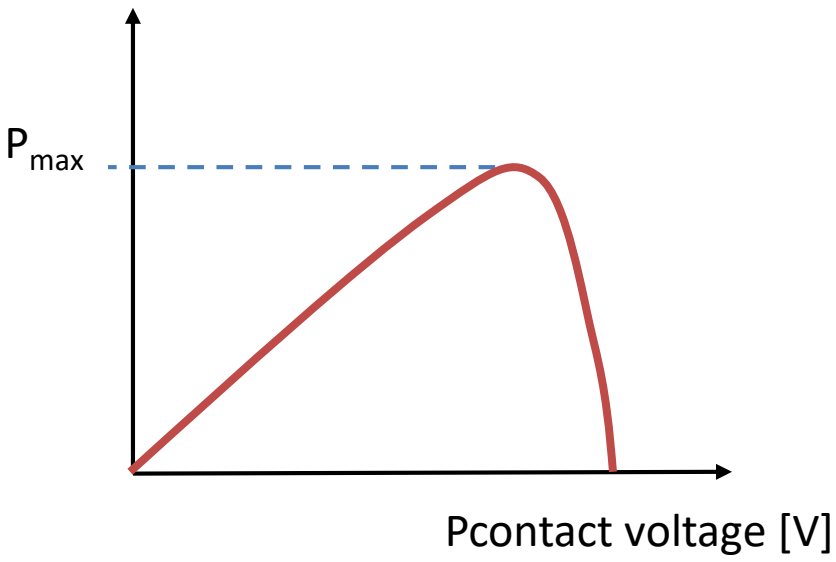
In svisual, create a new variable representing the power (voltage x current, with negative sign) and plot it as a function of Pcontact voltage.

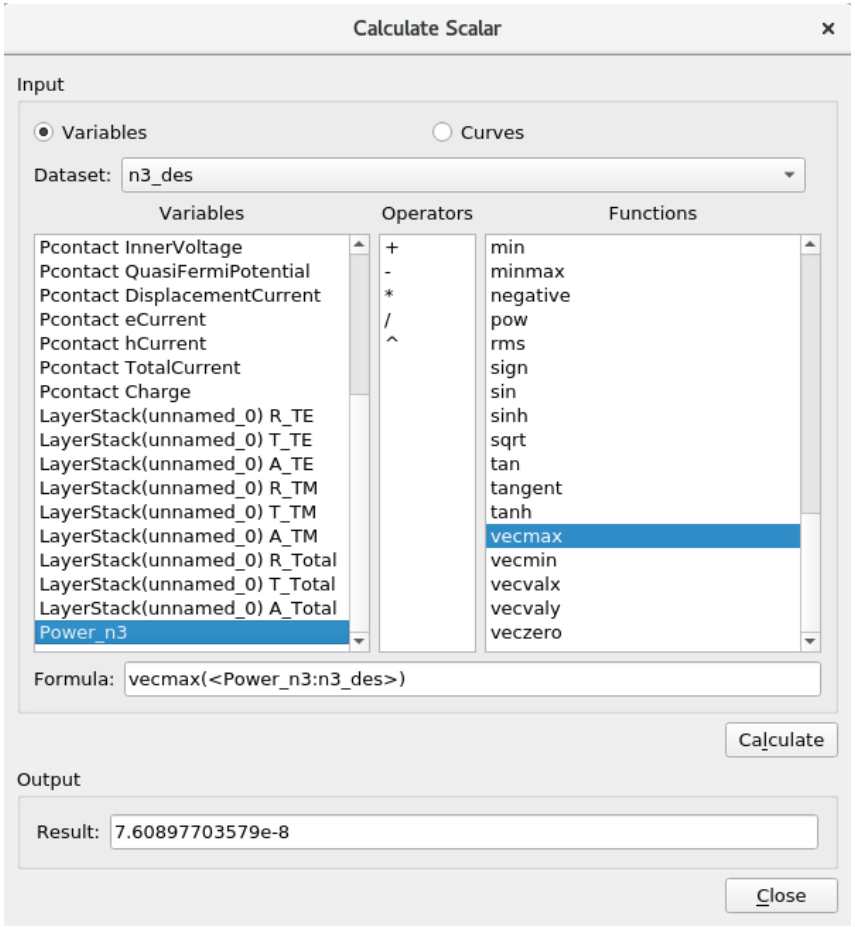


Example 1a. Maximum power calculation

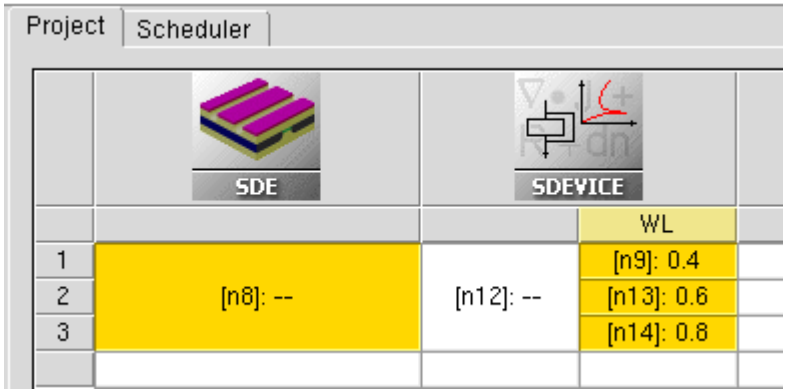
In svisual, after plotting the PV curves, open the «Calculate Scalar» dialog box from menu Tools

Use function vecmax(<curve_name>) to calculate the maximum power





Example 1b. Reverse bias



Simulate I-V curves with:
V(Pcontact) = 0
V(Ncontact) = 0 → 10V

Plot the **I-V curves** for the 3 different wavelengths and **calculate the responsivity ($R = I_{ph}/Popt$ [A/W])** for each wavelength
Report the responsivity in the spreadsheet

File:
`P4EX1_Photodiode_sdevice2.txt`

Example 1b. Responsivity calculation

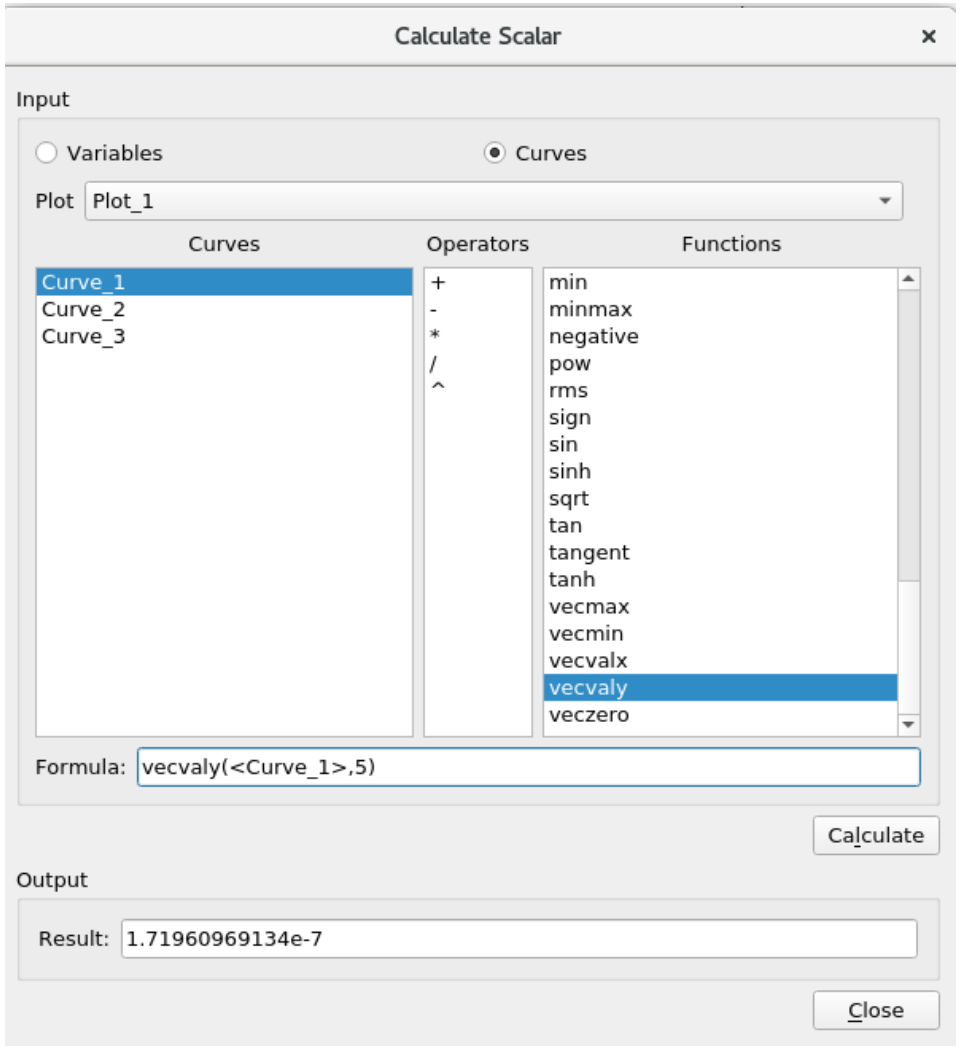
Responsivity:

$$R = \frac{I_{ph}}{P_{opt}}$$

In svisual, after plotting the IV curves in reverse bias,
Open the «Calculate Scalar» dialog box from menu Tools

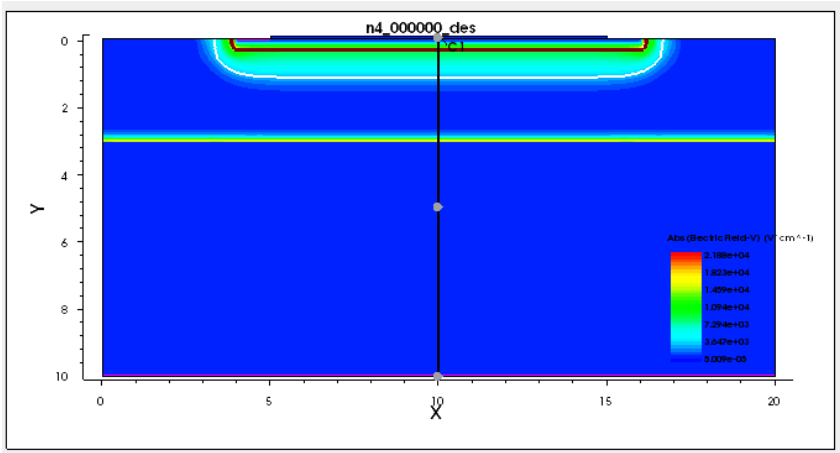
Estimate the current at 5V on the 3 curves using the function vecvaly(<Curve_name>, x_value)

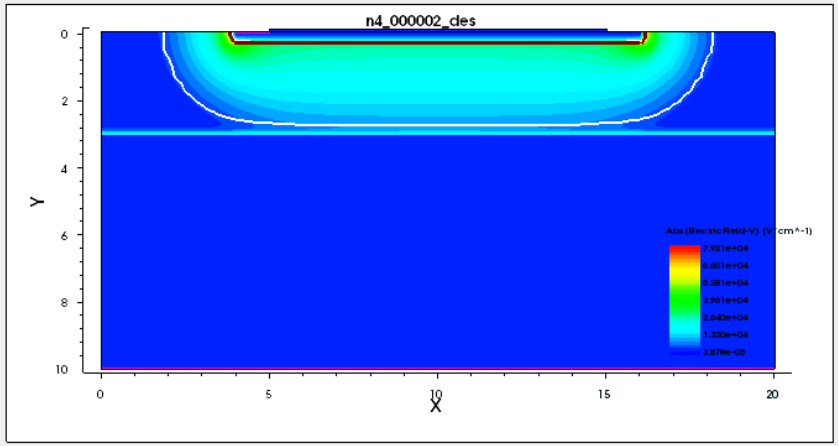
The optical power is 10W/cm^2, the device area is 10µm x 1µm

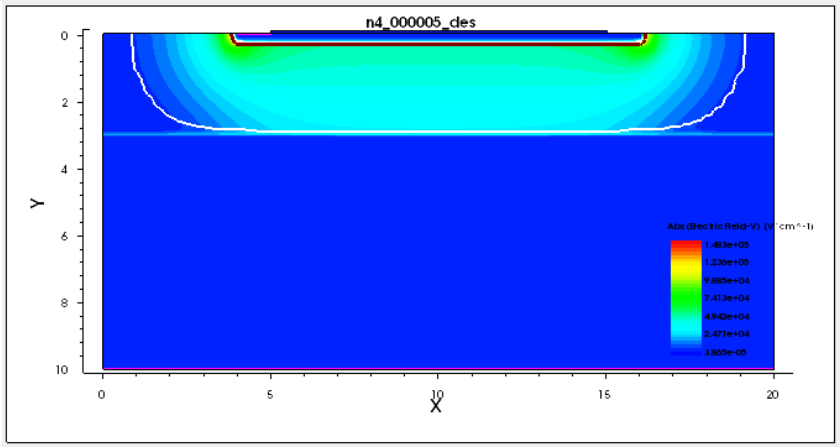


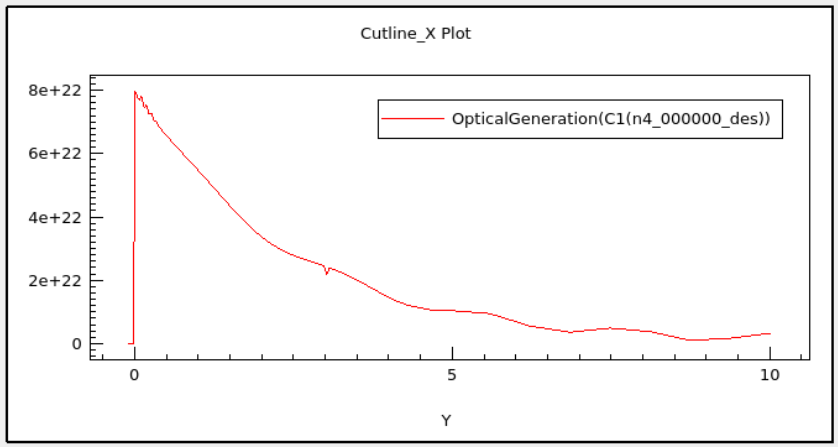
Example 1b

- Plot the **optical generation rate** for the 3 wavelengths
- Plot the **electric field** at 0V, 4V and 10V reverse bias

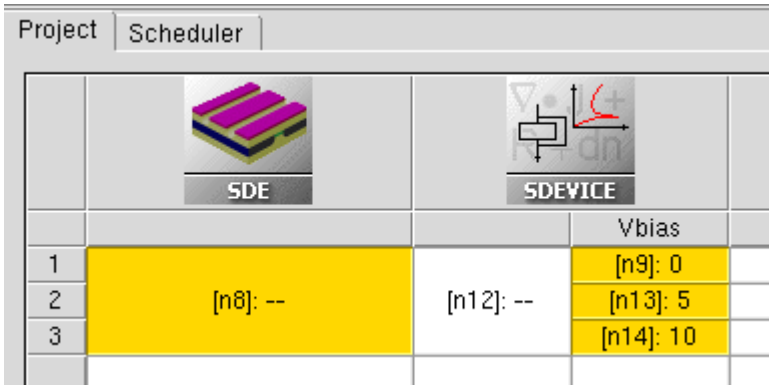






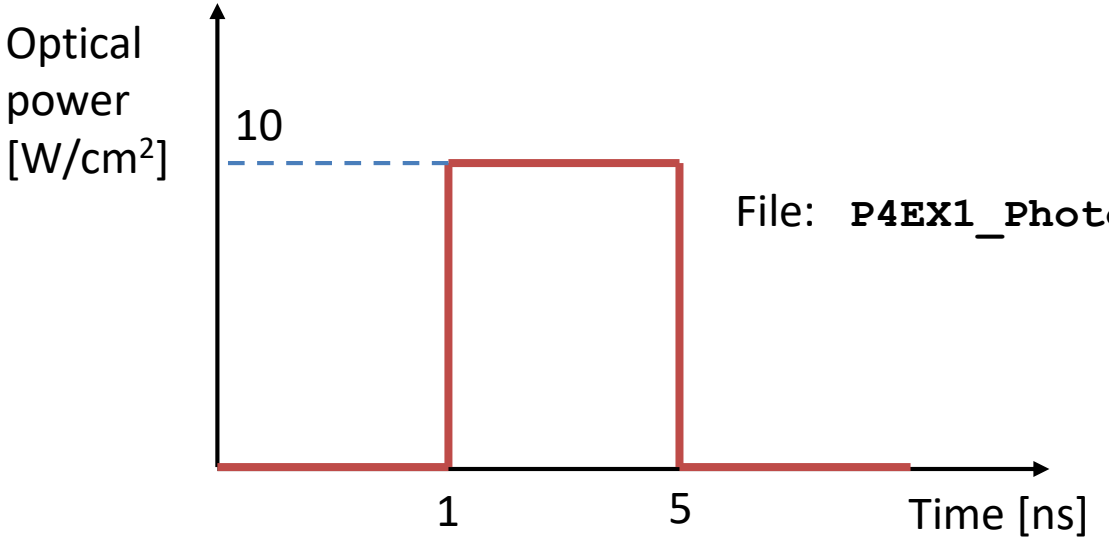


Example 1c. Transient simulation



Simulate the transient response to a light pulse at 3 different bias voltages: 0V, 5V, 10V

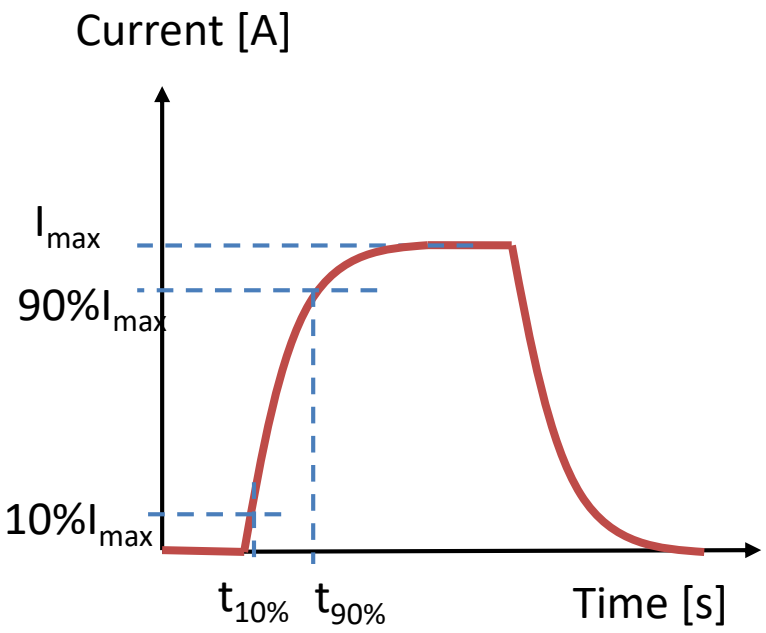
Plot and compare the photo-current vs. time for the 3 voltages. Report the **rise time 10% - 90%** in the spreadsheet

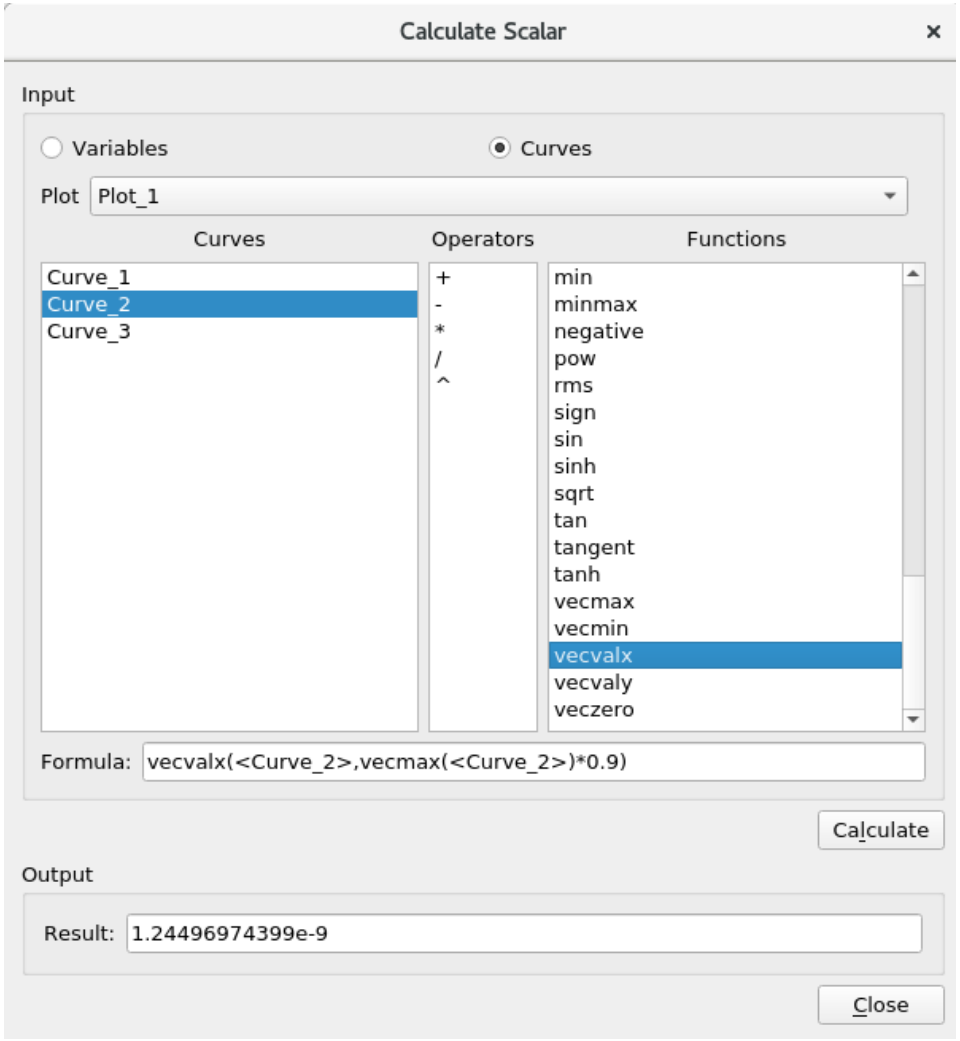


File: **`P4EX1_Photodiode_sdevice3.txt`**

Example 1c: rise time calculation

Use functions
vecvalx(<curve_name>, y_value)
and vecmax(<curve_name>)

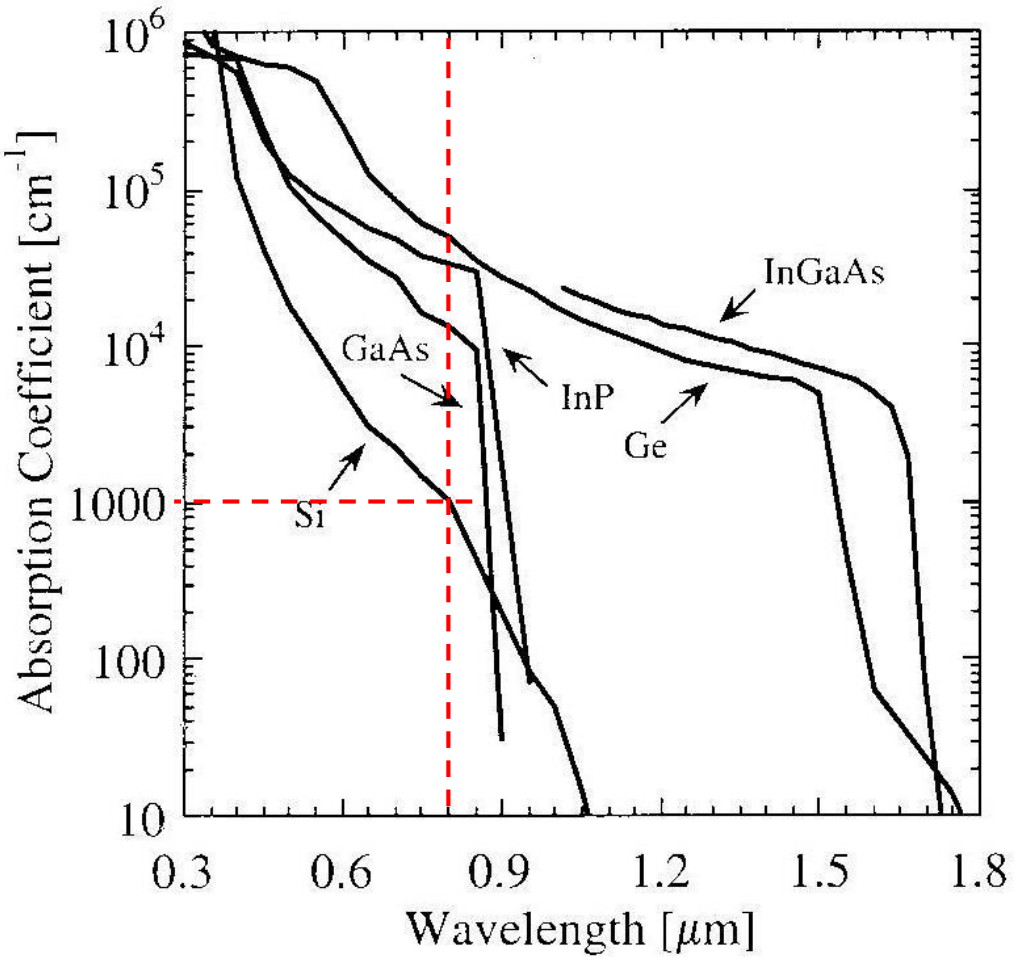




Exercise 1. Optimization for NIR light

- Modify the device geometry/doping to improve the responsivity at 800nm: parametrize the epitaxial layer thickness (5, 10 and 15 µm) and use the reverse bias simulation to analyze the photocurrent. Report the **responsivity** at 800nm for the different thicknesses in the spreadsheet

- Simulate the transient response of the new device with 800-nm light and report the **rise time at Vbias = 5V** for the 3 different thicknesses in the spreadsheet.



Handbook of Optical Constants of Solids, edited by Edward D. Palik, (1985), Academic Press NY.