Overview

1) Simulating thin films

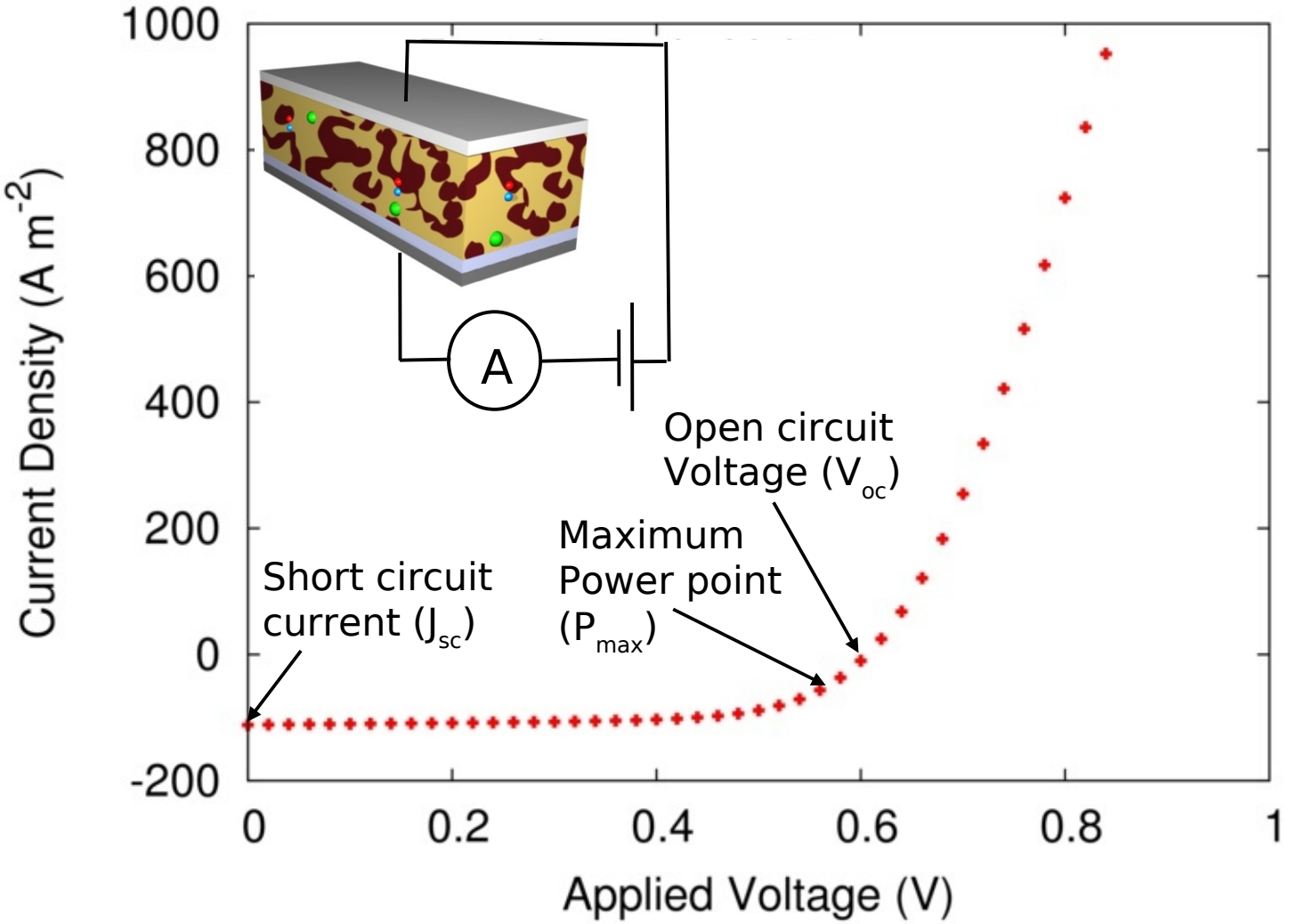
2) Electrical characterization of OPVs

3) Diffusion limited recombination in OPVs

4) The open circuit voltage

5) Conclusions

Simple electrical measurements: JV measurements - light



- Power conversion efficiency

$$\eta = \frac{P_{max}}{P_{light}}$$

- Fill factor

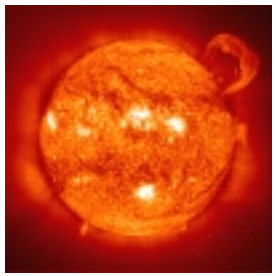
$$FF = \frac{P_{max}}{V_{oc} I_{sc}}$$

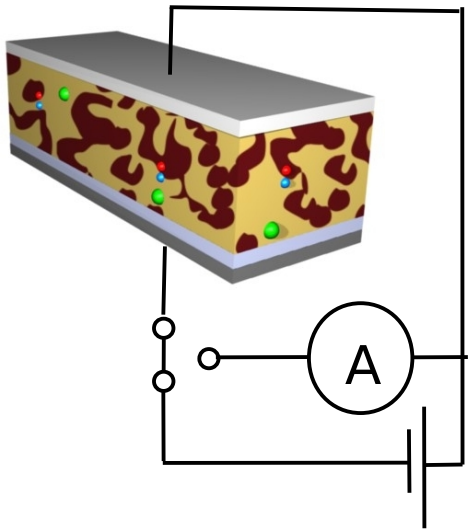
Charge extraction: How much charge is in the device?

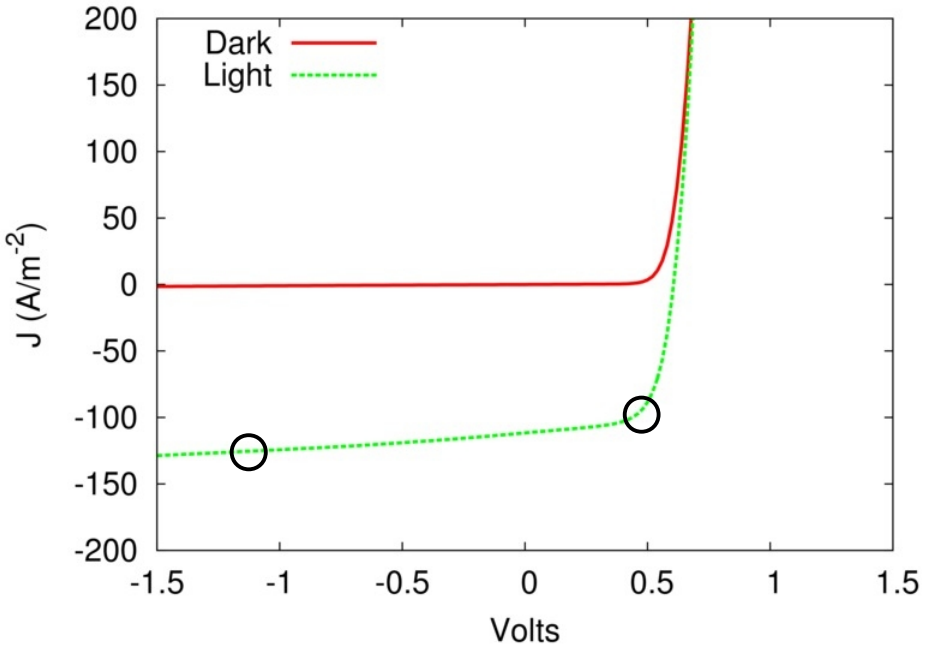
- Before we can model the device we must know how much charge is in it:

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

- Charge extraction experiment:

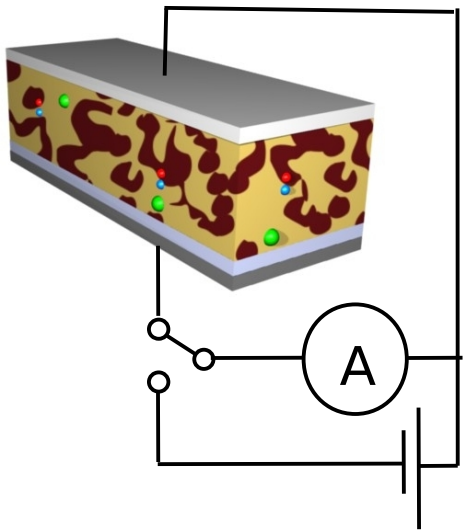


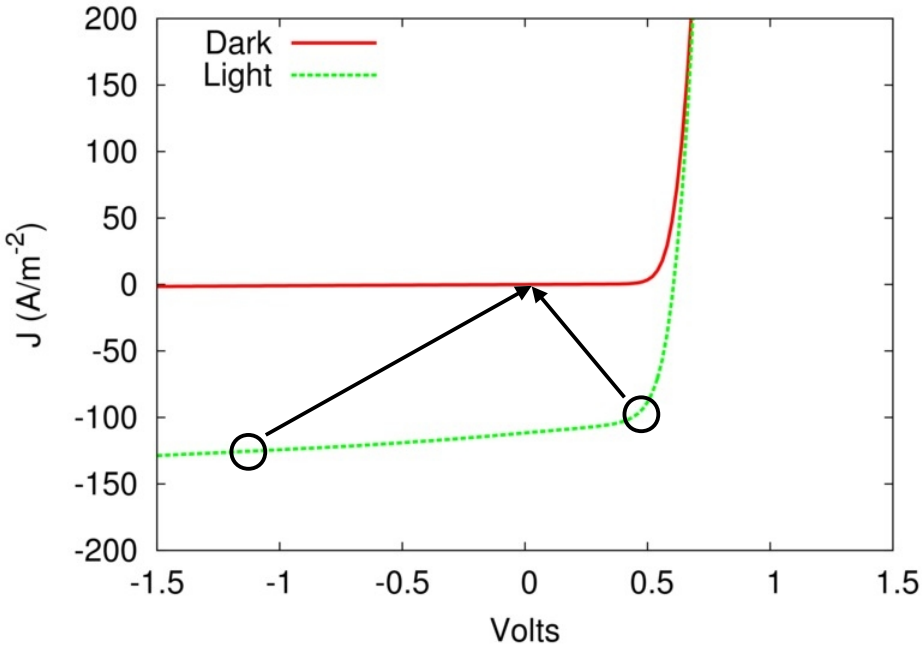




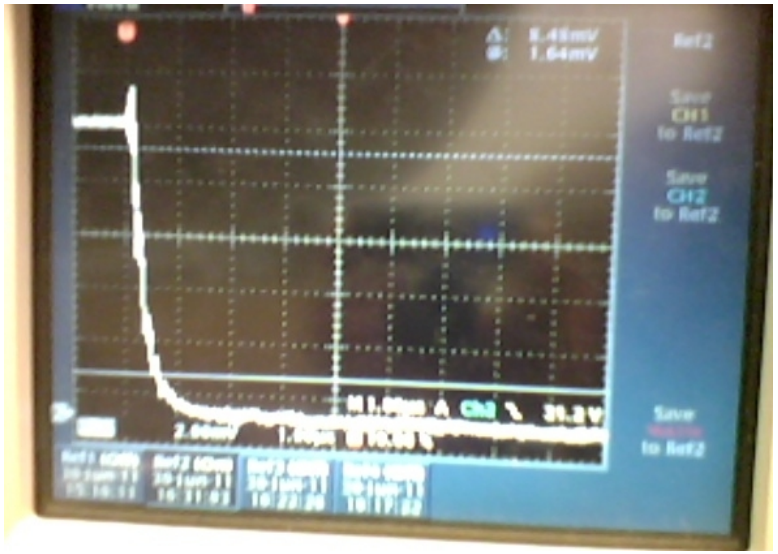
Charge extraction: How much charge is in the device?

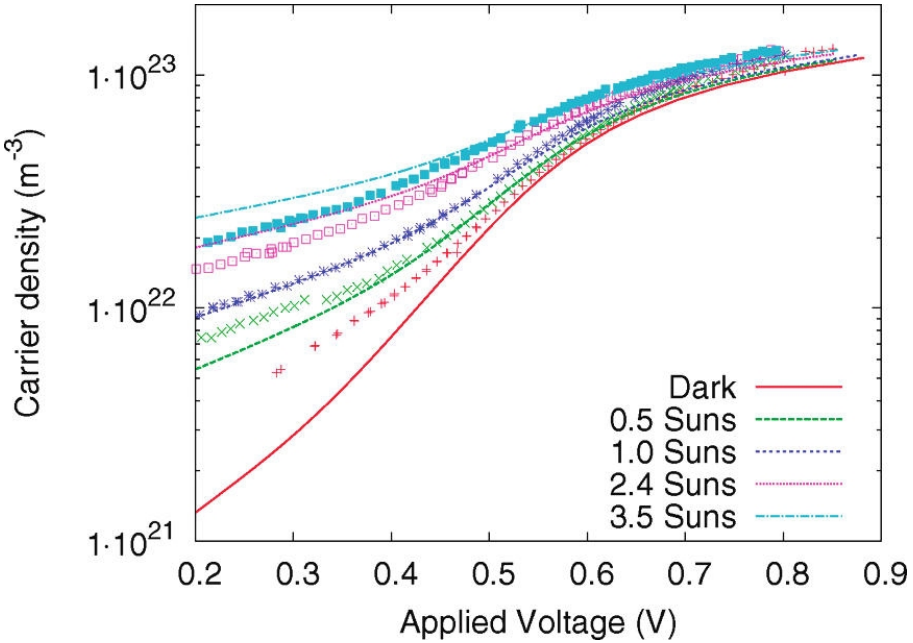
- Then turn the light off and short the device across an ammeter.
- Count the current which flows out of the device and integrate over time.
- This gives the charge trapped within the device.
- The extracted charge is far higher than would be expected from a parallel plate capacitor





Charge extraction





$$n = \int_0^{\infty} i(t)\,dt - VC$$

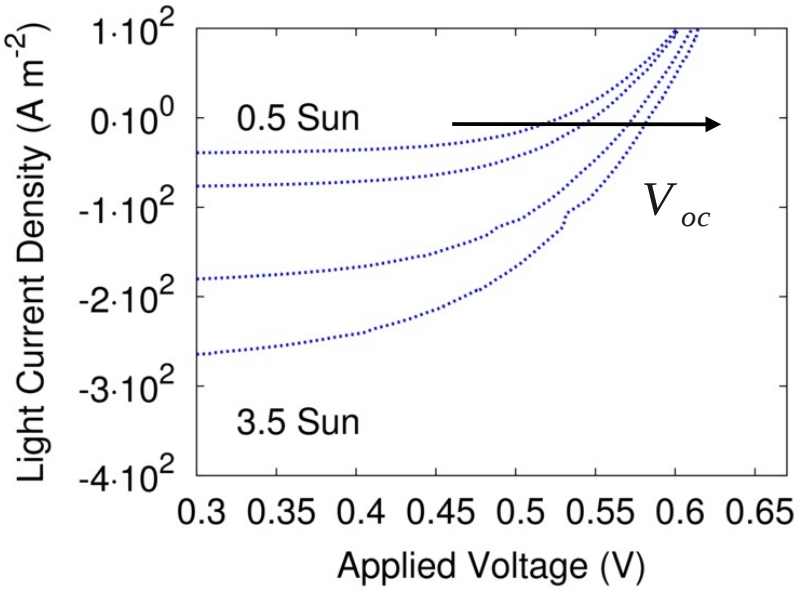
Repeat Across JV curve

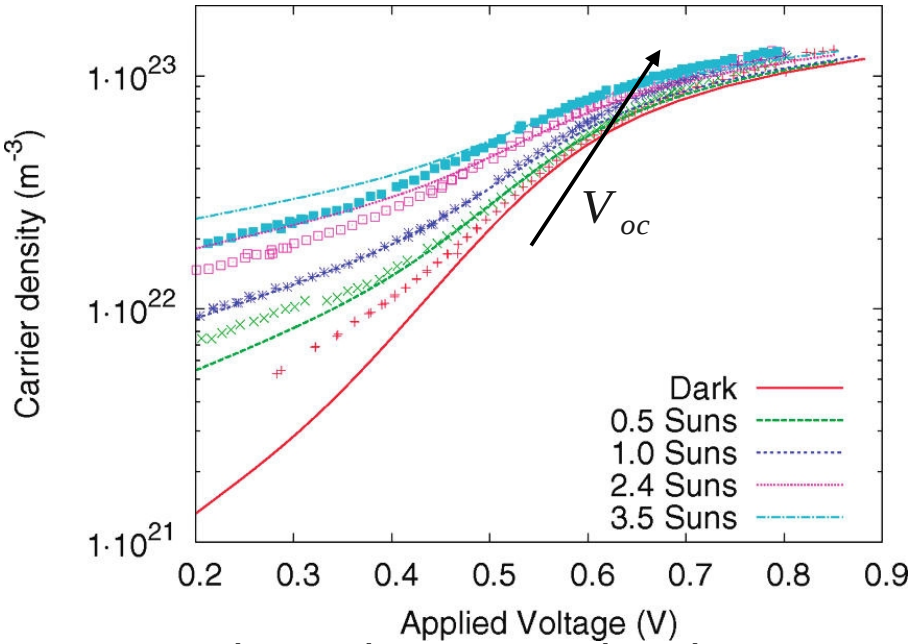
Charge extraction

- Advantages:
  - Tells you how much charge is in the device
  - It's relatively easy experiment.

- Complications:
  - Charge can recombine whilst you are extracting it, this is especially a problem with some of the newer narrow band gap polymers where recombination is faster than in P3HT:PCBM.

Transient Photo Voltage: Measuring the recombination rate

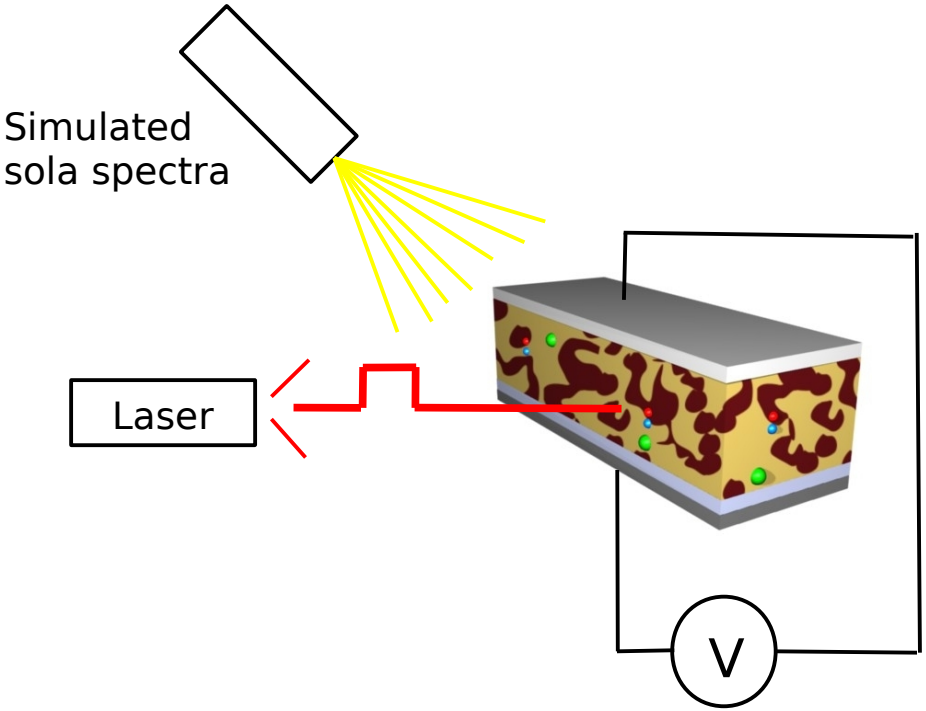


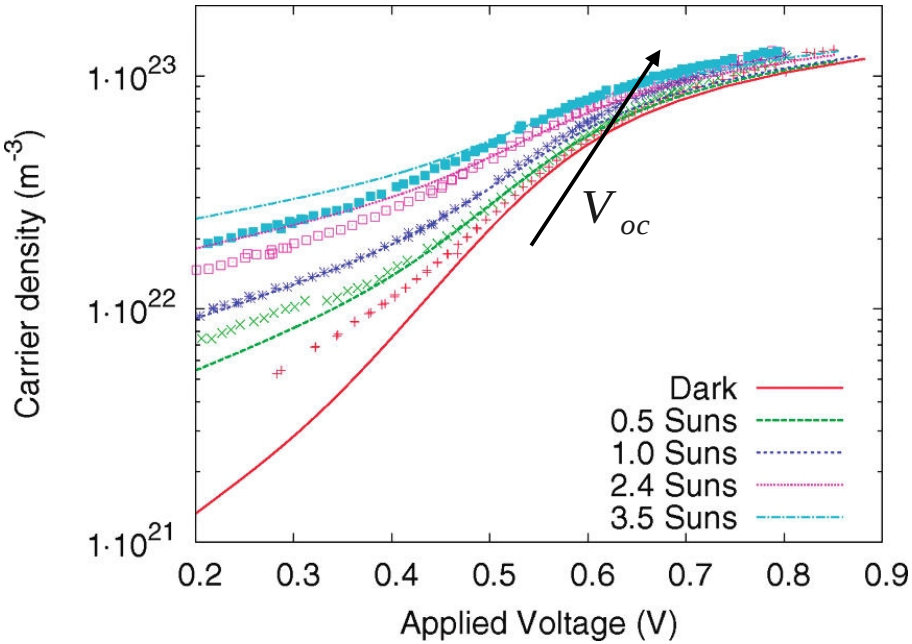


- As the background light intensity increases so does the open circuit voltage.
- As the open circuit voltage increases the charge density within the device increases increases.
- Therefore in the small perturbation regime we can think of a change in Voc as being proportianal to a change in carrier density

$$\frac{d\Delta V_{oc}}{dt} \approx \frac{d\Delta n}{dt}$$

Transient Photo Voltage: Measuring the recombination rate





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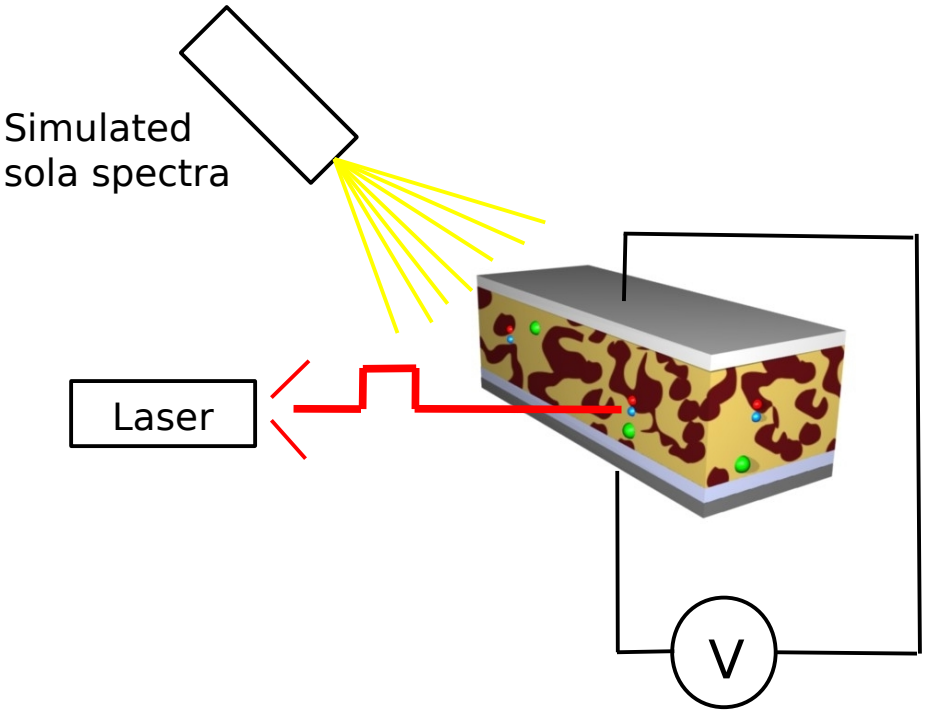
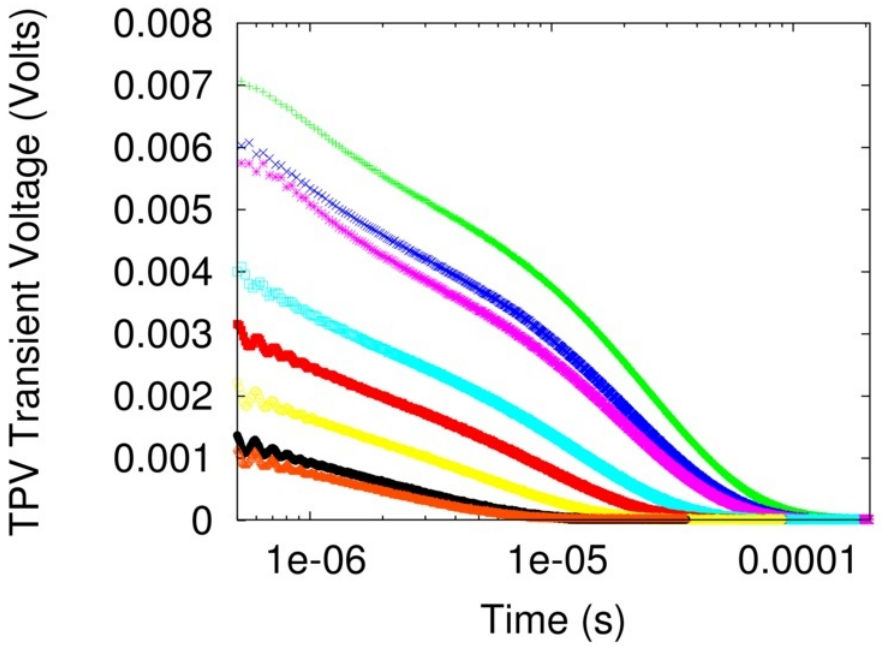
Transient Photo Voltage: Measuring the recombination rate





- Thus TPV can give us a the recombination directly.
- It has been compared against TAS and produces the same results.

$$\frac{d\Delta V_{oc}}{dt} \approx \frac{d\Delta n}{dt}$$

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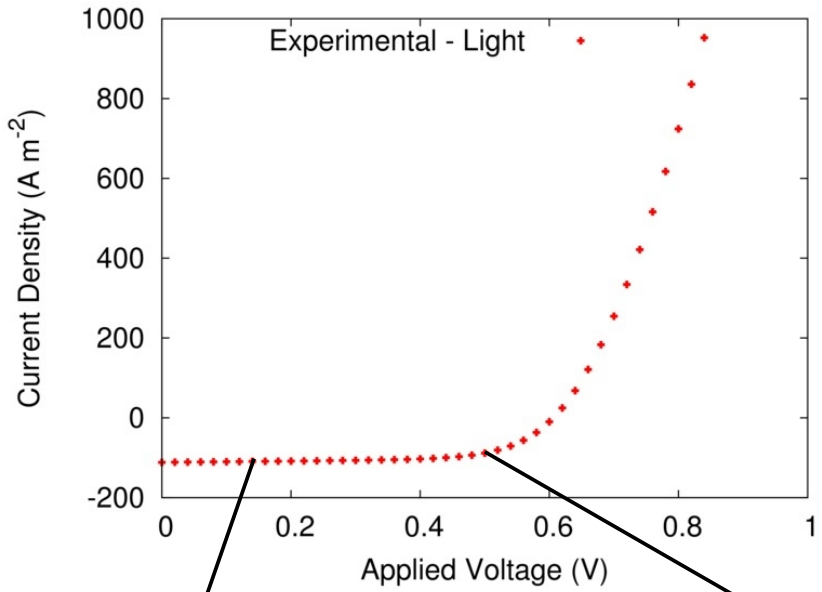
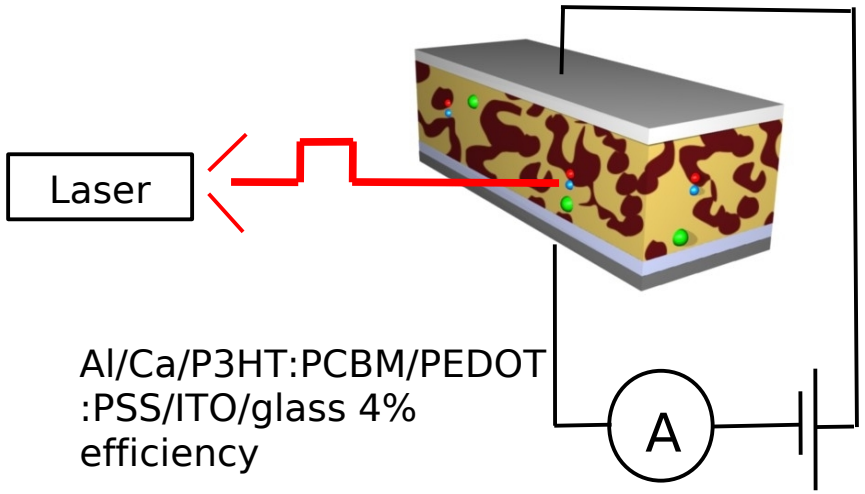
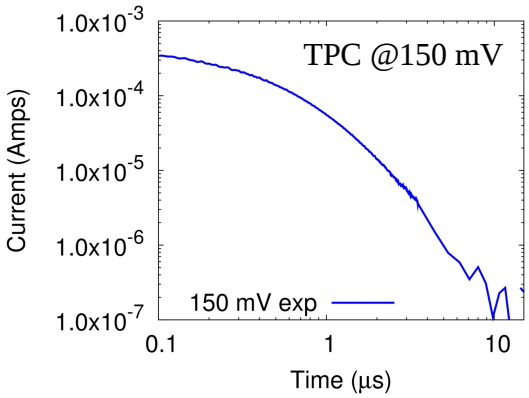
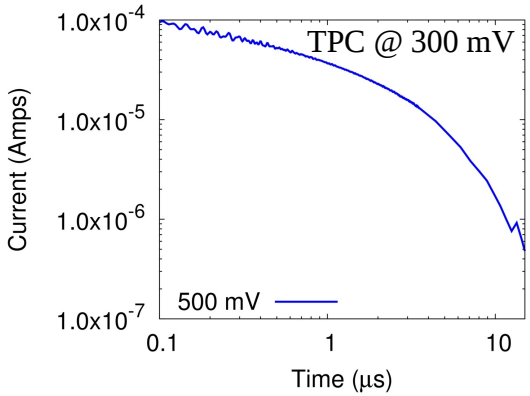
What is a transient Photo-current (TPC) measurement?









- The transient contains information on carrier recombination, transport, and trapping across the entire JV curve.
- They are quite complex therefore need a model to help us understand them.