Emission: Internal Quantum Efficiency

In this tutorial we demonstrate how to calculate the internal quantum efficiency of a multi-quantum well structure as the function of the applied forward bias.

Physics Model

nextnano++ is capable of simulating recombination processes such as *Shockley-Read-Hall (SRH)*, *Auger* and *radiative* recombination. Only the radiative *(direct)* recombination process generates photons (spontaneous emission). If it is summed up over the full device, it equals the total number of photons emitted from the device per second, the photocurrent: $I_{\rm photon}$.

$$R_{\rm sp}= c_r (n p- n_i n_i)$$

$$I_{\rm photon} = \int\limits_{V_0} R_{\rm sp} {\rm d}V$$

If the injected charge carrier current is I_{charge}, than the internal quantum efficiency is

$$\eta_{qe} = \frac{I_{photon}}{I_{charge}}$$

Input file structure

Drift Diffusion

```
recombination_model{
      SRH             = yes       # Shockley-Read-Hall recombination
      Auger           = yes       # Auger recombination
      radiative       = yes       # radiative recombination (direct
recombination)
   }
```

The internal quantum efficiency is automatically calculated when the radiative recombination is switched on

```
     radiative      = yes       # radiative recombination (direct
recombination)
```

Results

Bandstructure

The band structure of the **MQW** structure can be seen of figure 1 without bias voltage.

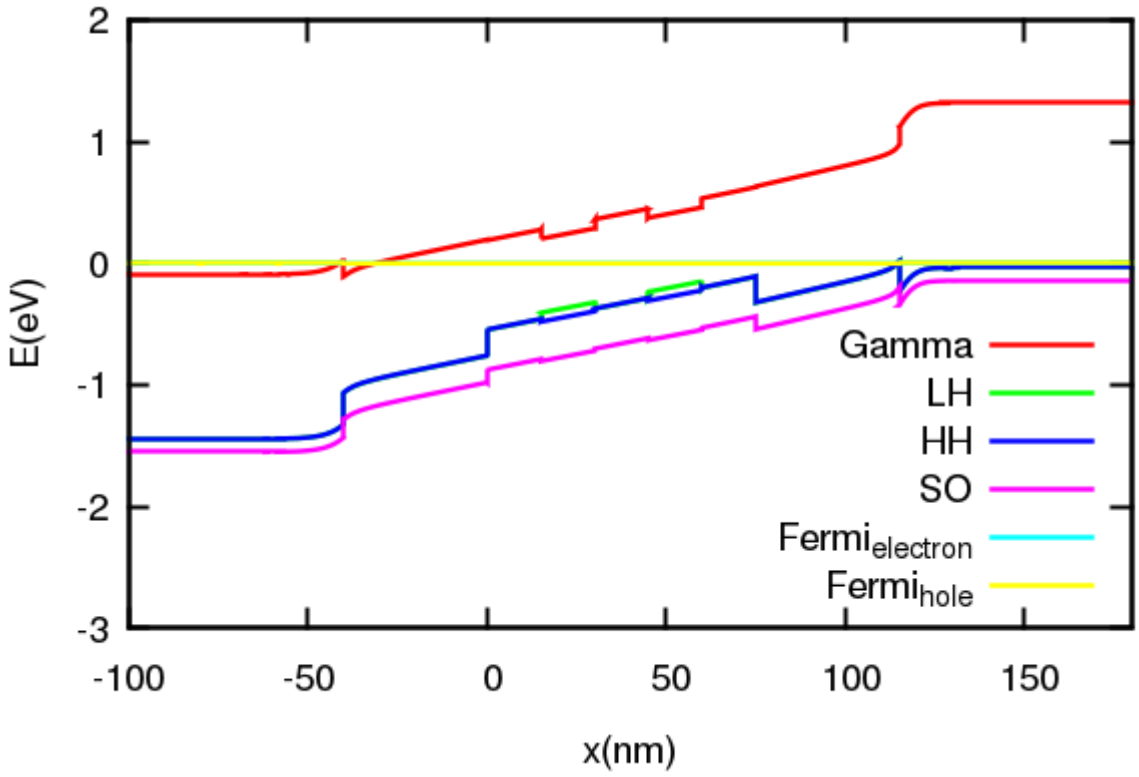

Figure 1: Bandstructure with zero bias. Two Quantum wells with alloy structures *In(0.7)Ga(0.3)As*, and well barriers *In(0.53)Ga(0.47)As*

Recombination

An example for the distribution of the recombination processes is plotted in figure 2

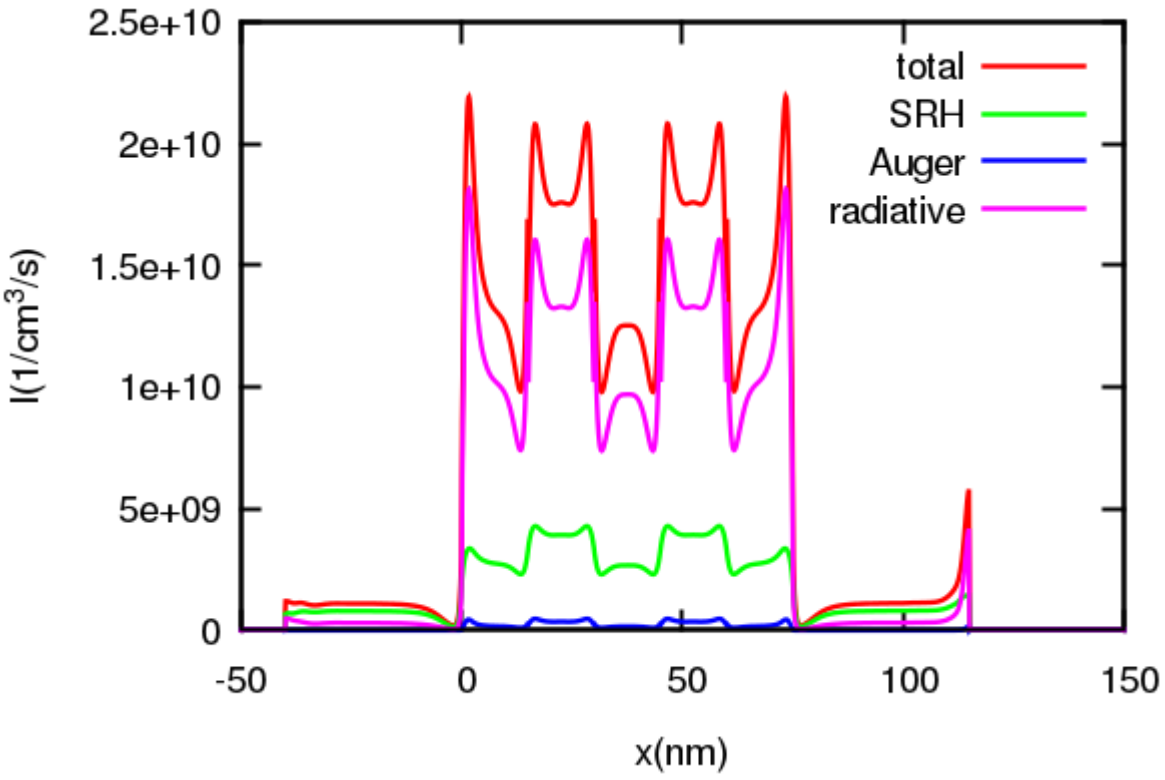

Figure 2: Comparison of different recombination processes

UI Characteristics

The $I-U$ characteristics of the device is plotted in figure 3, where additionally the full photo-current is plotted.

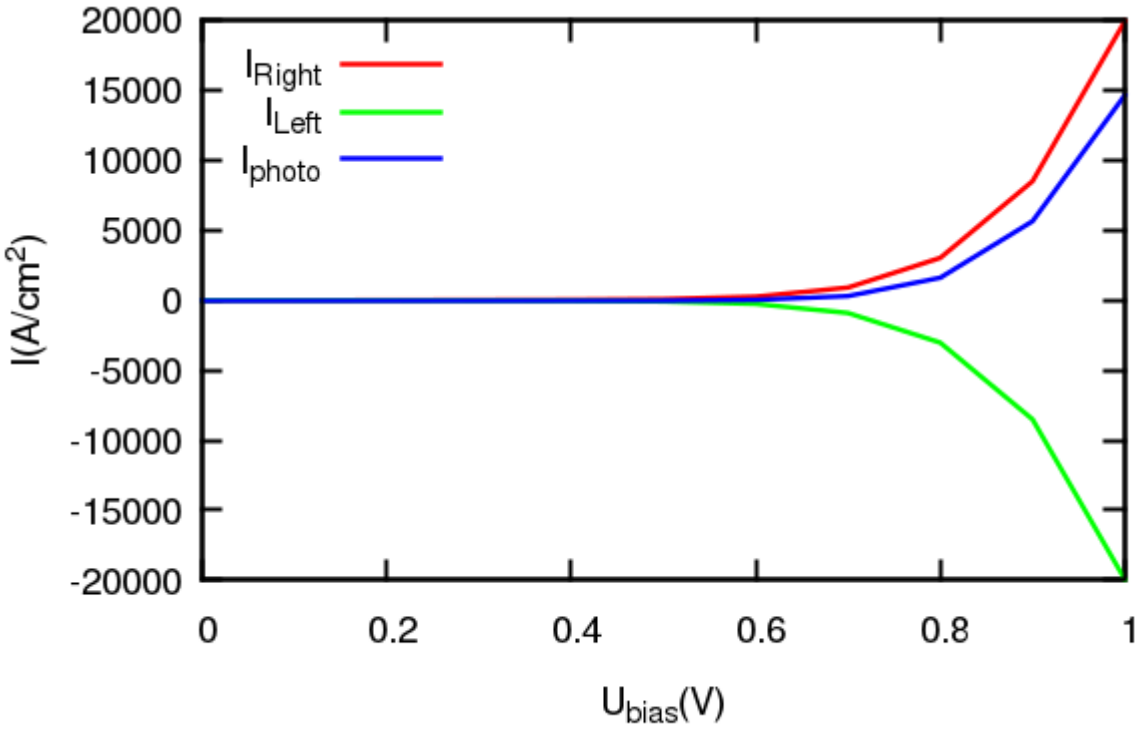

Figure 3: $I-U$ characteristic of the device with additional photo-current. The device had just two contacts which means the charge carrier currents on the left and the right contacts are equal in absolute value.

Quantum Efficiency

The internal quantum efficiency is plotted in figure 4

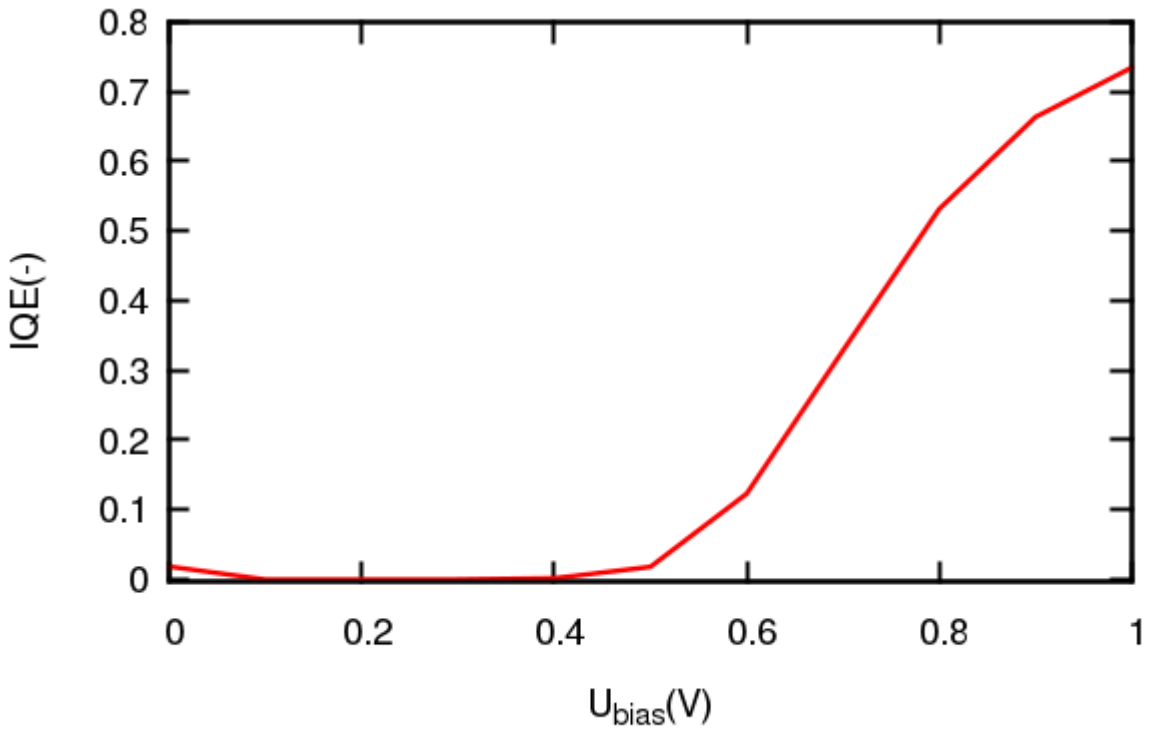

Figure 4: Internal quantum efficiency in the function of the forward bias voltage