Emission: Internal Quantum Efficiency

In this tutorial we demonstrate how to calculate the internal quantum efficiency of a multi-quantum well structure as a 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 (spontaneous emission) generates photons. If radiative recombination $R_{\rm sp}(x)$ is summed up over the full device, it equals the total number of photons emitted from the device per second, the photocurrent: $I_{\rm photon}$.

$$R_{\rm sp}= c_r (n p- n_{\rm i}^2)$$

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

If the injected charge carrier current is $I_{\rm charge}$, then the internal quantum efficiency $\eta_{\rm qe}$ is

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

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 calculated automatically 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 in figure 1 without bias voltage.

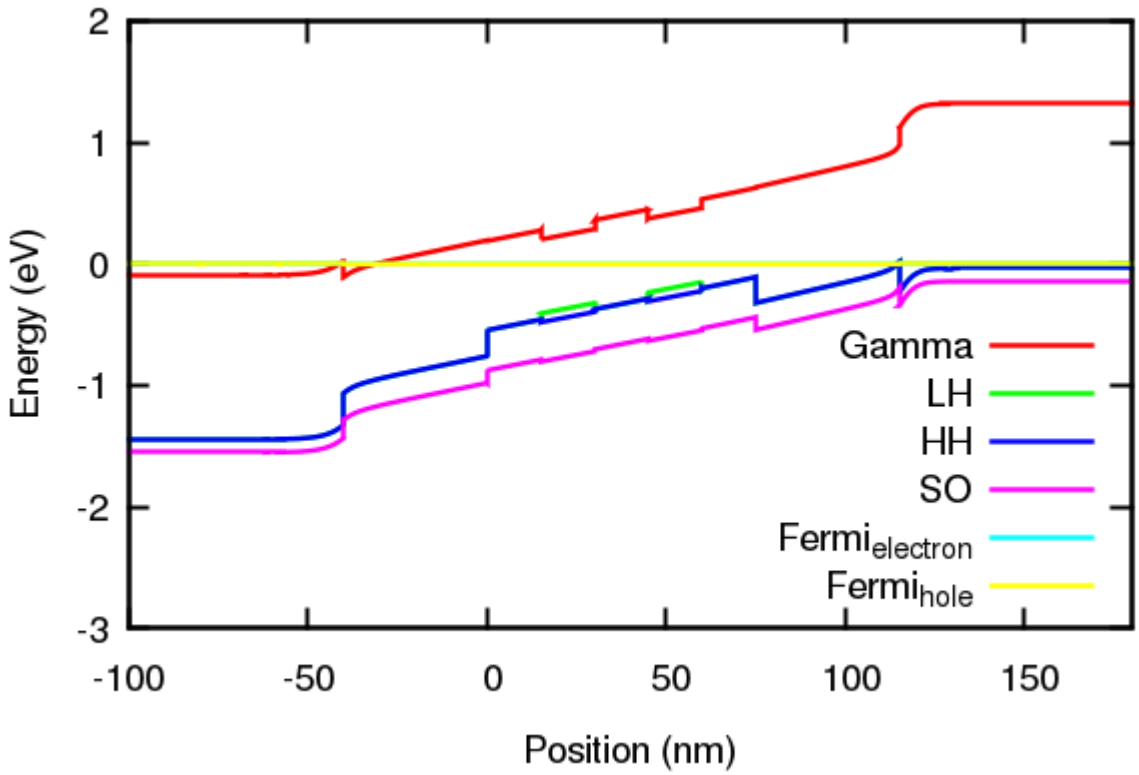

Figure 1: Band structure at zero bias. The two quantum wells consist of ${\rm In}_{0.7}{\rm Ga}_{0.3}{\rm As}$ and are surrounded by ${\rm In}_{0.53}{\rm Ga}_{0.47}{\rm As}$ barriers.

Recombination

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

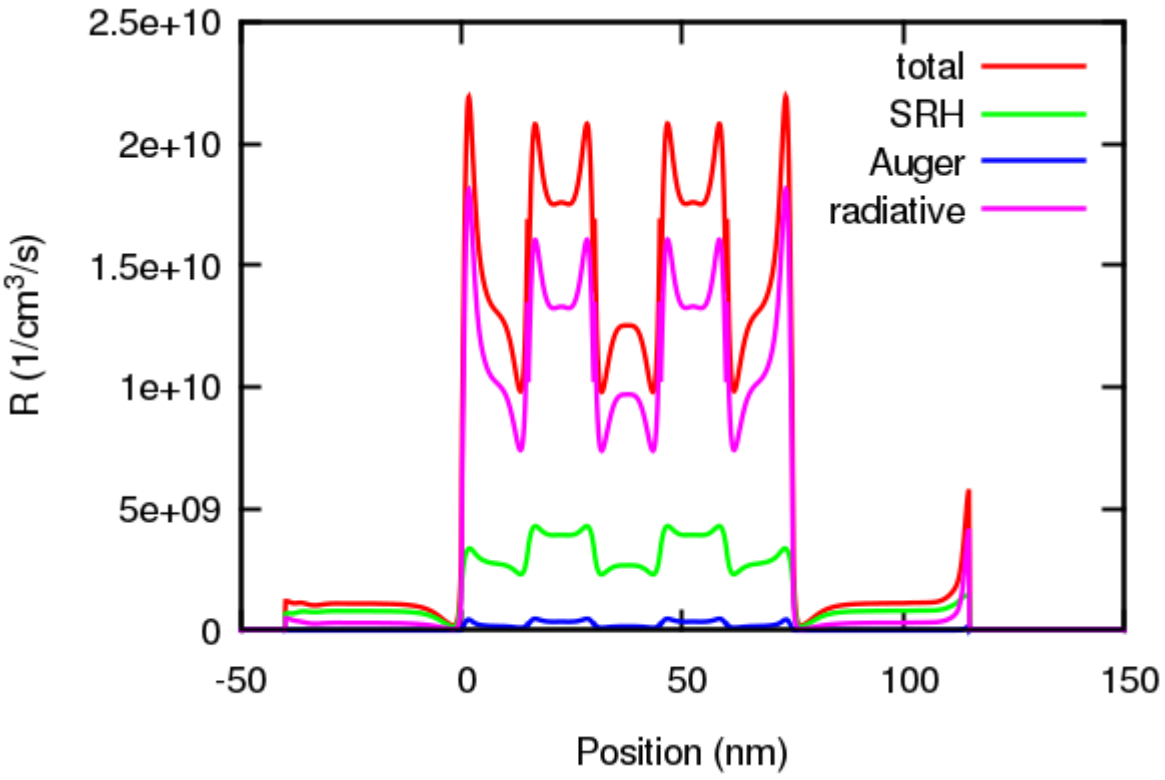

Figure 2: Comparison of different recombination processes

Current-Voltage Characteristics

The $I-V$ characteristics of the device is plotted in figure 3. This figure also includes the full photo current.

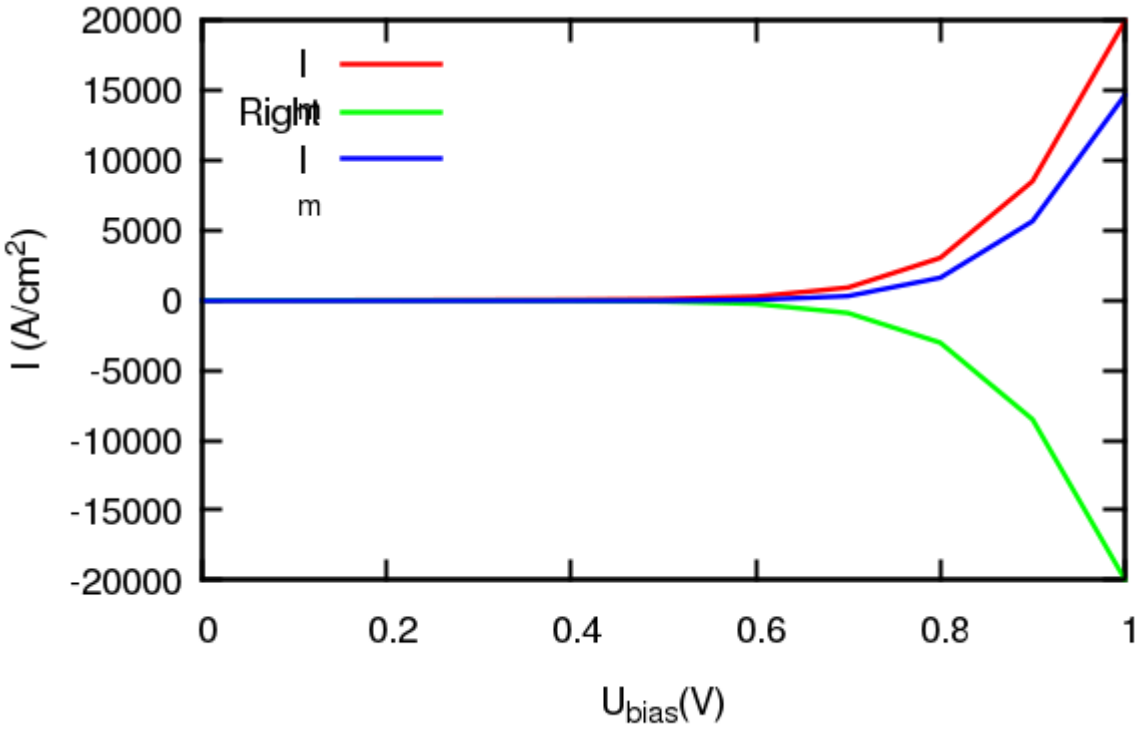

Figure 3: $I-U$ characteristic of the device with additional photo-current. The device had just two contacts which means the charge carrier currents on the left and the right contacts are equal in absolute value.

Quantum Efficiency

The internal quantum efficiency is plotted in figure 4

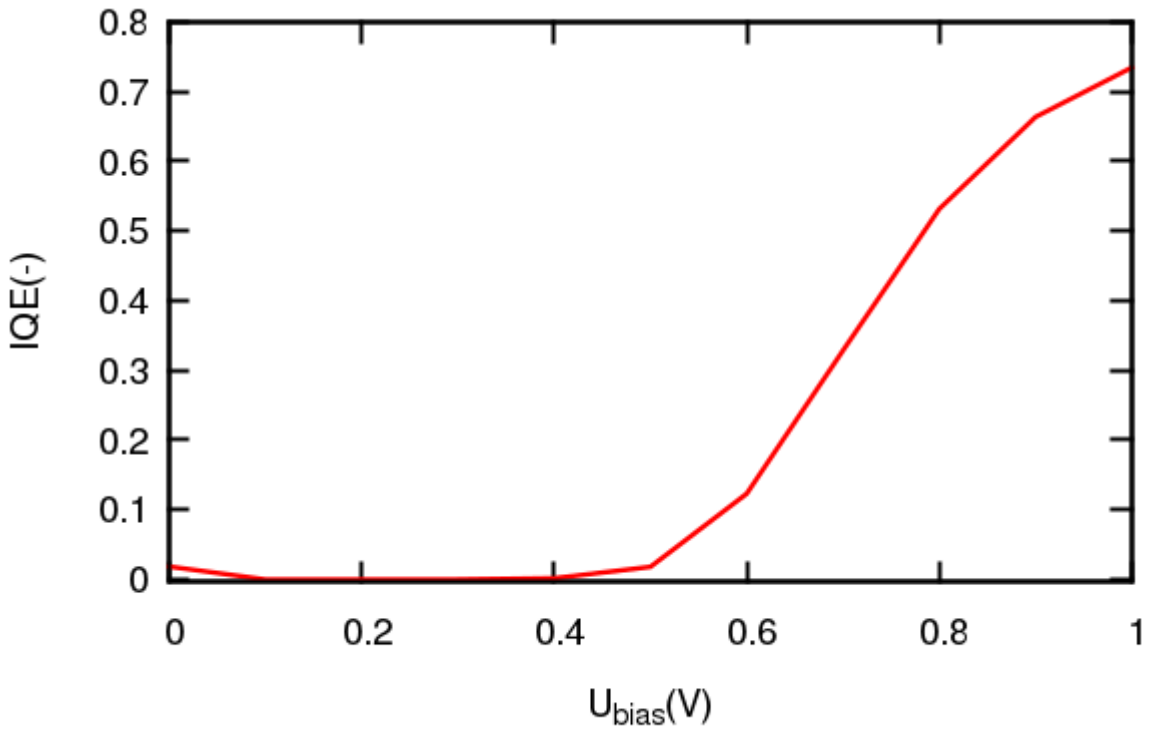

Figure 4: Internal quantum efficiency in the function of the forward bias voltage