Crosslight TCAD Simulation of Micro-LED
Contents

• Advanced models and capabilities
• Effect of sidewall defects
• MQW barrier design
• AC modulation
Advanced models

• Self-consistent MQW model based on $k \cdot p$ band structure calculations
• Quantum tunneling for EBL leakage
• Various trap models for the sidewall defects
• Self-heating thermal models
• AC/transient analysis
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\[ \frac{1}{\tau} = 1.23 \times 10^{23} \times 1.5 \times 1.0 \times 10^{-18} = 1.23 \times 10^{10} \Rightarrow \tau = 0.1 \text{ns} \]

\[
\text{doping impurity=trap_2 charge_type=donor} \&\& \\
\text{max_conc}=1.0e23 \ 	ext{level}=1.3 \&\& \\
\text{x_prof}=[15.00, 20, 1., 1.] \&\& \\
\text{y_prof}=[0, 50, 0.1, 0.1] \\
\text{doping impurity=trap_3 charge_type=acceptor} \&\& \\
\text{max_conc}=1.0e23 \ 	ext{level}=1.6 \&\& \\
\text{x_prof}=[15.00, 20, 1., 1.] \&\& \\
\text{y_prof}=[0, 50, 0.1, 0.1]
\]
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Big question: if the sidewall defects are not dense enough to quench all radiative recombination/emission there, how do we design the MQW to enhance it?
Smaller barrier seems enhance radiative emission from defect region
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New application for uLED: free space telecom

Fig. 1. (a) Plan-view optical micrograph image of the fabricated series-biased μLED array operating at 0.32 kA/cm²; (b) schematic diagram of the setup for different-distance VLC measurements, the optical images of the transmitter and receiver modules are inserted as well.
How to compute the modulation characteristics of uLED

After setting the DC bias, impose a fast Guassian pulse to probe how the uLED respond to it.

```plaintext
scan var=current_1 value_to=50. &&
init_step=0.1 min_step=1e-3 max_step=3

scan var=time value_to=10.e-9 &&
var2=current_1 function_label2=gs_func &&
init_step=0.01e-9 max_step=0.1e-9
scan_function label=gs_func type=gaussian gsn_dt=2.e-9 &&
gsn_s1=50 gsn_s2=60

scan var=time value_to=100.e-9 max_step=2.e-9 &&
var2=current_1 value2_to=50.
```
Convert impulse response using Fourier transform

$ modulation response is
20\log(\text{led}\_\text{power}(\text{freq})/\text{current}\_1(\text{freq}))

plot\_scan \text{scan\_var}=\text{time variable}=\text{current}\_1
plot\_scan \text{scan\_var}=\text{time variable}=\text{led}\_\text{power}
\text{fourier}\_\text{power} \text{input\_var}=\text{current}\_1 \text{output\_var}=\text{led}\_\text{power} 
\&\&
\text{log}\_\text{freq}=\text{yes} \text{freq}\_\text{start}=6 \text{freq}\_\text{end}=8.5
Response sensitive to injection current and uLED side, as well as defect properties
Conclusions

- Crosslight TCAD tool convenient and powerful for analysis of uLED
- The sidewall defects should be characterized using details trap parameters in both spatial and energy distribution
- Impulse response can be used to obtain modulation response for telecom applications
Thanks for your attention!