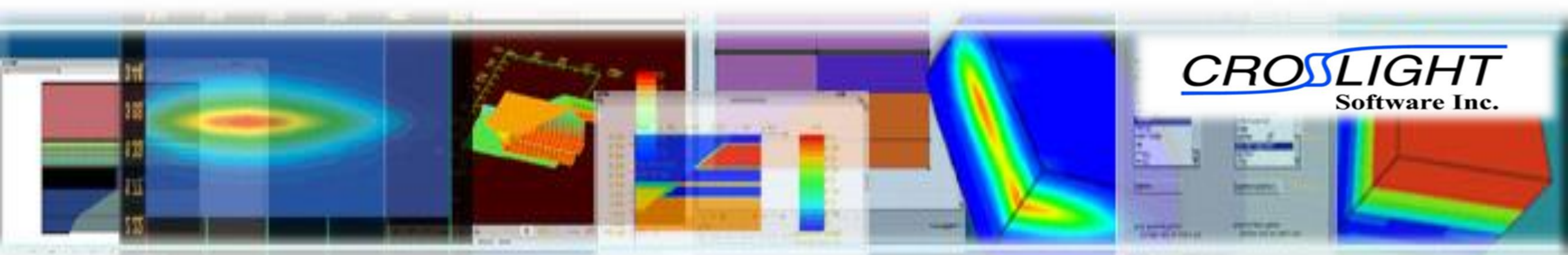

Crosslight TCAD Simulation of Micro-LED

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Contents

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

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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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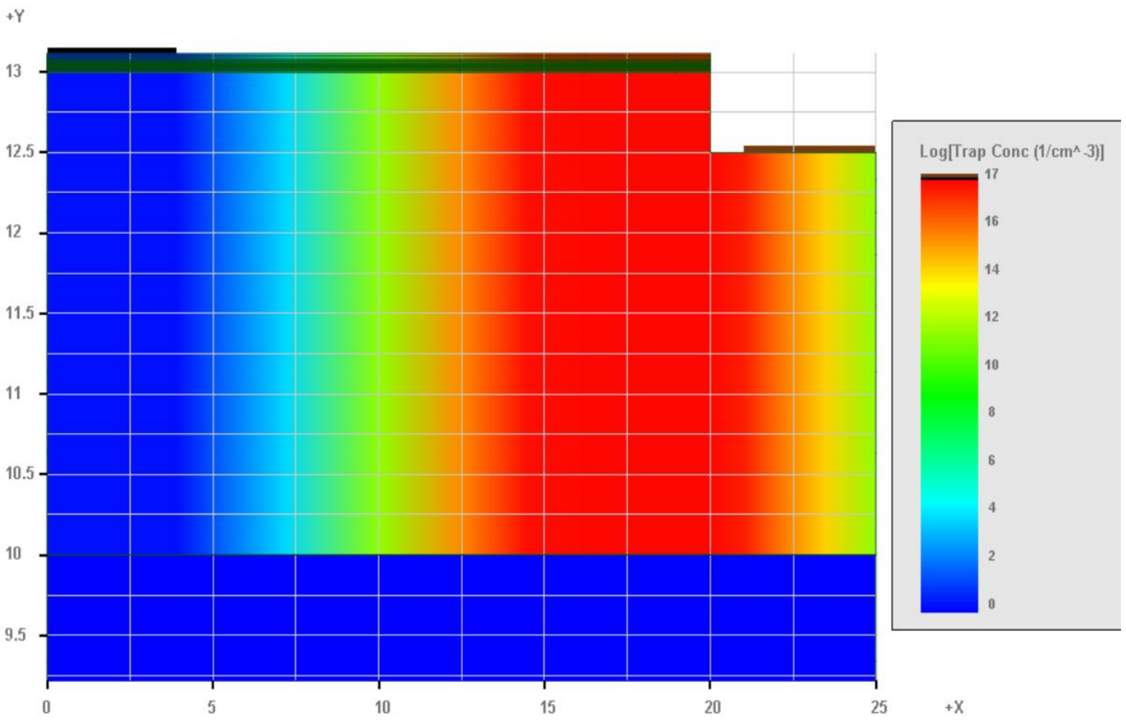


```
start_loop symbol=%m value_from=1 value_to=9
trap_ncap_2 value=1.e-17 mater=%m
trap_pcap_2 value=1.e-17 mater=%m
trap_level_2 value=1.3 mater=%m
trap_ncap_3 value=1.e-17 mater=%m
trap_pcap_3 value=1.e-17 mater=%m
trap_level_3 value=1.6 mater=%m
end_loop symbol=%m value_from=1 value_to=9
```

```
$ ---traps for defects near the vertical wall of uLED
$ since trap_1 is reserved for SRH lifetime setting, it is
$ better we define additional traps using trap_2, trap_3,
$  etc....
$ trap level measured from conduction band
$ 1/lifetime=
$ trap_density*thermal_velocity*trap_cap_cross_section
$ 1/sec=(1/m**3)*(m/s)*trap_cap
$ roughly vtherm=1.e5 m/s, trap_cap=1nm**2,
conc=1.e23 m**-3
$ 1/tau=1.e23*1.e5*1.e-18=1.e10  => tau=0.1ns
$
doping impurity=trap_2 charge_type=donor &&
  max_conc=1.0e23  level=1.3 &&
  x_prof=[15.00, 20, 1.,  1.]  &&
  y_prof=[0, 50, 0.1 0.1]
doping impurity=trap_3 charge_type=acceptor &&
  max_conc=1.0e23  level=1.6 &&
  x_prof=[15.00, 20, 1.,  1.]  &&
  y_prof=[0, 50, 0.1 0.1]
```


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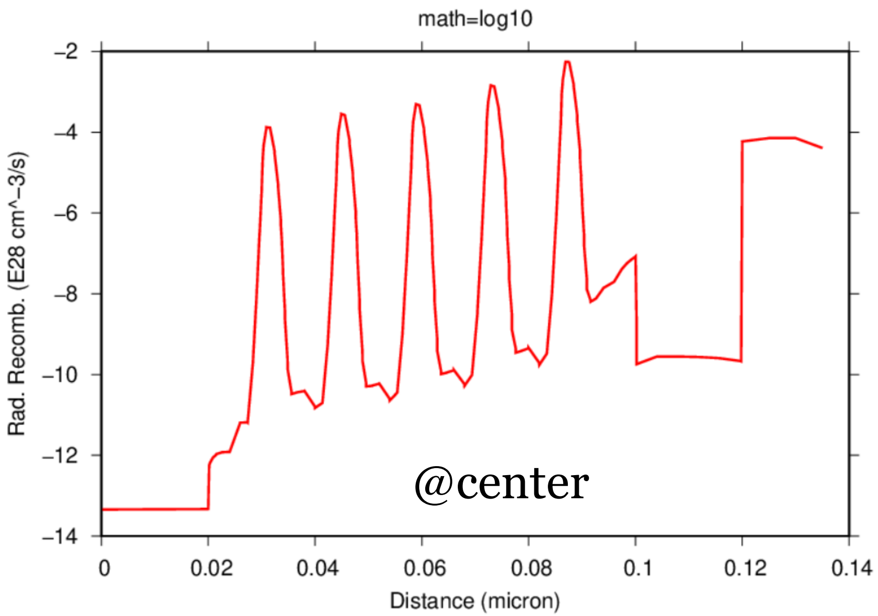

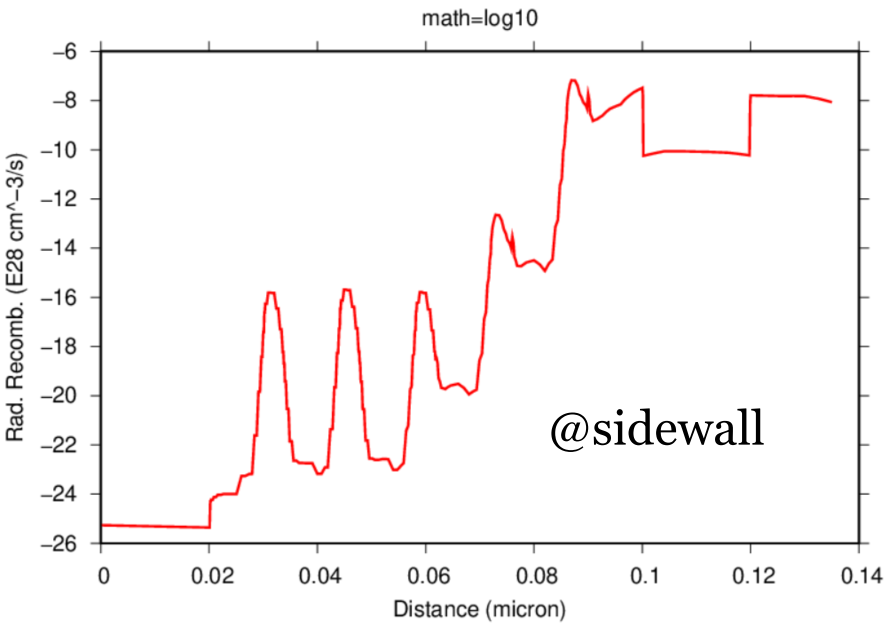

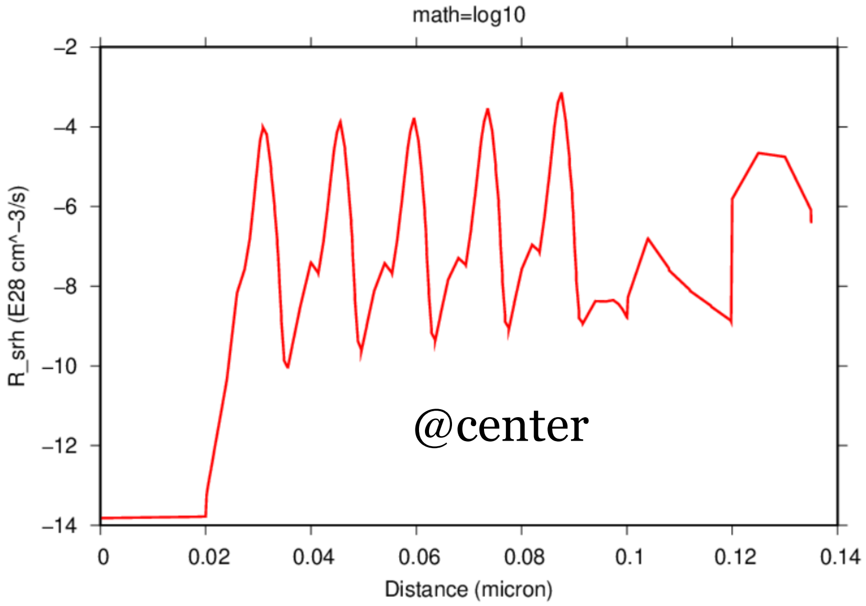

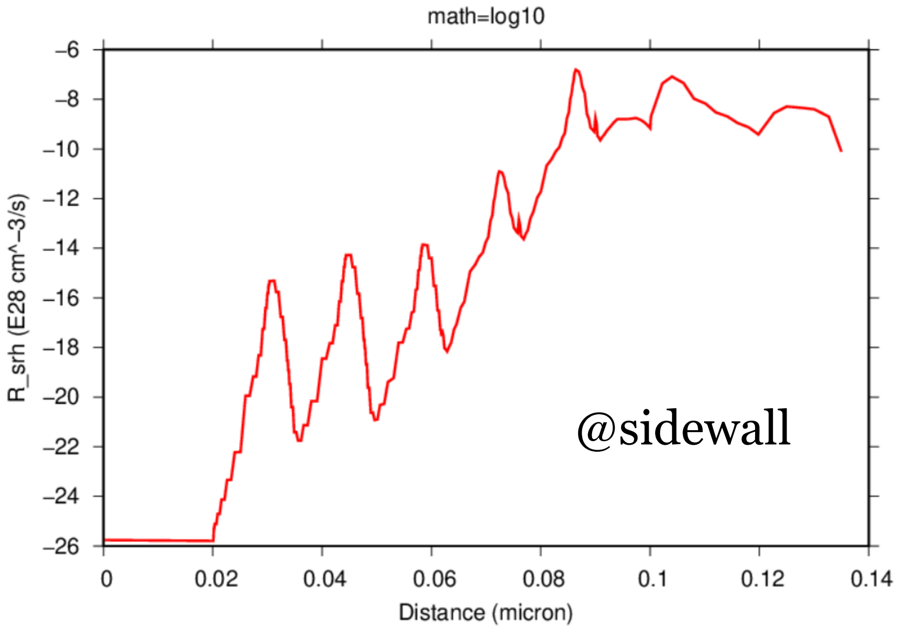

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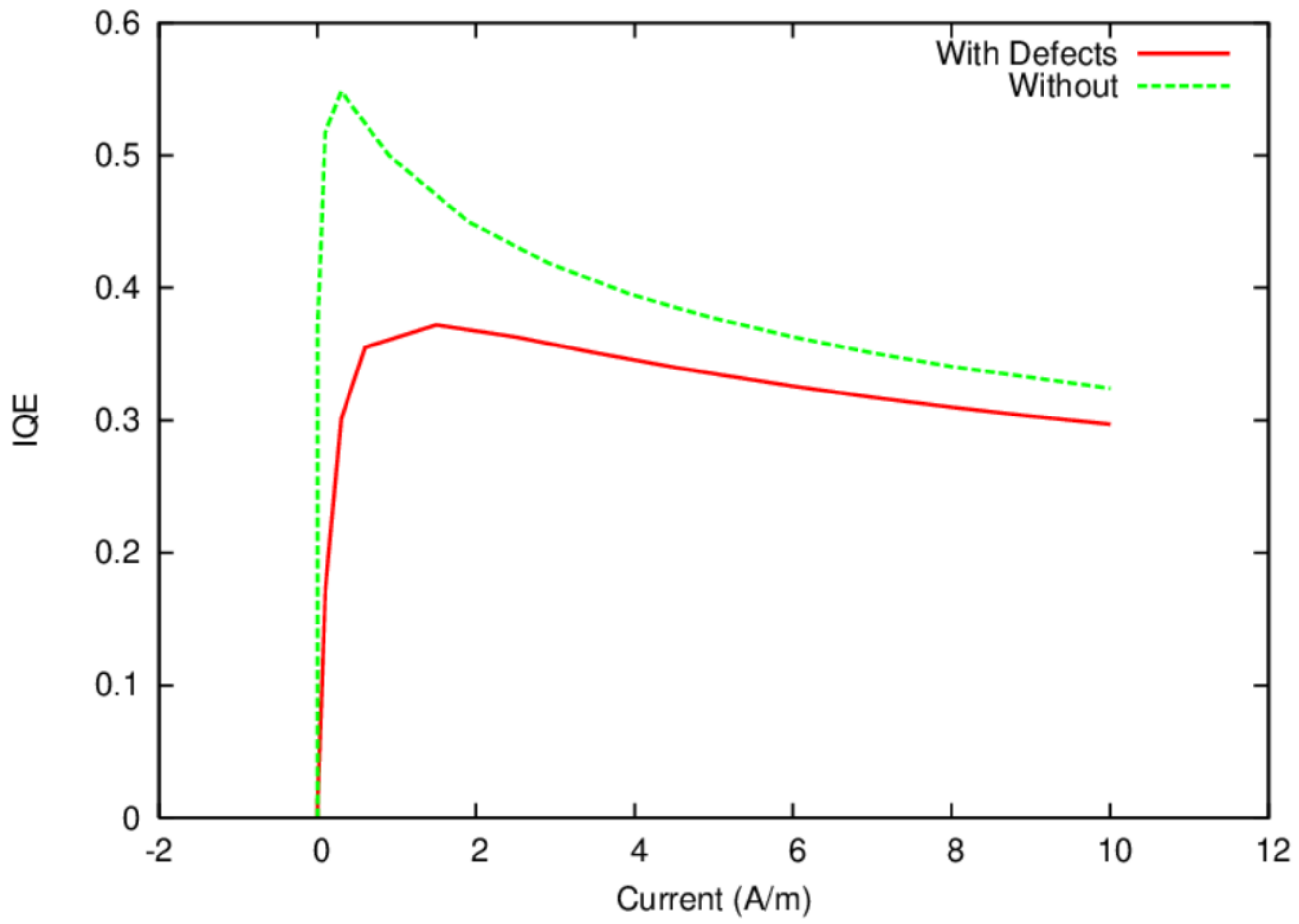
With Defects
Without
IQE
0.6
0.5
0.4
0.3
0.2
0.1
0
-2
0
2
4
6
8
10
12
Current (A/m)

Contents

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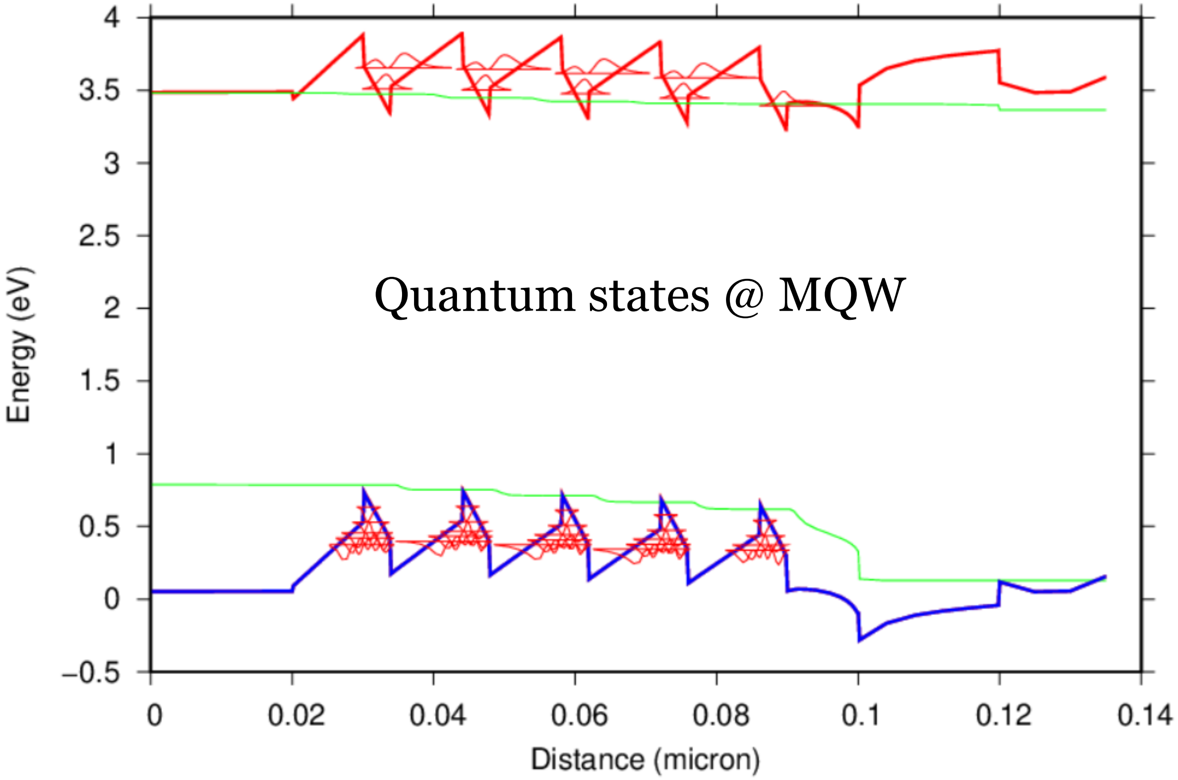

Big question: if the sidewall defects are not dense enough to quench all radiative recombination/emission there, how do we design the MQW to enhance it?

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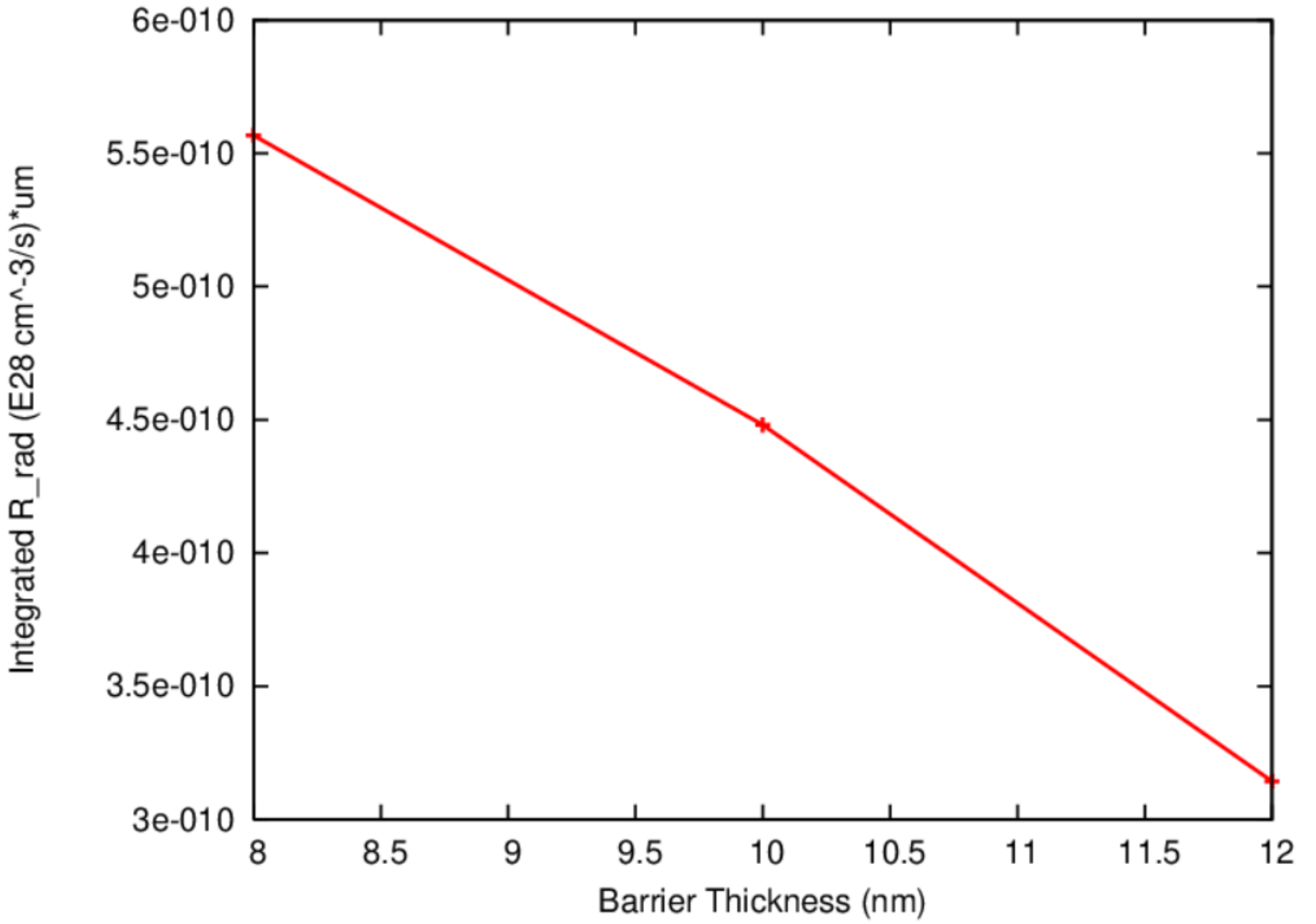
Smaller barrier seems enhance radiative emission from defect region



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New application for uLED: free space telecom

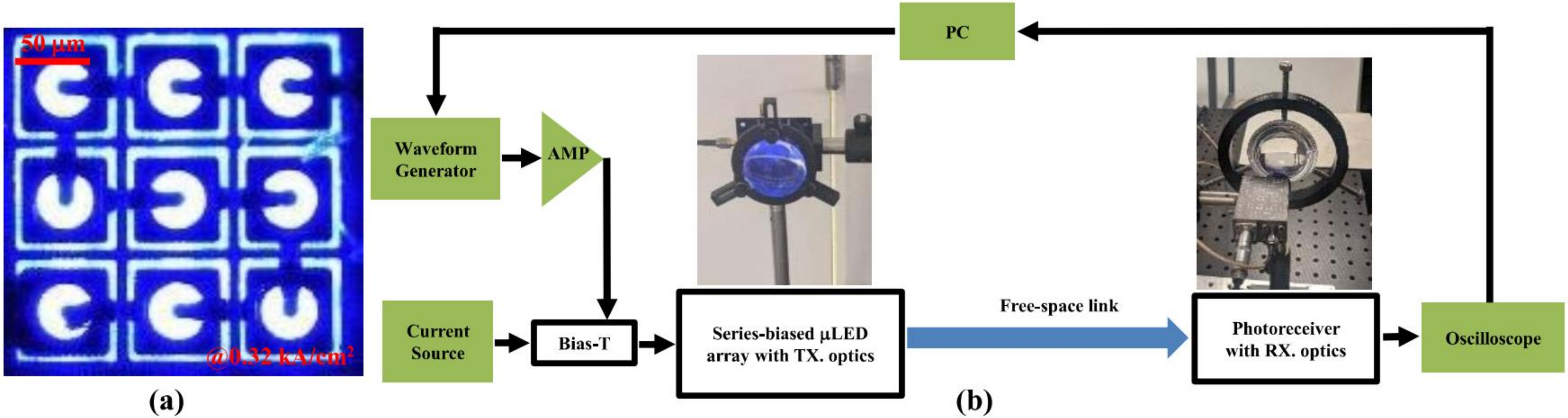

Fig. 1. (a) Plan-view optical micrograph image of the fabricated series-biased μLED array operating at 0.32 kA/cm^2; (b) schematic diagram of the setup for different-distance VLC measurements, the optical images of the transmitter and receiver modules are inserted as well.

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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.

```
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.
```


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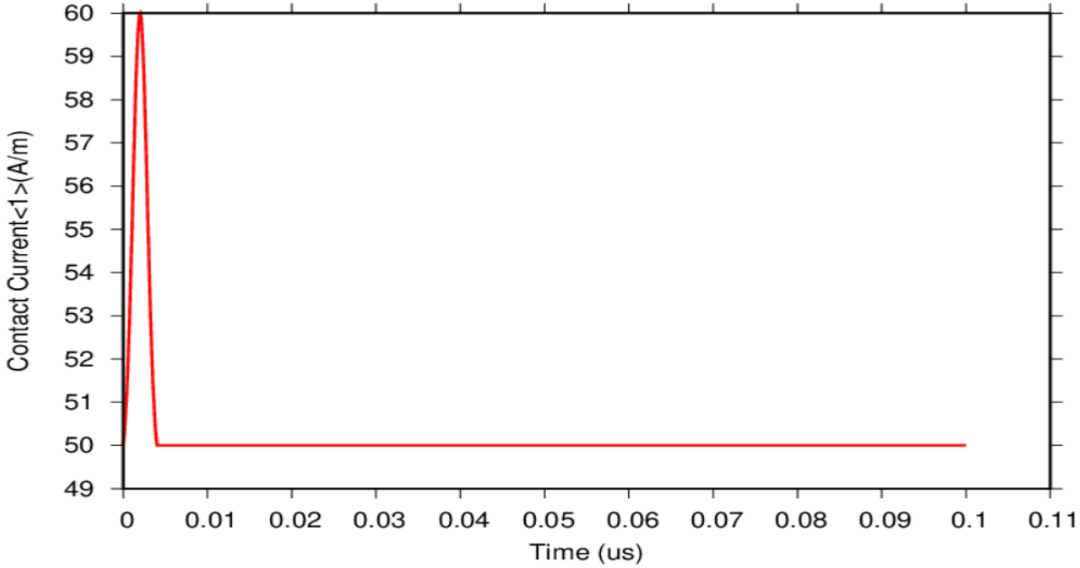
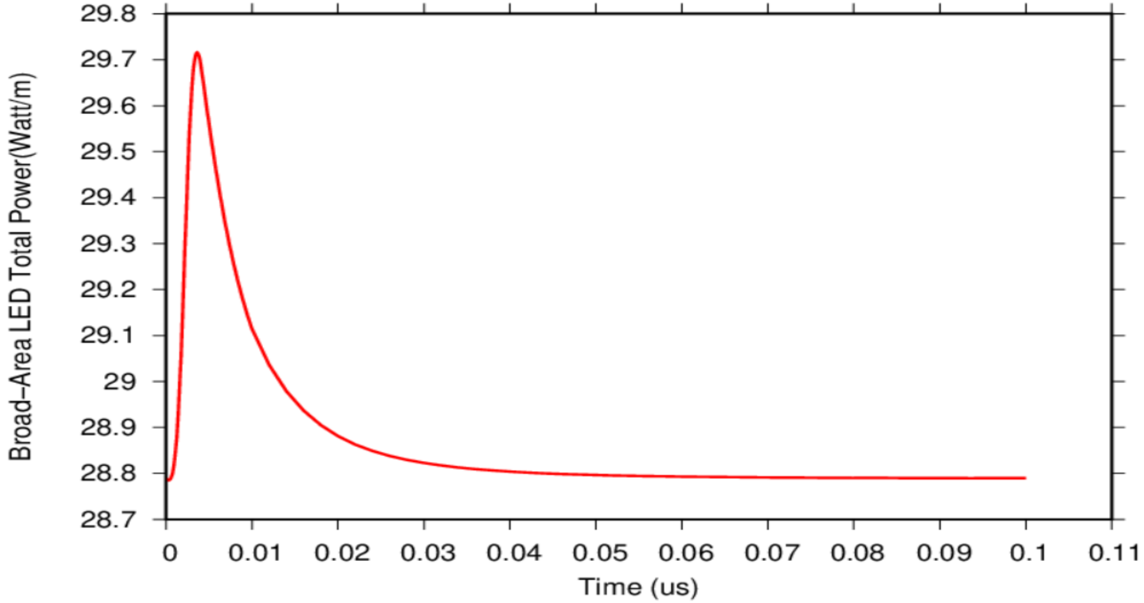
Convert impulse response using Fourier transform

$ modulation response is
20log(led_power(freq)/current_1(freq))
plot_scan scan_var=time variable=current_1
plot_scan scan_var=time variable=led_power
fourier_power input_var=current_1 output_var=led_power &&
  log_freq=yes freq_start=6 freq_end=8.5





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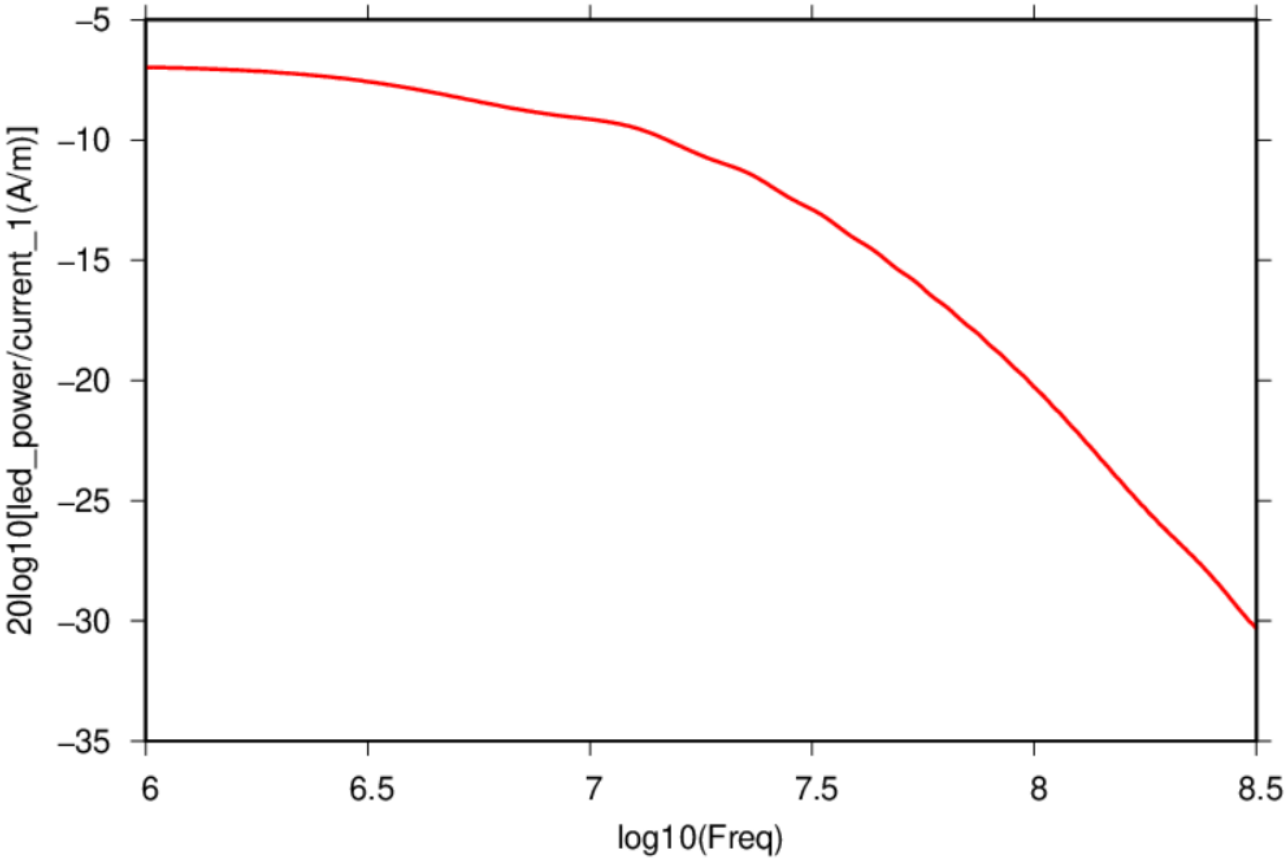

Response sensitive to injection current and uLED side, as well as defect properties

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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

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Thanks for your attention!

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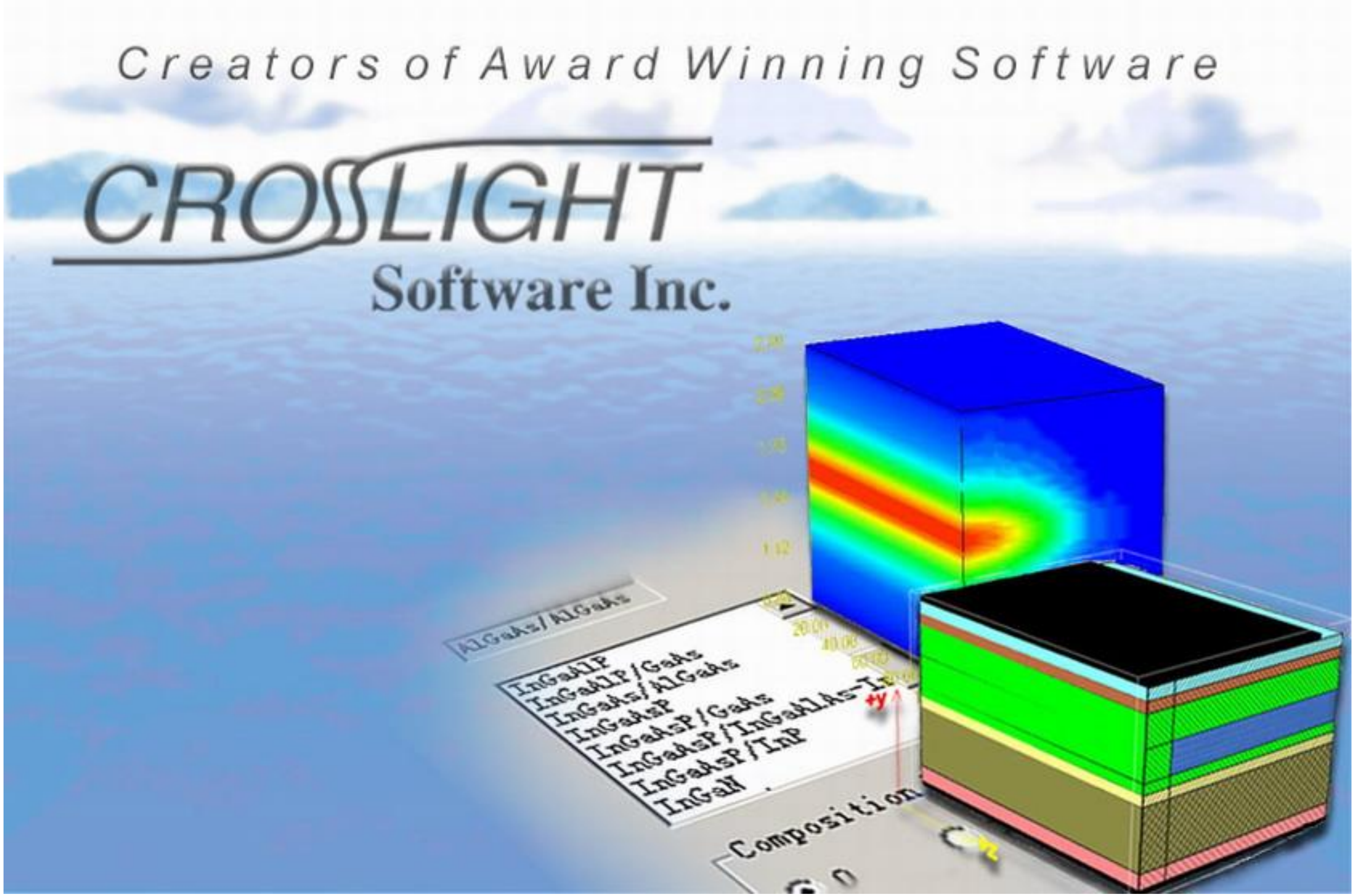

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