UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Exploring Possibility of Replacing 248 nm KrF with AlGaN Photolithography

Electrical & Computer Engineering

ECE443 Final Project presented by Ming-Yan Hsiao

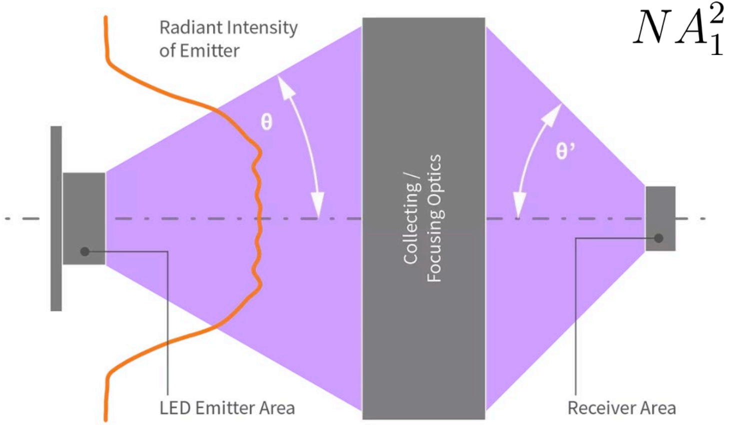
04/22/2024

Motivation

- DUV IQE and EQE State-of-art improvements
- Expensiveness and low efficiency of Excimer Laser
- Trend of UV LEDs replacing Hg lamps

Parameters to Meet and Source Mask Optimization

Estimation for the Area of Light Source



Matching LED output to an optical system (etendue matching)

$$NA_1^2 * A_1 = NA_2^2 * A_2$$

n_{AlGaN}~2.19,

$\arcsin(0.54/2.19) = 14.27^{o}$

$$radius \approx 18.617mm$$

$$0.54^2 A_{light} = 0.63^2 (20\sqrt{2})^2; A_{light} \approx 1088.888889mm^2$$

param.	Wavelength	Optical Power	NA light source	NA wafer	Exposed image field
spec.	248 nm	10 W	0.54	0.63 - 0.75	$(20\sqrt{2})^2$ mm^2

Free Form Light source for Source Mask Optimization

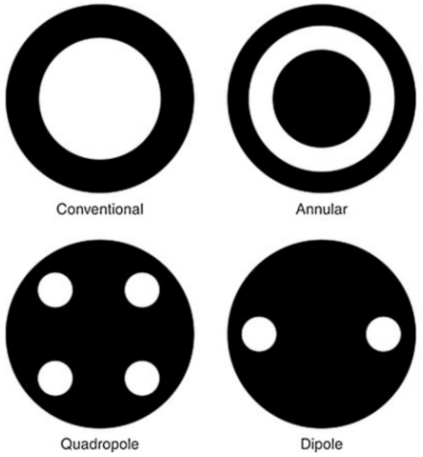
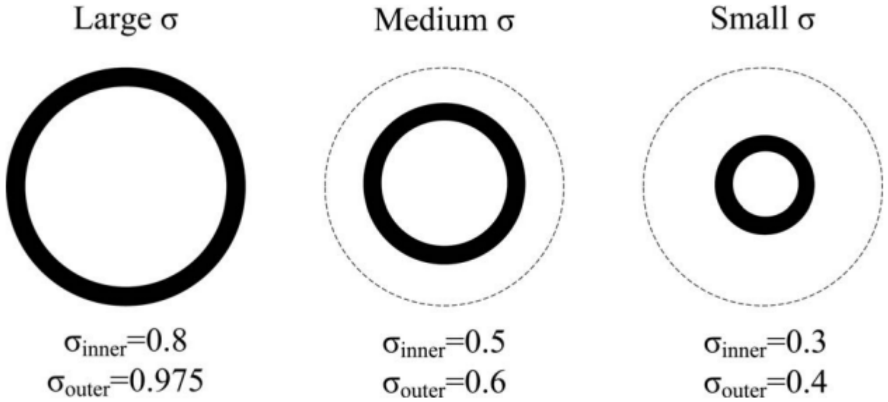
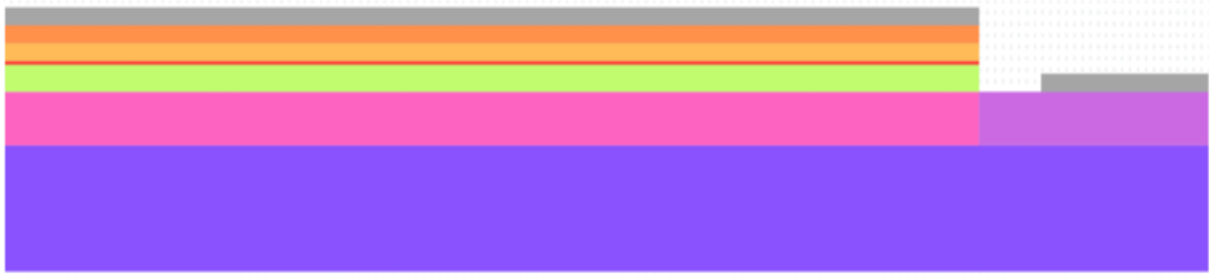


Fig. 8 Illumination source-shape examples



Structure of AlGaN LED

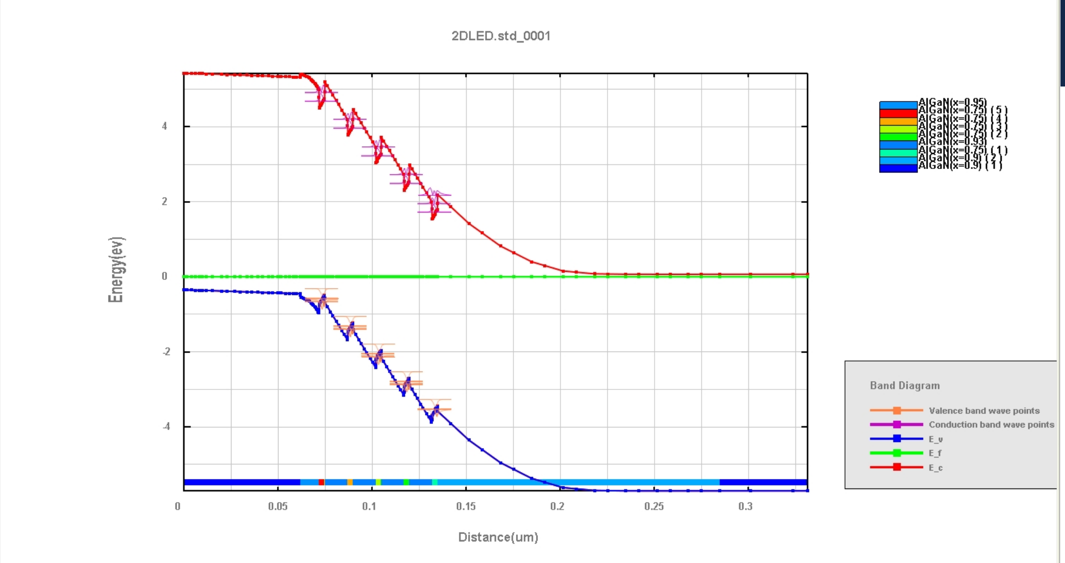
Structure:

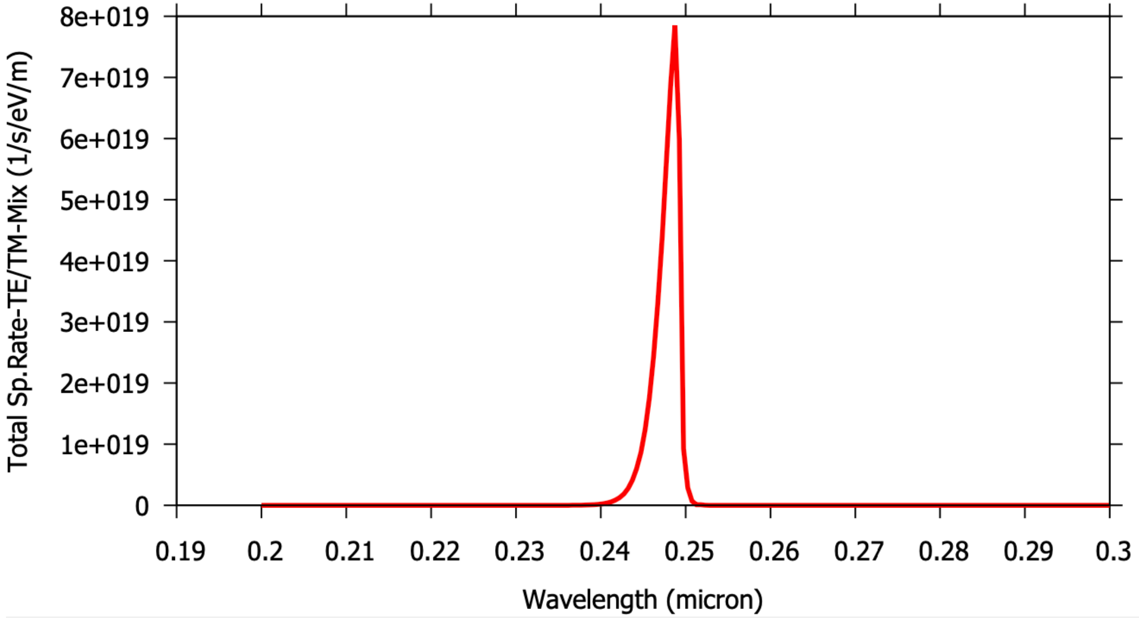


Color	Composition	Doping [m^-3]	Height (um)	Purpose
	AlGaN, x= 0.9	Si:3E+24	2.50E+00	substrate
	AlGaN, x= 0.9	Si:3E+23	5.00E-01	against polarization
	AlGaN, x= 0.9	Si:1E+26	1.50E-01	n+ for contact
	MQW	N/A	7.50E-01	Five quantum wells
	AlGaN, x= 0.95	Mg:5E+24	1.00E-02	PEBL
	AlGaN, x= 0.9	Mg:1E+20	5.00E-02	P junction
	AlGaN, x= 0.9	Mg:1E+20	5.00E-02	Hole Injection
	Metal			Contact

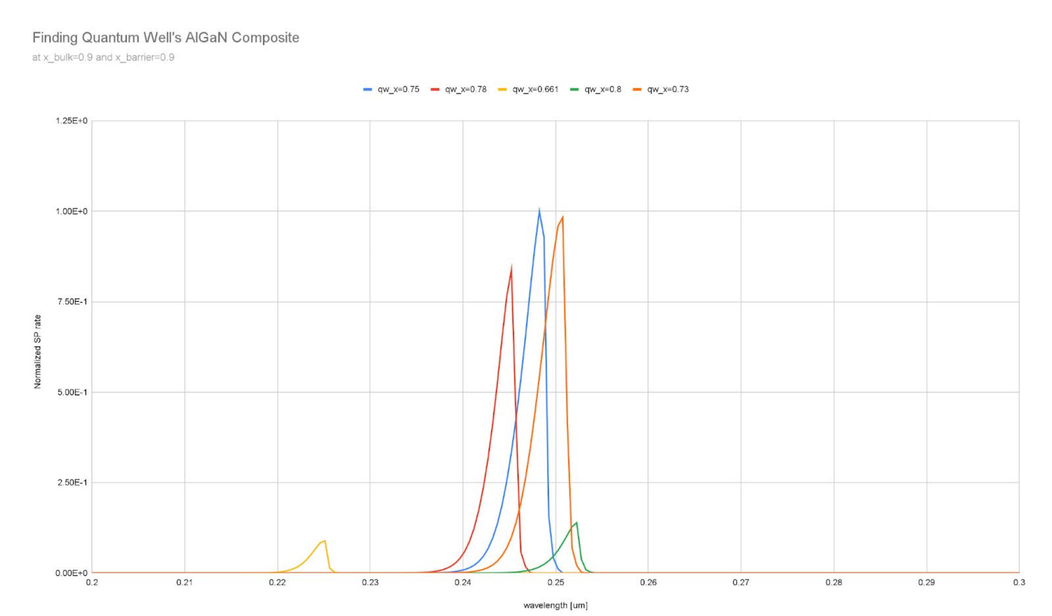
MQW:

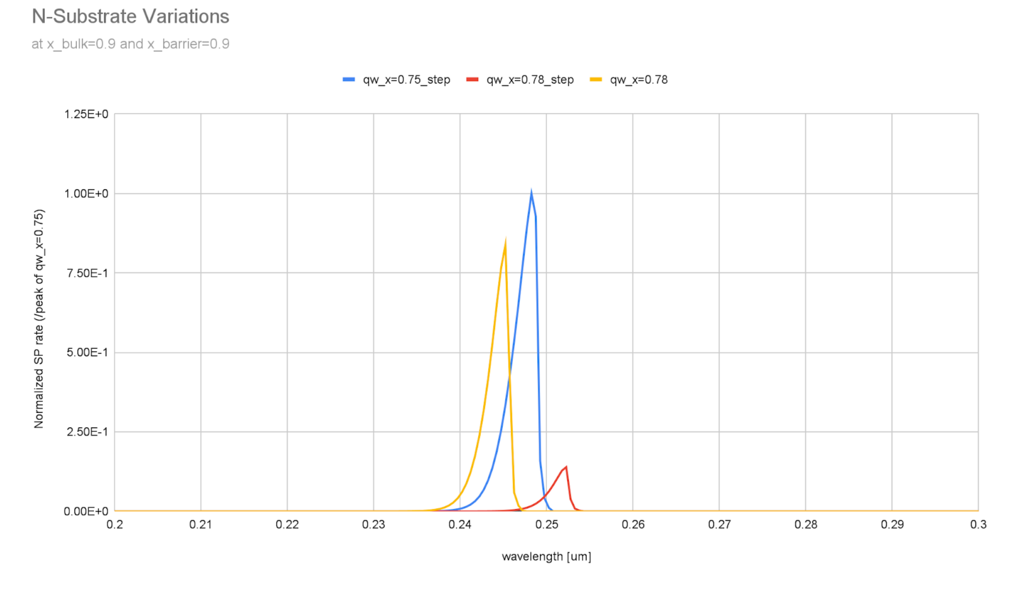
Color	Composition	Height (um)	Purpose
	AlGaN, x= 0.93	1.20E-02	Barrier
	AlGaN, x= 0.75	3.00E-03	Quantum Well

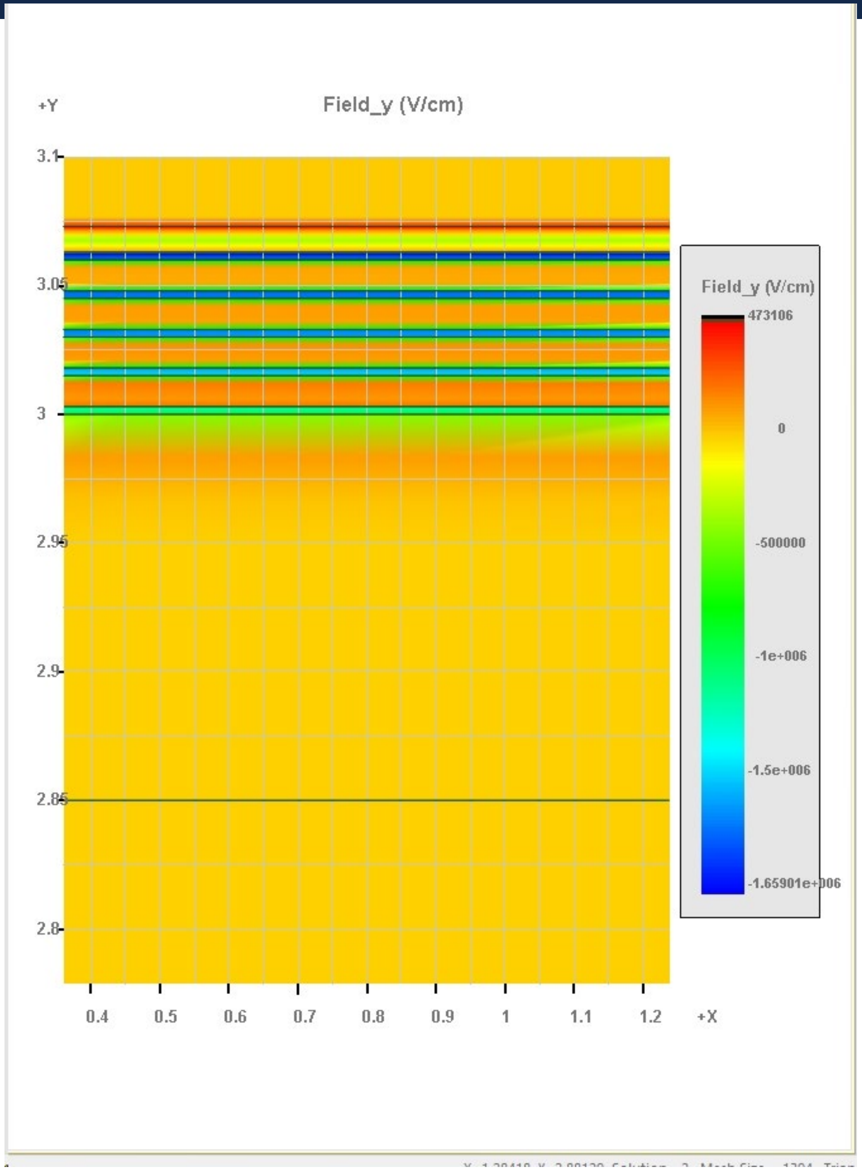




Simulation - Tuning to 248 nm and Adding Depletion Layer against Polarization







Simulation – Precise Simulation; leakage of electrons

Turned on parameters:
- set_polarization
- self_consistent
- independent_mqw
- q_transport_mqw_bundle

	Auger_n	Auger_p	lifetime_n	lifetime_p	Rad. Recomb.
material	3.4e-30 m^6/s	3.4e-30 m^6/s	1E-6 sec^{-1}	1E-6 sec^{-1}	default
Active region	3.4e-30 m^6	3.4e-30 m^6/s	1E-6 sec^{-1}	1E-6 sec^{-1}	2e-10 m^2/s

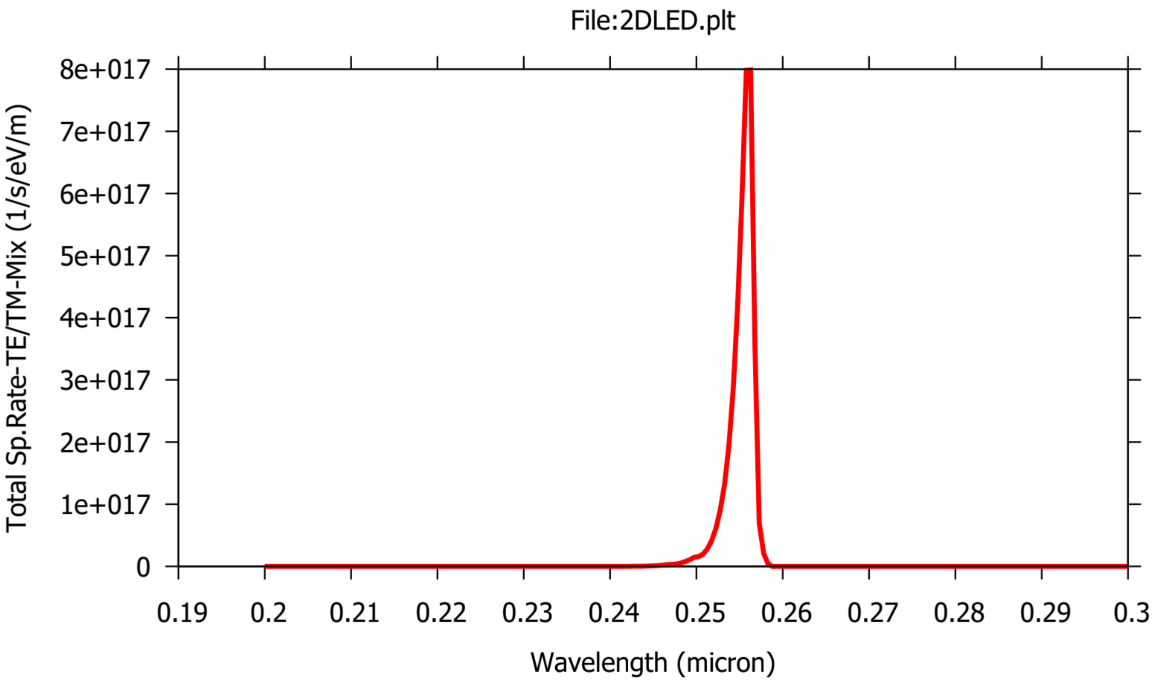
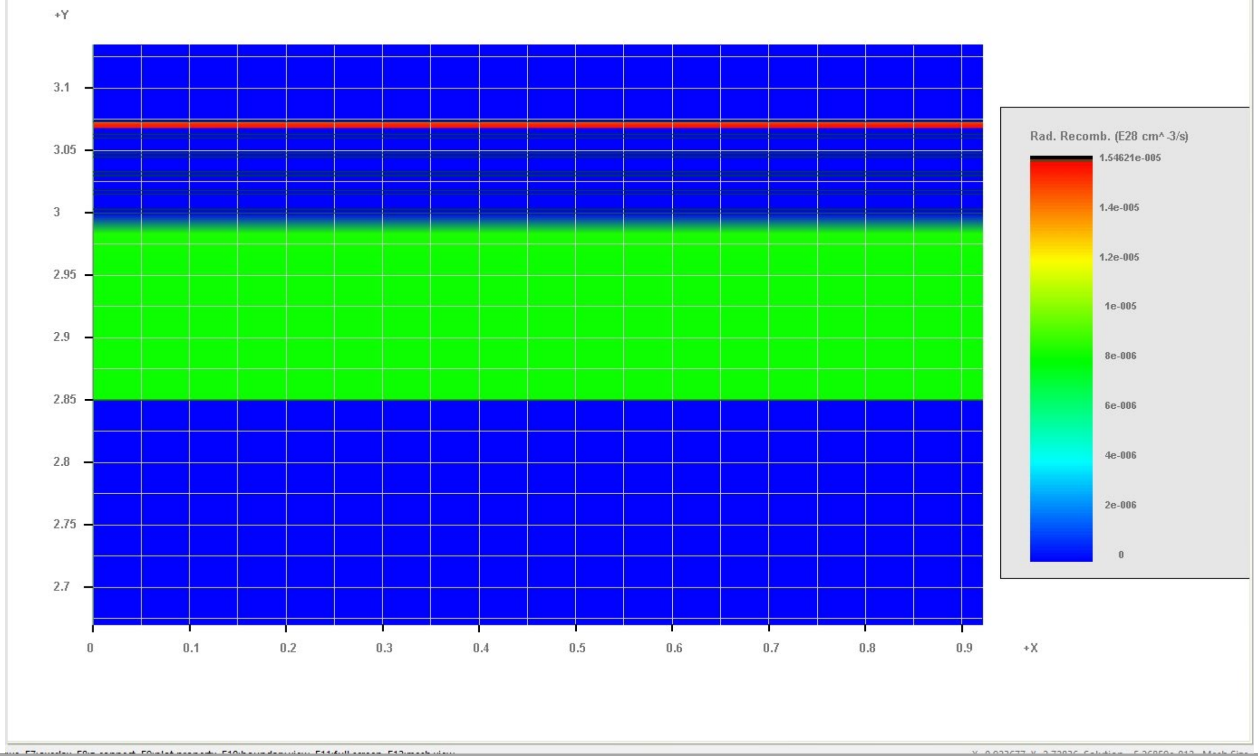
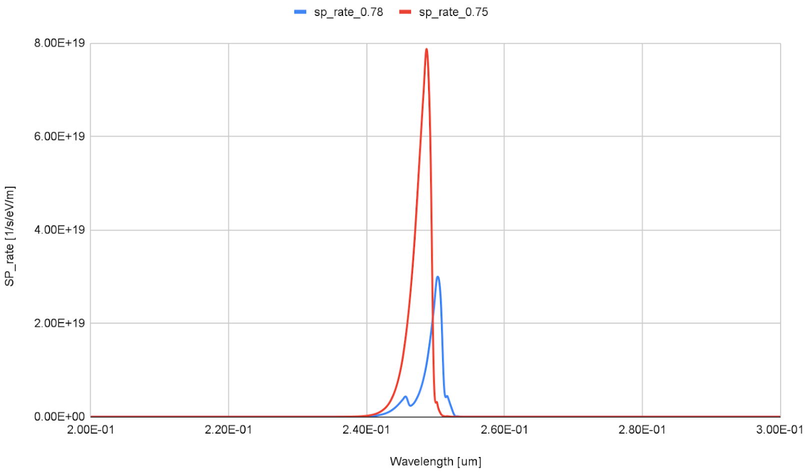


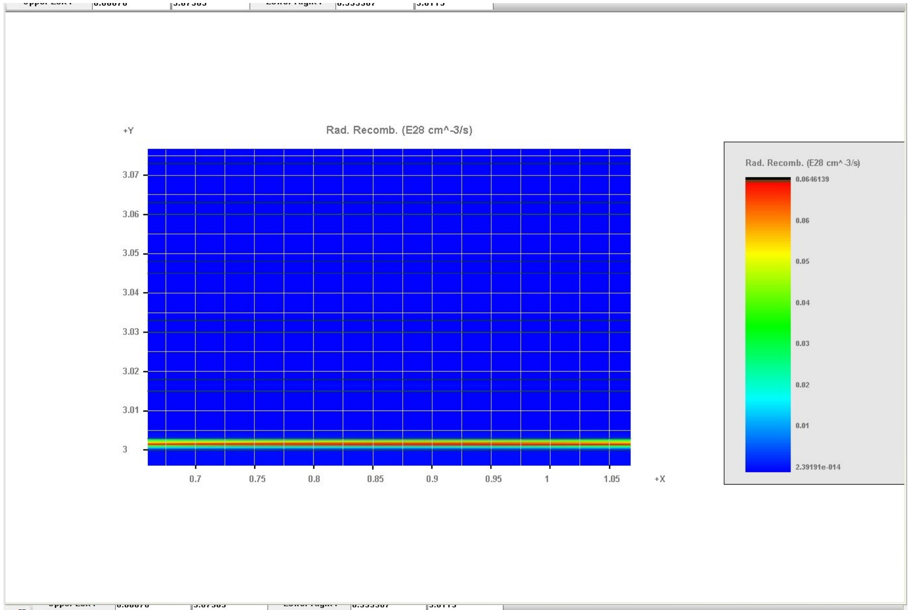
Figure 9, Radiative Recombination diagram of x_qw = 0.75 and x_barrier=0.9

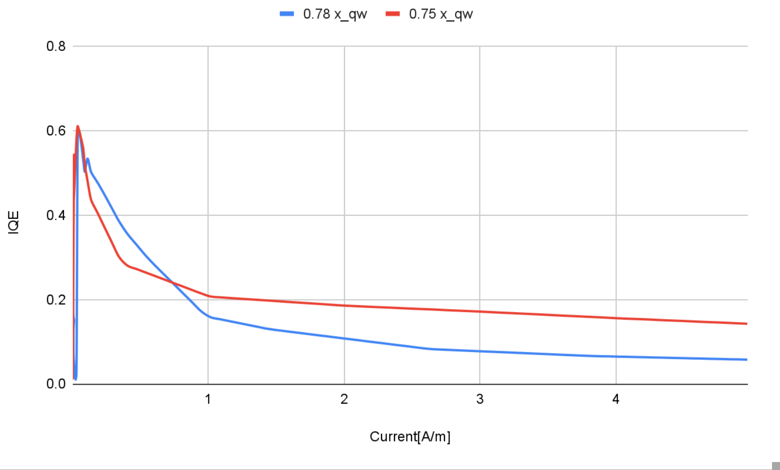


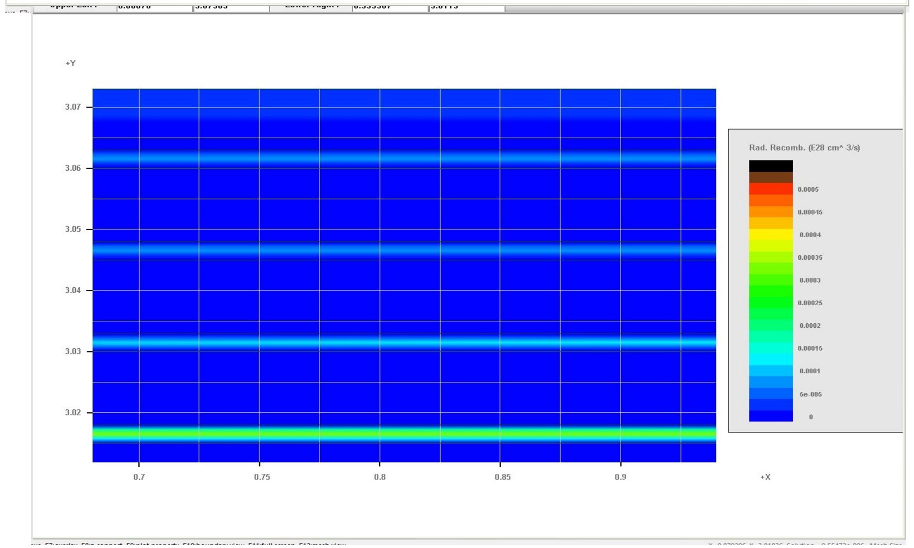
Simulation – Precise Simulation; Tuning Quantum barrier and Well

The x_quantum barrier is changed to 0.93 (higher barrier)
The x_quantum_well = 0.75 & 0.78 are simulated.
Both simulations have one dominant quantum well near n-substrate.









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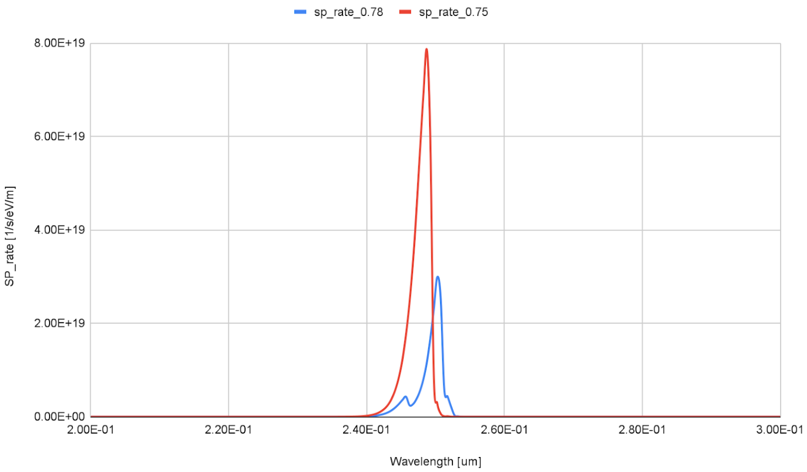
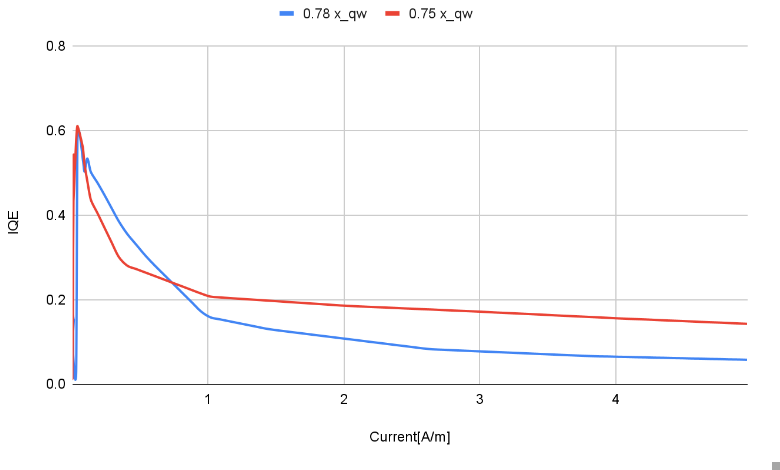
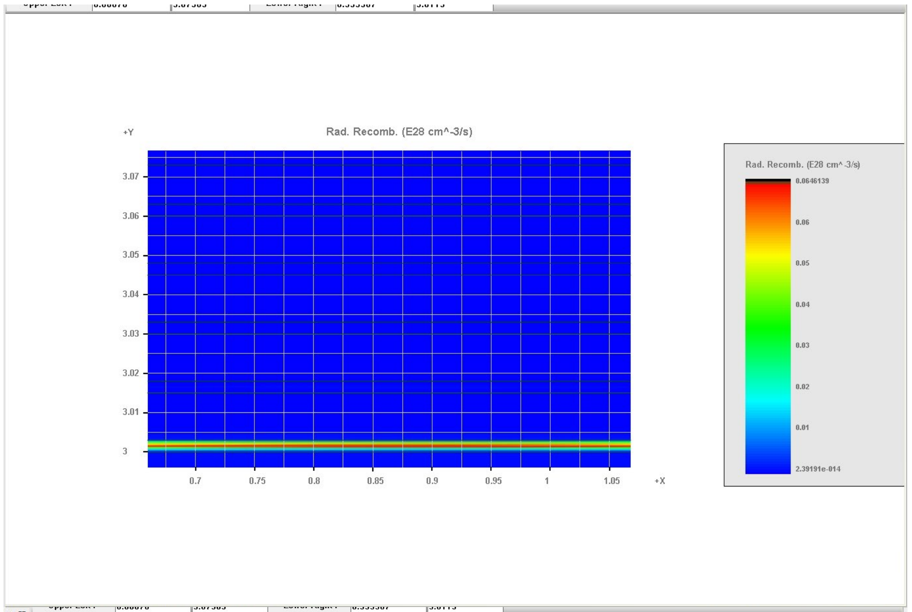
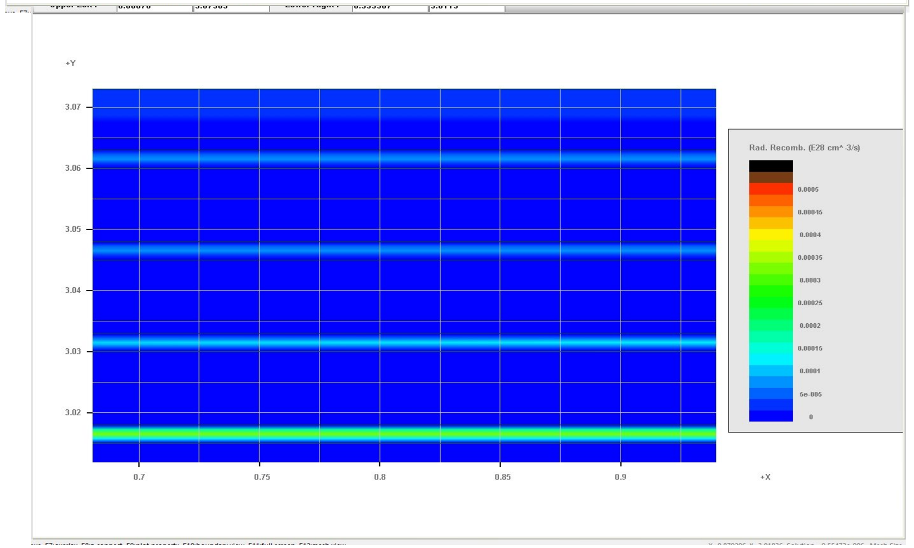
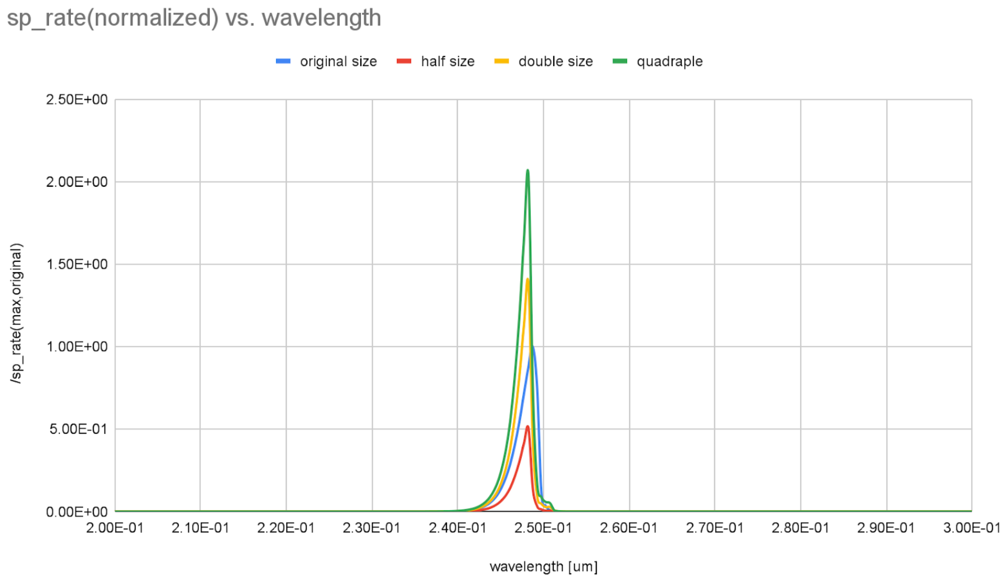


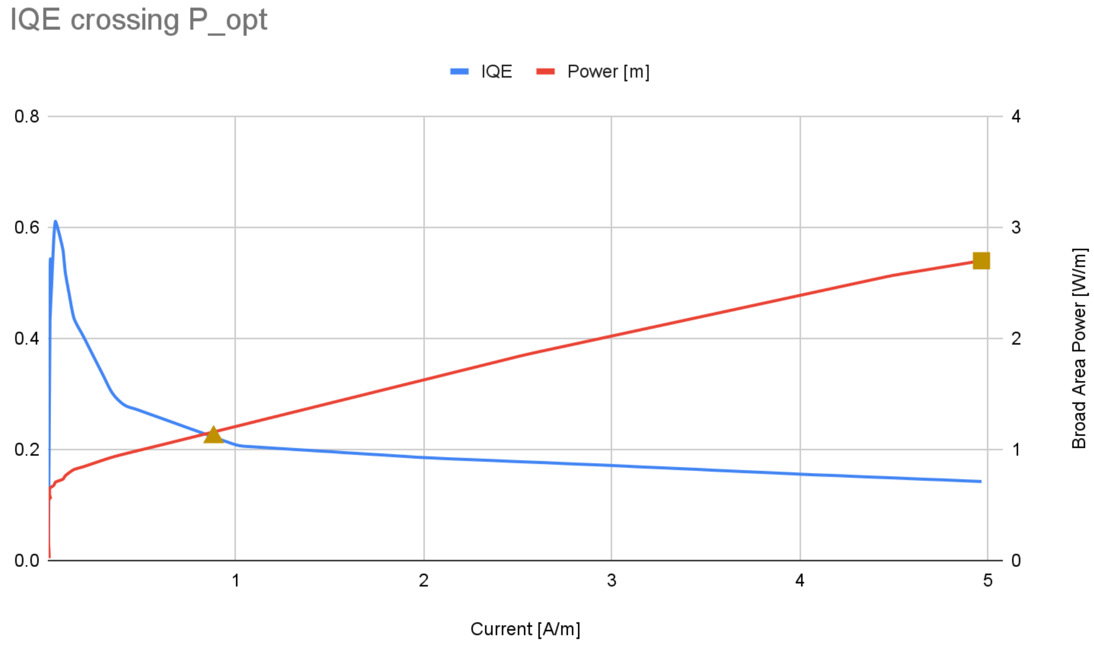


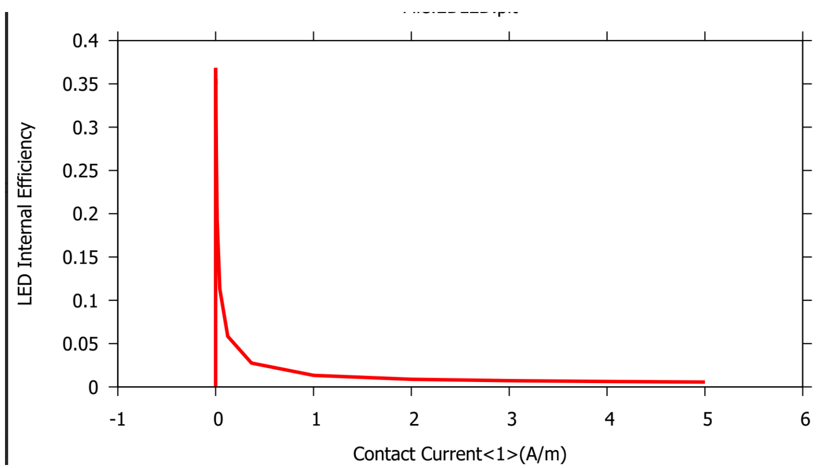




Post Simulation Light Source Design -1







Current [A/m]	IQE	WPE	P_elec [W/m]	P_opt [W/m]
0.815	0.231	0.221	4.075	0.905
4.9656	0.143	0.112	31.62	3.538

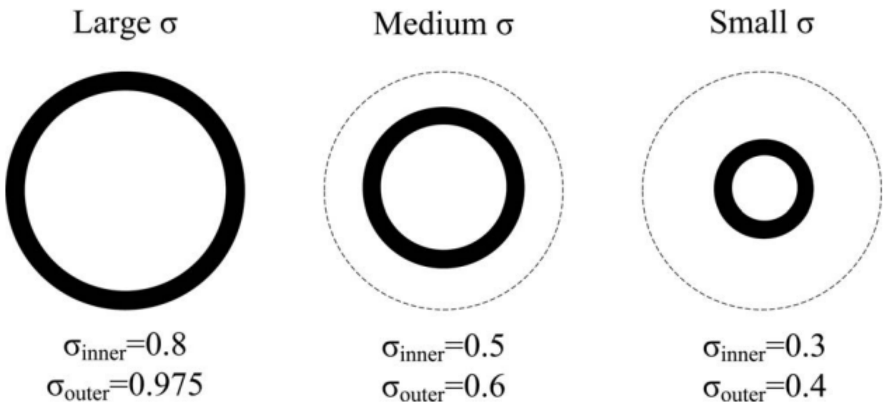
Post Simulation Light Source Design -2

Current [A/m]	IQE	WPE	P_elec [W/m]	P_opt [W/m]
0.815	0.231	0.221	4.075	0.905
4.9656	0.143	0.112	31.62	3.538

$$P_{tot} = n * 3.538 * 10^{-6} = 0.0828W$$

$$number = \frac{2\pi * r}{5 * 10{-}3} = 23395$$

5W/0.0828W=181.159, meaning that we need at least 182 arrays more of LED within this circular closed pack. That assume 190 arrays to be conservative, $190*5*10^{-3}$=0.95mm. The minimum σ is thus clear: 0.95/18.617 = 0.051.



$$\int_a^b 2\pi * r\, dr \ \div d^2 \geq \frac{15W}{3.538 * 10^{-6}W}$$

$$d = 5 * 10^{-3}mm; r \in [0, 18.617]mm$$

Sincere Appreciation for Listening

The Grainger College of Engineering

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