Designing Blue-Wavelength Free White Light: A Dichromatic Approach Using Violet and Yellow-Green LEDs

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ECE 443

Background

The natural light where the sun rises and sets at specific times in the day synchronizes the circadian system with the environment

The specific wavelengths of light that disrupt the circadian system are between 460 nm and 480 nm as it causes acute plasma melanin suppression [1].

The blue wavelength is the dominant wavelength that is present in most white lights

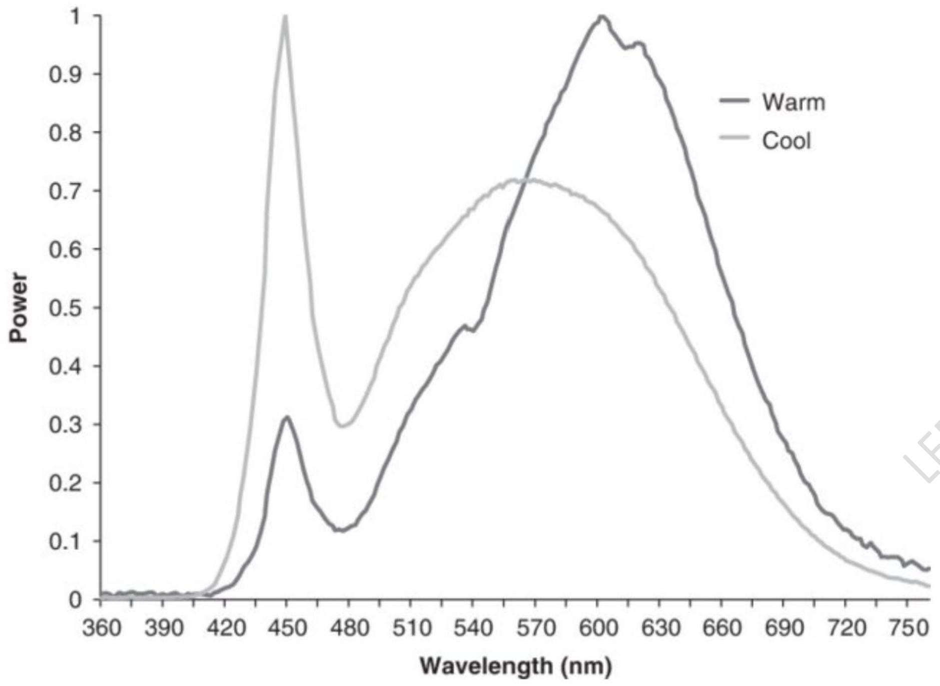
There are four methods to producing white light

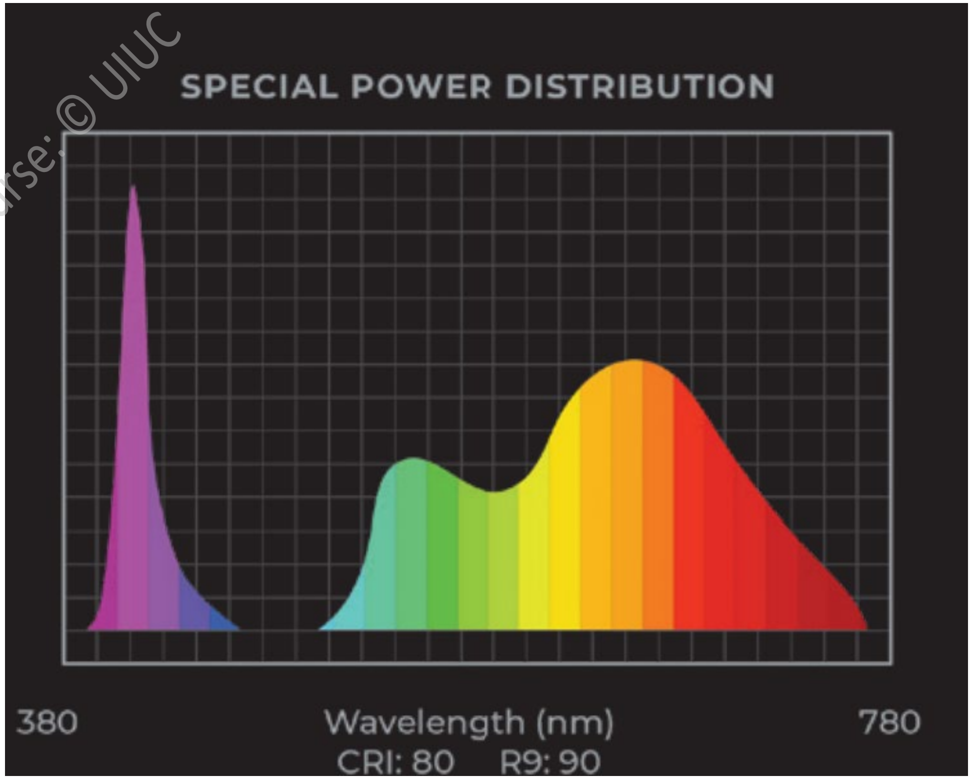
[1] G. C. Brainard, D. Sliney, J. P. Hanifin, G. Glickman, B. Byrne, J. M. Greeson, S. Jasser, E. Gerner, and M. D. Rollag, “Sensitivity of the human circadian system to short-wavelength (420-nm) light,” Journal of Biological Rhythms, vol. 23, no. 5, pp. 379–386, 2008.

State-of-the Art Solutions

1) Warmer Lights [2]

2) Soraa uses the violet wavelength to replace blue wavelength [3]

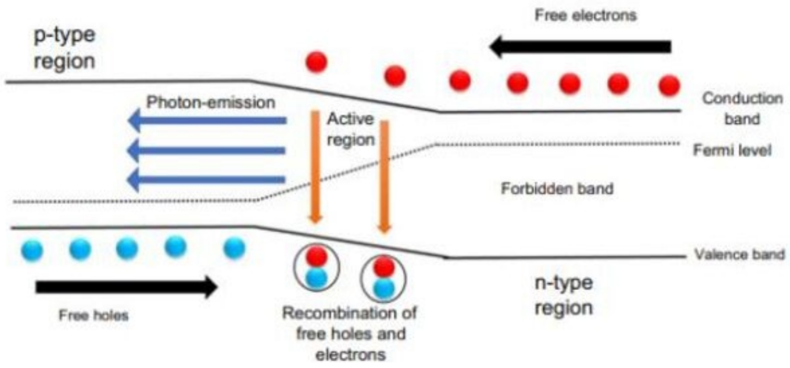




[2] G. S. Archer, "Color temperature of light-emitting diode lighting matters for optimum growth and welfare of Broiler Chickens," Animal, vol. 12, no. 5, pp. 1015–1021, 2018.

[3] "The only blue-free, sleep-friendly light," *SORAA*. [Online]. Available: https://www.soraa.com/soraa-pro/technology/zeroblue.php. [Accessed: 23-Apr-2023].

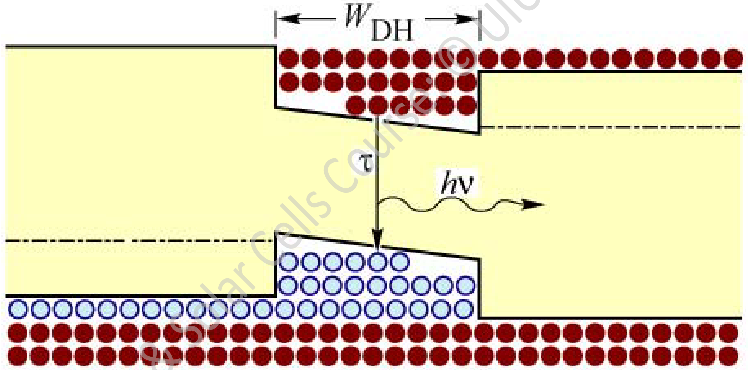
Technical Background



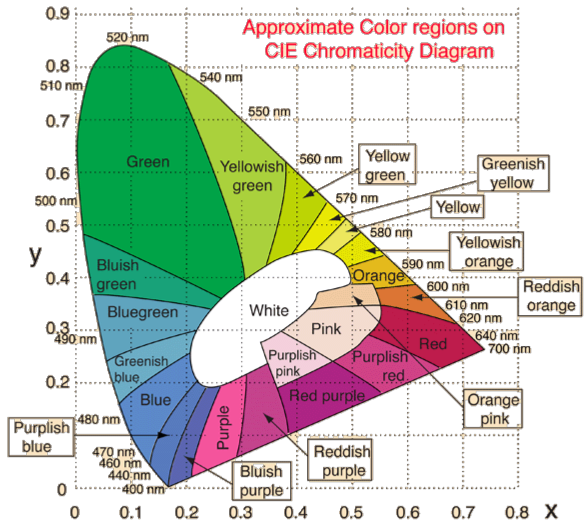
$$B * \Delta n^2$$

$$\frac{j * \tau_{total}}{q * d}$$

$$\eta_{IQE} = \frac{B * \Delta n^2}{A * n + B * \Delta n^2 + C * \Delta n^3}$$



$$E_n = \frac{n^2 \pi^2 \hbar^2}{2ma^2}$$



$$E_g(A_{1-x}B_xC) = (1-x) * E_g + x * E_g(B) - b$$

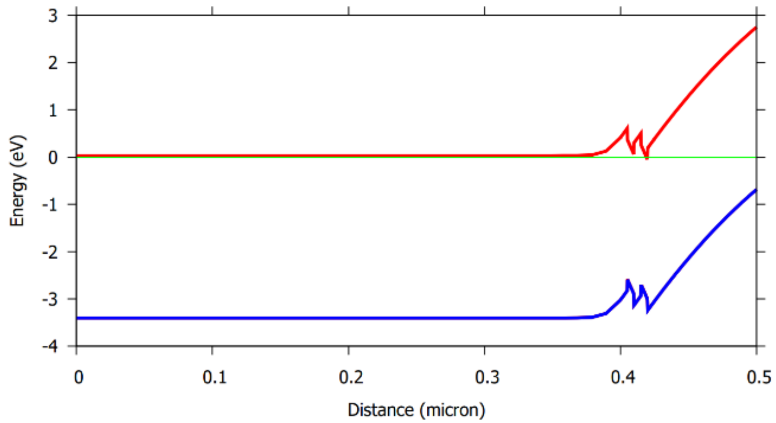
Device Optimization

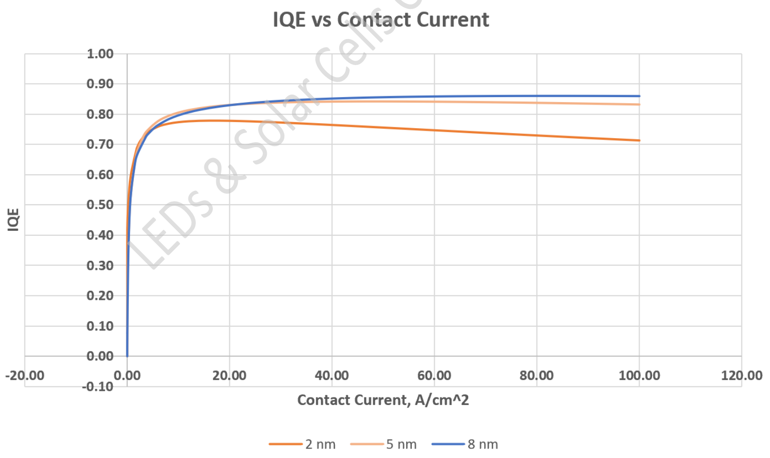
Polarization

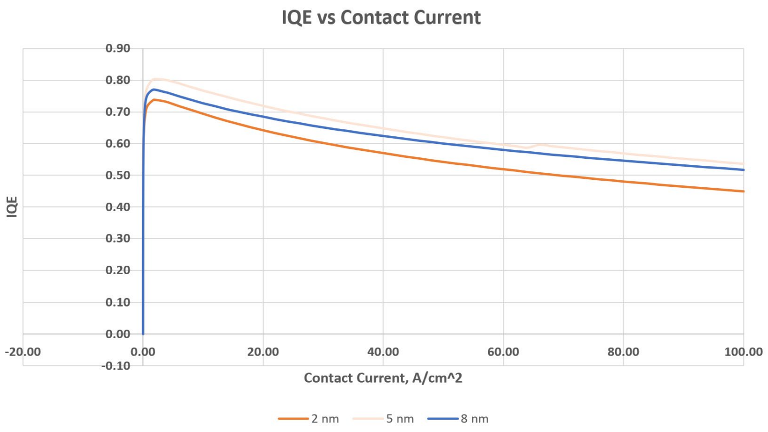
- More realistic simulation

Manipulating Quantum Well Widths

- Increasing Quantum Well Width:
  - Increases radiative recombination
  - Decreases confinement



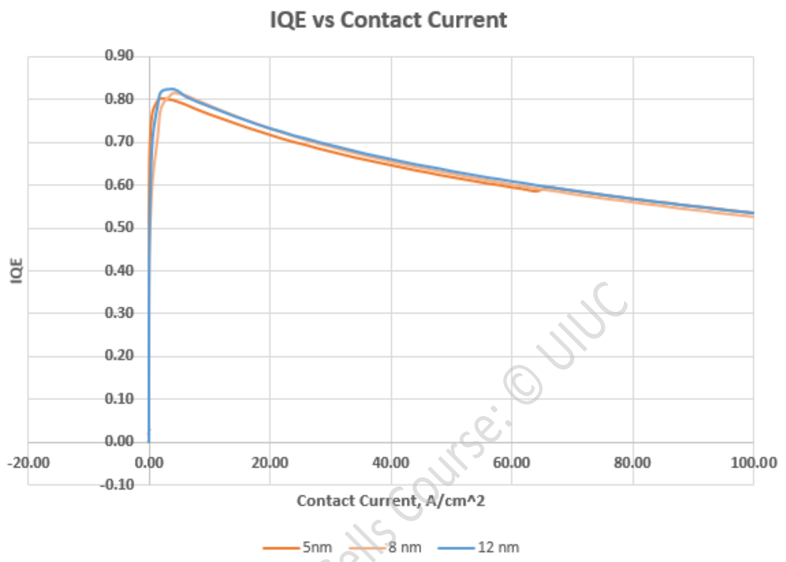


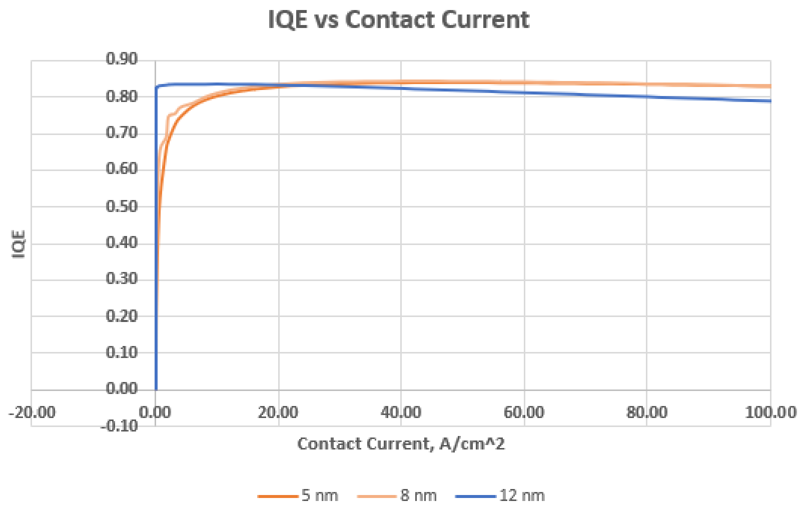


Manipulating Barrier Widths

- Decreasing Barrier Width:
  - Decreases electric field
  - Decreases electron leakage

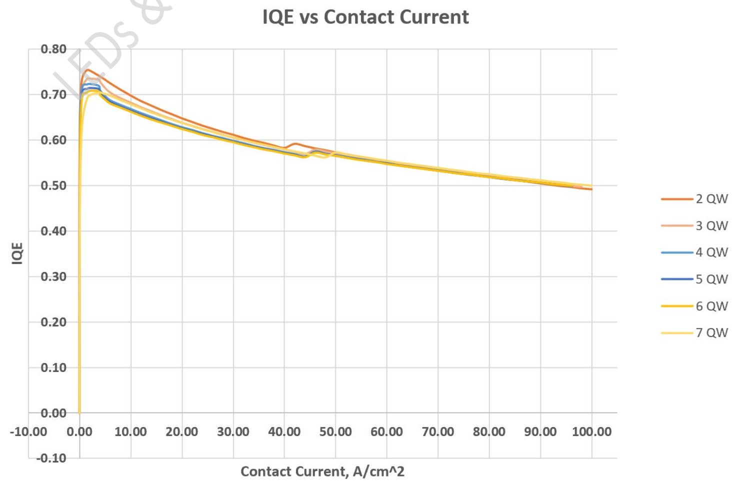
Device Optimization

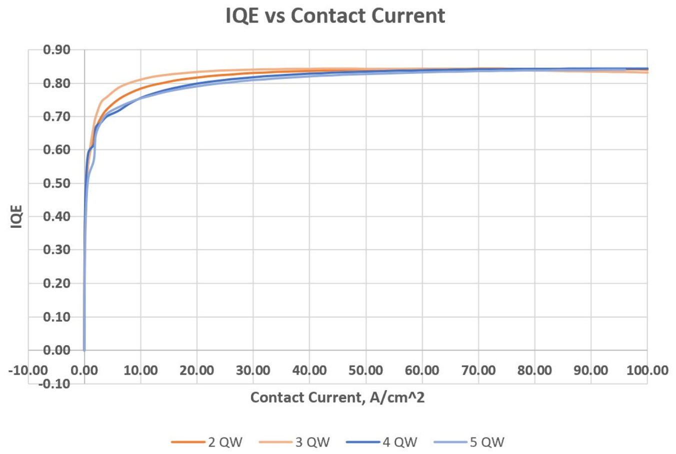




Manipulating Quantum Well Number

- Increasing Quantum Well Number:
  - Increases active layer
  - Decreases droop

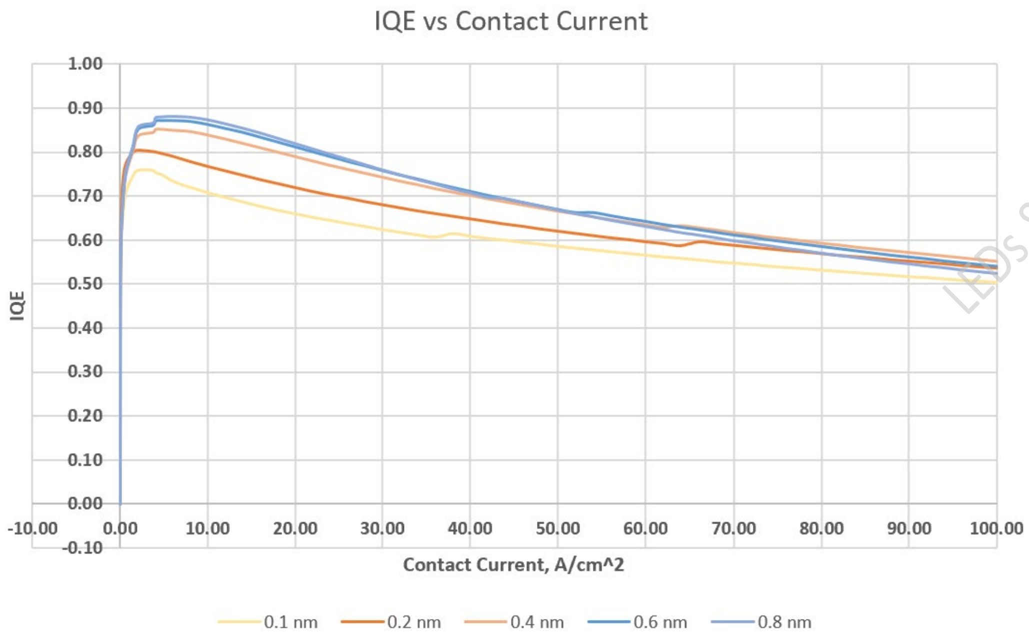




Design Optimization and Future Work

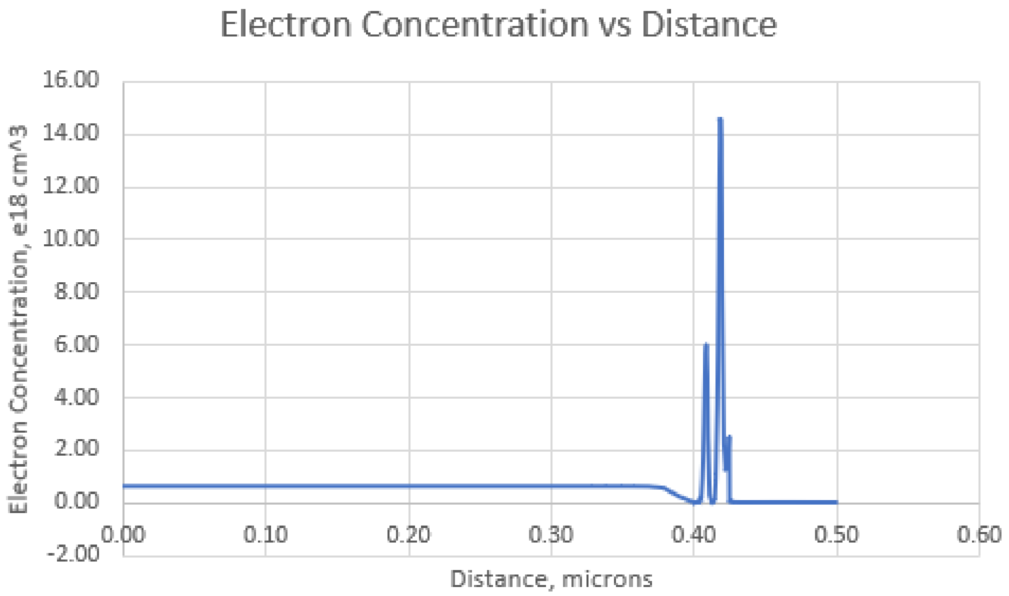
Manipulating p-doped bulk region

- Increasing region width:
  - Increases carriers
  - Increases IQE peak

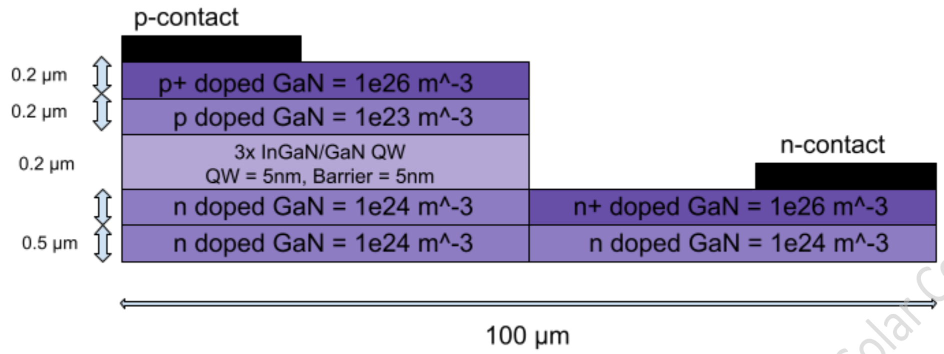


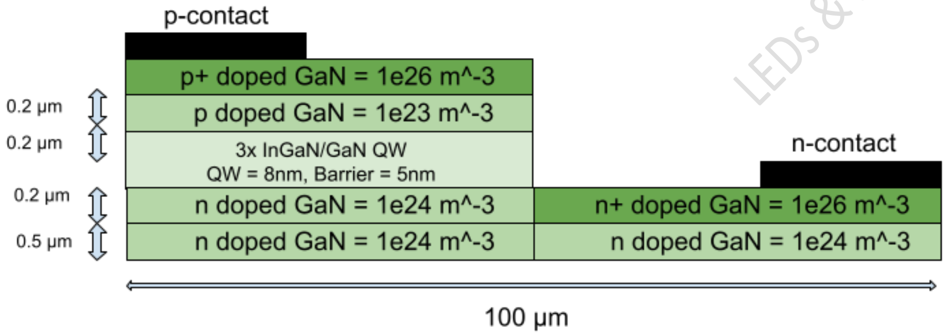
Improving electron leakage

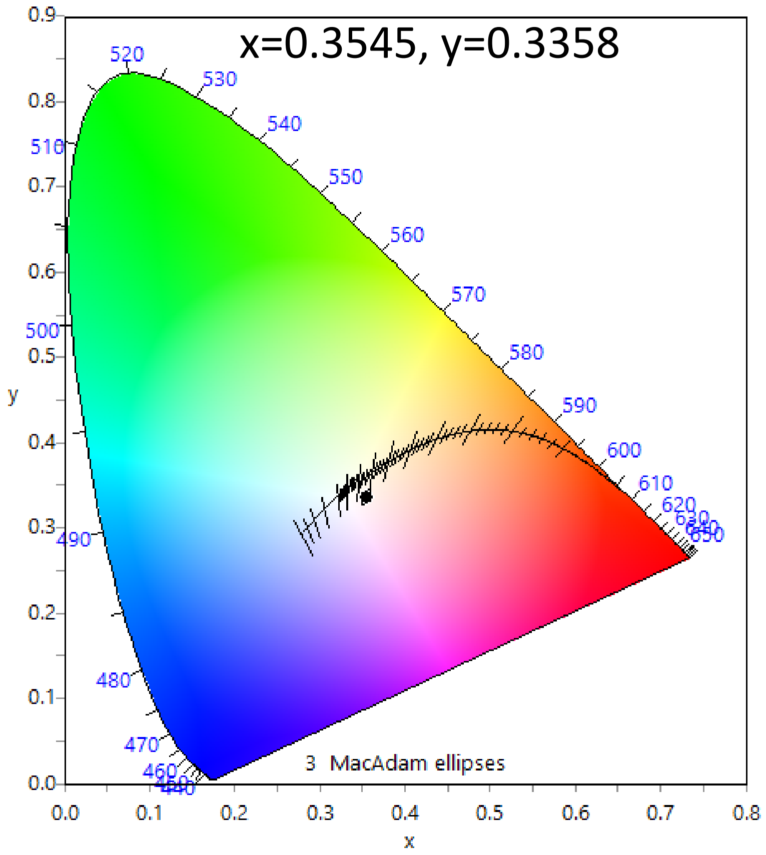
- Add p-AlGaN



Final Design and Resulting CIE Coordinates







Conclusion

It is feasible to produce white light without the blue-wavelength

It is important to optimize parameters such as the quantum well width, barrier width, number of quantum wells, and width of doped layers.

The CRI of an LED can be improved by increasing spectral coverage which can be done by adding phosphors.

This is a design solution for the future when cubic GaN becomes cheaper and more commercially available.