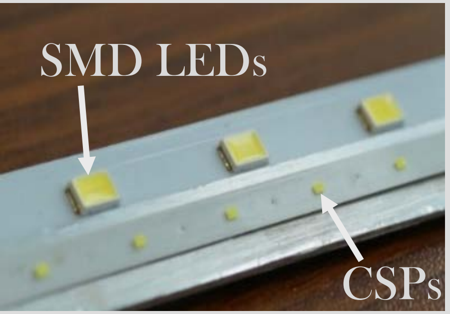
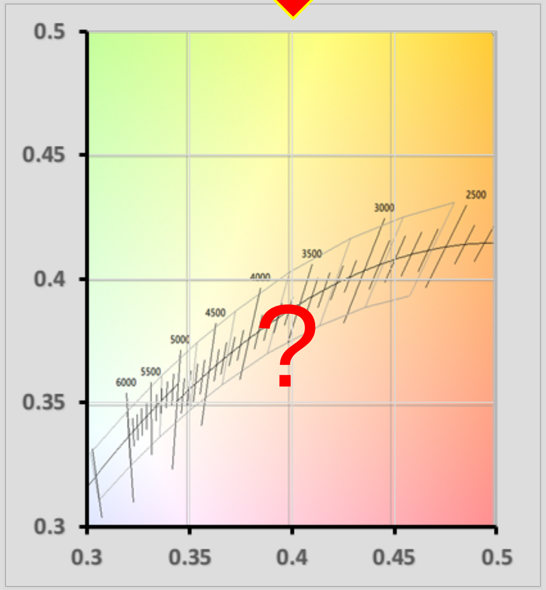
The Extended Beer-Lambert theory for Ray Tracing Modeling of LED Chip-Scaled Packaging Application with Multiple Luminescence Materials

Dr. Cadmus Yuan

www.Ichijouriki.com

- Problem description:





Parameters:

- Mixing ratio of phosphors,
- Dimensions of phosphors layer,
- Material properties of phosphors and LED chip.

Ray tracing tools

How??

This is the goal of this paper

Result:

- CCT=?? K
- Efficacy=?? Lum/W

- The computation platform can be based on the Beer-Lambert Law:

Absorption:

The Beer-Lambert Law describes how light absorbed by mater (Phosphors).

$$\frac{OD}{L} = K \cdot C \cdot ab(\lambda)$$

Emission:

By introducing the quantum efficiency: .

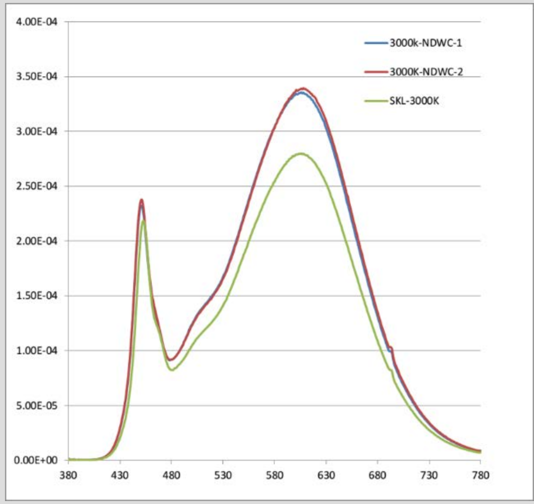
$$I_{em} = q \cdot I_{ab} \cdot em(\lambda)$$

LED Chip

\+

Phosphors

SINGLE TYPE OF PHOSPHORS ALLOWED



BUT, THIS PLATFORM IS LIMITED TO SINGLE TYPES OF PHOSPHORS. HOW TO EXTEND??

- This paper introduces **Equivalent Spectrums** to resolve it:
  - ✓ Given i types of phosphors, the absorption and emission wavelengths are represented by $ab_i(\lambda)$ and $em_i(\lambda)$, respectively.
  - ✓ These materials are mixing by r_i ($\sum_{i=1}^{n} r_i = 1$) with quantum efficiencies of q_i, the equivalent luminescence material properties can be computed as:

Absorption:

The equivalent spectrum can be written as:

$$ab_{eq}(\lambda) = \sum_{i=1}^{i=n} r_i \cdot ab_i(\lambda)$$

Emission:

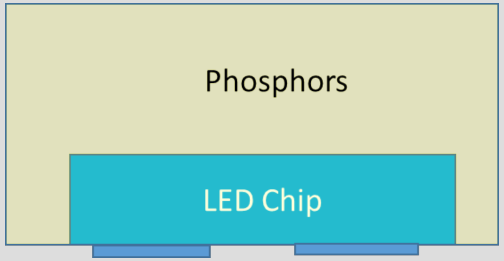
The equivalent spectrum can be written as

$$em_{eq}(\lambda) = \sum_{i=1}^{i=n} k_i' \cdot em_i(\lambda)$$

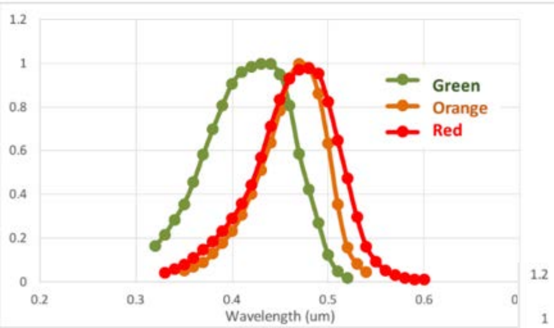
USE THESE SPECTRUMS AS INPUT OF BEER-LAMBERT BASED RAYTRACING ALGORITHM

where, k_i' is an equivalent ratio, which corrects the inter-absorption of the multiple phosphor system. Details in paper.

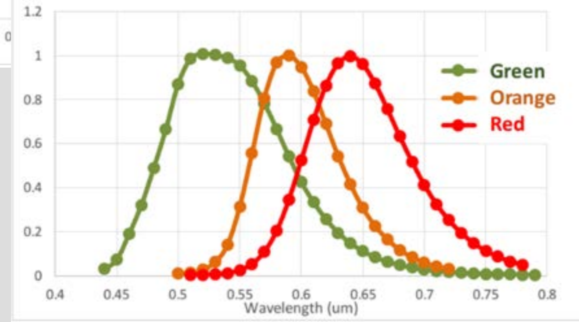
- Validation: **LED CSP**



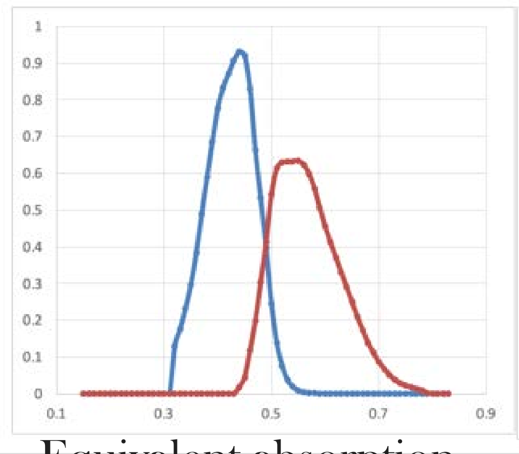
Using 3 types of phosphors



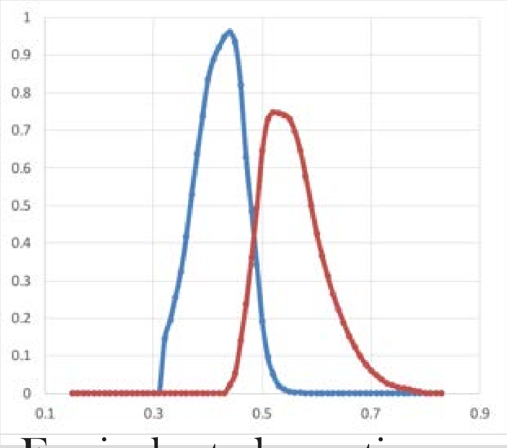
Absorption spectrum



Emission spectrum



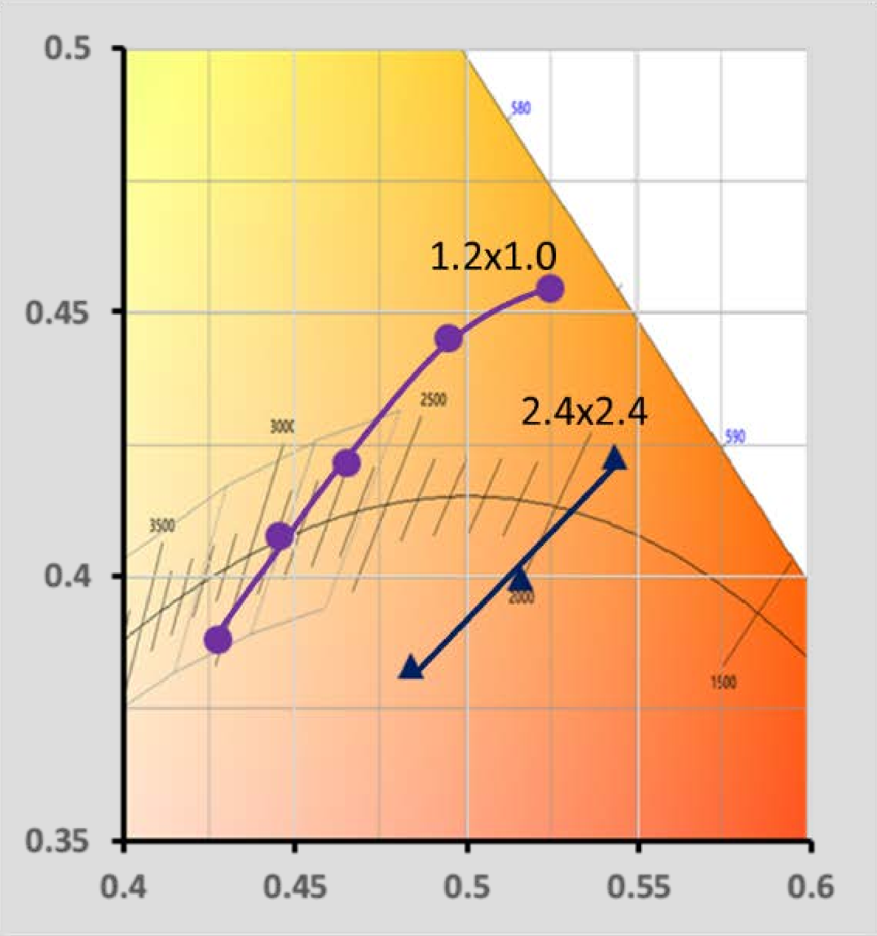
Equivalent absorption (blue) and emission (red) spectrums for 5000K



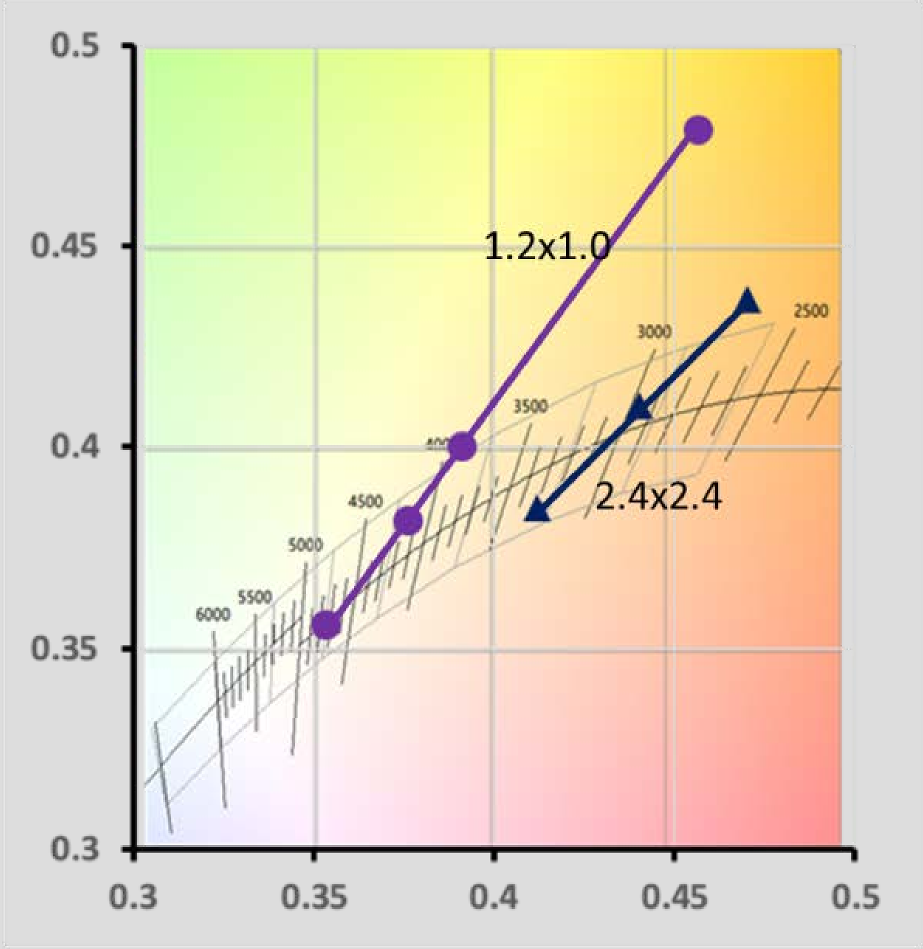
Equivalent absorption (blue) and emission (red) spectrums for 3000K

Color point		3000K	5000K
Exp	X	0.4224	0.3449
	Y	0.3864	0.3624
	Efficacy	97.06	89.79
Sim	X	0.4271	0.3534
	Y	0.3884	0.356
	Efficacy	110.24	95.10

- Virtual prototyping of **LED CSP**



(a)



(b)

- Conclusion

  - The ray tracing optical simulation can be extended into fluorescence material system by simply Beer's law, and such algorithm can be easily extended to multiple fluorescence material system, by **equivalent phosphor excitation/emission spectrum**.

  - A LED chip scaled packaging (CSP) structure is used to validate the theory, which gives color point prediction accuracy of 0.0079 (x-y distance on 1931 CIE diagram) and efficacy of 10.6%.

  - Based on the proposed theory, researchers are able to virtual prototype the color temperature and efficacy of newly designed LED packaging.