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Spatial distribution of photon flux density created by LED grow lights

László BALÁZS and József NÁDAS

Kálmán Kandó Faculty of Electrical Engineering

Institute of Microelectronics and Technology

Outline

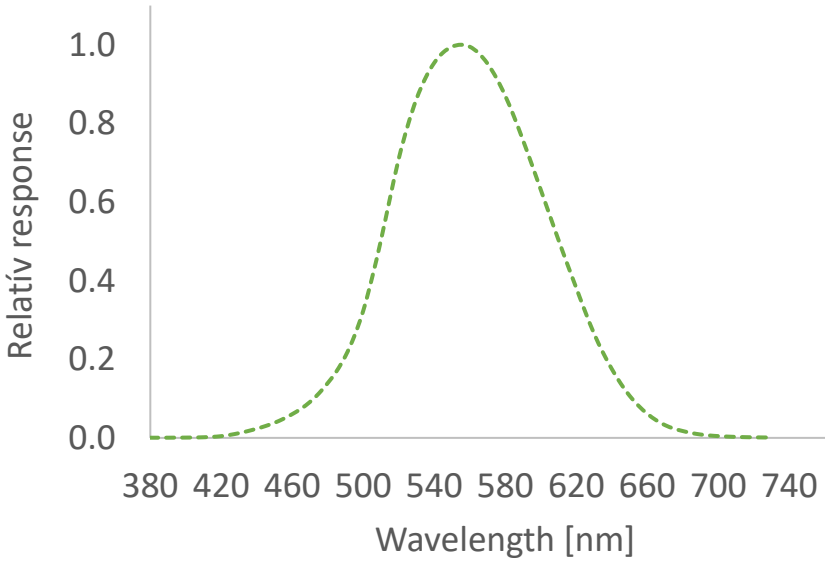
1. Differences between general and horticultural lighting

2. Optimization of LED lights for 1 m × 1 m plant growth units

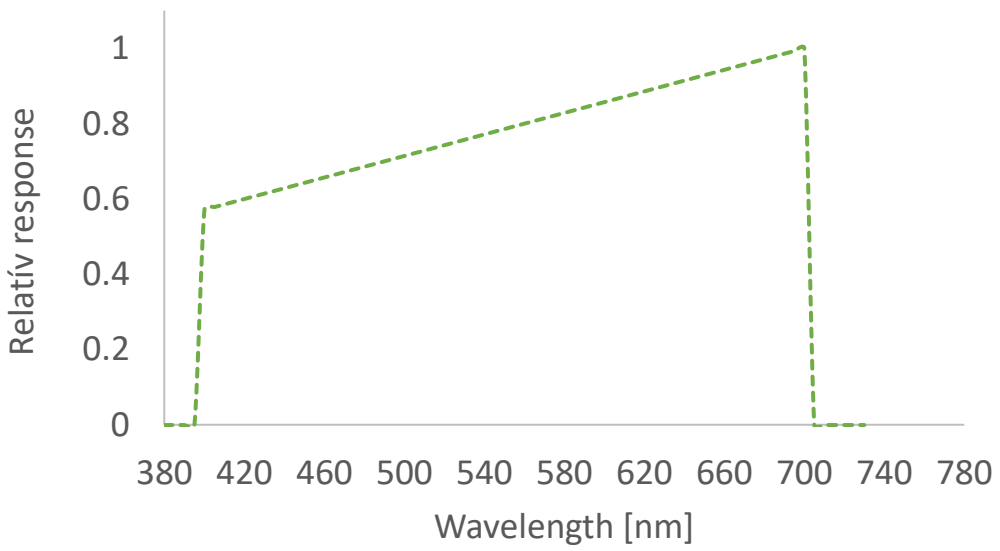
Physical quantities for humans and plants

$$\Phi = 683 \sum_{\lambda=380}^{780} V(\lambda)\, \Phi_e(\lambda)\Delta\lambda$$

$$PPF = \frac{10^6}{hcN_A} \sum_{\lambda=400}^{700} \lambda\, \Phi_e(\lambda)\Delta\lambda$$

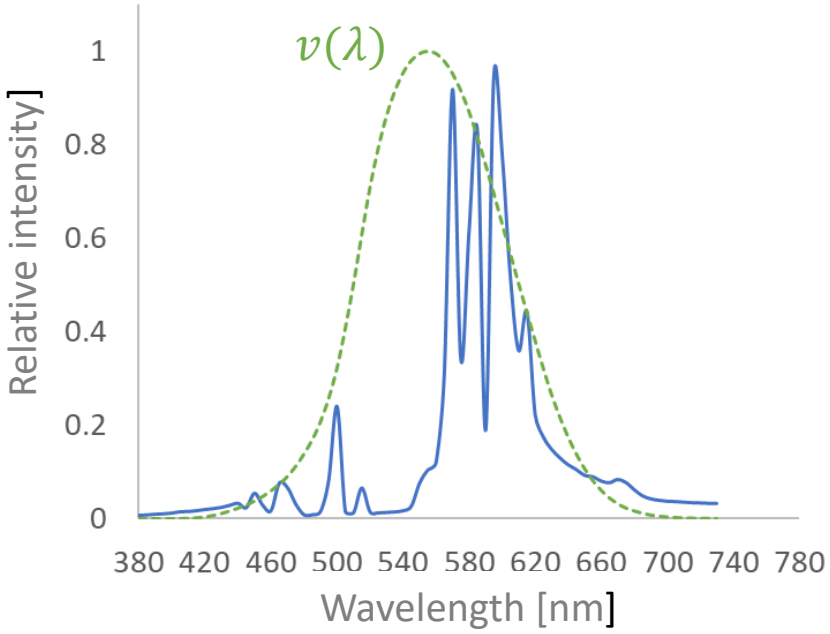


"photon counting"

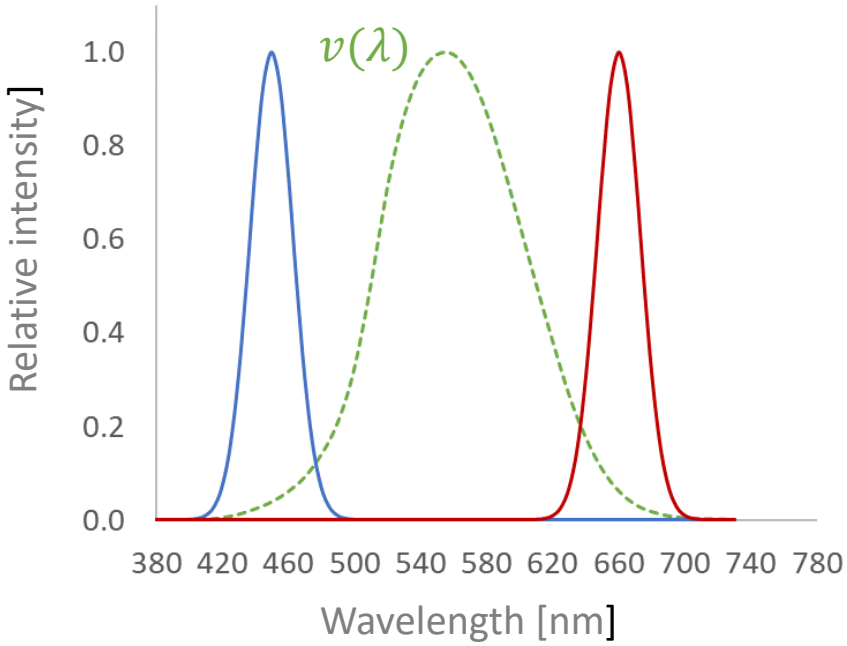


Measurement challenges for narrowband LED

High Pressure Sodium Lamp



Narrowband LED

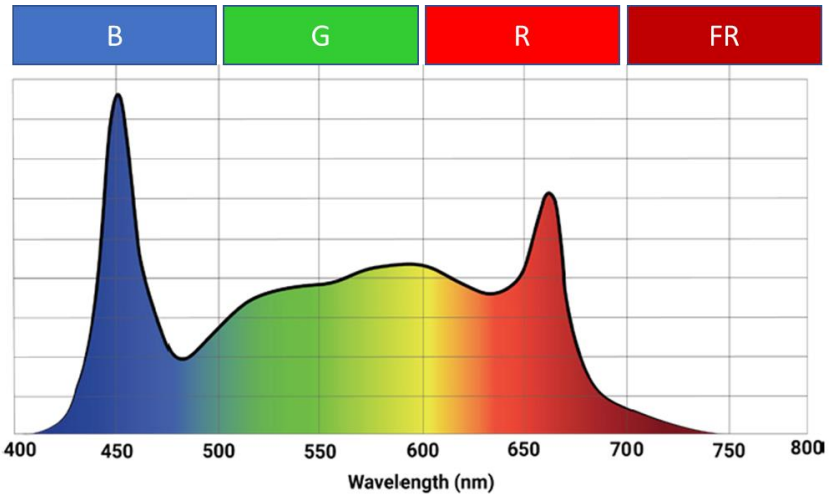


Specifying spectra

General Lighting

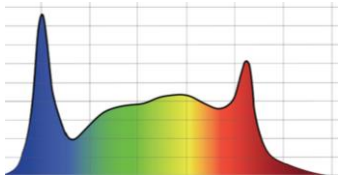
- CCT
- CRI

Horticultural Lighting



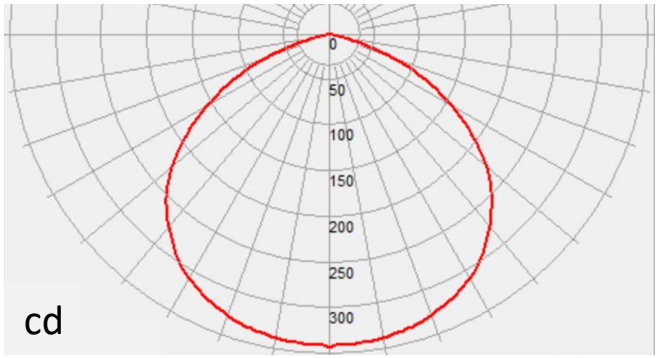
PAR

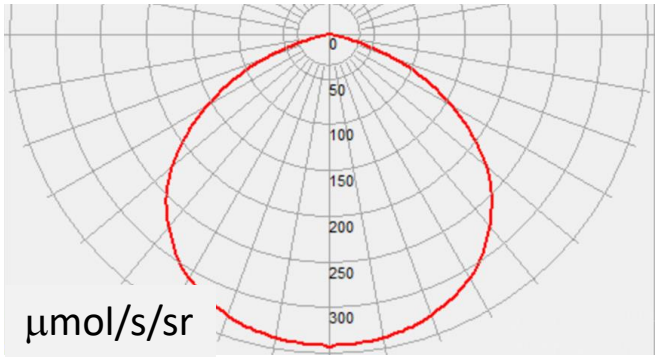
Converting luminous intensity distribution to photon intensity distribution



Assumption:
Relative Spectral power distribution is constant

Luminous intensity distribution → Photon Intensity distribution





Application differences
LEDs can be placed closer to plants than HPS lamps

HPS toplight
height > 2m

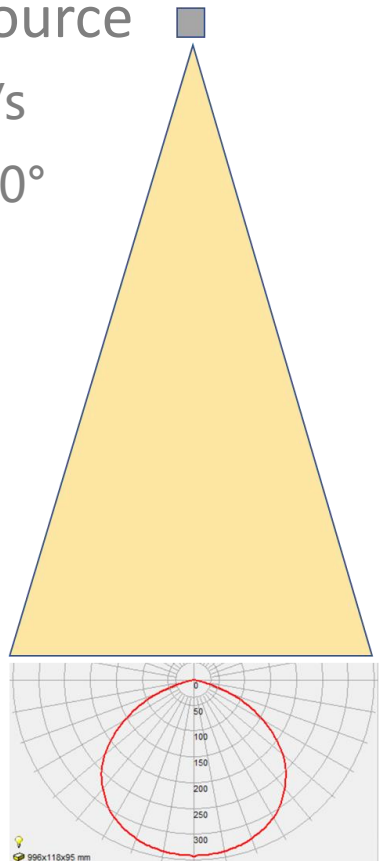
LED vertical farming
height < 0.5 m

Point source vs. linear array with same photon intensity distribution

single point source

PPF = 10 µmol/s

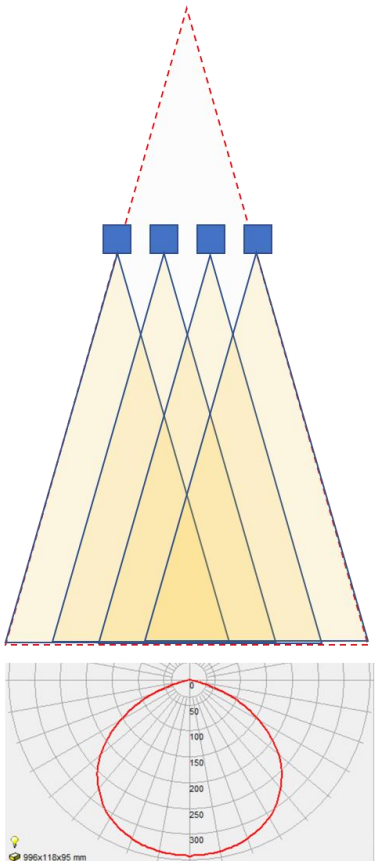
Beam angle: 120°



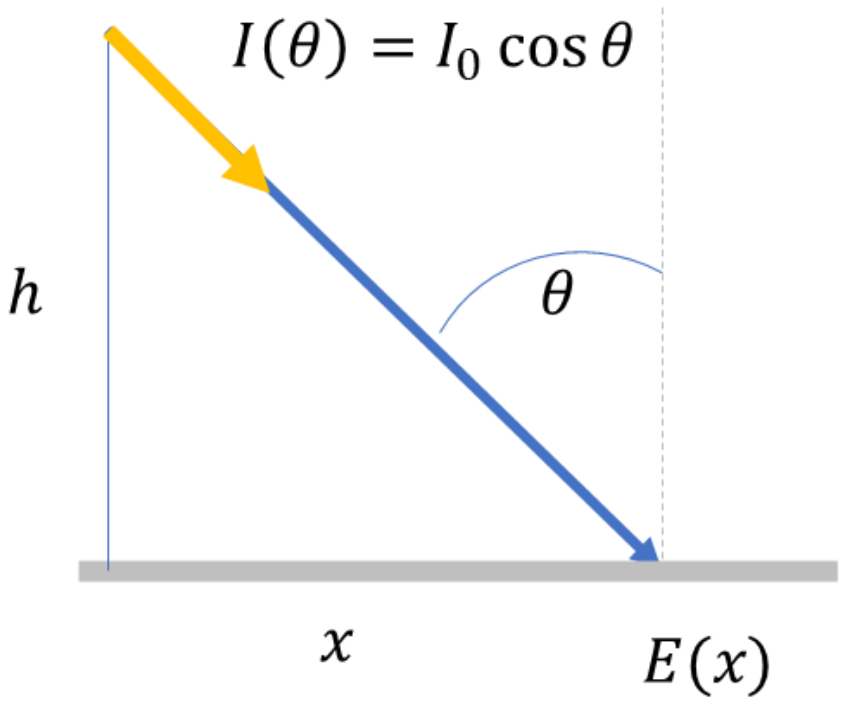
LED array

PPF = 4 × 2.5 µmol/s

Beam angle: 120°

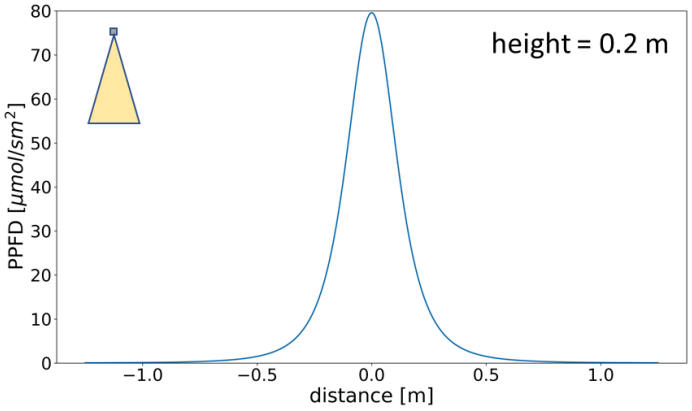


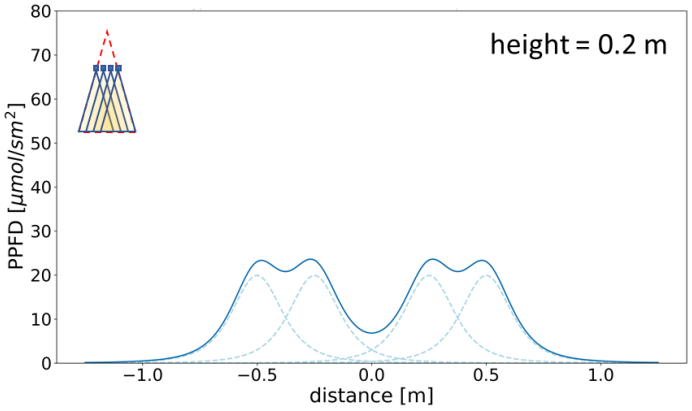
Calculating photon flux density

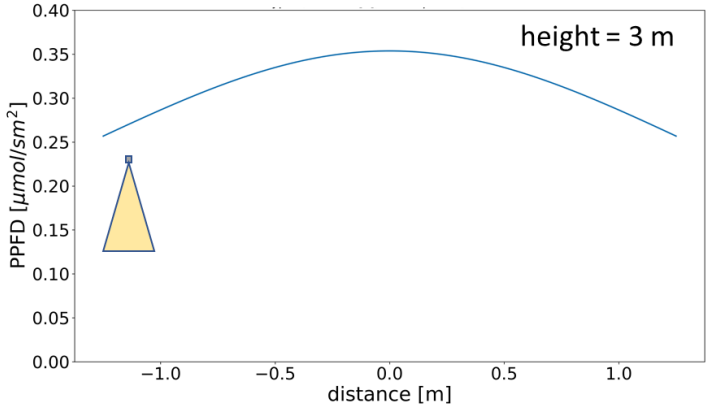


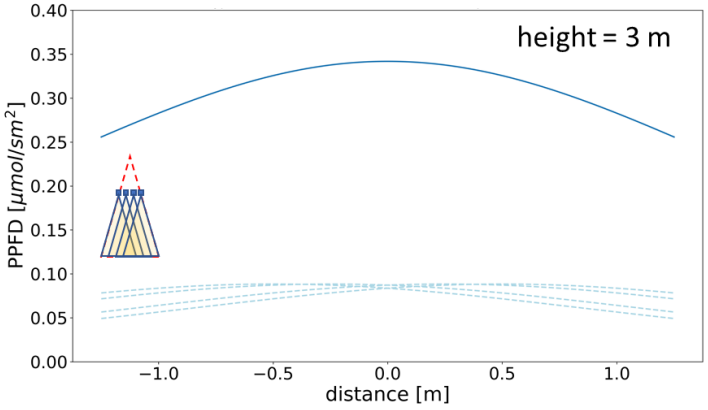
$$E(\theta) = \frac{I(\theta)}{h^2} \cos^3\theta$$

Comparing PPFD distributions

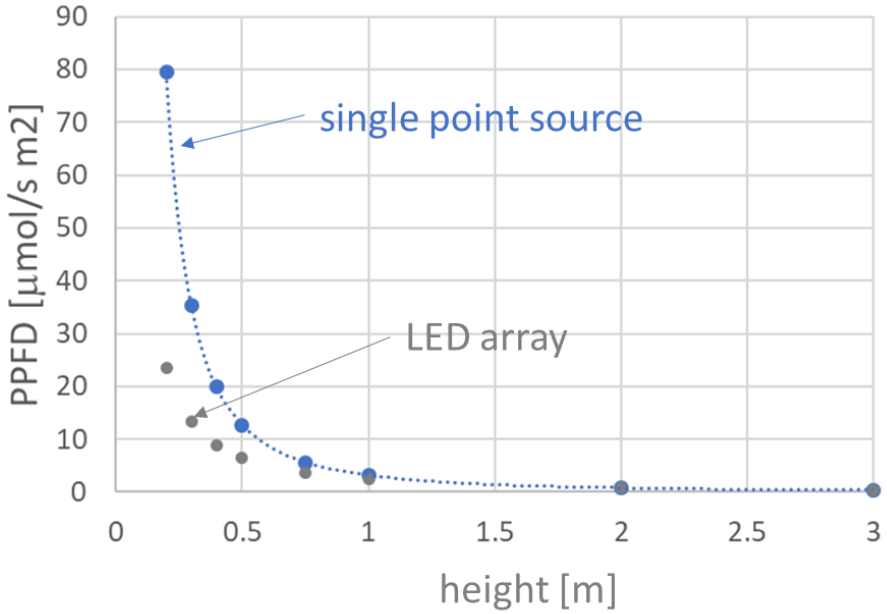


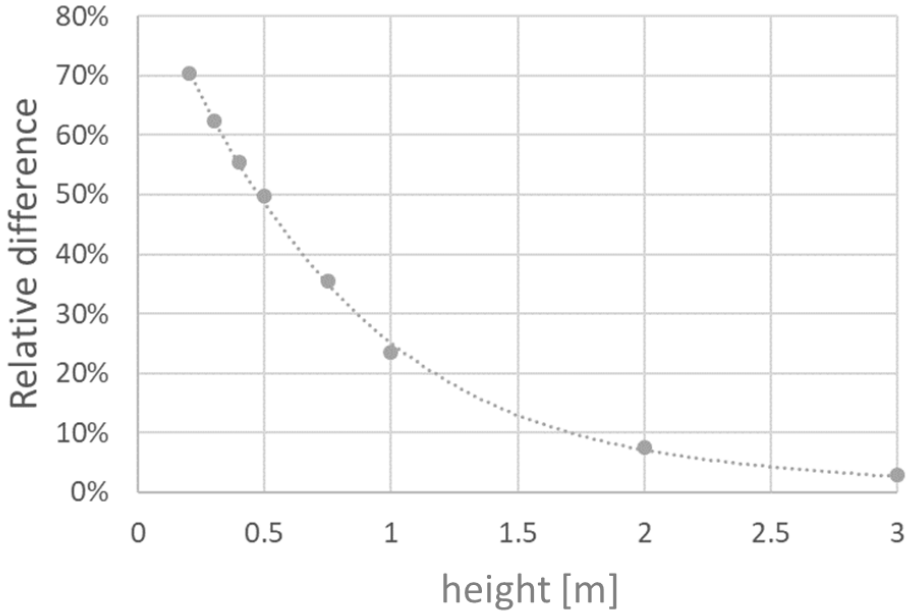






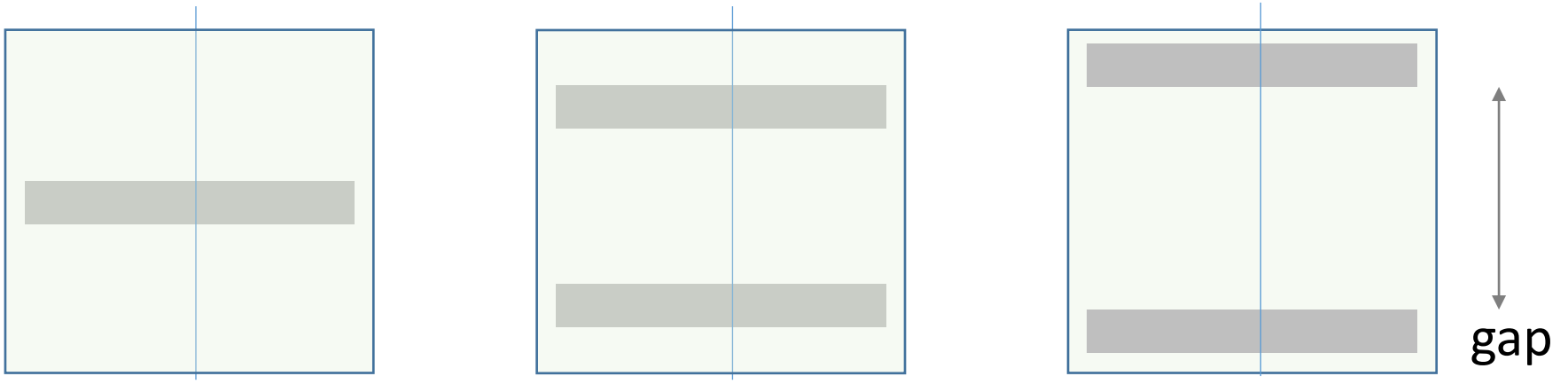
Photon Flux Density in the optical axis as a function of height





Greenhouse lighting

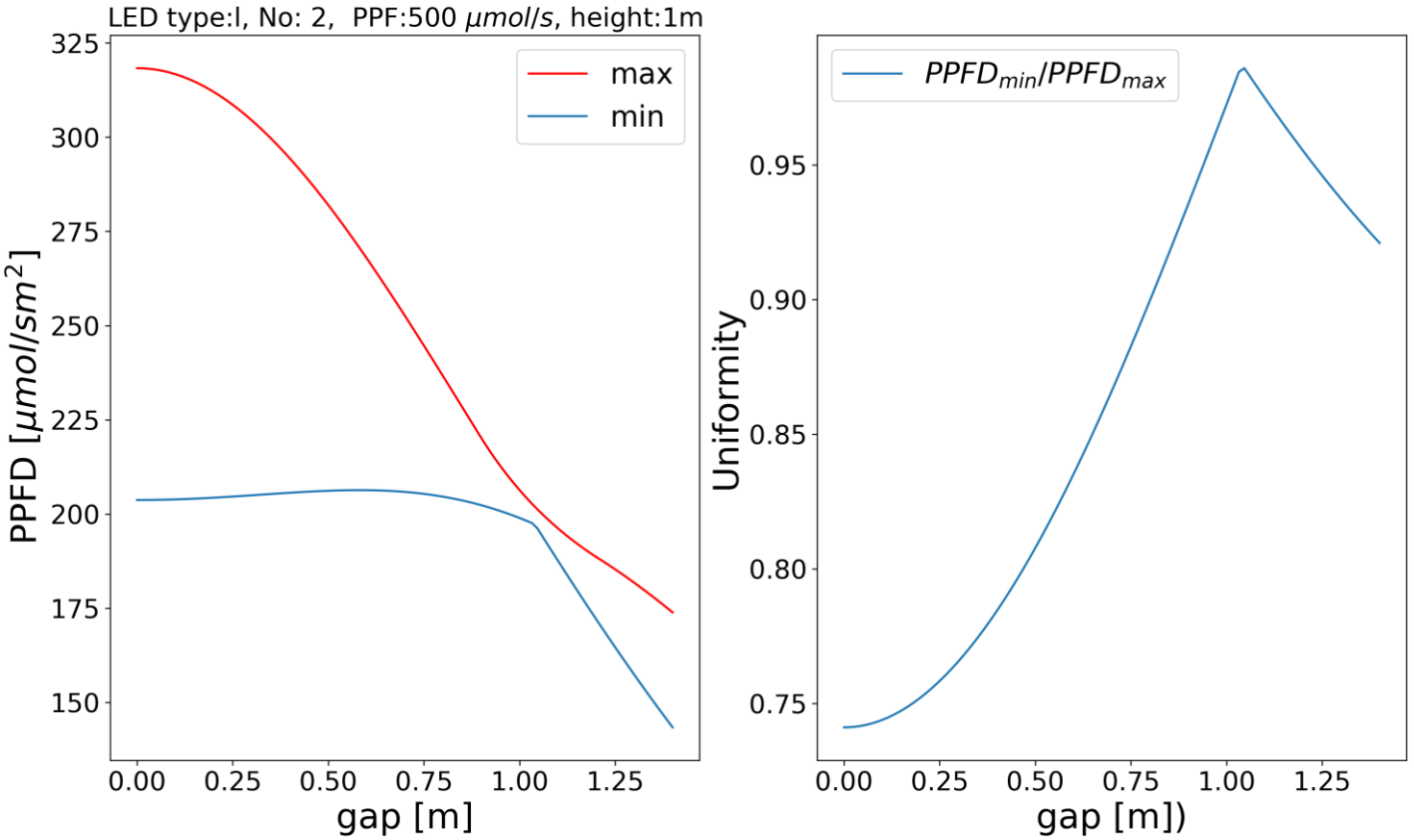
PPFD in 1m × 1m cells



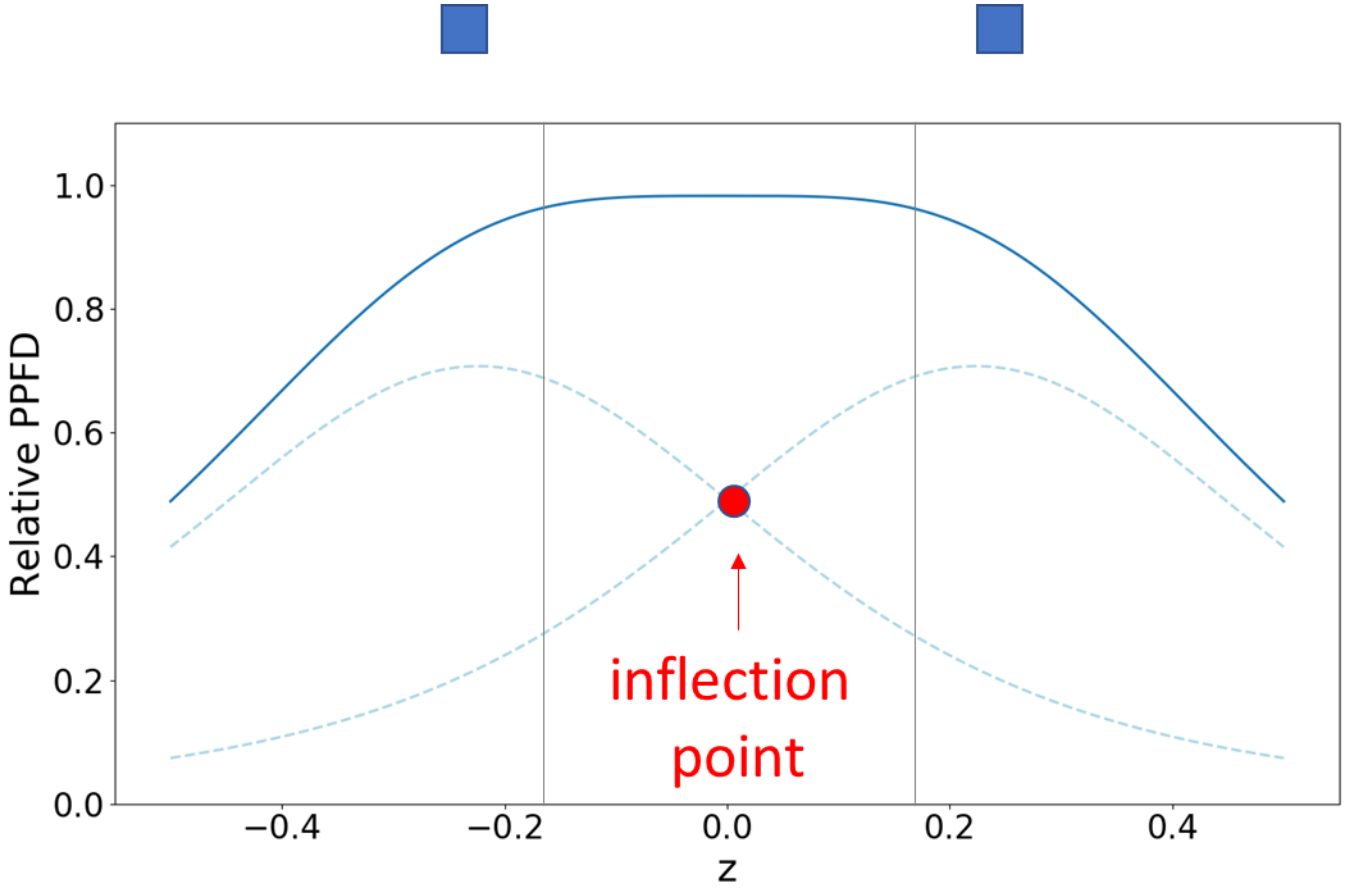
gap: 0 m 0.6 m 0.8 m

Green house lighting optimization

120° beam angle



Optimum gap size



Thank You for Your Attention!