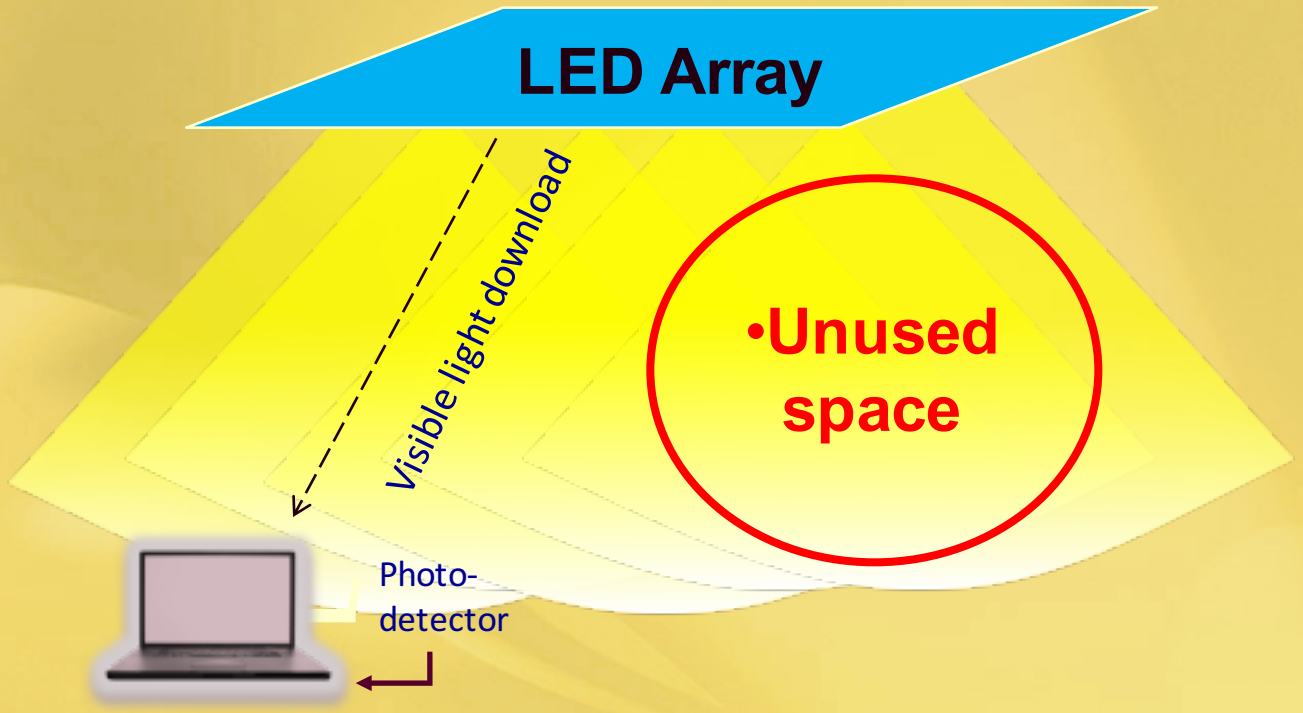
UNIVERSITY OF CENTRAL FLORIDA

Optimal Multi-Element VLC Bulb Design with Power and Lighting Quality Constraints

Sifat Ibne Mushfique and Murat Yuksel

- **Project website:** https://sites.google.com/site/nsfvlc/

Why Multi-Element/Stream VLC?



Single data stream
PHY solution
Large divergence – for smooth lighting

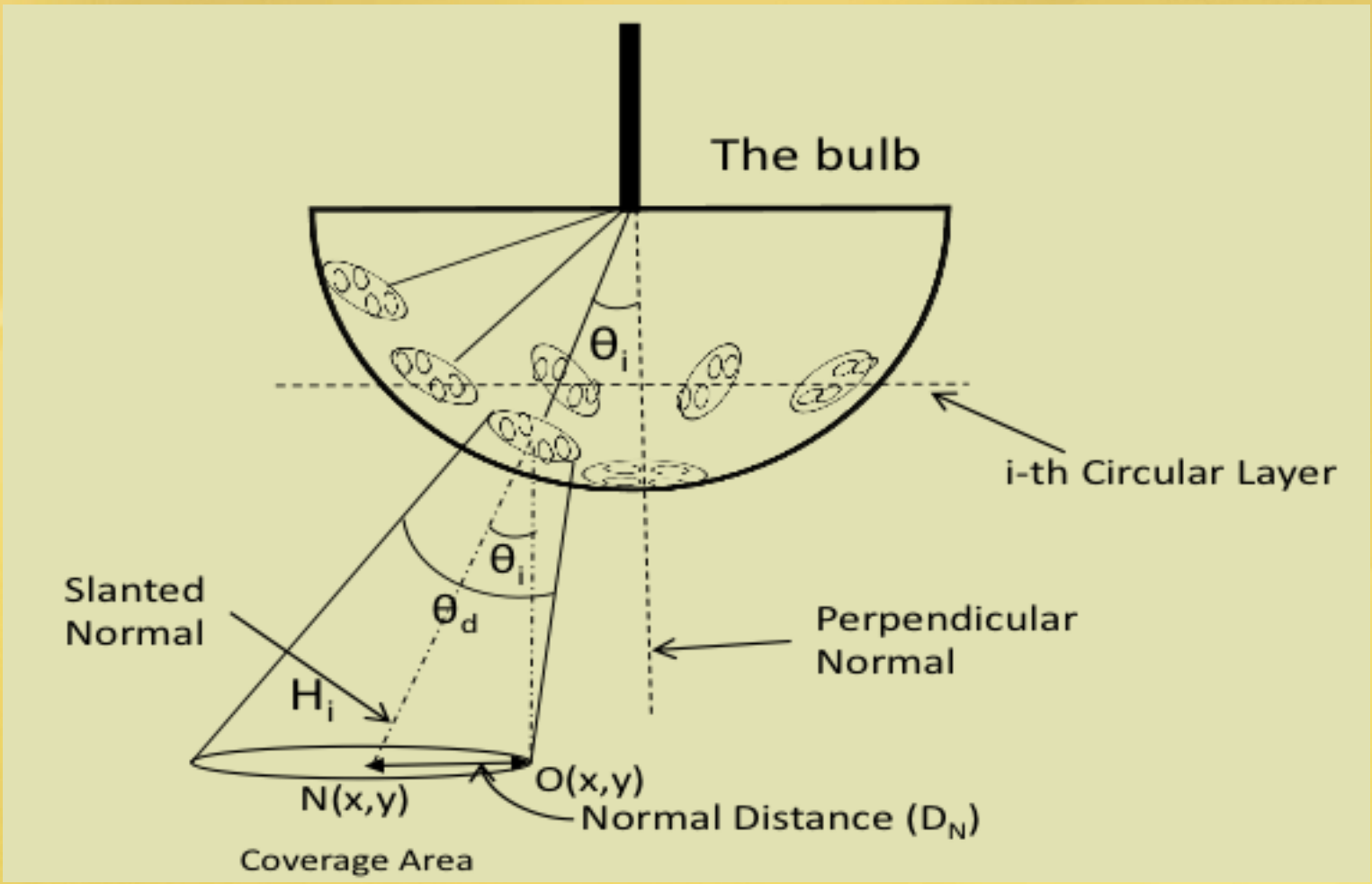
Multiple data streams
Narrow divergence – for higher spatial reuse
Spherical structures – to retain smooth lighting

Problem Statement

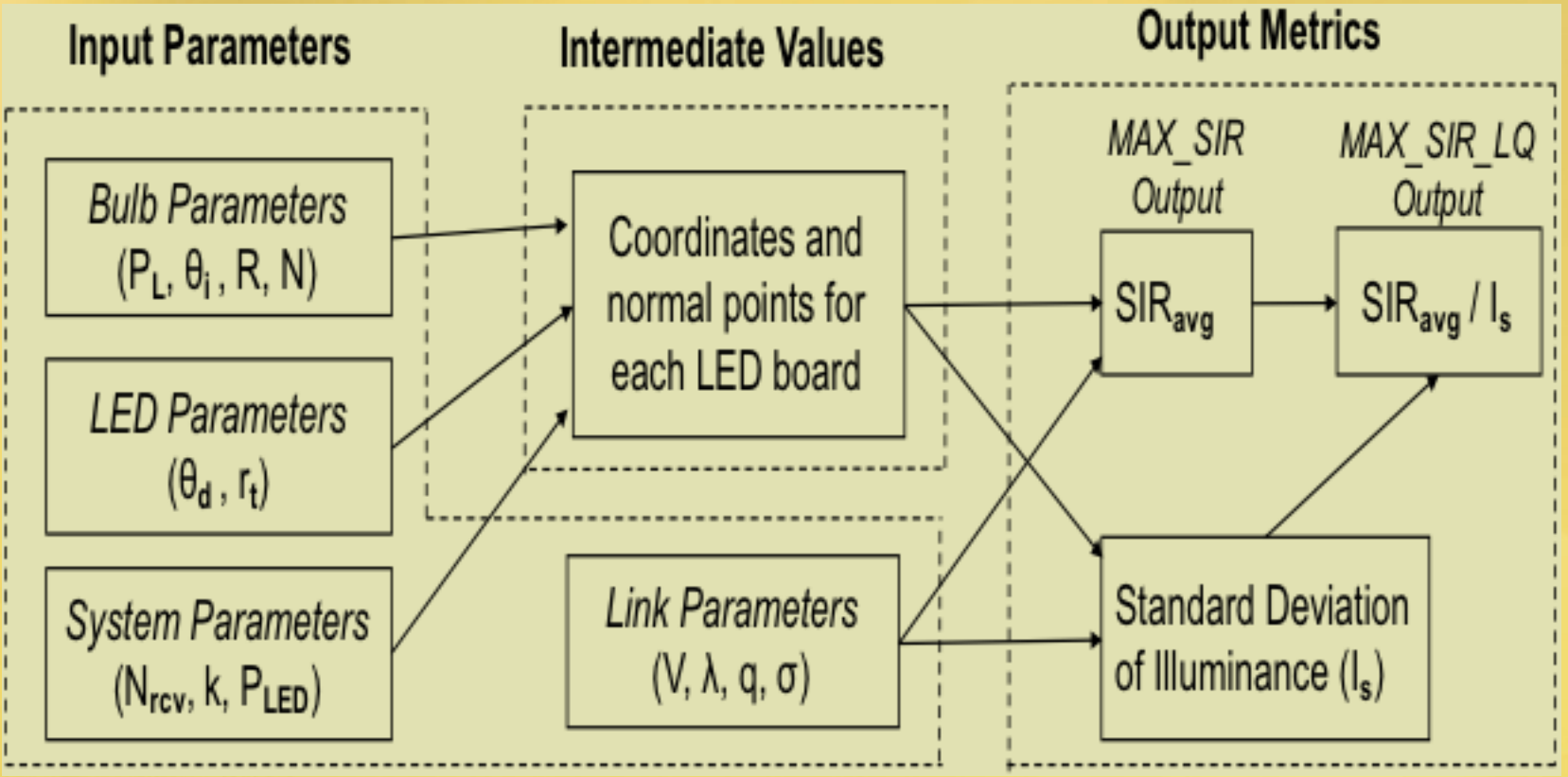
- **Introduce an framework of a Multi-element Bulb Design that –**
  - Optimizes the placement of LED boards/transmitters
    - Maximizing the signal-to-interference ratio (SIR)
    - Maintain a minimum evenness of the lighting on the room floor
  - Also, explores the optimization characteristics
    - Under various constraints

- **Challenges of a Multi-element Bulb Design**
  - Handle the line-of-sight (LOS) alignment management
  - Implement seamless communication across the room
  - Resolve inter-LED interference
  - Balance the tradeoff: uniform lighting and high spatial reuse

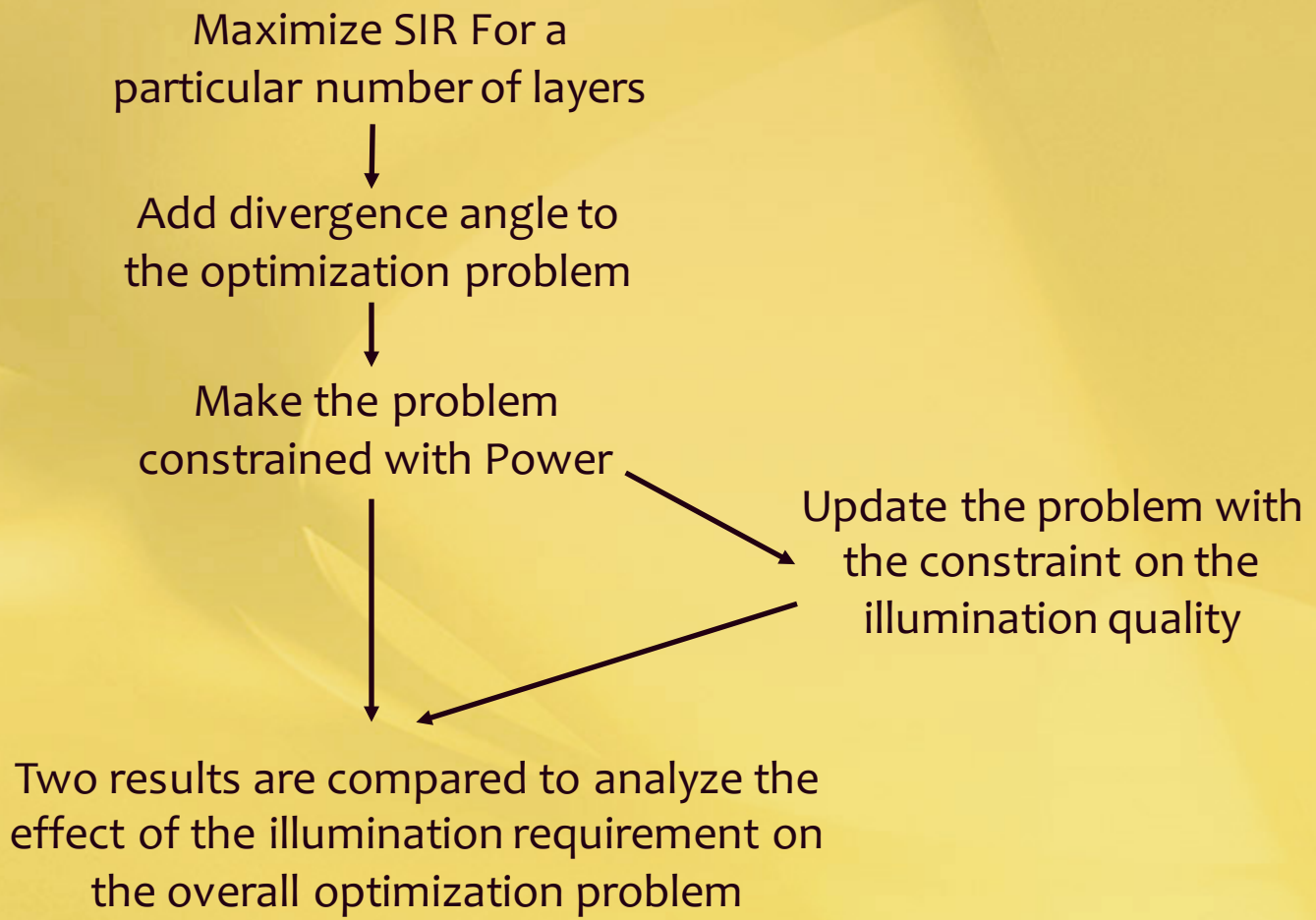
Multi-element Bulb Configuration



System Model



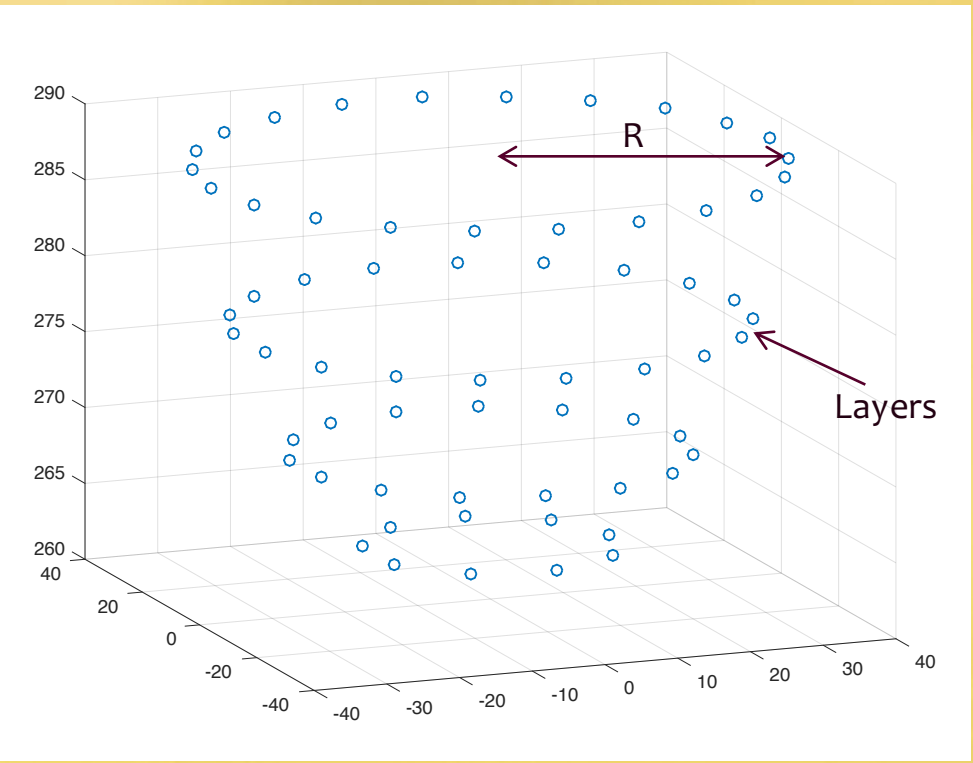
Optimization Objective



Maximum SIR Problem (MAX_SIR)

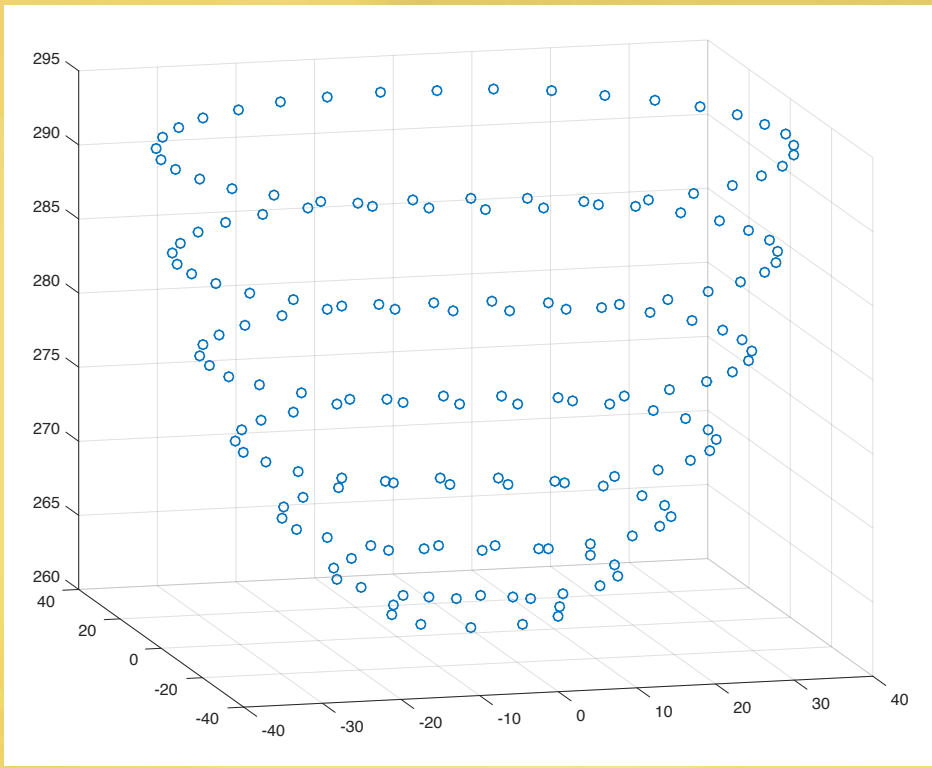
- **Variable Parameters**
  - k_i , Number of Transmitters in Layer i
    - LED boards can be placed in layers in many different ways
    - k_i depends on the size of the LED boards (r_t) and the Bulb radius (**R**)
  - θ_d, Divergence Angle of LEDs
    - Large divergence angles → better lighting
    - Narrow divergence angles → increased spatial reuse & higher SIR
    - Different divergence angles are tried to find the configurations yielding maximum SIR

Placement of the Transmitters



R = 40 cm, r_t = 5.5 cm

No. of Layers = 4



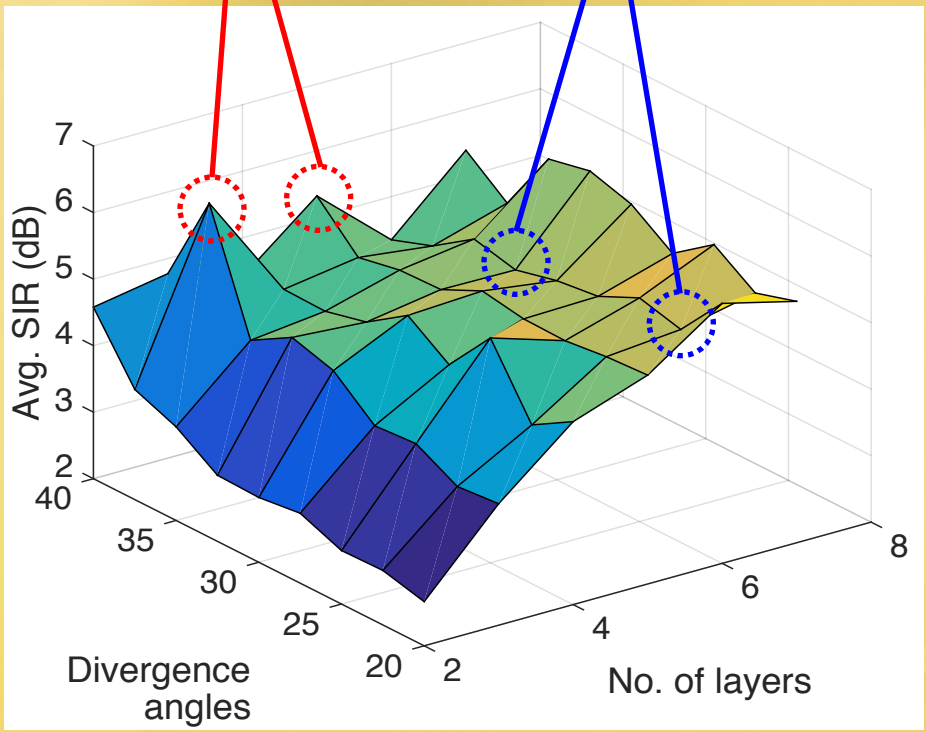
R = 40 cm, r_t = 3.5 cm

No. of Layers = 7

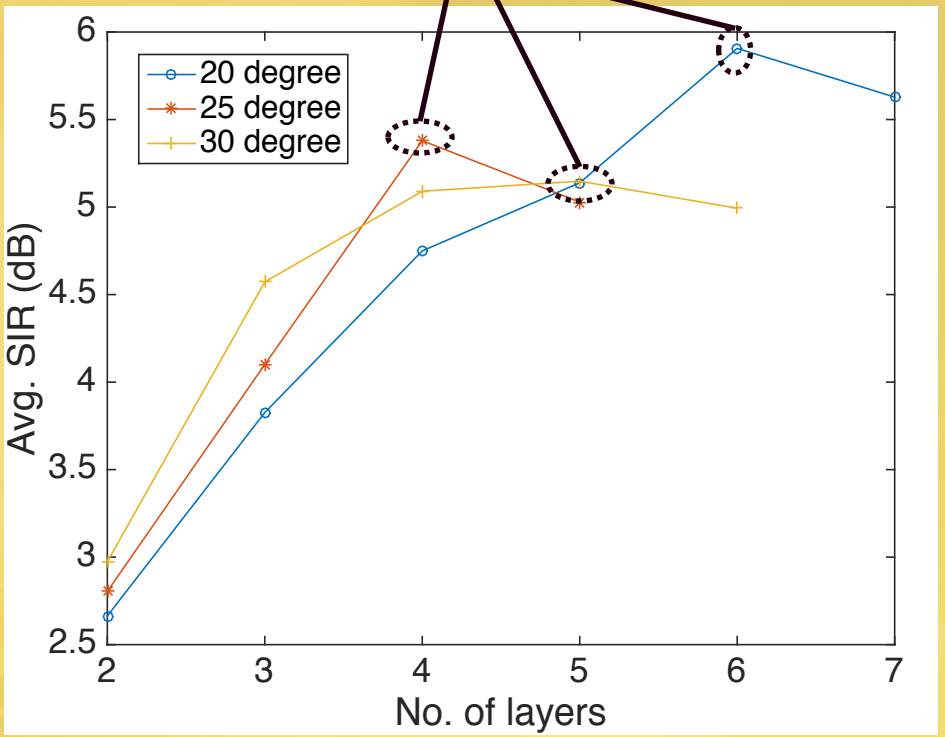
Maximum SIR Problem (Contd.)

- **Fixed Parameters**
  - **Room size** - 6m x 6m x 3m
  - **R**, Radius of the Hemispherical Bulb – 40 cm
  - $\mathbf{r_t}$, Radius of the LED Board/Transmitter - 3.5cm
  - **l**, Number of Layers - Depending on **R** and $\mathbf{r_t}$
    - Minimum number of layers → **2**
    - Maximum number of layers → calculated from **R** and $\mathbf{r_t}$
    - The number of Layers and LED boards is varied between this **minimum** and **maximum** value

Non-Linearity of the Objective Function



Multiple Local Maxima and Minima



Saturation of the SIR Value

Updating the Maximum SIR Problem (MAX_SIR_LQ)

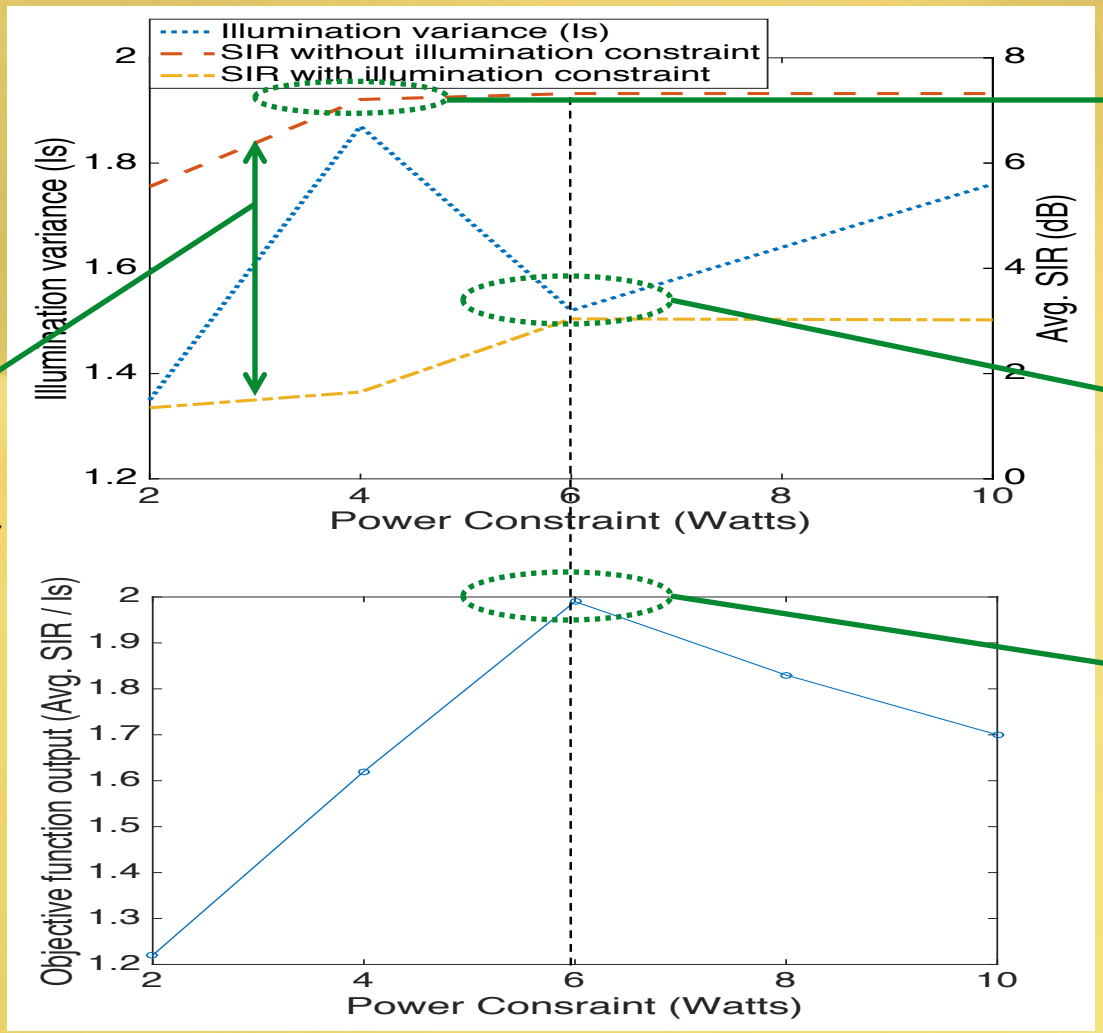
- Illumination Constraint (I_s) is added to obtain smooth lighting
- I_s is calculated by continuously taking average luminous intensity of 100 random points until the value converges
- Maximum allowed illumination variance, $I_s^{max} = 5$
- The new objective function output is then (SIR / I_s) instead of SIR

Results

Objective	l (number of layers)	k_1	k_2	k_3	θ_d (in degrees)
MAX_SIR	2	19	2	--	39.5
	3	16	26	2	47.2
MAX_SIR_LQ	2	6	28	--	16

- MAX_SIR has much fewer LEDs in the higher layer
- MAX_SIR_LQ puts more LEDs in the higher layer to achieve more even lighting across the room

Results (Contd.)



Optimum SIR is significantly lower in MAX_SIR_LQ

SIR value saturates

Lighting Quality starts to deteriorate as I_s increases

(SIR / I_s) starts to fall from the same time

Summary and Future Work

- A framework is introduced to optimize a multi-element bulb design for both illumination and communication quality of VLC in a room
- In the future, this can be done for different room size and bulb parameters
- Trying with bulbs of some other shapes (Triangular, Square etc.) can be interesting
- Multiple number of bulbs can be considered as well

UNIVERSITY OF CENTRAL FLORIDA

QUESTIONS?