Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Requirement for VLC channel modeling]
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Re: [Call for contributions for TG7 for channel modeling]

Abstract: [Summary of VLC channel modeling requirement]

Purpose: [Contribution to IEEE 802.15 TG-VLC]

Requirement for VLC channel modeling

2009.01.21

Samsung Electronics

Contents

- RF wave vs Optical wave
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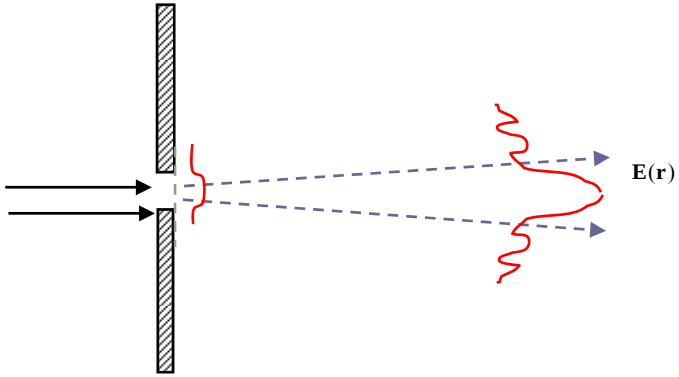
Radio wave vs Optical wave

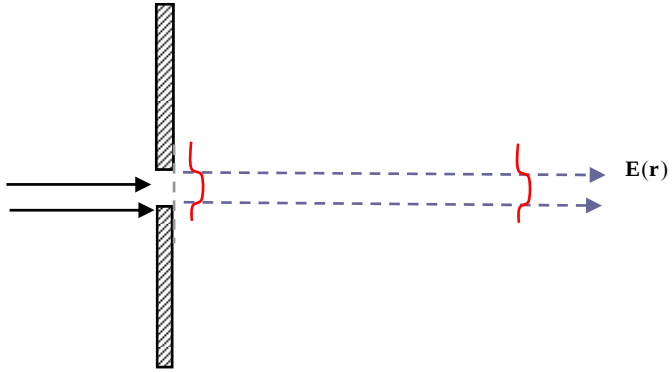
- Radio wave
  - Long wavelength
    - Usually, specular reflection
  - Edge
    - More diffraction

Radio wave (~ GHz)



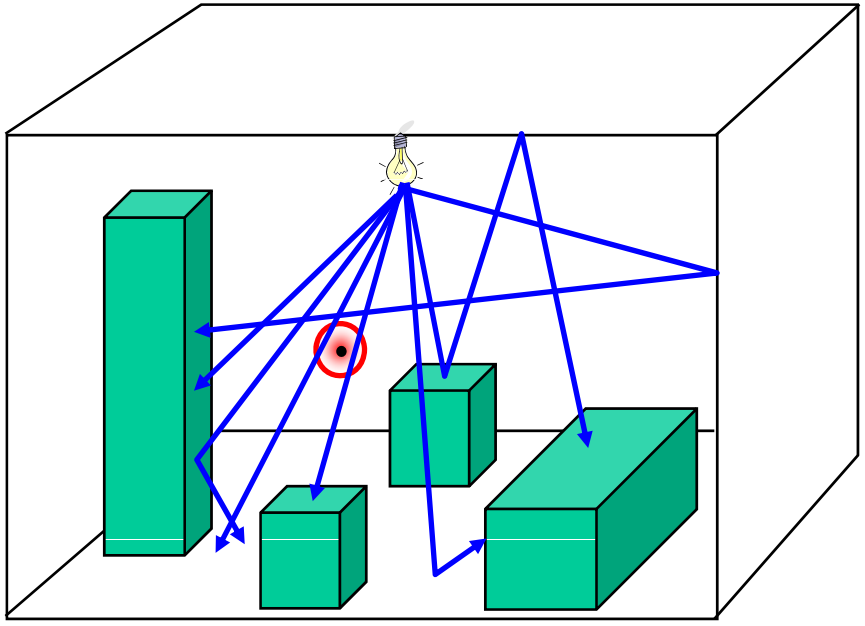
- Optical wave
  - Short wavelength
    - Usually, lambertian reflection
  - Edge
    - Less diffraction

Optical wave (~THz)



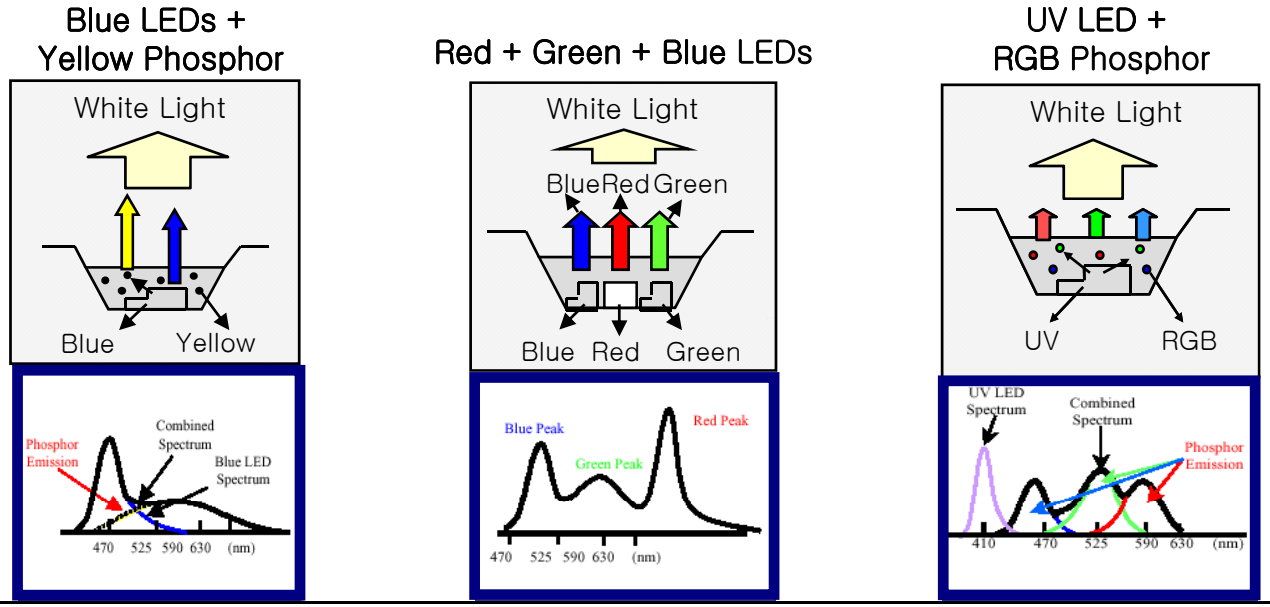
Photon model

- Photon Model [1]
  - Based on quantum theory
  - Used in computer graphics



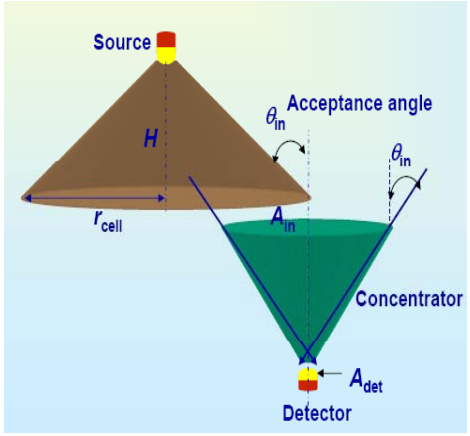
Transmitter model – wave length

- Different wavelength spectrum
  - BLUE LED
  - RGB LED
  - UV LED



Transmitter model – radiant pattern

- Radiant pattern
  - Same as Antenna pattern
  - FOV(field of view)
  - Lens



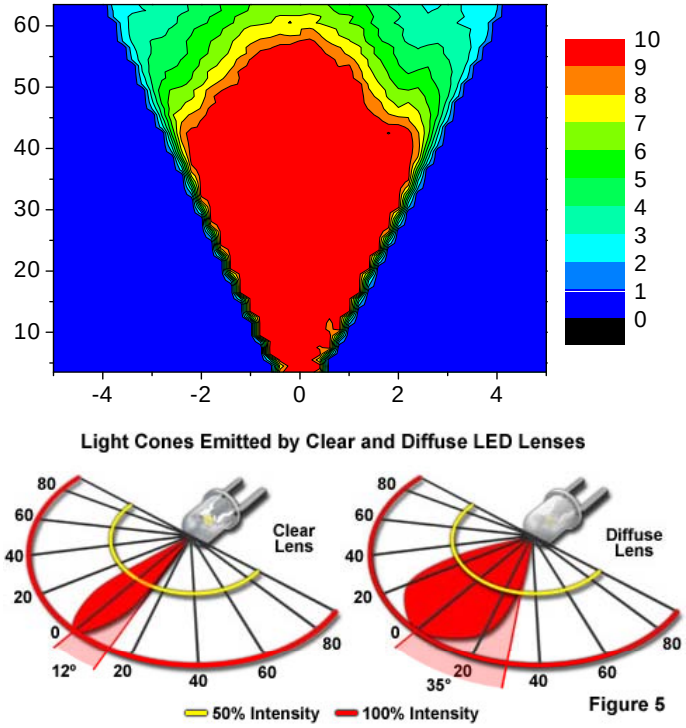


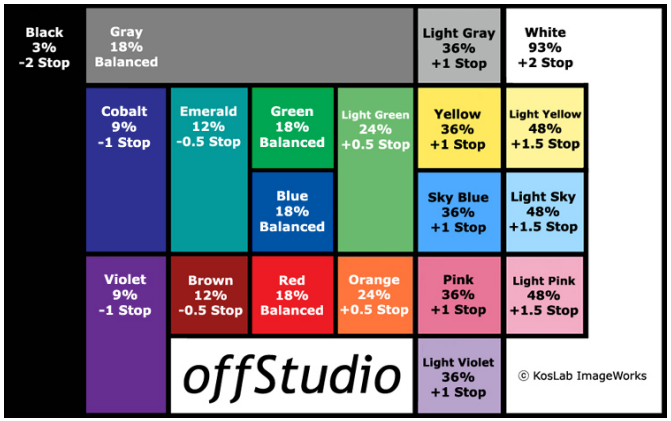
Figure 5

Transmitter model – source type

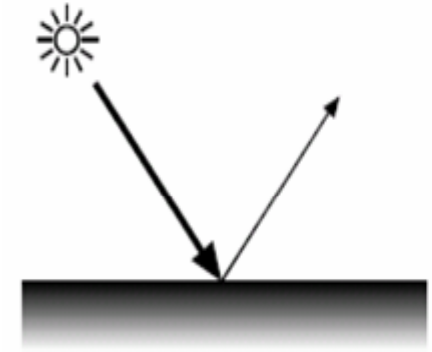
- Point source
  - Replacement of incandescent la mp
- Rectangular source
  - Replacement of fluorescent lamp
- Directional source
  - Interference: Other illumination ramp or Sun

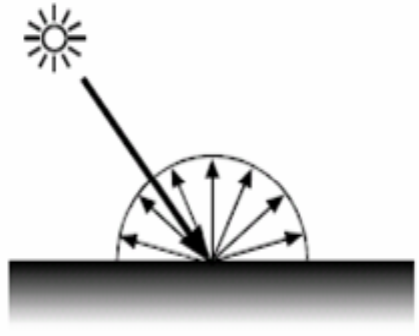
Reflection index

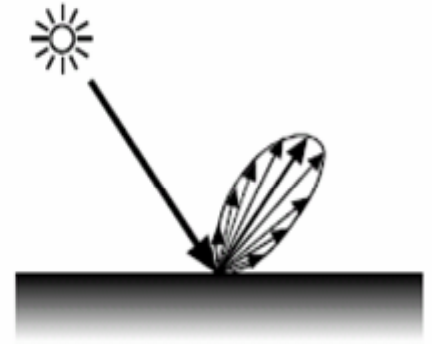
- Reflection index in indoor environment
  - Reflection index based on colors
  - Depends on application environment
    - School:
      - Wall(40~50%), floor(20~30%),desk(25~40%)
    - Shop and store:
      - Warm feeling, natural daylighting (Increase sale)
      - Depends on goods
    - Office: 30%
      - Wall(40~60%), floor(20%~)
    - Industry:
      - Wall(60~70%), floor(25%~40%)
    - Hospital:
      - Mental stability
  - Window:8~10%



Reflection Types



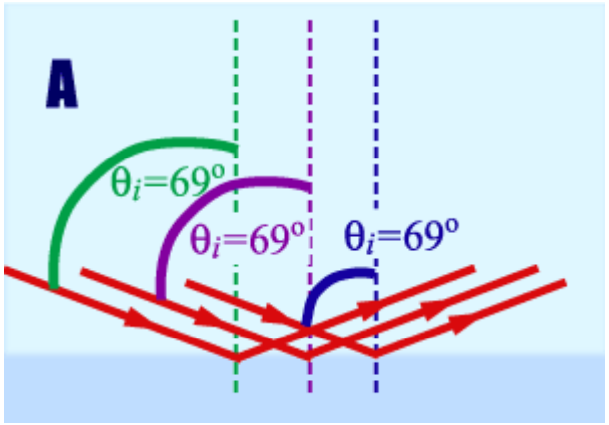




- Mirror
  - Smooth surface
    - Mirror or calm water
- Diffuse
  - Rough surface
    - Clothing, paper and asphalt road
  - Lambertian reflection
- Glossy
  - BRDF(Bidirectional Reflectance Distribution Function)

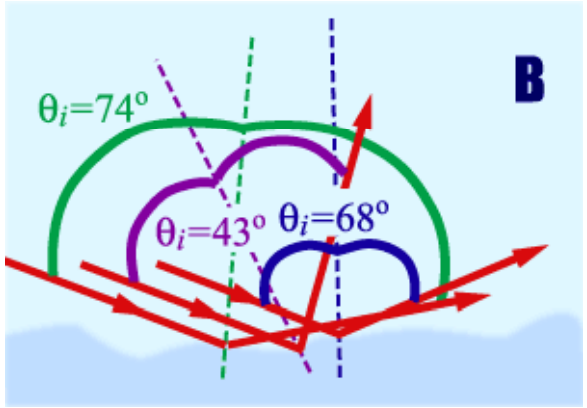
Mirror Reflection

- Mirror reflection is the perfect, mirror-like reflection of light from a surface.
- A single incoming direction is reflected into a single outgoing direction.
  - As the beam strikes the surface, each region of the beam of light will produce the same angle of incidence.
- Such behavior is described by the law of reflection.
- Smooth surface
  - Mirror, calm water



Diffuse Reflection

- Reflection of light from an uneven or granular surface
  - Rough surface
    - Clothing, paper, asphalt road
- Incident ray is seemingly reflected at a number of angles.
- Not follow law of reflection
- It is the complement to mirror reflection.
- Lambertian Reflection



Glossy Reflection (1/2)

- Gloss is an optical property, which is based on the interaction of light with physical characteristics of a surface.
- The factors that affects gloss are the refractive index of the material, the angle of incident light and the surface topography.
- Not diffuse, mirror reflection
- BRDF (Bidirectional Reflectance Distribution Function)

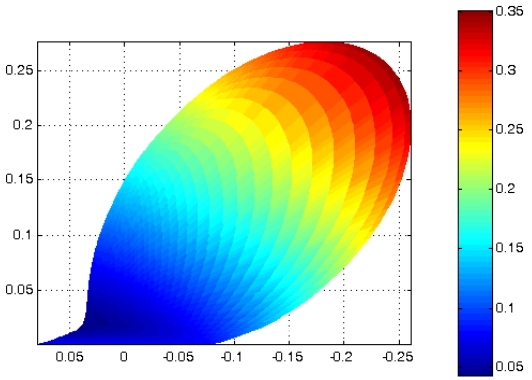
Glossy Reflection (2/2)

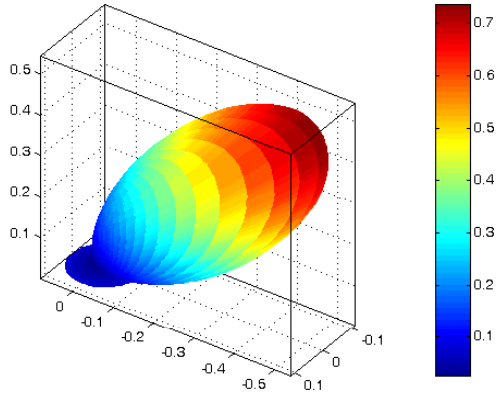
- BRDF
  - Bidirectional Reflectance Distribution Function
    - 4-dimensional function that defines how light is reflected at an opaque surface
    - Used in computer graphics for photorealistic rendering

- Schlick's BRDF

$$\theta_i = \frac{\pi}{4}, \quad \sigma = 0.1, \quad \psi = 1$$

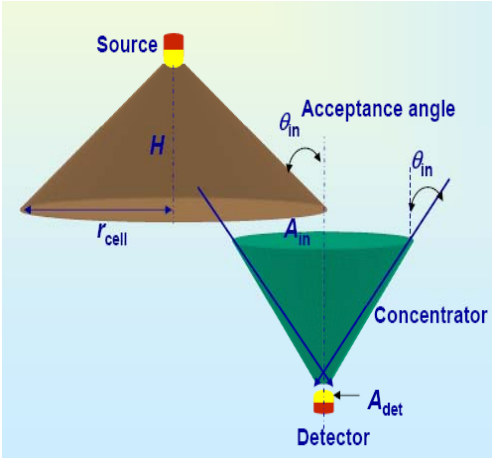
σ : roughness (0~1) (0 perfectly smooth, 1 randomly rough)
Ψ : anisotropy (0~1) (0 anisotropic, 1 isotropic)

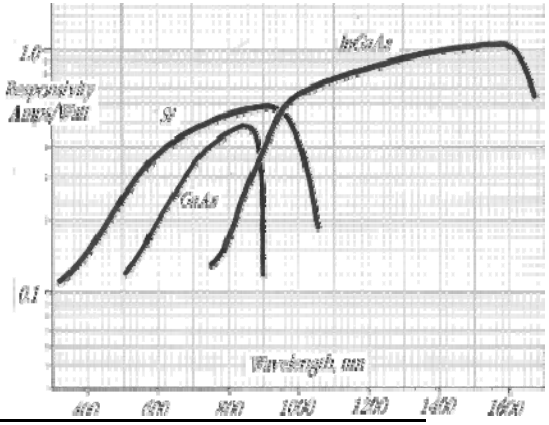




Receiver model

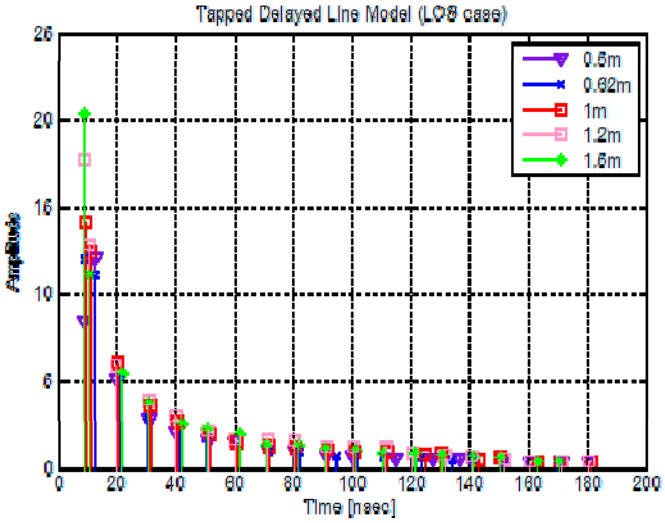
- FOV(field of view)
- PD (Photo Diode) sensitivity
  - Different wavelength sensitivity because of material

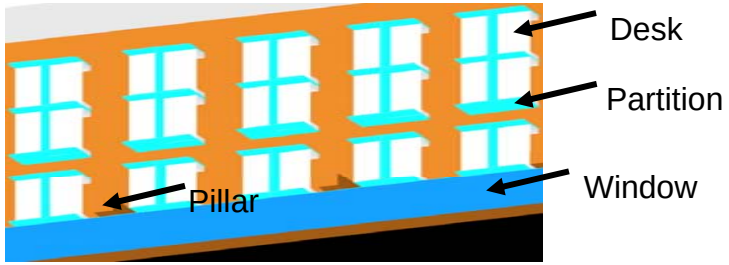


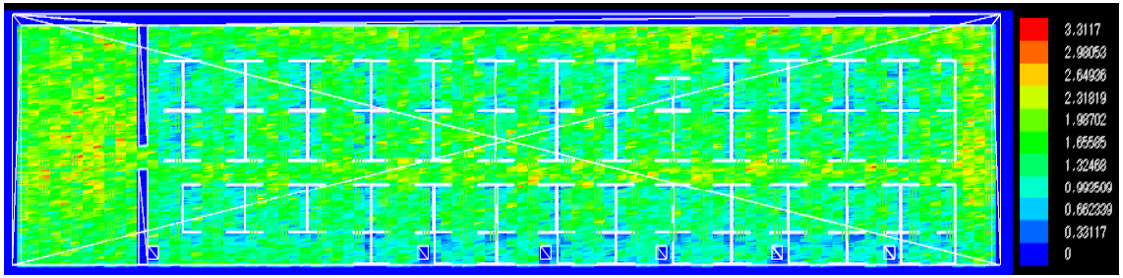


Simulation Example (1/2)

- Office environment
  - LED:
    - Flat spectrum
    - No radiant pattern
    - Rectangular source
  - Reflection index based on color
    - Floor: 93%, Ceil: 93%, Wall: 93%
      Desk: 48%, Partition: 18%
    - Window glass: 8%
  - Mirror reflection
  - PD:
    - Fov: 60°

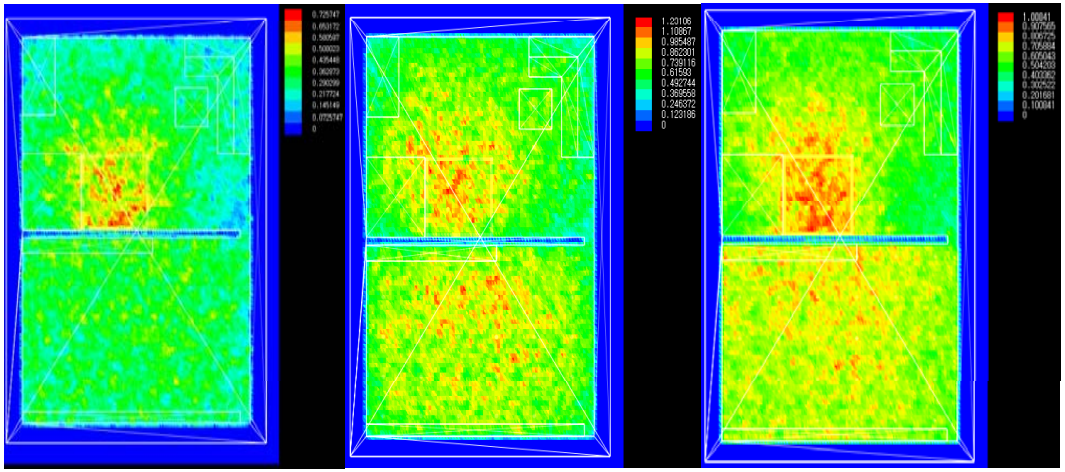


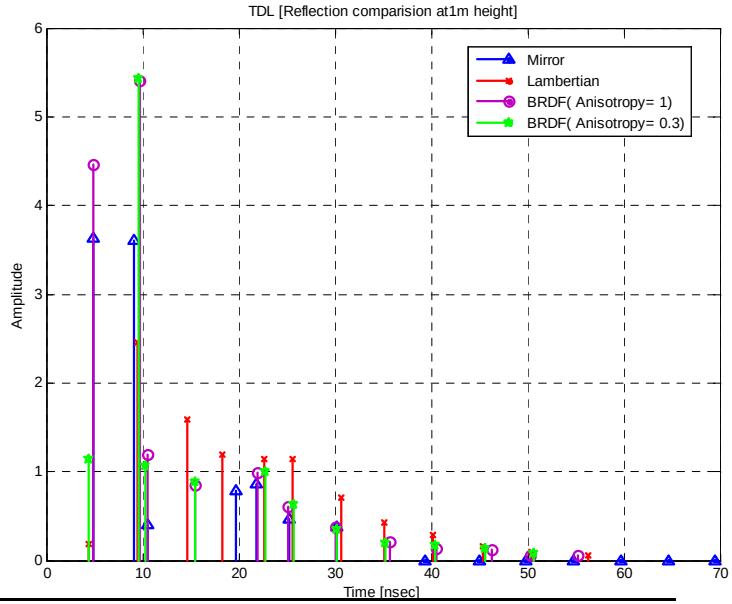




Simulation Example (2/2)

- Simulation result based on different reflection types
  - Mirror
  - Lambertian
  - BRDF





Conclusion

- Channel modeling requirement
  - LED side
    - FOV
    - Radiant pattern
    - BLUE LED, RGB LED,UV LED
  - Reflection index
    - Based on VLC application environment
  - Reflection type
    - Mirror, Diffuse (Lambertian), Glossy (BRDF)
  - PD side
    - FOV
    - Wavelength sensitivity

Future Works

- VLC application categorization
- Channel modeling simulation
  - BER performance comparison
    - To check the influence of reflection type
  - RGB LED channel modeling

Thank You~

Q&A

Reference

[1] H.W.Jensen, “Global illumination using photon maps”, Eurographics, vol.7, pp.21-30,1996