(De) Focusing on Global Illumination for Active Scene Recovery

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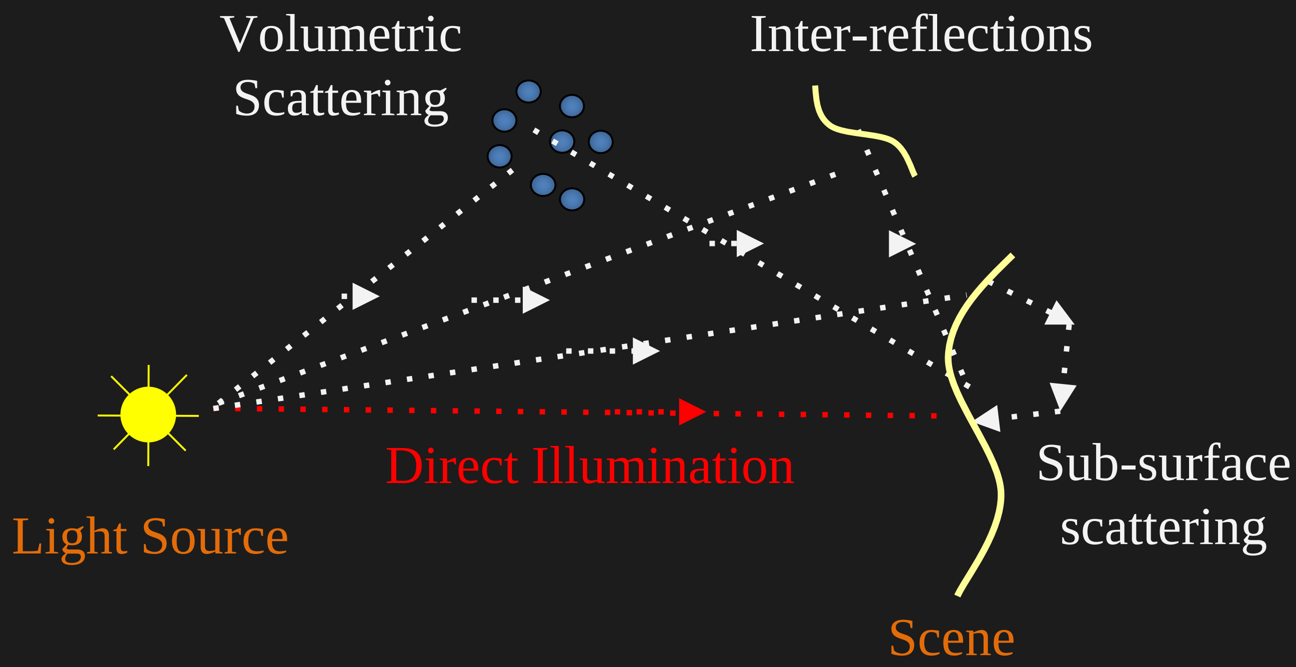
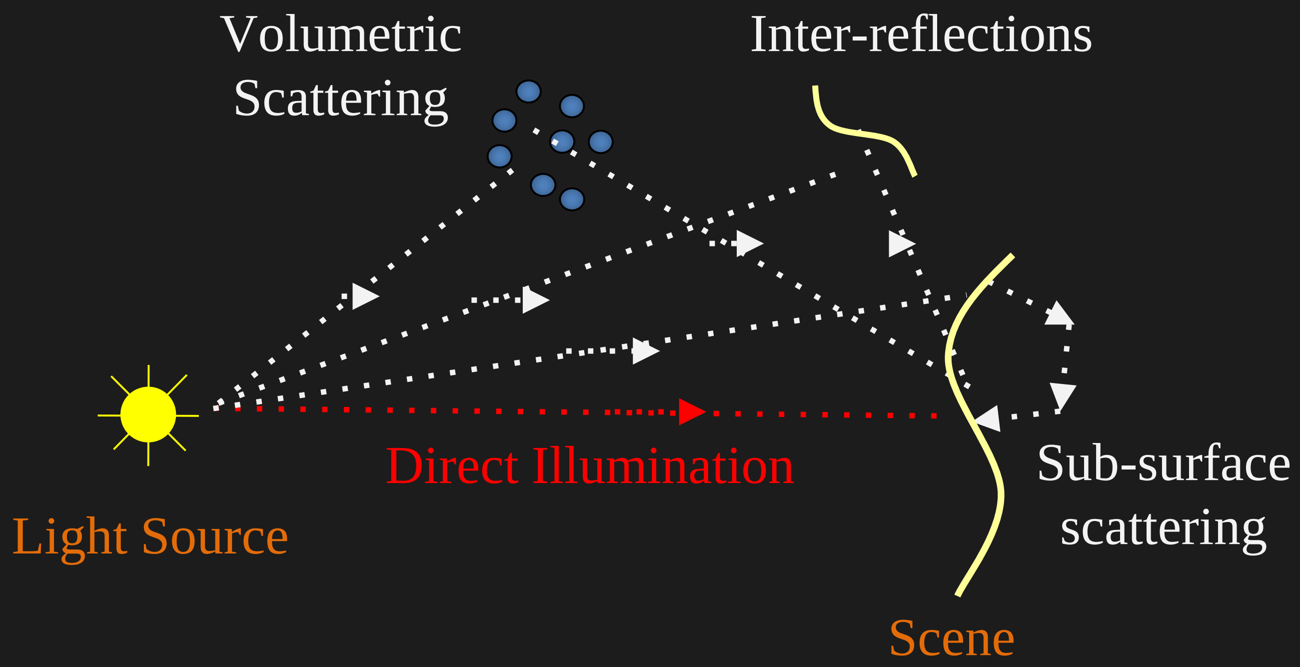
Presented by Rick and Chia-Yin

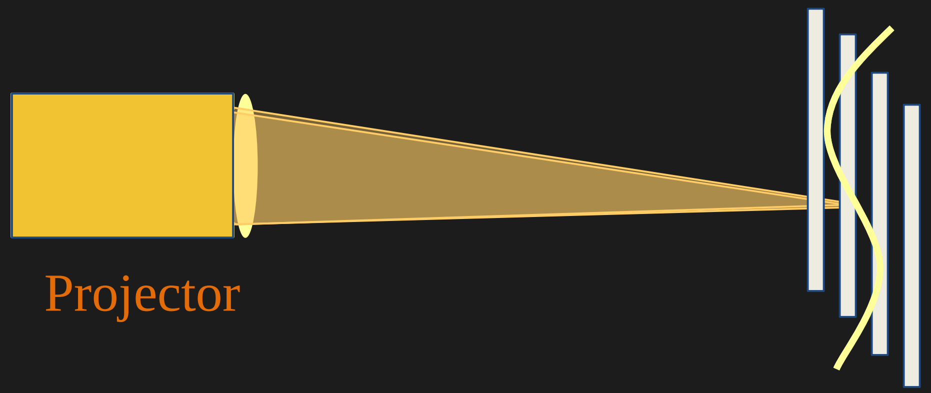
Global Illumination is Everywhere



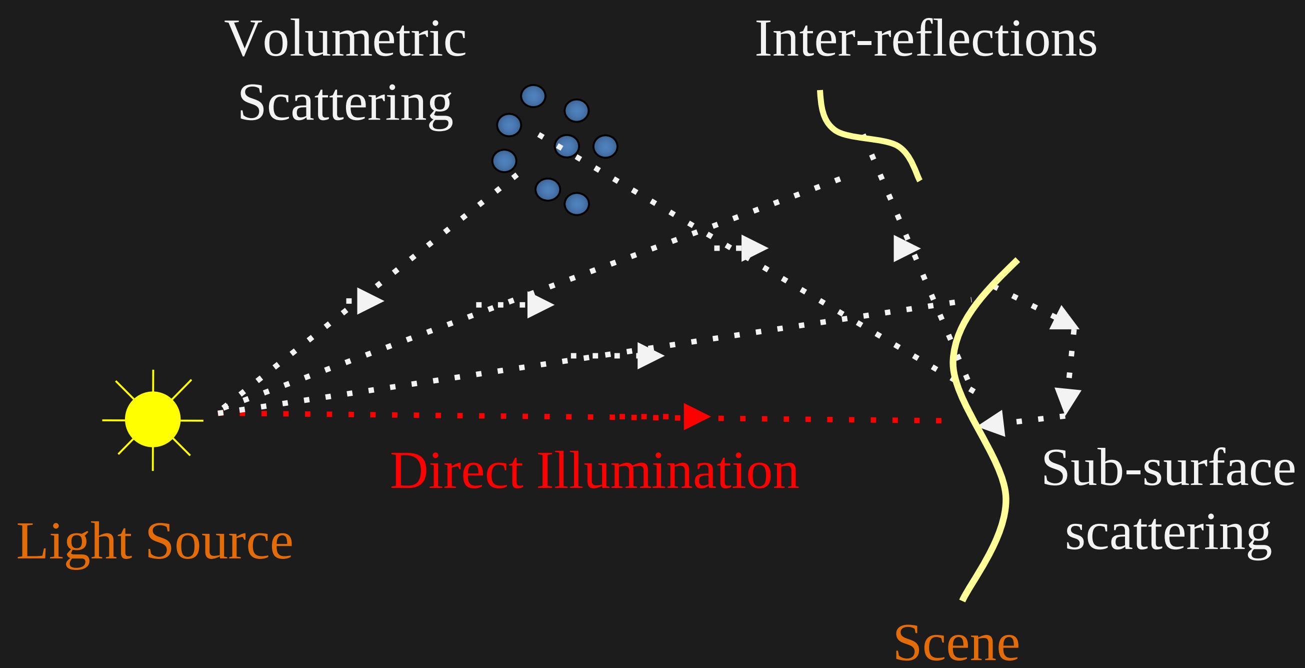


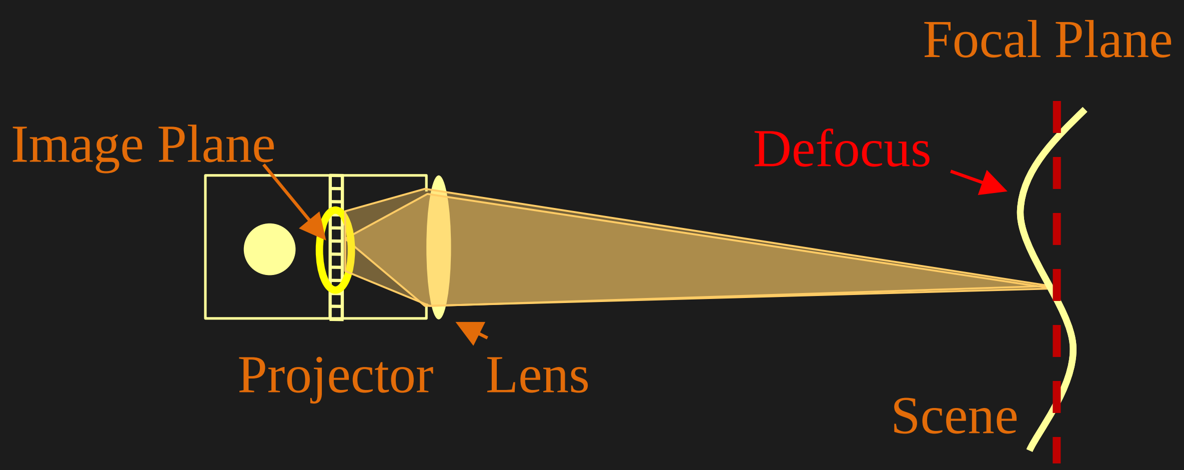

Separate Direct and Global Illumination



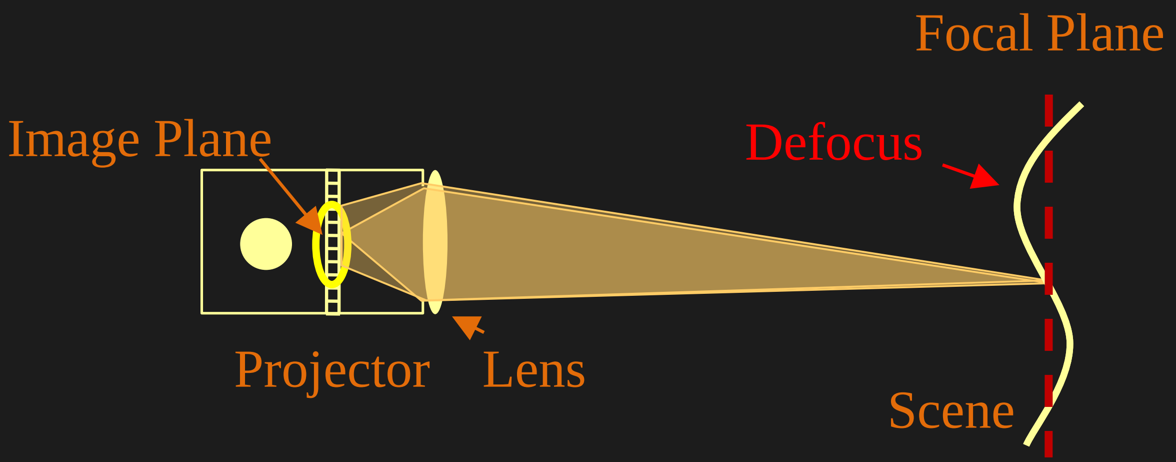


Separate Direct and Global Illumination





Defocused Illumination



Slide adapted from Zhang et al

Defocused Illumination: Low Pass Filter

With Defocus

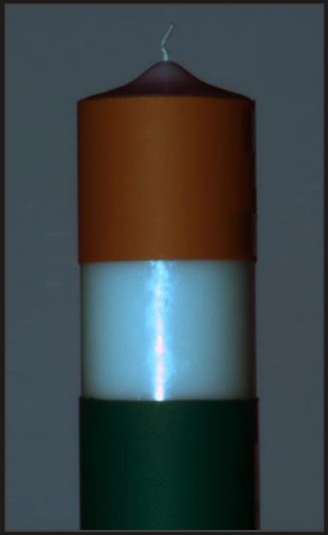
No Defocus

Global Illumination: Low Pass Filter

No Global Illumination

With Global Illumination

Defocused Illumination + Global Illumination



Defocused Illumination (Direct component)

Direct component:

focal plane

time location

$$e_i(t, f) = \alpha_i \ p_i(t) * b_i(t, f)$$

radiance

Defocused Illumination + Global Illumination

Direct component:

focal plane location

time

$$e_i(t, f) = \alpha_i \; p_i(t) * b_i(t, f)$$

radiance

BRDF, orientation, intensity fall-off

Defocused Illumination + Global Illumination

Direct component:

focal plane location

illumination pattern

time

$$e_i(t, f) = \alpha_i \; p_i(t) * b_i(t, f)$$

radiance

BRDF, orientation, intensity fall-off

Defocused Illumination + Global Illumination

Direct component:

time

focal plane location

illumination pattern

$$e_i(t, f) = \alpha_i \; p_i(t) * b_i(t, f)$$

radiance

BRDF, orientation, intensity fall-off

defocus blur kernel

Defocused Illumination + Global Illumination

Direct and Global component:

$$e_i(t,f) = \alpha_i \; p_i(t) * b_i(t,f) + \sum_{j \neq i} m_{ij} \; p_j(t) * b_j(t,f)$$

fraction of
direct component
from j to i

Defocused Illumination + Global Illumination

Direct and Global component:

$$e_i(t,f) = \alpha_i\ p_i(t) * b_i(t,f) + \sum_{j \neq i} m_{ij}\ p_j(t) * b_j(t,f)$$

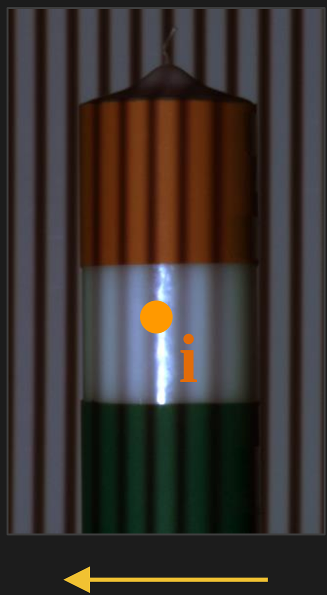
$$m_{ii} := \alpha_i$$

$$e_i(t,f) = \sum_j m_{ij}\ p_j(t) * b_j(t,f)$$

Fourier transform

$$E_i(\omega,f) = \sum_j m_{ij}\ P_j(\omega) B_j(\omega,f)$$

Defocused Illumination + Global Illumination



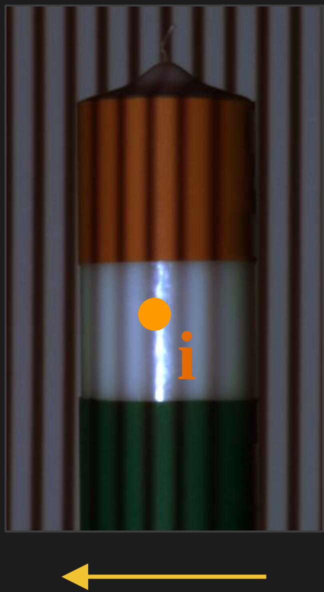
$$E_i(\omega, f) = \sum_j m_{ij} \; P_j(\omega) B_j(\omega, f)$$

Since periodic pattern shifting

$$P_j(\omega) = P(\omega) \exp(-I\omega\phi_j)$$

$$E_i(\omega, f) = P(\omega) B_i(\omega, f) \sum_j m_{ij} \exp(-I\omega\phi_j) \frac{B_j(\omega, f)}{B_i(\omega, f)}$$

Defocused Illumination + Global Illumination



$$E_i(\omega, f) = \sum_j m_{ij} \; P_j(\omega) B_j(\omega, f)$$

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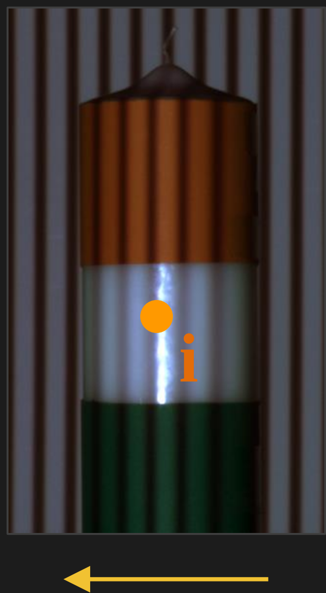
defocus
blur kernel

global
illumination
blur kernel

Defocused Illumination + Global Illumination



$$E_i(\omega, f) = \sum_j m_{ij}\; P_j(\omega) B_j(\omega, f)$$

Since periodic pattern shifting

$$P_j(\omega) = P(\omega)\exp(-I\omega\phi_j)$$

$$E_i(\omega, f) = \underbrace{P(\omega) B_i(\omega, f)}_{\text{defocus blur kernel}} \underbrace{\sum_j m_{ij} \exp(-I\omega\phi_j) \frac{B_j(\omega, f)}{B_i(\omega, f)}}_{\text{global illumination blur kernel}}$$

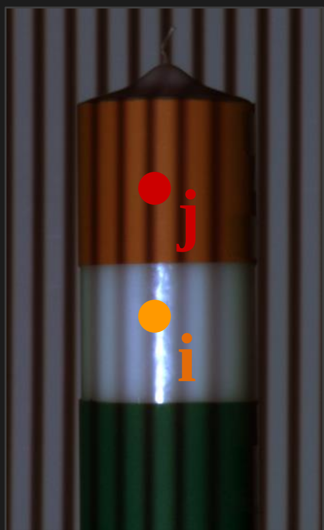
defocus
blur kernel

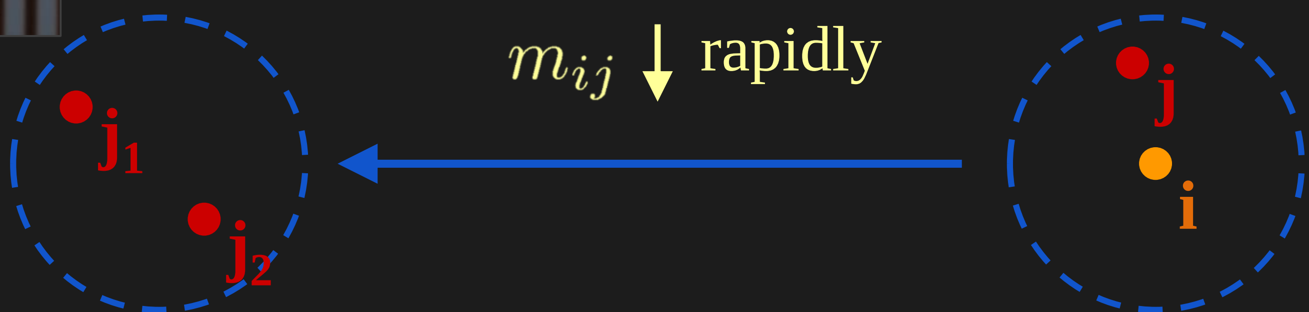
global
illumination
blur kernel

(Nearly independent
to focal location f !)

Global Illumination is Nearly Indep. to f

$$m_{ij} \exp(-I\omega\phi_j) \frac{B_j(\omega, f)}{B_i(\omega, f)}$$

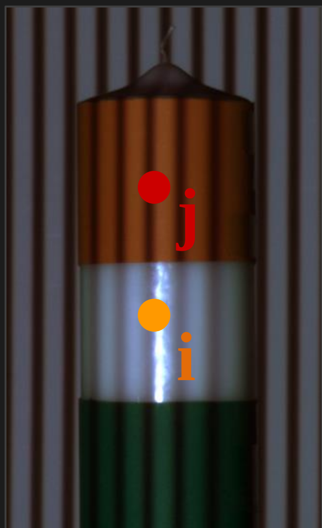




$$\sum \exp(-I\omega\phi_j) \sim 0$$

$$\frac{B_j(\omega, f)}{B_i(\omega, f)} \sim 1$$

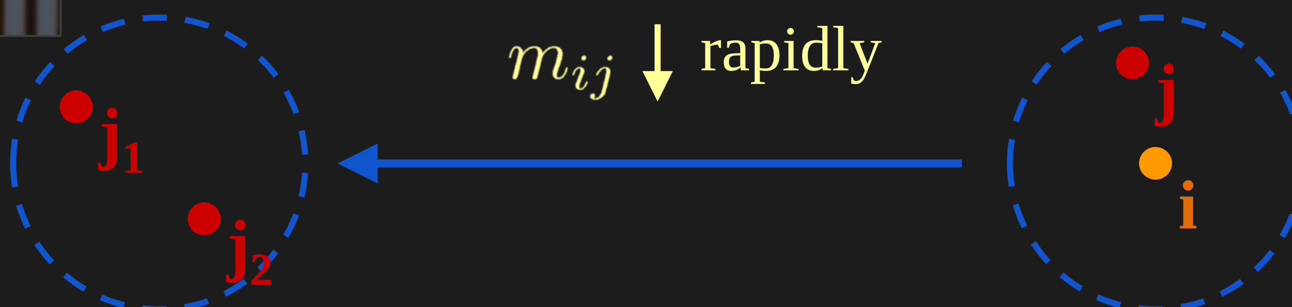
Global Illumination is Nearly Indep. to f



$$\sum_j m_{ij} \exp(-I\omega\phi_j) \frac{B_j(\omega, f)}{B_i(\omega, f)}$$

Nearly independent to focal location f !

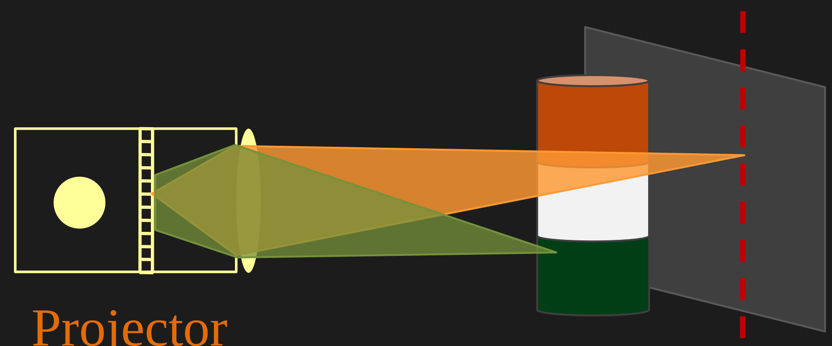
$m_{ij} \downarrow$ rapidly



$\sum \exp(-I\omega\phi_j) \sim 0$

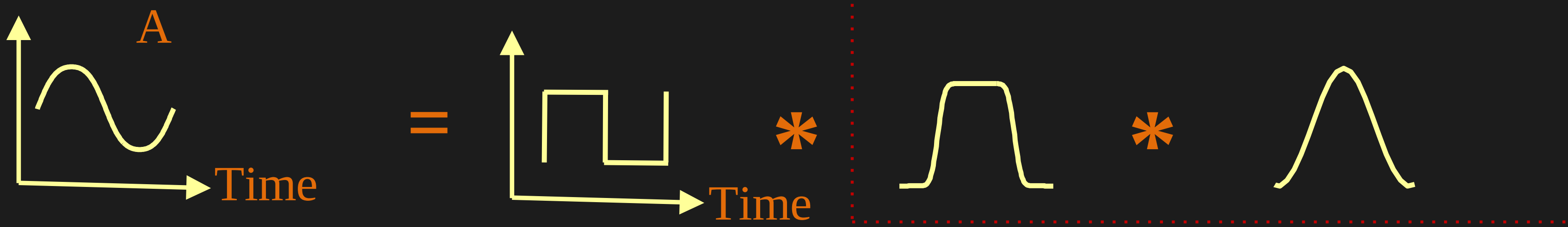
$$\frac{B_j(\omega, f)}{B_i(\omega, f)} \sim 1$$

Defocused Illumination + Global Illumination

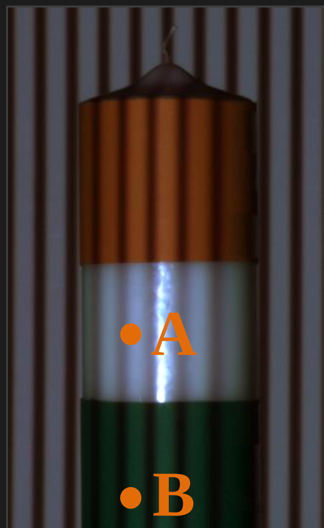


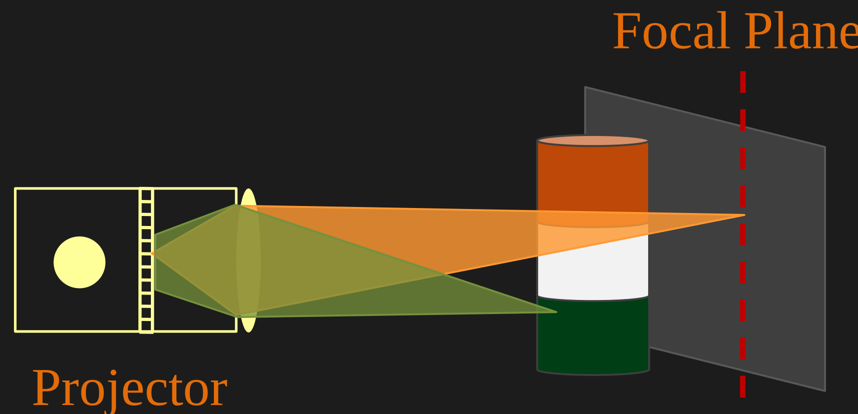
Combined Blur Kernel

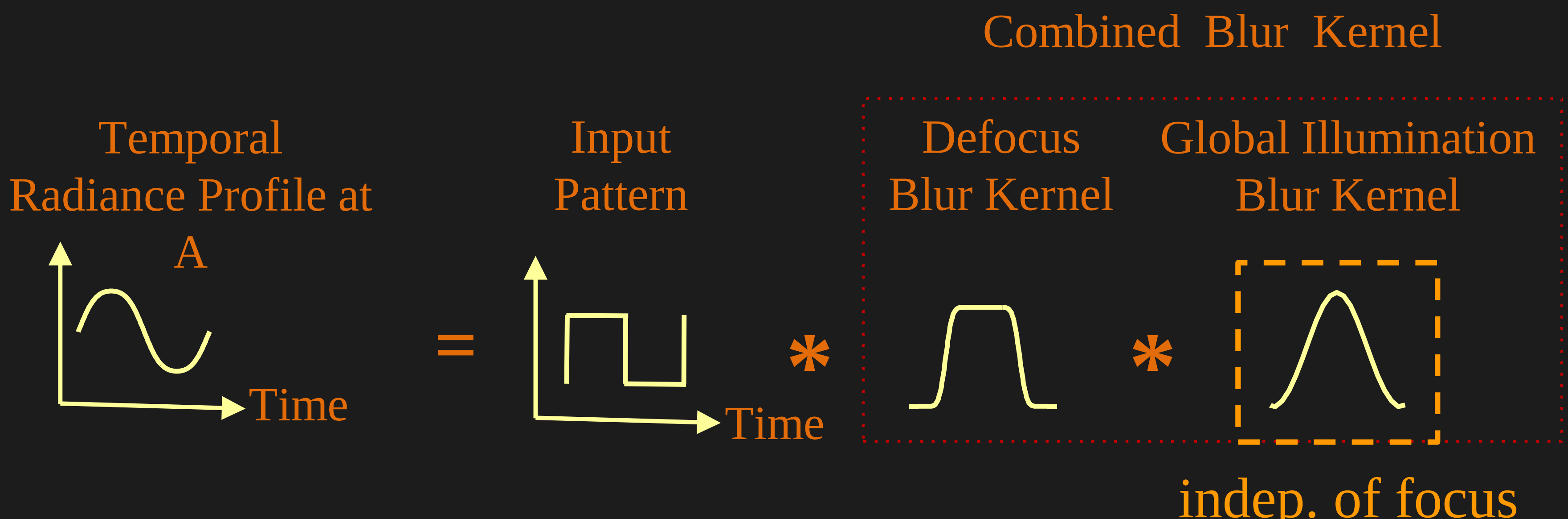
Temporal Radiance Profile at A | Input Pattern | Defocus Blur Kernel | Global Illumination Blur Kernel



Defocused Illumination + Global Illumination







Depth Recovery in the presence of Global Illumination

Depth using Multiple Focal Plane Positions

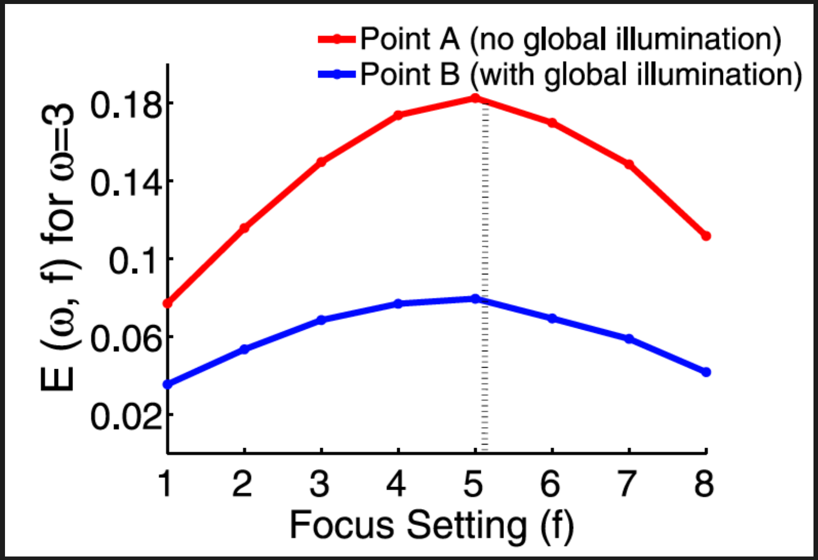
Input

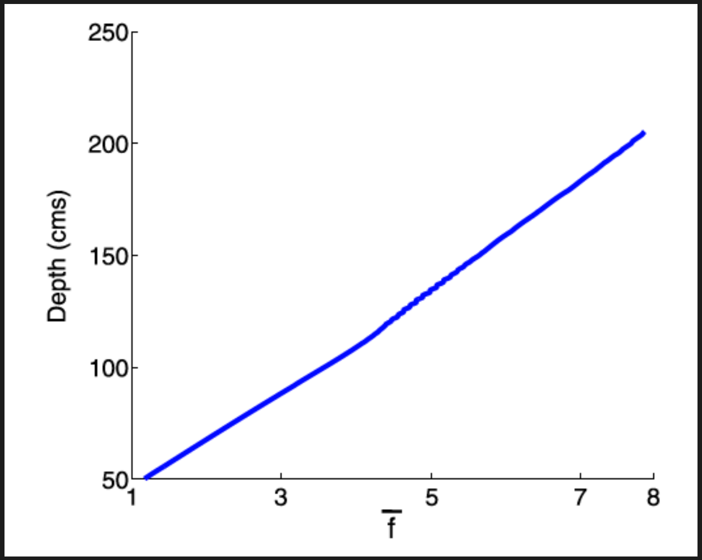
Focal Plane Position 1

Focal Plane Position 2

Focal Plane Position 3

…

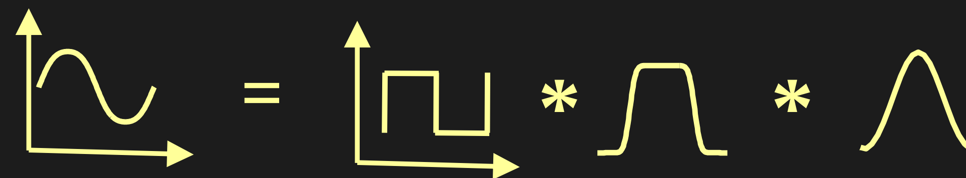




Depth using Two Focal Plane Positions

Input

Focal Plane Position 1



Focal Plane Position 2

Intensity Profile

Input Pattern

Defocus Kernel

Global illumination blur Kernel

Depth using Two Focal Plane Positions

Input

Focal Plane Position 1

Focal Plane Position 2

$$e_1(\omega) = p(\omega) \times d_1(\omega) \times g(\omega)$$

$$e_2(\omega) = p(\omega) \times d_2(\omega) \times g(\omega)$$

Ratio of DFT Coefficients:

$$\Omega = \frac{e_1}{e_2} = \frac{d_1}{d_2}$$

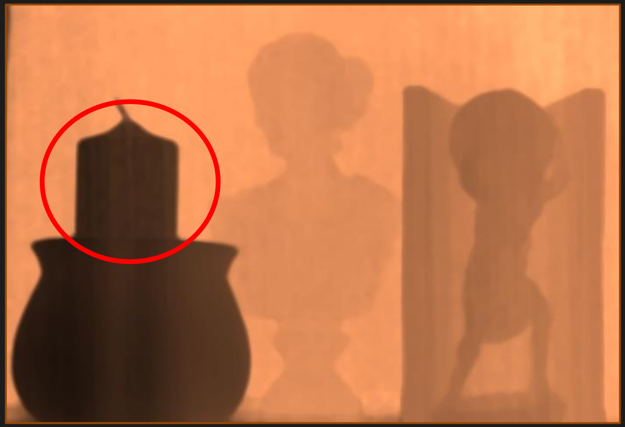
Ω is invariant to Global Illumination

Comparison

Scene

One Focal Plane [Zhang et al]

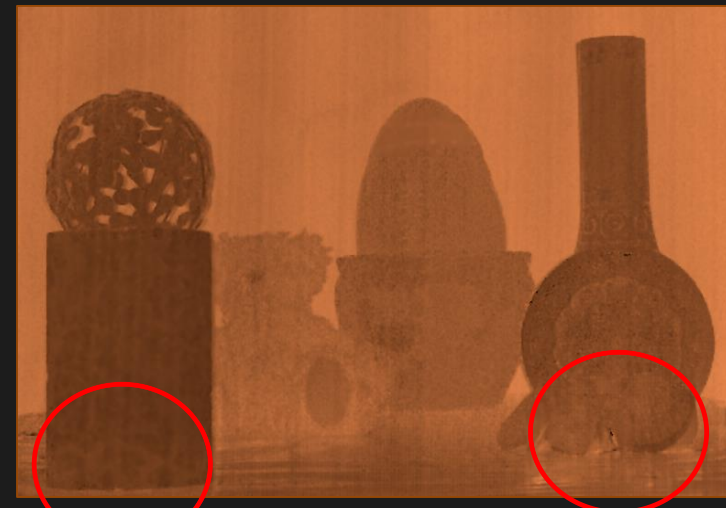
Two Focal Planes [This Paper]



Multiple Focal Planes [This Paper]

Depth Recovery

Scene



One Focal Plane [Zhang et al]

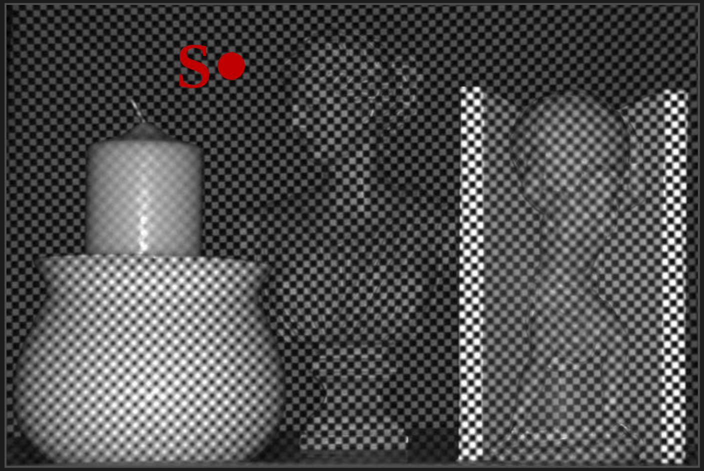
Two Focal Planes [This Paper]

Multiple Focal Planes [This Paper]

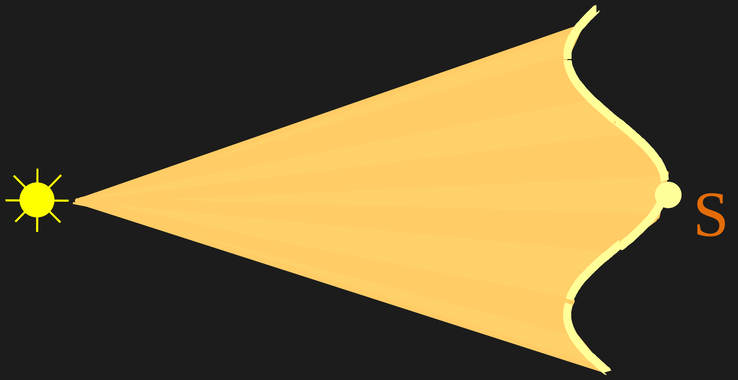
Direct-Global Separation in the presence of Projector Defocus

Separation of Direct and Global Components

[Nayar et al' 06]



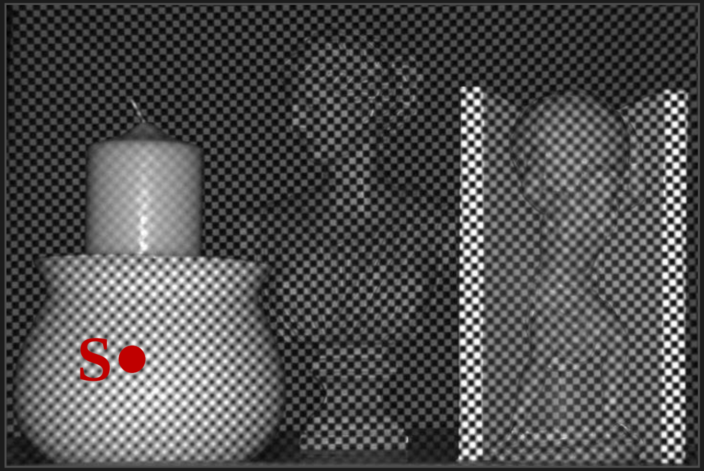
Checker-board pattern projected on the scene



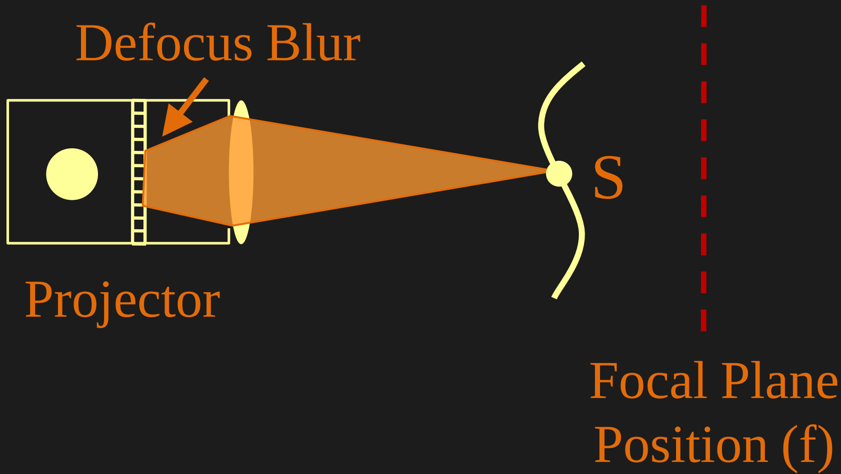
$$E_{\max} = E_{direct} + 0.5\,E_{global}$$

$$E_{\min} = 0.5\,E_{global}$$

How does Defocus affect Direct-Global Separation?



Checker-board pattern
projected on the scene



Defocus blur
considered.

$$E_{\max} = E_{direct} + 0.5\,E_{global}$$

$$E_{\max}^{f} = \alpha_{\max}^{f}\,E_{direct} + 0.5\,E_{global}$$

$$E_{\min} = 0.5\,E_{global}$$

$$E_{\min}^{f} = \alpha_{\min}^{f}\,E_{direct} + 0.5\,E_{global}$$

How does Defocus affect Direct-Global Separation?

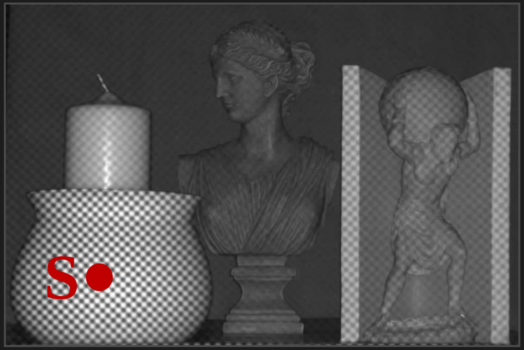
Direct Component

Global Component

Focal plane moving from the front to the back

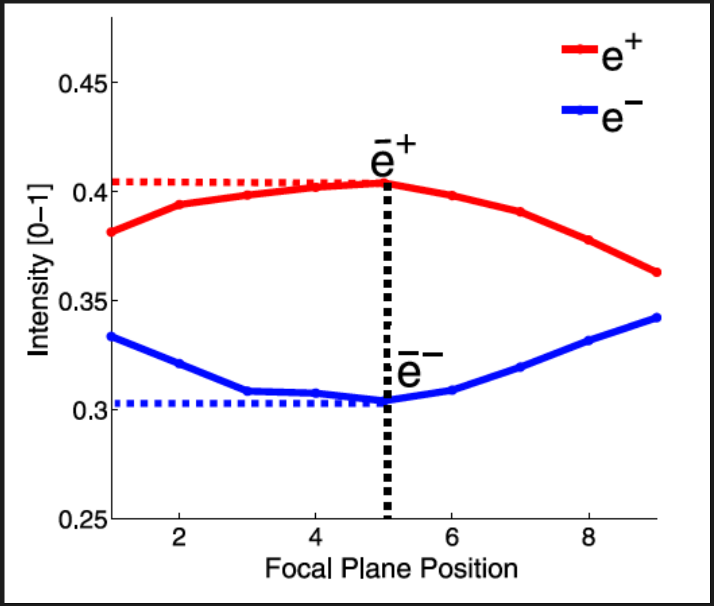
Separation using Multiple Focal Plane

Input



Max Intensity: $E_{max} = \alpha_{max} E_{direct} + 0.5 E_{global}$

Min Intensity: $E_{min} = \alpha_{min} E_{direct} + 0.5 E_{global}$

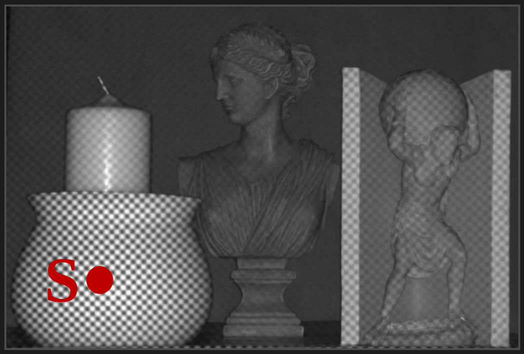


$$E_{max} = E_{direct} + 0.5 E_{global}$$

$$E_{min} = 0.5 E_{global}$$

Separation using One Focal Plane + Depth map

Input



Max Intensity: $E_{\max} = \alpha_{\max} E_{direct} + 0.5 E_{global}$

Min Intensity: $E_{\min} = \alpha_{\min} E_{direct} + 0.5 E_{global}$

Depth Map

Direct Component: $$E_{direct} = \frac{E_{\max} - E_{\min}}{\alpha_{\max} - \alpha_{\min}}$$

Global Component: $$E_{global} = E_{total} - E_{direct}$$

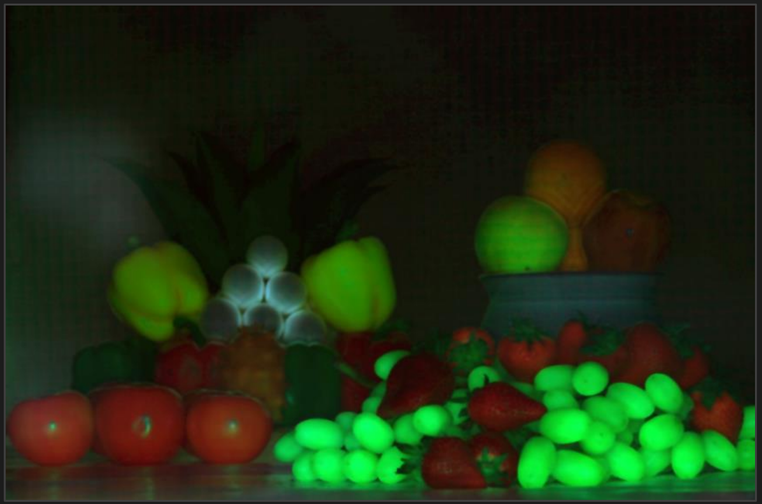
Separation using a Single Focal Plane + Depth Map

Direct Component

Global Component

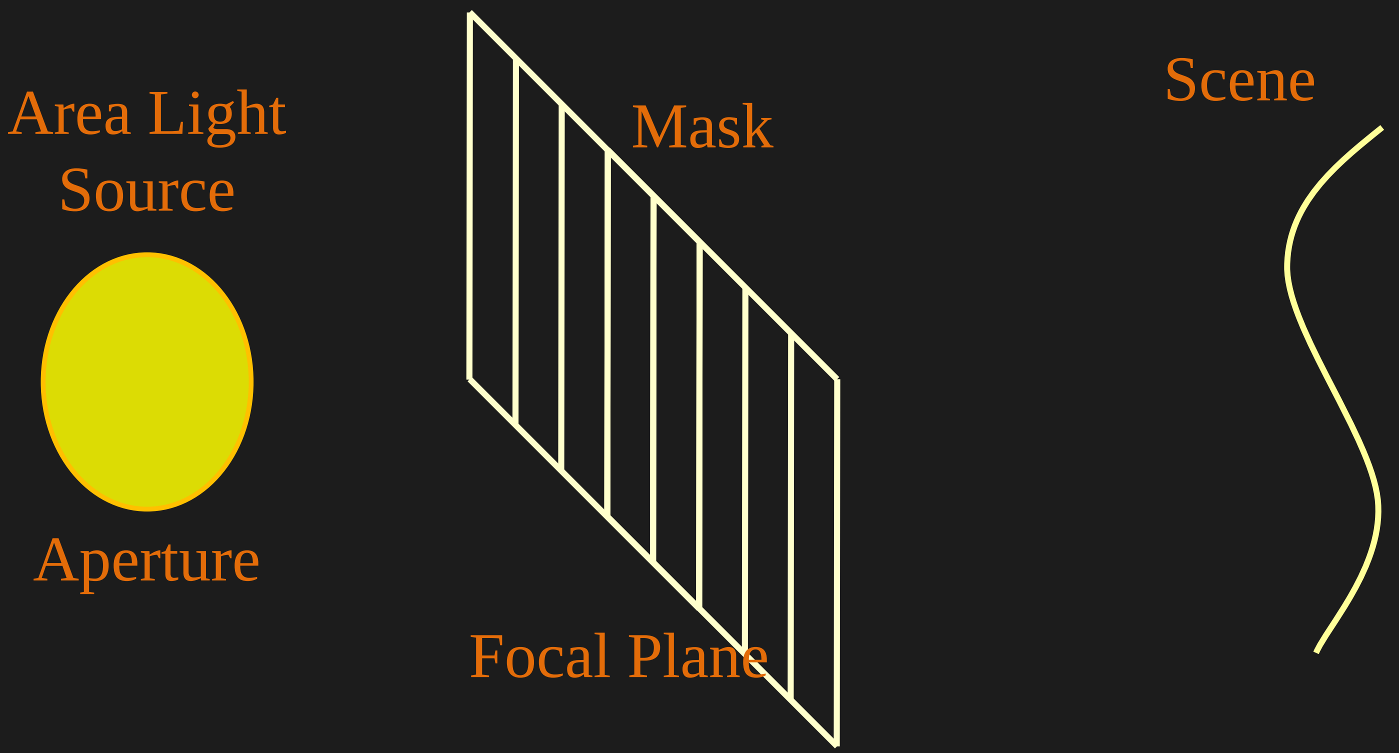
Separation using a Single Focal Plane + Depth Map

Direct Component



Global Component

Illumination Defocus using an area light source



Sun for Outdoor Scene Recovery

Thoughts

- Score: 1.5
- Good:
  - Solve the practical defocus issue
  - Propose practical algorithms for scene depth estimation and global/direct light separation.
- Bad:
  - Does not discuss how to select the width of the illumination (freq too high it will be blurred, too low violates its assumption and increases acquisition time)