KU LEUVEN

Ministerie van Infrastructuur en Waterstaat

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Development of a new Road Lighting Concept

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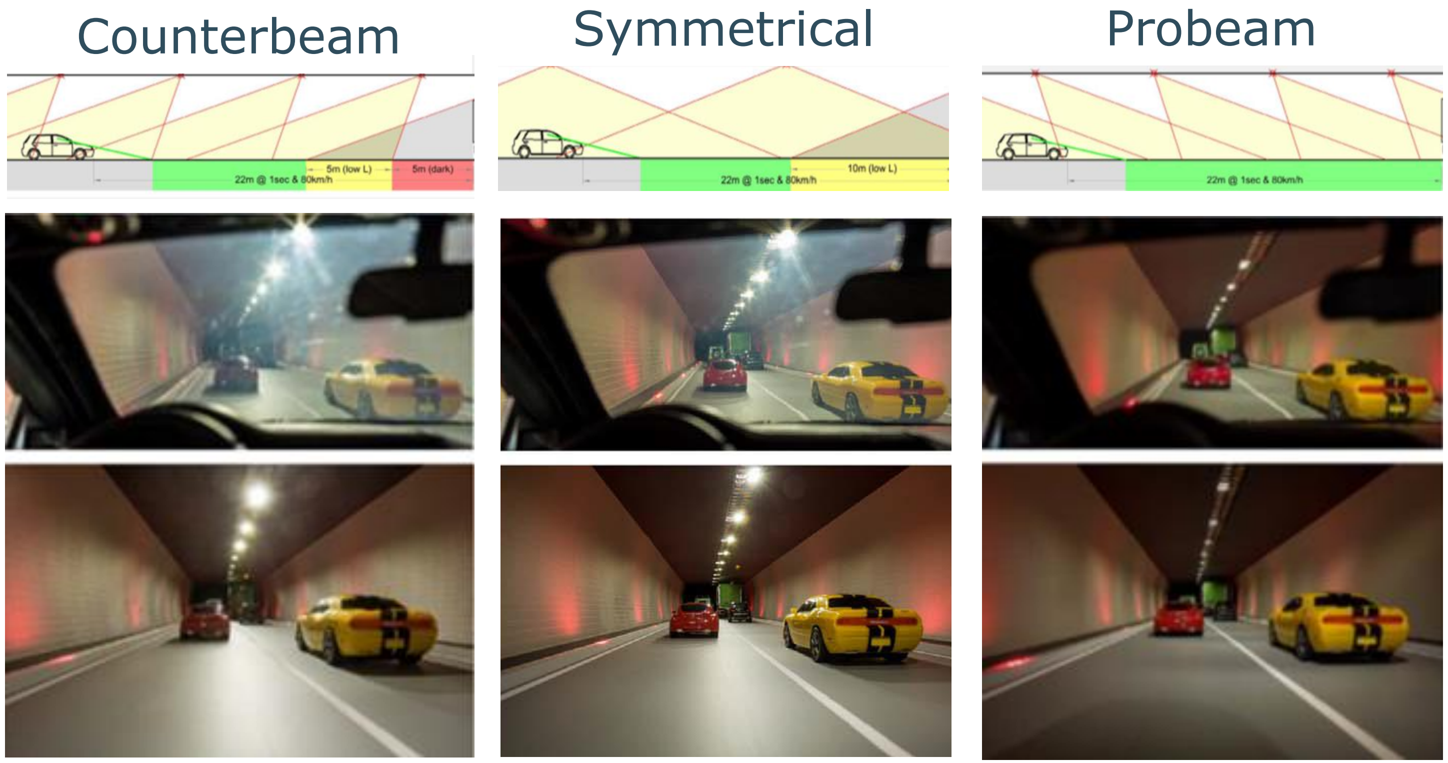
Why develop a new road lighting concept?

- Project issued by *Rijkswaterstaat*
- Technological advancements in road lighting and road markings
  - Road lighting
    - Transition to LEDs
    - Dimming
    - Beam Control

Natrium LEDs

Why develop a new road lighting concept?

- Technological advancements in road lighting and road markings
  - Road lighting
    - Asymmetrical lighting proves useful in tunnel lighting research
    - Gap in research about asymmetrical lighting in road lighting



Source: Renzler, M., Reithmaier, N., Reinhardt, R., Pohl, W., & Ußmüller, T. (2018). A road tunnel model for the systematic study of lighting situations. Tunnelling and underground space technology, 72, 114-119.

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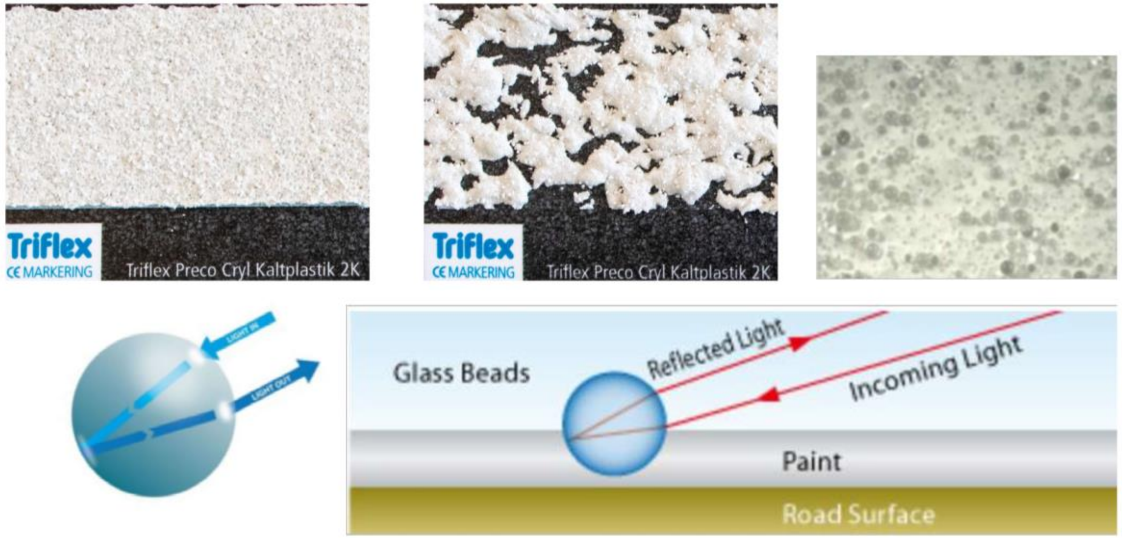
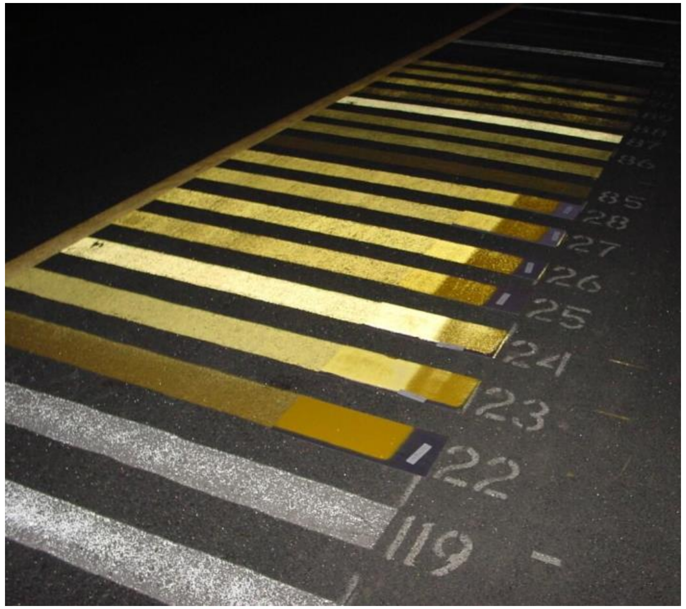
Why develop a new road lighting concept?

- Technological advancements in road lighting and road markings
  - Road markings
    - New road markings with embedded glass beads allow for a better (retro)reflection
    - Mostly optimized for headlights, but gap in research about the optimization for road lighting

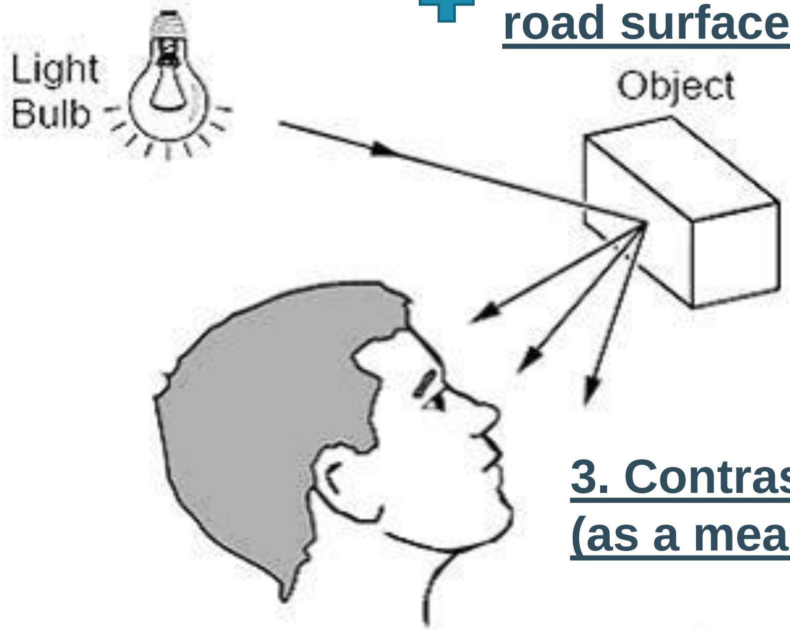




How to develop a new road lighting concept?

- 3 topics are key to realize a new road lighting concept:

1. Light intensity distribution (LID) of light source + **2. Reflection characteristics (BRDF) of road surface and road marking** ⇨ *Rendering of a scene in a physical based renderer*



3. Contrast Perception (as a measure for the visual guidance/road safety)

Subdivision of main topics:

1. LID
2. BRDF
3. Perception
4. (Rendering)

Car:

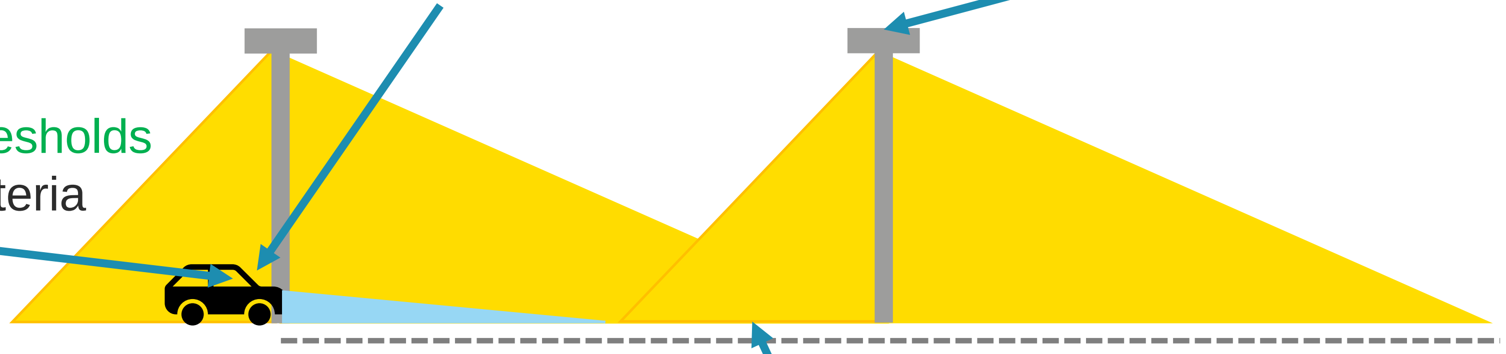
- Windshield
  - Scattering
  - Cut-off angle
- Dashboard luminance
- Headlights
  - LID
  - Disability/discomfort glare

Luminaire:

- LID Optimization
- Disability/discomfort glare
- Road lighting norms and standards

Driver:

- Contrast perception
  - Adaptation
  - Glare
  - Age
  - Contrast thresholds
  - Contrast Criteria



Additional:

- Outreach and normalization
- Proof of concept
- Spectral radiance measurements
- Luminance measurements
- Road lighting measurements of norms and standards
- Setting up experiments
- Executing experiments
- Analyzing data
- Statistics and data modelling

Rendering:

- Physical based rendering
- Typical highway rendering
- LID to UV mapping
- Importing BRDF models

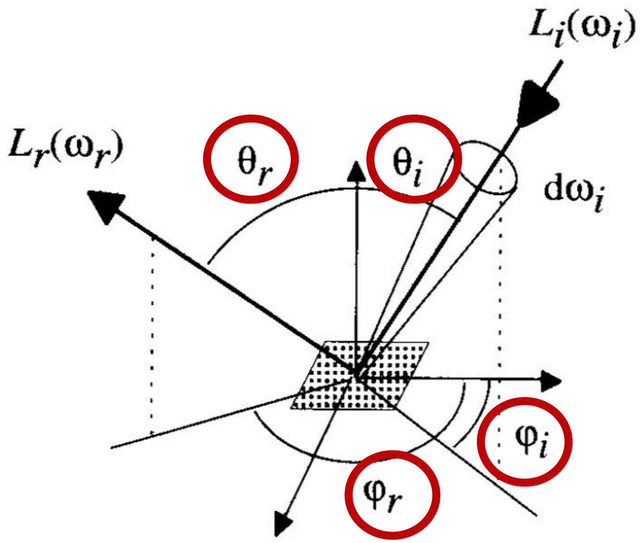
Road:

- Road Markings
  - BRDF Measurements
  - BRDF Modelling
  - BRDF Optimization
- Road Surface
  - BRDF Measurements
  - BRDF Modelling

a) BRDF

- Bidirectional Reflectance Distribution Function (BRDF)
  - The surface property that reflected radiance is proportional to the incident radiance as a function of position and direction
    - BRDF term (sr^{-1})
      - $f_r(\theta_i, \varphi_i, \theta_{r,o}, \varphi_{r,o})$
    - Differential of the reflected radiance ($W \cdot m^{-2} \cdot sr^{-1}$)
      - $dL_r(\theta_{r,o}, \varphi_{r,o})$
    - Differential of irradiance ($\frac{W}{m^2}$)
      - $dE(\theta_i, \varphi_i)$

$$f_r(\theta_i, \varphi_i, \theta_{r,o}, \varphi_{r,o}) = \frac{dL_r(\theta_{r,o}, \varphi_{r,o})}{dE(\theta_i, \varphi_i)} = \frac{dL_r(\theta_{r,o}, \varphi_{r,o})}{L_i(\theta_i, \varphi_i) \cos\theta_i \, d\omega_i}$$

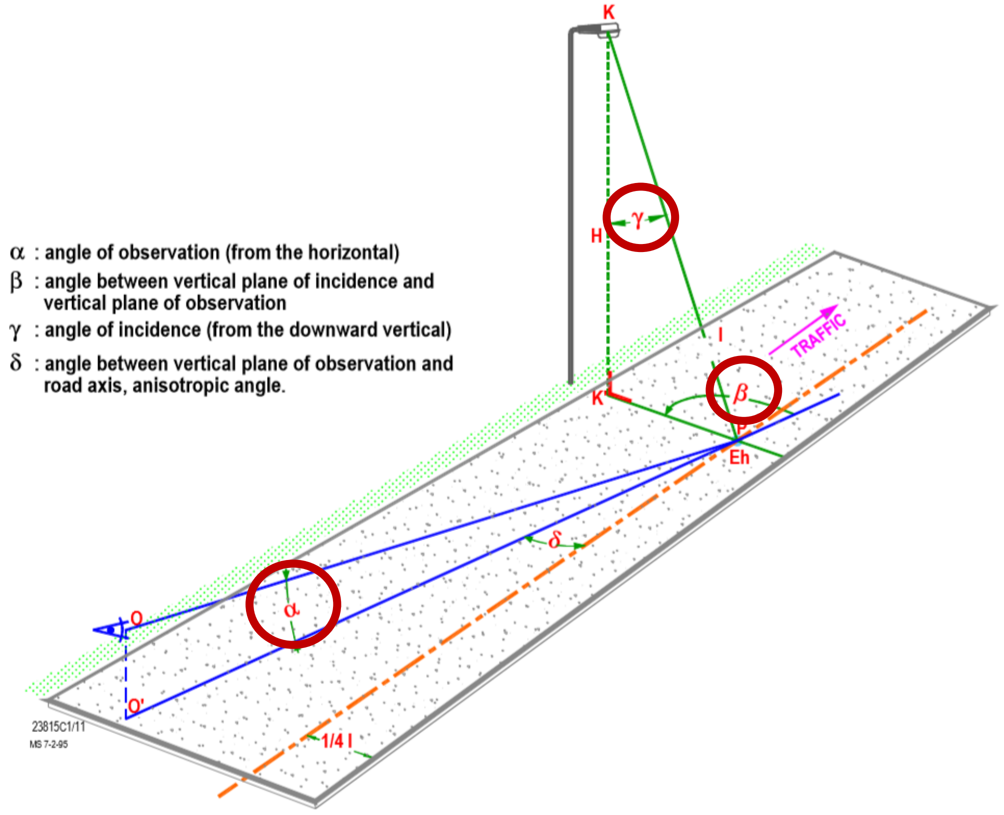


Source: chapter 9 of "Physically Based Rendering" by Pharr&Humphreys

a) BRDF: Road Surface

- CIE 114:2001 Road surface and road marking reflection characteristics
  - The R-Table

β (º) / tanγ	0	2	5	10	15	20	25	30	35	40	45	60	75	90	105	120	135	150	165	180
0.00	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
0.25	4657	4657	4585	4585	4528	4457	4400	4400	4328	4257	4200	4000	3871	3742	3685	3614	3557	3485	3428	3428
0.50	4914	4914	4842	4842	4657	4528	4400	4257	4128	3942	3742	3357	3100	2914	2842	2842	2842	2842	2771	2771
0.75	5100	5042	5042	4842	4585	4328	4071	3814	3485	3171	2914	2514	2257	2128	2128	2128	2071	1942	1942	2000
1.00	5171	5171	5028	4657	3942	3557	3228	2914	2585	2257	2000	1685	1485	1428	1428	1428	1428	1428	1428	1428
1.25	5100	5100	4971	4257	3485	2971	2514	2200	1942	1685	1485	1185	1042	1000	1014	1057	1100	1100	1100	1114
1.50	5042	4971	4657	3814	3100	2514	2071	1671	1428	1228	1114	1029	857	814	828	857	857	857	871	885
1.75	4842	4785	4328	3300	2457	1814	1485	1271	1128	1000	885	728	642	628	642	657	642	642	657	671
2.00	4657	4585	4000	2714	1942	1428	1171	1014	885	771	685	557	485	485	485	500	514	514	528	542
2.50	4128	4000	3171	1814	1228	928	771	628	542	485	357	328	314	328	342	342	342	342	342	357
3.00	3614	3357	2328	1214	757	542	442	357	328	285	257	214	214	200	214	214	228	228	242	242
3.50	3100	2771	1742	857	500	357	314	271	228	214	185	142	128	128	142	157	157	171	171	185
4.00	2714	2328	1285	614	371	285	228	200	171	142	128	100	100	100	114	114	128	128	128	142
4.50	2328	1942	1042	442	285	214	171	142	128	114	114	71	71	71	71	85	100	114	114	128
5.00	2071	1557	857	342	228	171	128	114	114	100	85	57	48	42	57	57	71	100	100	100
5.50	1814	1342	671	257	200	142	114	100	85	85										
6.00	1614	1100	514	214	157	128	114	100	71											
6.50	1485	971	428	157	114	85	71	57												
7.00	1357	857	342	128	100	71	57	42												
7.50	1242	757	300	100	71	57	57													
8.00	1185	671	242	85	57	57	42													
8.50	1114	600	214	71	57	42	42													
9.00	1042	542	171	57	42	28														
9.50	985	485	142	57	57	28														
10.00	928	457	128	42	28	28														
10.50	885	414	114	42	28	28														
11.00	842	371	100	42	28	28														
11.50	800	342	85	28	28															
12.00	757	314	85	28	28															

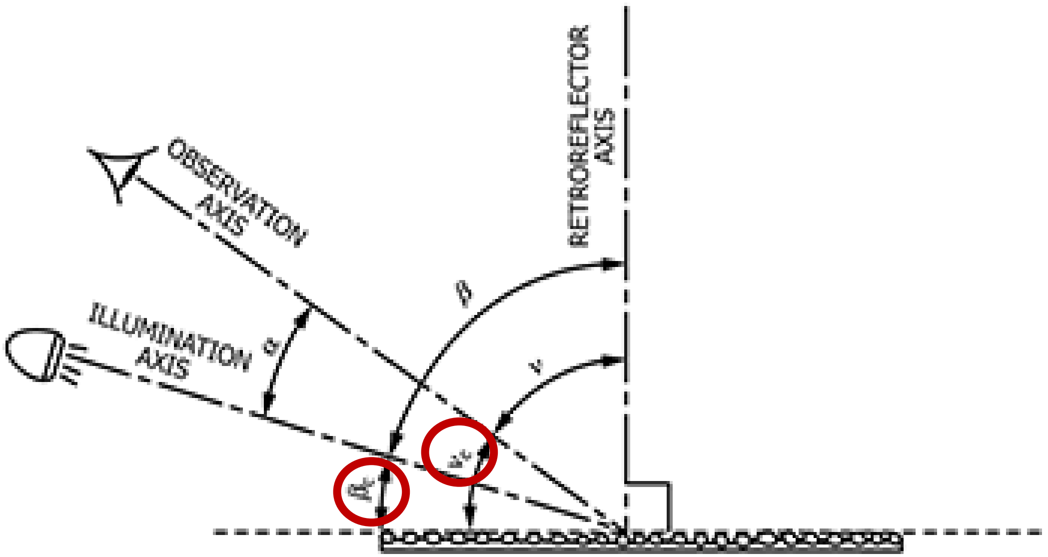


Source: Schreder

a) BRDF: Road Markings

- NEN-EN 1436
  - Standardization Road markings
    - βc = 1.24°
    - Vc = 2.29°
    - α = 1.05°

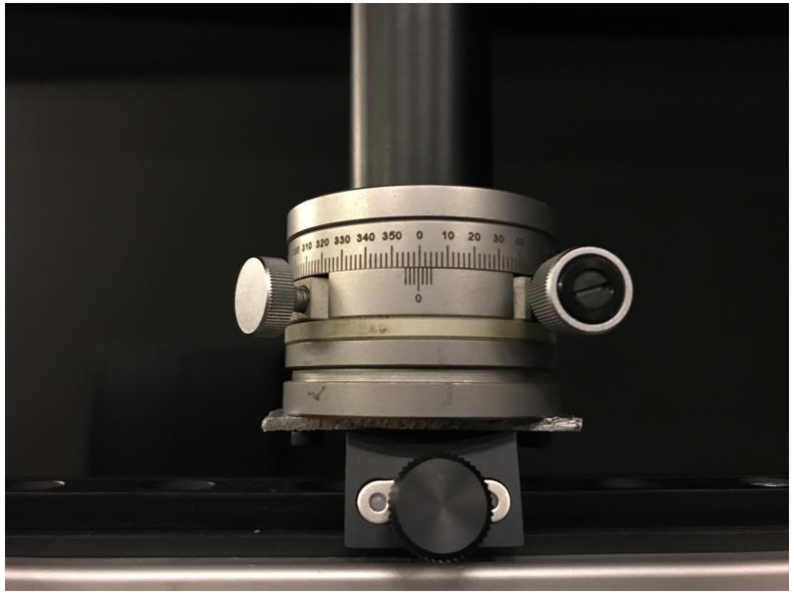
    - Night time visibility coefficient
      - R1 $(\frac{mcd}{\frac{m^2}{lx}})$
    - Day time visibility coefficient
      - Qd $(\frac{mcd}{\frac{m^2}{lx}})$



Source: ASTM D4061-13(2018)
https://www.techstreet.com/standards/astm-d4061-13-2018?product_id=2025492

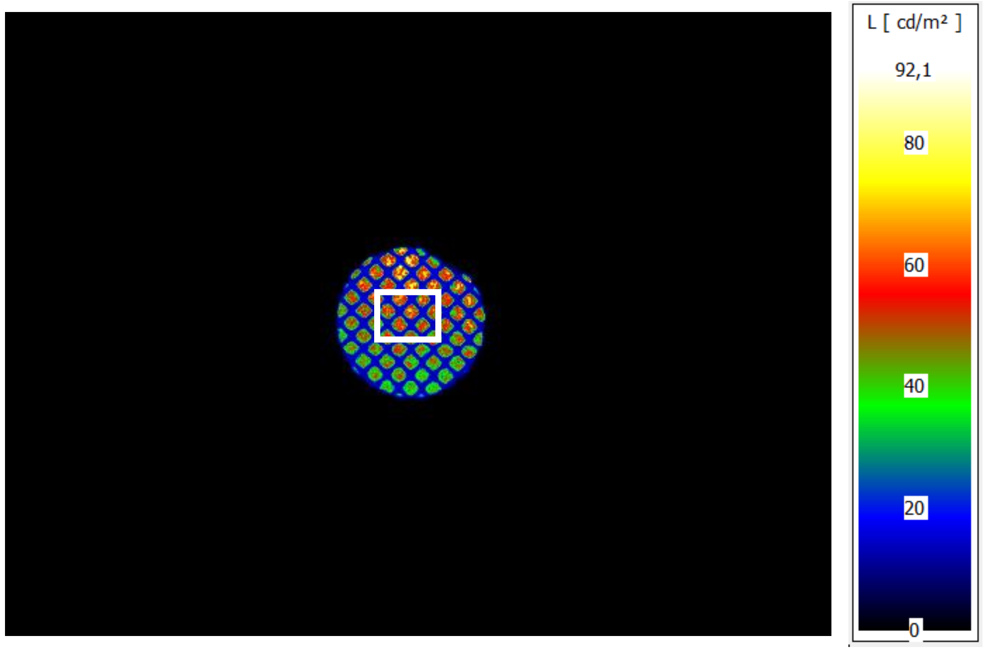
a) BRDF: Measurements

- Measuring a BRDF
  - Experimental setup
    - Large Near Field Goniometer
      - Overexposure of light



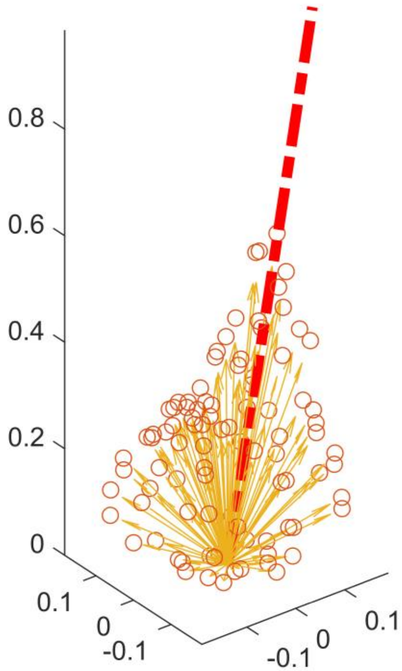
a) BRDF: Measurements

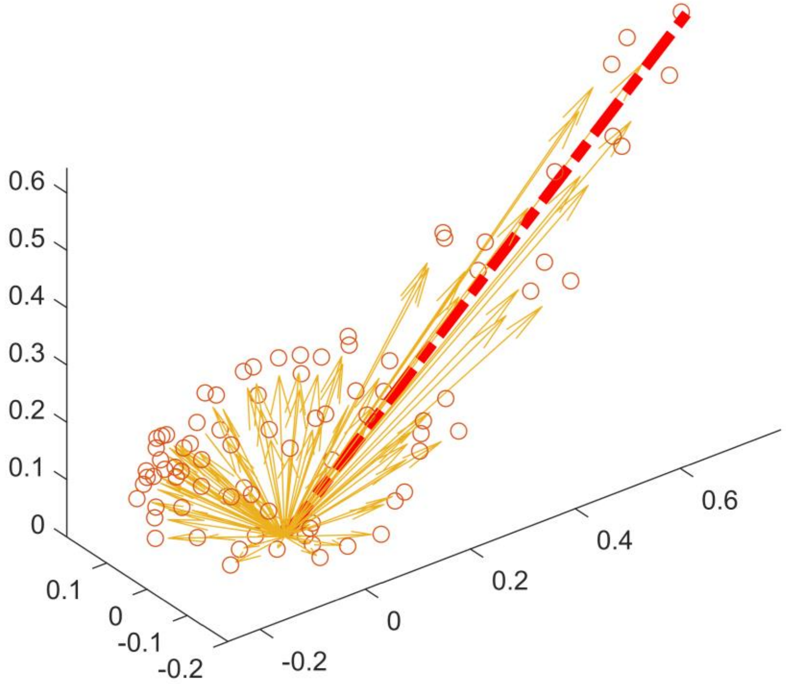
- Measuring a BRDF
  - Determine BRDF
    - HDR Luminance images
      - Method:
        - Take average over small group of middle pixels
    - Measure illuminance at $\theta_i = 0 \ \& \ \varphi_i = 0$
    - $f_r(\omega_i, \omega_o) = \frac{dL_o(\theta_o, \varphi_o)}{dE(\theta_{i=0}, \varphi_{i=0})\cos(\theta_i)}$



a) BRDF: Measurements

- Measuring a BRDF
  - Road Marking Sample
    - Swarco Road Marking
    - Limboplast D480
    - Megalux 0.6-1.5 KT14





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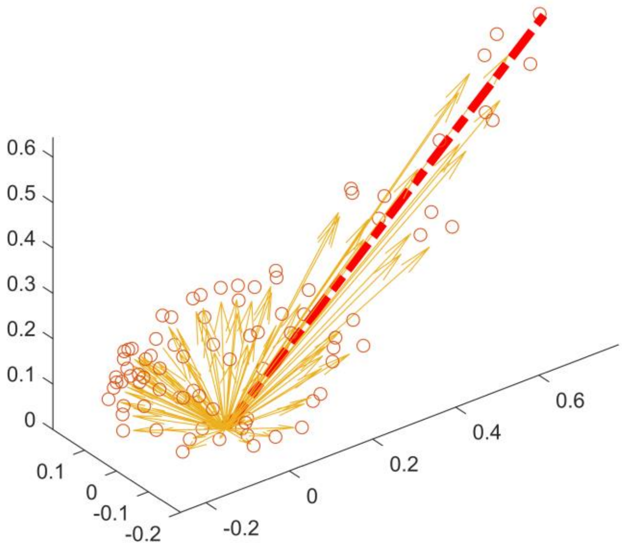
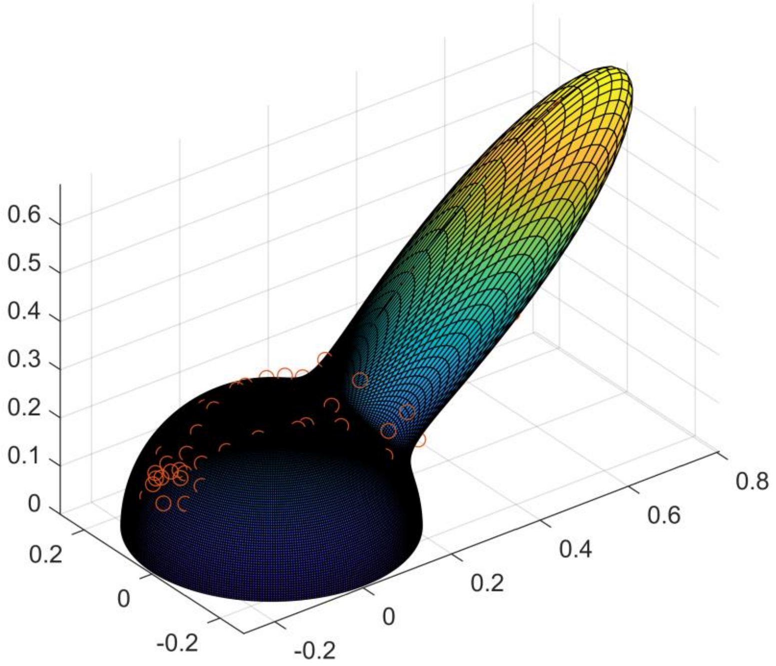
a) BRDF: Measurements

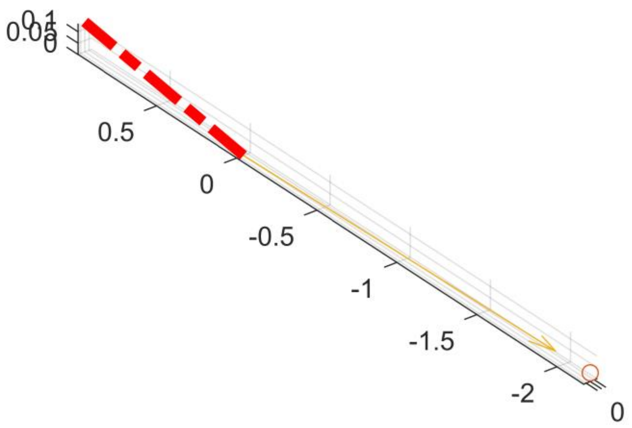
- Optimizing a BRDF to the measurements
    - Road Marking Sample

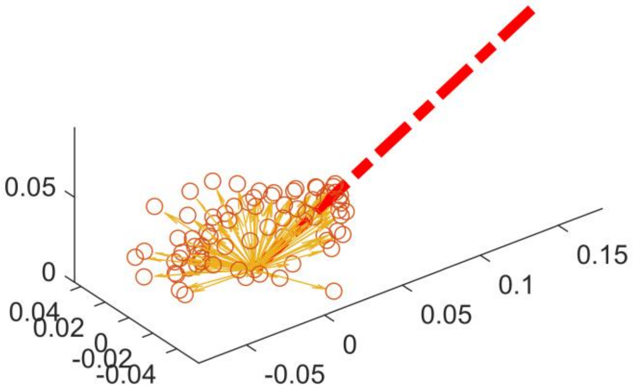




a) BRDF: Measurements

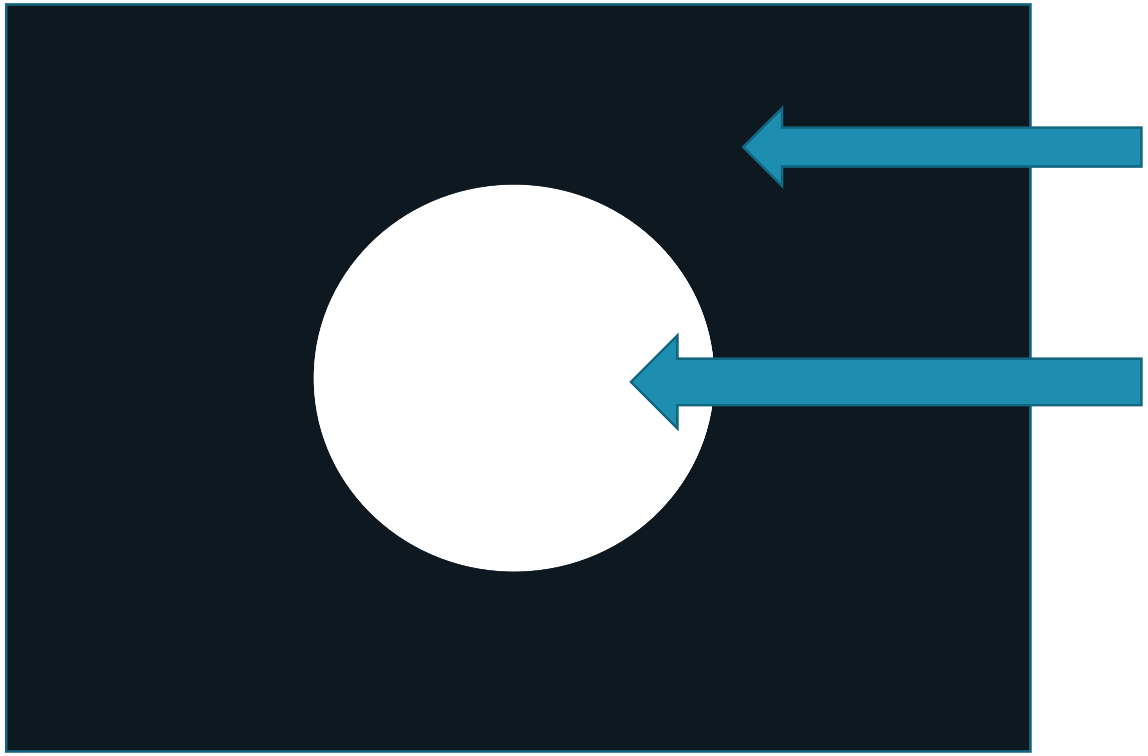
- Measuring a BRDF
  - Road Surface Sample
    - Road surface
      - R-Table 40 De Kruijter ZOAB basis





b) Contrast and Contrast Thresholds

- 1946 Blackwell ‘Contrast Thresholds of the Human Eye’

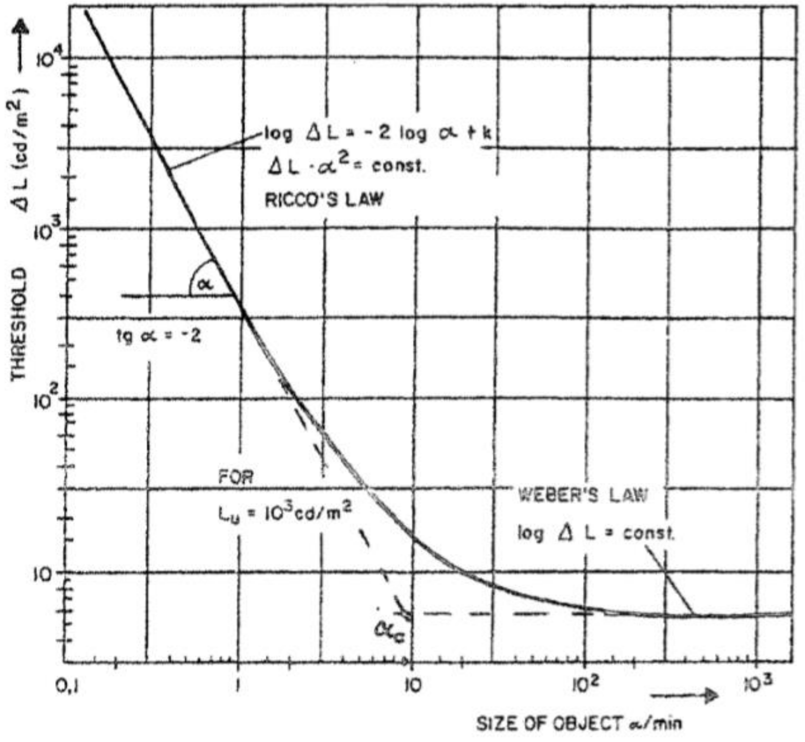


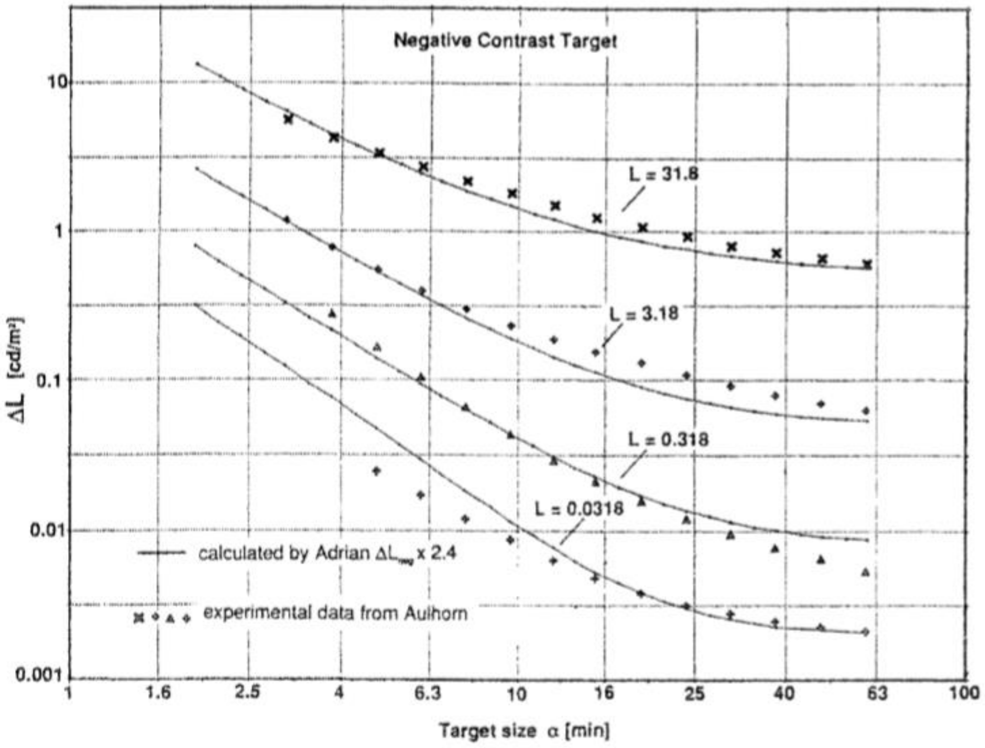
Background
- Luminance

Target
- Size
- Luminance

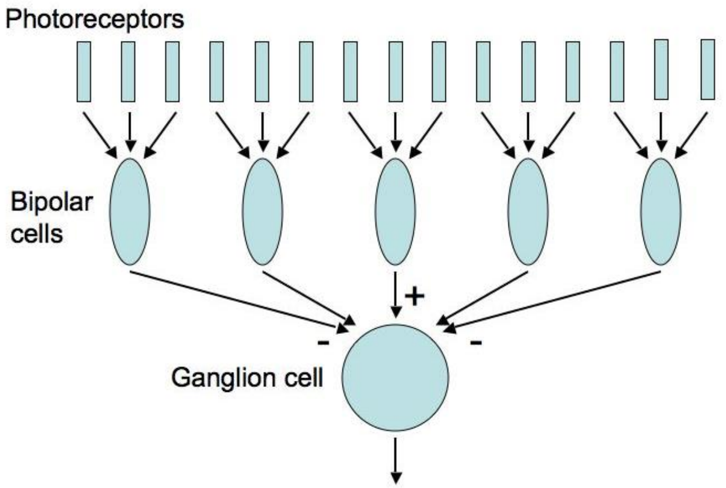
b) Contrast and Contrast Thresholds

- 1989 Adrian ‘Visibility of targets: Model for calculation’

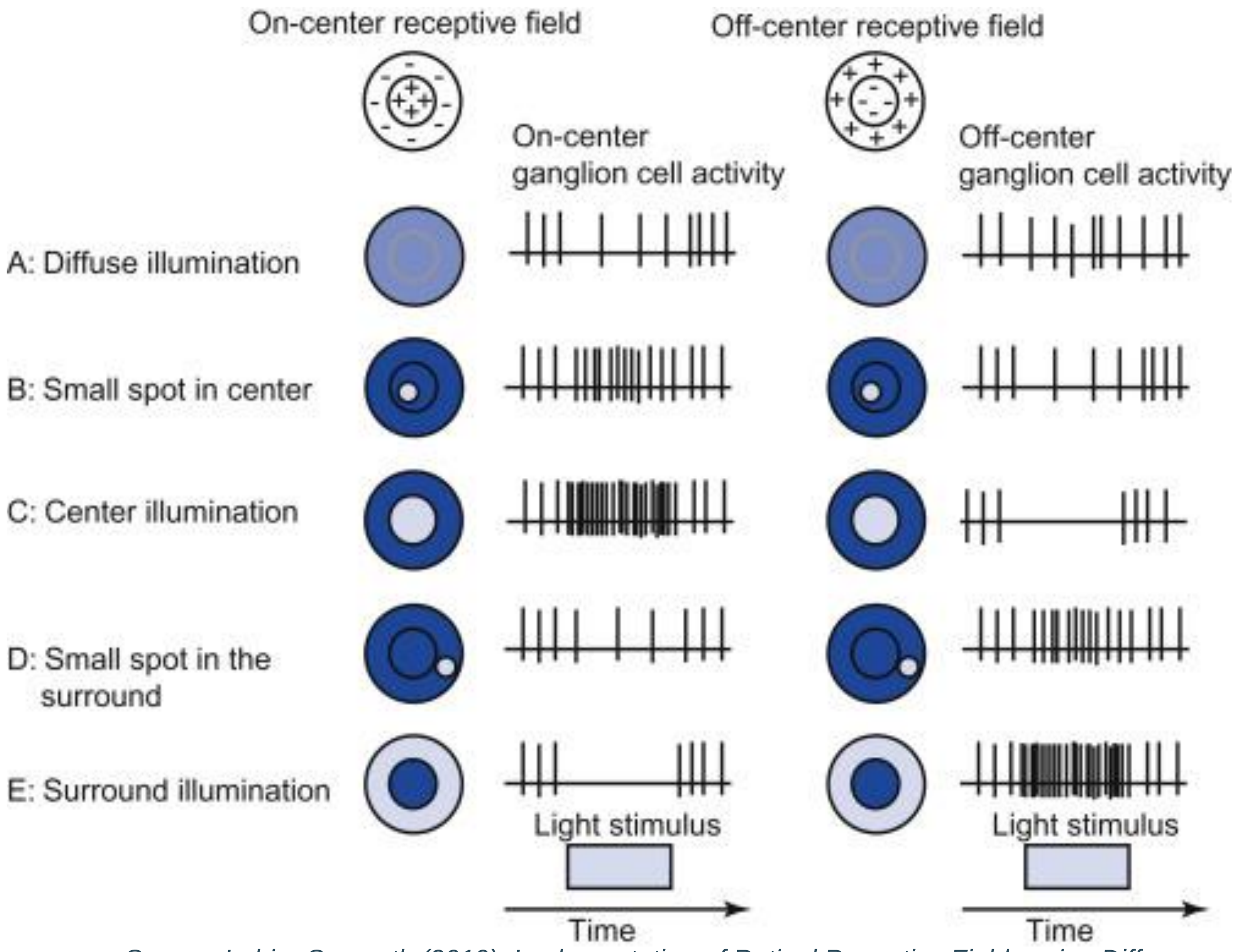




b) Contrast and Contrast Thresholds



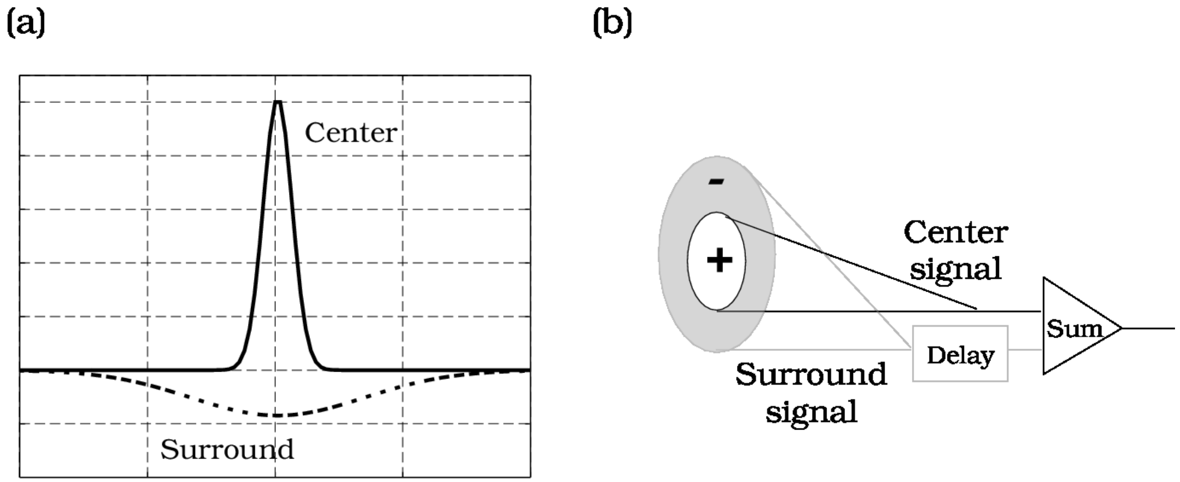
Source: *David Heeger (2006). Lecture notes, Retinal Ganglion Cells*



Source: *Lahira Sampath (2019). Implementation of Retinal Receptive Fields using Difference of Gaussian Kernel.*

b) Contrast and Contrast Thresholds

- 2000 Tadmor and Tolhurst ‘Calculating the contrasts that retinal ganglion cells and LGN neurones encounter in natural scenes’



Source: Stanford University, Chapter 5 The Retinal Representation

$$\mathrm{Centre}(\mathrm{x},\mathrm{y}) = \exp\left[-\left(\frac{x}{r_c}\right)^2 - \left(\frac{y}{r_c}\right)^2\right]$$

$$Surround(x,y) = \left(\frac{r_c}{r_s}\right)^2 exp\left[-\left(\frac{x}{r_c}\right)^2 - \left(\frac{y}{r_c}\right)^2\right]$$

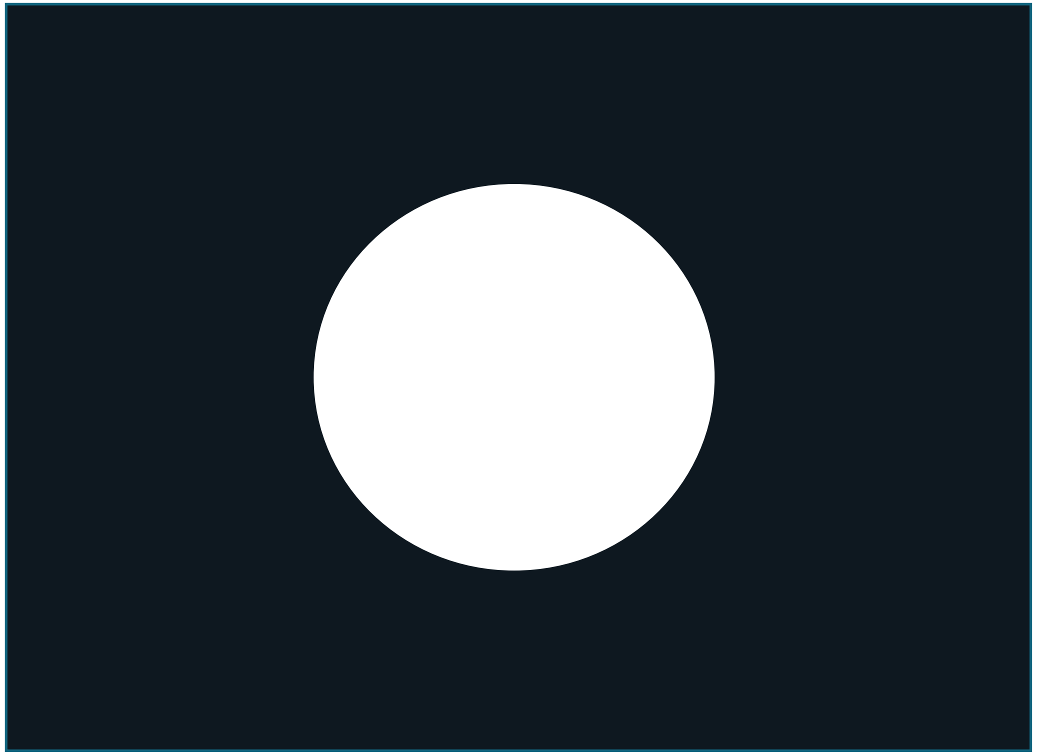
$$R_c(x,y) = \sum_{i=x-3r_c}^{x+3r_c} \sum_{j=y-3r_c}^{y+3r_c} Centre(i-x, j-y)L(i,j)$$

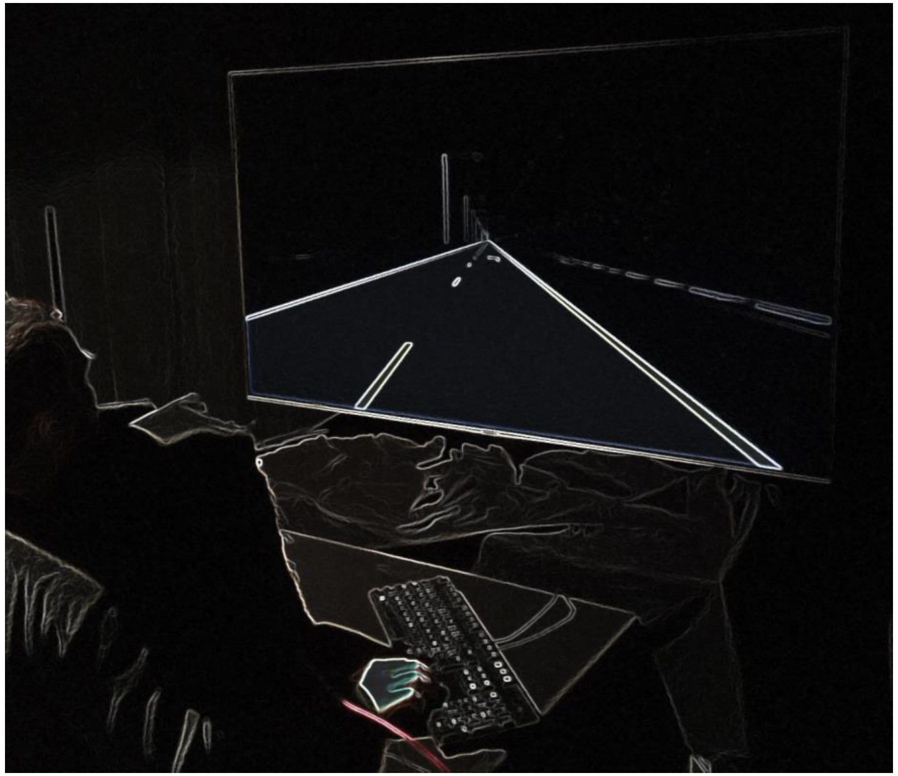
$$R_s(x,y) = \sum_{i=x-3r_s}^{x+3r_s} \sum_{j=y-3r_s}^{y+3r_s} Surround(i-x, j-y)L(i,j)$$

$$DoG(x,y) = R_c(x,y) - R_s(x,y)$$

b) Contrast and Contrast Thresholds

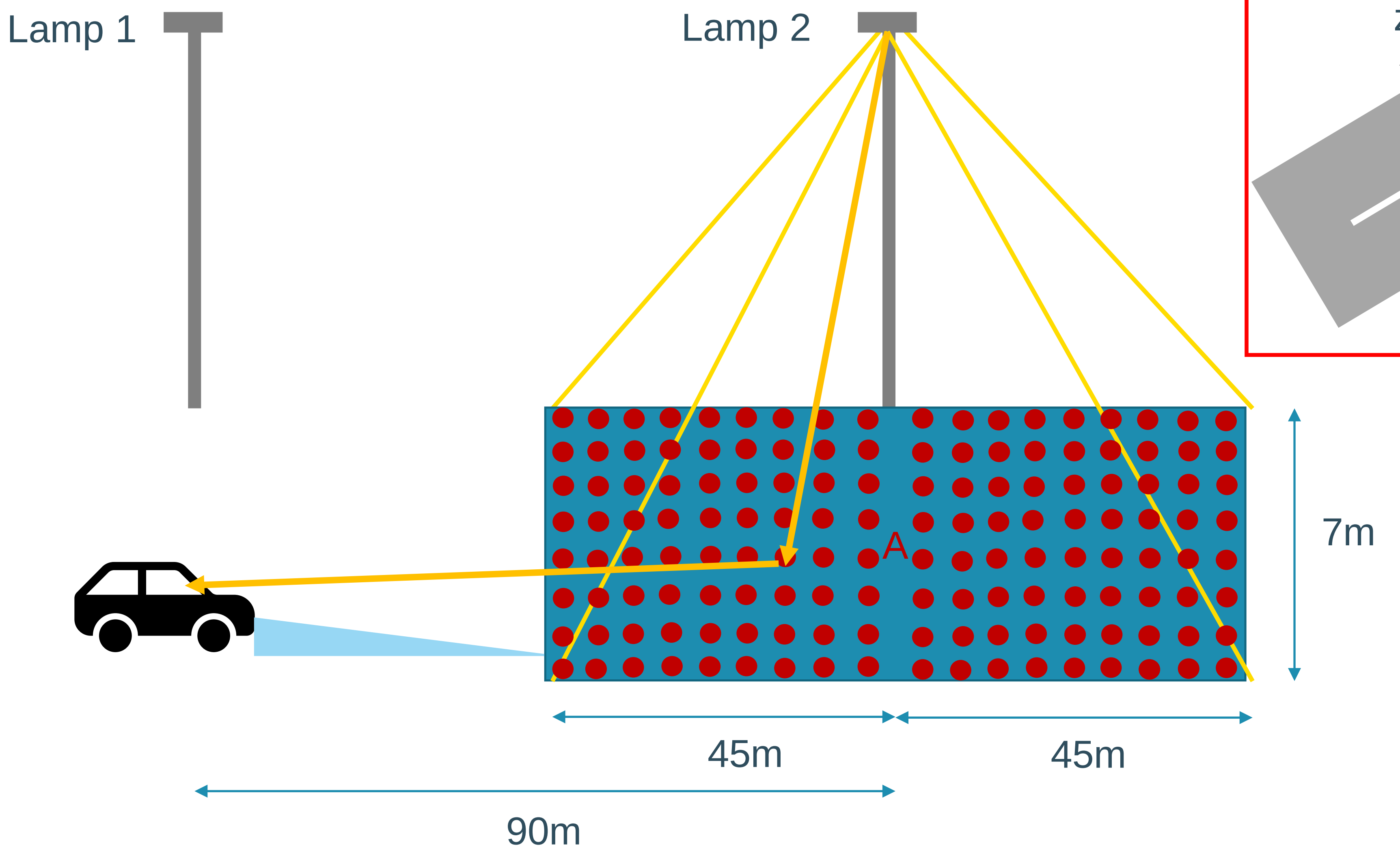
Contrast visual experiment

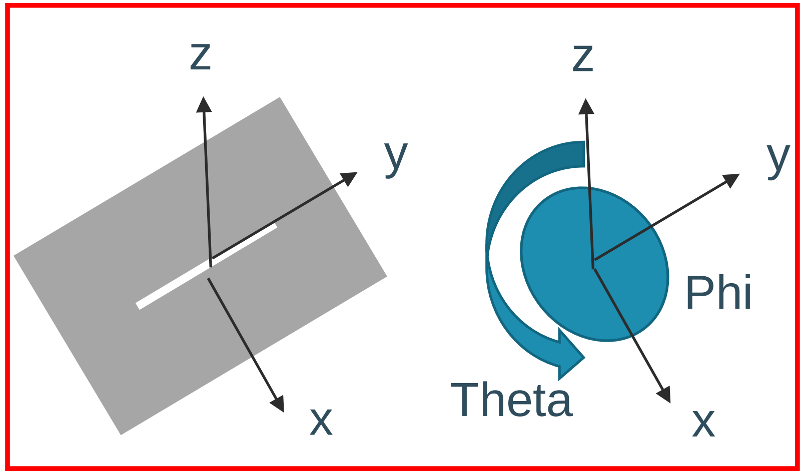




c) Determine LID

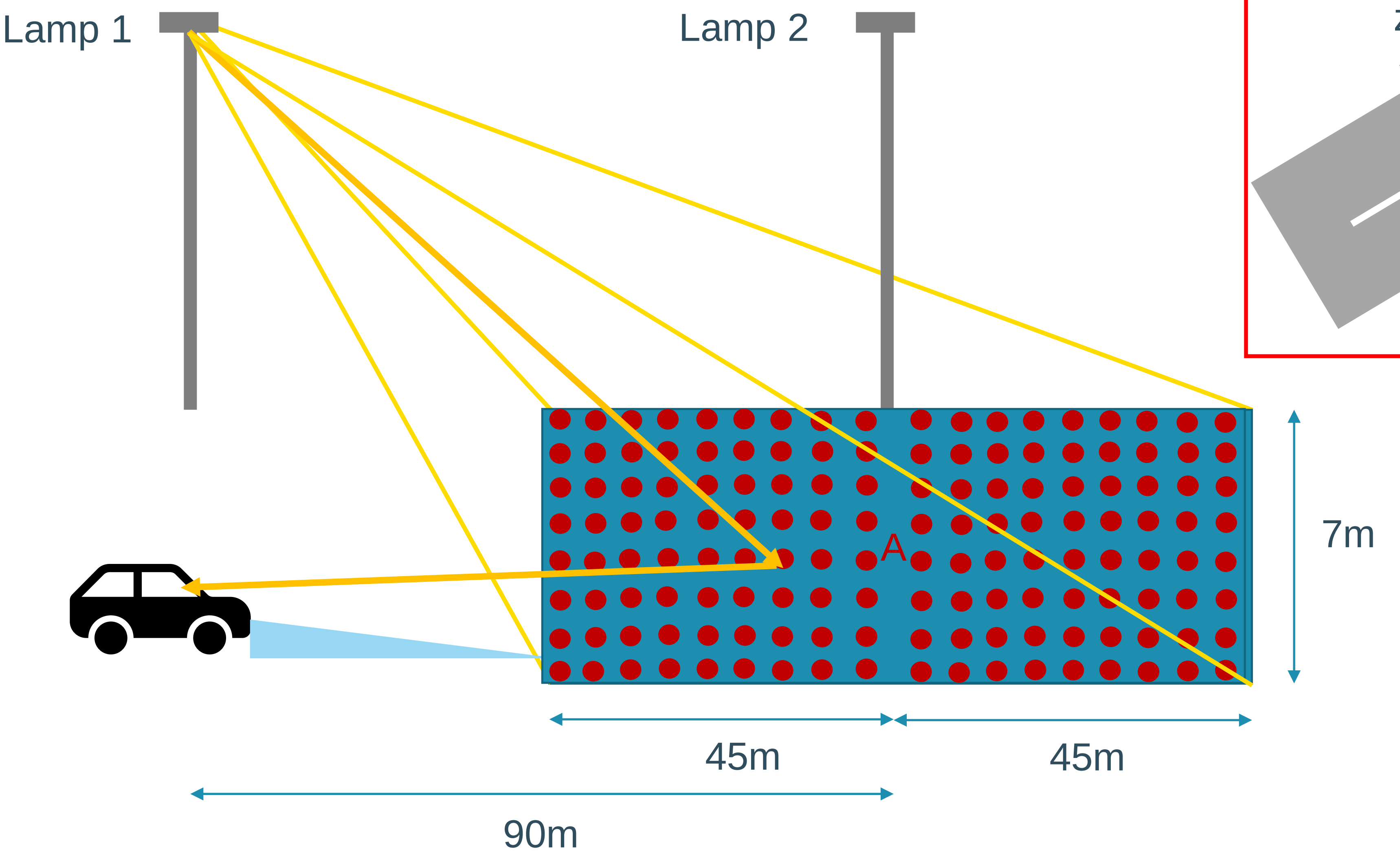
Calculate angles for each measurement point:
$\theta_{i,p}$, $\varphi_{i,p}$, $\theta_{o,p}$ & $\varphi_{o,p}$

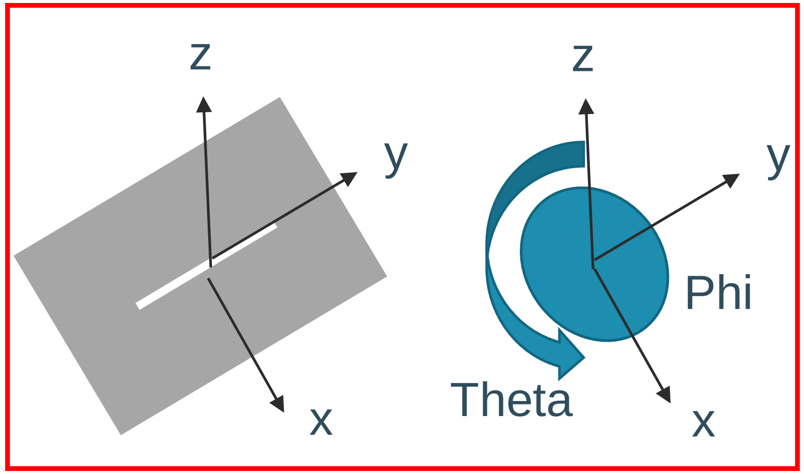




c) Determine LID

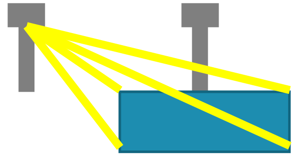
Calculate angles for each measurement point:
$\theta_{i,p}$, $\varphi_{i,p}$, $\theta_{o,p}$ & $\varphi_{o,p}$





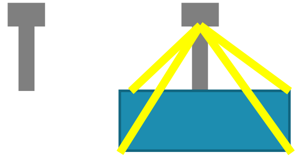
c) Determine LID

$$L_{Road} = 0.8$$



Lamp 1

L_{road}	-45	-40	-35	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40	45
0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
1	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
2	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
3	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
4	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
5	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8

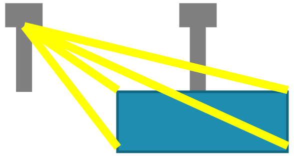


Lamp 2

L_{road}	-45	-40	-35	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40	45
0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
1	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
2	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
3	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
4	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
5	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8

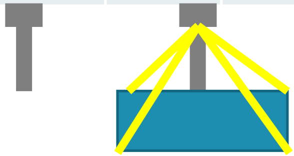
c) Determine LID

$$E_h = \frac{L_{Road}}{BRDF_{Road}(\theta_i,\varphi_i,\theta_o,\varphi_o)} = \frac{0.8}{BRDF_{Road}(\theta_i,\varphi_i,\theta_o,\varphi_o)}$$



Lamp 1

E_h	-45	-40	-35	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40	45
0	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
1	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
2	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
4	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
5	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
6	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
7	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3



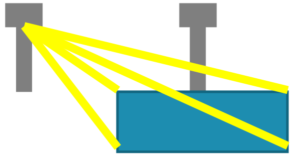
Lamp 2

E_h	-45	-40	-35	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40	45
0	4.6	5.4	6.5	8.0	9.5	10.8	11.7	12.1	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
1	4.1	5.0	6.3	7.8	9.4	10.8	11.7	12.1	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
2	3.9	4.9	6.2	7.8	9.4	10.8	11.7	12.1	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
3	3.9	4.9	6.3	7.9	9.5	10.9	11.7	12.1	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
4	4.2	5.2	6.6	8.2	9.7	11.0	11.8	12.1	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
5	4.6	5.7	7.1	8.6	10.0	11.2	11.8	12.2	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
6	5.4	6.5	7.7	9.1	10.4	11.4	11.9	12.2	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
7	6.5	7.4	8.5	9.7	10.8	11.5	12.0	12.2	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3

TU/e KU LEUVEN

c) Determine LID

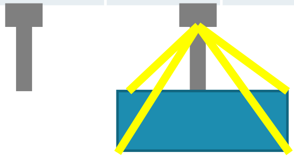
$$I = \frac{E_h D^2}{\cos(\theta_i)}$$



Φ = 12376.9

Lamp 1

I	-45	-40	-35	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40	45
0	77765	102507	132383	167900	209571	257907	313418	376617	448015	528123	617456	716523	825837	945911	1077256	1220384	1375809	1544042	1725594
1	77814	102562	132442	167964	209640	257981	313497	376701	448104	528218	617555	716627	825946	946025	1077375	1220509	1375938	1544176	1725734
2	77963	102725	132620	168157	209848	258203	313734	376953	448371	528500	617852	716939	826274	946368	1077733	1220882	1376327	1544579	1726153
3	78212	102998	132917	168478	210194	258574	314129	377373	448816	528970	618347	717460	826820	946939	1078329	1221504	1376974	1545252	1726850
4	78561	103380	133332	168928	210678	259093	314683	377962	449440	529629	619041	718189	827584	947738	1079164	1222374	1377880	1546194	1727827
5	79009	103872	133868	169507	211301	259760	315396	378719	450242	530476	619934	719127	828567	948767	1080239	1223494	1379045	1547404	1729084
6	79559	104474	134523	170216	212064	260577	316267	379645	451223	531513	621025	720274	829770	950025	1081552	1224863	1380470	1548885	1730620
7	80211	105187	135299	171055	212967	261544	317298	380741	452384	532738	622316	721630	831191	951512	1083105	1226481	1382154	1550635	1732436



Φ = 11865.4

Lamp 2

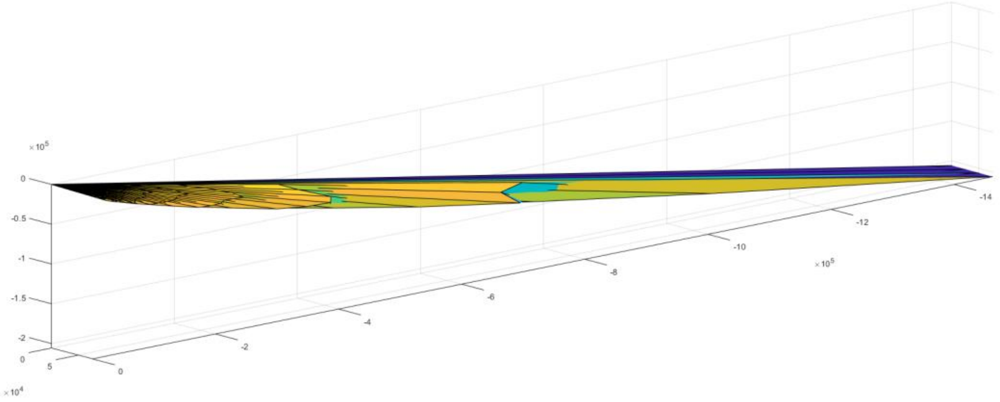
I	-45	-40	-35	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40	45
0	28849	25240	22156	18995	15463	11728	8356	5872	4438	3982	4453	5964	8787	13307	19969	29250	41642	57646	77765
1	26037	23581	21249	18571	15314	11702	8369	5892	4457	4000	4472	5985	8811	13334	20001	29286	41683	57690	77814
2	24769	22959	21022	18559	15389	11790	8445	5957	4515	4056	4530	6048	8883	13417	20095	29394	41804	57825	77963
3	24930	23351	21481	18970	15692	11992	8585	6067	4612	4149	4627	6154	9003	13555	20254	29573	42006	58050	78212
4	26549	24789	22643	19802	16216	12303	8788	6224	4750	4281	4763	6304	9173	13750	20476	29826	42289	58366	78561
5	29806	27357	24524	21038	16942	12715	9052	6428	4929	4452	4940	6499	9393	14002	20763	30151	42655	58773	79009
6	34964	31137	27106	22635	17839	13216	9375	6679	5150	4664	5160	6739	9665	14311	21116	30550	43102	59271	79559
7	42201	36099	30292	24507	18863	13790	9752	6977	5416	4920	5423	7027	9989	14680	21535	31024	43634	59862	80211

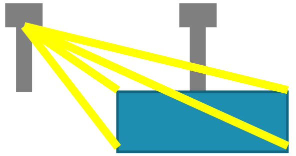
TU/e KU LEUVEN

c) Determine LID

$$I = \frac{E_h D^2}{\cos(\theta_i)}$$

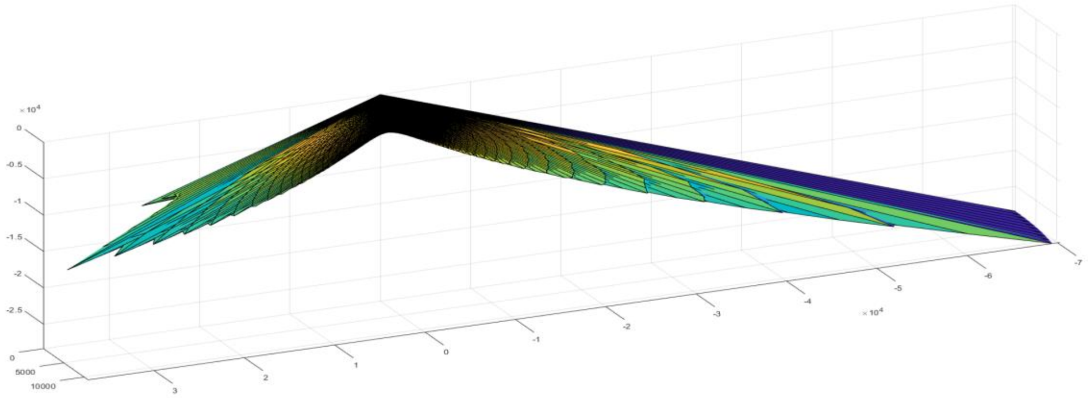
Lamp 1

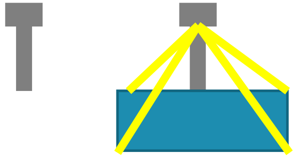




Φ = 12376.9

Lamp 2

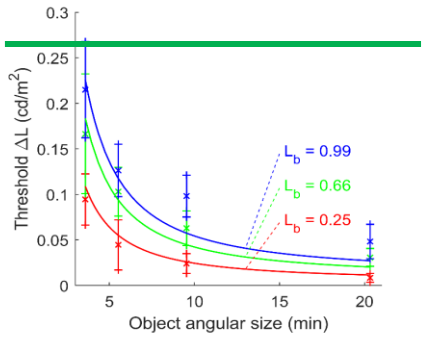


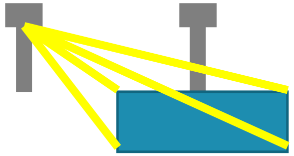


Φ = 11865.4

$$\Delta L = L_{Road\ Marking} - L_{Road} = BRDF_{RM} \times E_h - 0.8$$

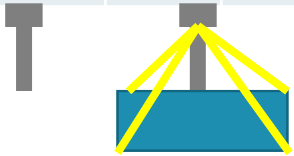
c) Determine LID





Lamp 1

ΔL	-45	-40	-35	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40	45
0	2.0	2.1	2.3	2.5	3.0	3.5	4.2	5.0	6.0	7.0	8.2	9.4	10.6	11.9	13.3	14.6	16.0	17.4	18.8
1	2.0	2.1	2.3	2.5	3.0	3.5	4.2	5.0	6.0	7.0	8.2	9.4	10.6	11.9	13.3	14.6	16.0	17.4	18.8
2	2.0	2.1	2.3	2.5	3.0	3.5	4.2	5.0	6.0	7.0	8.2	9.4	10.6	11.9	13.3	14.7	16.0	17.4	18.8
3	2.0	2.1	2.3	2.5	3.0	3.5	4.2	5.0	6.0	7.0	8.2	9.4	10.6	11.9	13.3	14.7	16.0	17.4	18.8
4	2.0	2.1	2.3	2.6	3.0	3.5	4.2	5.0	6.0	7.0	8.2	9.4	10.6	12.0	13.3	14.7	16.0	17.4	18.8
5	2.0	2.1	2.3	2.6	3.0	3.5	4.2	5.1	6.0	7.1	8.2	9.4	10.7	12.0	13.3	14.7	16.1	17.4	18.8
6	2.0	2.1	2.3	2.6	3.0	3.5	4.2	5.1	6.0	7.1	8.2	9.4	10.7	12.0	13.3	14.7	16.1	17.5	18.8
7	2.0	2.1	2.3	2.6	3.0	3.6	4.3	5.1	6.0	7.1	8.2	9.4	10.7	12.0	13.3	14.7	16.1	17.5	18.8

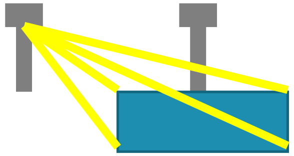


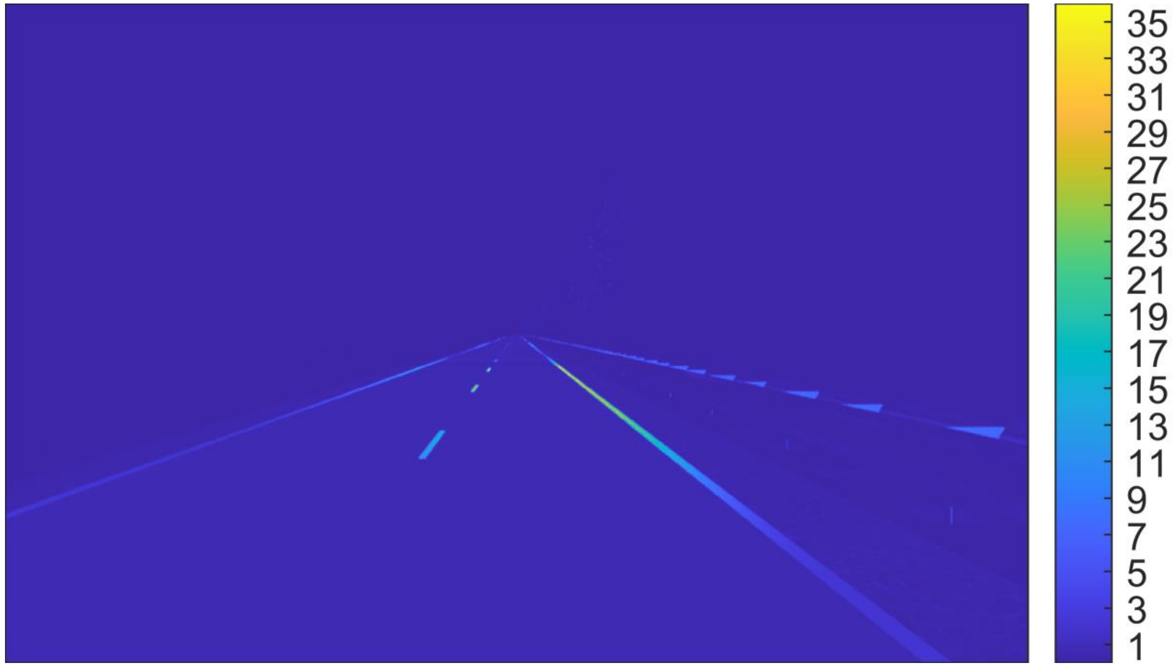
Lamp 2

ΔL	-45	-40	-35	-30	-25	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40	45
0	0.2	0.4	0.7	1.0	1.3	1.6	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	2.0
1	0.1	0.3	0.6	0.9	1.3	1.6	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	2.0
2	0.1	0.3	0.6	0.9	1.3	1.6	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	2.0
3	0.1	0.3	0.6	1.0	1.3	1.6	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	2.0
4	0.1	0.4	0.7	1.0	1.4	1.7	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	2.0
5	0.2	0.5	0.8	1.1	1.4	1.7	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	2.0
6	0.4	0.6	0.9	1.2	1.5	1.7	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	2.0
7	0.6	0.9	1.1	1.4	1.6	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	2.0

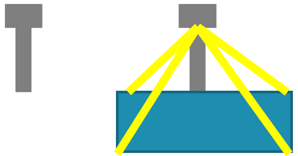
d) PBR Renderings

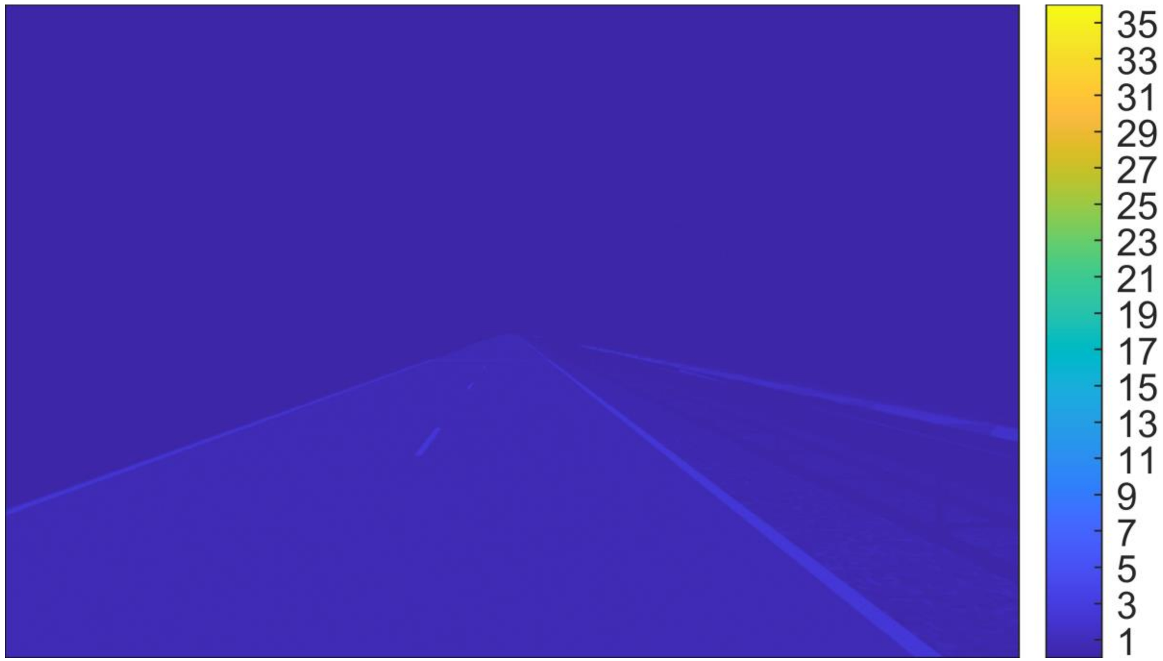
Lamp 1
$\Phi = 11865.4$

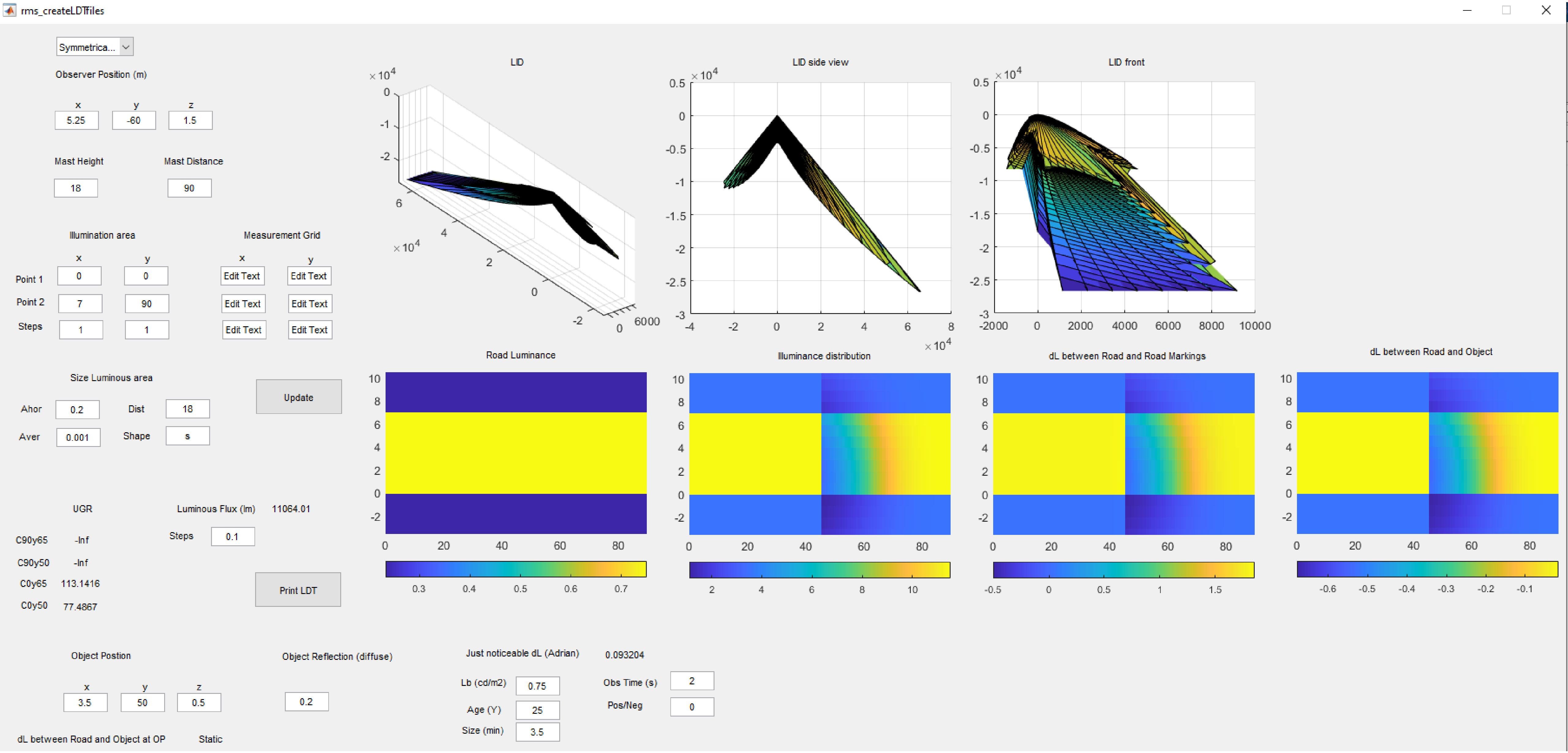




Lamp 2
$\Phi = 11865.4$



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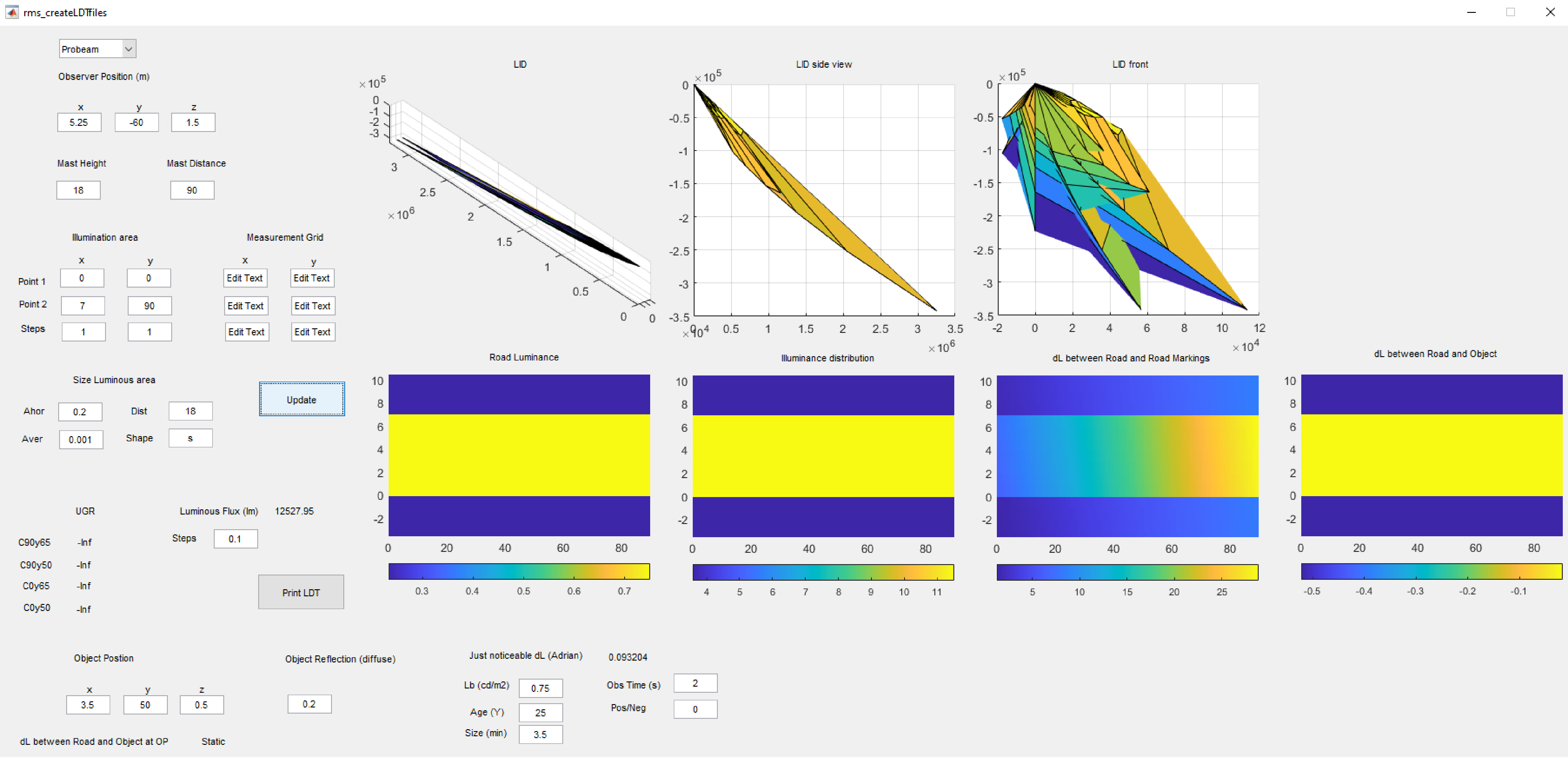
Symmetrica...
Observer Position (m)
x 5.25
y -60
z 1.5
Mast Height 18
Mast Distance 90
Illumination area
Measurement Grid
Point 1 0 0
Point 2 7 90
Steps 1 1
Edit Text
Size Luminous area
Ahor 0.2
Aver 0.001
Dist 18
Shape s
Update
UGR
C90y65 -Inf
C90y50 -Inf
C0y65 113.1416
C0y50 77.4867
Luminous Flux (lm) 11064.01
Steps 0.1
Print LDT
LID
LID side view
LID front
Road Luminance
Illuminance distribution
dL between Road and Road Markings
dL between Road and Object
Object Postion
x 3.5
y 50
z 0.5
Object Reflection (diffuse) 0.2
Just noticeable dL (Adrian) 0.093204
Lb (cd/m2) 0.75
Age (Y) 25
Size (min) 3.5
Obs Time (s) 2
Pos/Neg 0
dL between Road and Object at OP
Static


rms_createLDTfiles
Probeam
Observer Position (m)
x y z
5.25 -60 1.5
Mast Height
18
Mast Distance
90
Illumination area
x y
Point 1 0 0
Point 2 7 90
Steps 1 1
Measurement Grid
x y
Edit Text
Size Luminous area
Ahor 0.2
Aver 0.001
Dist 18
Shape s
Update
UGR
C90y65 -Inf
C90y50 -Inf
C0y65 -Inf
C0y50 -Inf
Luminous Flux (lm) 12527.95
Steps 0.1
Print LDT
LID
LID side view
LID front
Road Luminance
Illuminance distribution
dL between Road and Road Markings
dL between Road and Object
Object Postion
x y z
3.5 50 0.5
Object Reflection (diffuse)
0.2
dL between Road and Object at OP
Static
Just noticeable dL (Adrian) 0.093204
Lb (cd/m2) 0.75
Age (Y) 25
Size (min) 3.5
Obs Time (s) 2
Pos/Neg 0

Questions?

rik.spieringhs@kuleuven.be

EINDHOVEN UNIVERSITY OF TECHNOLOGY