Synopsys Optical Solutions for the Comprehensive Design and Analysis of Pixel Light Headlamps

US DVN Workshop

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Outline

- Introduction
- Synopsys Pixel Light Workflows
- Conceptual Pixel Light Driving Simulation
- Physics-Based Pixel Light Driving Simulation
- Example: FMVSS ADB Headlight Glare Evaluation
- Summary

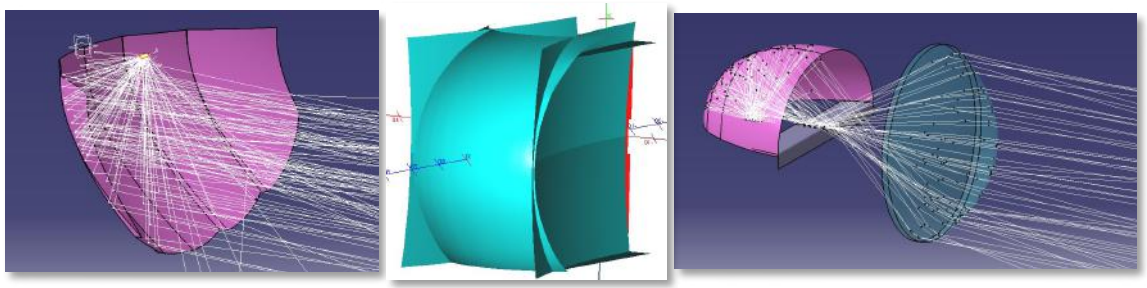
Introduction

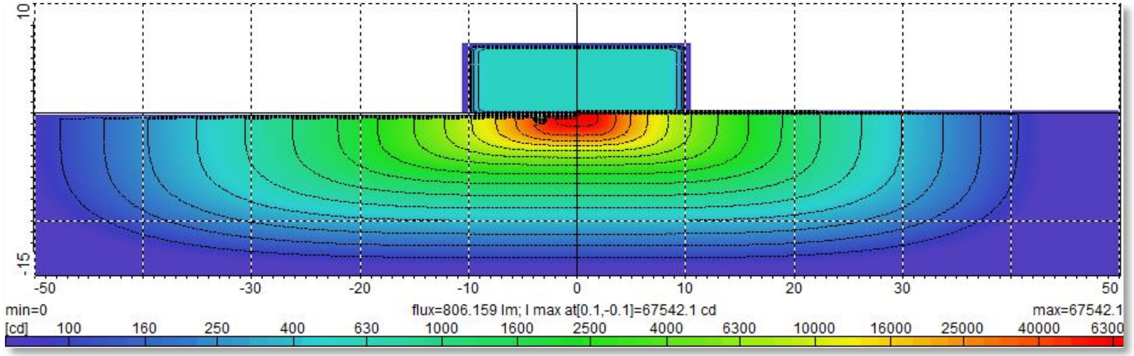
Pixel Light Headlamps

In contrast to conventional automotive illumination designs, an **expanded design toolset is required for the development of these systems.**

Automotive Headlamp Types

Reflector/Lens/Projector Module

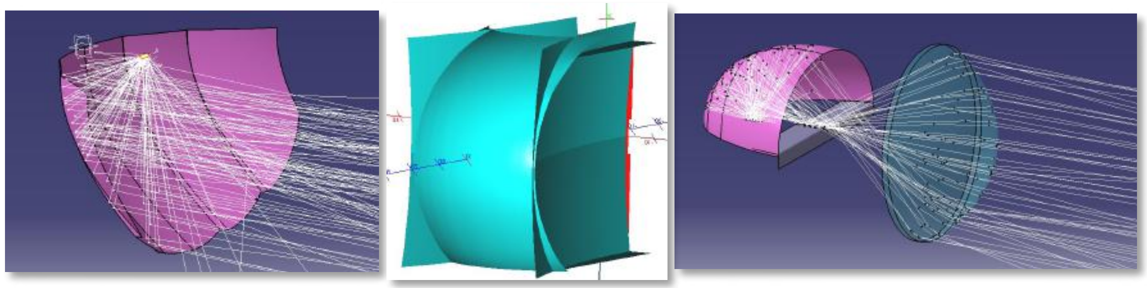


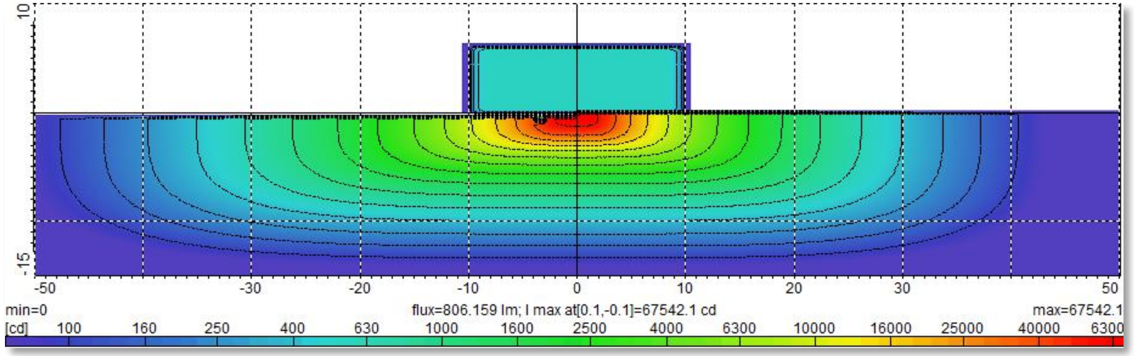


Illumination Design → Functional Geometry (Freeform Surface Design)

Automotive Headlamp Types

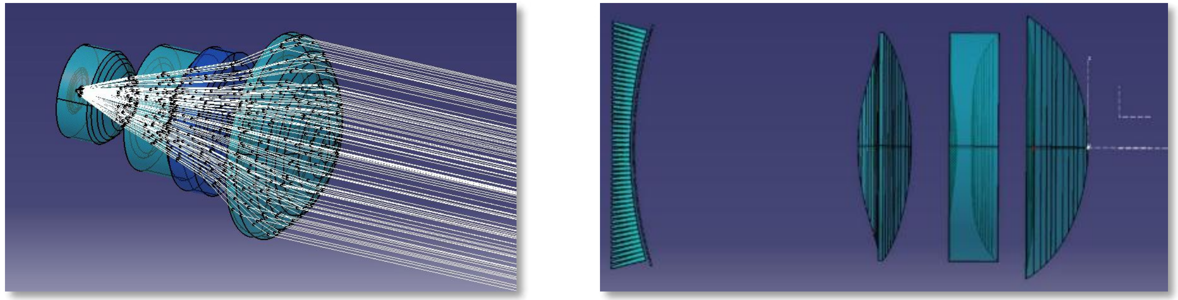
Reflector/Lens/Projector Module

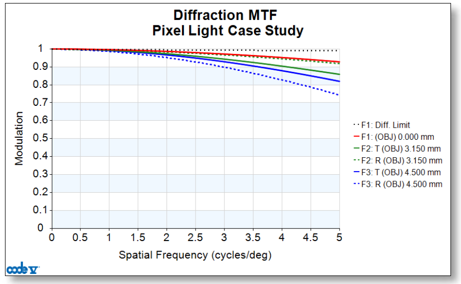


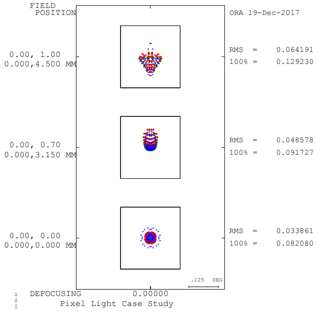


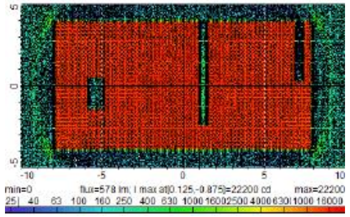
Illumination Design → Functional Geometry (Freeform Surface Design)

Multi-Lens Pixel Light Design









Imaging Design → Lens Design using Optimization

Illumination Design → Primary Optics (Freeform Surface Design)

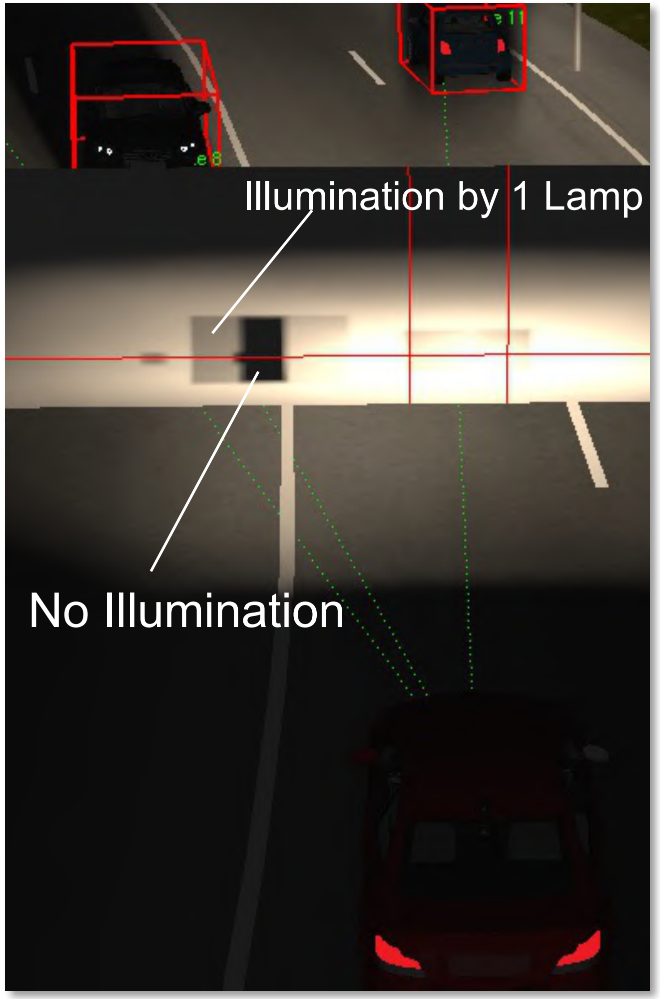
Synopsys Pixel Light Workflows

Conceptual Pixel Light Driving Simulation

Synopsys Pixel Light Workflows

- Principle
  - Calculates shadow masks based on the bounding boxes of the vehicles and **modifies the light distributions** accordingly.
- Pros
  - Excellent tool during requirements gathering
  - Real-time performance during driving simulation
  - User only needs to provide a single 2d light distributions per pixel light.
  - Low memory requirements for light distributions
- Cons
  - Reduced accuracy caused by ideal masking

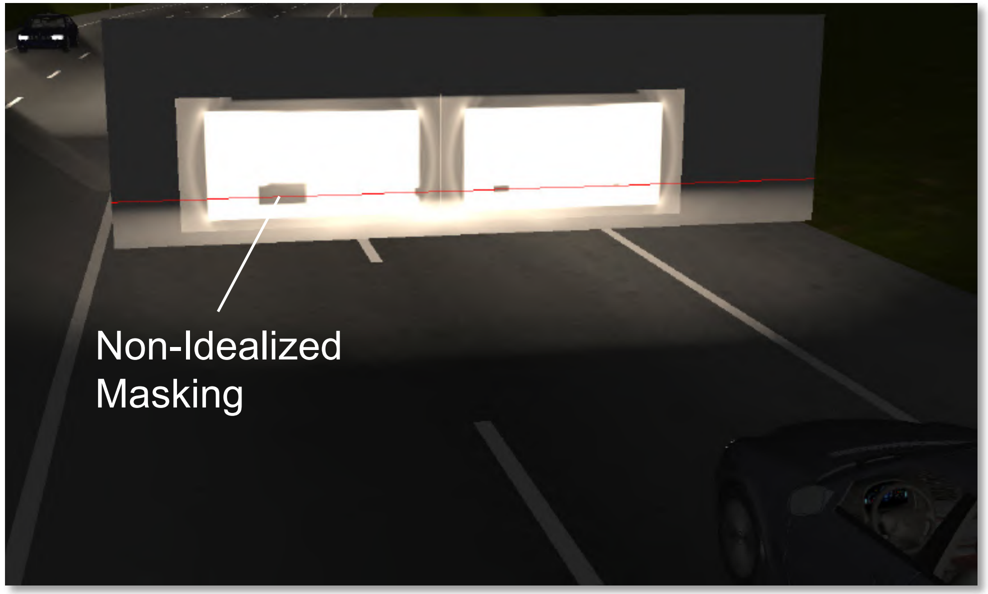
This level of accuracy is ***not*** suitable for meaningfully validating the performance and regulation compliance of pixel light systems.



Physics-Based Pixel Light Driving Simulation

Synopsys Pixel Light Workflows

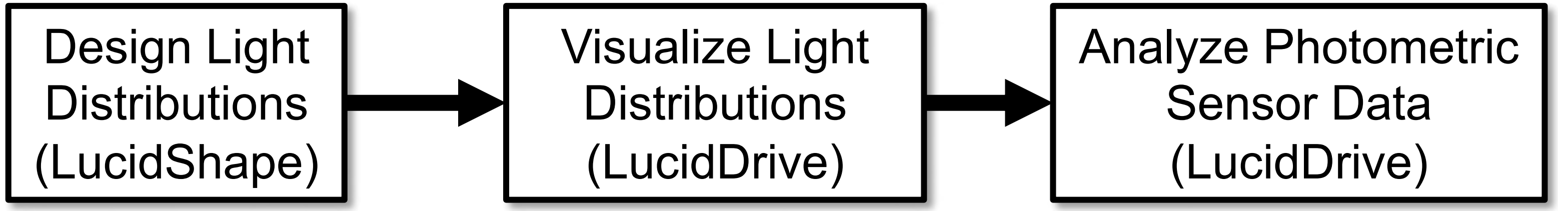
- Principle
  - The **simulated light distribution** for **each individual source pixel** is used during the driving simulation.
- Pros
  - Ideally suited for verifying optical system type selection
  - Ideally suited for the design of a pixel light system
  - High accuracy due to physics-based driving simulation
  - Real-time performance during driving simulation (achievable only with suitable hardware)
- Cons
  - Demanding memory requirements for multi-dimensional light distribution (multi-GByte) for high resolution light distributions



Example:

- Pixel Light System with 80x40 pixels
- Driving simulation: 30 frames/s
- Need to update 3200 light distributions 30 times/s
- LucidDrive can handle it!

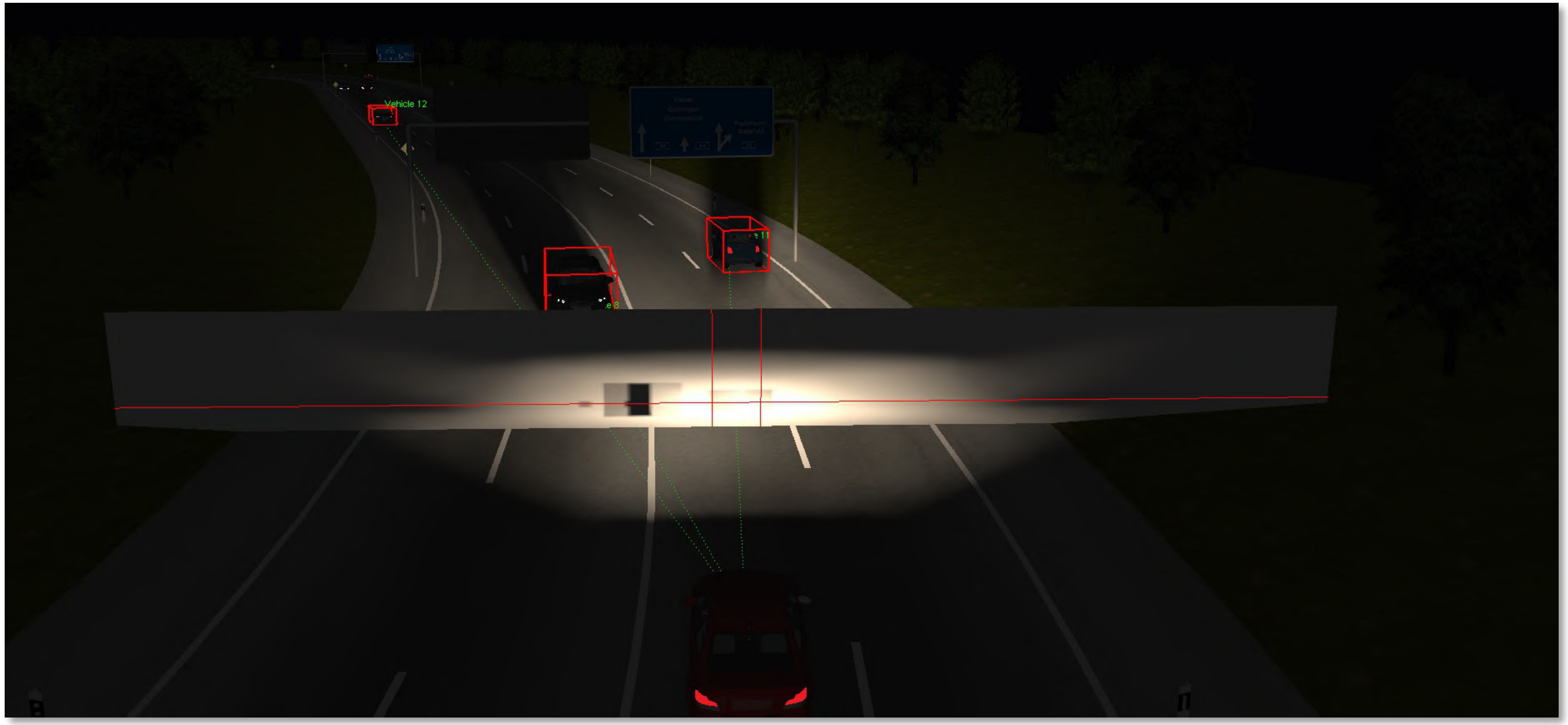
Conceptual Pixel Light Driving Simulation



Overview

Conceptual Pixel Light Driving Simulation

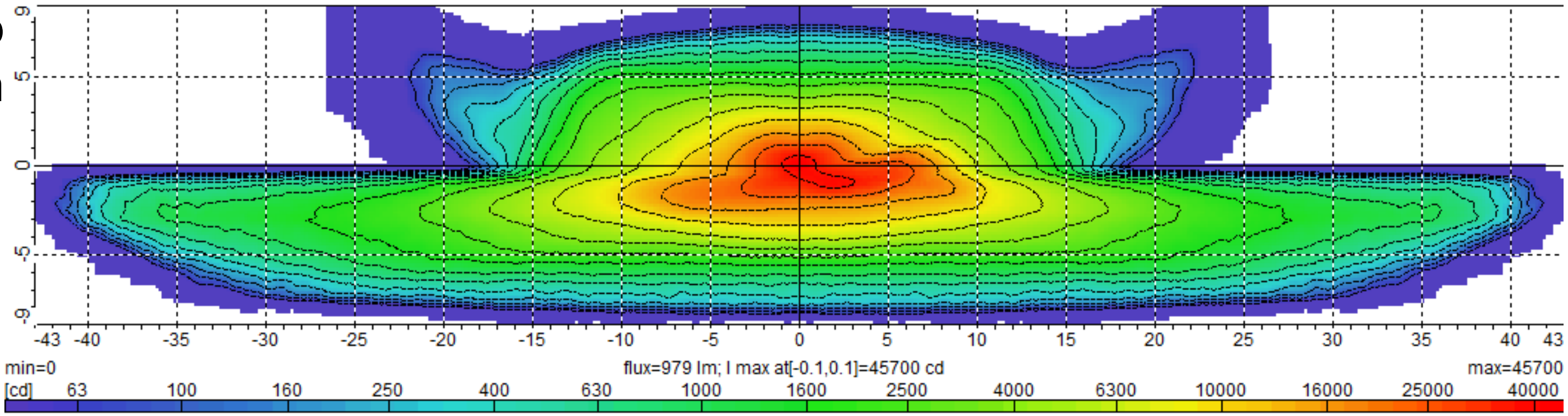
The Masking Pixel Light capability detects vehicles, calculates shadow masks based on the bounding boxes of the vehicles, and modifies the light distributions accordingly.



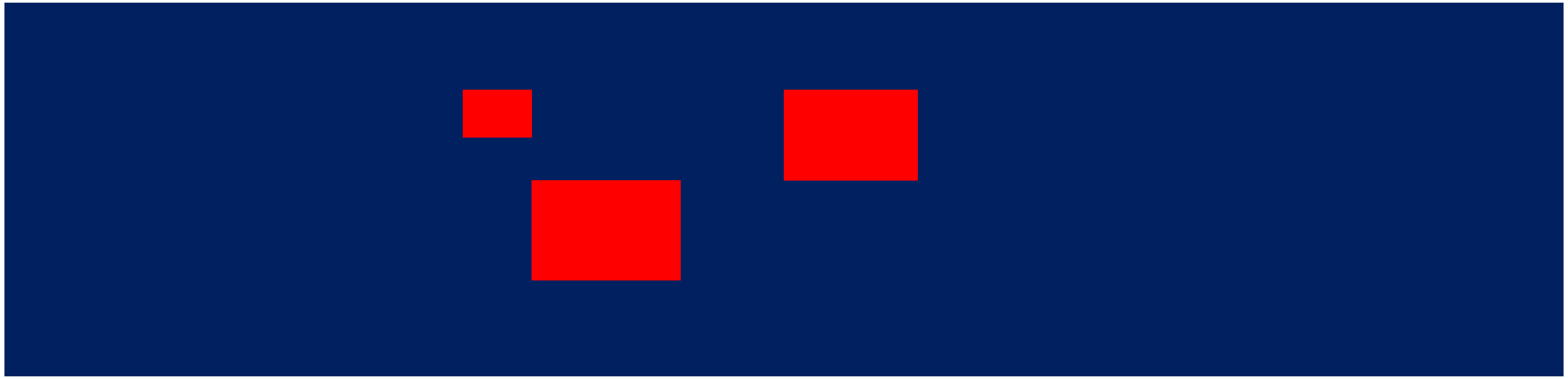
Concept

Conceptual Pixel Light Driving Simulation

Left full headlamp light distribution



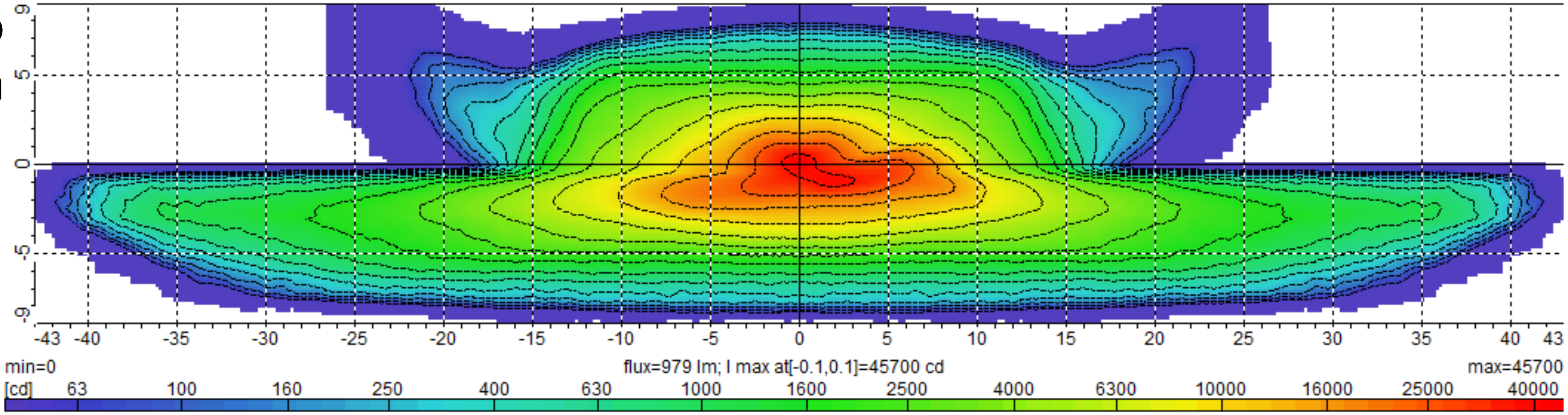
Stencil mask calculated from bounding boxes



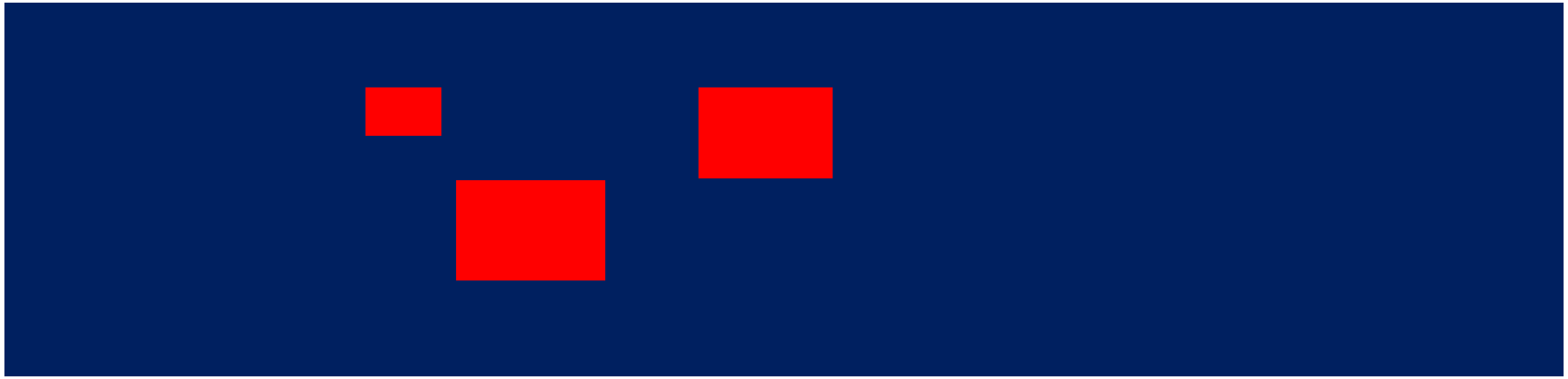
Concept

Conceptual Pixel Light Driving Simulation

Right full headlamp light distribution



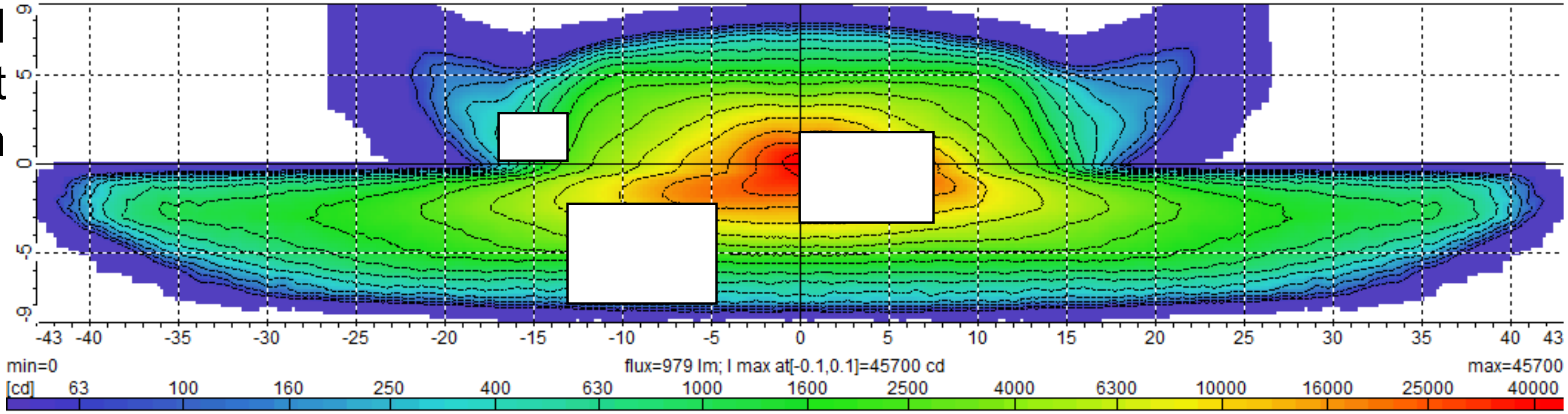
Stencil mask calculated from bounding boxes



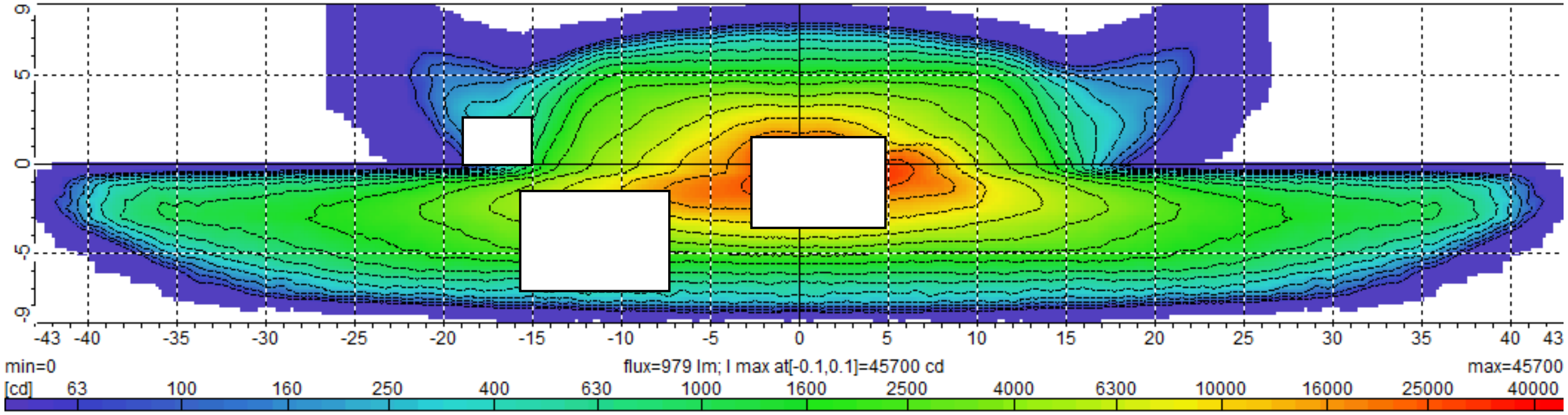
Concept

Conceptual Pixel Light Driving Simulation

Left masked headlamp light distribution



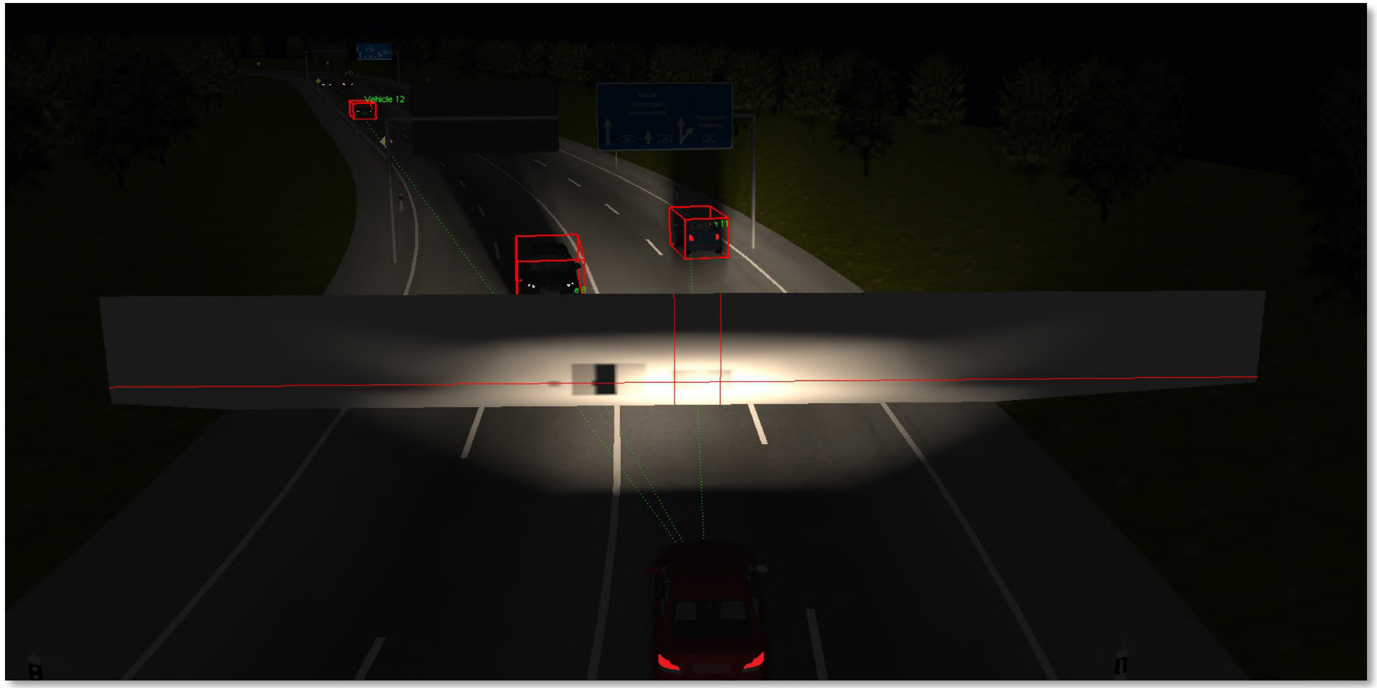
Right masked headlamp light distribution



Other Capabilities

Conceptual Pixel Light Driving Simulation

- Definition of mask size relative to vehicle bounding box
- Exclusion of masks below horizon
- Pixel resolution for mask
- Headlamp sets to be masked
- Vehicle detection range



Other Capabilities

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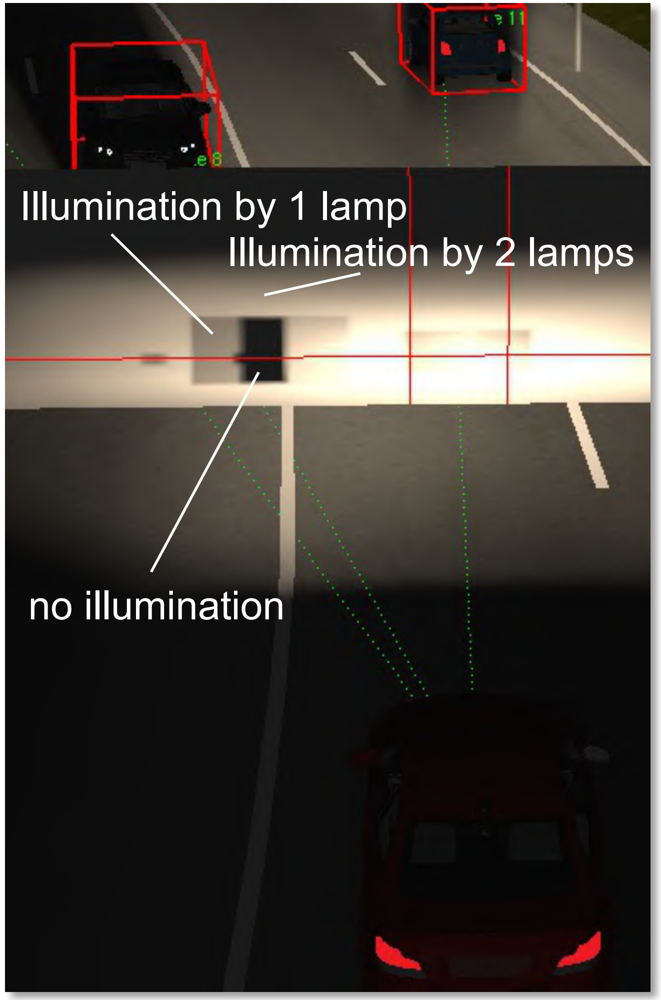
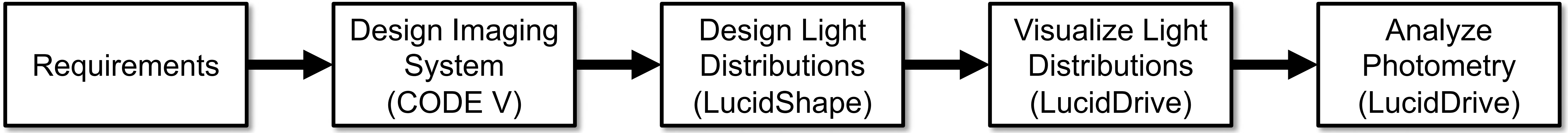
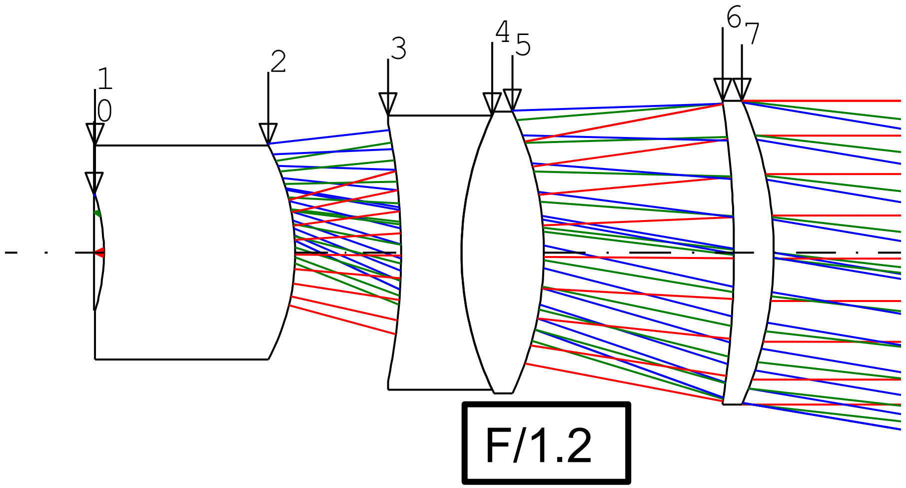


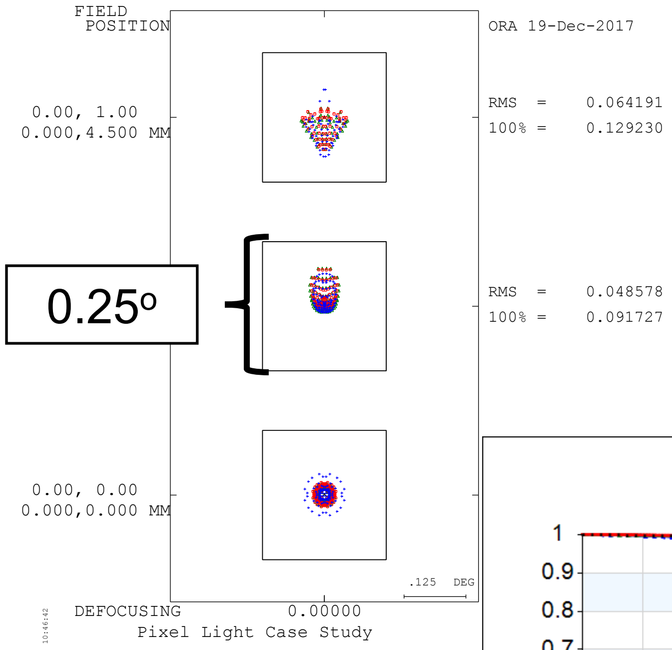
Physics-Based Pixel Light Driving Simulation

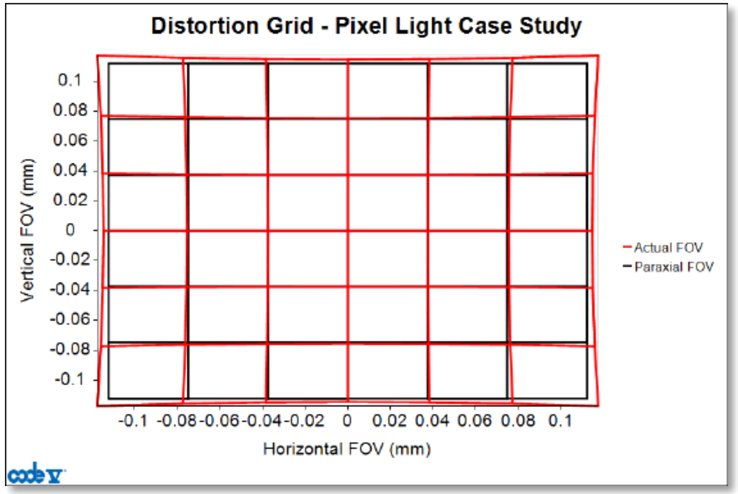


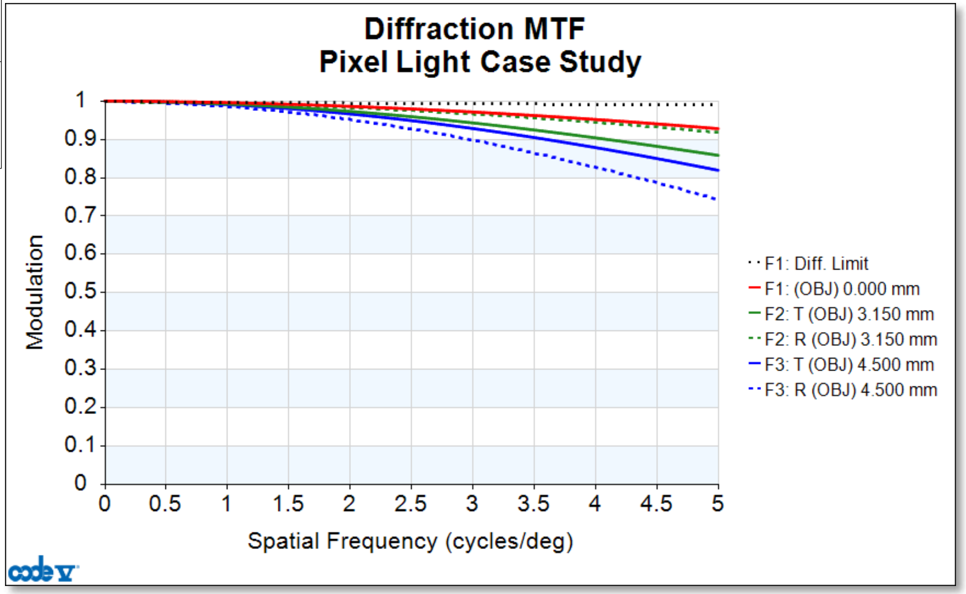
Imaging Design

Physics-Based Pixel Light Driving Simulation





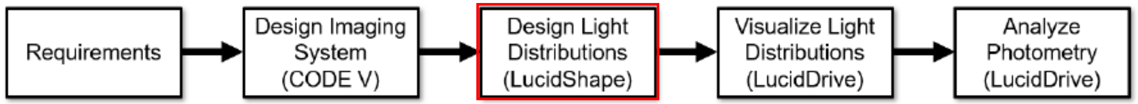




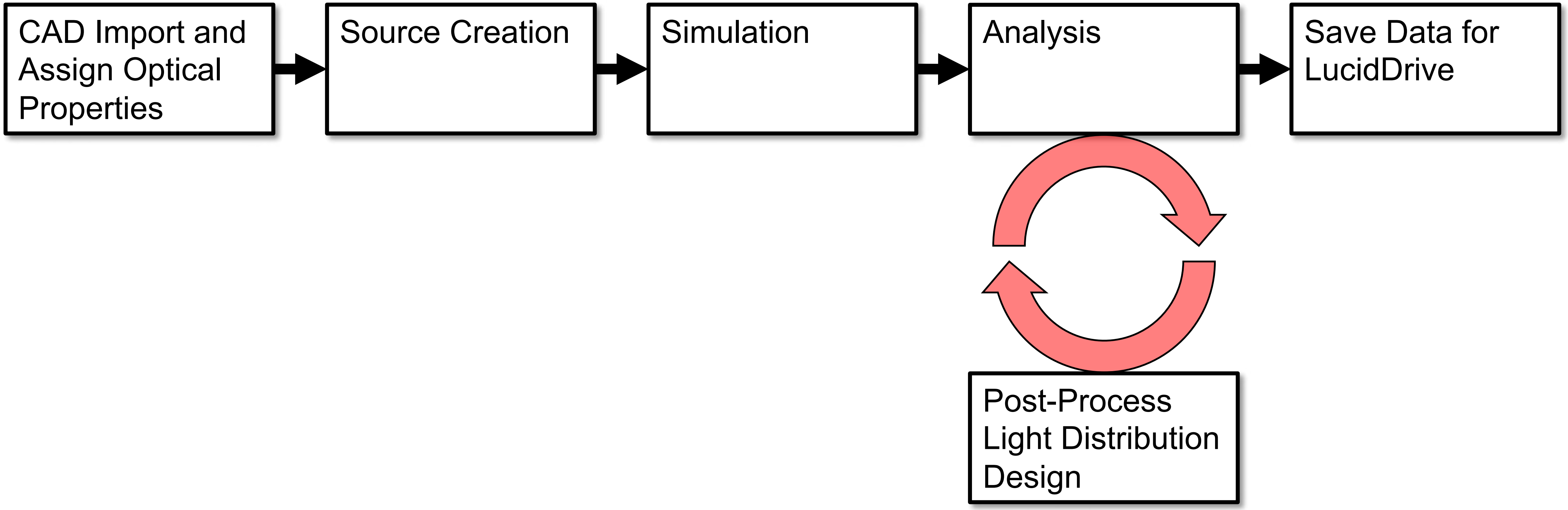
Surface #	Surface Name	Surface Type	Y Radius	Thickness	Glass	Refract Mode	Y Semi-Aperture
Object			Infinity	0.7782			
1			-14.2320 V	14.0000 V	743972.44 V		4.5208
2			-16.6155 V	13.0608 V			8.3373
3			-53.6579 V	1.4000 V	755201.27 V		10.0431
4			29.6577 V	5.7613 V	620410.60 V		10.6924
5			-26.5508 V	12.3725 V			10.9699
6			-111.2909 V	3.2535 V	646753.55 V		11.6541
Stop			-29.9542 V	20.0000			11.8385
Image			Infinity	0.0000 V			15.5922

Design Workflow in LucidShape

Physics-Based Pixel Light Driving Simulation



Design Light Distributions (LucidShape)

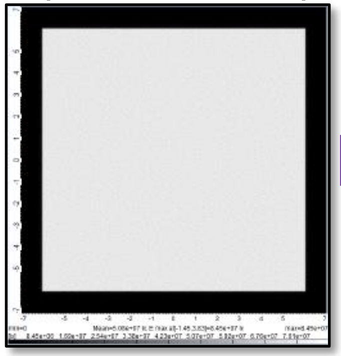


Illumination Simulation

Physics-Based Pixel Light Driving Simulation

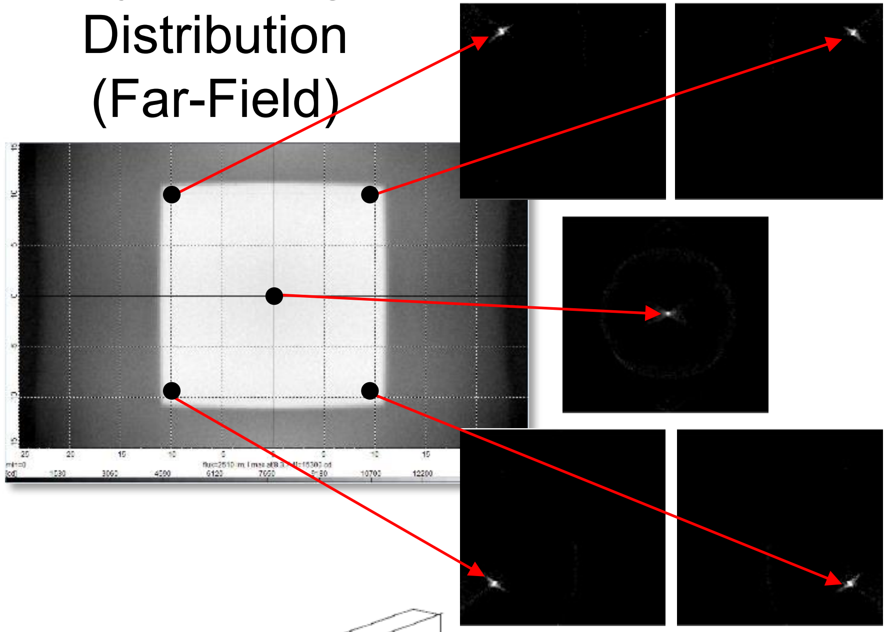
- What does the illumination look like?
- To find out, we'll run the simulation separately for each pixel.
- Number of Pixels: 80x40=3200

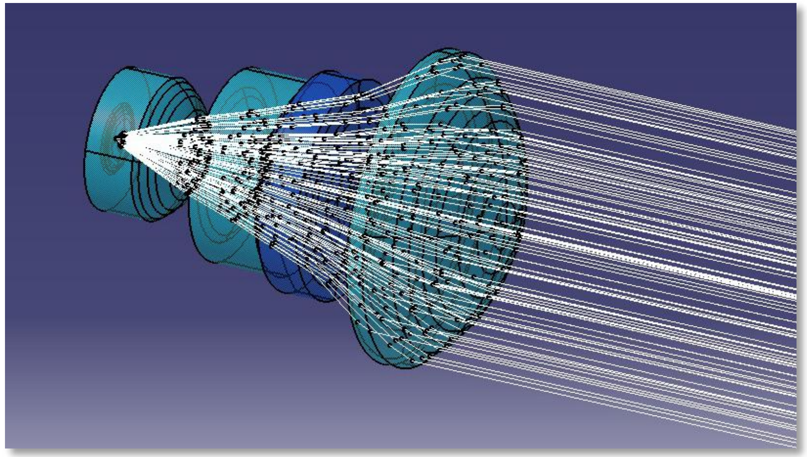
Pixel Light Source (Near Field)



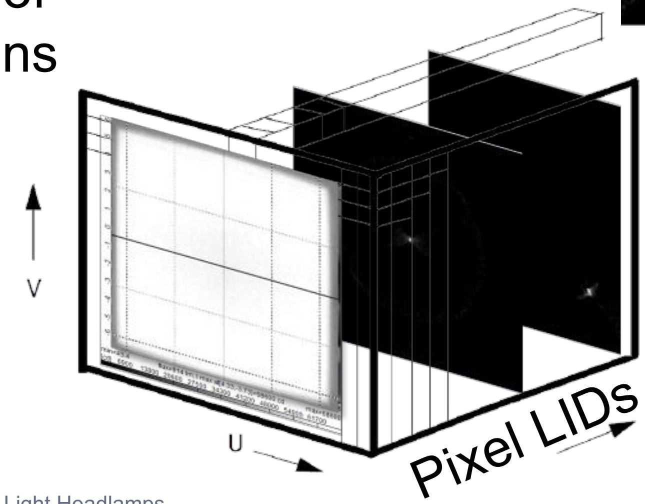
Projected Light Distribution (Far-Field)

Pixel LIDs





3D-LID = Array of Light Distributions

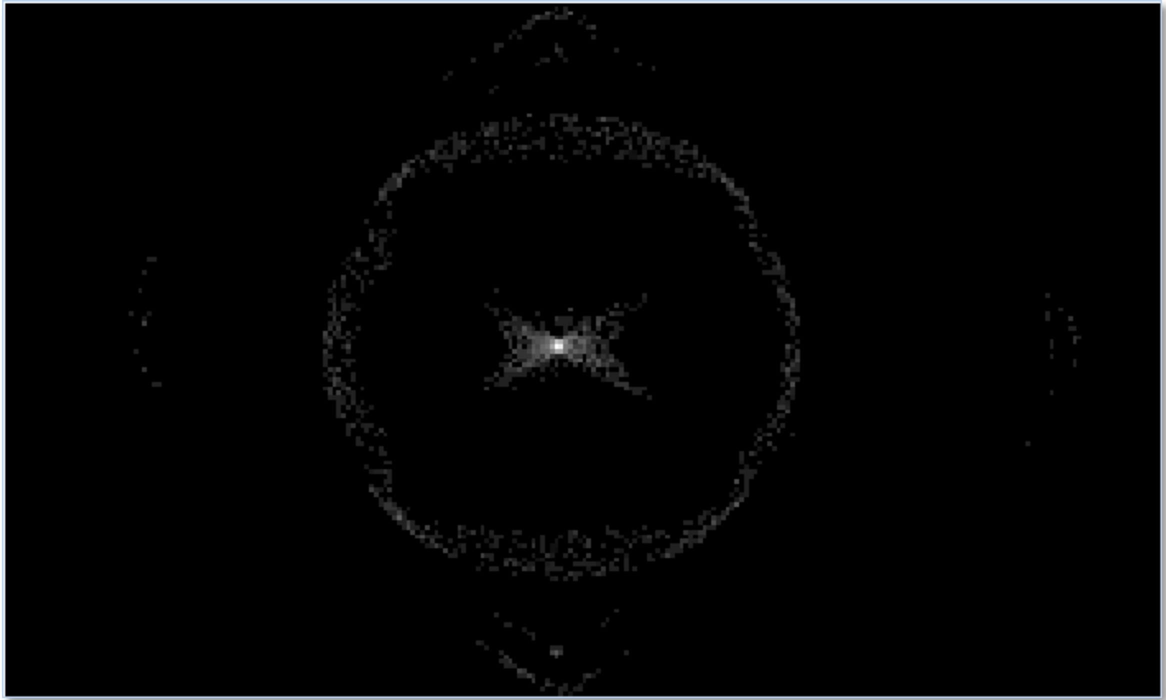


Individual Layers of 3D-LID Simulation Results

Physics-Based Pixel Light Driving Simulation

Far field, upper left corner

Far field, center



- Intensity distributions of individual pixels include pixel blur caused by aberrations, stray light, ghost images, etc.
- Design limitations can be identified and addressed early in the design process long before actual hardware is developed.

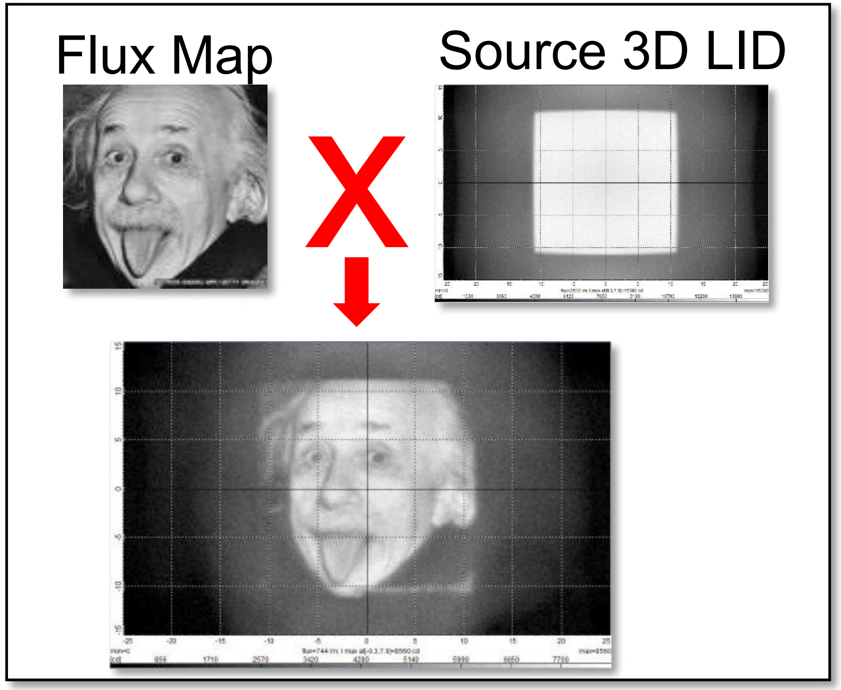
Light Distribution Design

Physics-Based Pixel Light Driving Simulation

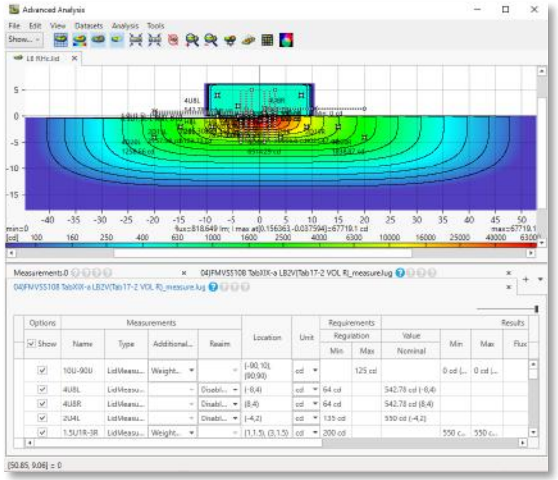
- **Source flux modification** in post-processing by multiplying candela distributions of each pixel by scaling factors provided in flux map (Einstein image)
- **Target modification** mode, to intuitively modify road illumination
- **Reverse transformation** to extract source flux for ECU programming

- The computationally expensive simulation (hours or days) needs to be carried out only once!
- All subsequent transformations can be carried out by post-processing (~200ms).
- Photometry compliance can be assessed in LucidShape.

Light Distribution Design



Light Distribution Compliance Verification



Physics-Based Pixel Light Driving Simulation

Enabling the most accurate virtual testing of non-idealized Pixel Light systems, including:

- Fresnel reflections
- Aberrations
- Stray light effects

Physics-Based Pixel Light Driving Simulation

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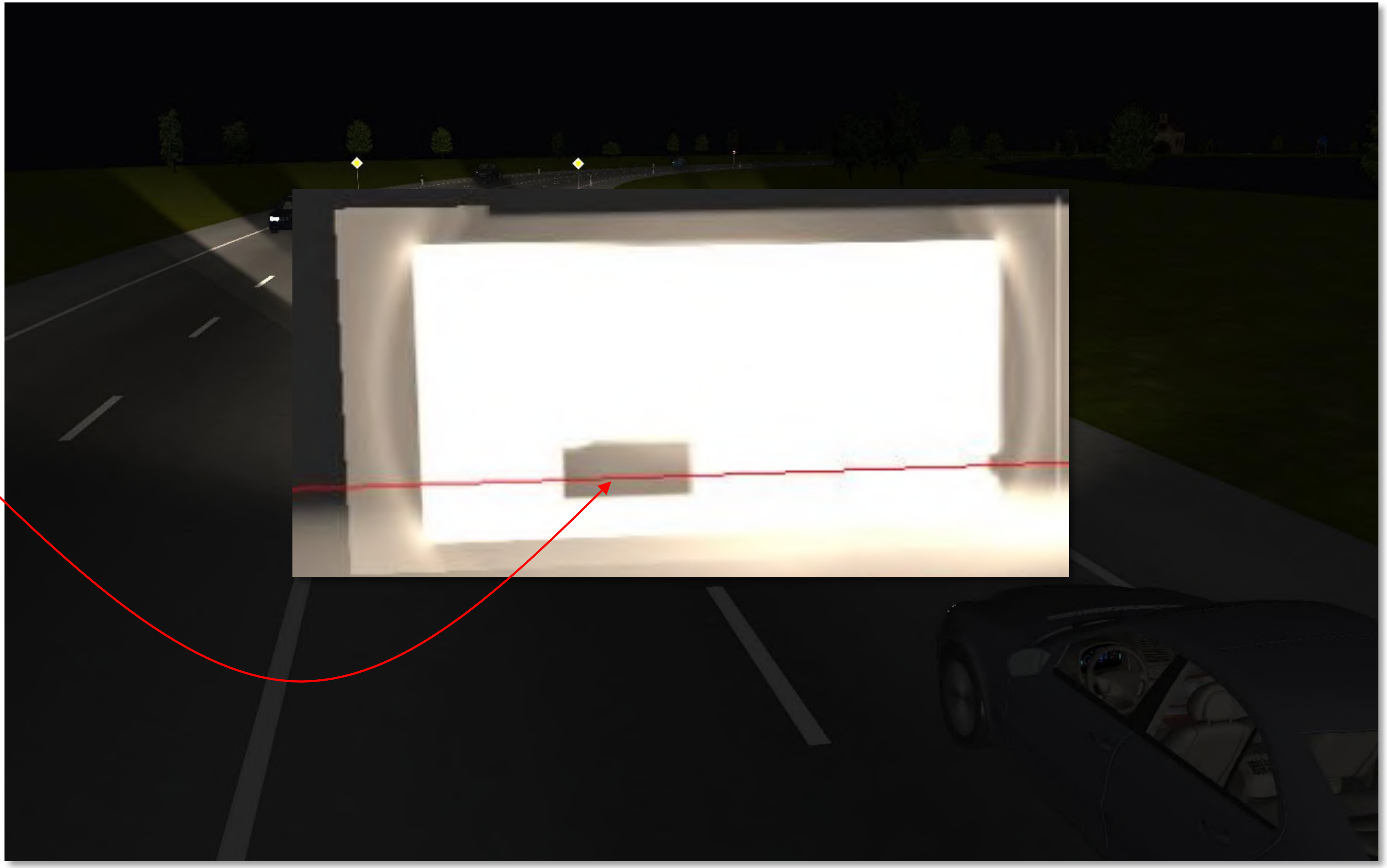

Example: FMVSS ADB Headlight Glare Evaluation

Regulation Overview

Example: FMVSS ADB Headlight Glare Evaluation

- Federal Motor Vehicle Safety Standard (FMVSS) No.108
  - Approved the usage of adaptive driving beams (ADBs) for US market
  - Defined test track with straight and curved roads
  - Defined vehicle emulators (stimulus test fixtures) consisting of lights and sensors
    - (a) Headlamps stimulate ADB.
    - (b) Sensors measure glare.

LucidDrive provides pre-defined configurations to easily assess FMVSS ADB Headlight Glare.

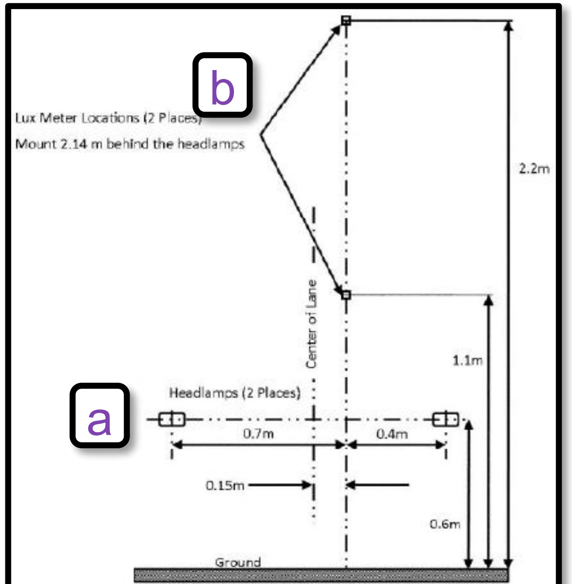

Image: Courtesy of FMVSS
Car / Truck opposite direction stimulus test fixture dimensions

Table XXII

Adaptive Driving Beam System Test Matrix

Scenario No.	Test vehicle speed (km/h)	Orientation	Radius of curve (m.)	Curve direction	Superelevation (%)	Mea
1	96.6-112.7 [60-70mi/h]	Opposite Direction	Straight	N/A	0-2	Greate less th
2	40.2-48.3 [25-30mi/h]	Opposite Direction	85-115	Left	0-2	Greate less th
3	64.4-72.4 [40-45mi/h]	Opposite Direction	210-250	Left	0-2	Greate less th
4	80.5-88.5 [50-55mi/h]	Opposite Direction	335-400	Left	0-2	Greate less th
5	64.4-72.4 [40-45mi/h]	Opposite Direction	210-250	Right	0-2	Greate less th
6	80.5-88.5 [50-55mi/h]	Opposite Direction	335-400	Right	0-2	Greate less th
7	96.6-112.7 [60-70mi/h]	Same Direction	Straight	N/A	0-2	Greate less th
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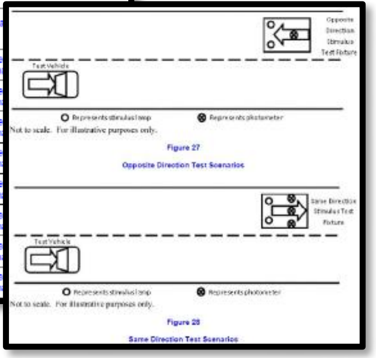
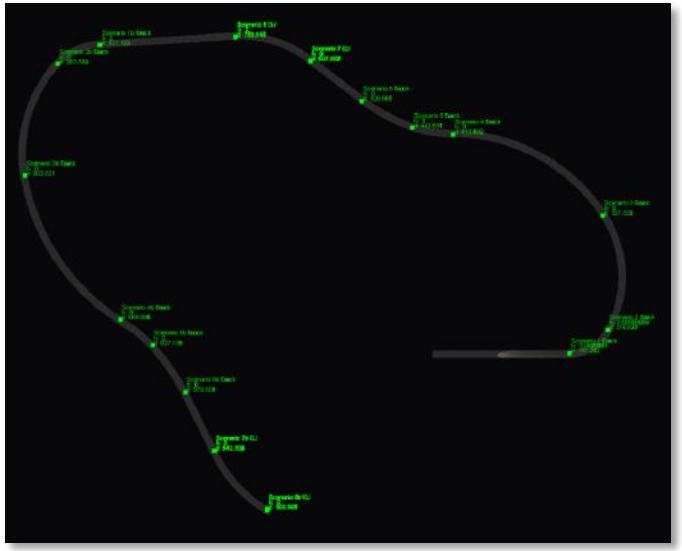
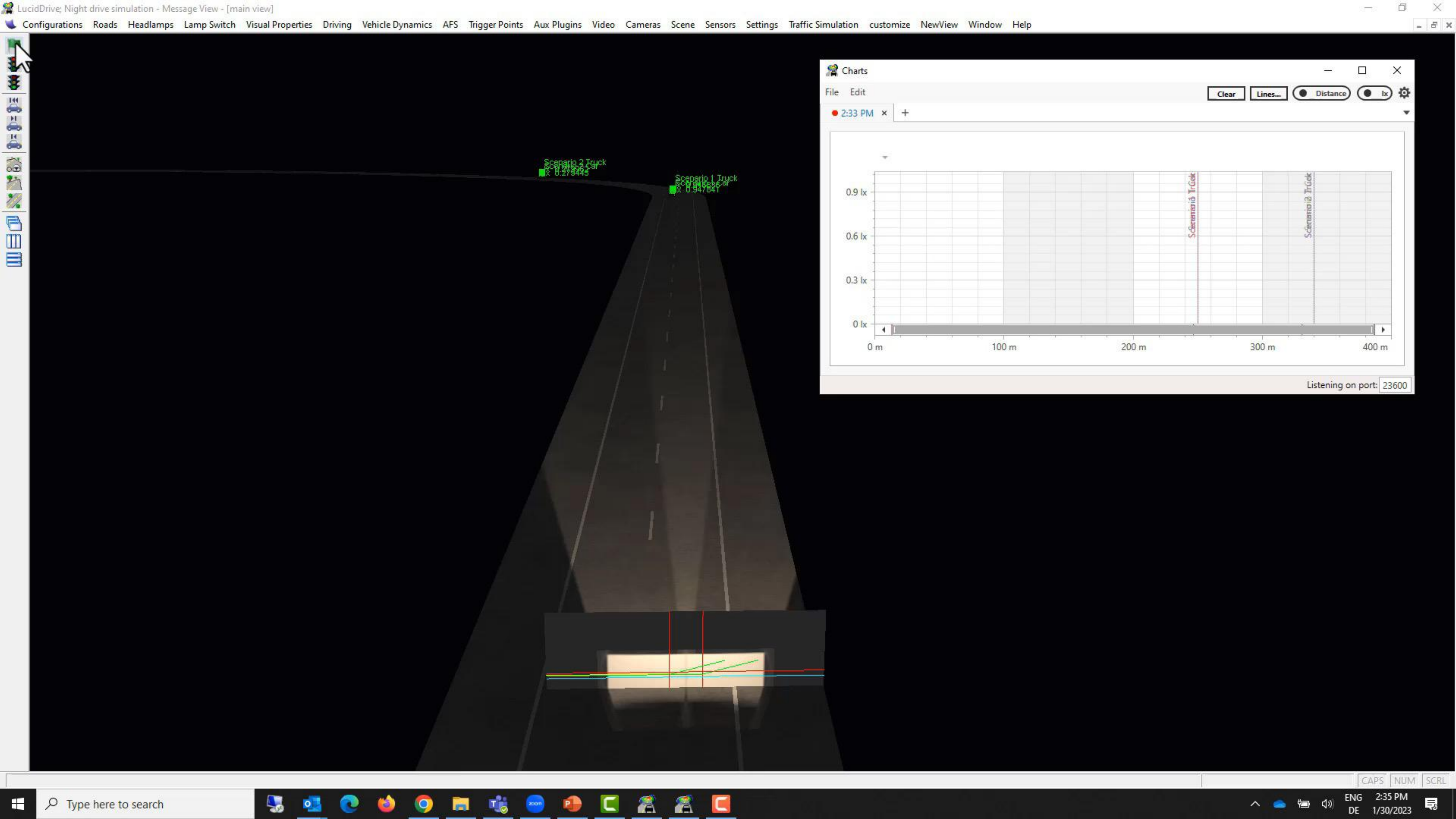




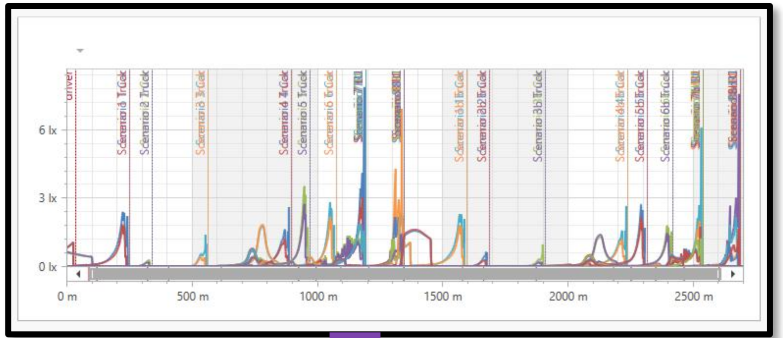


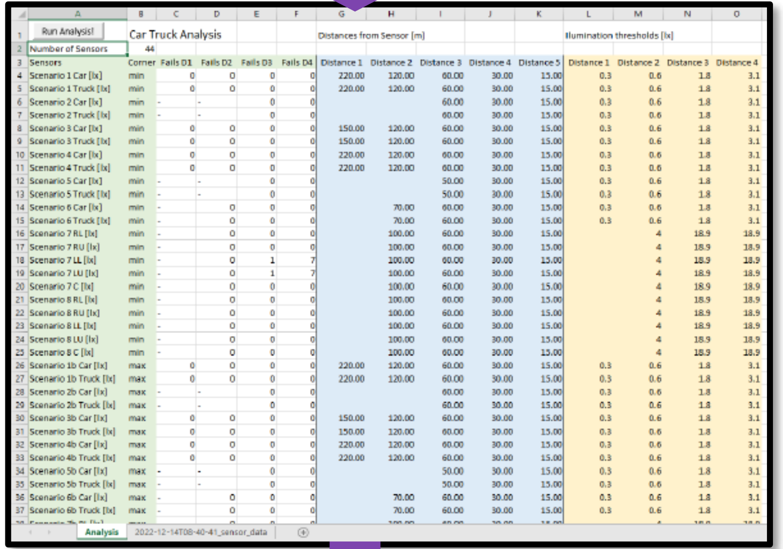
LucidDrive; Night drive simulation - Message View - [main view]
Configurations
Roads
Headlamps
Lamp Switch
Visual Properties
Driving
Vehicle Dynamics
AFS
Trigger Points
Aux Plugins
Video
Cameras
Scene
Sensors
Settings
Traffic Simulation
customize
NewView
Window
Help
Scenario 2 Truck
lx 0.273445
Scenario 1 Truck
lx 0.947841
Charts
File
Edit
Clear
Lines...
Distance
lx
2:33 PM
0.9 lx
0.6 lx
0.3 lx
0 lx
0 m
100 m
200 m
300 m
400 m
Scenario 1 Truck
Scenario 2 Truck
Listening on port: 23600
CAPS
NUM
SCRL
Type here to search
ENG
DE
2:35 PM
1/30/2023

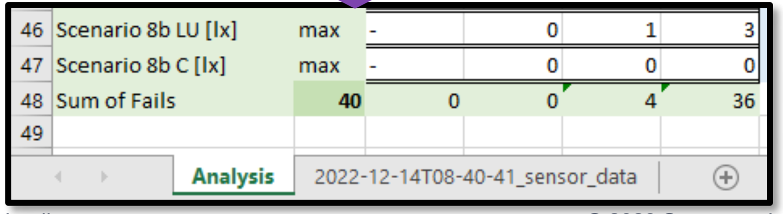
Driving Simulation – Photometric Analysis

Example: FMVSS ADB Headlight Glare Evaluation

- LucidDrive includes Microsoft Excel analysis spreadsheets available for the FMVSS 108 ADB glare evaluation (Car/Truck and Motorcycle).
- The results can be seen under Sum of Fails. In the example to the right, the number is 40 fails.
- Regulation compliance requires 0 fails.







46	Scenario 8b LU [lx]	max	-		0	1	3
47	Scenario 8b C [lx]	max	-		0	0	0
48	Sum of Fails	40	0		0	4	36
49							

Analysis | 2022-12-14T08-40-41_sensor_data

Summary

- Pixel Light Systems require an expanded development toolset for optical engineers.
- Synopsys Optical Solutions can provide you with the necessary tools to virtually design, analyze and test these systems, including
  - **CODE V** allows you to design the projection optics.
  - **LucidShape** enables you to perform the illumination simulation (result is resolved by pixel) and design of light distributions.
  - **LucidDrive** empowers you to virtually test the pixel light design in a drive simulation in the context of other vehicles.

Thank You

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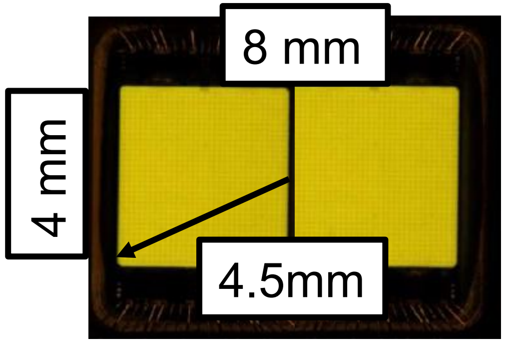
Appendix

Requirements and Design Starting Point Selection

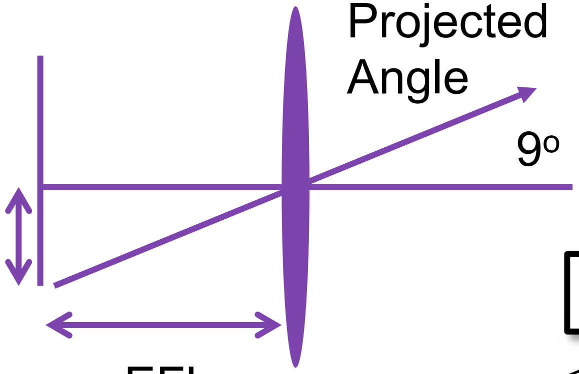
Physics-Based Pixel Light Driving Simulation

We want a 9º FOV and fast F/#

- Pixel light system includes a total of 4 modules (2 modules per side)
- FOV (per module) target is ~ 9º
- Display size = 4.5mm



Display Size = 4.5mm



EFL = Display Size / tan (Projected Angle) = 28.4 mm

Field of View

F-number (F/#)

F/# = EFL/EPD

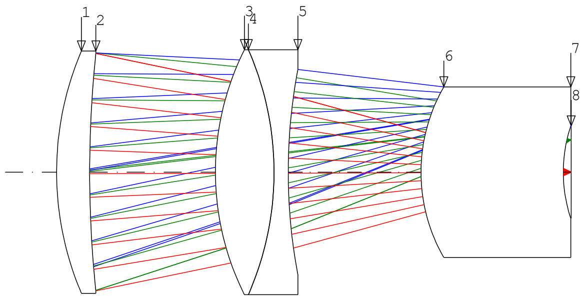
Source: https://www.spiedigitallibrary.org/conference-proceedings-of-spie/9793/97930N/Easy-to-use-software-tools-for-teaching-the-basics-design/10.1117/12.2223079.full?SSO=1

A Petzval lens may be a good choice!

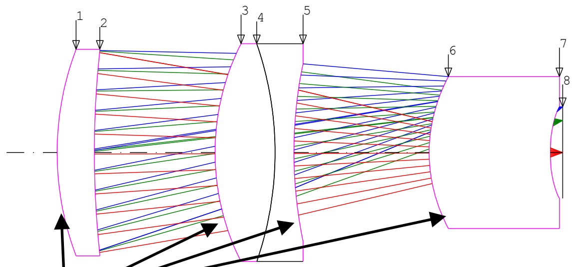
Optimization

Physics-Based Pixel Light Driving Simulation

Starting Design (F/1.2)

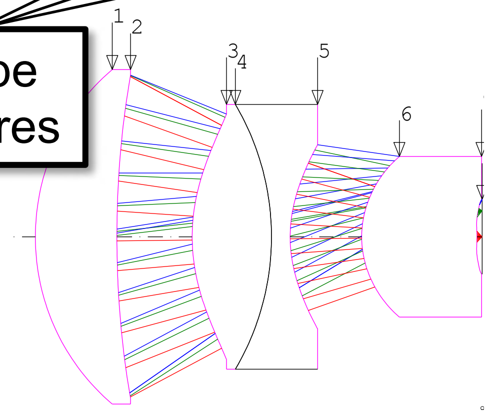


Intermediate Solution

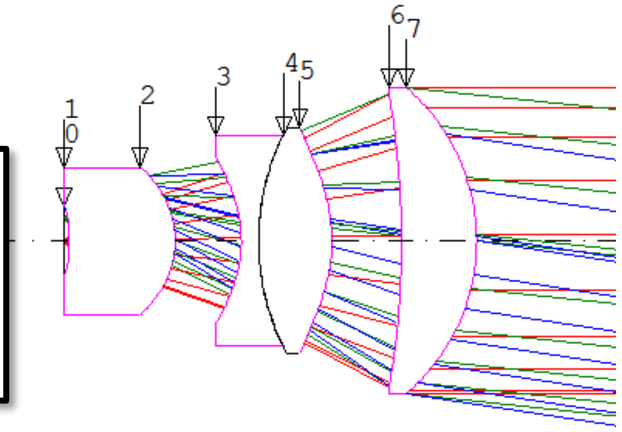


Q-Type Aspheres

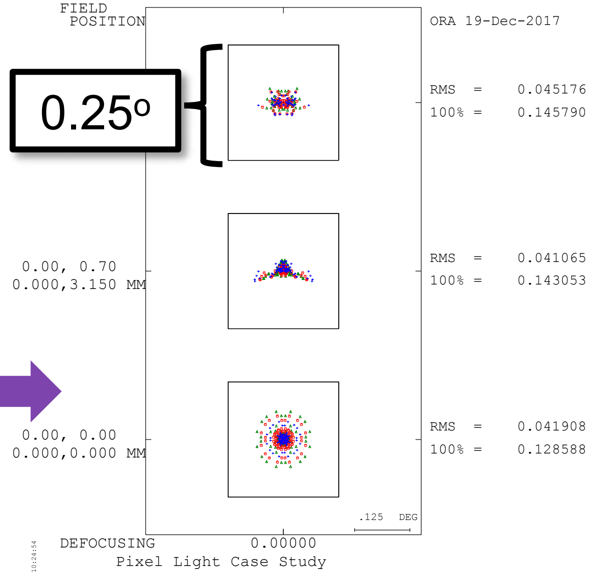
Optimized Design (F/0.7)



Optimized Design (F/0.7), Flipped for Analysis



0.25°



Spots are better than 0.05° (RMS)

Similar performance, but the faster system will project more light!

F/1.2 collects ~15% of light
F/0.7 collects ~34% of light