

**Interoperability between
Zemax OpticStudio and
Ansys simulation platform
for ADAS and AV development**



Ansys SPEOS for automotive camera system

New SPEOS Lens System

Ansys SPEOS and Zemax OpticStudio interoperability



Ansys SPEOS for automotive camera system

Ansys

Main capabilities for automotive camera development

CAD-agnostic 3D geometrical environment

- Large road environment
- Moving vehicles and pedestrians

Light emission

- Natural light: sky and sun
- Artificial lights: luminaires, front/rear lamps
- Thermal sources, up to far infrared

Light-matter interaction

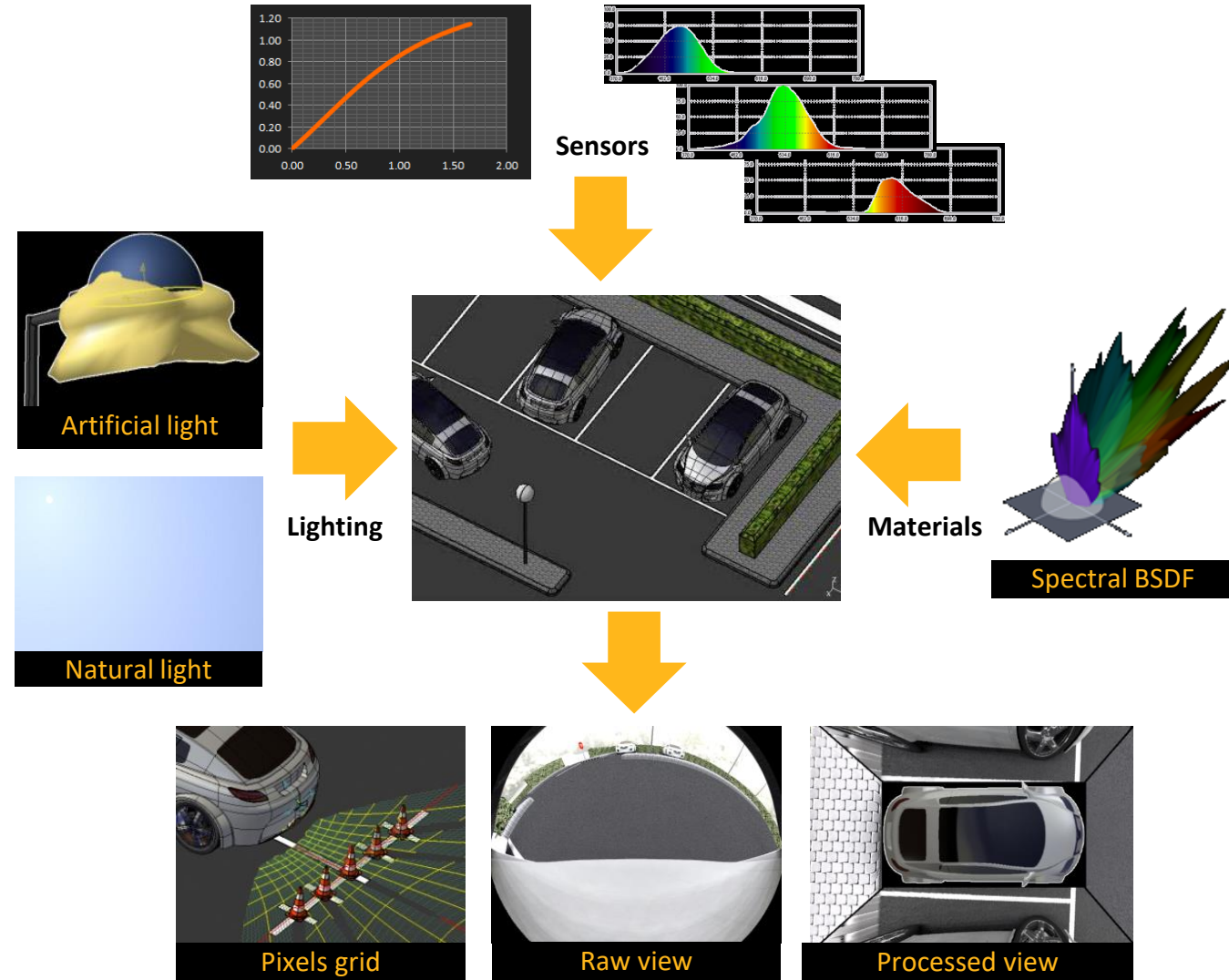
- Spectral BSDF
- Volume scattering

Light collection

- Spectral irradiance sensor (detailed model)
- Pin-hole camera (simplified model)

Dedicated features

- Pixel grid projection
- Image processing interface (plugin, API)



Simplified camera model

Benefits

- Provide sufficient **camera model for camera layout** on vehicle with **minimal optical lens input parameters** (mainly distortion curve) obtainable by optical design analysis or physical characterization

Limitations

- **Constant entrance pupil position (EPP)** is appropriated for far field, however, could lead to incorrect field of view with wide angle lenses and very near occulting vehicle's parts
- Pinhole model requiring less computational resources but don't reflect some lens design characteristics such as image vignetting or sharpness needed for detection testing in critical lighting conditions

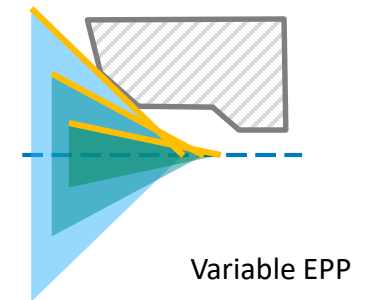
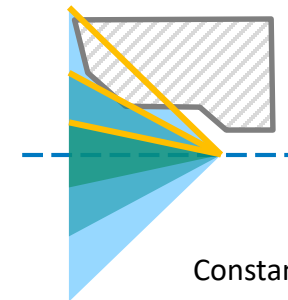
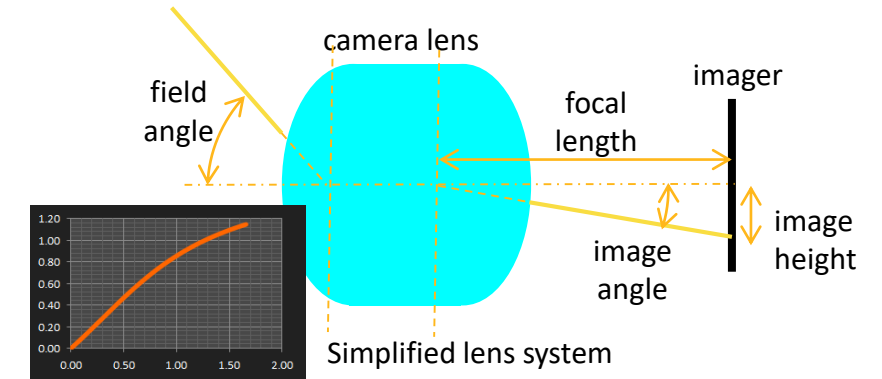


Image: aeye.ai



Image: vedecom.fr

Detailed camera model

Benefits

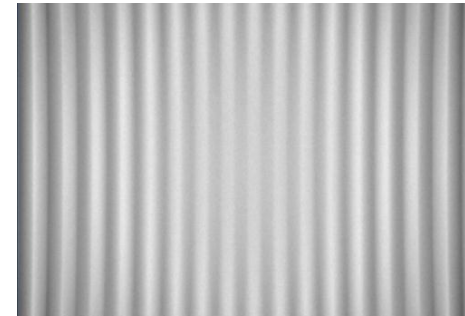
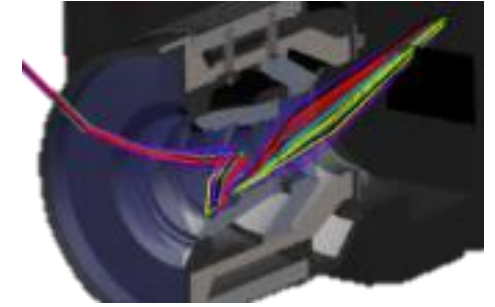
- Models (almost) **all aspects of camera optical and mechanical design** to generate accurate simulated image.
- Access to **spectral irradiance per pixels by API** to add imager electronics (e.g. noise addition) and image processing (e.g. white balance, gamma correction)

Drawbacks

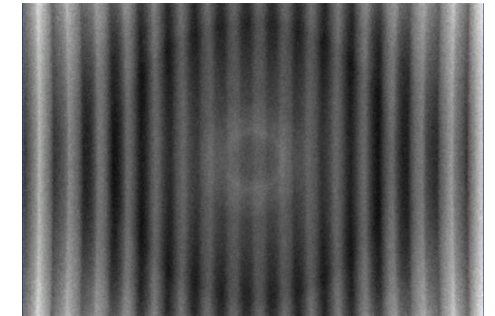
- Models creation requires time-consuming and error-prone operations
- Detailed optical designs contain intellectual properties that lens suppliers are reluctant to share
- Rays propagation in camera optical system including mechanical and optical parts and in the entire environment leads to prohibitive computational resources for in-driving scenario



Camera lens flare and stray light analysis

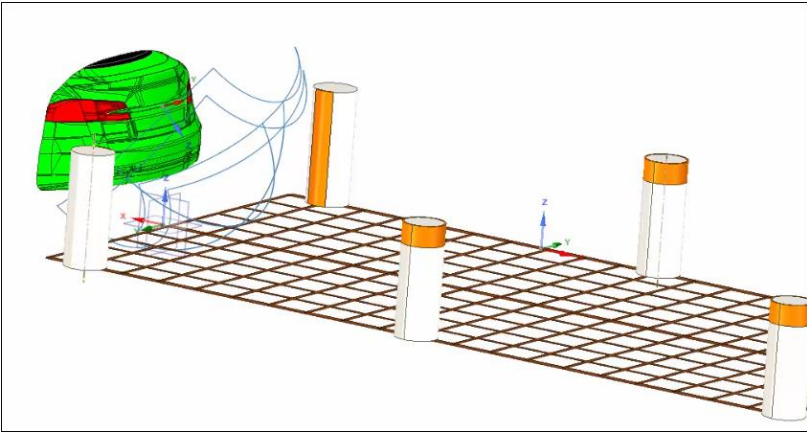
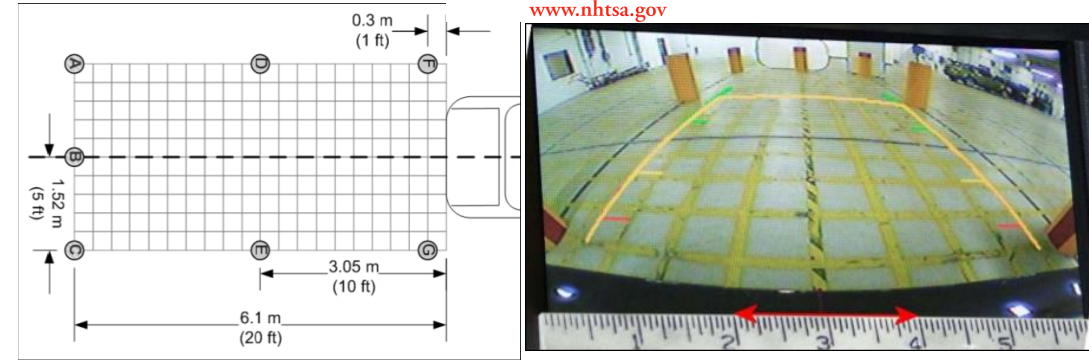


Narcissus effect simulation infrared camera

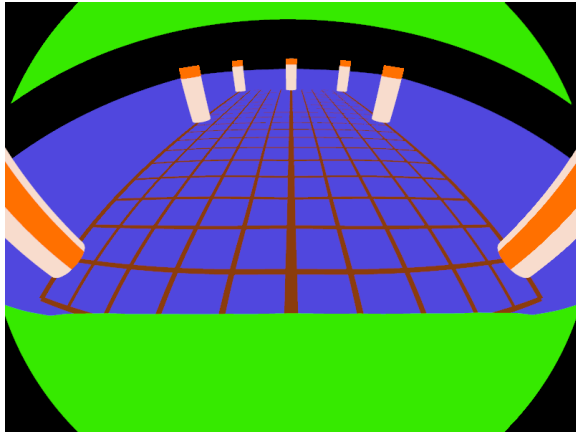


Use case: Rear visibility

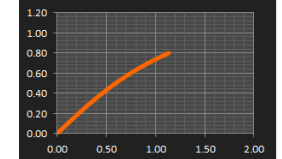
Virtually validate automotive rearview image against the Federal Motor Vehicle Safety Standard 111 (FMVSS111) of the National Highway Traffic Safety Administration (NHTSA)



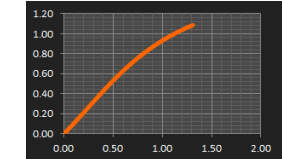
3D model



Camera view



HFOV
130°



HFOV
150°

Stripe of F visible	false
Stripe of G visible	false
A detected	true
B detected	true
C detected	true
D detected	true
E detected	true
Average visual angle test	true
Average visual angle	21.87
Visual angle A test	true
Visual angle A	23.51
Visual angle B test	true
Visual angle B	21.05
Visual angle C test	true
Visual angle C	21.05
NHTSA FMVSS111 - Rearview image testing	false

Stripe of F visible	true
Stripe of G visible	true
A detected	true
B detected	true
C detected	true
D detected	true
E detected	true
Average visual angle test	true
Average visual angle	15.05
Visual angle A test	true
Visual angle A	16.23
Visual angle B test	true
Visual angle B	15.05
Visual angle C test	true
Visual angle C	13.87
NHTSA FMVSS111 - Rearview image testing	true



Use case: Parking assistance

Assemble cameras on vehicle

- Avoiding blind spots
- Minimizing styling impacts

Test embedded image processing

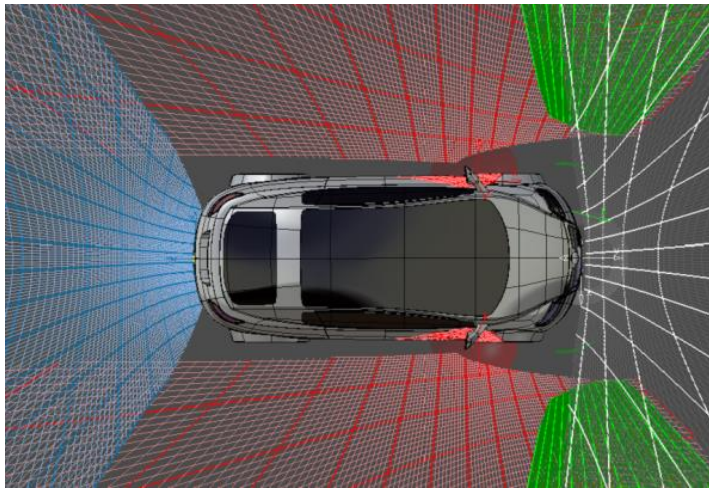
- Generating camera raw view of parking scenario
- Reducing visual artifacts (color matching, stitching)



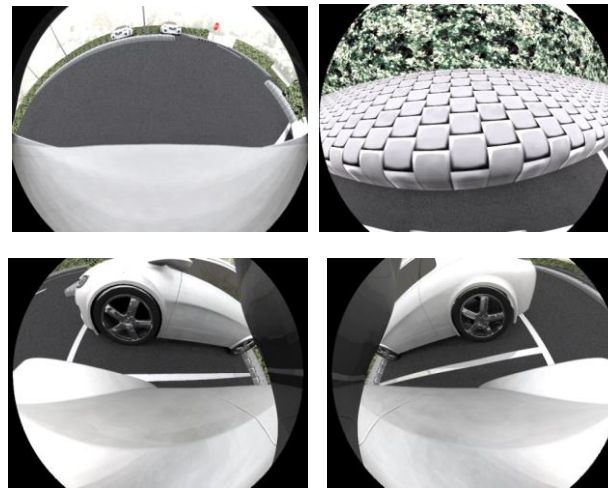
side mirror camera



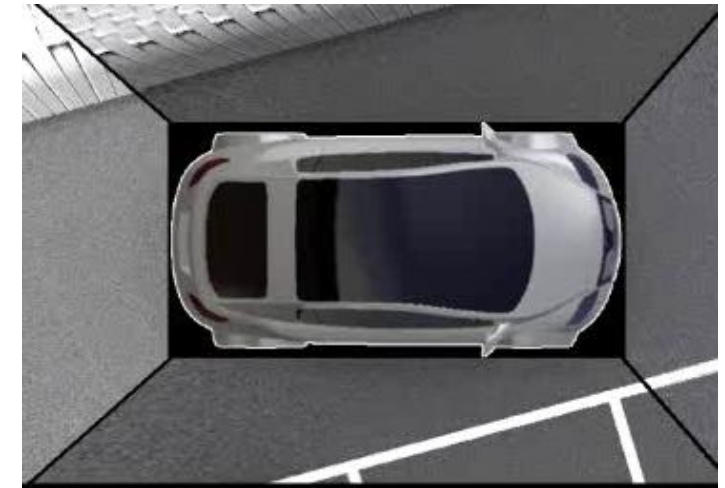
video: [youtube.com](https://www.youtube.com/watch?v=...)
BMW X3 3D Surround View



Interactive camera layout / Blind spot detection

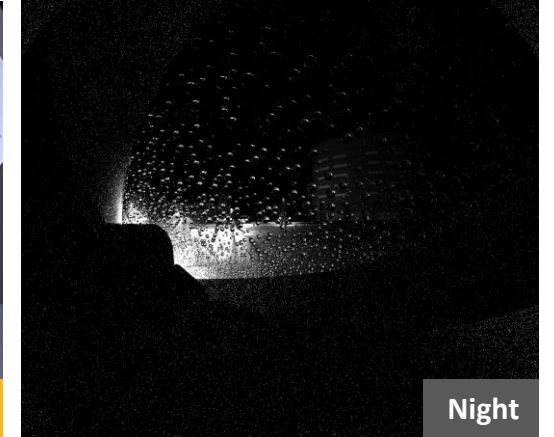
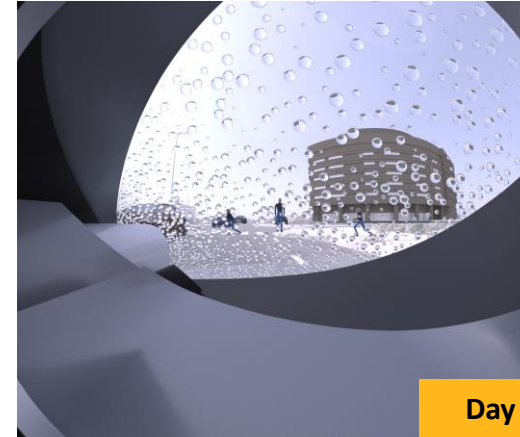
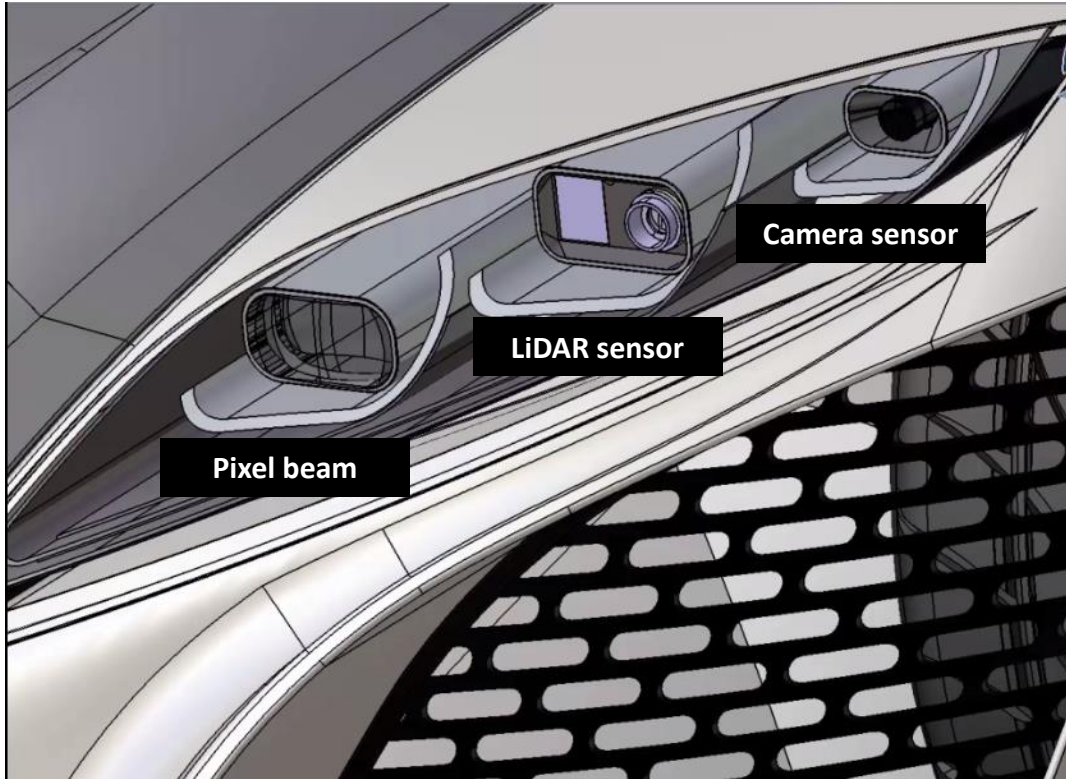


Individual camera raw views



Stitching processing

Customer example: 3M hydrophobic film



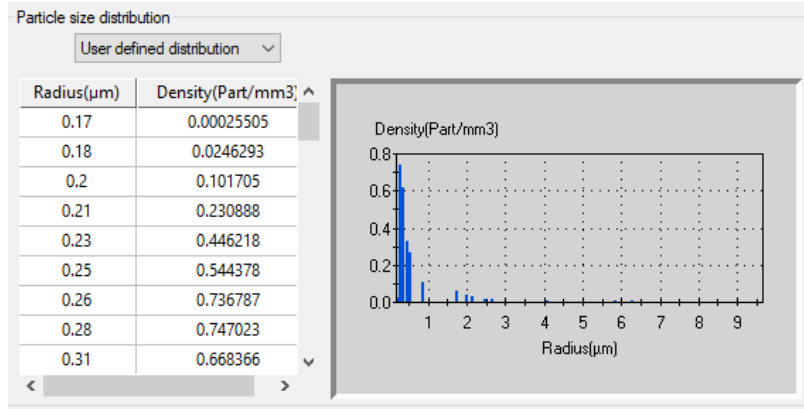
Headlamp outer lens with water droplet build-up



Headlamp outer lens with 3M hydrophobic film



Customer example: FLIR thermal camera



Particles density vs radius

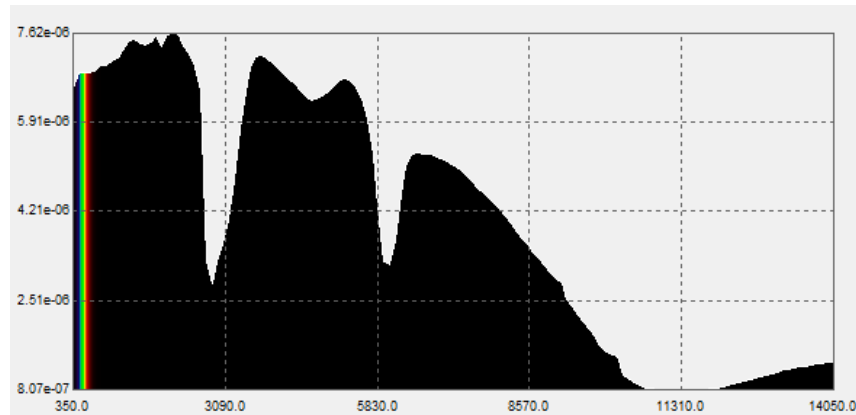


Visible camera (B&W)



FLIR camera (BOSON)

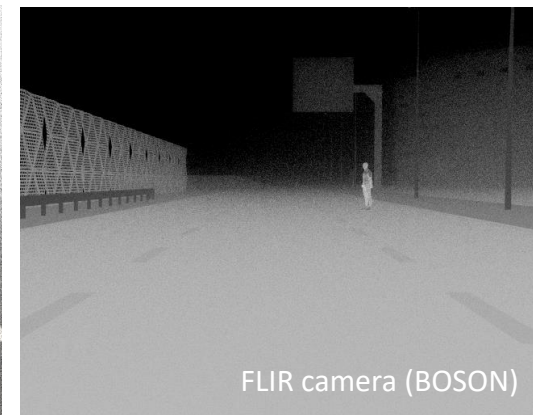
Night-time condition



Fog scattering



Visible camera (B&W)



FLIR camera (BOSON)

Heavy fog condition



/ Ansys & Flir Systems - Enhance Autonomous Vehicles Safety



**Why Autonomous Vehicles
Need Thermal Cameras**

Learn More



**Ansys & Flir Systems collaborate to deliver superior
hazard detection capabilities for future assisted
driving and autonomous vehicles (AVs)**

Learn More



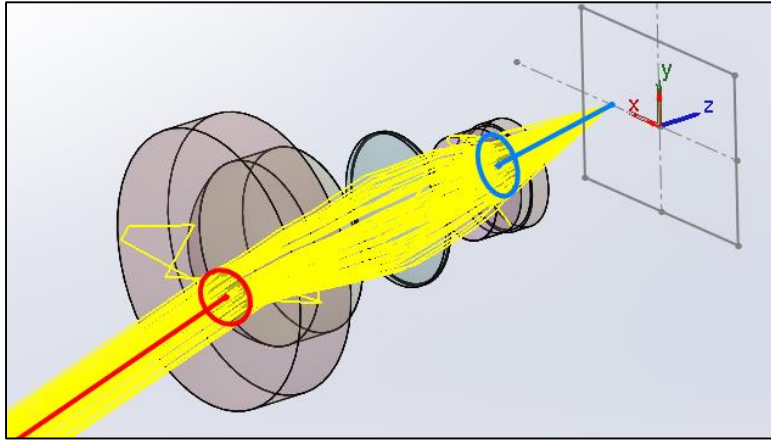
Ansys SPEOS Lens System

Ansys

Camera model enhancements

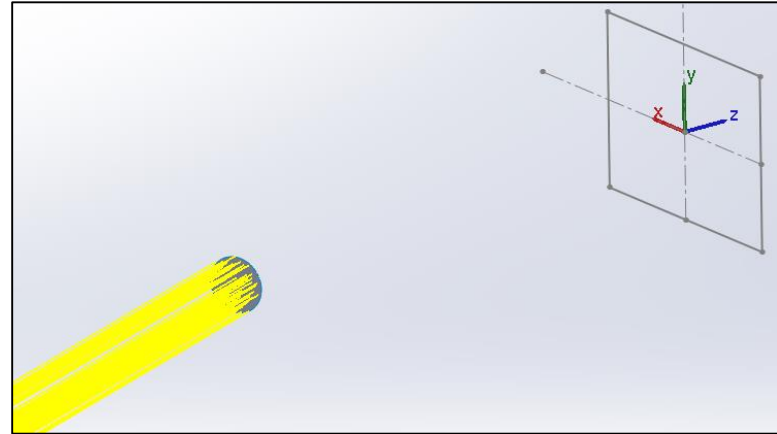
Requirements	Solutions
Process hundreds or thousands of variations with existing typical computational resources Dynamic scenarios, multiple test cases	Optimized camera model with adapted level of details Compatibility with distributed computing calculation running on HPC infrastructure
Calculate spectral irradiance distribution on image sensor to feed actual embedded image processing and get accurate outputs of detection/perception algorithm	Camera model extension with variable efficiency of lens system and variable entrance pupil size
Consider lens optical defects impacting image quality to virtually generate images for detection/perception algorithm testing in edge cases (low visibility, different operating temperature, ...)	Camera model extension with focus distance and resolution and simulating image sharpness losses (defocus, depth of field)
Assess field of view of wide-angle lenses with occulting parts in near field	Camera distortion model enhancement with variable entrance pupil position on & off-axis

Achievement: Performance gain

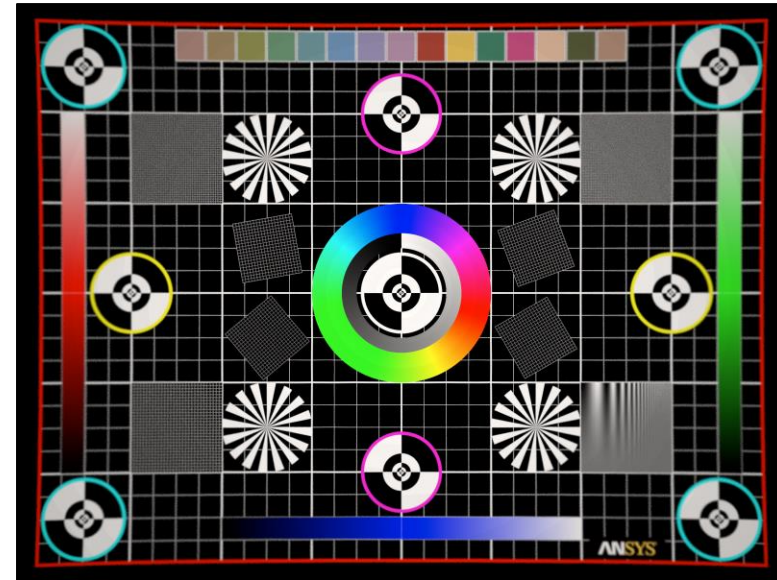
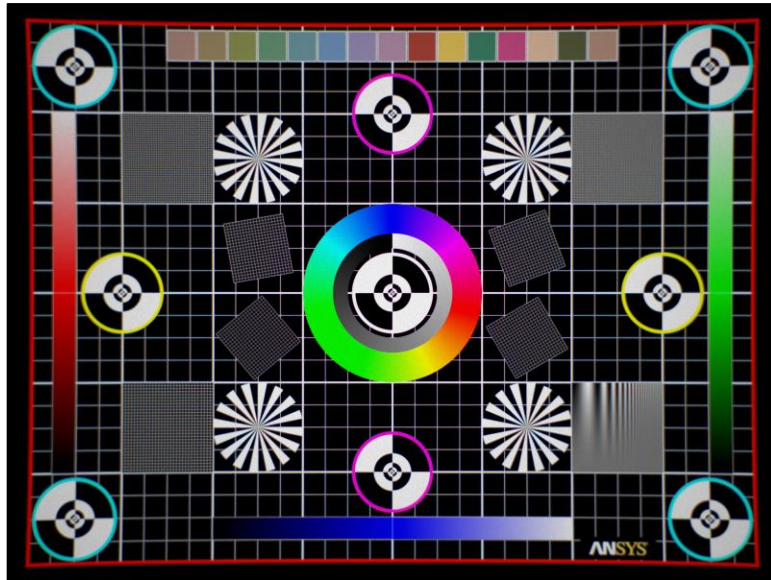


Rays propagation in detailed camera model

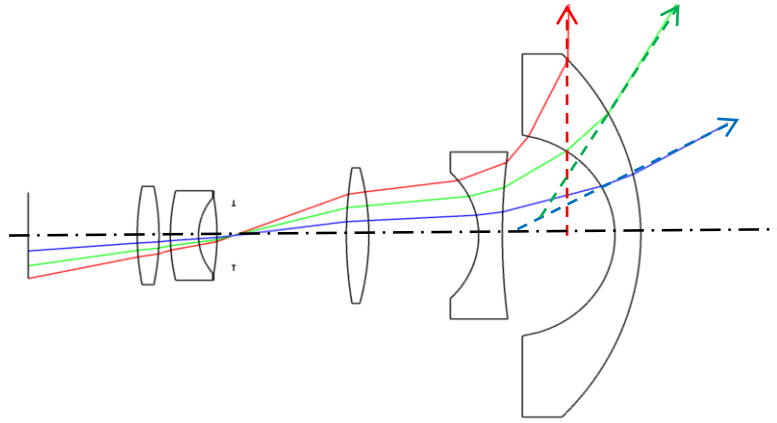
~100x



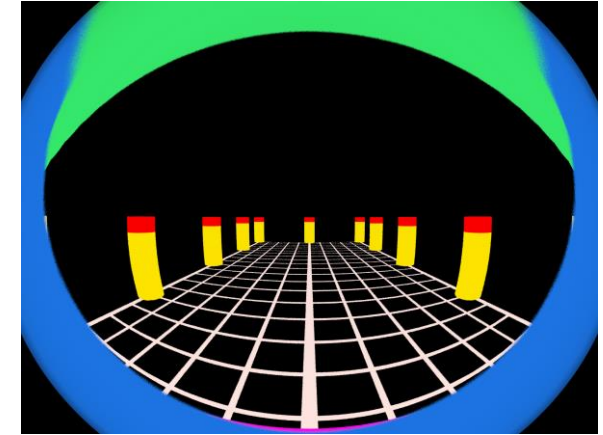
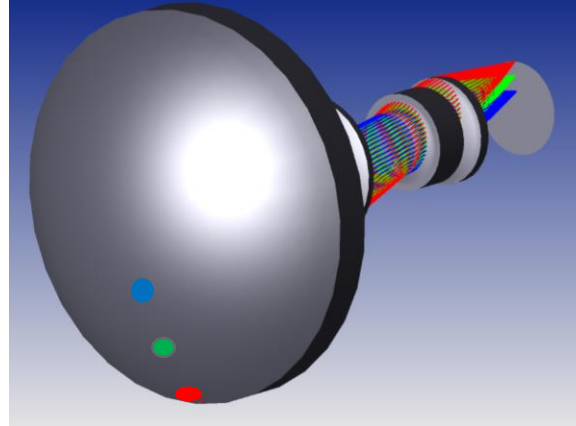
Rays propagation in simplified camera model



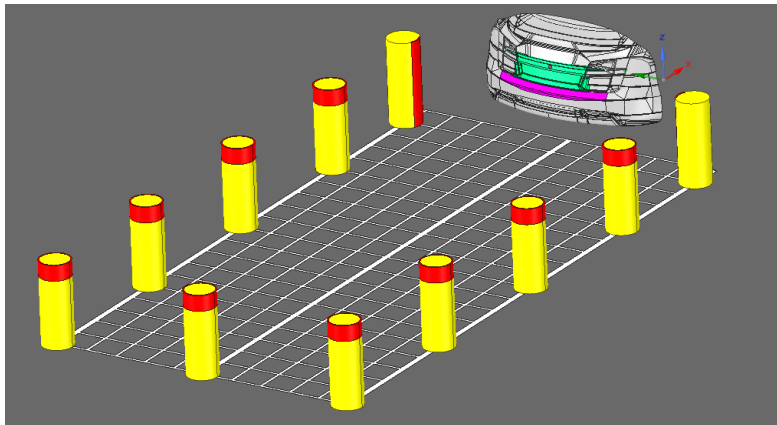
Achievement: Field of view evaluation with variable EPP



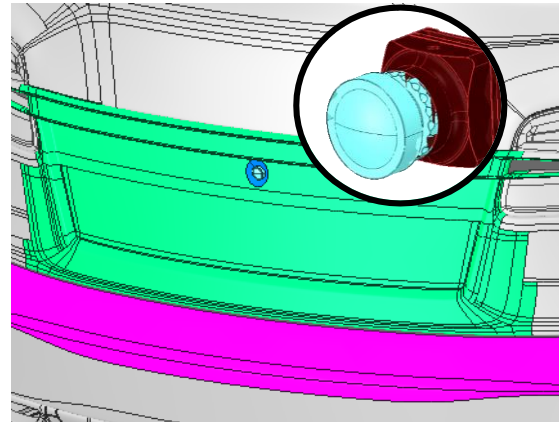
Fish-eye lens variable entrance pupil position and shape



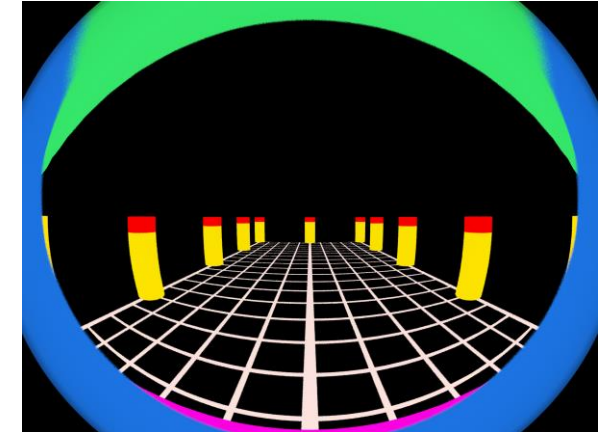
Field of view evaluation
Constant entrance pupil position



Test environment



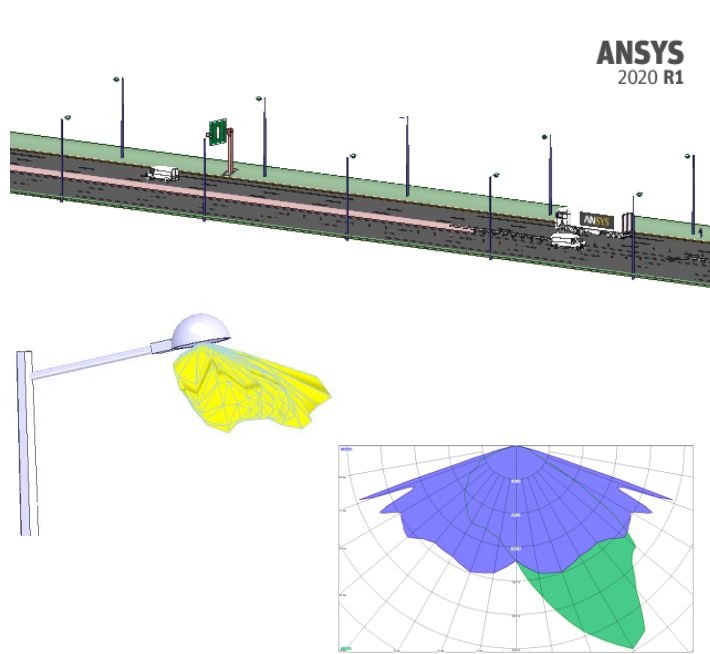
Backup camera mounting



Field of view evaluation
Variable entrance pupil position

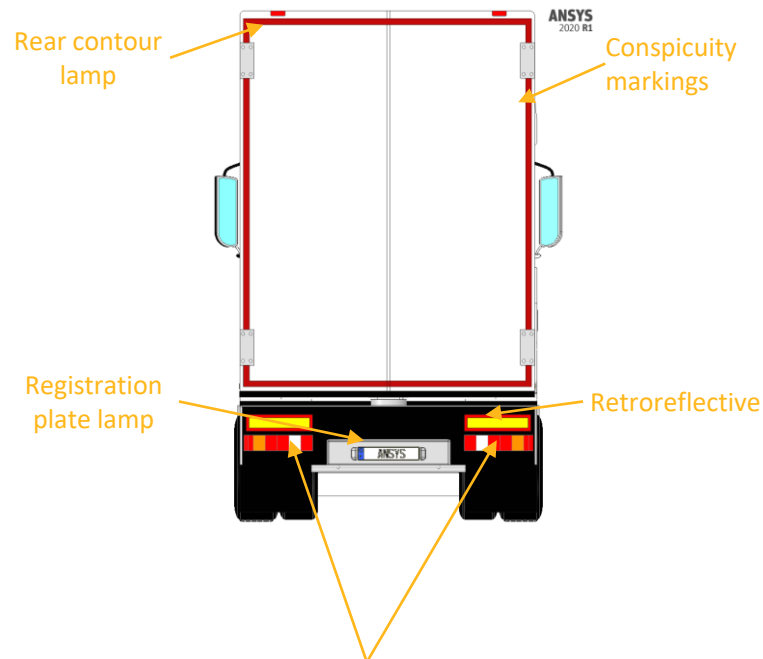
Achievement: performance vs. lighting conditions

Streetlights



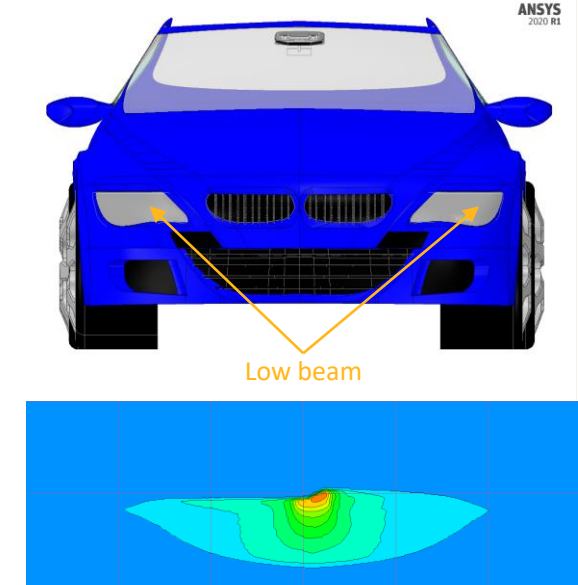
EN13201 Class	Luminance of the road surface of the carriageway (dry conditions)		
	Lm	Uo	Ul
MEW1	2.5cd/m ² ≥2.0 cd/m ²	0.9 ≥0.4	0.8 ≥0.6

Rear lamps



Rear fog 150cd	Reversing 80cd	Position 4cd	Stop lamp 60cd	Indicator lamp 50cd	Outline Marker lamp
UNECE ECE R38	UNECE ECE R23	UNECE ECE R7	UNECE ECE R7	UNECE ECE R6	UNECE ECE R7
Rear Fog Lamp	Reversing Lamp Manoeuvring Lamp	Position Lamp End Outline Marker Lamp Stop Lamp	Position Lamp End Outline Marker Lamp Stop Lamp	Direction Indicators	Position Lamp End Outline Marker Lamp Stop Lamp

Headlamps



ID	Name	Value	Units	Formula	Minimum	Maximum	Range	Maximum Specification	Minimum Specification	Range Specification
101	Average	2000.00	lm	100 (percent)	1000.0000	3000.0000	200.0%	100% (100%)	200.0%	200.0%
102	Average	1000.00	lm	50 (percent)	500.0000	1500.0000	150.0%	50% (50%)	150.0%	150.0%
103	Average	200.00	lm	10 (percent)	100.0000	300.0000	30.0%	10% (10%)	30.0%	30.0%
104	Average	50.00	lm	2.5 (percent)	25.0000	150.0000	15.0%	2.5% (2.5%)	15.0%	15.0%
105	Average	10.00	lm	0.5 (percent)	5.0000	50.0000	5.0%	0.5% (0.5%)	5.0%	5.0%
106	Average	2.00	lm	0.1 (percent)	1.0000	20.0000	2.0%	0.1% (0.1%)	2.0%	2.0%
107	Average	0.50	lm	0.025 (percent)	0.2500	5.0000	0.25%	0.025% (0.025%)	0.25%	0.25%
108	Average	0.10	lm	0.005 (percent)	0.0500	1.0000	0.05%	0.005% (0.005%)	0.05%	0.05%
109	Average	0.02	lm	0.001 (percent)	0.0100	0.2000	0.01%	0.001% (0.001%)	0.01%	0.01%
110	Average	0.005	lm	0.00025 (percent)	0.002500	0.050000	0.0025%	0.00025% (0.00025%)	0.0025%	0.0025%
111	Average	0.001	lm	0.00005 (percent)	0.000500	0.010000	0.0005%	0.00005% (0.00005%)	0.0005%	0.0005%
112	Average	0.0002	lm	0.00001 (percent)	0.000100	0.002000	0.0001%	0.00001% (0.00001%)	0.0001%	0.0001%
113	Average	0.00005	lm	0.0000025 (percent)	0.00002500	0.00050000	0.000025%	0.0000025% (0.0000025%)	0.000025%	0.000025%
114	Average	0.00001	lm	0.0000005 (percent)	0.00000500	0.00010000	0.000005%	0.0000005% (0.0000005%)	0.000005%	0.000005%
115	Average	0.000002	lm	0.0000001 (percent)	0.00000100	0.00002000	0.000001%	0.0000001% (0.0000001%)	0.000001%	0.000001%
116	Average	0.0000005	lm	0.000000025 (percent)	0.0000002500	0.0000050000	0.00000025%	0.000000025% (0.000000025%)	0.00000025%	0.00000025%
117	Average	0.0000001	lm	0.000000005 (percent)	0.0000000500	0.0000010000	0.00000005%	0.000000005% (0.000000005%)	0.00000005%	0.00000005%
118	Average	0.00000002	lm	0.000000001 (percent)	0.0000000100	0.0000002000	0.00000001%	0.000000001% (0.000000001%)	0.00000001%	0.00000001%
119	Average	0.000000005	lm	0.00000000025 (percent)	0.000000002500	0.000000050000	0.0000000025%	0.00000000025% (0.00000000025%)	0.0000000025%	0.0000000025%
120	Average	0.000000001	lm	0.00000000005 (percent)	0.000000000500	0.000000010000	0.0000000005%	0.00000000005% (0.00000000005%)	0.0000000005%	0.0000000005%
121	Average	0.0000000002	lm	0.00000000001 (percent)	0.000000000100	0.000000002000	0.0000000001%	0.00000000001% (0.00000000001%)	0.0000000001%	0.0000000001%
122	Average	0.00000000005	lm	0.0000000000025 (percent)	0.00000000002500	0.00000000050000	0.000000000025%	0.0000000000025% (0.0000000000025%)	0.000000000025%	0.000000000025%
123	Average	0.00000000001	lm	0.0000000000005 (percent)	0.00000000000500	0.00000000010000	0.000000000005%	0.0000000000005% (0.0000000000005%)	0.000000000005%	0.000000000005%
124	Average	0.000000000002	lm	0.0000000000001 (percent)	0.00000000000100	0.00000000002000	0.000000000001%	0.0000000000001% (0.0000000000001%)	0.000000000001%	0.000000000001%
125	Average	0.0000000000005	lm	0.000000000000025 (percent)	0.0000000000002500	0.0000000000050000	0.00000000000025%	0.000000000000025% (0.000000000000025%)	0.00000000000025%	0.00000000000025%
126	Average	0.0000000000001	lm	0.000000000000005 (percent)	0.0000000000000500	0.0000000000010000	0.00000000000005%	0.000000000000005% (0.000000000000005%)	0.00000000000005%	0.00000000000005%
127	Average	0.00000000000002	lm	0.000000000000001 (percent)	0.0000000000000100	0.0000000000002000	0.00000000000001%	0.000000000000001% (0.000000000000001%)	0.00000000000001%	0.00000000000001%
128	Average	0.000000000000005	lm	0.00000000000000025 (percent)	0.000000000000002500	0.000000000000050000	0.0000000000000025%	0.00000000000000025% (0.00000000000000025%)	0.0000000000000025%	0.0000000000000025%
129	Average	0.000000000000001	lm	0.00000000000000005 (percent)	0.000000000000000500	0.000000000000010000	0.0000000000000005%	0.00000000000000005% (0.00000000000000005%)	0.0000000000000005%	0.0000000000000005%
130	Average	0.0000000000000002	lm	0.00000000000000001 (percent)	0.000000000000000100	0.000000000000002000	0.0000000000000001%	0.00000000000000001% (0.00000000000000001%)	0.0000000000000001%	0.0000000000000001%
131	Average	0.00000000000000005	lm	0.0000000000000000025 (percent)	0.00000000000000002500	0.00000000000000050000	0.000000000000000025%	0.0000000000000000025% (0.0000000000000000025%)	0.000000000000000025%	0.000000000000000025%
132	Average	0.00000000000000001	lm	0.0000000000000000005 (percent)	0.00000000000000000500	0.00000000000000010000	0.000000000000000005%	0.0000000000000000005% (0.0000000000000000005%)	0.000000000000000005%	0.000000000000000005%
133	Average	0.000000000000000002	lm	0.0000000000000000001 (percent)	0.00000000000000000100	0.00000000000000002000	0.000000000000000001%	0.0000000000000000001% (0.0000000000000000001%)	0.000000000000000001%	0.000000000000000001%
134	Average	0.0000000000000000005	lm	0.000000000000000000025 (percent)	0.0000000000000000002500	0.0000000000000000050000	0.00000000000000000025%	0.000000000000000000025% (0.000000000000000000025%)	0.00000000000000000025%	0.00000000000000000025%
135	Average	0.0000000000000000001	lm	0.000000000000000000005 (percent)	0.0000000000000000000500	0.0000000000000000010000	0.00000000000000000005%	0.000000000000000000005% (0.000000000000000000005%)	0.00000000000000000005%	0.00000000000000000005%
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138	Average	0.000000000000000000001	lm	0.00000000000000000000005 (percent)	0.000000000000000000000500	0.000000000000000000010000	0.0000000000000000000005%	0.00000000000000000000005% (0.00000000000000000000005%)	0.0000000000000000000005%	0.0000000000000000000005%
139	Average	0.0000000000000000000002	lm	0.00000000000000000000001 (percent)	0.000000000000000000000100	0.000000000000000000002000	0.0000000000000000000001%	0.00000000000000000000001% (0.00000000000000000000001%)	0.0000000000000000000001%	0.0000000000000000000001%
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143	Average	0.0000000000000000000000005	lm	0.000000000000000000000000025 (percent)	0.0000000000000000000000002500	0.0000000000000000000000050000	0.00000000000000000000000025%	0.000000000000000000000000025% (0.000000000000000000000000025%)	0.00000000000000000000000025%	0.00000000000000000000000025%
144	Average	0.0000000000000000000000001	lm	0.000000000000000000000000005 (percent)	0.0000000000000000000000000500	0.0000000000000000000000010000	0.00000000000000000000000005%	0.000000000000000000000000005% (0.000000000000000000000000005%)	0.00000000000000000000000005%	0.00000000000000000000000005%
145	Average	0.00000000000000000000000002	lm	0.000000000000000000000000001 (percent)	0.0000000000000000000000000100	0.0000000000000000000000002000	0.00000000000000000000000001%	0.000000000000000000000000001% (0.000000000000000000000000001%)	0.00000000000000000000000001%	0.00000000000000000000000001%
146	Average	0.000000000000000000000000005	lm	0.00000000000000000000000000025 (percent)	0.000000000000000000000000002500	0.000000000000000000000000050000	0.0000000000000000000000000025%	0.00000000000000000000000000025% (0.00000000000000000000000000025%)	0.0000000000000000000000000025%	0.0000000000000000000000000025%
147	Average	0.000000000000000000000000001	lm	0.00000000000000000000000000005 (percent)	0.000000000000000000000000000500	0.000000000000000000000000010000	0.0000000000000000000000000005%	0.00000000000000000000000000005% (0.00000000000000000000000000005%)	0.0000000000000000000000000005%	0.0000000000000000000000000005%
148	Average	0.0000000000000000000000000002	lm	0.00000000000000000000000000001 (percent)	0.000000000000000000000000000100	0.000000000000000000000000002000	0.0000000000000000000000000001%	0.00000000000000000000000000001% (0.00000000000000000000000000001%)	0.0000000000000000000000000001%	0.0000000000000000000000000001%
149	Average	0.00000000000000000000000000005	lm	0.0000000000000000000000000000025 (percent)	0.000000000000000000000000002500	0.000000000000000000000000050000	0.000000000000000000000000000025%	0.0000000000000000000000000000025% (0.000000000000		

/ Achievement: performance vs. lighting conditions

1.2-megapixels
Day-time, clear condition
~15 core.h / image



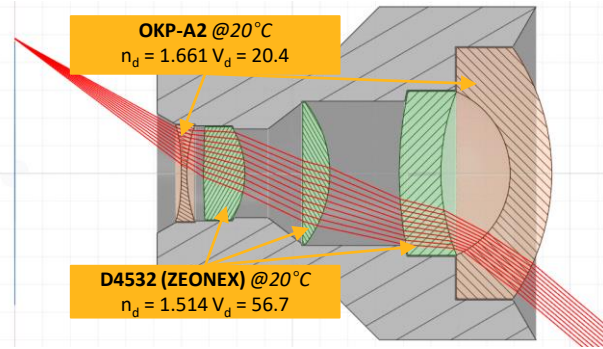
1.2-megapixels
Day-time, fog condition
~50 core.h / image



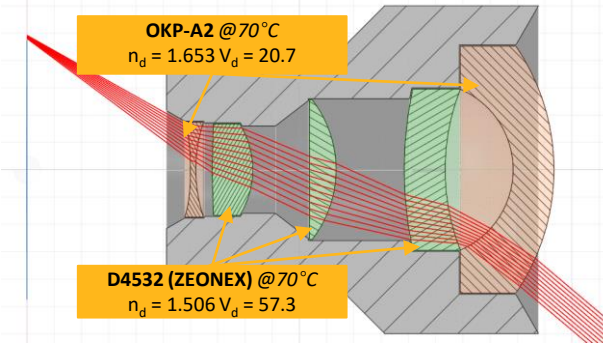
1.2-megapixels
Night-time, clear condition
~100 core.h / image



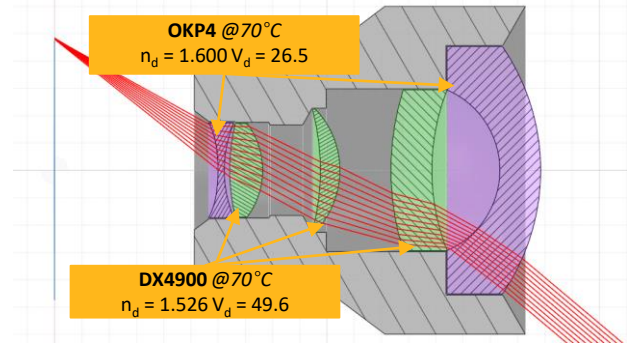
Achievement: sharpness vs. operating temperature



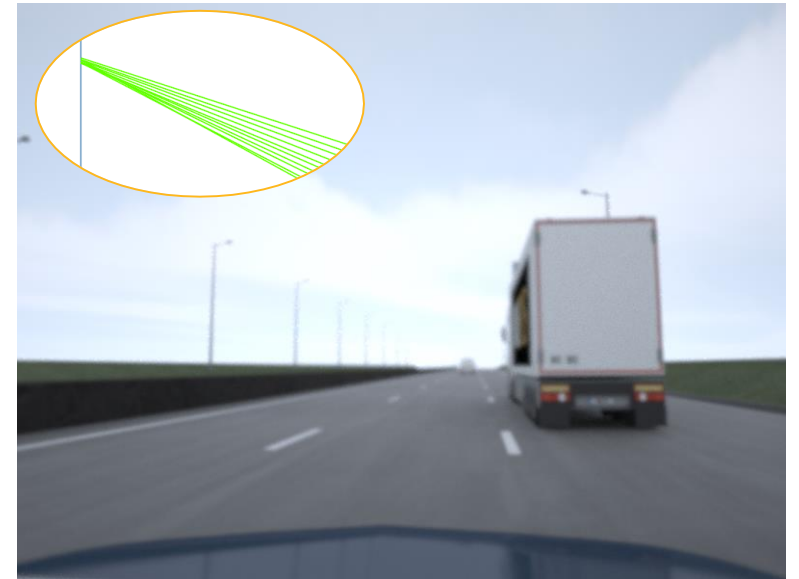
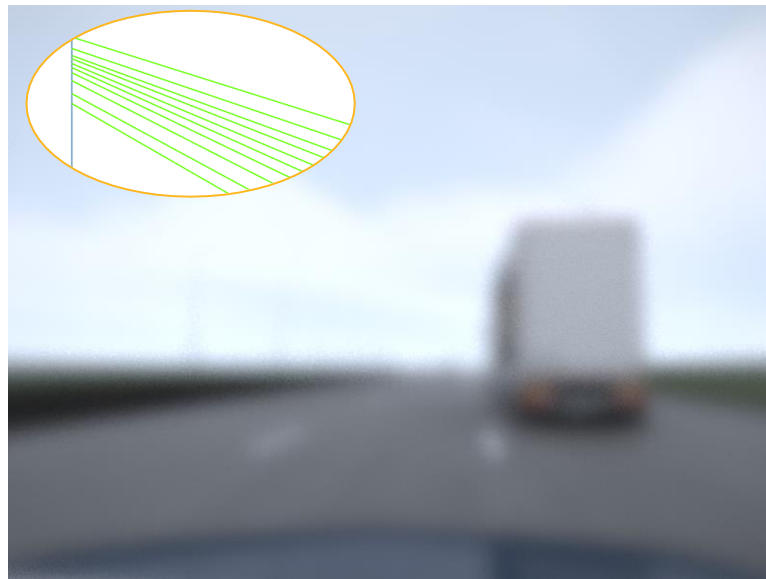
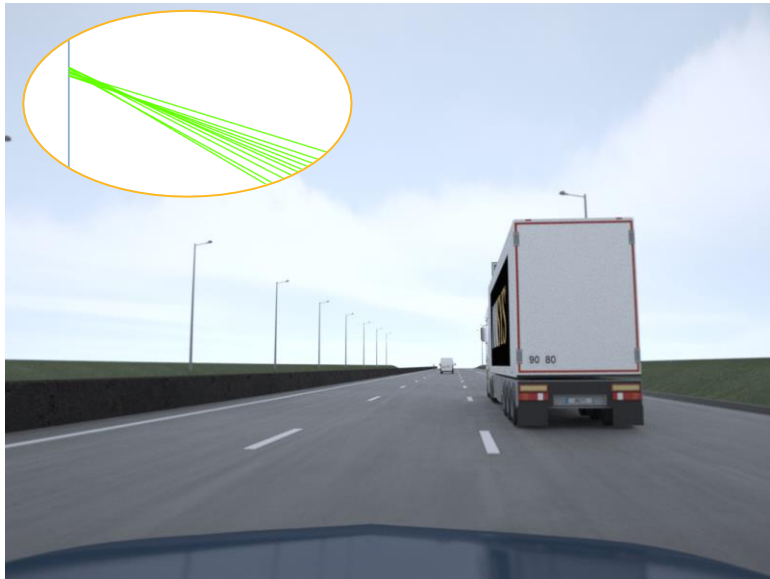
Plastic lens @20°C



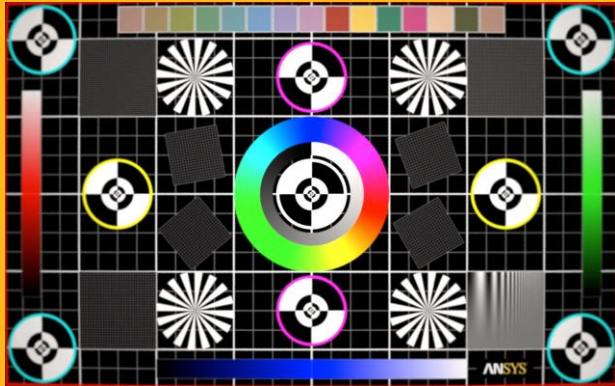
Plastic lens @70°C



Redesigned plastic lens @70°C



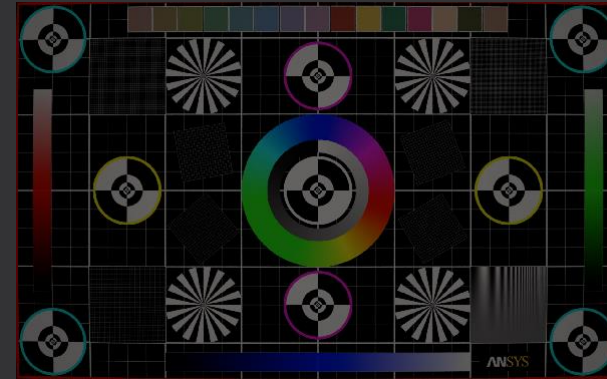
Achievement: sharpness vs. lens aperture



full aperture - $f/\# = 1.8$



blurred image
higher irradiance (less motion blur)



reduced aperture - $f/\# = 5.6$

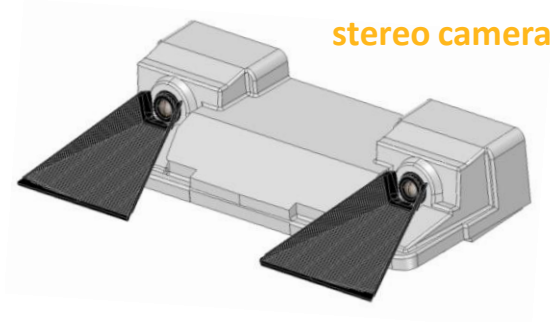


sharper image
lower irradiance (more motion blur)

Achievement: Scalability on dynamic scenario



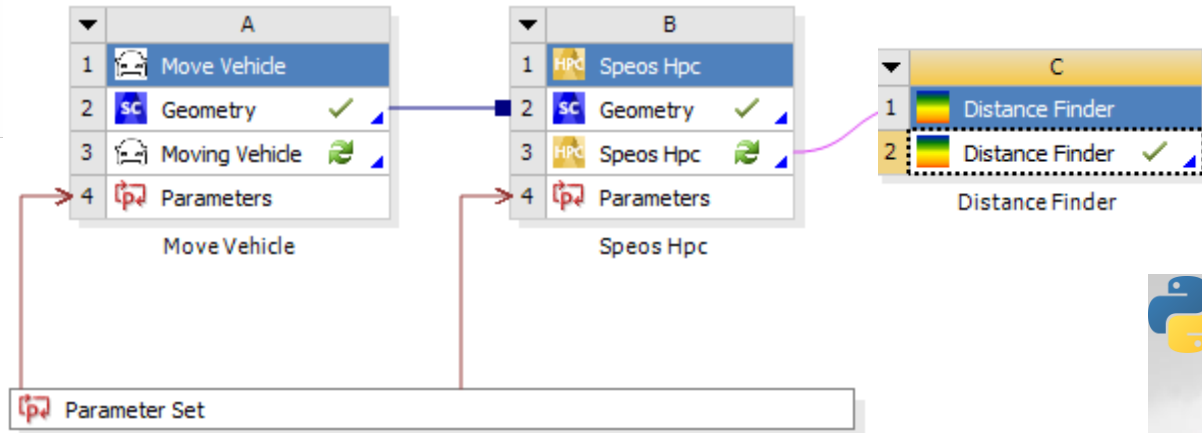
Trajectories



stereo camera



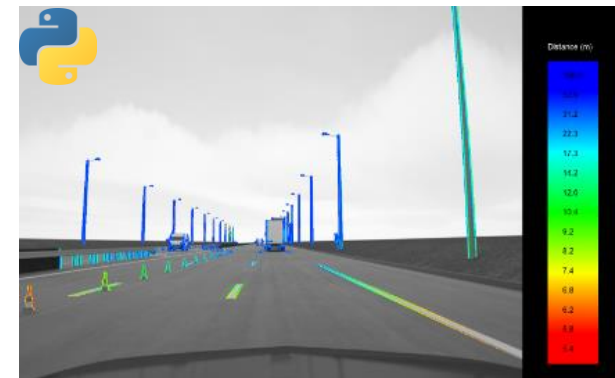
left & right camera raw view



WB of Design Points

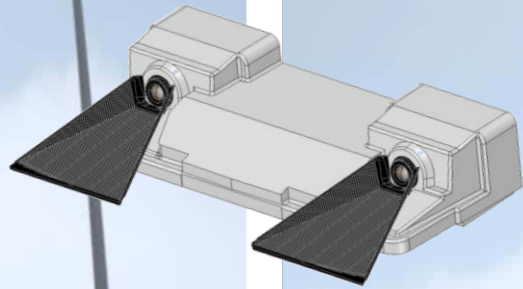
	A	B	C	D
1	Name	P1 - VUT_Position	<input type="checkbox"/> Retain	Retained Data
2	DP 0 (Current)	0.1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
3	DP 1	0.2	<input type="checkbox"/>	<input type="checkbox"/>
4	DP 2	0.3	<input type="checkbox"/>	<input type="checkbox"/>
5	DP 3	0.4	<input type="checkbox"/>	<input type="checkbox"/>

table of design points



distance detection

/ Achievement: Scalability on dynamic scenario



Achievement: Scalability on dynamic scenario

150 rays / pixels

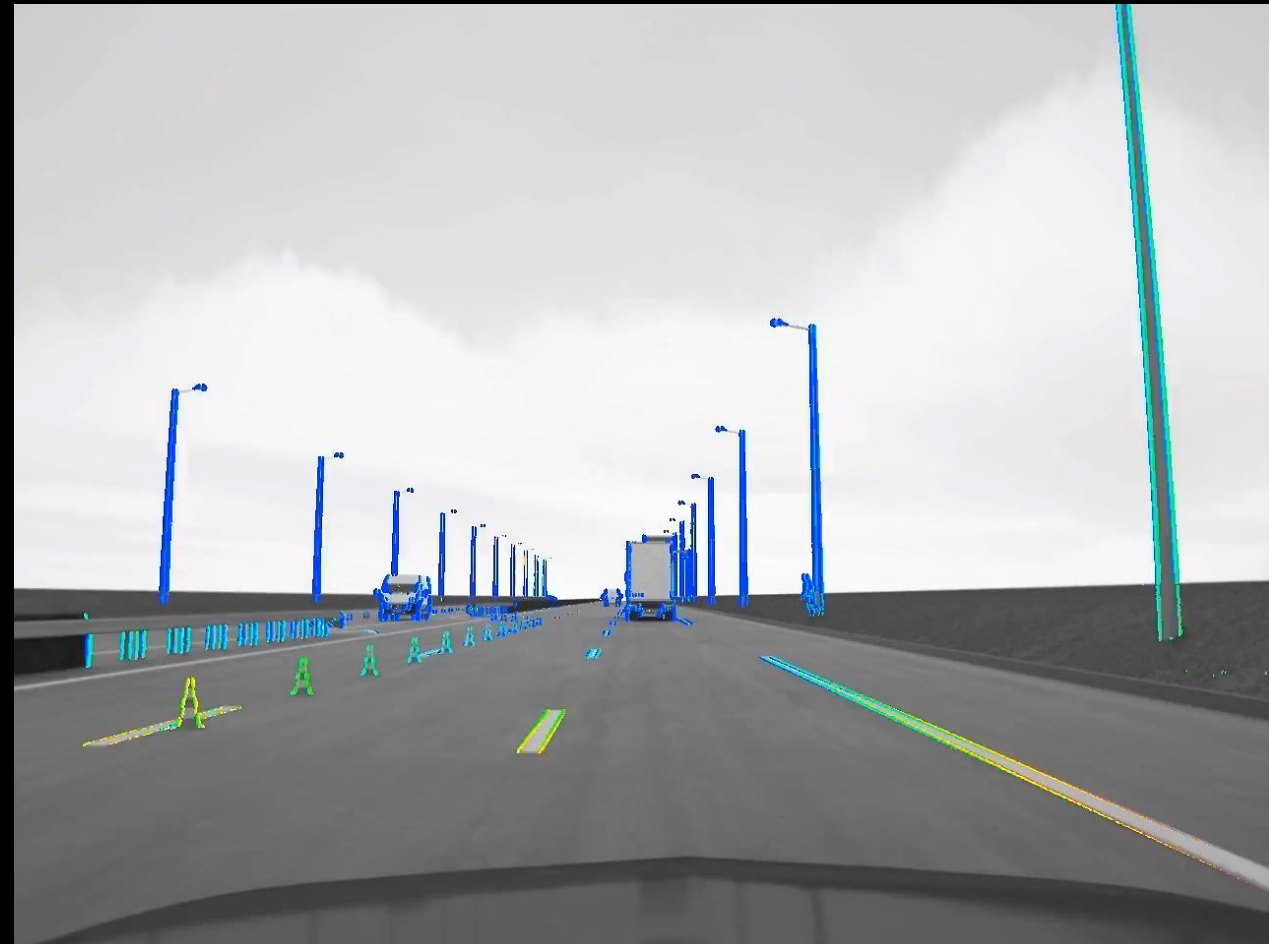
~2.5-megapixel (2 x 1280 x 960 pixels)

~10 core.h / image

300+ images (~10 s @ 30 fps)

256-core cluster: ~12 h

1024-core cluster: ~3 h



Distance (m)





Ansys SPEOS and Zemax OpticStudio interoperability

Ansys

Anslys and Zemax: Drive Autonomous Vehicle Optical Sensor Development

Anslys | B L O G



Learn More on the
Anslys and Zemax Partnership

“

Anslys offers the automated execution of simulation plans to solve complex problems in the design of autonomous vehicles. The end-to-end optical testing solution from Anslys and Zemax enables us to exchange optical transfer functions – which determines the quality of the projected image – while protecting our sensitive design data. This workflow will empower our team to explore new camera designs faster, cheaper and with less risk.

”

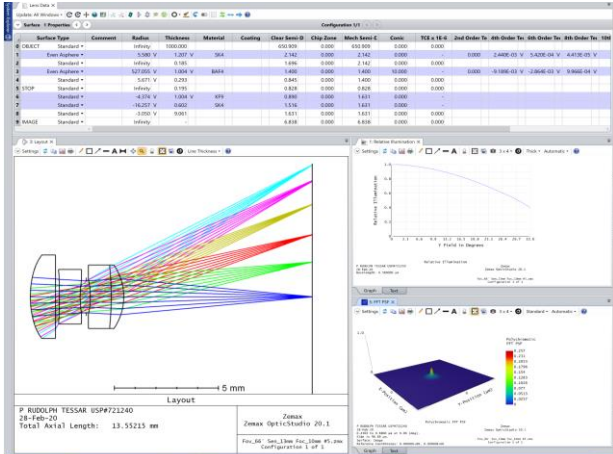
Konrad Rothenhäusler, design for Six Sigma Coach,
ADAS business unit at **Continental**



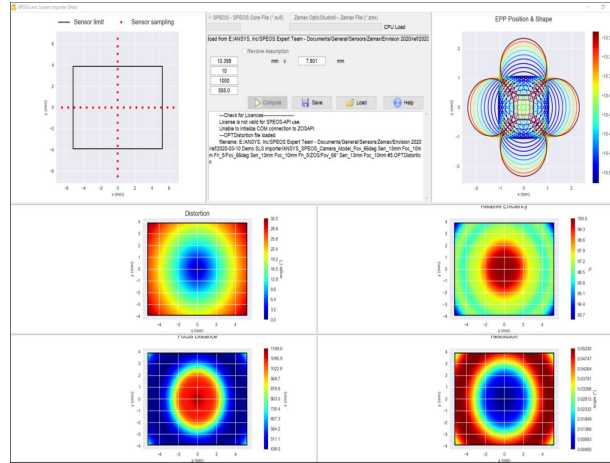
Workflow enhancements

Requirements	Solutions
Productivity increase to avoid detailed optical system remodeling in Ansys SPEOS	SPEOS Lens System creation from Zemax OpticStudio model using ZOS API
Collaboration workflow between Zemax OpticsStudio and Ansys SPEOS protecting lens optical design Intellectual Properties	Data exchange based on Zemax blackbox mechanism or SPEOS lens System

Collaboration workflows



Lens design



SPEOS Lens System Importer



Camera simulation

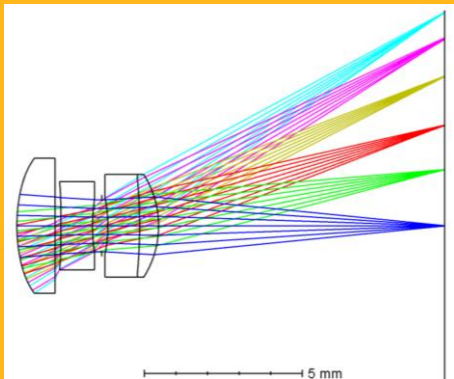


/ SPEOS Lens System Importer licensing



Premium

to process lens system file
from Zemax OpticStudio



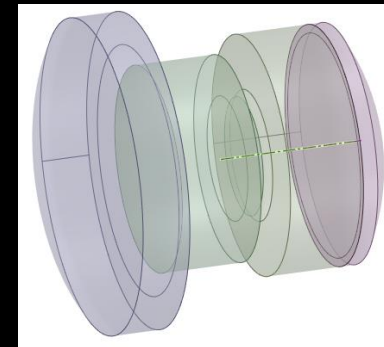
OR



SPEOS

Pro

to process lens system file
from Ansys SPEOS



SPEOS Lens System Importer UI

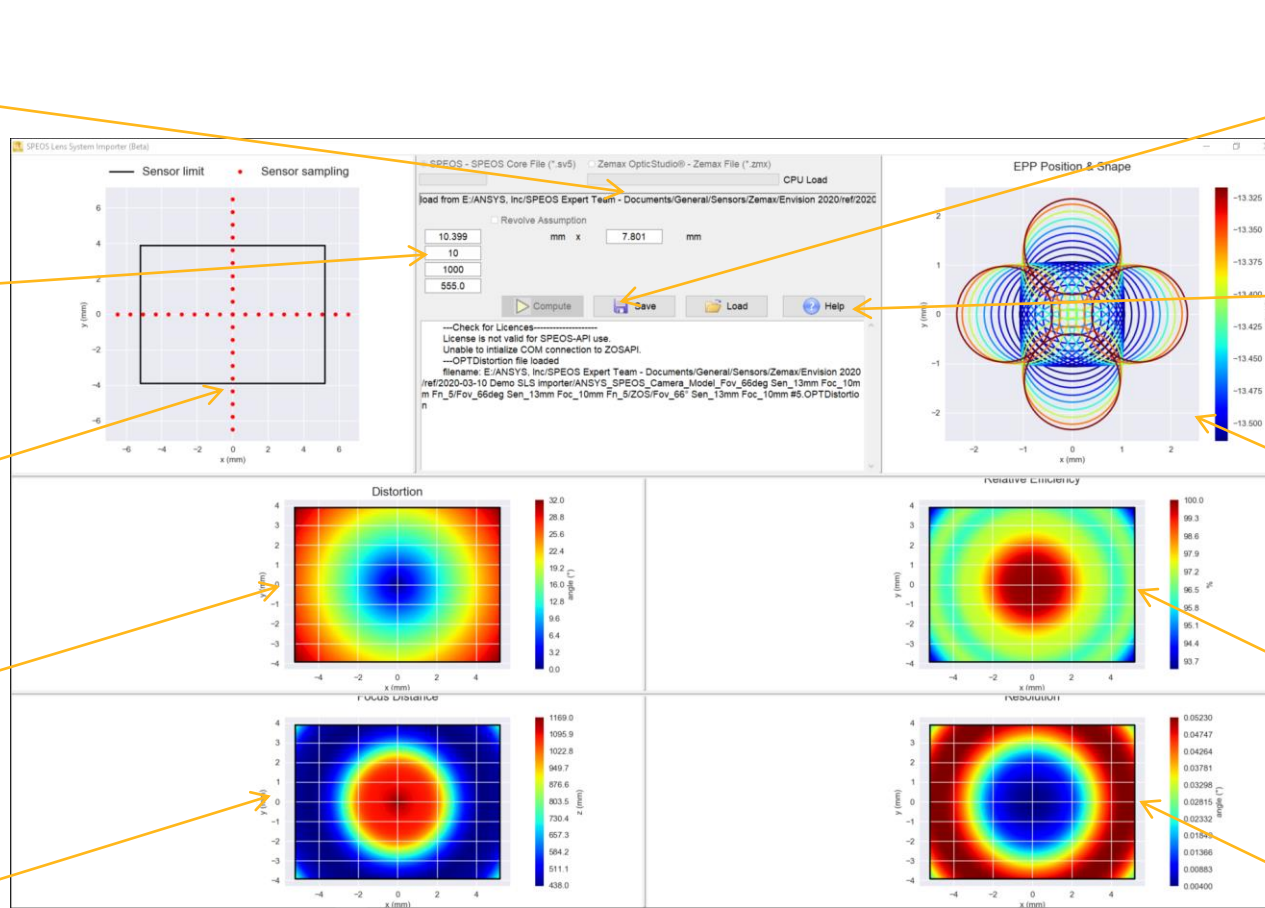
ZOS or SPEOS input file

Processing parameters

Imager sampling

Distortion

Focus distance



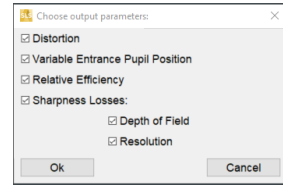
Commands

User guide

Entrance pupil

Relative efficiency

Resolution





Recycle Bin



LENS.ZMX



ANSYS SSO



Approved Softwar...



ANSYS Employee ...



Use Case - Rear Park ...



OpticStudio

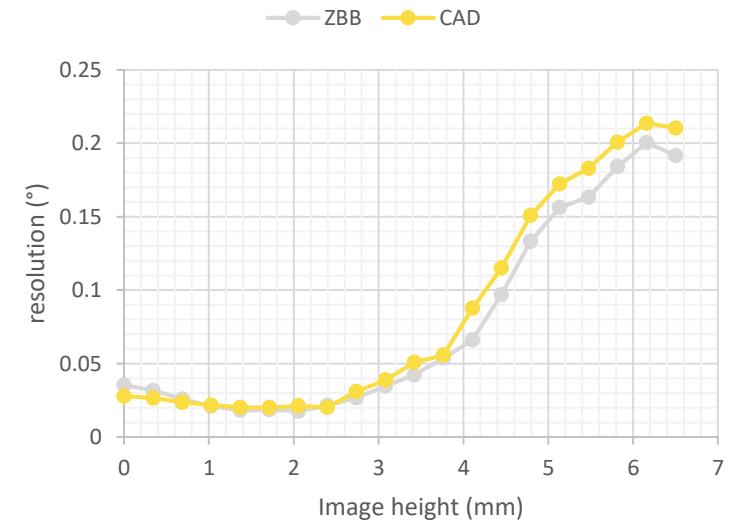
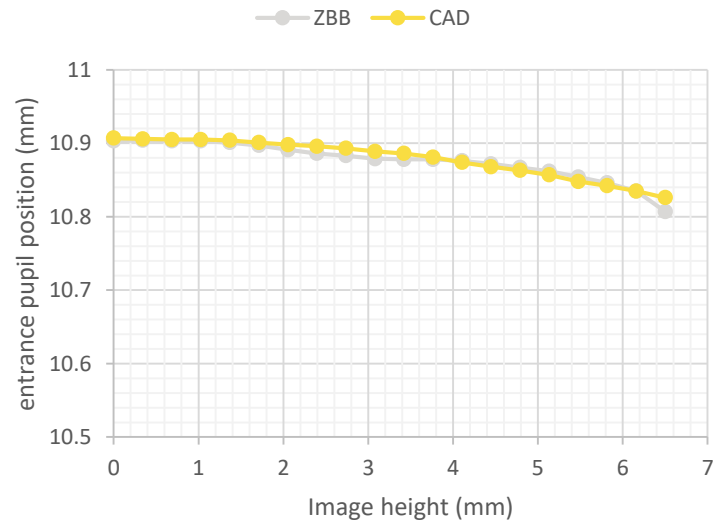
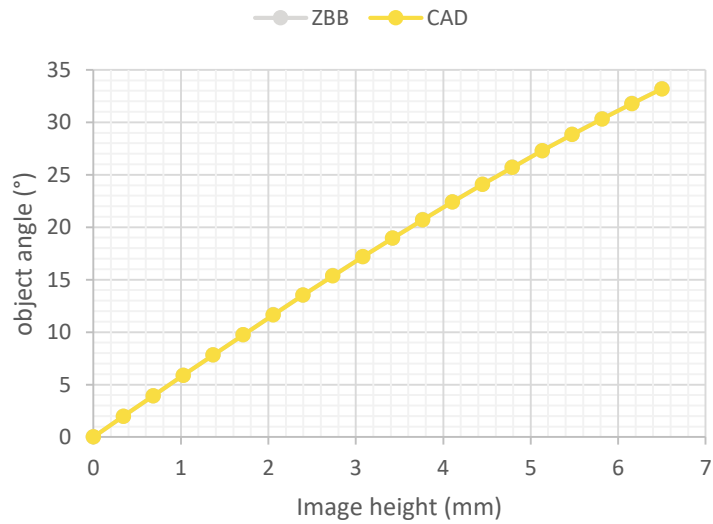
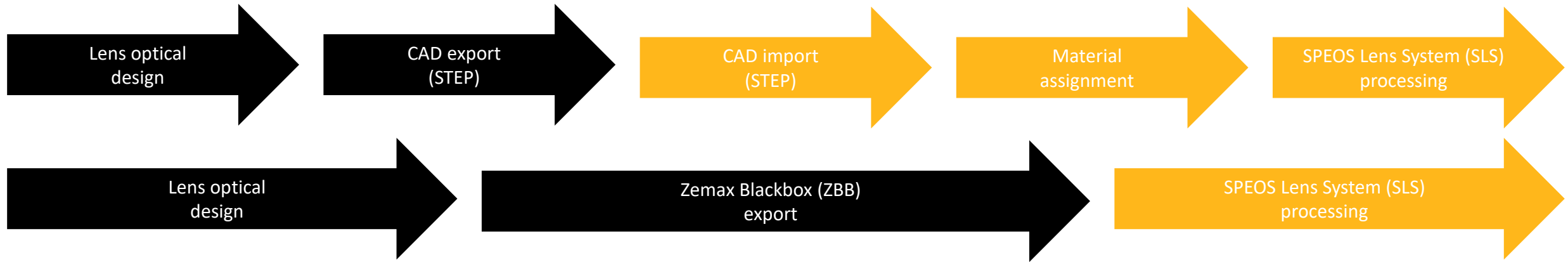


SPEOS Lens system Im...

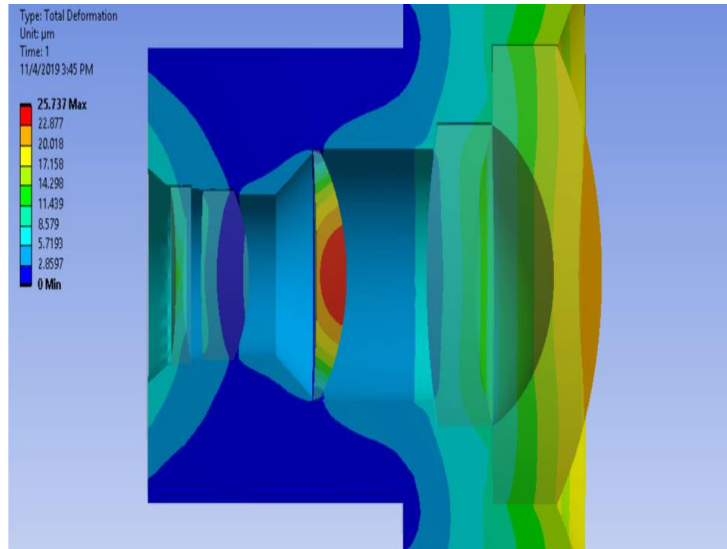


ANSYS SPEOS 2020 R1

Workflows comparison



Work in progress



SPEOS Lens System capability



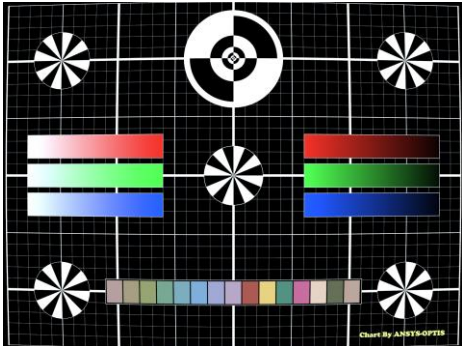
SPEOS Lens System use case

Interoperability with Ansys Mechanical for Structural Thermal Optical Performance (STOP) analysis

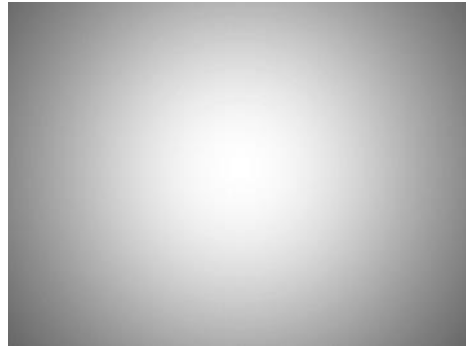
Application for mobile lens camera to support image processing development

SPEOS Lens System: Scalable camera model adapted for edge cases requiring **full-physics radiometric simulation** in 3D environment

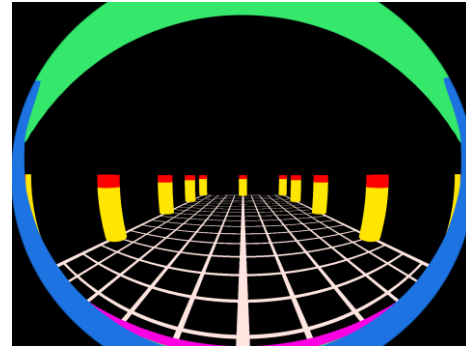
Distortion



Vignetting



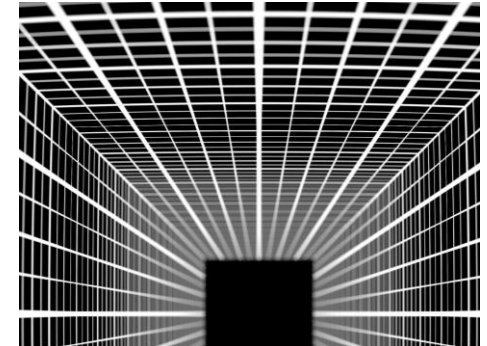
Entrance pupil position



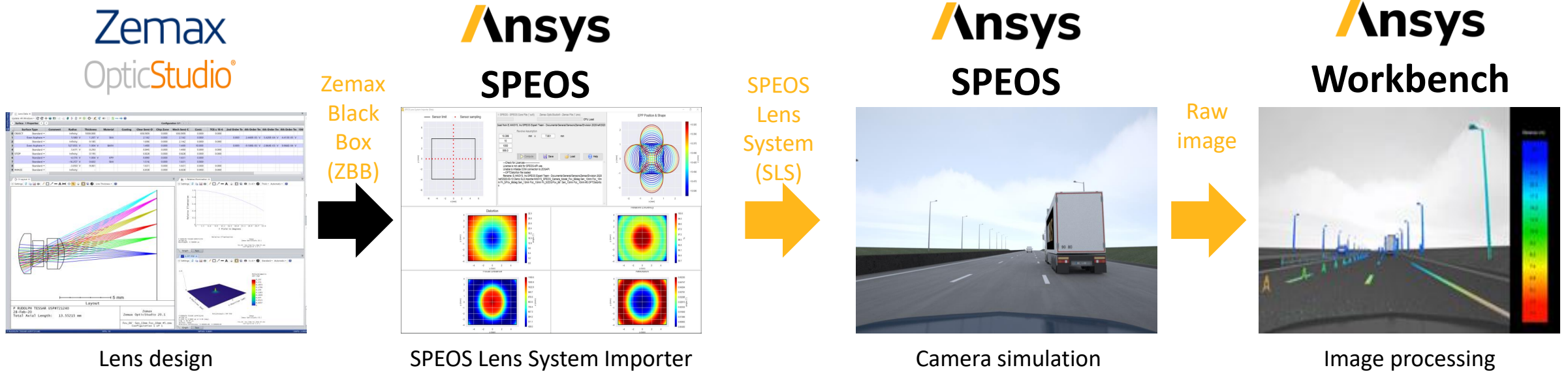
Resolution



Focus



SPEOS Lens System Importer: Interoperability between Ansys SPEOS and Zemax OpticStudio for collaboration workflow protecting optical design Intellectual Properties



 **Ansys**

