Hochschule Pforzheim – Pforzheim University
Fakultät für Technik - School of Engineering

HS PF

Optische Messmethoden für Komponentenoptimierung und für Displays / LEDs

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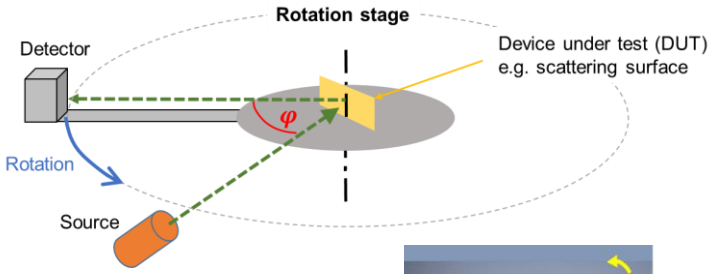
Optical Measurement & Design: Overview & Competences

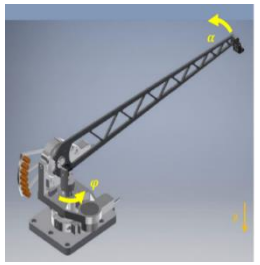
- **Optical metrology**:
  - Light scattering measurements
  - Angular light distribution for fibers, light distributions of LEDS
  - Intensity (xy-) distribution measurements for laser & lamp characterization, DOEs
- **Electronics:**
  - Development of electronic amplifiers to magnify low level light from photodiodes
- **Machine Vision**:
  - Camera calibration using python → new & objective measures and methods
  - Measurements with cameras
- **Optical Design**:
  - Ray optics simulations with ZEMAX
  - Diffractive optics design

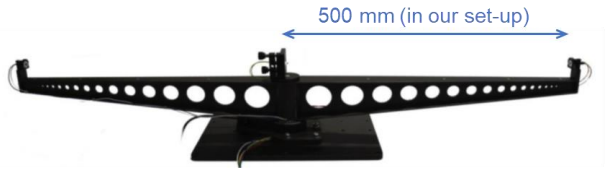
We measure, prototype and/or evaluate your optical idea!

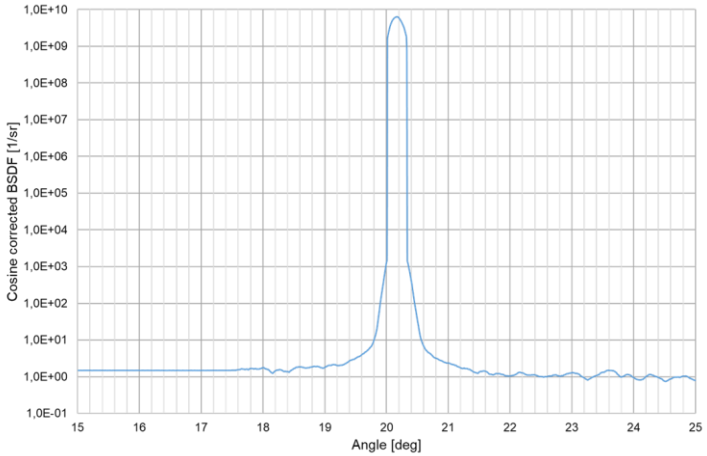
Optical metrology: light scattering measurements

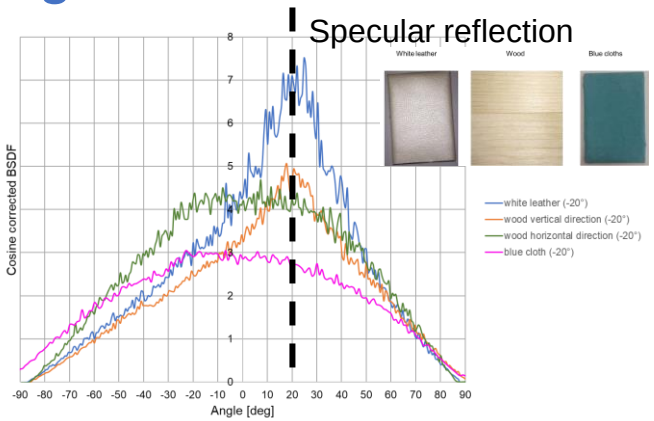
- **Goniophotometer set-up**:
  - Single angle device (360°)
  - Two angle (half-sphere) device
- **Fully computer controlled**
- Located inside a dark room
- **Results**:
  - Dynamic range: ~ 10 decades
  - Accuracy: < 0.08% 2 standard deviation
- **Stray light characterization of different materials**





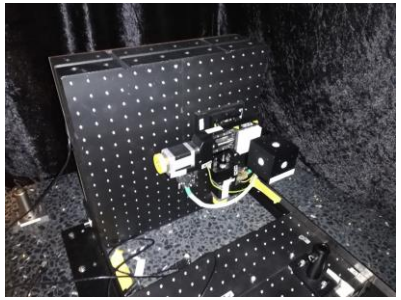






Development and improvement of a photonics instrument for light scattering metrology
https://doi.org/10.1117/12.2608504, Proceedings SPIE 12008, 2022

Optical metrology: light (xy-) distribution measurements

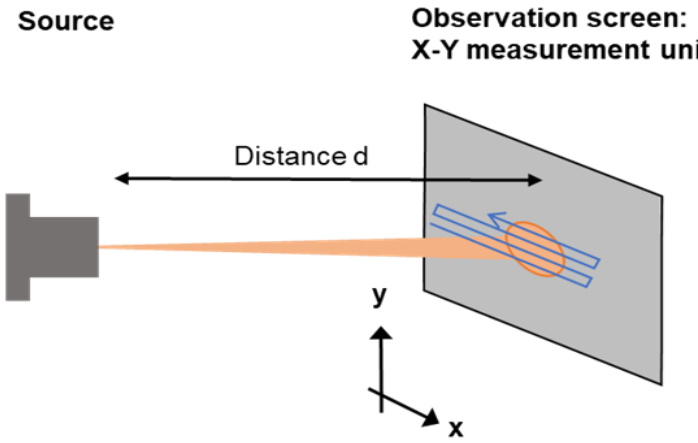


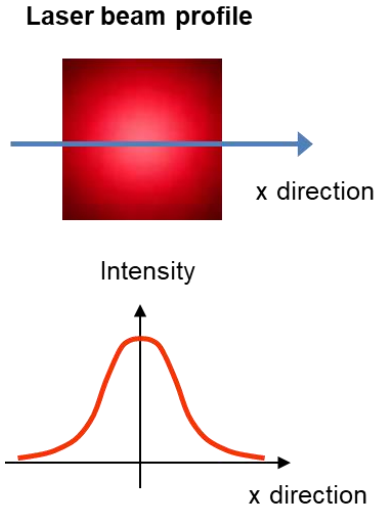
➢ Set-up:

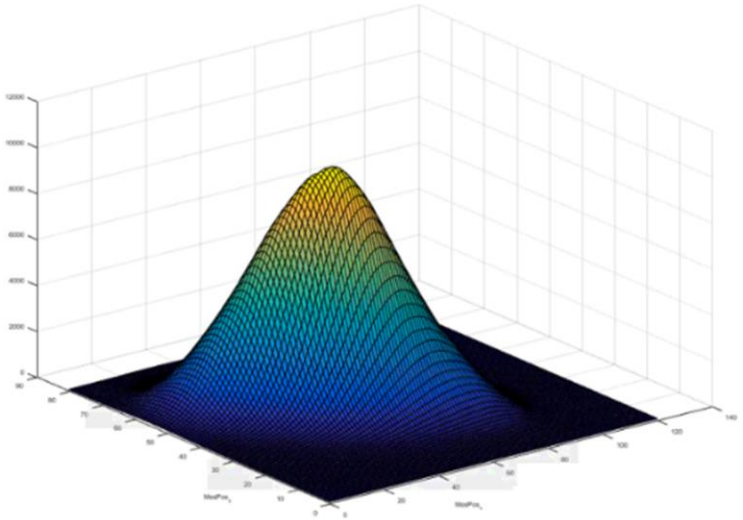
- XY table

➢ Specifications:

Specification	Value
Max. scan area in x-direction	52.0 mm
Max. scan area in y-direction	52.0 mm
Lowest step size Δx in x-direction	0.2 µm
Lowest step size Δy in y-direction	0.2 µm
Unidirectional repeatability	0.5 µm
Aperture (in front of photodiode)	Ø >0.2 mm
Detector wavelength	400 nm … 1000nm
Measurement accuracy (2 sigma)	< 0.29%
Automation	Fully







➢ Applications:

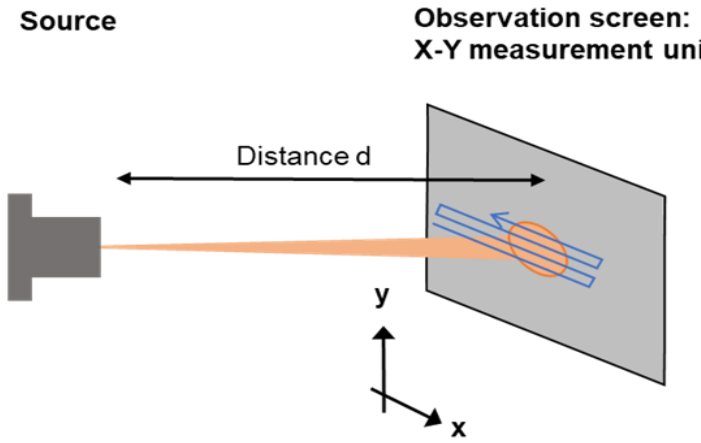
- Light distribution measurements
- M^2 measurements (laser)
- Numerical aperture
- DOE spot characterization

Zuverlässigkeitsanalyse einer ortsaufgelösten Intensitätsmessung mittels eines voll-automatisierten x-y-Verschiebetisches
DGaO Proceedings 2019 – http://www.dgao-proceedings.de – ISSN: 1614-8436 – urn:nbn:de:0287-2019-P026-7

Optical metrology: measurements on diffractive optics

- **Set-up**: XY-Table

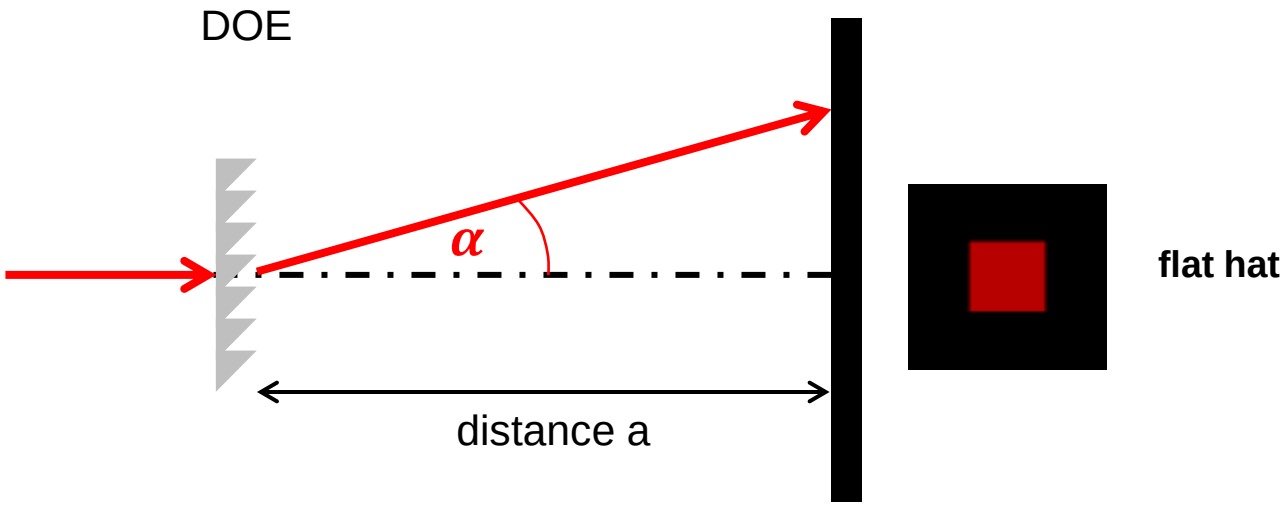
- **Principle**:
  - Measure power inside region-of-interest (ROI)
  - Measure total diffracted power
  - Get diffraction efficiency



Observation screen

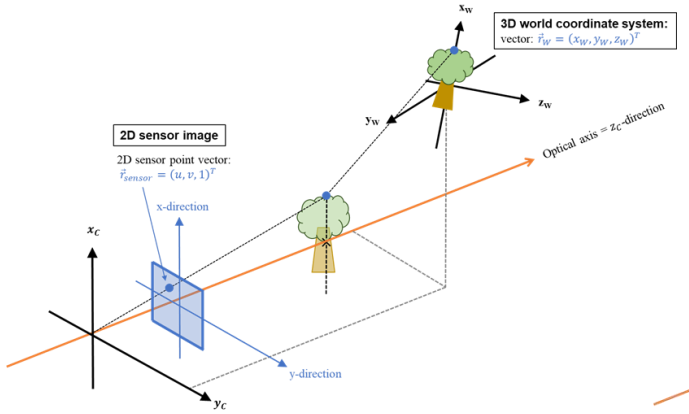
- Reference:

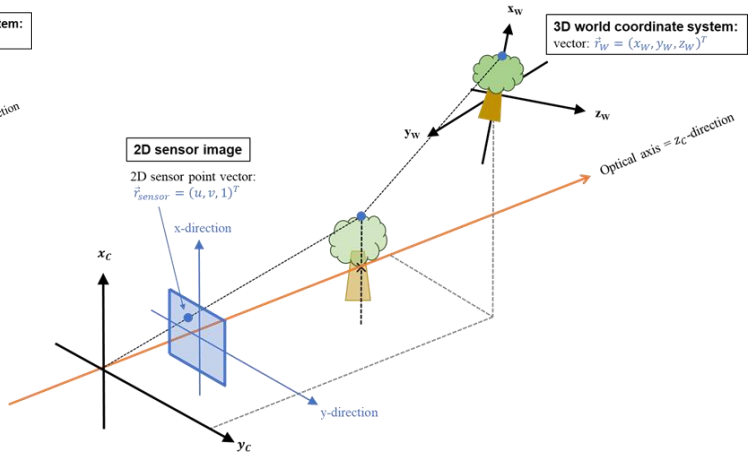
S. Reichel: Diffraktive Optiken, Kap. 15
In Löffler-Mang, Naumann, Schröder (Eds.),
Handbuch Bauelemente der Optik,
Carl Hanser Verlag 2020

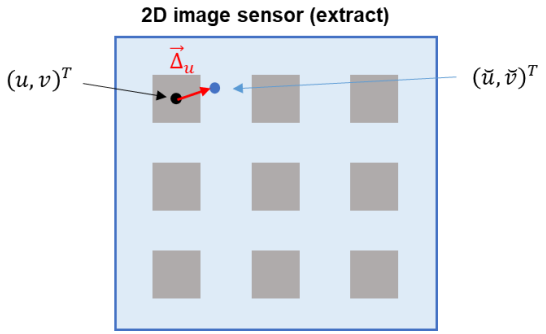


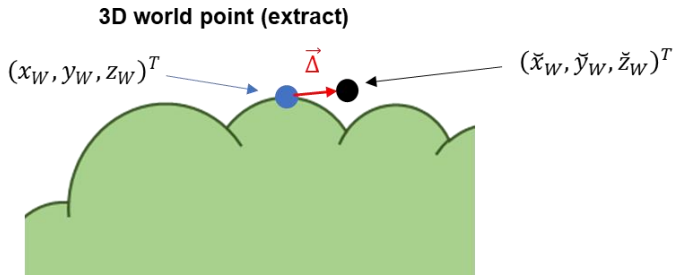
Machine Vision: camera calibration

- **Model**:
  - Pin-hole camera including distortions
- **Code**:
  - Python
- **Evaluation**:
  - Re-projection error and
  - Forward projection error (3D world)
  - Machine learning method
- **Result**:
  - New and objective method





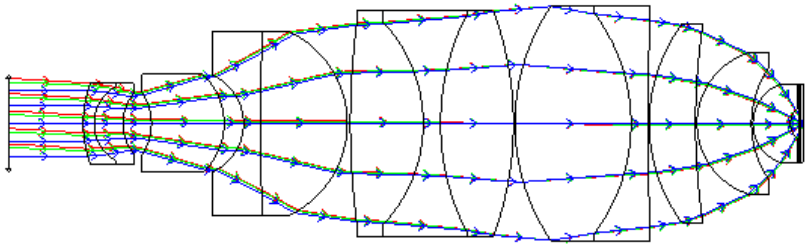




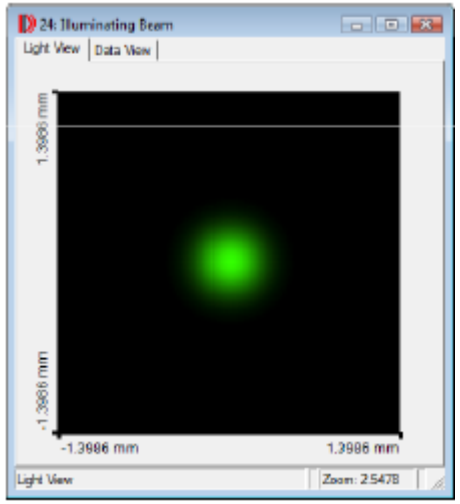
Kamera-Kalibrierung für optische Messaufgaben mit erweiterter Berechnung und Bewertung
DGaO-Proceedings 2021 – http://www.dgao-proceedings.de – ISSN: 1614-8436

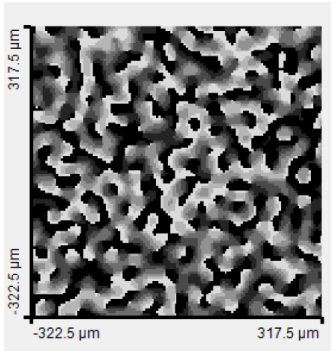
Optical Design: ray optics and diffractive optics

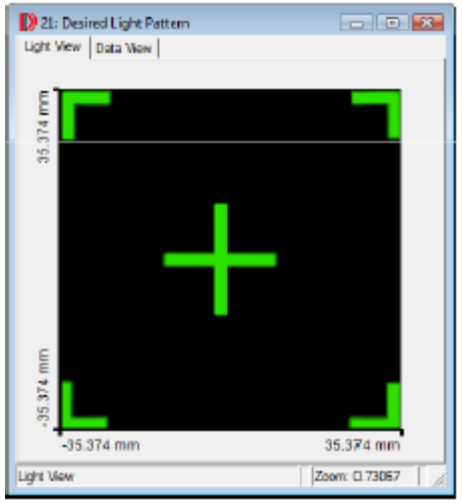
➢ Zemax



➢ DOE Design experience

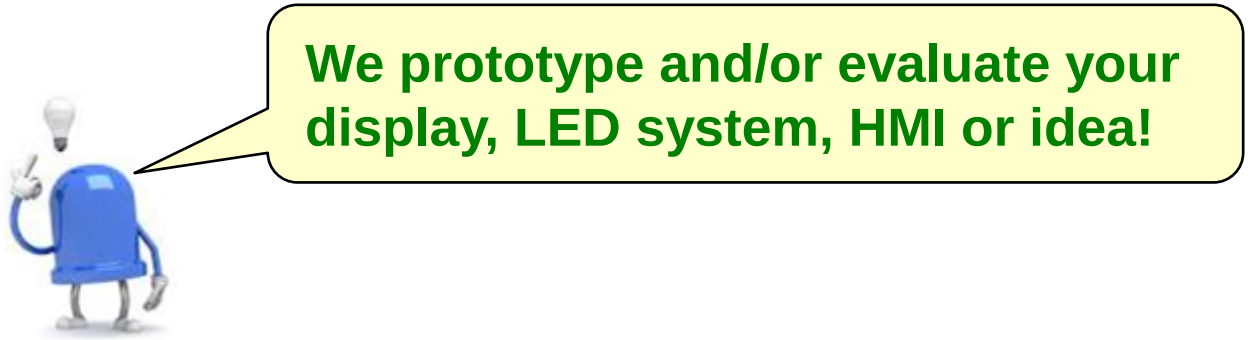






Displays & LEDs: Overview & Competences

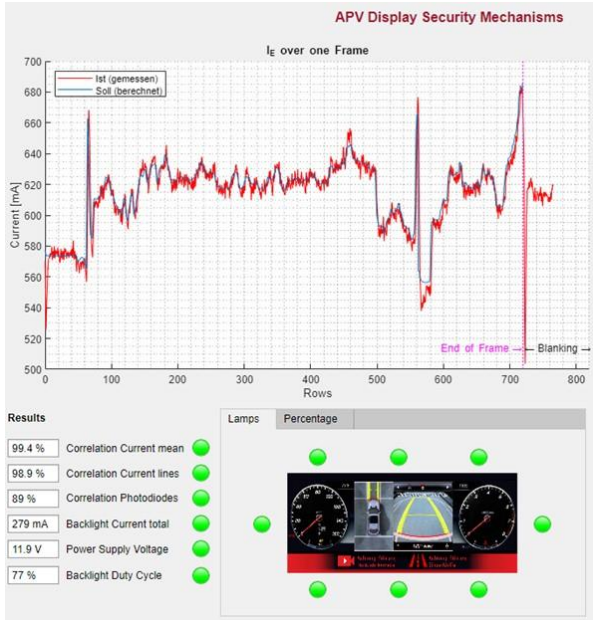
- **Optical metrology for displays and LEDs:**
  Photometric measurements (spot and imager), response time, spectrum …
- **Electronics:** Micro controllers, display interfaces, LED drivers …
- **Software:** Dedicated test patterns, image enhancement, uniformity algorithms …
- **Systems design:** New concepts, prototypes, user interfaces, evaluation and validation …
- **Evaluations and assessments:** User studies incl. comparison to measurements …



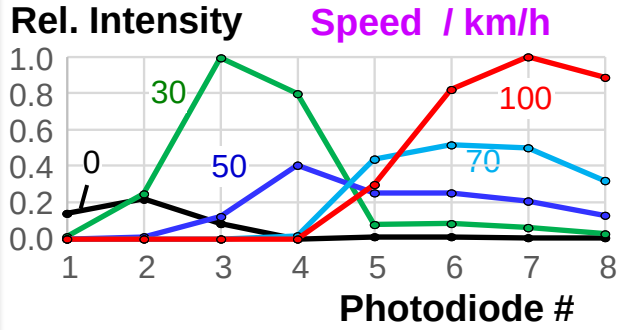
„Light-to-Light“ Safety for Camera Monitor Systems

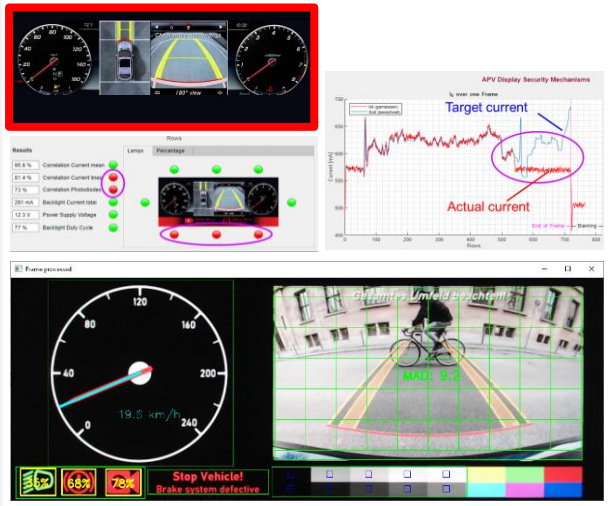
- **Today:** Only digital interface data supervised, no light of display
- **Here:** Optical supervision of display output by photodiodes and camera
- **Methods:**
  - ~10 photodiodes & line current
  - Camera incl. AI (best for remote)
- **Results:**
  - Validation of both methods ☑
  - “Detection” of essential failures ☑
  - Image compression for remote operator okay with AI ☑

Demonstrator



Examples





Advanced CMS safety

JSID 2020/1 https://doi.org/10.1002/jsid.909, https://doi.org/10.1002/jsid.1079

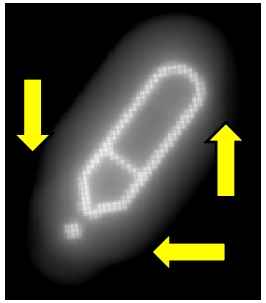
Single Pixel Measurement Method for Halo on OLED and FALD LCD

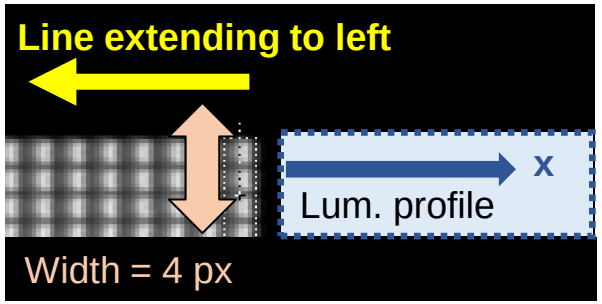
- **Background:** Halo is judged as caused by low quality display (in social media). It is mostly noticed at FALD LCDs. No “good” measurement method exists.
- **Our work:** Find and evaluate an advanced method to access single pixel halo
- **Method:**
  - 5 step procedure with imager
  - Macro lens and simulation of fits
- **Result:**
  - Single pixel halo can be measured
  - FALD LCD halo = 10x of OLED

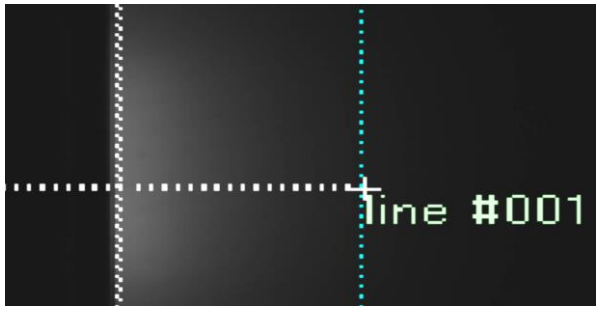
Halo & Method

Halo is spreading of light from bright content into dark surrounding

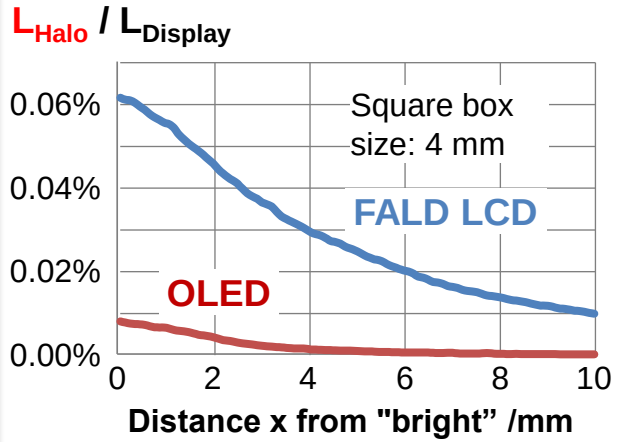
“Uneven” halo (↑) of FALD LCD ➞

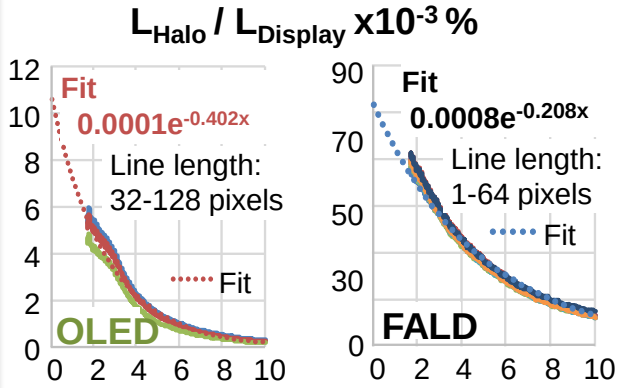






Examples

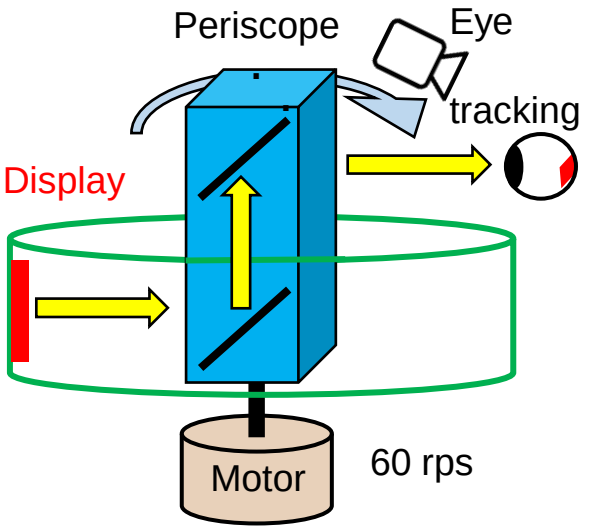


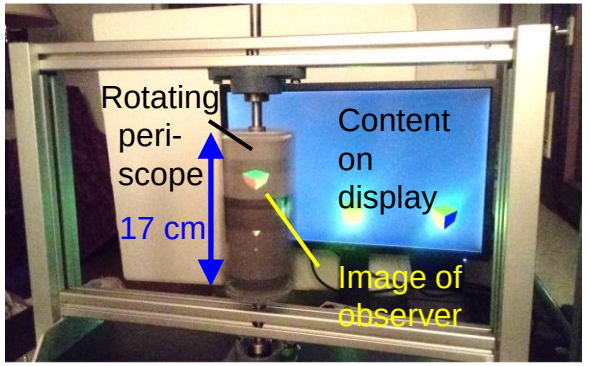


3D Multi-View Display

- **Today:** 3D image is the same for all observers → no perspective view
- **Here:** Development and evaluation of a 3D display for up to three observes with dedicated perspective
- **Methods:**
  - Rotating periscope visualizes images of large display
  - Dynamic perspective by eye tracking
- **Results**:
  - Multi-view (different 3D perspectives), see mark in green
  - Surprising effect → Science museums ...
  - Limits: Relatively small and dark images are less suitable

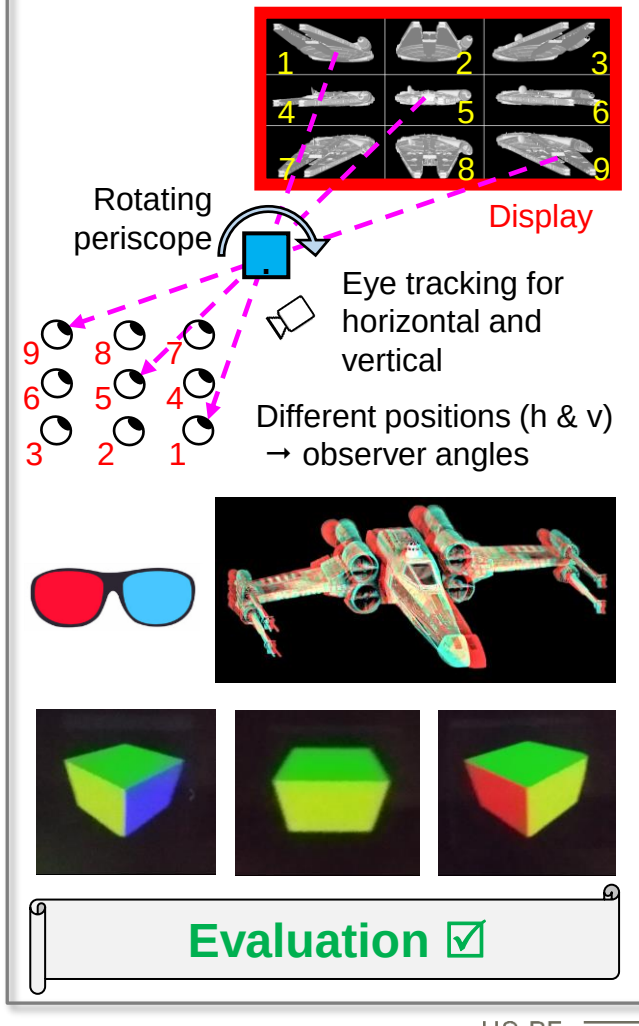
Demonstrator





(All parts were later painted black)

Examples



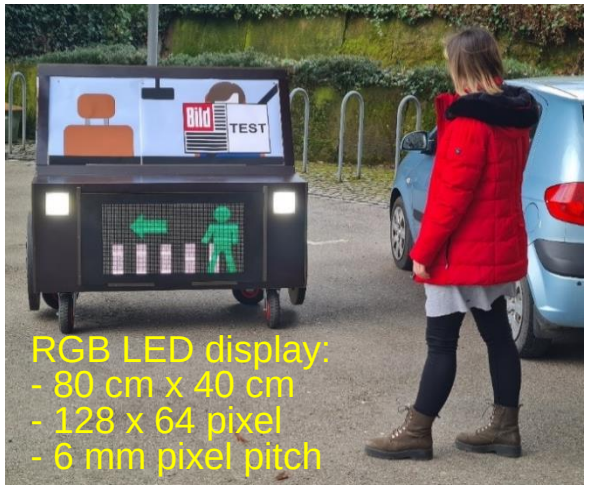
Evaluation ☑

SPIE 2021 https://doi.org/10.1117/12.2576972

Exterior Displays for Autonomous Cars Raise Safety

- **Visual communication since ~1900:**
  Break light, traffic light, turn indicator …
- **Here:** Graphic displays can provide more such as warnings, pedestrians
- **Mock-Up:** Simulation of use cases Pedestrian, oncoming and following cars, autonomous driving mode …
- **Results:**
  - Size > 30 cm x 30 cm, 6+ mm pixel
  - Text: 10 cm readable from 40+ m
  - Signs: 30+ cm for 50+ m
  - Pedestrians feel safe to cross

Mock-Up



Test Image Examples

Height of 40 cm

SPIE 2022 https://doi.org/10.1117/12.2606887, SID & ICDT accepted

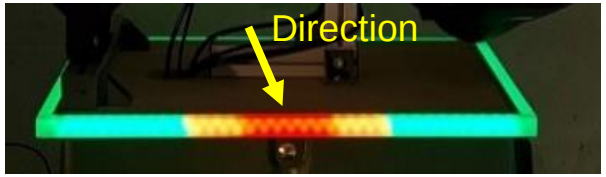
Human Robot Interaction (HRI) for Autonomous (Cleaning) Robots

- **Today:** Discomfort of subjects as no or only blue light visualization
- **Here:** Measurements and evaluation of various display technologies
- **Methods:**
  - Mock-up with different visualizations
  - Measurements, legibility acc. CIELUV
- **Results:**
  - Pico projector is best incl. integration
  - LED stripe for attention grabbing
  - Show laser, tablet, large projector are less suitable

Demonstrator

Display	L_w /cd/m²	Max. E /lx (CR = 2:1)
Pico-proj.	33	300
GOBO	1,900	17,000
Show laser	3,000	27,000
LED stripe	3,200	44,000

Examples



Trajectory reduces fear

SID 2021 https://doi.org/10.1002/sdtp.14749, BMBF “RobotKoop” PhoSmA

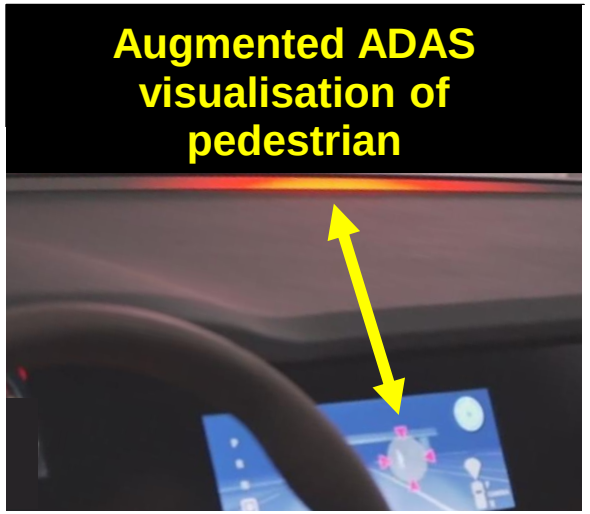
Low Cost „HUD“ for Safety and Comfort

- **„Scheibenwurzel-Display“:** as comfort function
- **Here:** Parameters for visualization of safety (warnings …)
- **Mock-Up:** Simulation of all features incl. luminance, RGB ratio and per-ceived brightness up to blinding sunlight
- **Results:**
  - RGB luminance ratio of 35 : 50 : 15
  - $L_{White} \geq 3{,}300$ cd/m² (3x L of today)
  - $L_{Blue} \geq 500$ cd/m²
  - RGBB LED for white point adjustme

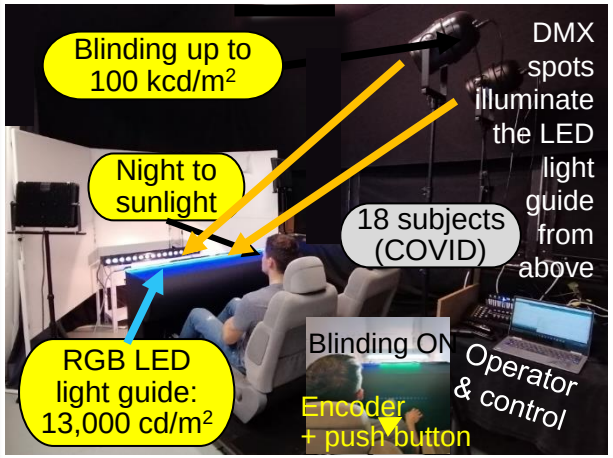
Motivation

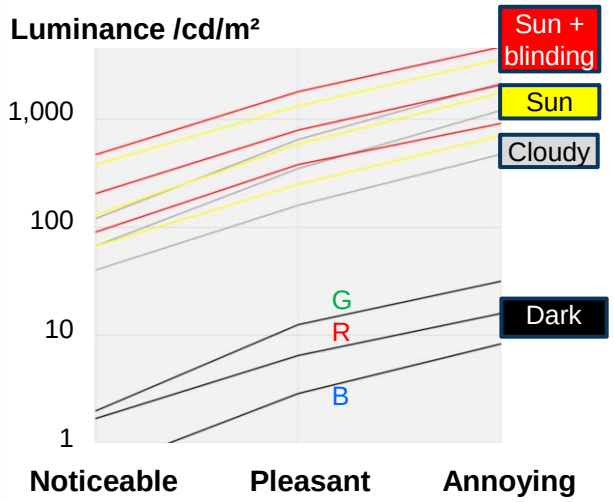
Design Questions

- Luminance for RGB?
- Luminance @ bright light



Evaluation





SPIE 2021 https://doi.org/10.1117/12.2599859

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