LAB MEASUREMENT AND FIELD TESTING OF INTEGRATED SYSTEMS

Dr.-Ing. Jan de Boer, Dr.-Ing. Carolin Hubschneider

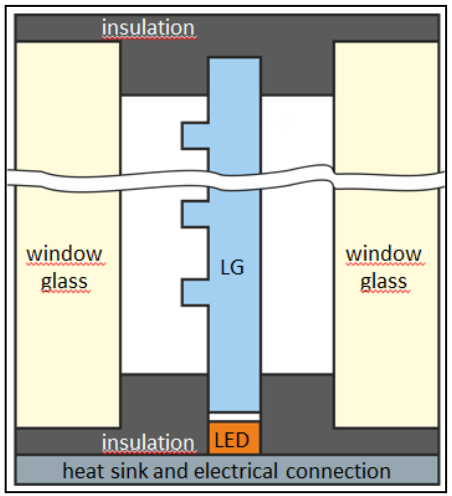
Fraunhofer Institute for Building Physics

Fraunhofer IBP

Overview

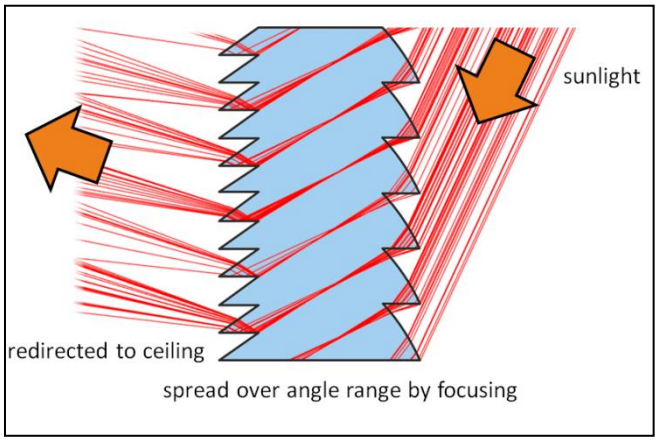
- Performance assessment
  - Impact on indoor lighting
  - Energy demand
  - User acceptance
- Integration into design tools
- Benchmarking

LED Light Guide (LG)



Source: M. Jakubowsky

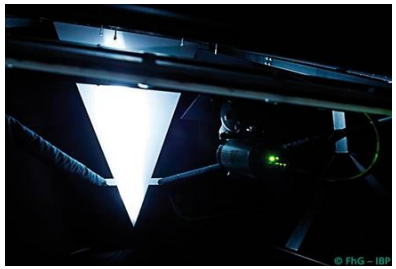
Sunlight redirecting structure (SL)



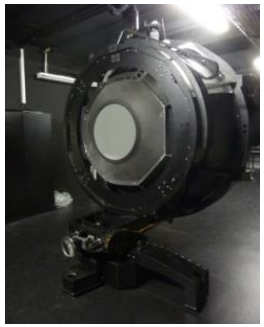
Source: M. Jakubowsky

Lab testing facilities

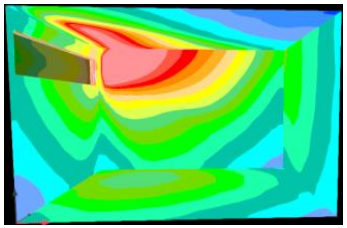
Photogoniometer



Ulbrichtsphere



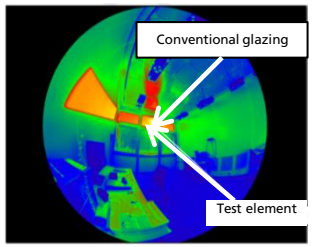
Data & models for design practice

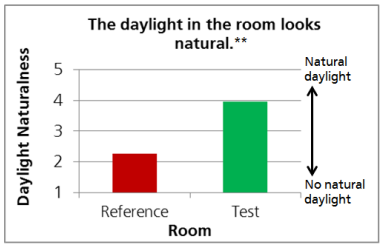


Field testing facilities

2 test façades with test cells

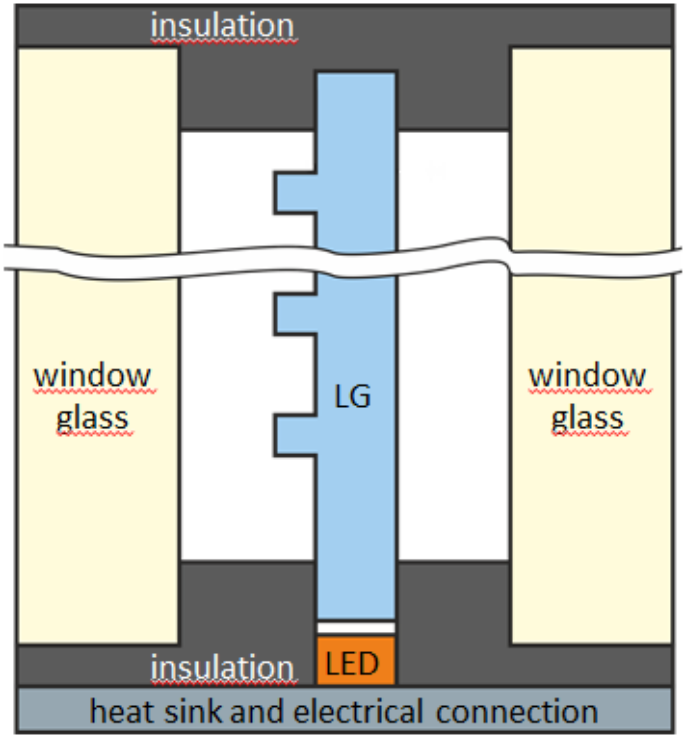
Energy performance and user acceptance





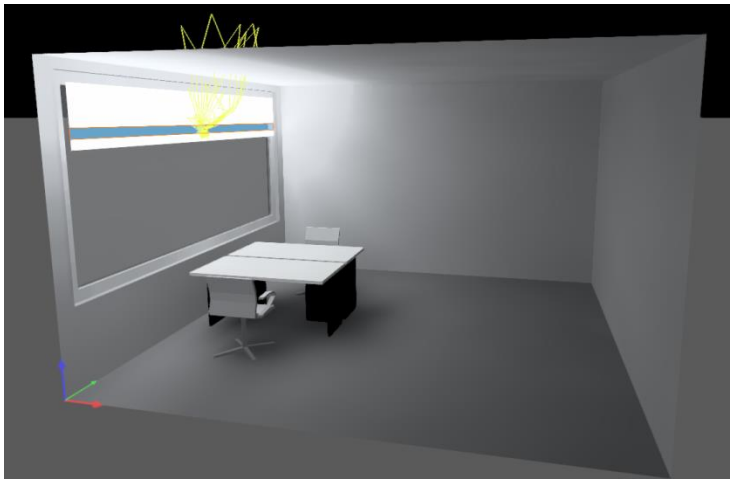
Fraunhofer IBP

LED Light Guide (LG)

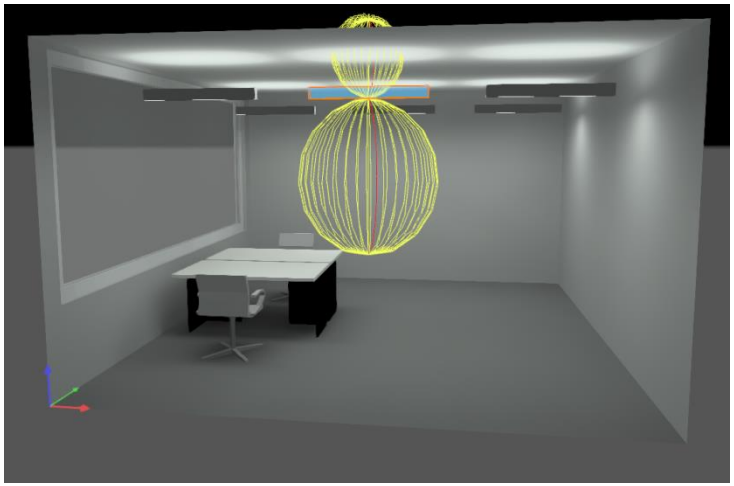


LED Light Guide (LG)
Photometric and energy related performance

Room illumination by
LED Light Guide (LG)



Room illumination by
Standard pendular luminaires



?

Illuminance E_m

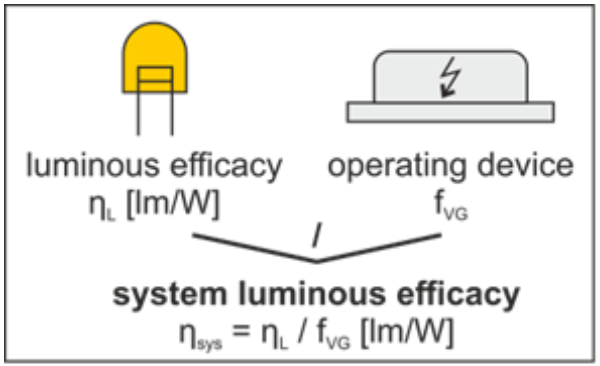
Uniformity U_0

Visual Comfort

Energy performance

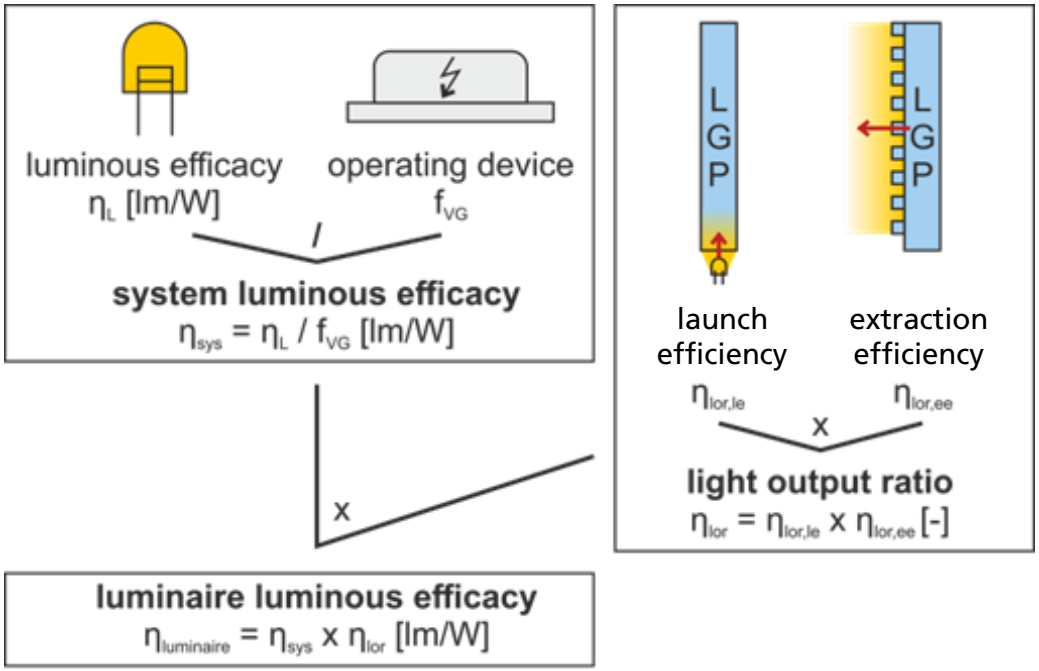
LED Light Guide (LG)

Photometric and energy related performance



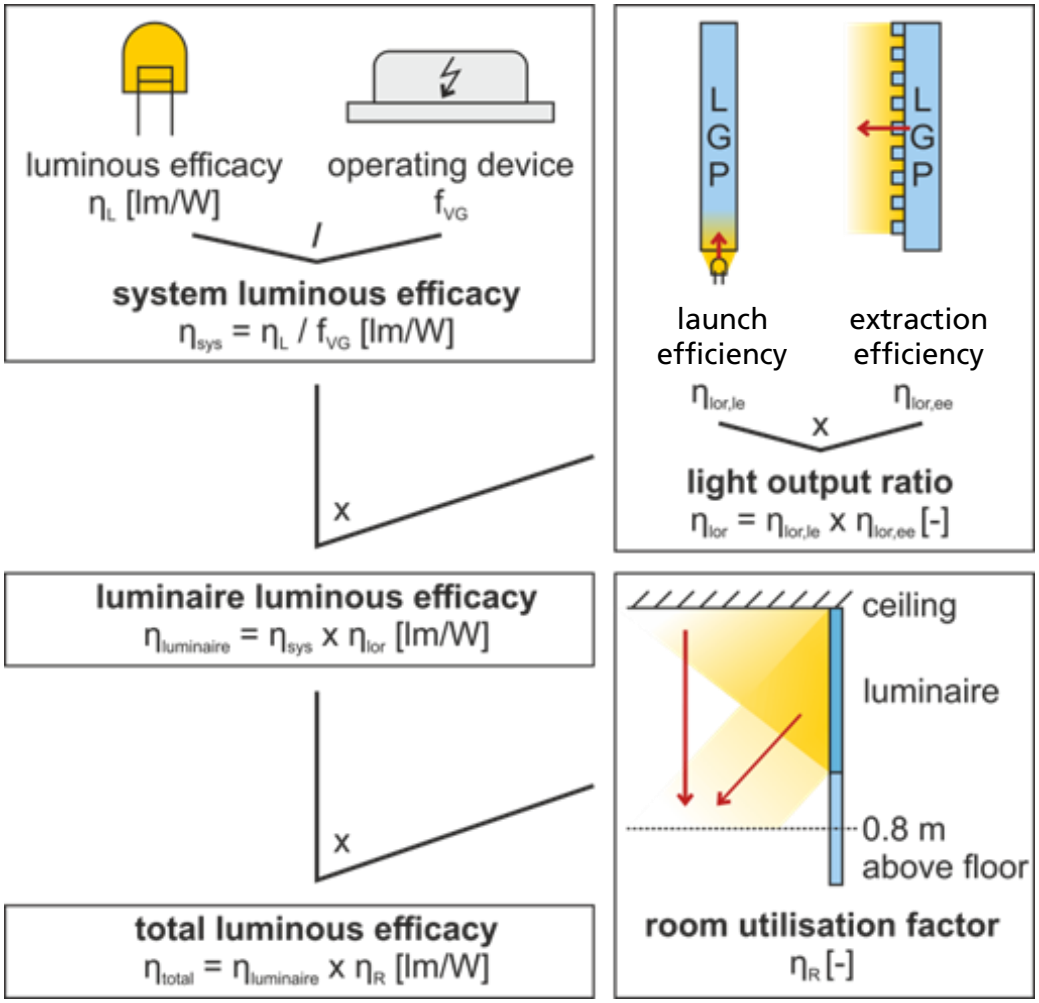
LED Light Guide (LG)

Photometric and energy related performance



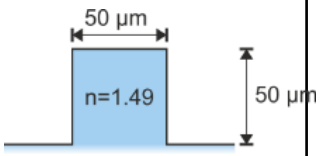
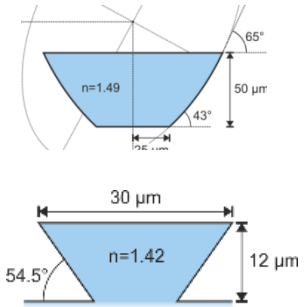
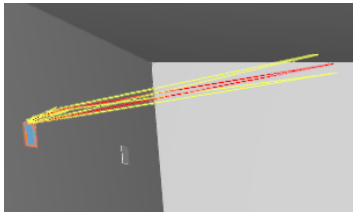
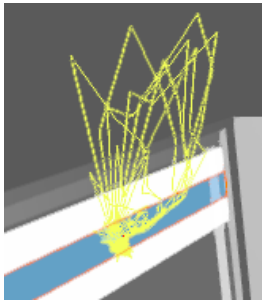
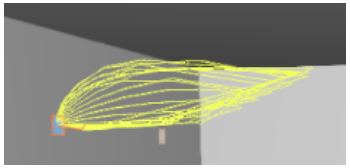
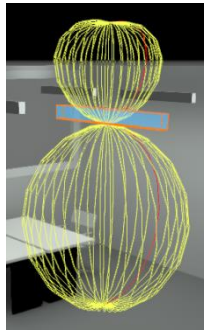
LED Light Guide (LG)

Photometric and energy related performance



Fraunhofer IBP

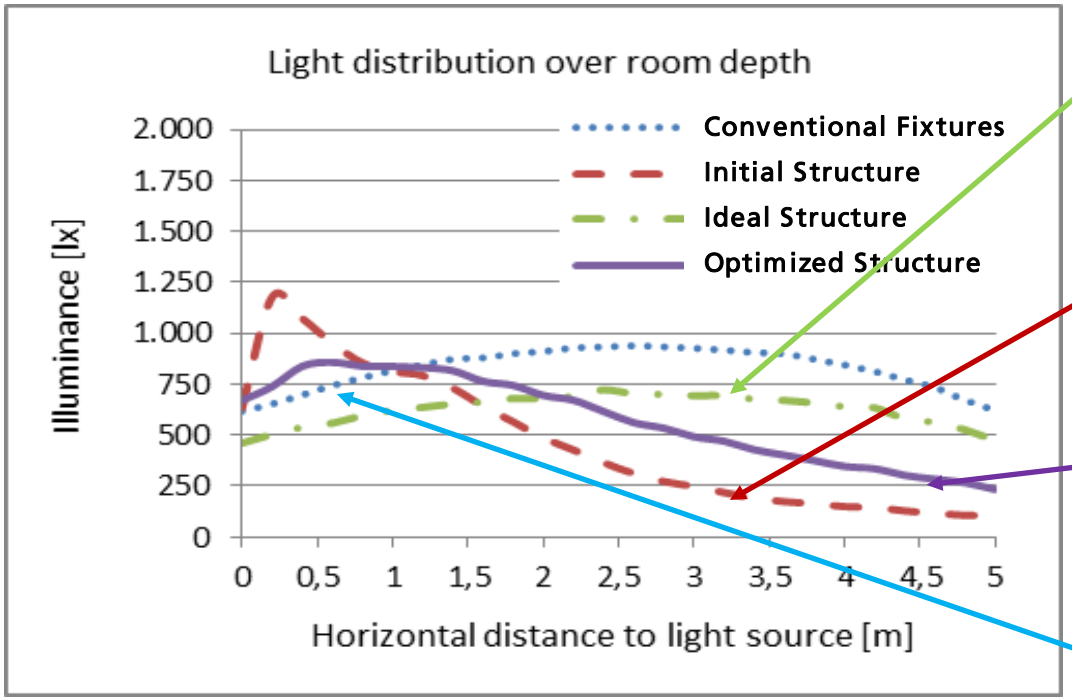
LED Light Guide (LG)
Considered Structures

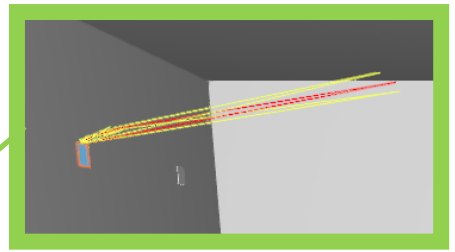
	Ideal Structure	Initial Structure	Optimized Structures	Benchmark Conventional Fixtures
Producible	no	yes	with limitations	yes
Structure	–			
Luminous intensity distribution				

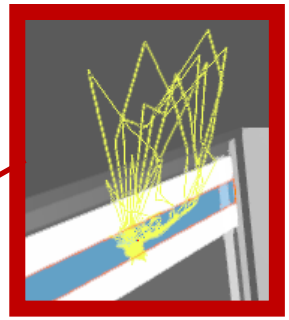
Source schematic structure figures: M. Jakubowsky, C. Hubschneider et al., Microstructured light guiding plate for single-sided light emission as light source for room illumination, Applied Optics, in preparation

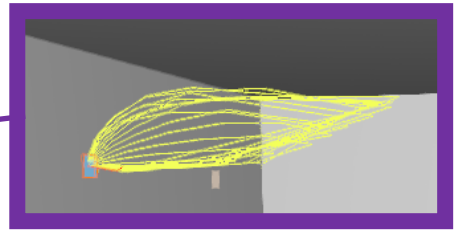
Fraunhofer IBP

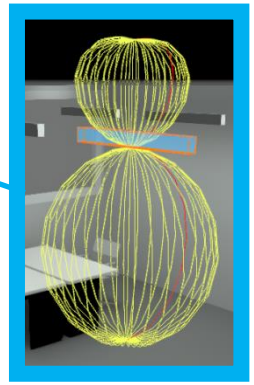
LED Light Guide (LG)
Illuminance Distribution









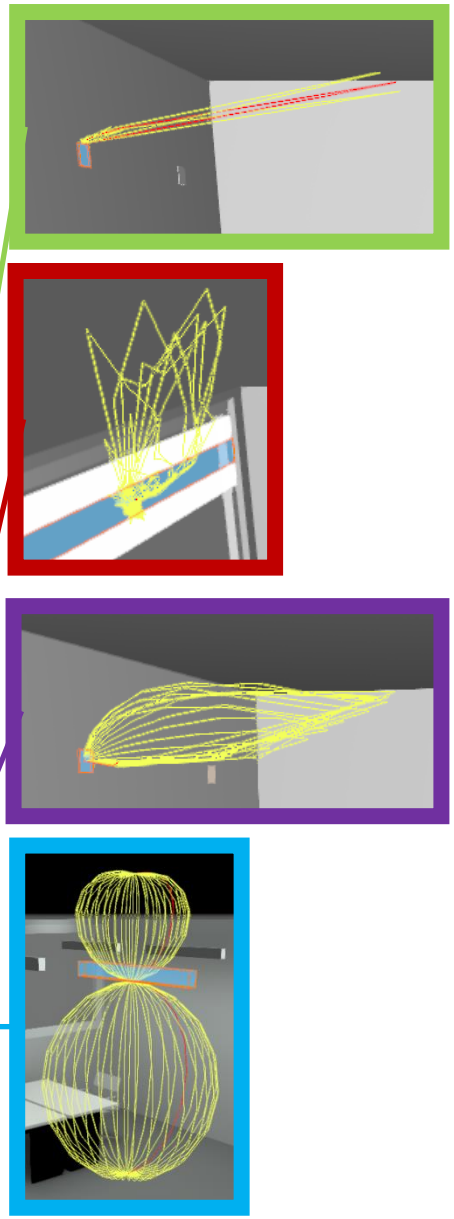


Fraunhofer IBP

LED Light Guide (LG)

Photometric and energy related performance

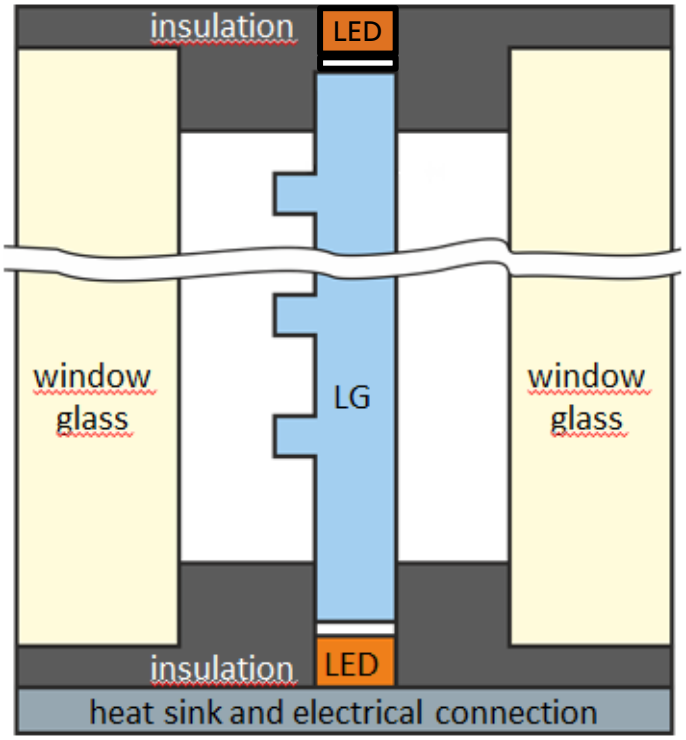
No.	Description	LED-System			Luminaire					LED-System + Luminaire	Room, total		
		Luminous Efficacy	Factor, electronic ballast	System Luminous Efficacy	LOR, only Panel	Transmission only glazing	LOR (panel + glazing)	Single-sided emission	Room-sided LOR (panel + glazing)	Luminaire, Luminous Efficacy	Room Utilization factor	Total Luminous Efficacy	Installed Power for 500 lx
		η_L	f_{EB}	η_{Sys}	$\eta_{LB,P}$	τ_v	$\eta_{LB,PG}$		$\eta_{LB,PR}$	$\eta_{Luminaire}$	η_R	η_{tot}	p_{inst}
		[lm/W]	[-]	[-]	[-]	[-]	[-]		[-]	[lm/W]	[-]	[lm/W]	[W/m²]
1	Ideal Structure	195	1,00	195	1,00	1,00	1,00	0,00	1,00	195	0,32	62	8,0
2	Initial Structure	167	1,09	153	0,64	0,81	0,52	0,75	0,39	60	0,25	15	33,5
3	Optimized Structures	167	1,09	153	0,80	0,81	0,65	0,96	0,62	95	0,29	28	18,1
5	Benchmark Conventional Illumination	167	1,09	153	-	-	-	-	0,78	119	0,49	58	8,6

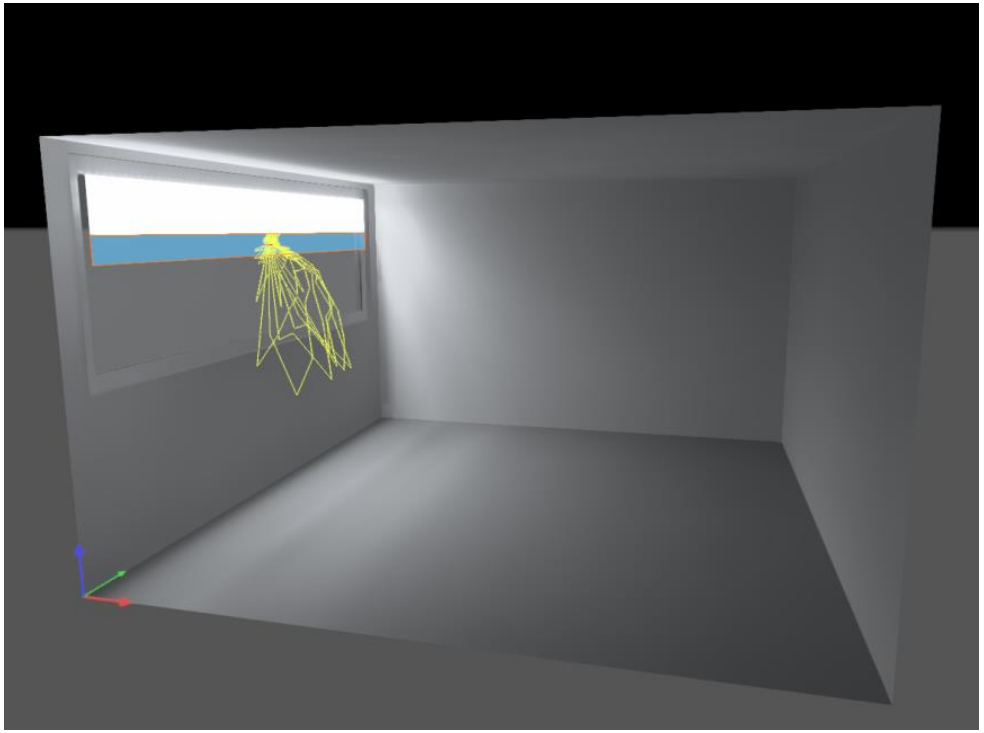


Source schematic structure figures: M. Jakubowsky, C. Hubschneider et al., Microstructured light guiding plate for single-sided light emission as light source for room illumination, Applied Optics, in preparation

Fraunhofer IBP

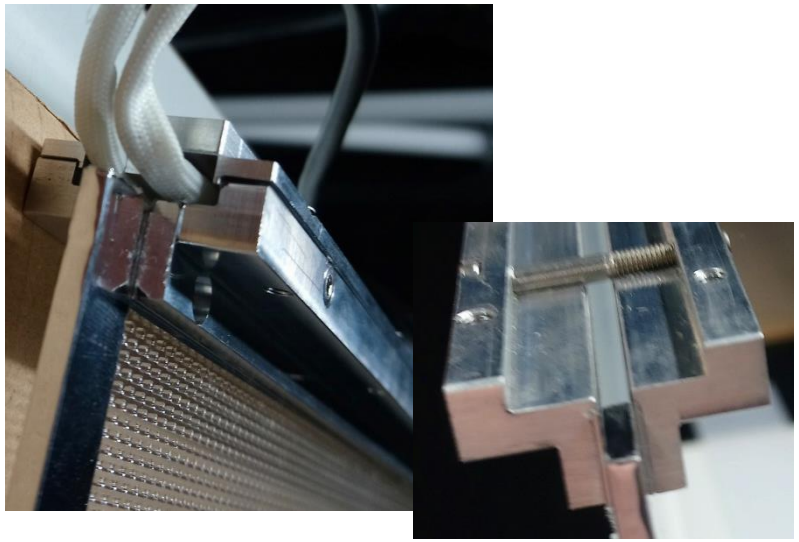
LED Light Guide (LG)
Further Optimization: Adding a direct component

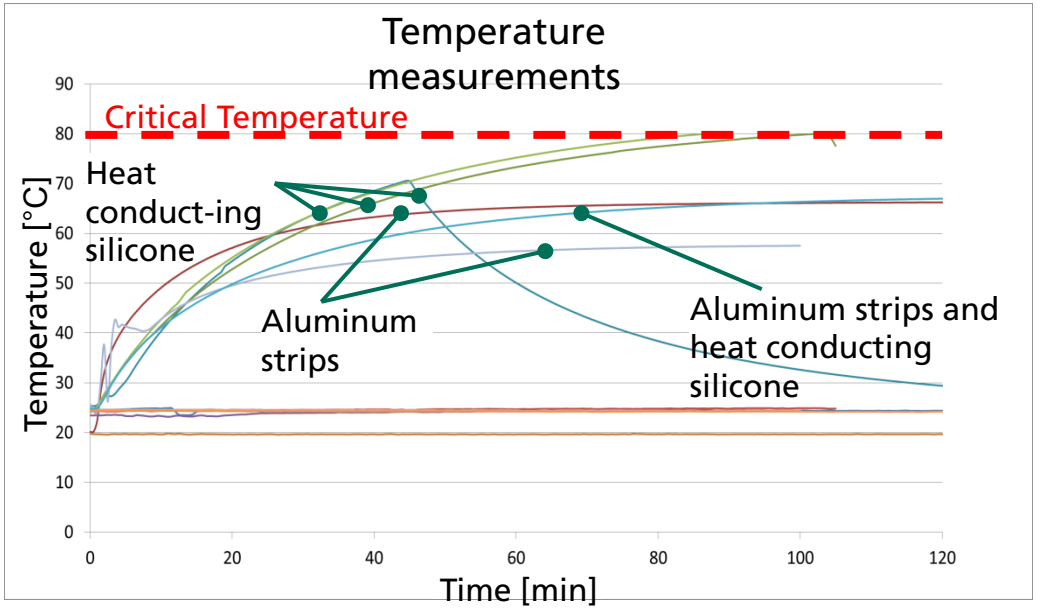


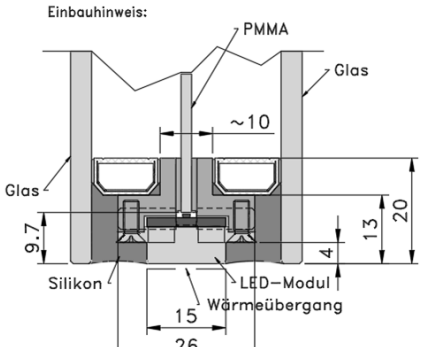


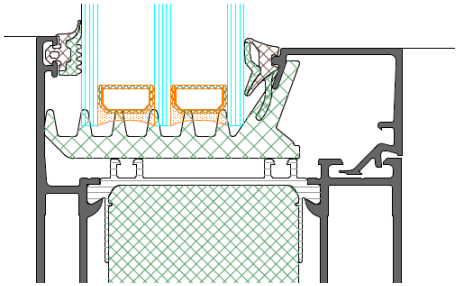
LED Light Guide (LG)
Thermal behaviour

- Load 45 W per lineal meter
- Flexible copper Braid and copper blocks that connect LED module and window frame



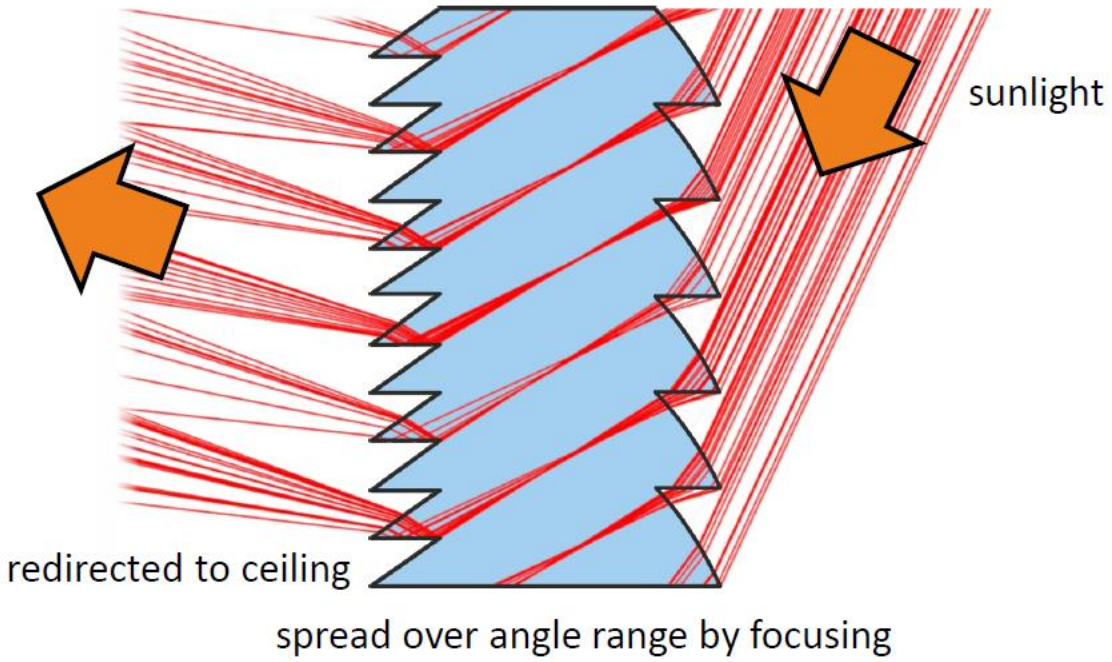






Fraunhofer IBP

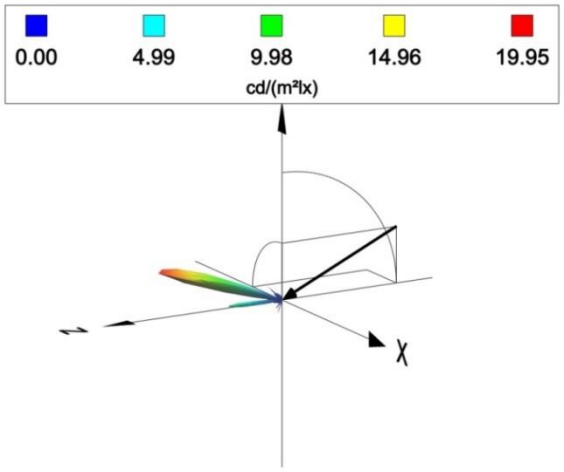
Sunlight redirecting structure (SL)



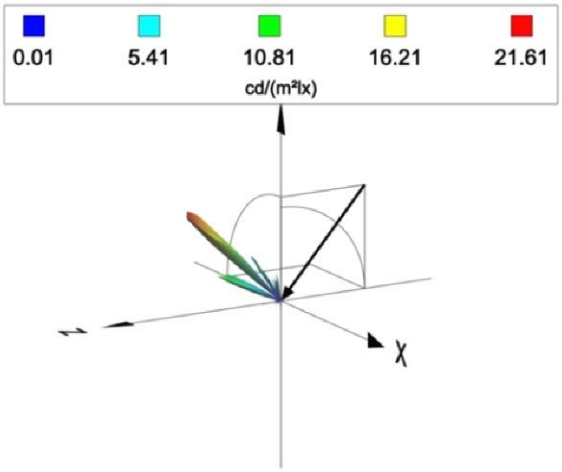
Source figure: M. Jakubowsky, "Optimized optical microstructures for daylight redirection and efficient LED-based planar light guides", ABS 2018, Bern

Sunlight redirecting structure (SL)
Photometry and simulation of room illumination

BTDF (luminance coefficient)

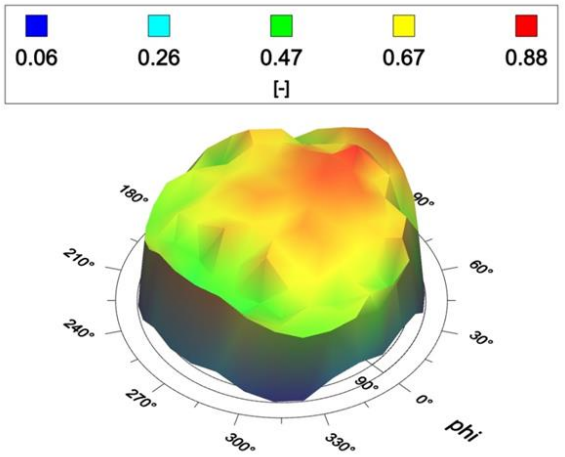


Elevation angle 24° , Azimuth 90°



Elevation angle 48° , Azimuth 90°

Direct hemispherical transmission



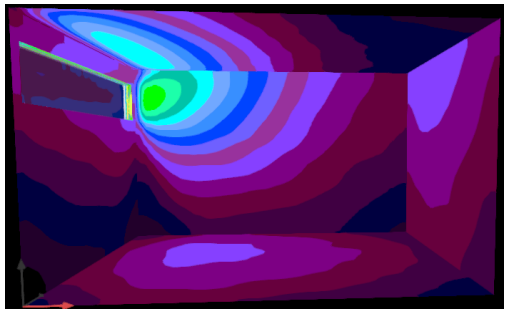
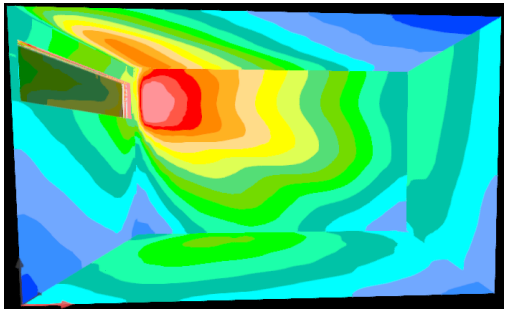
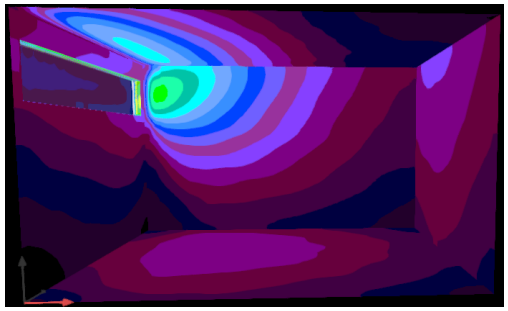
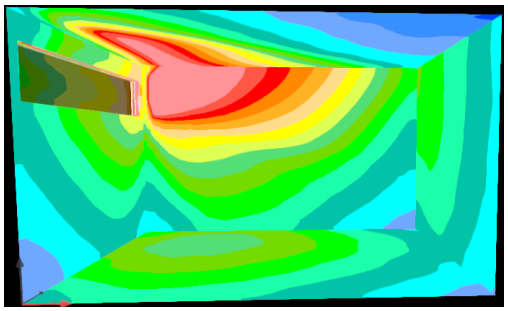
	Panel only (measured with Ulbricht sphere)	**IGU, SGG low -ε glazing** (calculated values)
Transmission τ_V [-]	0,82	0,51
Transmission τ_e [-]	0,75	0,36

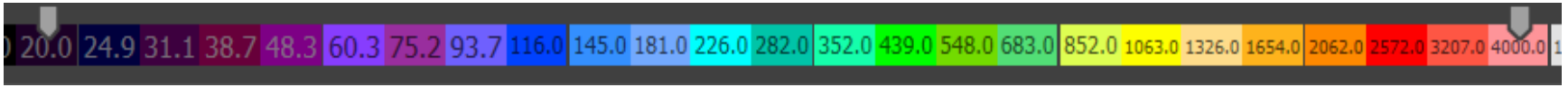
Fraunhofer IBP

Sunlight redirecting structure (SL)
Photometry and simulation of room illumination

Luminance distribution:

- 21.3 / 21.9 (Equinox)
- Clear sky with sun
- South orientation
- Different latitudes
- Software DIALuxevo

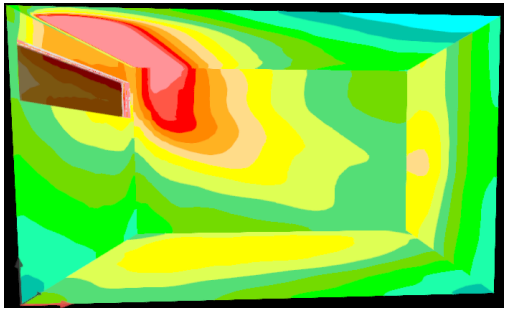
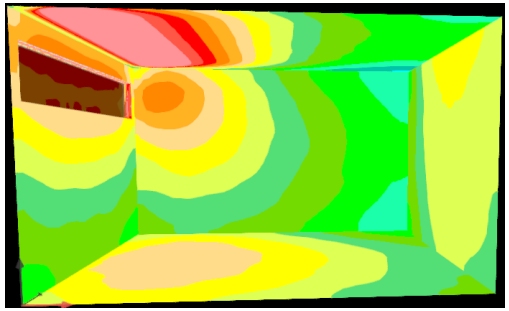
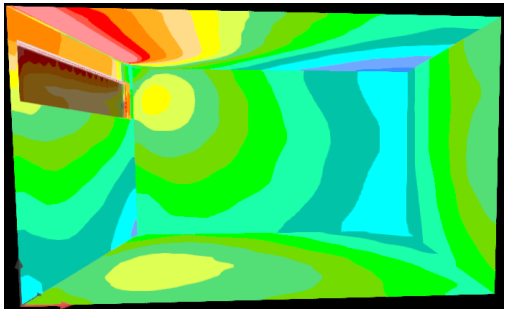
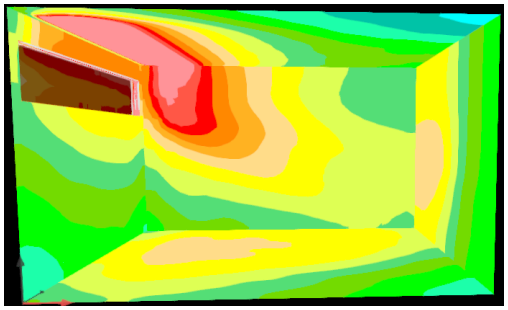
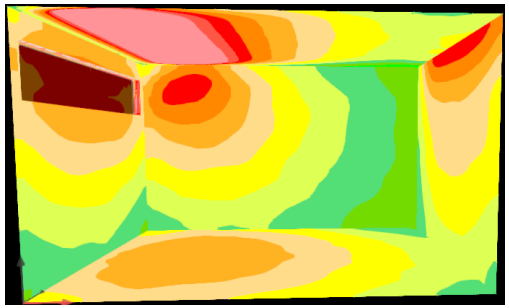
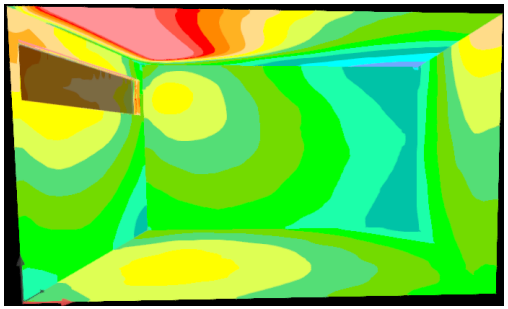
	8 am	10 am
Latitude 40°		
Latitude 51,22°		

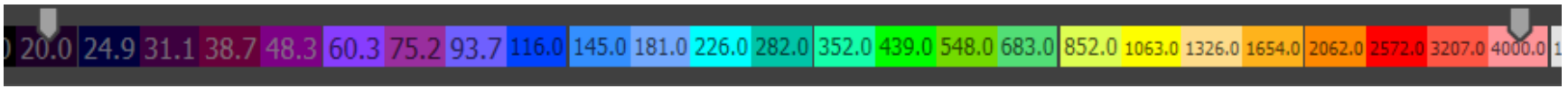


Fraunhofer IBP

Sunlight redirecting structure (SL)

Photometry and simulation of room illumination

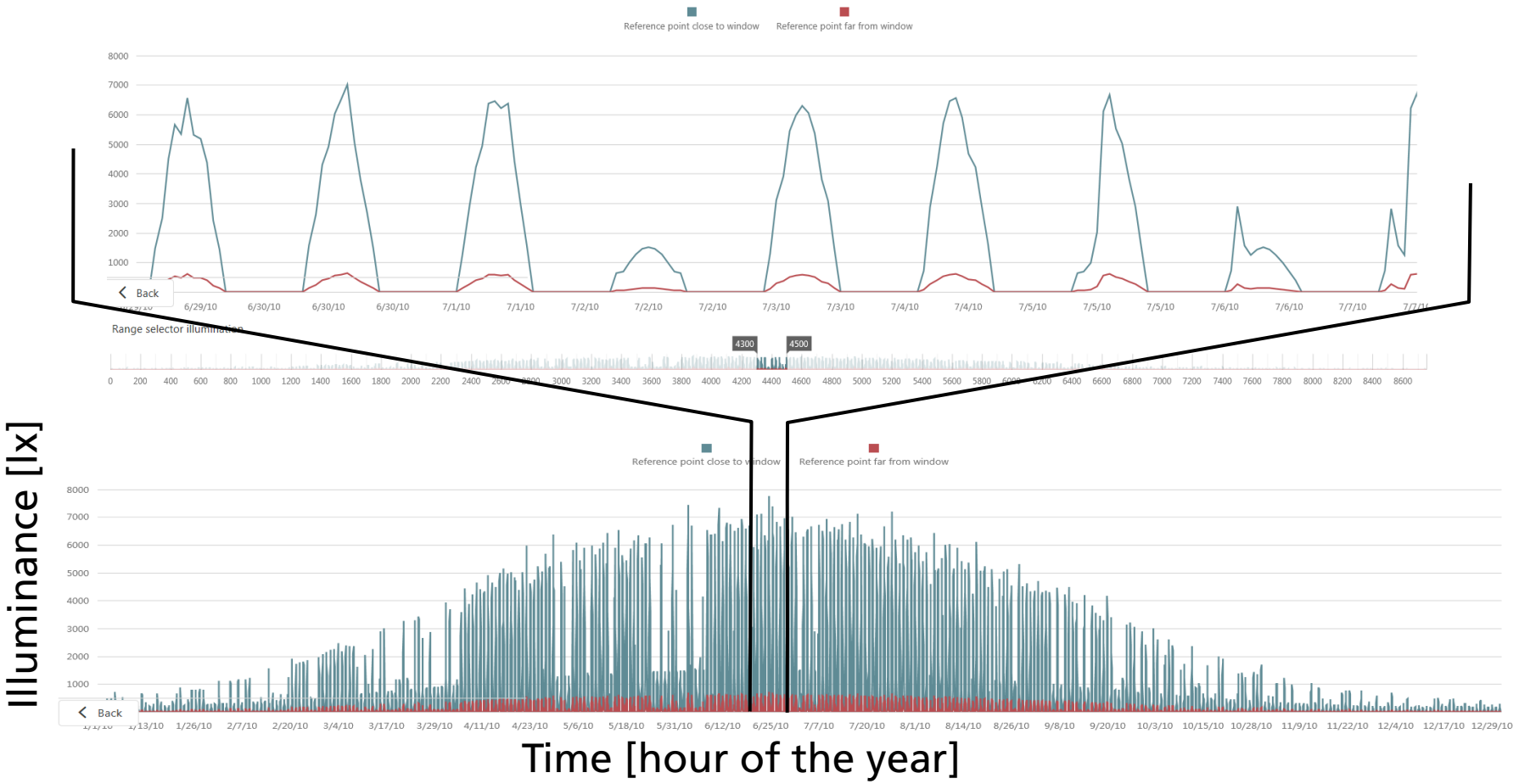
	12 am	2 pm	4 pm
Latitude 40°			
Latitude 51,22°			



Fraunhofer IBP

Sunlight redirecting structure (SL)

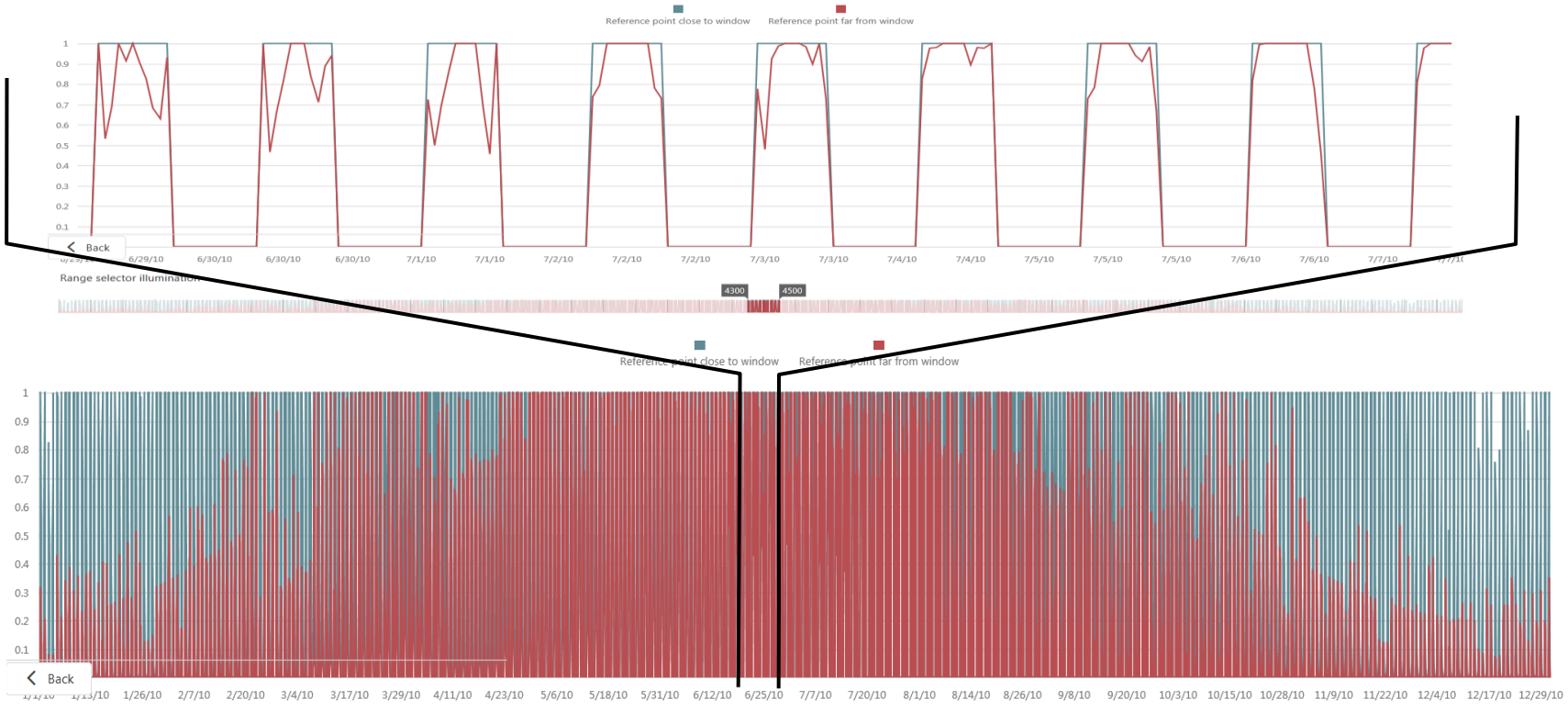
Annual simulation: Illuminances



Fraunhofer IBP

Sunlight redirecting structure (SL)

Annual simulation: Luminous exposure (Daylight autonomy)

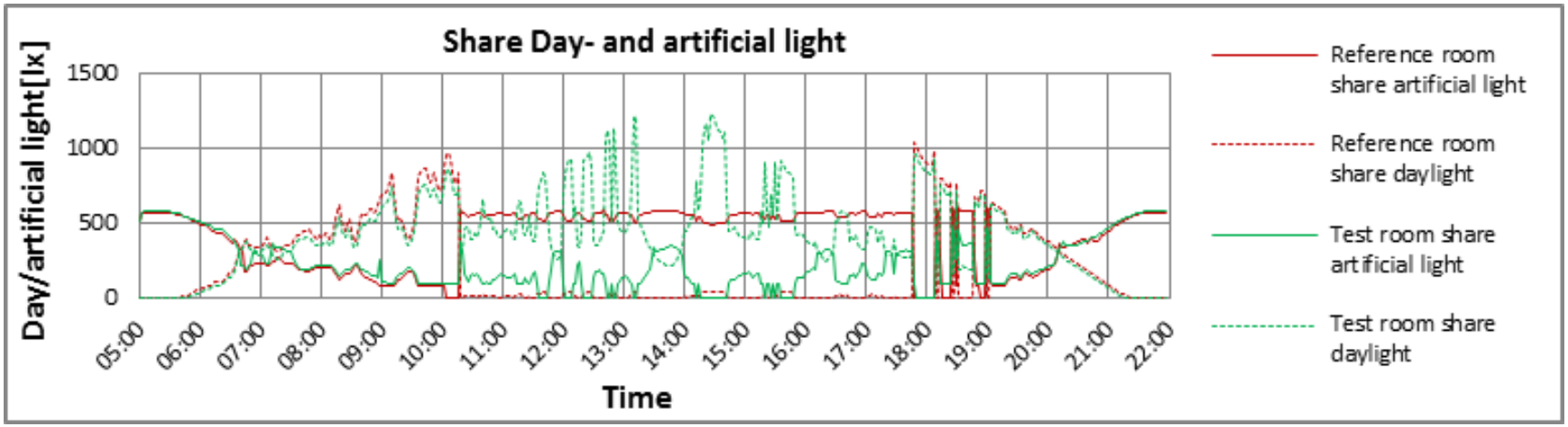


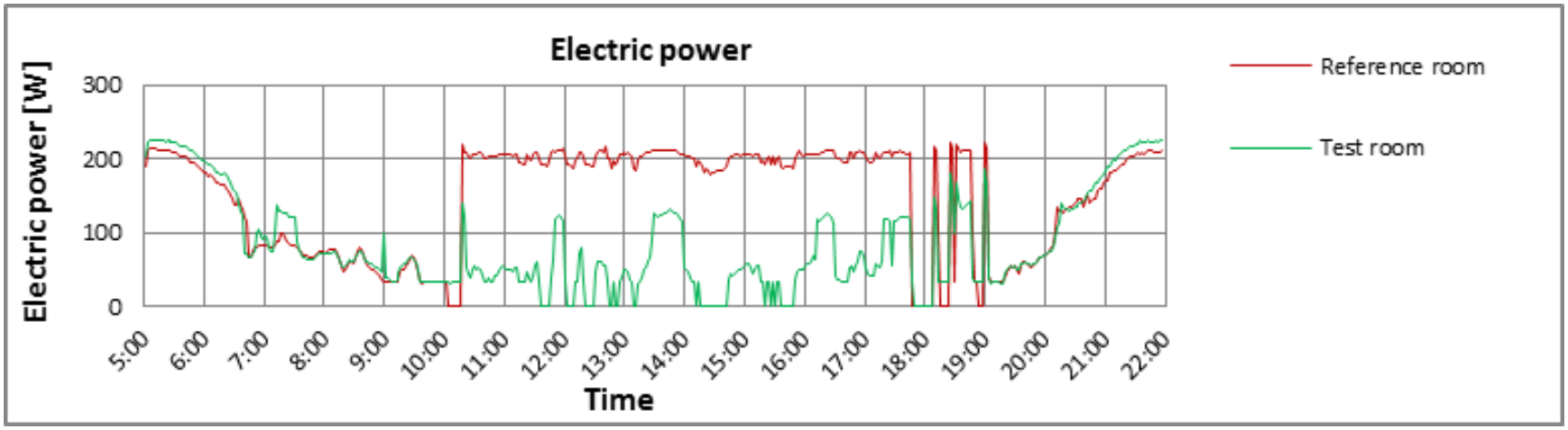
Fraunhofer IBP

Sunlight redirecting structure (SL)
Room integration

Test room Sunlight redirecting structure (SL)	Reference room Venetian blinds
	

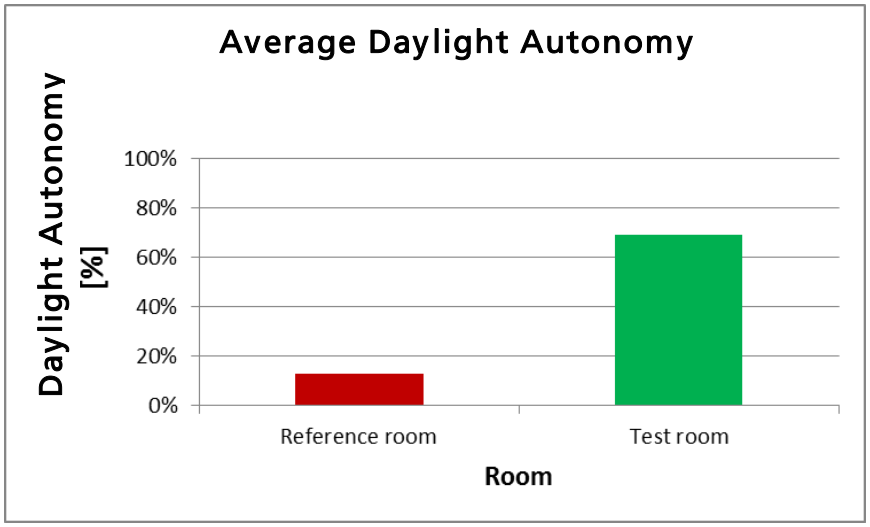
Sunlight redirecting structure (SL)
Energy performance

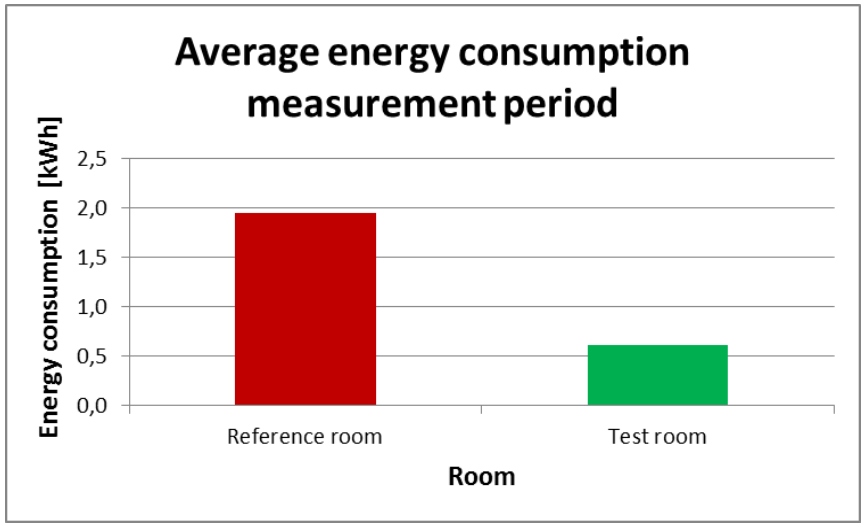




Fraunhofer IBP

Sunlight redirecting structure (SL)
Average values over measurement period

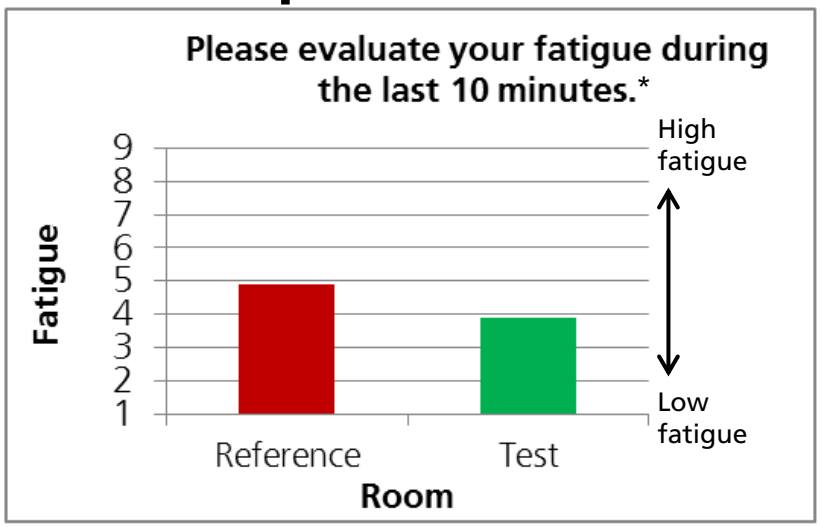


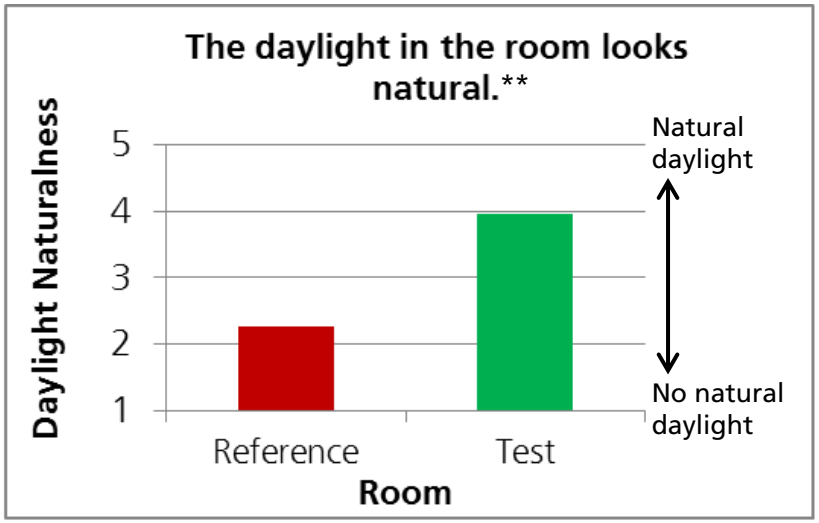


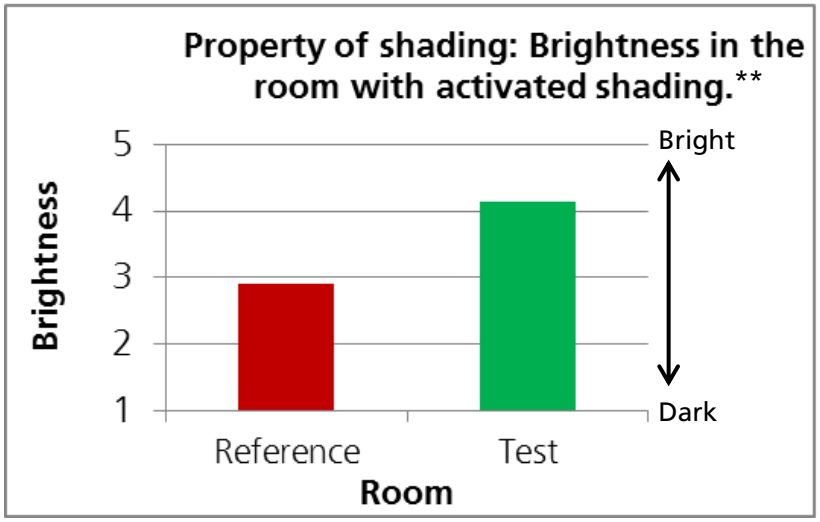
Fraunhofer IBP

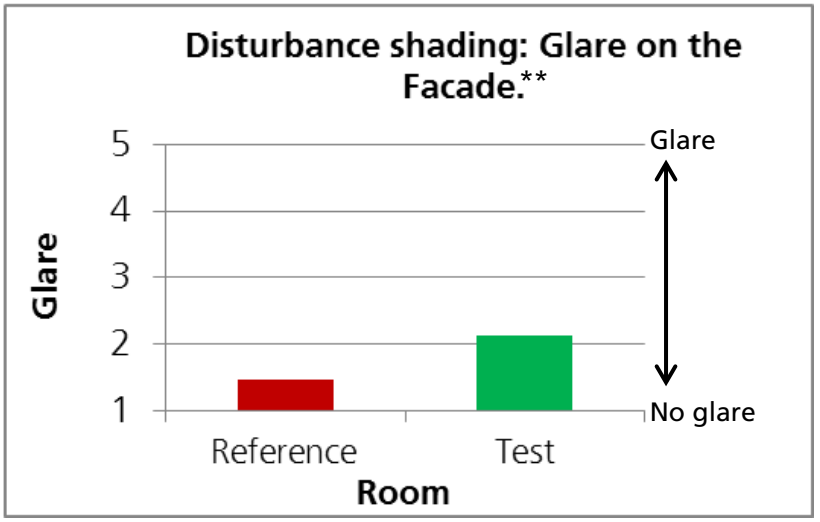
Sunlight redirecting structure (SL)

User acceptance studies









*Åkerstedt, T.; Gillberg, M. (1990): Subjective and Objective Sleepiness in the Active Individual. In: International Journal of Neuroscience 52 (1-2), S. 29–37.

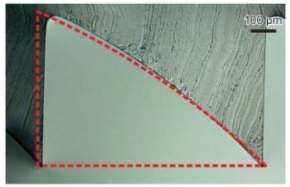
**Based on Schuster, H. G. (2006). Tageslichtsysteme im Spiegel der Nutzer.

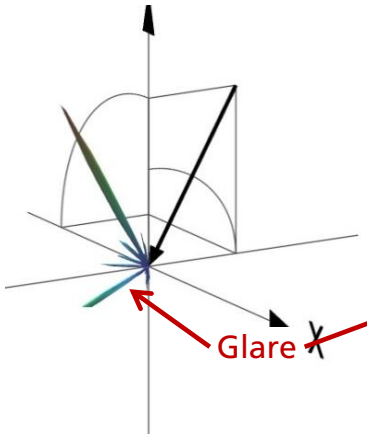
Fraunhofer IBP

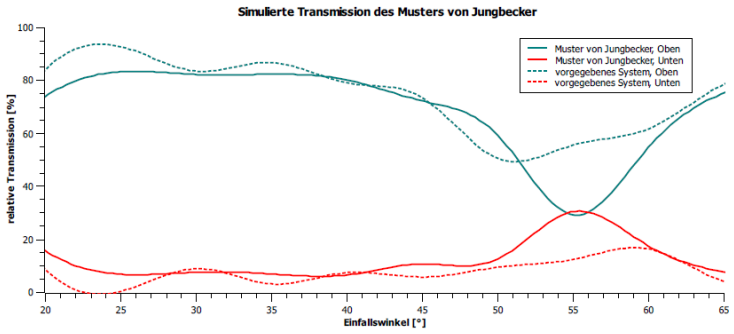
Sunlight redirecting structure (SL)
Final optimization based on testroom assessment

Current structure

Critical elevation angle at 55°







**Source figures: M. Jakubowsky, RiF*

Fraunhofer IBP

Conclusion / Outlook

- LED Light Guide (LG)
  - Efficiency of standard lighting systems will most probably not be reached
  - Trade off against “fixture free” ceiling
  - Final optimization:
    - Flat luminous intensity curve
    - Supplementing pure indirect with direct component
- Sunlight Redirecting Structure (SL)
  - Reduced energy demand for lighting
  - Good user acceptance
  - Close to “ready to market” product
- Data for application in design process / design tools