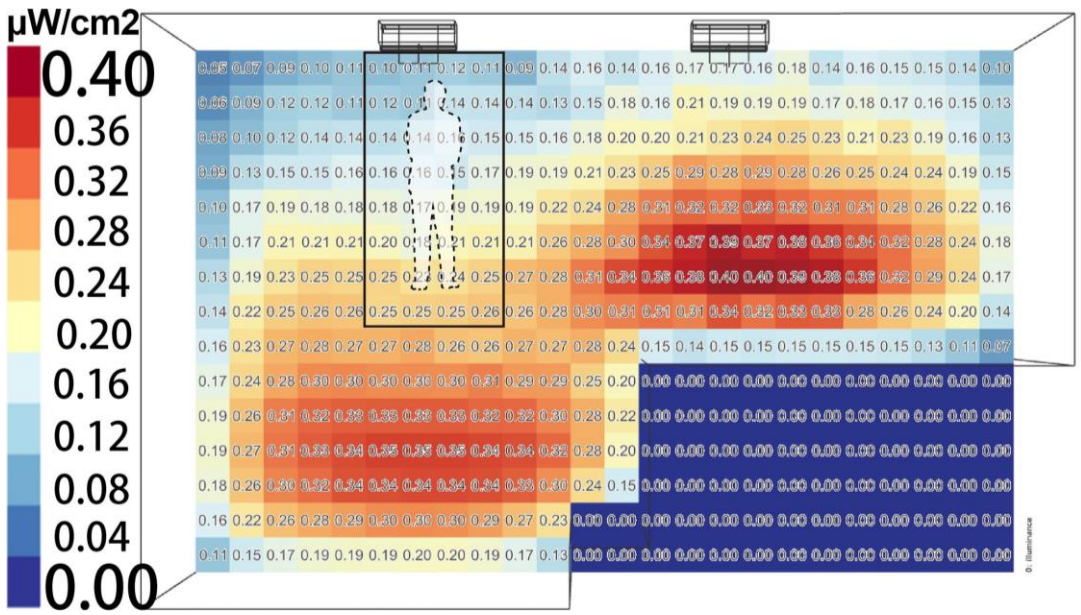
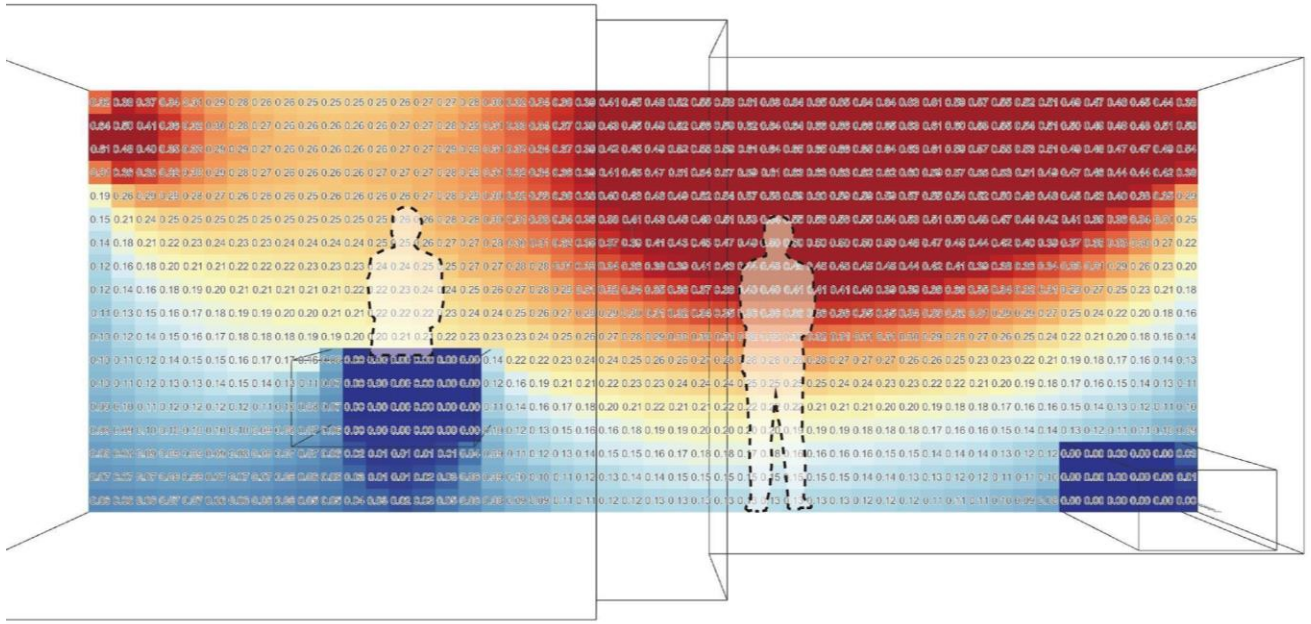
Spatial Analysis of the Impact of Upper Room Ultraviolet Germicidal Irradiation





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ASHRAE TC 9.6 Healthcare Facilities Main Meeting June 9 2021

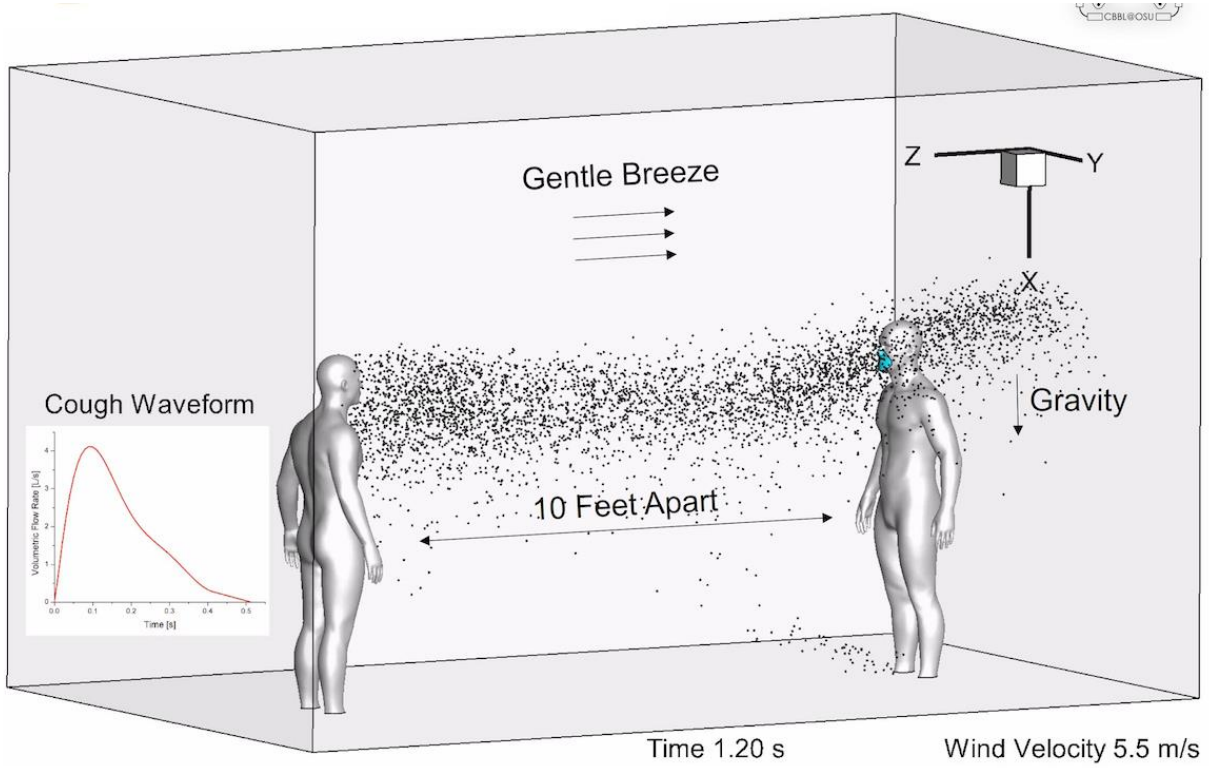
Virus is aerosolized:

- breathing,
- coughing
- talking

Virus moves from infector to susceptible

Upper room UVGI is very effective because it inactivates aerosolized virus in the space where it was released

Necessity for tools to quickly assess upper room UVGI zone kill zone



Note: Cough droplet sizes are enlarged for visualization purpose (droplet sizes are from 2 to 2000 microns)

Source: http//news.okstate.edu

INDOOR AIR
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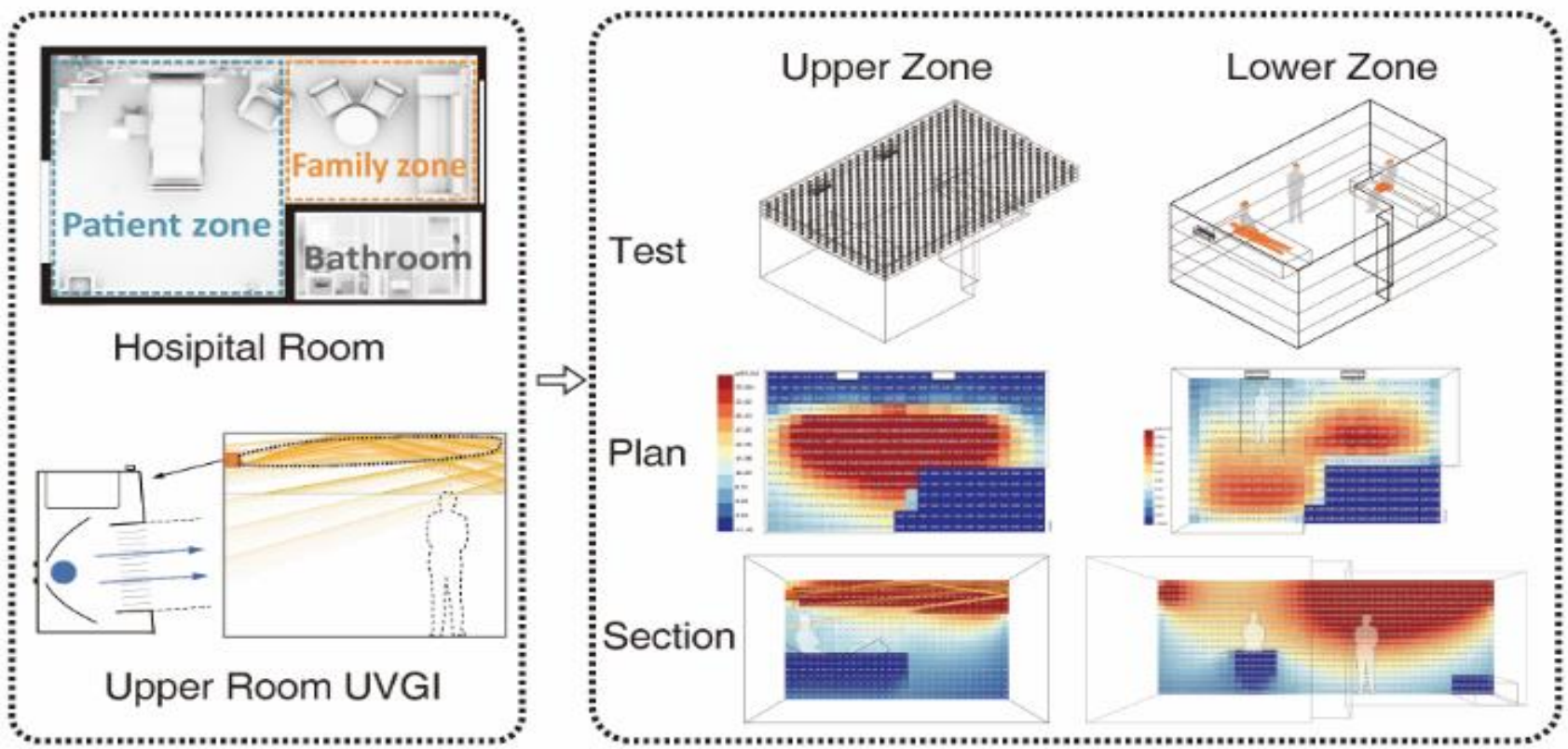
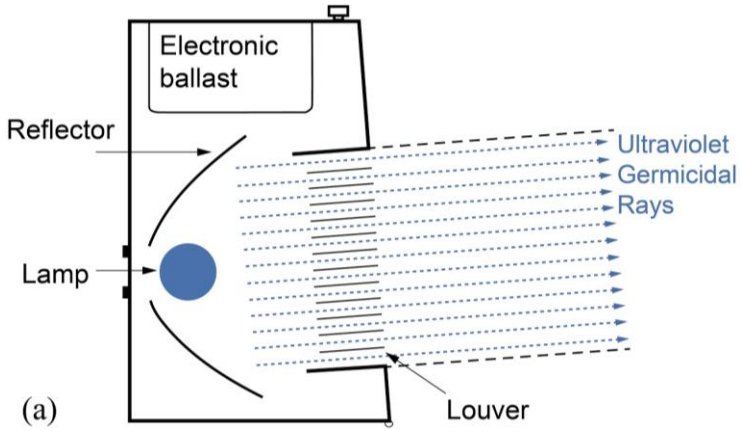
ORIGINAL ARTICLE

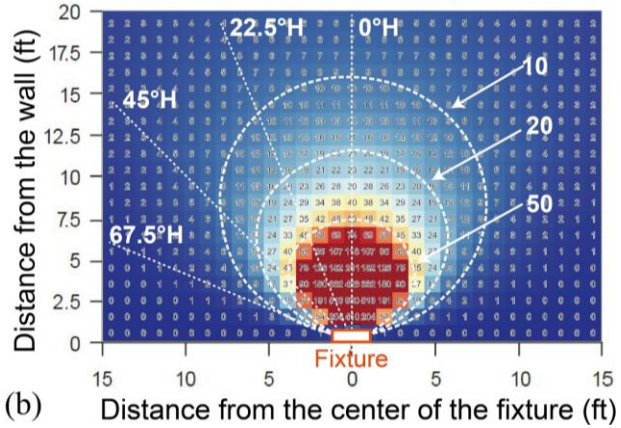
Spatial analysis of the impact of UVGI technology in occupied rooms using ray-tracing simulation

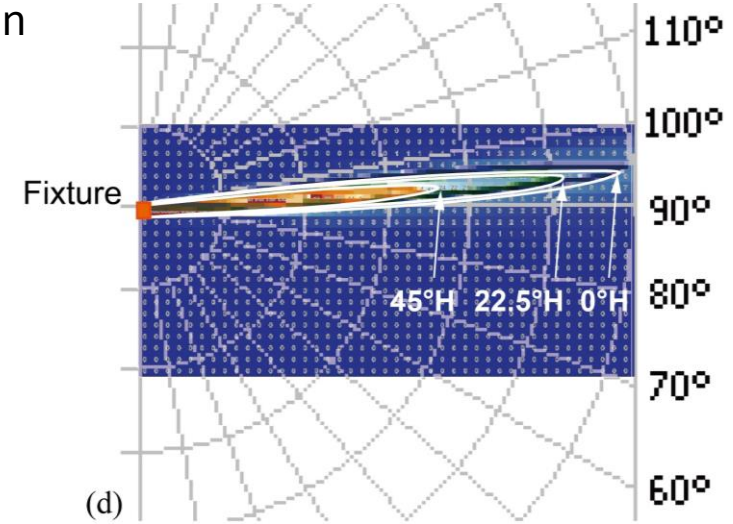
Miaomiao Hou, Jovan Pantelic, Dorit Aviv

First published: 26 March 2021 | https://doi.org/10.1111/ina.12827

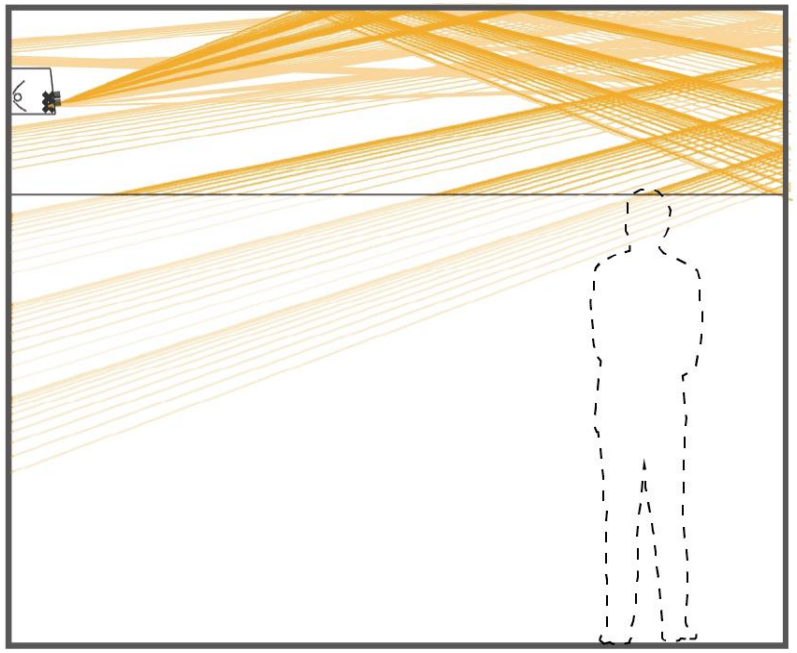


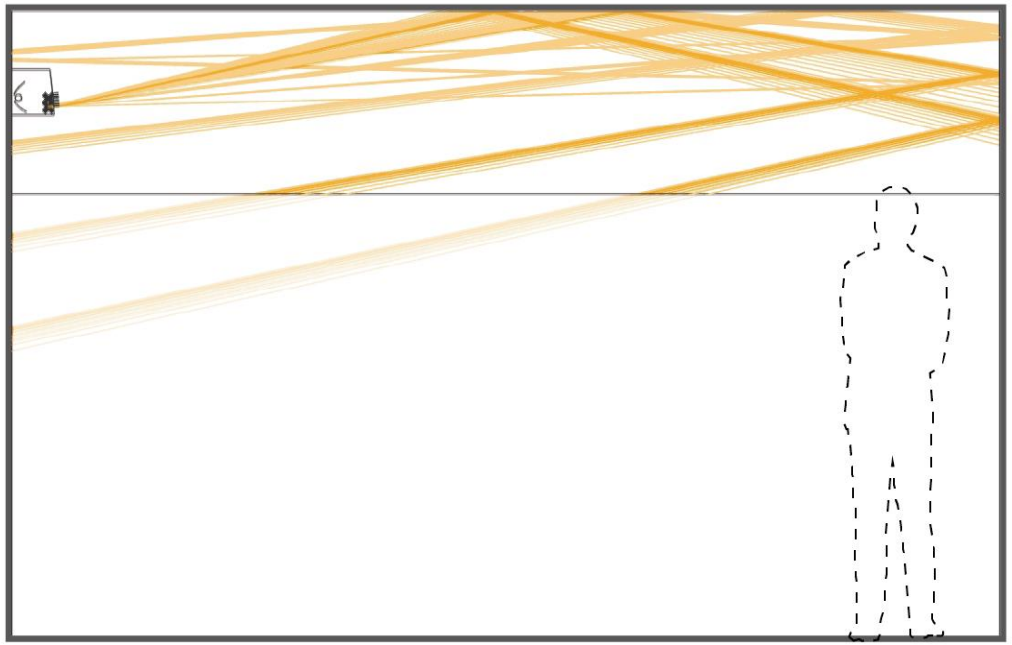


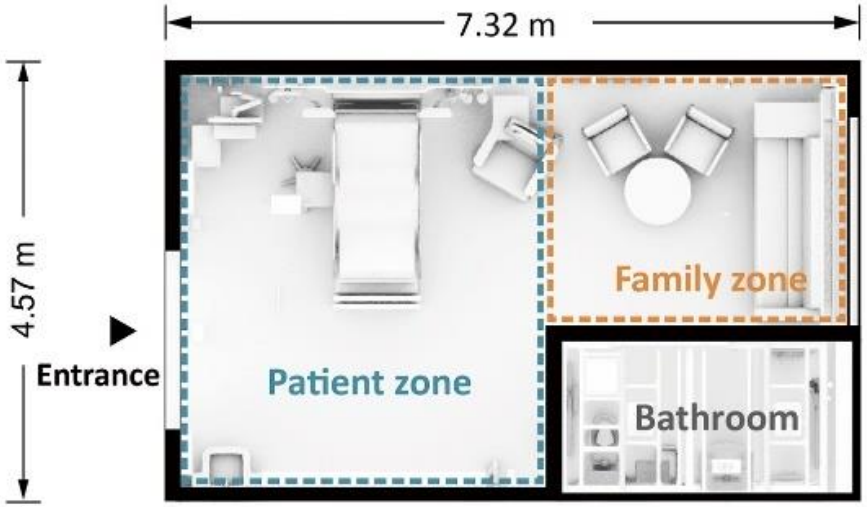


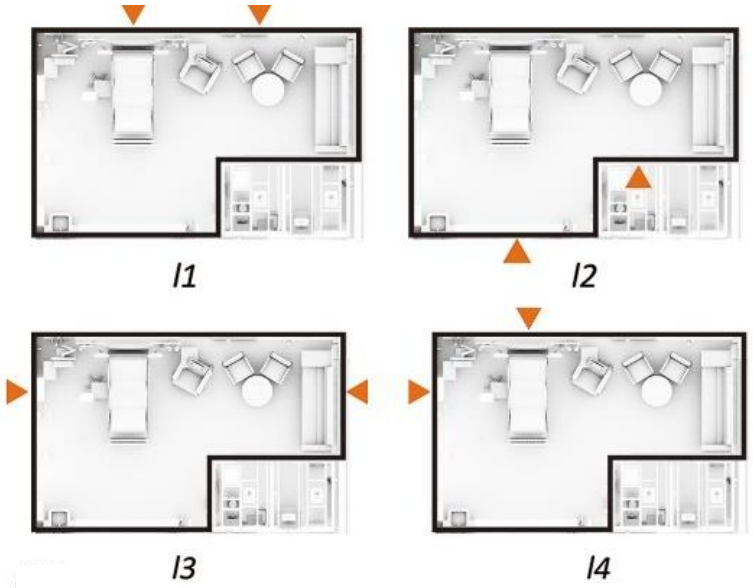


- Upper-room irradiance distribution for effective microorganism inactivation
- Lower-zone risk level assessment

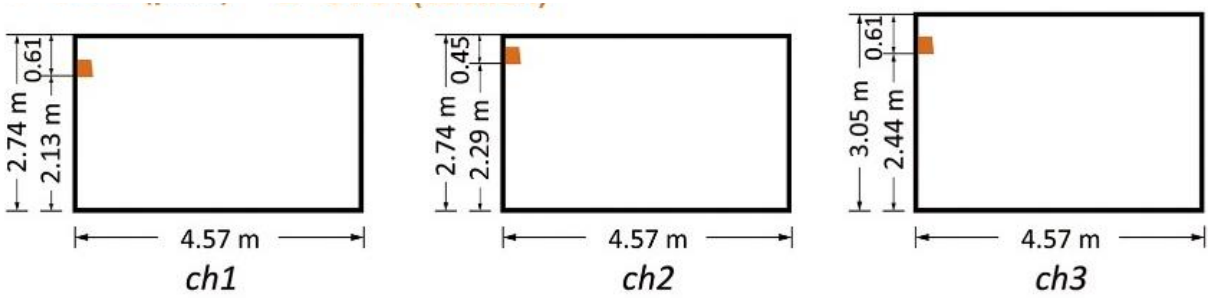








1. Device Location

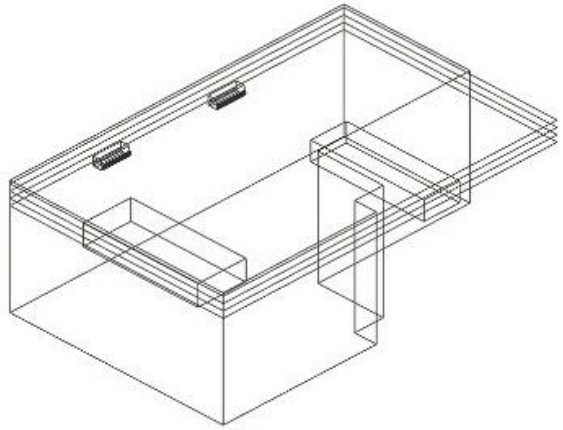


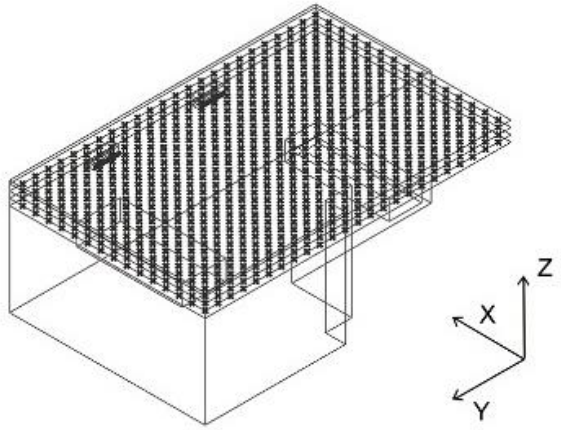
2. Device height and ceiling height

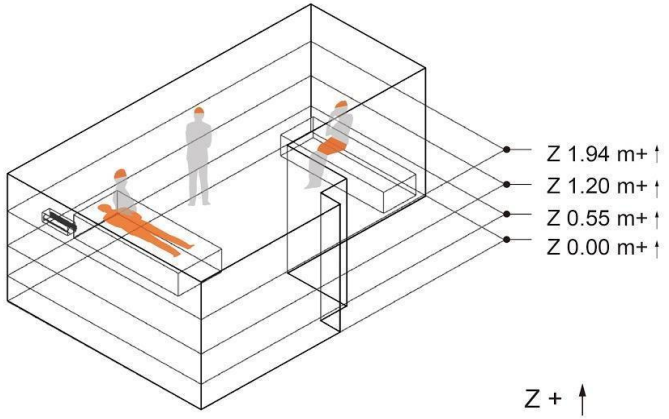
3. Room Layout

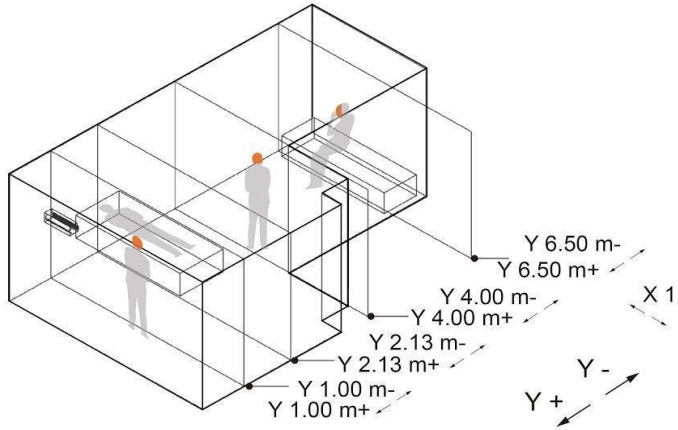
4. Reflectance

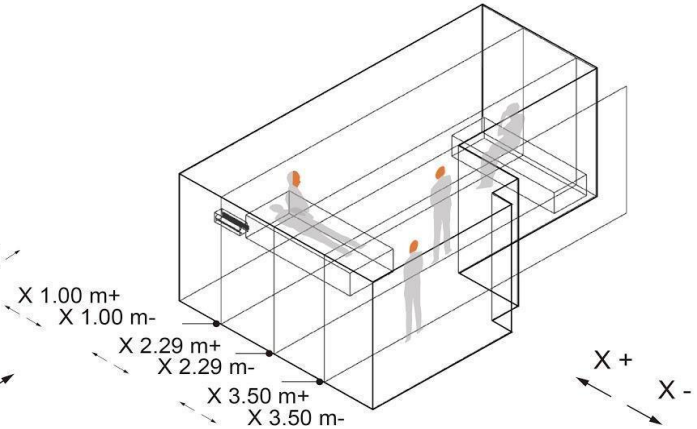
IRRADIANCE TEST PLANES

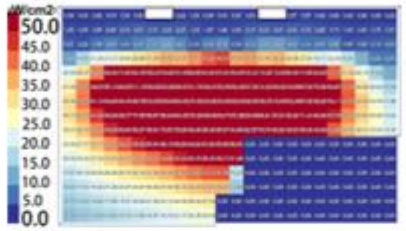
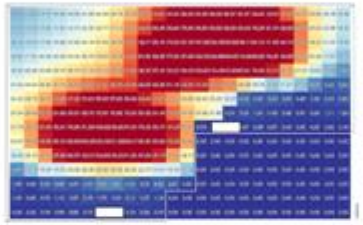
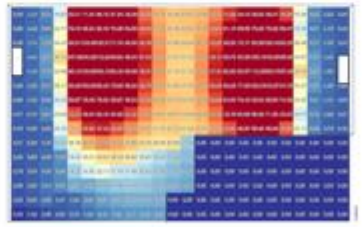
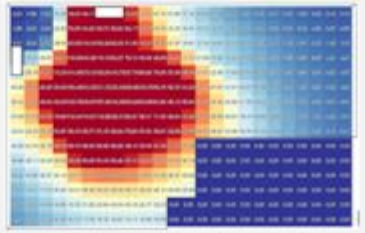








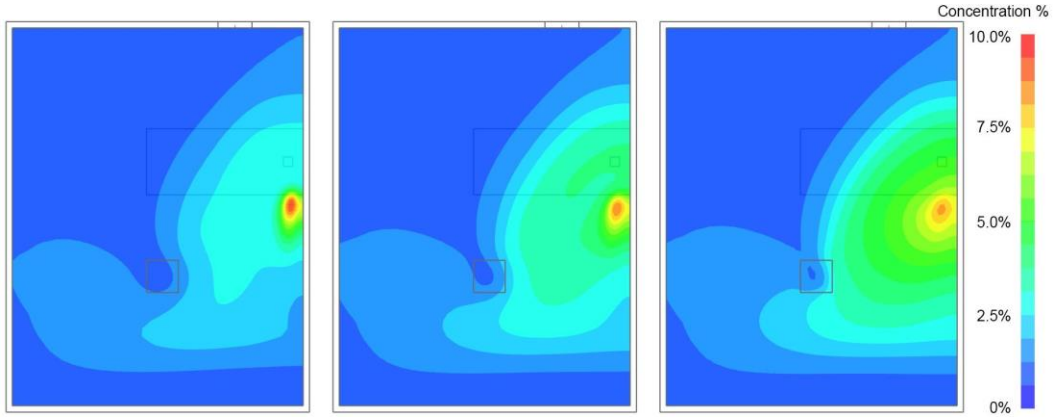


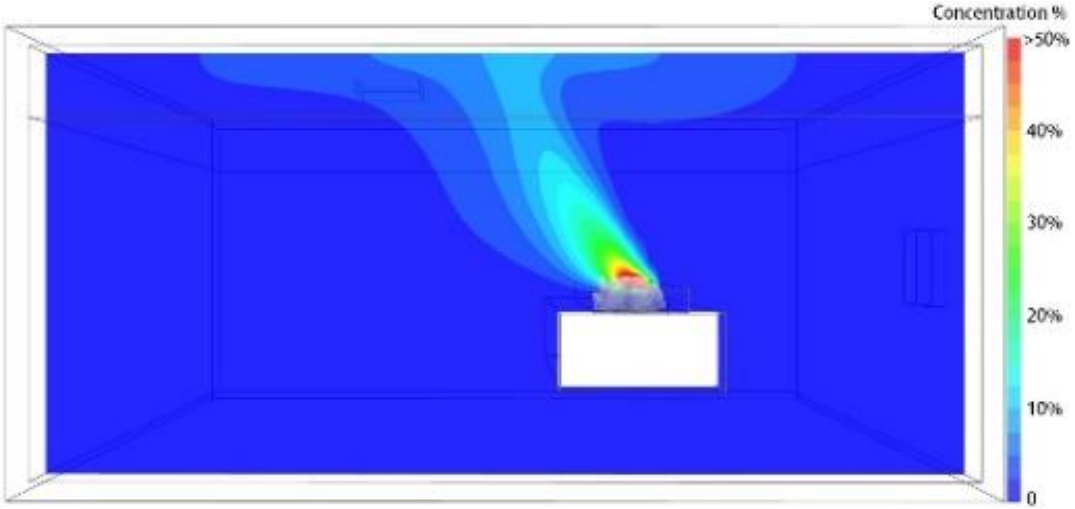
	Plan view at 2.52m	Percentage of area with effective disinfection coverage in the upper zone	Average fluence rate in the upper zone (μW/cm²) per test plane height			
		≥48μW/cm²‡	2.37 m	2.52 m	2.68 m	**Avg**
l1 (above bed)		18.85%	86.91	41.51	16.17	**48.19**
l2 (opposite bed)		15.40%	86.10	37.17	13.73	**45.67**
l3 (short walls)		14.14%	89.51	35.19	18.10	**47.60**
l4 (above bed & side) †		14.83%	87.33	39.01	19.50	**48.61**

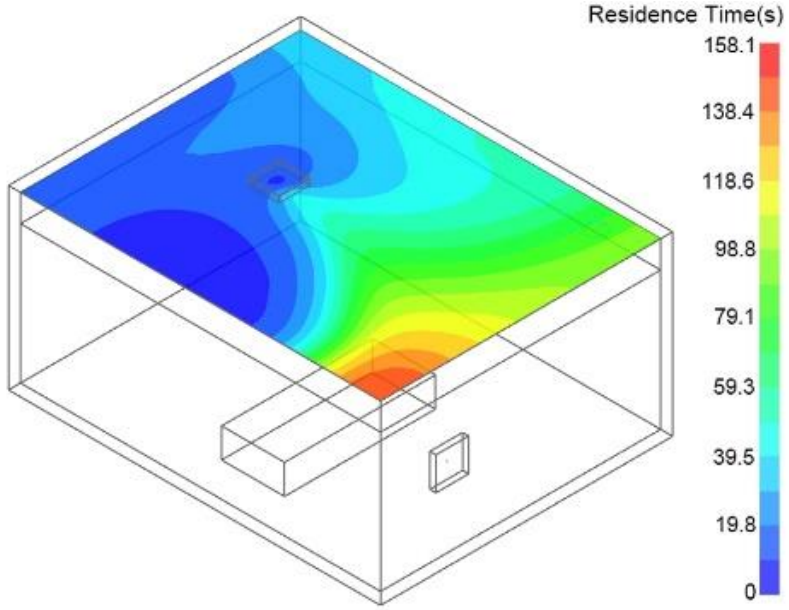
† Grey highlight indicates the location option with the most effective average distribution.

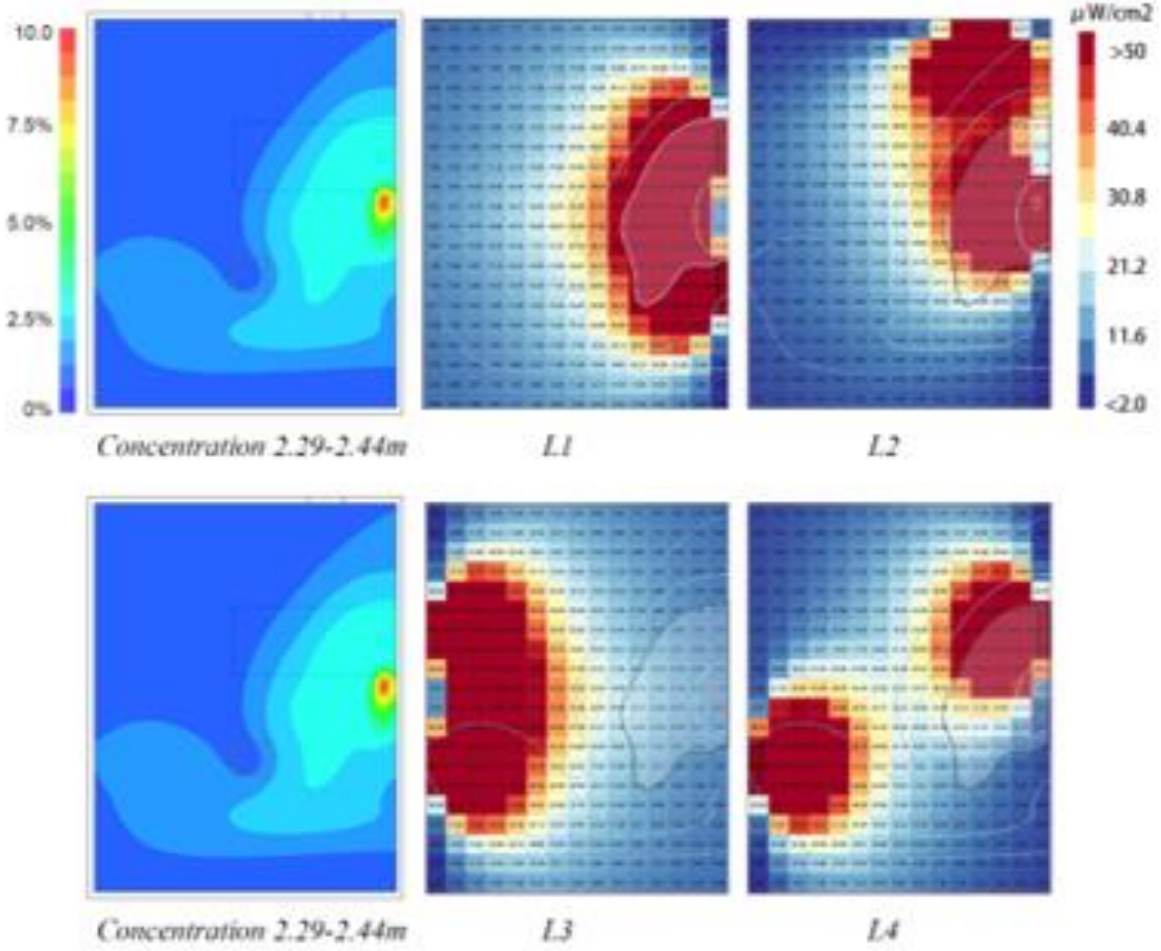
‡ 90% kill rate in 19 s for SARS-CoV-2 (with the required dose of 910 μJ/cm²).

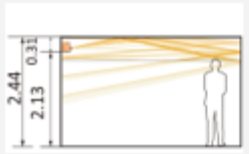
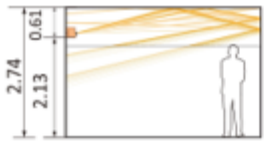
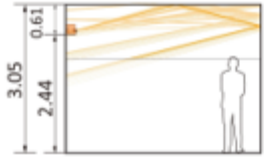
CFD INTEGRATION



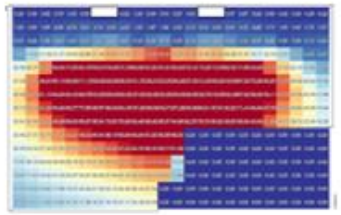
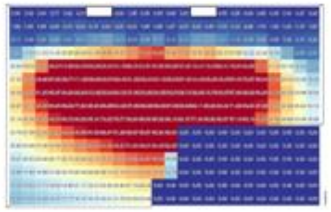
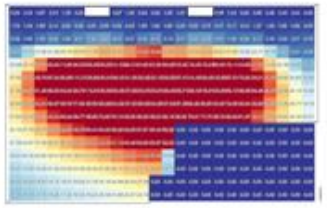
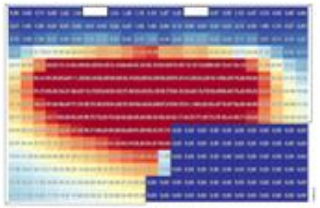
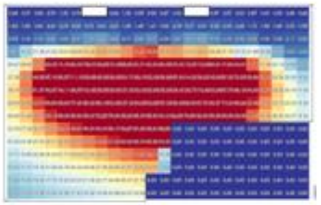
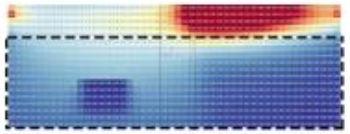
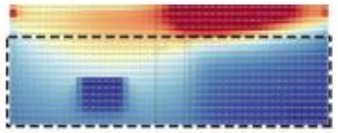
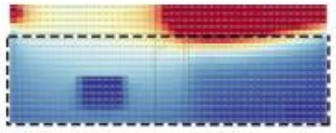
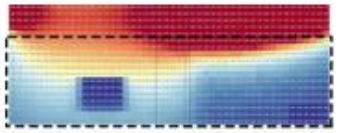
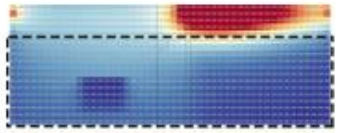


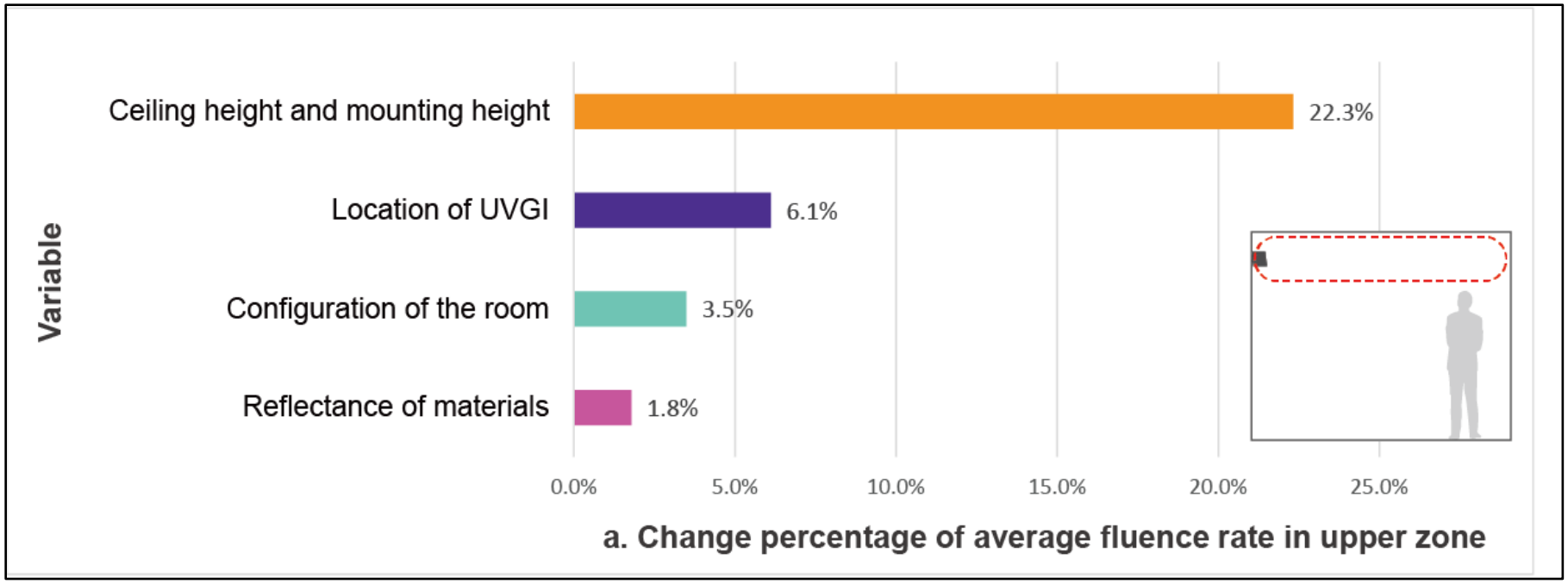



10.0
7.5%
5.0%
2.5%
0%
μW/cm2
>50
40.4
30.8
21.2
11.6
<2.0
Concentration 2.29-2.44m
L1
L2
Concentration 2.29-2.44m
L3
L4
Concentration 2.44-2.59m
L1
L2
Concentration 2.59-2.74m
L3
L4

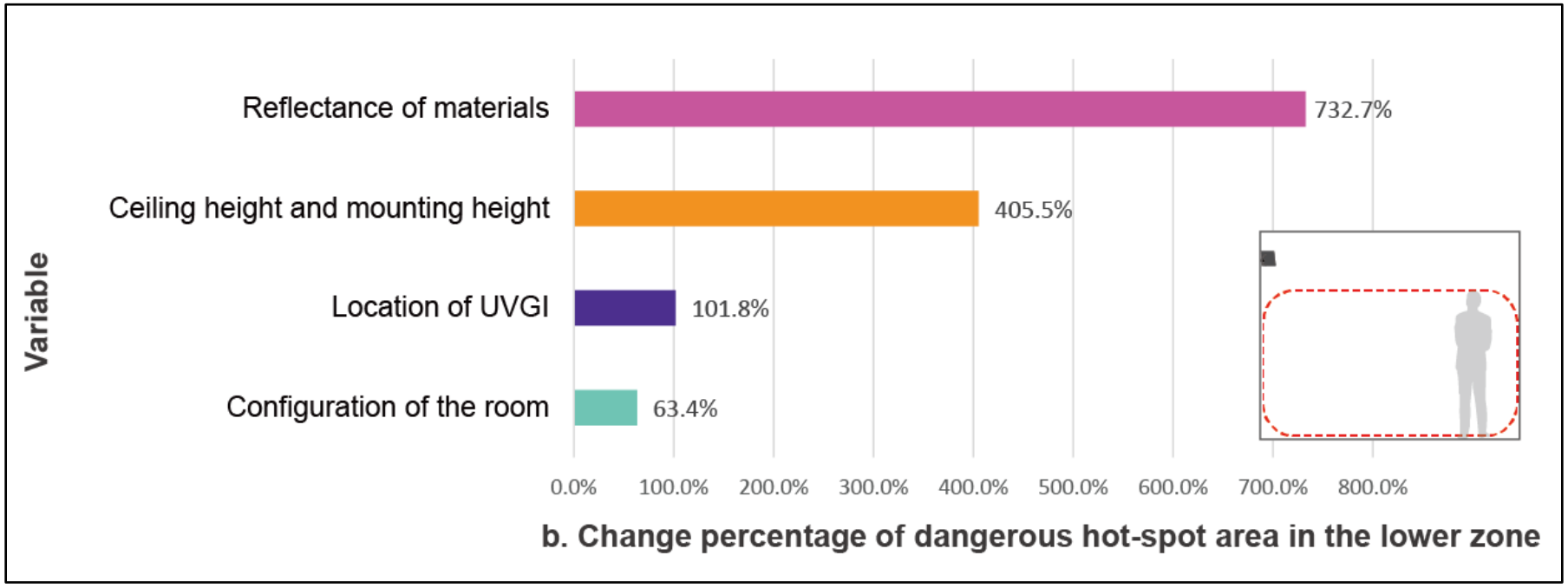
Ceiling height/ Device height	Upper zone volume (m^3)	Effective disinfection coverage in the upper zone	Average fluence rate in the upper zone per height ($\mu W/cm^2$)						
		≥48μW/cm²	2.22m	2.37m	2.52m	2.68m	2.83m	2.98 m	Avg.
h1 † 	4.81	18.27%	80.56	32.57	/	/	/	/	**56.56**
h2 	9.63	9.13%	80.52	32.49	12.25	3.18	/	/	**32.11**
h3 	7.22	12.18%	/	80.53	32.52	12.27	/	/	**41.77**
h4 	9.63	9.13%	/	/	80.52	32.49	12.25	3.17	**32.11**

† Grey highlight indicates the mounting/ceiling height option with the most effective average distribution.

	Ceiling 0.1	*Ceiling 0.2*	*Wall 0.1*	*Wall 0.2*	*Floor 0.2*
Plan view at 2.52 m 					
Max. irradiance at 1.83-1.98m	**0.36 µW/cm² (4.4h max)**	**0.61 µW/cm² (2.6h max)**	**0.56 µW/cm² (2.9h max)**	**1.07 µW/cm² (1.5h max)**	**0.32 µW/cm² (5.0h max)**
Max. irradiance at eye-height (1.78m)	**0.25 µW/cm² (6.4h max)**	**0.31 µW/cm² (5.2h max)**	**0.24 µW/cm² (6.7h max)**	**0.47 µW/cm² (3.4h max)**	0.13 µW/cm² (12.3h max)
Cross-section (X 2.29m-) 					

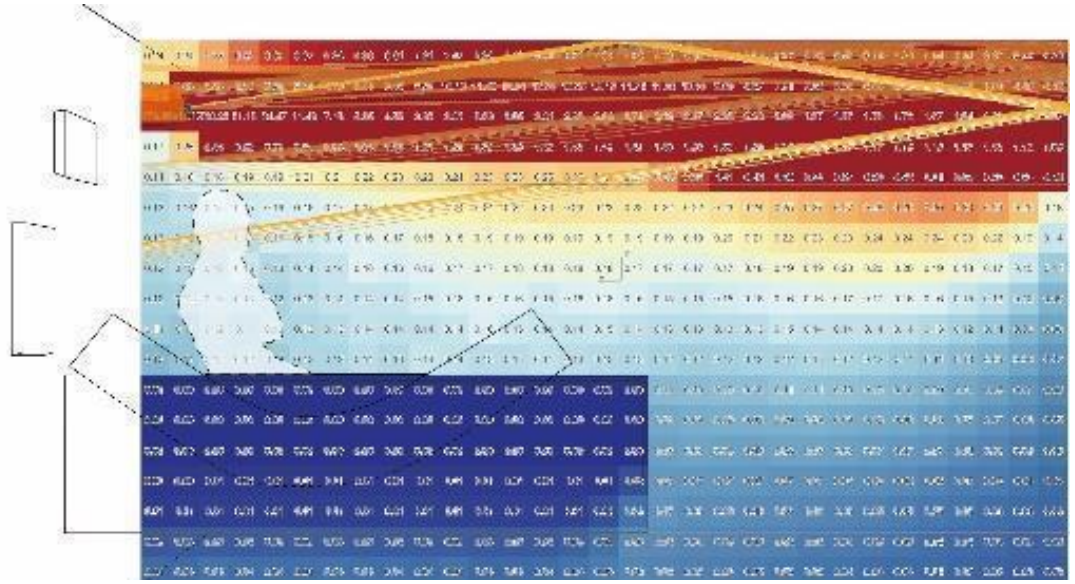


a. Change percentage of average fluence rate in upper zone



b. Change percentage of dangerous hot-spot area in the lower zone

Value of using a ray-tracing tool for UV irradiance analysis



- Interreflections can be a significant contributor
    - They depend on both room configuration and materials in relation to device location
- When combined with understanding of the room layout and airflow analysis, efficiency of the device can be increased
- Identifying dangerous hot-spots in occupied zone during design process