Revolutionizing PPE with highly integrated miniature Far UV-C modules

First International Congress on Far-UVC Science & Technology (ICFUST)

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BIODEFENSE SOLUTIONS

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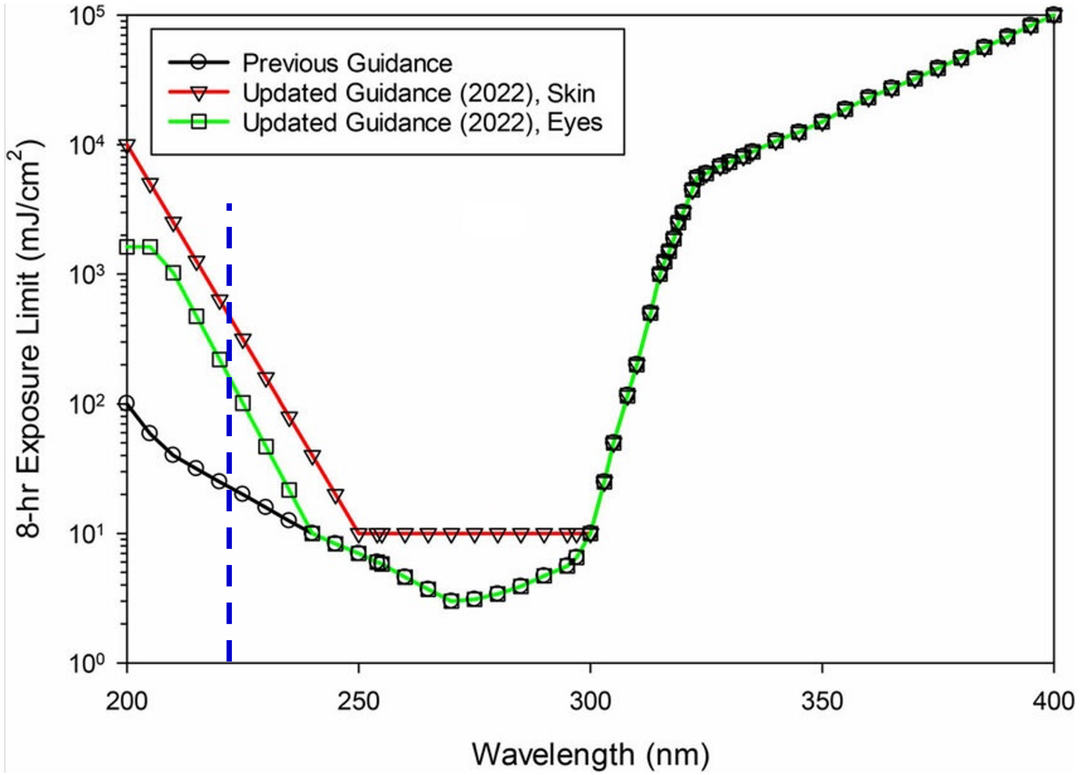
The Problem: Airborne Biothreats

- Biological threats represent a clear and present danger globally.
- Pharmaceutical interventions are reactive mechanisms, not preventative.
- PPE and decontamination methods have not had major technological innovation in decades.
- These challenges present an opportunity for new innovative solutions.

UV Exposure Limits: Skin and Eyes

American Conference of Governmental and Industrial Hygienists (ACGIH)



- ACGIH Sets Threshold Limit Values (TLVs)
- Revised Guidance in 2022 based on new scientific data
- Far UV-C (222nm) has limited human health risks
- Potential for use in public spaces

8-hr Exposure Limits (λ = 222 nm)
Previous Guidance = 23 mJ/cm^2
ACGIH New Guidance (2022): (Eyes) = 161 mJ/cm^2 (Skin) = 479 mJ/cm^2

Blatchley III, Ernest R., et al. "Far UV-C Radiation: An Emerging Tool for Pandemic Control." *Critical Reviews in Environmental Science and Technology*, vol. 53, no. 6, 2022, pp. 733–753, https://doi.org/10.1080/10643389.2022.2084315.

Far-UVC Source Examples

Commercially Available Sources

Care222 KrCl* Module

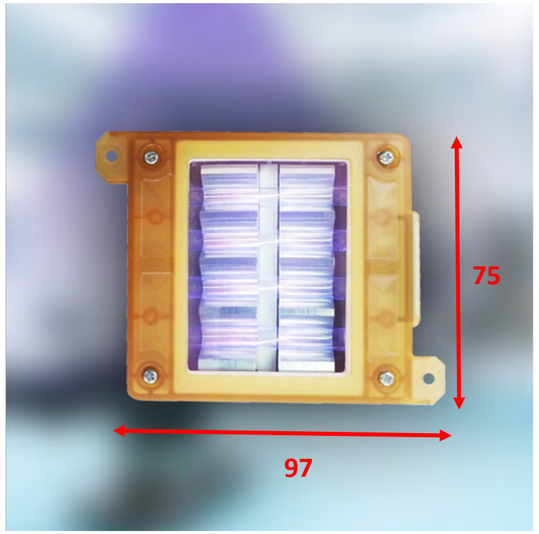


Image from www.ushio.com

Flat Microplasma KrCl* Lamp 222 nm

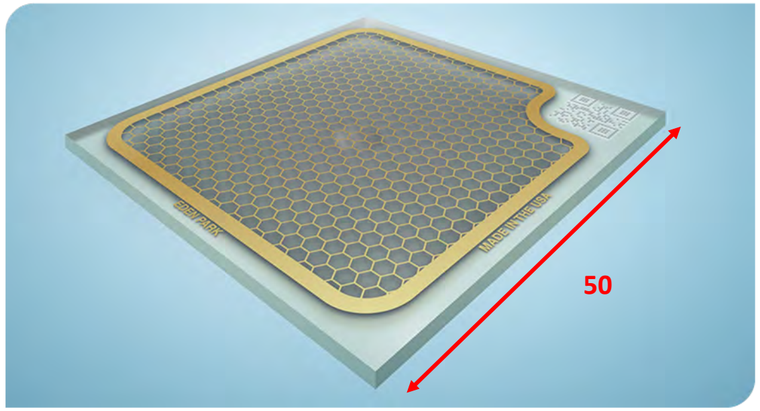


Image from www.edenpark.com

In Development

LED 235 nm

Images from https://silannauv.com

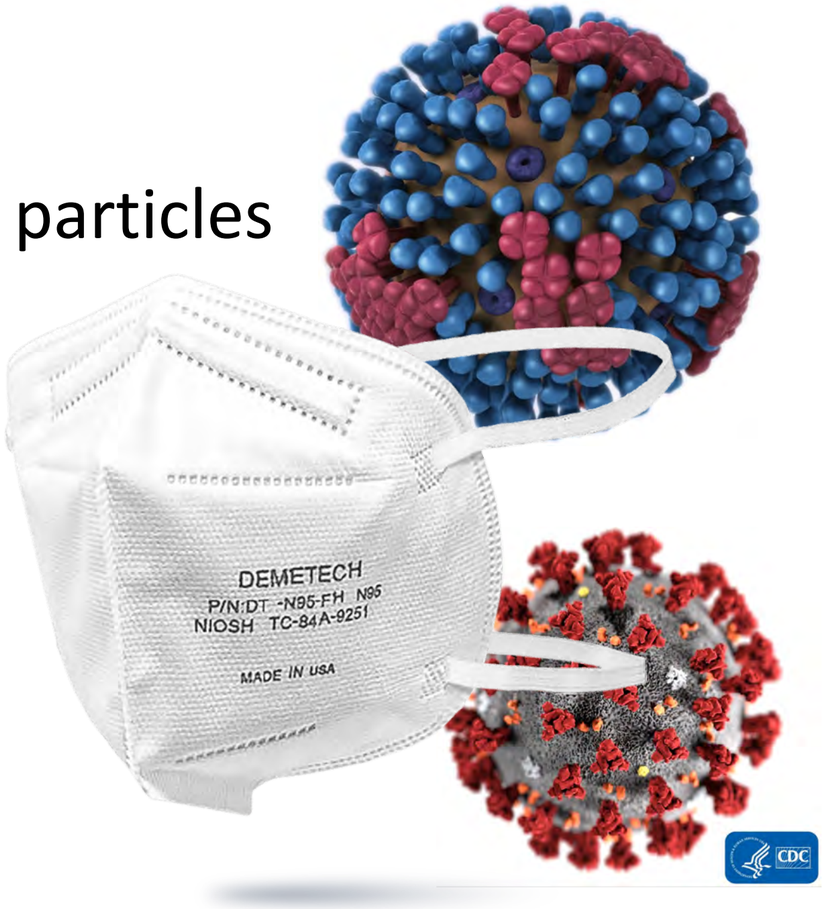
Comparing Respiratory PPE

	Mechanical Filtration					Inactivation
Comparing Technologies Designed to Protect from Airborne Pathogens Good Moderate Poor	**Face shields**	**Cloth Masks**	**Surgical Masks**	**N95 Mask**	**N100 Mask**	**Next Generation PPE**
Application adaptability						
Level of protection						
Ease of respiration						
Ease of communication						
Waste impact						
Ease of fitting						
Minimal eyeglass fogging						

- Next Generation Advantages
  - Enhanced protection via Far-UVC (viral inactivation) vs. Mechanical Filtration
  - Comfortable and low breathing resistance
  - Reusable / low ecological footprint
  - Adaptable for future threats (tunable, indiscriminate against variants)

Next Generation PPE Requirements

- Equivalent Effectiveness
  - NIOSH Approved N95 Mask
    - Filtration of 95 % of ≥ 0.3 micron particles
- Photobiological Requirements
  - Est. UVC Dose requirement
    - ≥ 1.3 log (95 % inactivation)
- Target Respiratory Pathogens
  - SARS-CoV-2 (~1.0 mJ/cm2)[1]
  - Influenza (~0.48 mJ/cm2)[2]



Images from: https://www.cdc.gov/

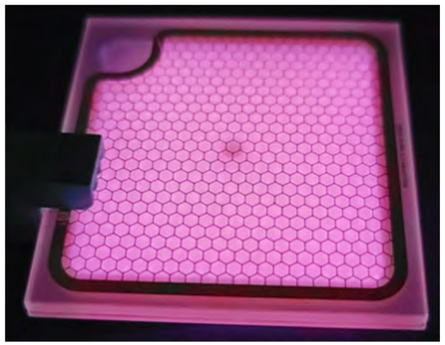
1) Ma, Ben, et al. “UV Inactivation of SARS-COV-2 across the UVC Spectrum: KrCl* Excimer, Mercury-Vapor, and Light-Emitting-Diode (LED) Sources.” *Applied and Environmental Microbiology*, vol. 87, no. 22, 2021, https://doi.org/10.1128/aem.01532-21.
2) Hessling , Martin, et al. “Sensitivity of Influenza Virus to Ultraviolet Irradiation.” *GMS Hygiene and Infection Control*, vol. 17, no. 20, 26 Oct. 2022, pp. 3–6, https://doi.org/doi: 10.3205/dgkh000423.

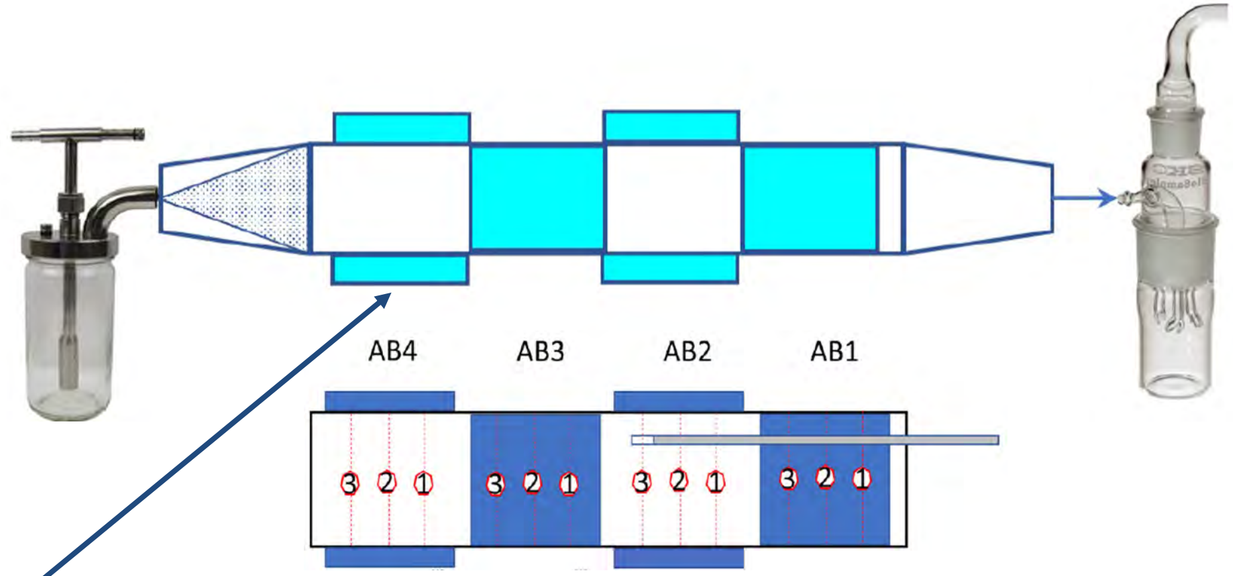
KrCl* Laboratory Measurements

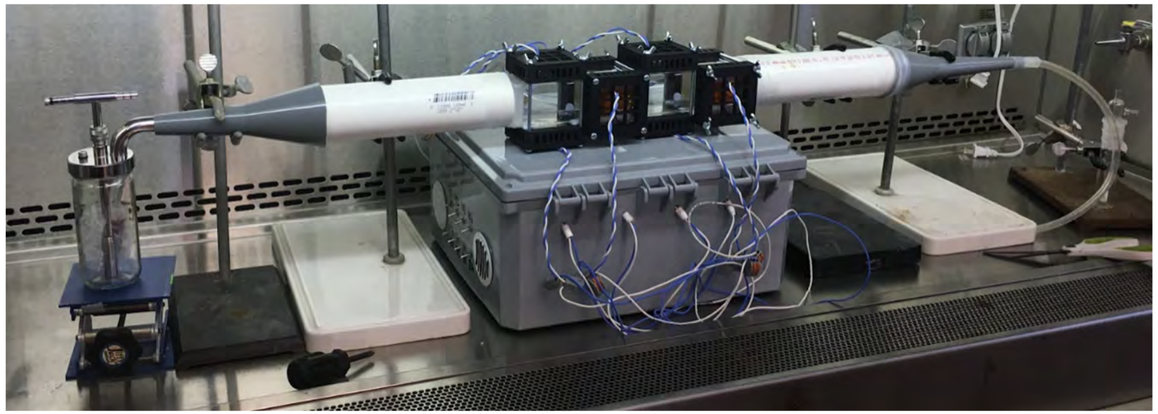
- "Square Quartz channel" reactor*
  - 4 opposing lamp pairs (turquoise rectangles)

- Fluence Rate Field Characterization/Quantification
  - Irradiance grid measurements
  - Est. UV Dose

Lamp Pair	Average UV_{222} Dose $\left(\frac{mJ}{cm^2}\right)$
AB1	4.62
AB2	3.87
AB3	5.07
AB4	3.51





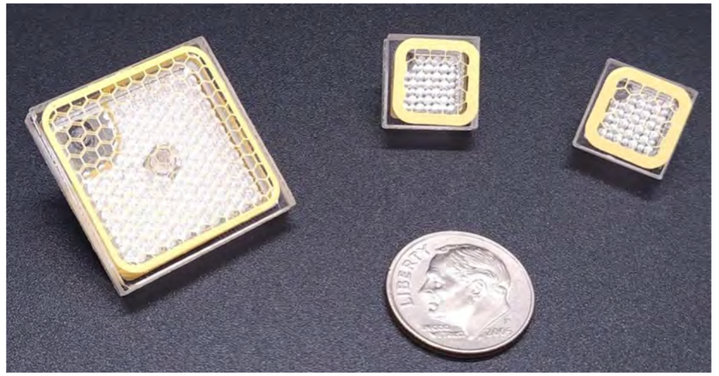


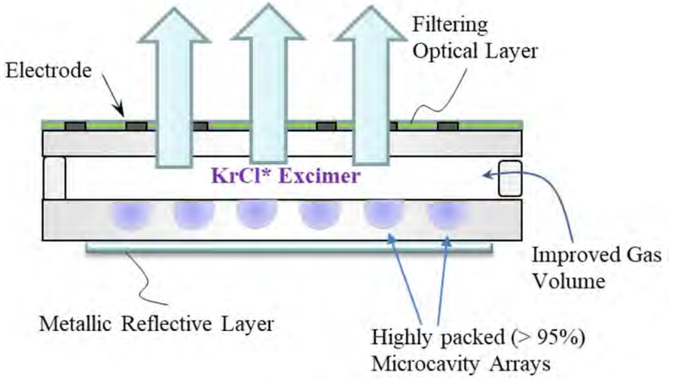
- Biological Experiments
  - Quantify inactivation
  - Surrogate virus (aerosolized T1 phage)
  - Inactivation Results
    - 1.6 log (97.5 %) T1
    - Equiv. 2.8 log (99-99.98 %) SARS-CoV-2 under similar conditions*

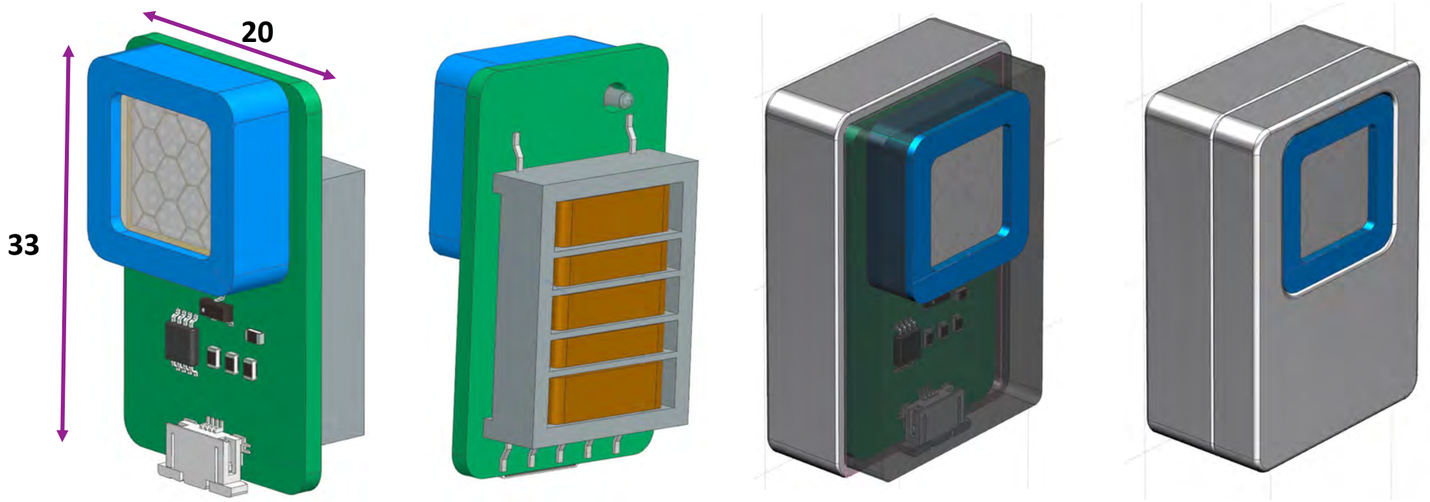
Quantification of Viral Aerosol UV_{222} Dose-Response Behavior Using a Square Quartz Channel Reactor (Xing Li and Ernest R. Blatchley III)

Monolithic Lamp Module Development

- Miniature KrCl* Microplasma Lamp (12X12mm)
  - Flat panel construction
  - High density microcavities (95 %)
  - Reflective coating
  - Integrated driver
  - Fully Encapsulated
  - SELV compliant
  - 1.5W/lamp*

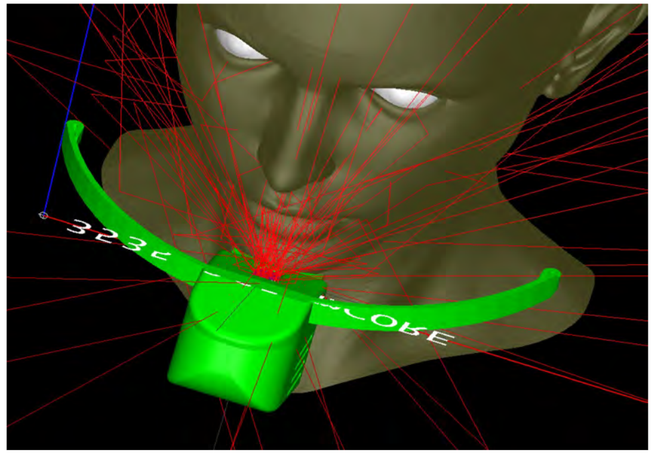


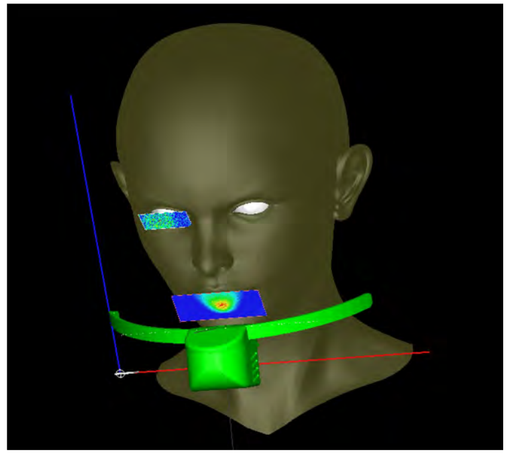




Next Gen PPE: Initial Prototype Mask

Directed miniature microplasma lamp

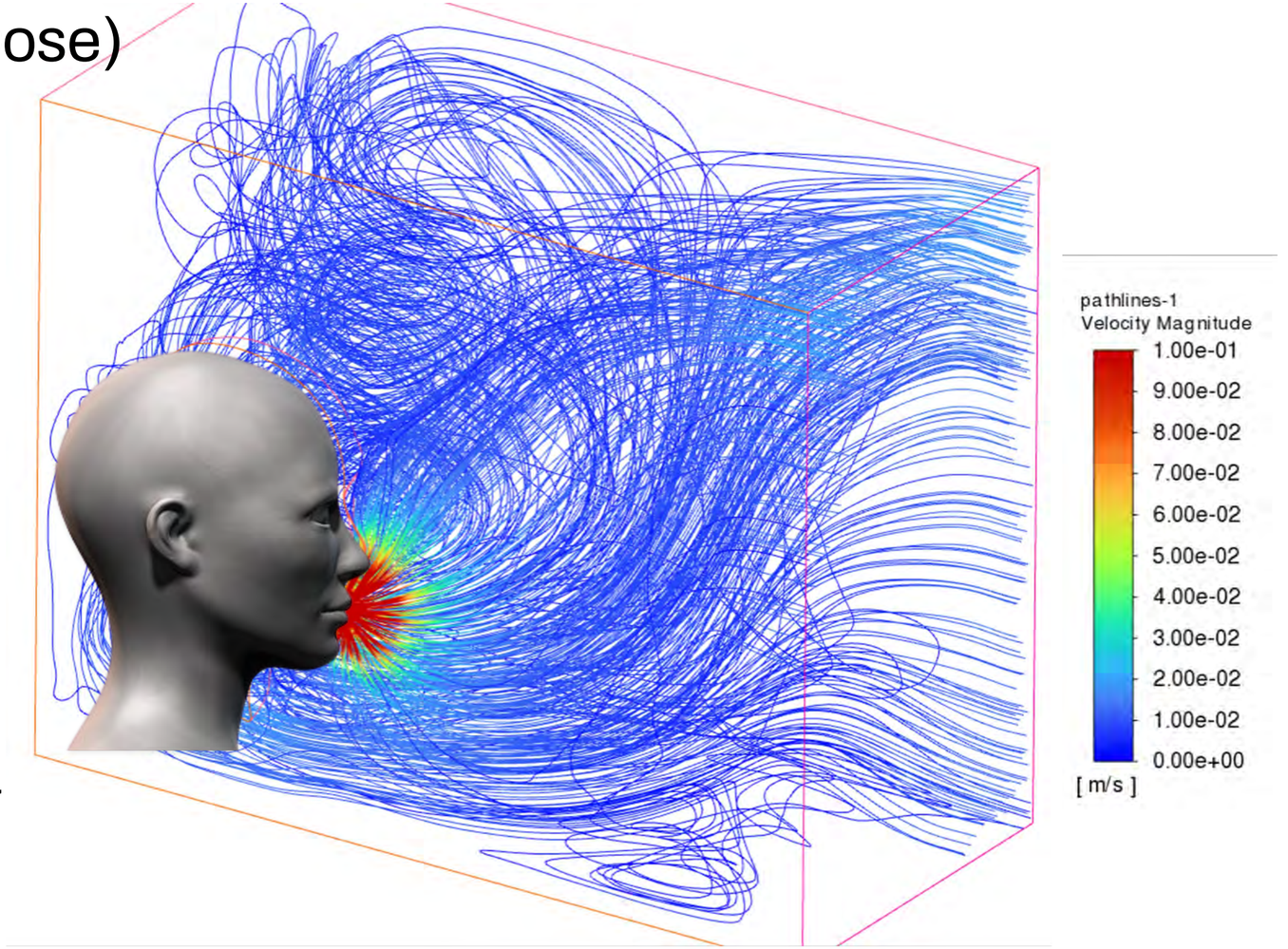




Ray-tracing and CFD simulation for aiding design of Far UV-C based PPE (C. Bowers, XCMR).

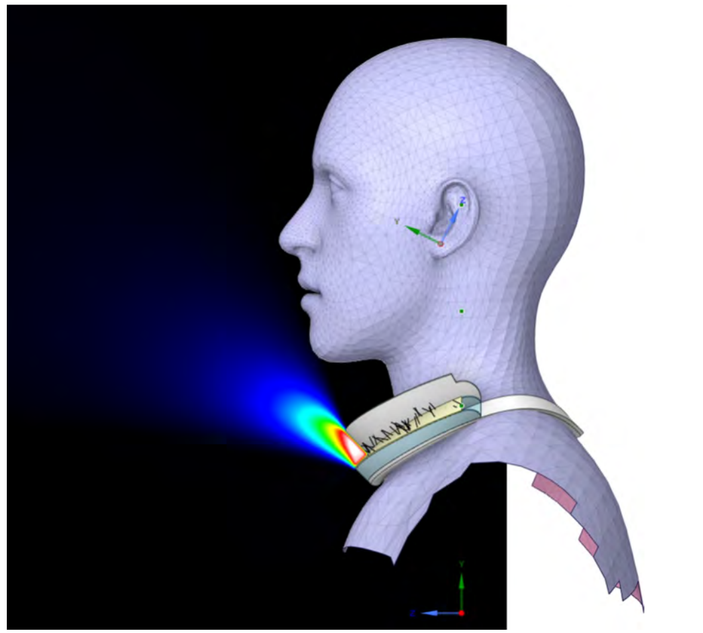
Disinfection Dilemma: UV Dose vs. TLV

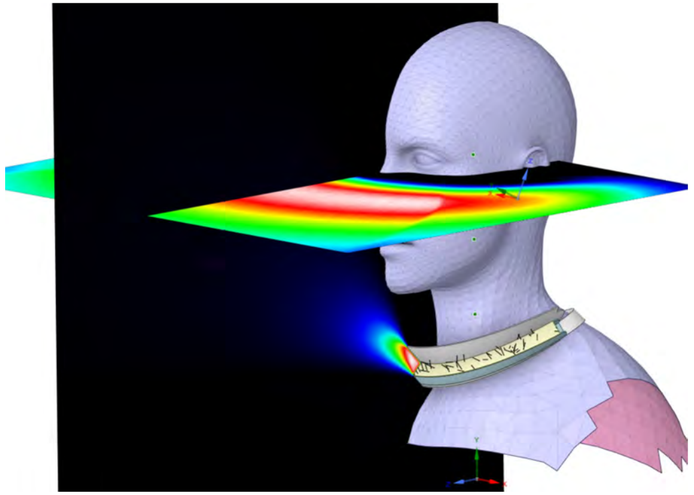
- Balancing UV disinfection energy (Dose) with TLV limits is challenging…
- Fast moving airborne particles = short residence times
- Peak velocity near nose/mouth area = shortest exposure
- High density of photons needed to achieve disinfection in target area



Current Research Focus

- Curved Microplasma lamp concept
- Lamp directed away from face/eyes
- Optically tuned dielectric Reflective Film (90 % 222 nm reflectance)
- 95 % inactivation (SARS-CoV-2) for normal breathing rates
- Comfortable
- Easy to breathe
- Safe to wear





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