CUDOFORM
IMPRESSIVE TECHNOLOGY

EPIC – UV Disinfection
UVC LED Beam Confinement and Concentration

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CudoForm sets the global benchmark for high-volume stamping (Latin: CUDO) of accurate shapes (FORM) for optical components.

As the vanguard of science and engineering in metal stamping, we partner with customers and develop, manufacture, and commercialize metallic optical components produced with our proprietary micro-optic technology.

Our solution help shape light for a safe, healthy, and connected world by improving optical performance and lowering assembly and test costs.

Advantages of Stamped Metallic Optical Components

Metal Properties

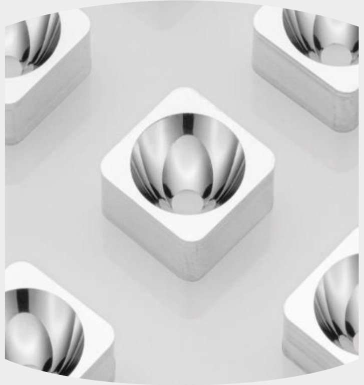
Thin

Solderable

Plateable

Ridged and rugged

Thermally conductive / matched



Reflective Free Form Optics

Beam and spot shaping

Confinement and Concentration

Redirecting beams

Expanding beams

No additional processing needed

Accurate Shapes and Locations

Accurate location of features

Passive or active alignment for optical fibers, lens, gratings, integrated circuits, substrates

Ease of assembly

Stamped Metallic Optical Reflectors for Ultraviolet Light Emitting Diodes

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Introduction

This paper presents metallic optical reflectors (MORs), made with stamping processes, as a new lens for UVC LEDs. Designs are described, tested, and validated for applications in SMD packages and chip-on-board (COB) modules. Aspherical mirror surface in MORs narrow the beam and achieve viewing angles as small as 15° FWHM with high efficiency. Simulations and tests demonstrate that this approach is suitable for germicidal irradiation of surfaces or air in upper-room applications.

The stamped MORs achieve optical quality, without secondary processing, and they have surface roughness as low as Sa = 7 nm with form typically better than +/ – 4μm.

Stamped metallic optical reflectors

Figure 1. Photographs of (a) a stamped MOR with 15°FWHM viewing angle and (b) COB module with MOR surrounding UVC LED

Stamped mirrors can have finishes better than Sa = 5 nm w/o secondary processes. The bore of the reflector can be stamped with an axisymmetric reflector, an aspherical reflector, or a freefor

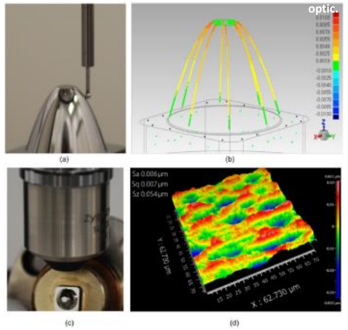
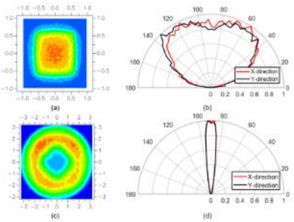


Figure 3. Metrology of stamping punch used to produce samples of 15° FWHM MORs (a) photograph of punch during CMM metrology, (b) deviations between actual punch and ideal CAD model, (c) punch in SWLI for roughness measurements, (d) 3D profile of punch

Samples of the 15° MOR were stamped using the Fig 3 punch. The measurement of the punch shows the form error about +5 μm to -1 μm, and the surface with average roughness Sa = 6 nm and RMS roughness Sq = 7 nm.

Optical Designs and Simulation



The resulting design yielded a 15° FWHM angle

Figure 4. Optical simulation of single bare die LED without and with MOR. (a) normalized near-field irradiance pattern and (b) normalized far-field irradiance polar plot for bare LED without MOR. (c) normalized near-field irradiance pattern at the output (d) far-field irradiance polar plot for bare LED with 15° FWHM MOR

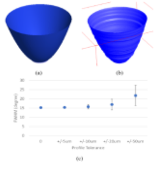


Figure 5. Tolerance study for optical design of MOR

A tolerance study assessed the robustness of the design to different amounts of manufacturing form error. The results suggest that the production tolerance on the form of the stamped MOR surface should be +/- 5 μm to avoid significant changes in the viewing angle.

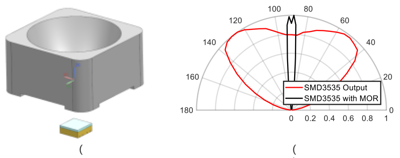


Figure 6. MOR for SMD packages (a)MOR for SMD3535 package and (b) far-field irradiance polar plots for SMD3535 without MOR (red) and with 15°FWHM MOR (black)

We designed a MOR with a parabolic reflective surface that narrows the beam output from a SMD package. The reflective surface again yields a 15°FWHM divergent angle.

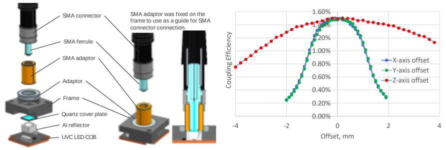


Figure 7. (a) mechanical design for a separable fiber-LED connection system that uses a stamped MOR, (b) sensitivity study relating coupling efficiency to location error between fiber and LED

A robust LED- multimode fiber coupling system can be achieved with +/- 400 micrometers of offset by using re-imaging MOR, the coupling efficiency remains better than 1.4%, close to the theoretical limit.

Experimental Validation

The performance of the UV-C LEDs with MORs was validated at the National Institute of Standard and Technology (NIST) using their gonio-spectroradiometer. A UVC LED is typically a 2π emitter, thus, the TSRF, $\Phi_{e,\lambda}(\lambda)$, is obtained by integration with Eq. 1, where θ is the angle of vertical rotation axis, φ is the angle of the horizontal rotation axis, and d is the measurement distance.

$$\Phi_{e,\lambda}(\lambda) = d^2 \int_{\theta=0}^{\pi/2} \int_{\varphi=0}^{2\pi} E_{e,\lambda}(\lambda,\varphi,\theta) d\varphi d\theta$$

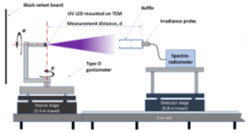


Figure 8. Type D gonio-spectroradiometer at the NIST used to characterize light emitted from UV-C LEDs and MORs

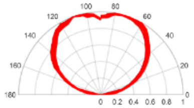


Figure 9. Normalized optical power as a function of angle θ for Sample 1 (bare die without lens or MOR)

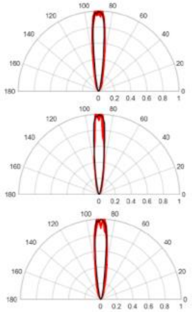


Figure 10. Normalized optical power as a function of angle θ for Sample 2 (bare die surrounded by 15° FWHM MOR)

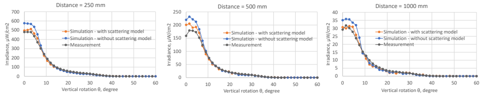


Figure 11. Comparison of measured and simulated irradiance profiles for (a) 250 mm, (b) 500 mm, and (c) 1000 mm

The similarity between the data indicates good agreement between the optical simulations and the measurements at NIST.

Conclusions

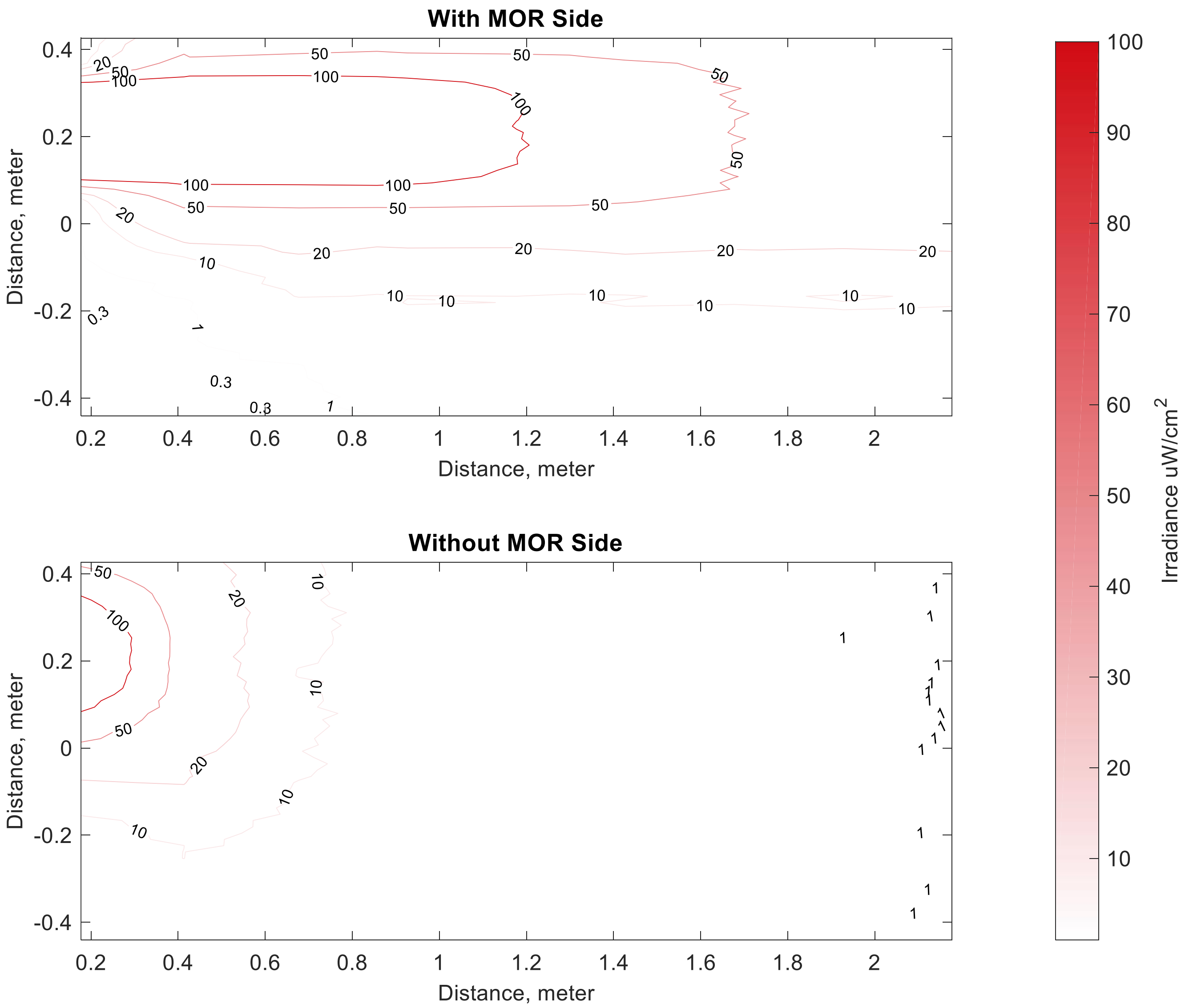
This paper expands the application of stamped optical components to include metallic optical reflectors (MORs) for illumination, particularly with UV-C LEDs needed for emerging applications in germicidal irradiation. Samples of MORs with a 15° FWHM viewing angle were stamped and evaluated at NIST. The agreement between the simulated data and NIST measurements confirms our optical model and simulation accuracy so that simulations can be used to predict the performance of germicidal irradiation systems.

Applying stamped metallic optical reflectors – pick priority knobs

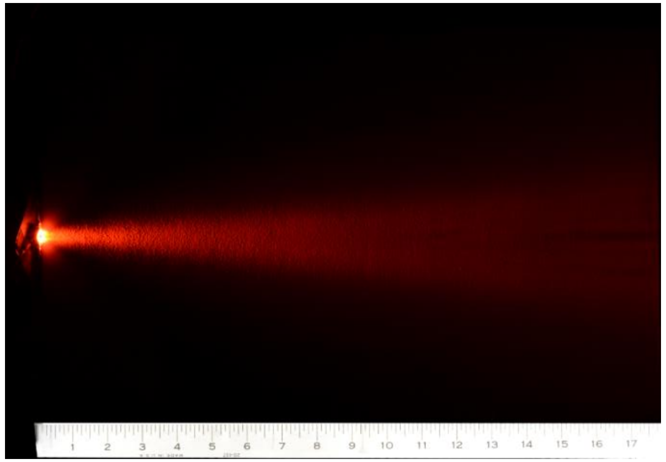
Objective:
Fine Tuning of individual and groups of UVC LEDs' Far Field irradiance

Optimize # of LEDs for cost control and aesthetics	AND / OR	Reduce electrical power usage	AND / OR	Reduce generated heat	AND / OR	Dose level and / or controlled optical radiation projection
↕		↓		↓		↕
Configure for photon patterning at a specific target		Enable battery operation		Raise reliability		Increase safety and boost efficacy Ease UL certification

Contours with and without **micro-optic beam shaping** – single 50 mW Extended optical reach in the x axis (w / small divergence in the y axis)

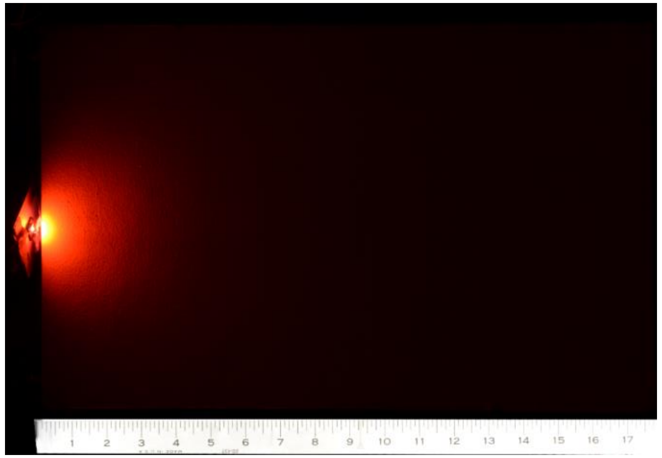


50mW UVC LED optical radiation visualized – the invisible is now visible



With CudoForm's metallic optical reflector, the optical radiation is concentrated and diverges over a narrow beam angle and high intensity extends beyond 50 cm and up to 2000 cm without suffering typical inverse square law loss.

Concentrated optical radiation demonstration shows beam can be shaped to be highly directional and the irradiance controlled using novel confinement.



Without reflector, the optical radiation rapidly spreads in all directions over full 180˚ angle and quickly decays over a short distance of a few inches.

Colorization of contour lines in the horizontal plane
calibrated to MOR + UVC LED measurements

Placeholder rendition

- ✓ Applicable to visualization of optical radiation of sources emitting between 200 nm to 400 nm
- ✓ Enhances product conceptualization, 3D simulations and designs, validation and certification, and at the point of installation re-confirmation
- ✓ Accurate ongoing and repeatable use verification of air, water, and surface treatment efficacy
- ✓ Provides feedback if operationally something has changed affecting efficacy or efficiency, and an optical adjustment is required

Thank you – Any questions?

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