Computational Fluid Dynamics Simulations Enable Effective Thermal Modeling of a Composite Phosphor-Conversion Platform

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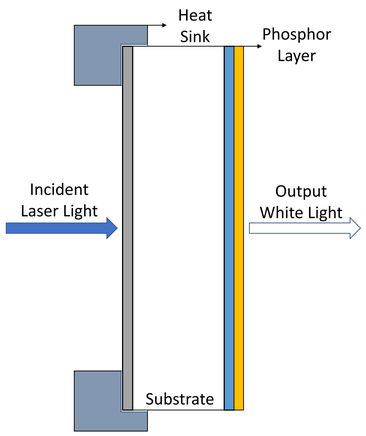
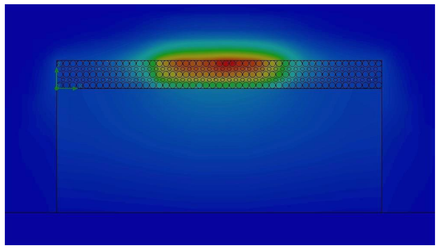
Phosphor-Converted Laser Light Sources Have High Optical Power Densities

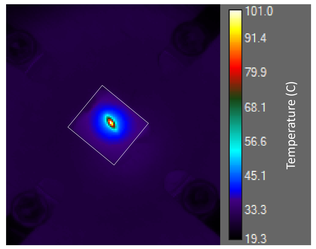



The Fluency Chip combines high power density and color quality.

Due to high optical power density and high color quality, phosphor converted laser light sources hold great potential in applications that require focused, high intensity lighting.
Phosphor converters are most efficient at low temperatures, making thermodynamics essential to their performance.

Computational Fluid Dynamics Simulations Allow In-Depth Thermal Analysis of the Phosphor Converter


Cut-plot extracted from SolidWorks Flow Simulation.



Thermal imaging of the converter.

Steady-State Computational Fluid Dynamics (CFD) simulations are proposed as an alternative to empirical measurements and theoretical models in order to estimate effective thermal conductivity.

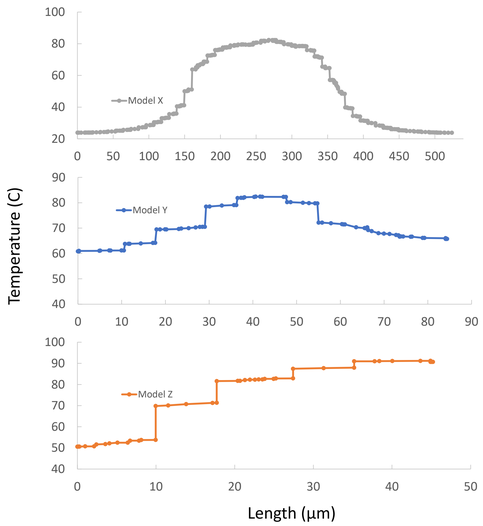
Fourier's Law of Conduction:

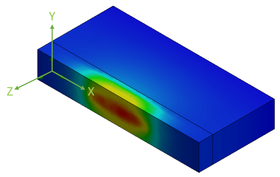
$$Q = -k\nabla T$$

Q : Local Heat Flux Density (W.m^{-2})
k : Material Conductivity (W.m^{-1}.K^{-1})
∇T : Temperature Gradient (K.m^{-1})

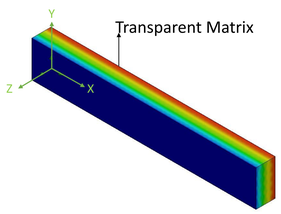
Heat Flux Densities and Temperature Gradients were Examined to Estimate Thermal Conductivity

Temperature gradients formed in the matrix were used in conjunction with Fourier's Law to estimate thermal conductivity.

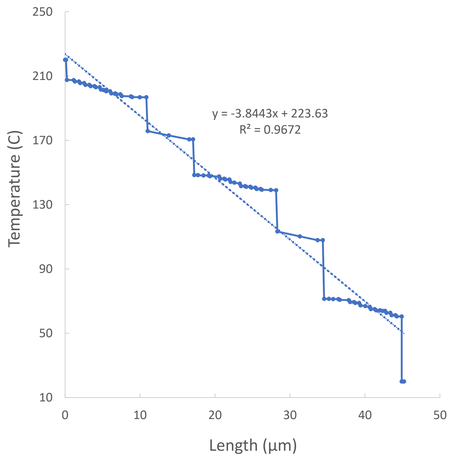


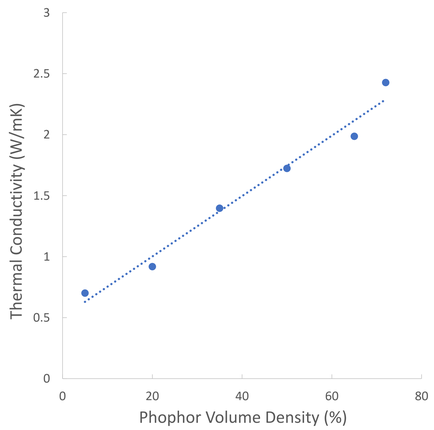


The realistic setup accounted for heat generation in the phosphors impacted by the laser beam.



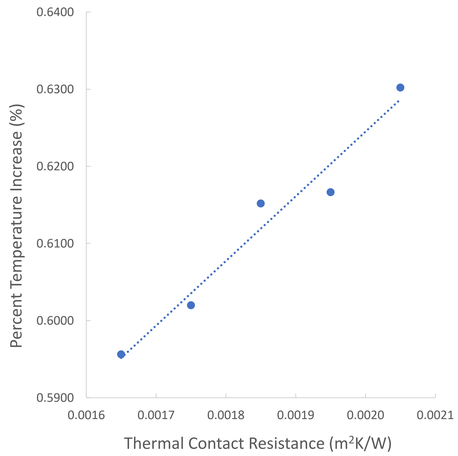
The idealized setup with constant boundary conditions was used to estimate thermal conductivity.

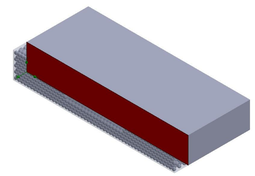




Thermal conductivity was shown to increase linearly with increasing phosphor volume densities. The matrix composite and the substrate can be treated as thermal resistances in series to find the total conductivity of the chip.

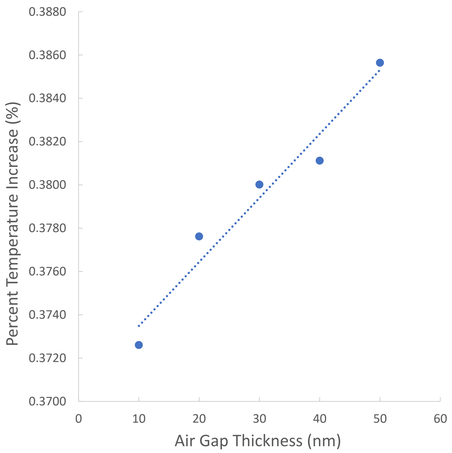
Parametric Equations Demonstrated the Role of Air Gaps and Contact Resistances in Heat Transfer




Thermal contact resistance at the substrate-matrix interface is caused by the limited effective contact area.

Air gaps were assigned to cover 25% of the surface area of the phosphor.


Air gaps functions as pockets of thermal resistance, limiting conduction and resulting in higher temperatures.



Characterizing the impact of impurities Is particularly significant in evaluating the manufacturing processes of the converter.

Using the Results to Improve Our Understanding of the Phosphor Converter

The effective estimation of thermal conductivity allows us to improve our modeling of the converter. The generated heat flux density maps can be used to review designs with a better understanding of heat transfer, and the parametric studies provide insight into the role of manufacturing processes in performance.

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