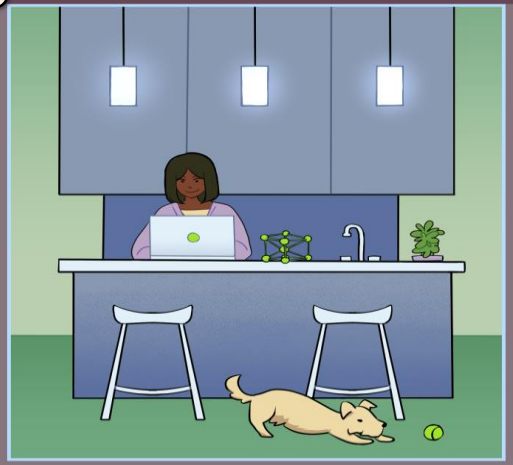
# Advancing Human-Centric Lighting



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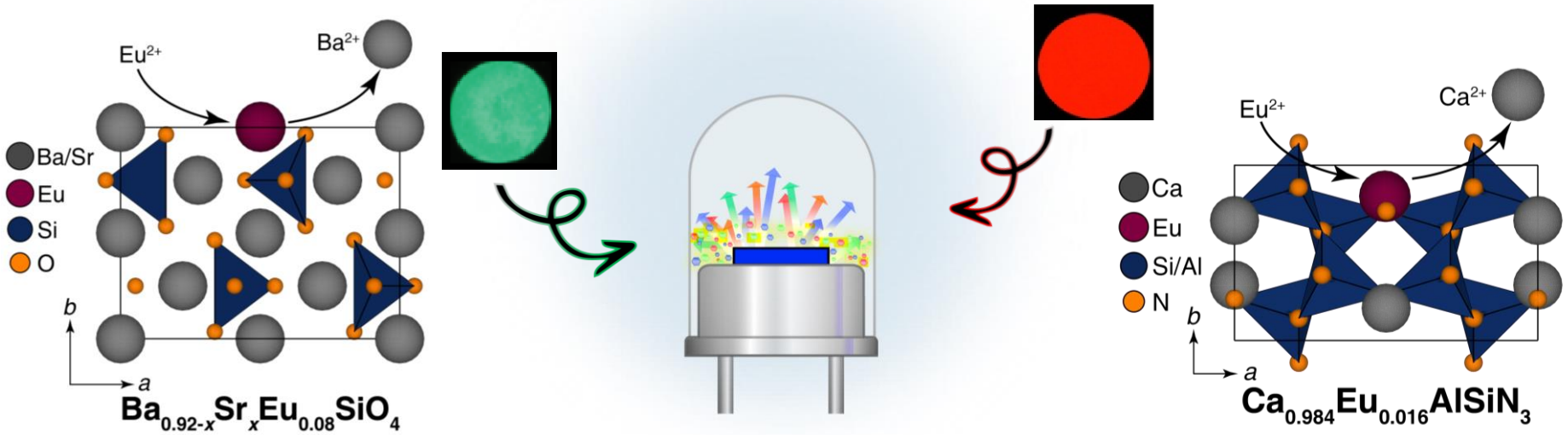
# Producing white light using a phosphor-converted LEDs

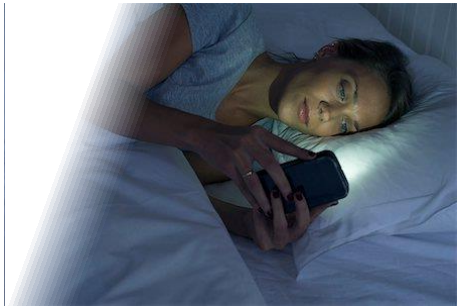
Energy-efficient LED light bulbs use an InGaN LED chip ($\lambda_{em}$ = 450 nm) and inorganic phosphors




These devices produce a functional white light that is ubiquitous in general illumination

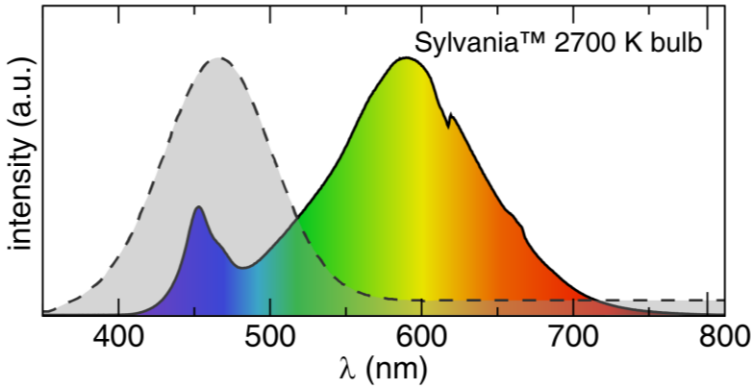
# The negative impacts of LED lighting

Long-term exposure to white LED lighting is known to suppress melatonin production



Blue LED emission significantly overlaps with a melatonin suppression curve

Chronic blue light exposure can cause macular degeneration, cataracts, and mood disorders




R. Nagare, B. Plitnick and M. Figueiro, *Lighting Research & Technology*, **2019**, *51*, 373-383.
A. Prayag, M. Münch, D. Aeschbach, S. L. Chellappa, C. Gronfier, *Clocks & Sleep* **2019**, *1*, 193-208.

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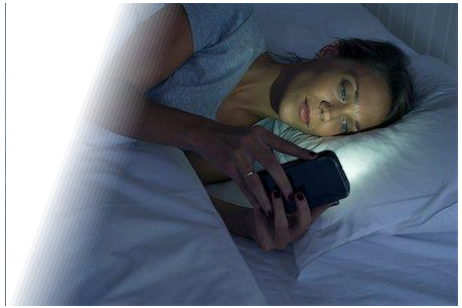

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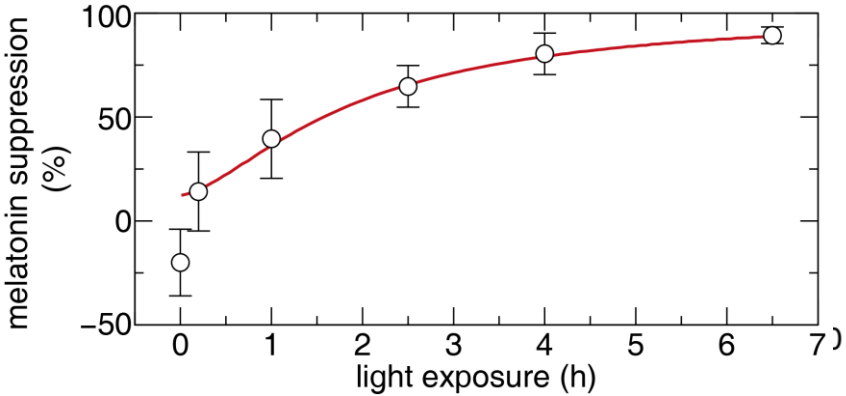


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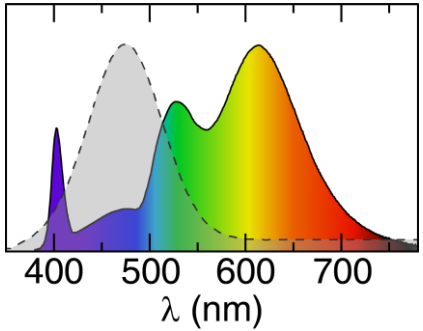
# Proposed solutions for blue LED exposure

Blue light blocking glasses


Dietary supplements

Conventional LED lighting

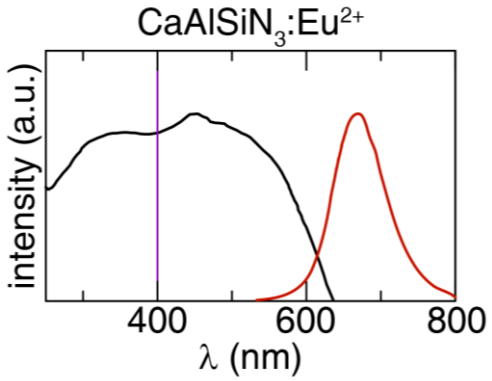
Turning on "Night mode"

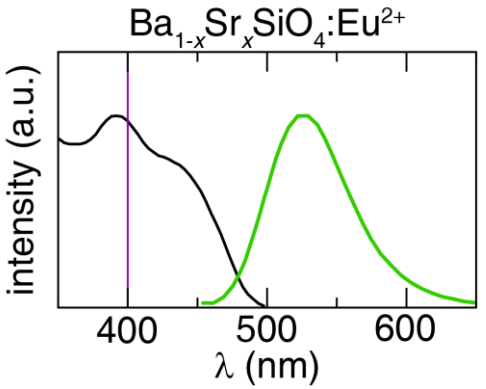



Move to violet-pumped lights

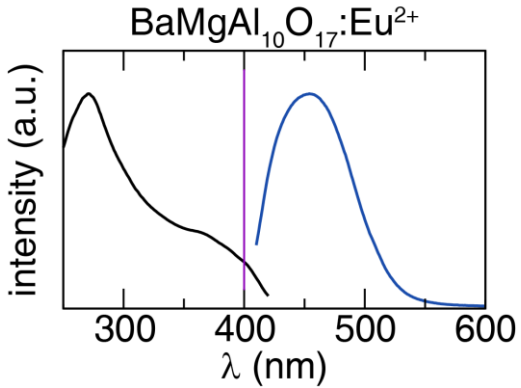
# Transitioning to violet LEDs can reduce blue light at the source

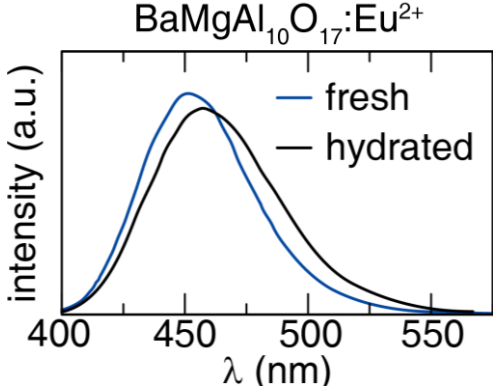
Violet ($\lambda_{em}$ = 405 nm) LEDs and compatible red, green, and **blue** phosphors can generate a "human-centric" white light




$BaMgAl_{10}O_{17}:Eu^{2+}$ has poor violet absorption and is not chemically stable





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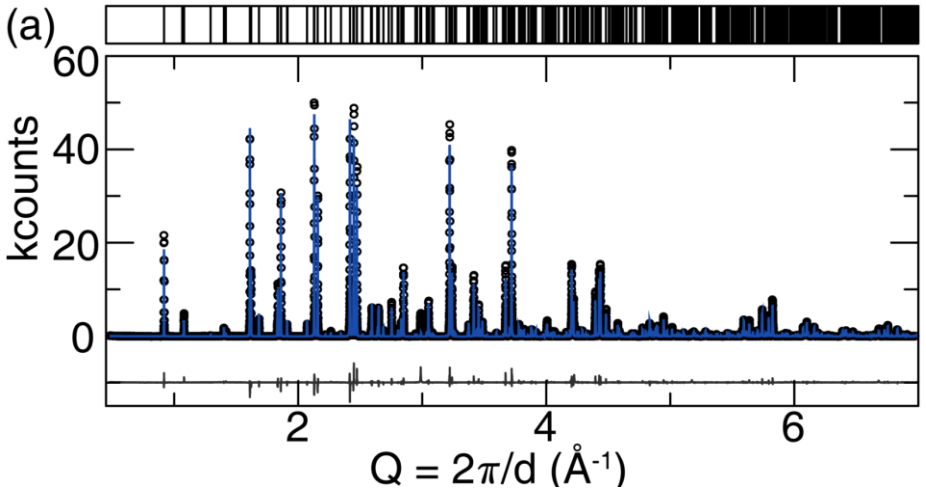
# One-step synthesis of $Na_{2-2x}Eu_xMgPO_4F$

$Na_{2-2x}Eu_xMgPO_4F$ can be synthesized in a one-step reaction by sintering at 825°C for 8 hours

A highly crystalline product can be readily obtained in scaled up reactions

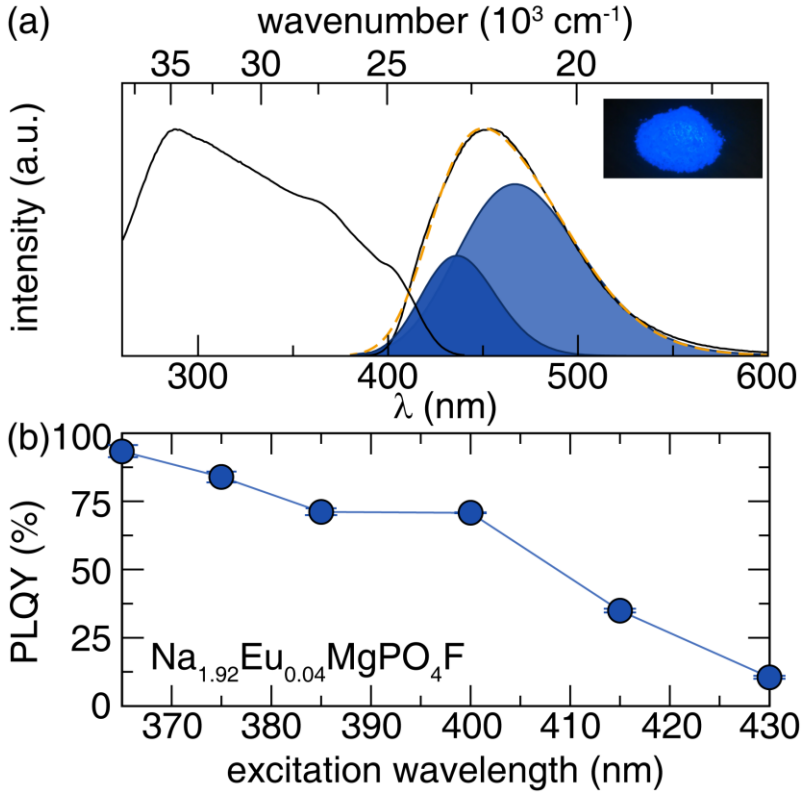




**S. Hariyani** and J. Brgoch, *ACS Appl. Mater. Interfaces* **2021**, *13*, 16669-16676.
J. Brgoch and **S. Hariyani**, Blue-emitting Phosphor and Methods of Use Thereof, PCT/US2021/060016, Filed November 19, 2020, *patent pending*.

# $Na_2MgPO_4F:Eu^{2+}$ produces a bright blue emission

The $Na_{2-2x}Eu_xMgPO_4F$ phosphors have a distinct excitation maxima at 400 nm producing broad blue emission

The quantum yield at 400 nm excitation is 71(1)%, making it compatible with violet LEDs

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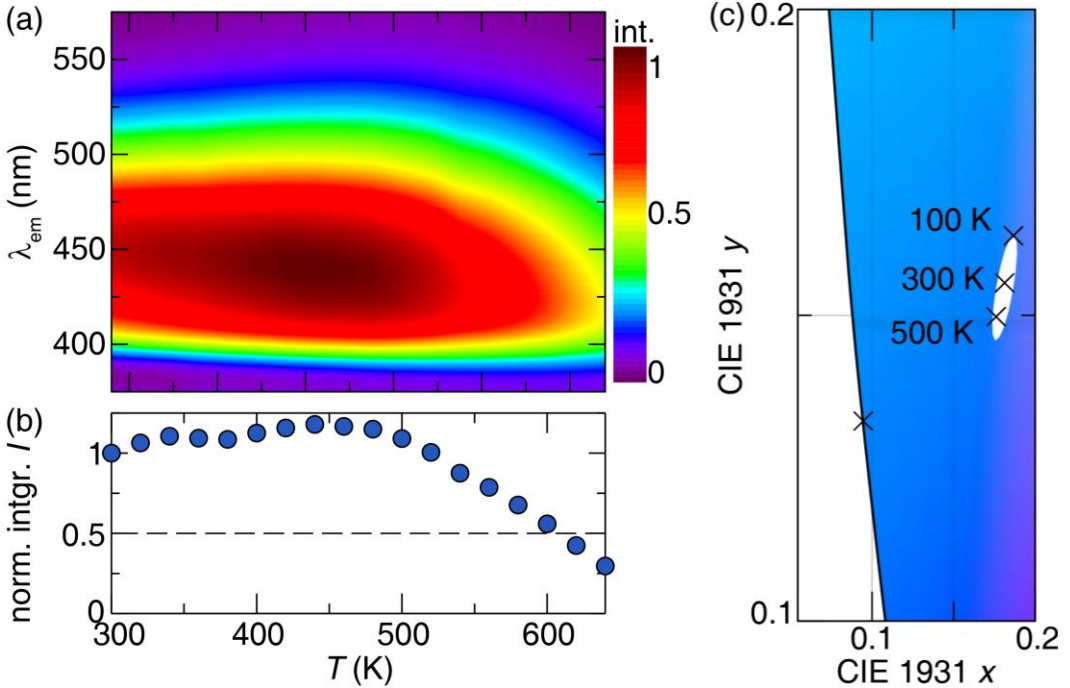
# Evaluating the thermal and chromatic stability of $Na_2MgPO_4F:Eu^{2+}$

Phosphors must retain > 50% of its emission intensity by 420 K

$Na_{1.92}Eu_{0.04}MgPO_4F$ maintains its intensity up to 500 K

The perceived color remains unchanged from 300 K to 500 K

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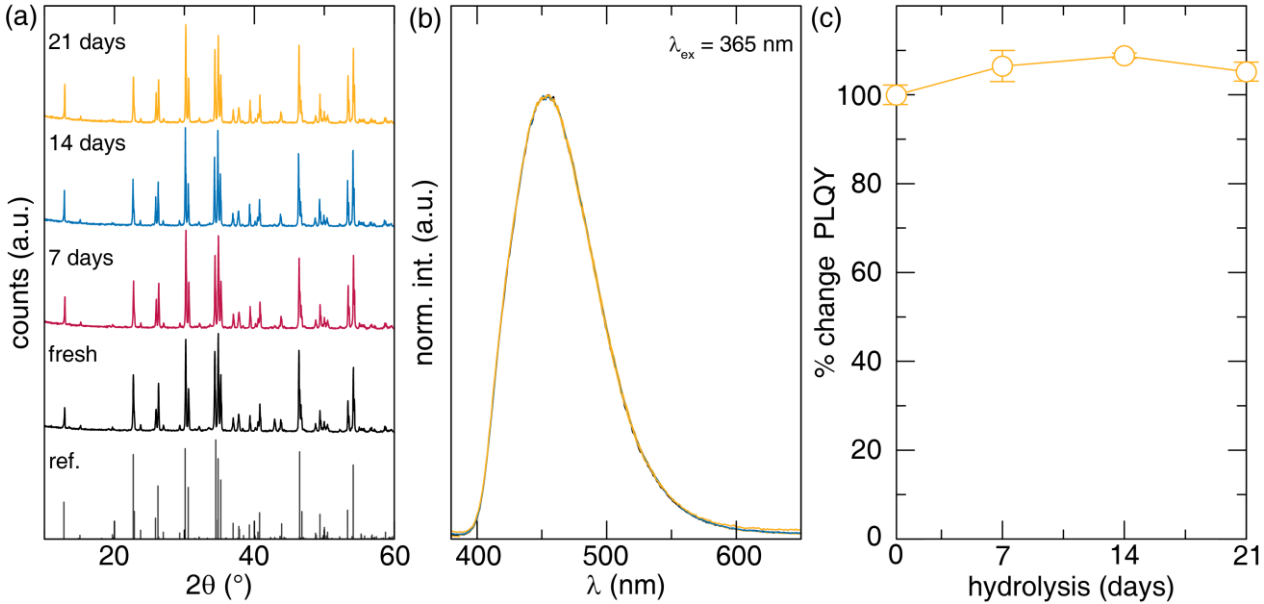
# Analysis of chemical stability: hydrolysis resistance

$Na_{1.92}Eu_{0.04}MgPO_4F$ was submerged and agitated in water for 21 days

Crystal structure and optical properties remain unchanged contrary to $BaMgAl_{10}O_{17}:Eu^{2+}$

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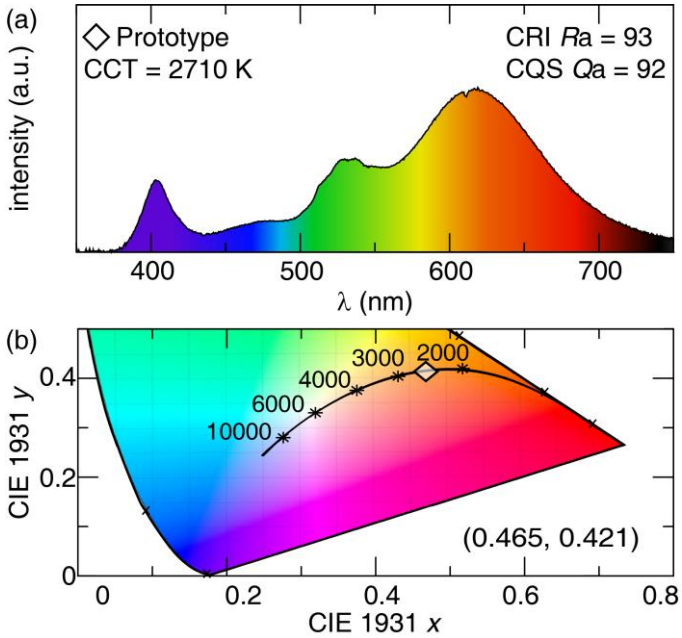
# Building a human-centric light using $Na_2MgPO_4F:Eu^{2+}$

Fabricating a white LED light driven by 405 nm GaN chip shows that we can produce light with a similar CCT but better color rendering than a Sylvania bulb

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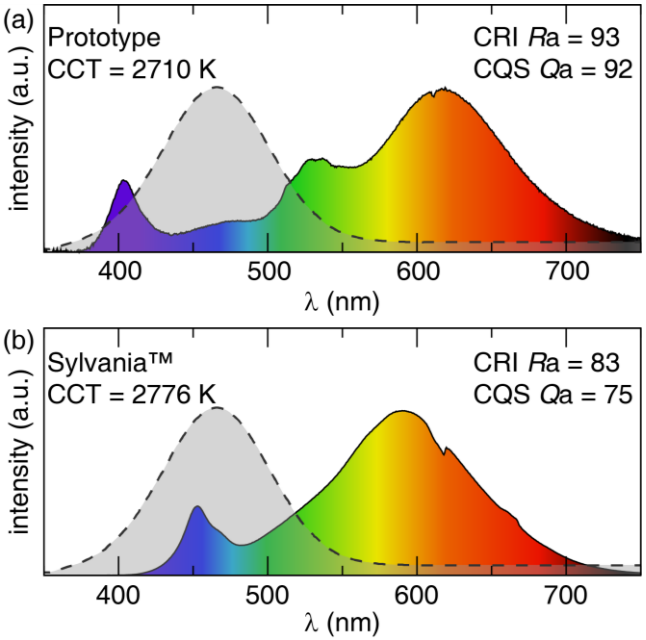


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# Conclusion and Future Work

The transition to LED light bulbs exposes humans to blue light causing insomnia and mood disorders

Shifting to violet LEDs allows for human-centric lighting, but new blue-emitting phosphors must be discovered

Using $Na_{1.92}Eu_{0.04}MgPO_4F$ and a violet LED produces a warm white light with minimal blue light exposure and higher color rendering than a commercial bulb

Future work: conduct chemical substitution experiments to narrow the emission spectrum for human-centric display lighting

# Acknowledgements


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THE Welch FOUNDATION

E-1981

NSF

CER-1911311

Argonne NATIONAL LABORATORY