

# Photometric far-field measurements on luminescent glass for LED applications

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The luminous intensity distribution from luminescent glass discs is investigated. For this, the discs are placed on top of a blue LED and the emission from the optically-activated glass is recorded in the far field. The experimental results are compared with optical calculations.

## 1 Introduction

The most common white LEDs consist of a blue-emitting LED chip with a yellow-emitting phosphor powder/polymer composite directly coated onto the chip. The phosphor powder/polymer composite acts as a frequency-downshifter for a significant part of the blue LED light. Heat-induced degradation of the composite, however, results in an efficiency decrease and color temperature change. Luminescent glasses represent an interesting alternative as frequency-downshifter due to their high thermal and chemical stability. This work focuses on the luminous intensity distribution of luminescent borate glass under excitation with 475-nm LED light.

## 2 Experimental Details

For the glass synthesis, boron oxide ( $B_2O_3$ ) as network former and lithium oxide ( $Li_2O$ ) as network modifier are used in a ratio of 2 to 1. To strengthen and to prevent devitrification of the glass, 10% of the  $B_2O_3$  is substituted by aluminum oxide ( $Al_2O_3$ ). For optical activation, europium oxide ( $Eu_2O_3$ ) is added.

The glass synthesis was carried out using the melt quenching technique. The raw chemicals were melted at 1000 °C in a Pt/Au (95/5) crucible over a period of approximately 3 hours in a furnace. The melt was then poured onto a 400 °C pre-heated brass plate with a round cutout to obtain 20 mm diameter discs.

Subsequently, the glass was slowly cooled to room temperature to relieve any residual mechanical and thermal stresses. The top and bottom surfaces of the glass discs were polished to optical quality. Fig. 1 shows the appearance of two differently doped samples and one undoped reference sample under UV excitation.

Far-field measurements were performed with a robot goniophotometer system ("robogonio") from opsira GmbH. A frc3-f-I photometer was used to record the luminous intensity; angularly-dependent emis-

sion spectra were recorded with a spec3 spectrometer. The luminescent glasses were excited with a 475-nm LED (Cree XP-E2) having an almost lambertian luminous intensity distribution. Transmittance measurements were carried out using a Cary 5000 UV-Vis-NIR spectrophotometer from Agilent Technologies. Optical calculations were performed with the software package LightTools®.



Fig. 1 From left to right: undoped, 0.46 at.%, and 2.29 at.%  $Eu^{3+}$ -doped borate glass discs under UV excitation.

## 3 Experimental Results

The principle setup used in the experiments is sketched in Fig. 2. The luminescent glass disc is placed in front of a blue LED at a distance of a few millimeters.

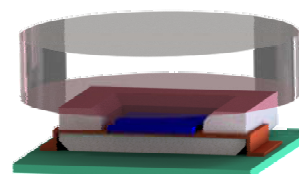
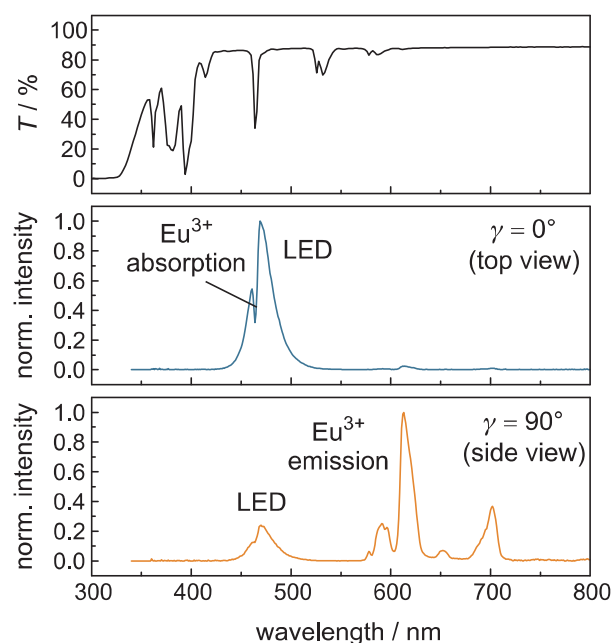


Fig. 2 Setup: Blue LED with a luminescent glass on top.

As it can be seen from Fig. 3 (top), the  $Eu^{3+}$ -doped glass provides several absorption bands in the visible spectral range with the strongest ones at 395 nm

and 470 nm due to transitions from the ground state  ${}^7F_0$  to the excited state  ${}^5L_6$  and  ${}^5D_2$ , respectively [1].

Fig. 3 also shows the emission spectra of the LED/disc combination, recorded at  $\gamma = 0^\circ$  (middle) and  $\gamma = 90^\circ$  (bottom). The  $\gamma = 0^\circ$  spectrum is dominated by the intense blue emission from the 475-nm LED. The sharp dip at 470 nm is caused by the corresponding  $\text{Eu}^{3+}$  absorption band. The  $\text{Eu}^{3+}$ -related emissions in the spectral range from 550 nm to 750 nm are barely visible. The  $\gamma = 90^\circ$  spectrum, however, is no longer dominated by the LED emission, but by the  $\text{Eu}^{3+}$  emissions which are clearly visible now. The emission bands can be assigned to transitions from the excited state  ${}^5D_0$  to the ground states  ${}^7F_J$  ( $J = 0, 1, 2, 3, 4$ ); the most intense band is at 615 nm and corresponds to the  ${}^5D_0$  to  ${}^7F_2$  transition [1].

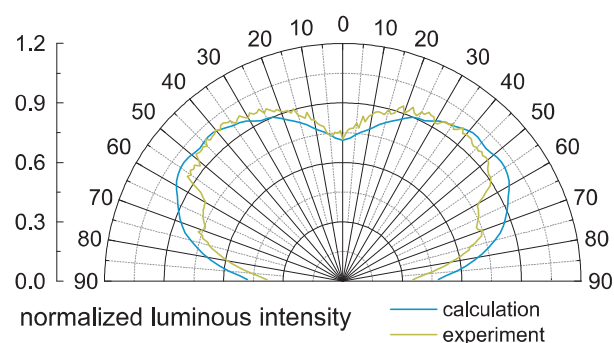


**Fig. 3** Transmission (top) and emission (middle and bottom) spectra of a 2.29 at.%  $\text{Eu}^{3+}$ -doped borate glass. The two emission spectra were recorded under 475-nm LED excitation.

To further analyze the luminous intensity distribution of the luminescent glass (as stated above, the luminous intensity distribution of the LED is lambertian), the angularly-dependent emission spectra are integrated in the spectral range from 550 nm to 800 nm, i.e., only the  $\text{Eu}^{3+}$ -related emissions are considered. The obtained luminous intensity distribution is as shown in Fig. 4. The plot shows the data for the C0-C180 plane.

To better understand the experimental data, the luminous intensity distribution of the glass was calcu-

lated. As input data, transmission, reflection, luminescence quantum efficiency as well as the geometry of the glass disc were used. Fig. 4 shows the calculated luminous intensity distribution in the far field in comparison to the experimental curve. Experiment and calculation are in good agreement.



**Fig. 4** Luminous intensity distribution of a 0.92 at.%  $\text{Eu}^{3+}$ -doped borate glass.

Future research will focus on double- and/or triple-doped glass (i.e., the glass will be doped with a combination of two and/or three different lanthanide ions) as well as on different geometries such as luminescent lenses and luminescent light guides.

#### 4 Conclusion

The luminous intensity distribution of a luminescent glass is analyzed under excitation with a lambertian light source (blue LED). Optical calculations are in good agreement to the experimental data and allow a better understanding of the observed luminous intensity distribution.

#### 5 Acknowledgment

The authors wish to thank the “Ministerium für Innovation, Wissenschaft und Forschung des Landes Nordrhein-Westfalen” for its financial support to the Fraunhofer Application Center for Inorganic Phosphors in Soest. In addition, the authors would like to thank the German Federal Ministry for Education and Research (BMBF) for its support to the South Westphalia University of Applied Sciences within the FHprofUnt 2014 project “LED-Glas” (project no. 03FH056PX4).

#### References

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