Luminescent borate glass: excitation power dependence and long-term stability

Franziska Steudel*, Lisa-Marie Reichelt**, Stefan Schweizer*,**

*Fraunhofer Application Center for Inorganic Phosphors, Branch Lab of Fraunhofer Institute for Microstructure of Materials and Systems IMWS, Lübecker Ring 2, 59494 Soest, Germany

**Faculty of Electrical Engineering, South Westphalia University of Applied Sciences, Lübecker Ring 2, 59494 Soest, Germany

mailto: Franziska.Steudel@imws.fraunhofer.de

Luminescent borate glass is investigated for its excitation power dependence and long-term stability. The glass is optically activated by the addition of different amounts of the lanthanide ions Eu^{3+} and Dy^{3+} leading to a bright luminescence in the red and yellow spectral range, respectively, upon appropriate excitation in the ultraviolet/blue spectral range.

1 Introduction

White light emitting diodes (LEDs) are increasingly replacing conventional lighting systems [1]. They usually consist of a blue-emitting LED chip, which is embedded in a yellow-emitting phosphor-polymer composite [2]. The demand for high luminous flux LEDs leads to an increase in the operating currents and thus to an increase in the power densities of the LEDs. The high temperature and radiation exposure leads to accelerated aging of the phosphors and thus to a reduction in the light output as well as to a shift of the colour impression. In particular for high-power laser-based illumination systems, such as automotive headlamps, highly stable phosphors are required.

Preliminary investigations on the excitation power dependence of Eu^{3+} in borate glass are published in [3]. The authors used a temperature-stabilized laser diode and varied the laser power by changing the diode current accordingly. However, the laser emission wavelength of 402 nm red-shifted to 403 nm resulting in a significantly reduced absorption due to the narrowness of the relevant Eu^{3+} absorption band at 396 nm. The luminescence intensity showed a seemingly saturation for increasing laser power.

In this work, the luminescence of Eu^{3+} and Dy^{3+} single-doped borate glass is investigated with respect to its excitation power dependence and long-term stability. The excitation power is varied by the use of different neutral density filters.

2 Experimental Details

The borate glasses investigated are doped with 0.5, 1.0, 1.5, and 2.5 at.% Eu^{3+} or 0.05, 0.25, and 0.5 at.% Dy^{3+} for optical activation. For details on the glass preparation, the reader is referred to [3] for Eu^{3+} and [4] for Dy^{3+} single-doped glass, respectively.

Absolute photoluminescence quantum efficiency (QE) measurements are performed with a commercial quantum yield spectrometer (Hamamatsu C9920-02G) coupled to an integrating sphere with a xenon lamp (150 W) as excitation source and a photonic multichannel analyser (PMA 12) as detector.

The Eu^{3+}-doped samples are excited with a 406-nm laser diode (Sanyo DL-5145-101S), while for the Dy^{3+}-doped samples a 451-nm laser diode (OSRAM Opto Semiconductors Inc. PL TB450B) is used. The laser diodes are operated in a temperature-controlled mount (Thorlabs GmbH TCLDM9 / LDC240C / TED200C) at a current of 45 mA (405 nm) and 1200 mA (451 nm). For both, the temperature is set to 40 °C. Two identical integrating sphere sensors with a photodiode (Thorlabs GmbH S142C) are used as detectors.

The experimental setup used for the excitation power dependence and the long-term stability investigations is as shown in Fig. 1. A set of neutral density filters (Schott AG) is placed in front of the laser diode to vary the excitation power. For the long-term stability investigations, a borosilicate crown glass (Schott AG N-BK7) is used as beam splitter.

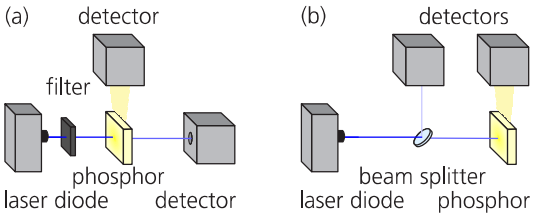

Fig. 1 *Experimental setup for (a) excitation power dependence and (b) long-term stability investigations.*

3 Results and discussion

The quantum efficiency values of the samples are listed in Tab. 1 for 406-nm excitation of Eu^{3+} ($^7F_0$ to

DGaO-Proceedings 2018 – http://www.dgao-proceedings.de – ISSN: 1614-8436 – urn:nbn:de:0287-2018-P049-8
submitted: 19.Jul.2018 published: 20.Jul.2018

$^5L_6$ transition) and 451-nm excitation of Dy^{3+} ($^6H_{15/2}$ to $^4I_{15/2}$ transition). For all Eu^{3+} concentrations investigated, the QE amounts to 44 % to 55 %, while the QE for Dy^{3+} is significantly lower between 5 % to 17 % with a maximum for 0.25 at.% Dy^{3+}. For higher concentrations, cross-relaxation [5] occurs resulting in a lower QE.

Eu^{3+} / at.%	QE / %	Dy^{3+} / at.%	QE / %
2.5	54	0.5	5
1.5	55	0.25	17
1.0	50	0.05	12
0.5	44		

Tab. 1 *Quantum efficiency values obtained for 406-nm excitation of Eu^{3+} and 451-nm excitation of Dy^{3+}.*

The linearity in luminescence intensity is shown in Figs. 2a and 2b for Eu^{3+} and Dy^{3+}-doping, respectively. Both sample sets show a linear increase in photodiode current and thus in luminescence intensity with increasing excitation power.

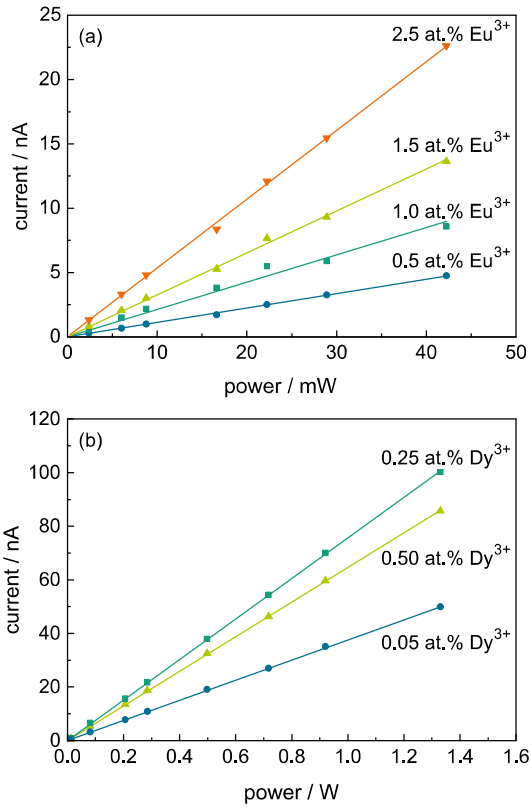

Fig. 2 *Photodiode current vs. excitation power of (a) Eu^{3+} and (b) Dy^{3+}-doped borate glasses. The solid lines represent a linear fit. Note that the excitation power for Dy^{3+} exceeds that for Eu^{3+} by a factor of approximately 30.*

Fig. 3 shows the long-term stability of Eu^{3+} and Dy^{3+} single-doped glass. The normalized current decreases only by 0.3 % for Dy^{3+} and 0.8 % for Eu^{3+}, which is within the measurement accuracy of the experimental setup.

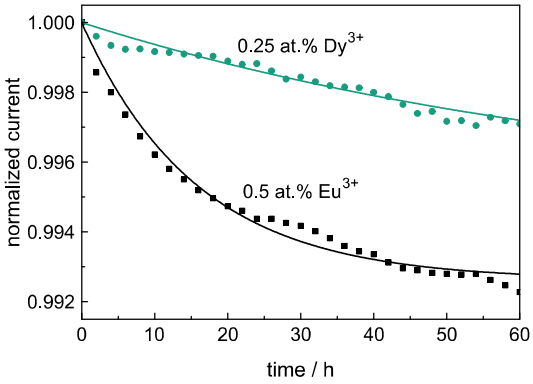

Fig. 3 *Long-term stability of single-doped borate glasses under continuous laser excitation (at 406 nm / 42 mW for Eu^{3+} and 451 nm / 1.33 W for Dy^{3+}). The solid curves represent a mono-exponential fit to the data.*

4 Conclusion

Eu^{3+} and Dy^{3+} single-doped glasses show a linear dependence on the excitation power. The luminescence intensity is stable, even under continuous long-term laser excitation, making these systems suitable for high-power laser-based illumination applications.

5 Acknowledgments

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 for support within the project “HipE” which is co-funded by the European Union (Investing in our future - European Regional Development Fund) and the German federal state North Rhine-Westphalia (NRW).

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