High Temperature Thermal Quenching Measurements on Luminescent Materials for Fluorescent Light Sources

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Background

In gas discharge and solid state light sources a limited number of luminescent materials were developed to an impressive maturaty level and are thus widely applied nowadays. Although these phosphors have been extensively studied in academia and industry, high quality luminescence spectra up to 800 K have not been published to our best knowledge yet.

Therefore, we monitored their emission spectra as function of temperature in the range from 100 to 800 K. The obtained data and corresponding emission integrals have been used to derive thermal quenching (TQ) curves, from which figures such as $TQ_{1/2}$ or $TQ_{1/10}$ can be derived.

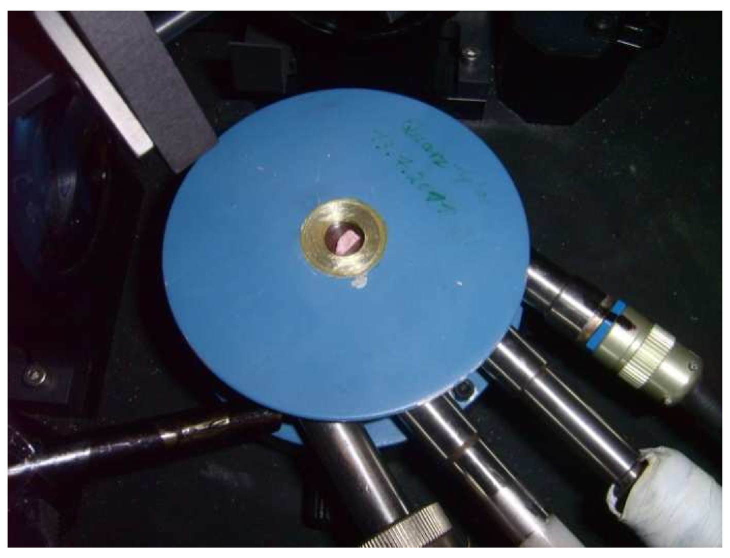


Fig. 1: MicrostatN with connectors for current, temperature detector, vacuum, liquid nitrogen in and gaseous nitrogen out

Fig. 2: High temperature sample holder with connectors for current, temperature detector, vacuum and water cooling

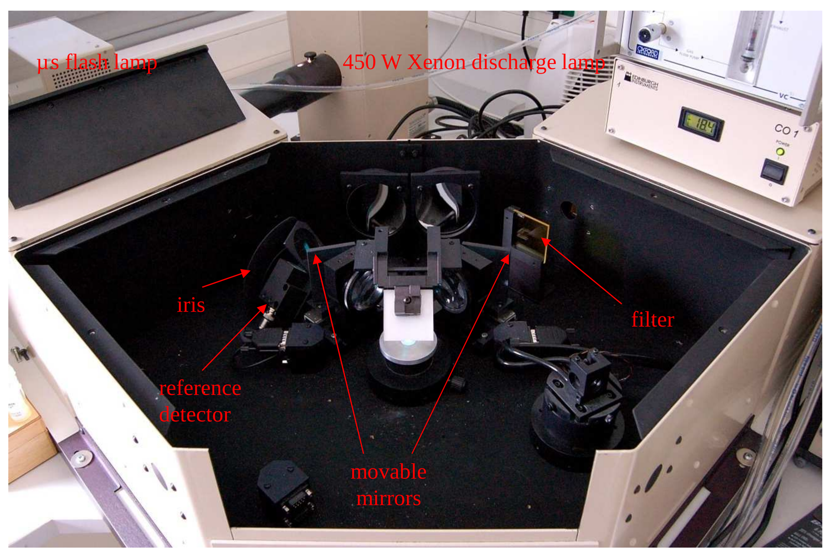


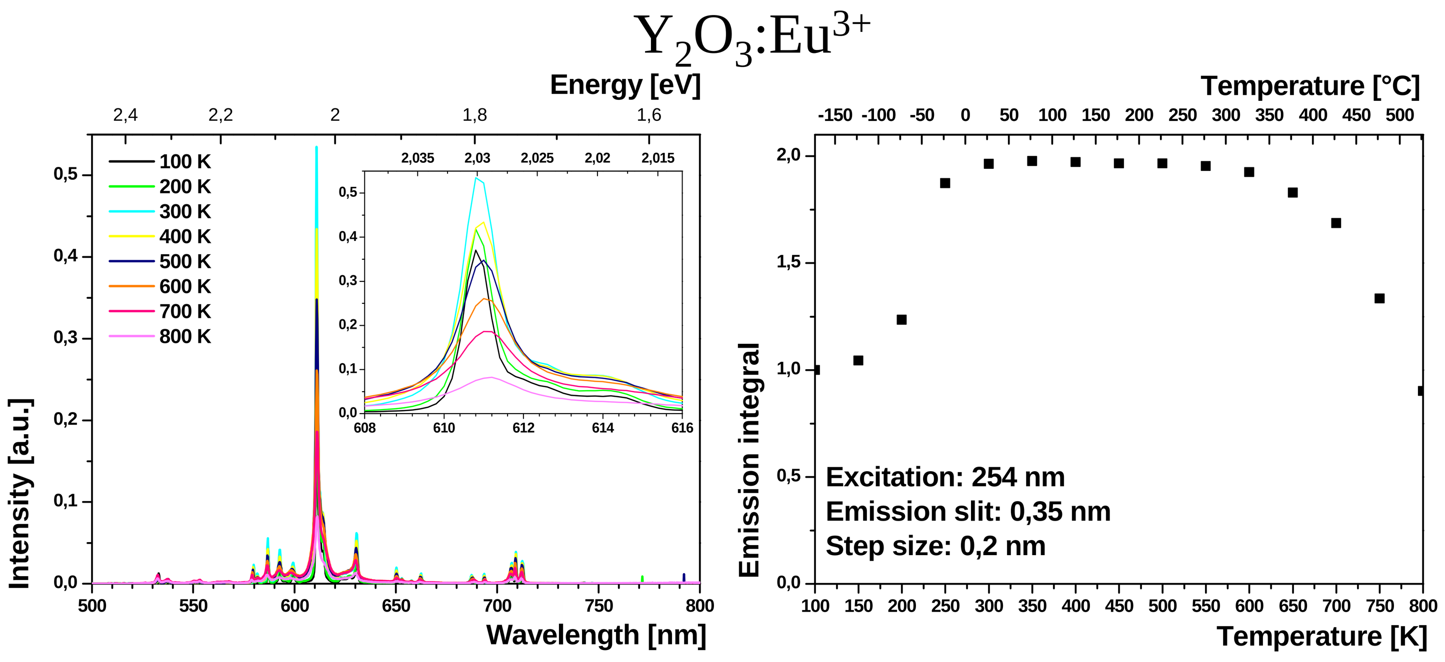
Fig. 3: Edinburgh Instruments FSL920, mirror optics for powder samples

Principle

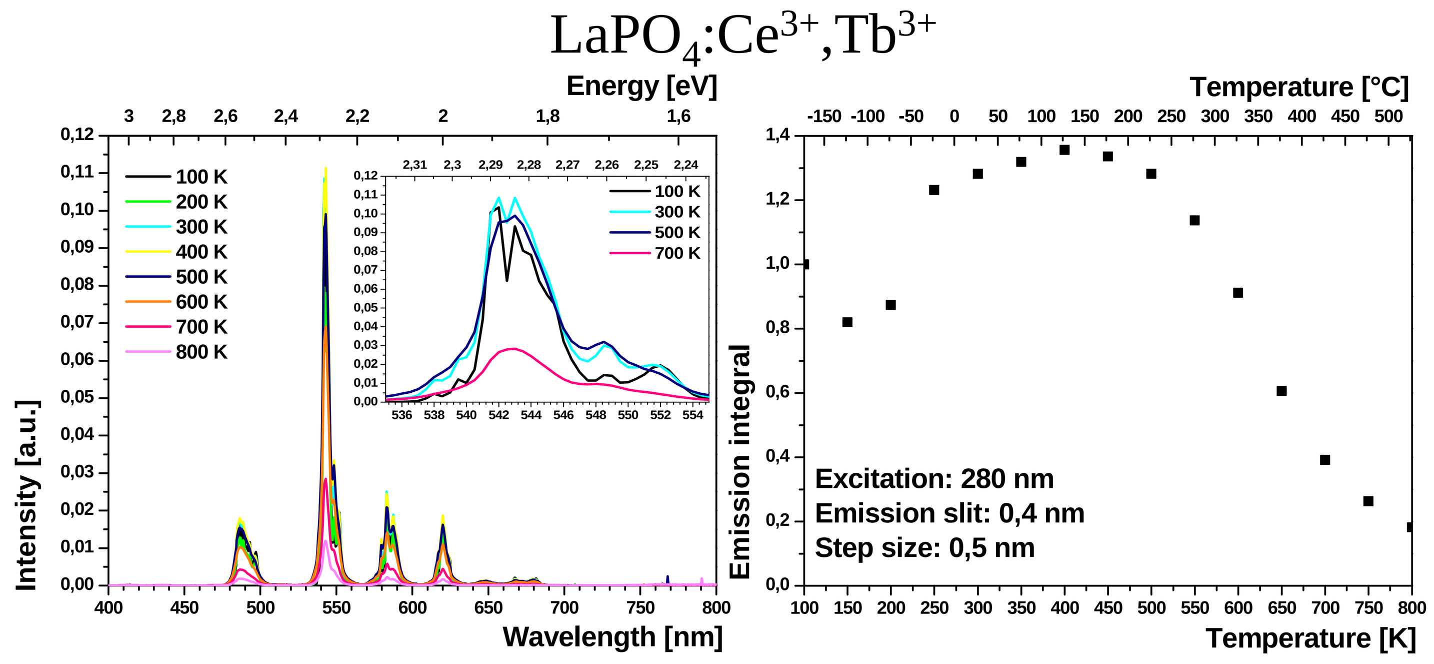
Most of the published thermal quenching measurements are limited to an upper temperature not higher than 500 K, since commercial sample holders for temperature dependent measurements cannot be driven above 500 K. These sample holders combine a heating and a cooling (cryostatic) element, in which the heater is limited to 500 K and the thermal insulation of the sample holder (passive system employing vacuum) is not sufficient for working at temperatures above 500 K. At higher temperatures part of the spectroscopic equipment, like mirrors or lenses, would undergo changes of their optical properties, e.g. due to thermal expansion, or might be even irreversibly damaged.

Therefore, we constructed a novel high temperature actively cooled sample holder (Fig. 2), which can be placed inside a fluorescence spectrometer's sample chamber. However, this new sample holder does not comprise a cooling system to cool down below room temperature, but an active one for the housing of the sample holder to protect the spectroscopic equipment. On the presented poster we show first results obtained by measurements employing the new high temperature sample holder, which can heat up the corresponding sample up to 800 K (527 °C) without changing the spectrometer set-up.

$Y_2O_3:Eu^{3+}$



$LaPO_4:Ce^{3+},Tb^{3+}$



$BaMgAl_{10}O_{17}:Eu^{2+},Mn^{2+}$

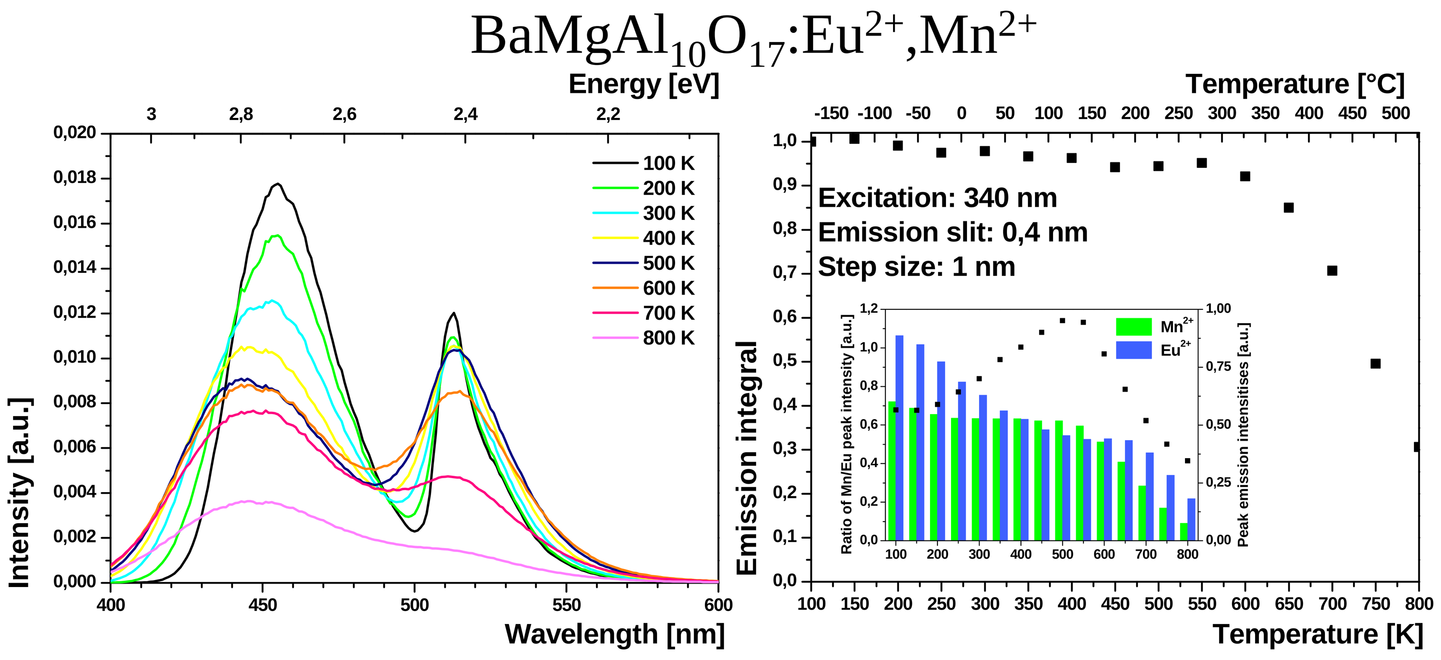


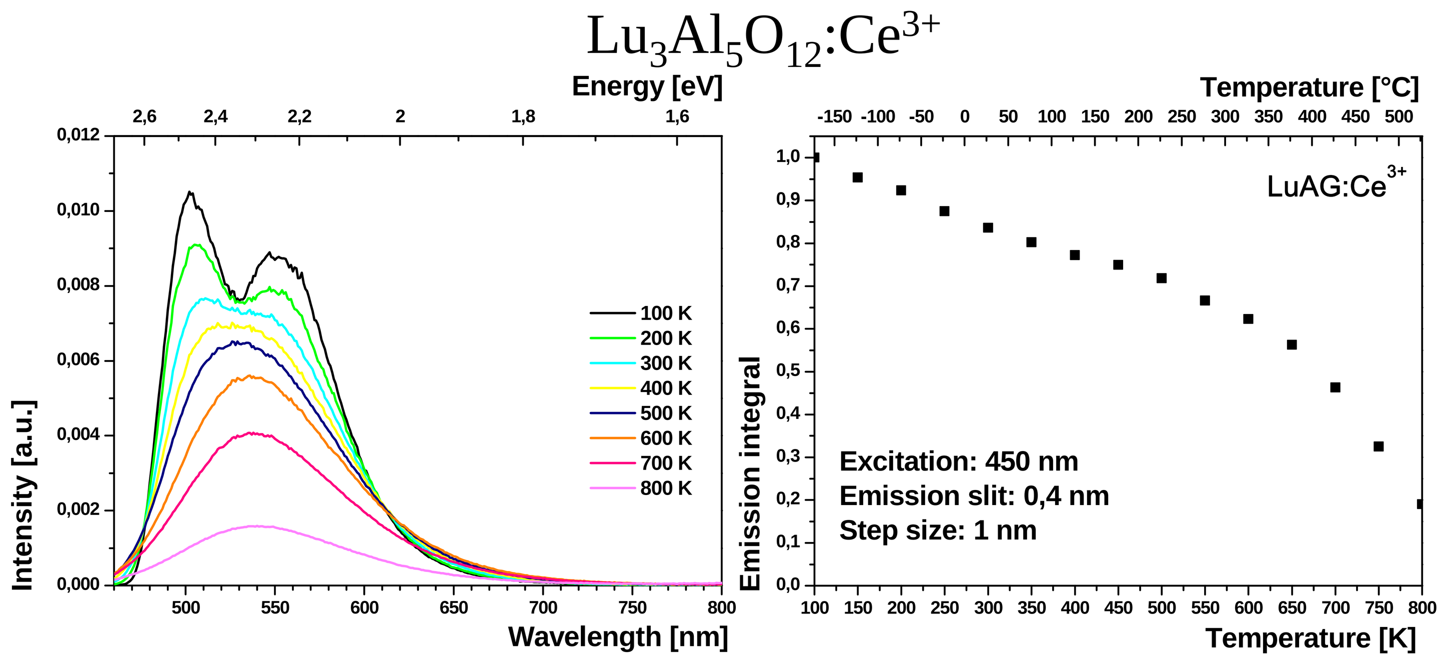
Fig. 4: Emission spectra and thermal quenching curves of $Y_2O_3:Eu^{3+}$, $BaMgAl_{10}O_{17}:Eu^{2+},Mn^{2+}$ and $LaPO_4:Ce^{3+},Tb^{3+}$

All emission spectra were recorded by using an Edinburgh Instruments FSL920 spectrometer equipped with a 450 W Xe arc lamp, mirror optics for powder samples (Fig. 3) and a cooled (-20 °C) single-photon counting photomultiplier from Hamamatsu (R2658P).

The cryostat "MicrostatN" from Oxford Instruments (Fig. 1) is used for the thermal quenching measurements from 100 to 500 K. Liquid nitrogen was used for cooling.

By using the novel high temperature sample holder the temperature between 350 and 800 K was investigated. The heating element under the sample is made of corundum ceramic and a heated filament made of ISA®-CHROM60 with a diameter of 0.5 mm. The housing of the sample holder is cooled by flowing water.

$Lu_3Al_5O_{12}:Ce^{3+}$



$Sr_2Si_5N_8:Eu^{2+}$

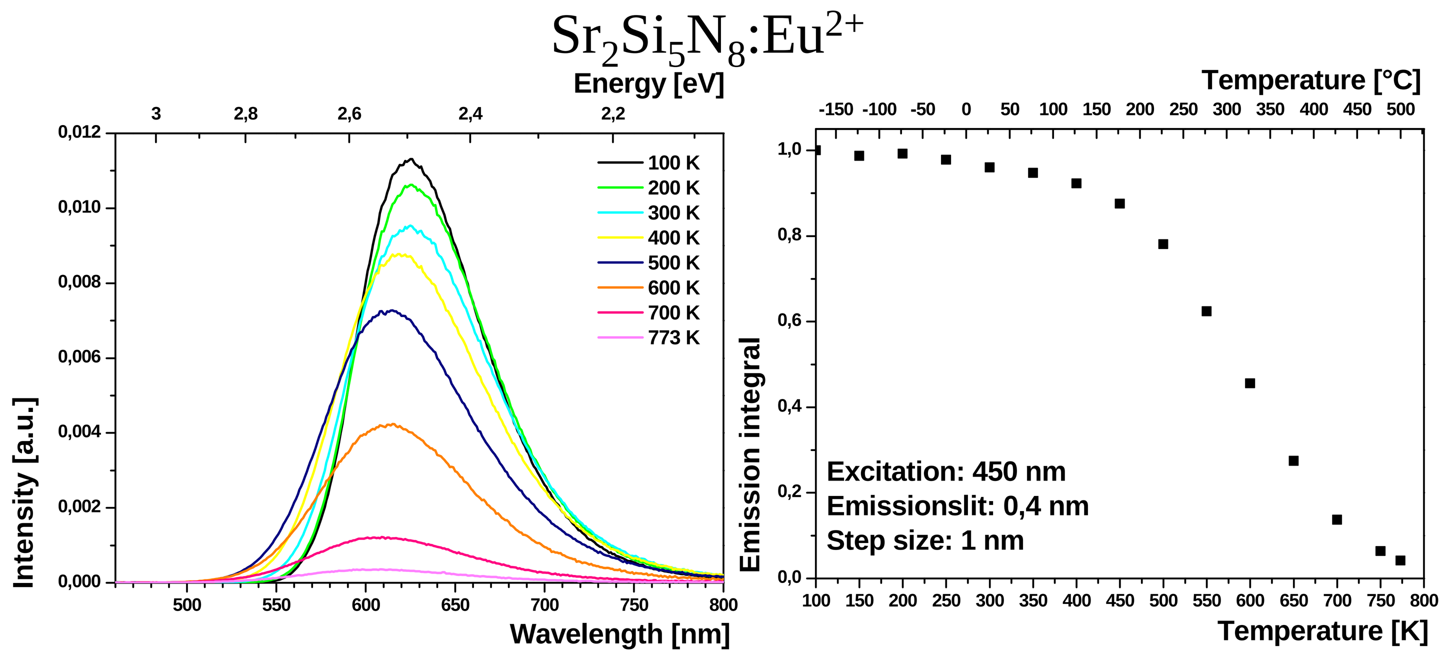


Fig. 5 Emission spectra and thermal quenching curves of $LuAG:Ce^{3+}$ and $Sr_2Si_5N_8:Eu^{2+}$

Results and Discussion

Fig. 4 and 5 reveal the shape and intensity of the emission spectra of the "big five" as function of temperature. The obtained data are required for those application areas, in which the phosphor operates at a temperature significantly higher than room temperature. It enables statements on the loss in quantum efficiency, change in lumen equivalent, and the colour point shift due to the different .thermal quenching mechanisms, such as e.g. photoionisation or multi-phonon quenching..

From the shape of the obtained thermal quenching curves one can also derive the efficiency of energy transfer as function of temperature, if the phosphor comprises more than one activator, as for instance in $LaPO_4$:CeTb and $BaMgAl_{10}O_{17}$:EuMn. In summary, thermal quenching measurements with an enlarged temperature range will deliver more data, so that the modeling and fitting of the thermal quenching curves can be improved.

Conclusions

The new sample holder enables us to measure phosphor samples within the spectrometer sample chamber at temperatures up to 800 K. Therefore, it is not only possible to record temperature-dependent emission and excitation spectra but also temperature-dependent decay curves as well as glow curves. The extended temperature range is of large interest for the characterization of storage phosphors and for those luminescent materials, which have to operate at an elevated temperature, as e,g, in high brightness LEDs.

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