Reflection Spectroscopy in the VUV Range

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Background

VUV phosphors have attracted tremendous interest due to their application in gas discharge displays and Xe excimer discharge lamps. Since the primary radiation spectrum of these devices is in the range between 140 and 200 nm, suitable phosphors must be efficient upon excitation in this regime, more precisely at 147 or 172 nm, which corresponds to the Xe atomic and Xe excimer emission. Therefore, a complete optical characterization of VUV phosphors must involve measurements upon excitation in this wavelength range. While the recording of excitation spectra in the VUV range is an established method, reflection spectra are normally recorded not below 230 nm due to the absorption edge of the most common reflectance standards such as $BaSO_4$ and $CaCO_3$.

Principle

The presented measurement technique [1] allows the take up of reflectance spectra in the range from 120 to 300 nm (4 to 10 eV). To this end, all VUV photons reflected by the sample are converted to visible photons, which in turn are collected by an Ulbricht sphere and are finally counted by a PMT. This requires a specially prepared integration sphere, viz. one that is coated with a phosphor, e.g. $BaMgAl_{10}O_{17}:Eu^{2+}$ showing an almost independent and high light output in the respective wavelength range.

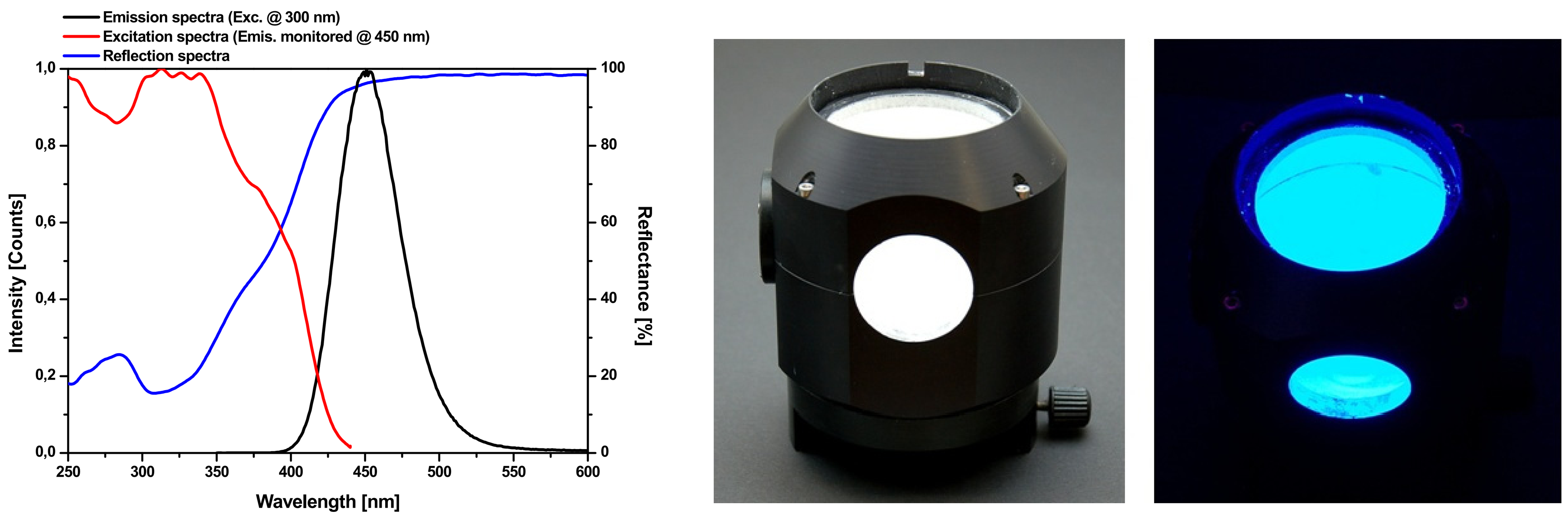

Fig. 1 Luminescence and reflection spectra of $BaMgAl_{10}O_{17}:Eu^{2+}$ (BAM:Eu) and an integrating sphere coated with BAM at daylight (left) and upon UV excitation (right).

More precisely, the deep UV photons reflected by the sample are completely absorbed by the coated integrating sphere, which in turn emits blue light with a peak wavelength of 450 nm. The excitation spectra of the sample and of the BAM:Eu powder, which has been used for the coating of the sphere are measured in the desired wavelength range, e.g. from120 to 400 nm. From these two excitation spectra the VUV/UV reflection spectrum easily of the sample is obtained by a simple division.

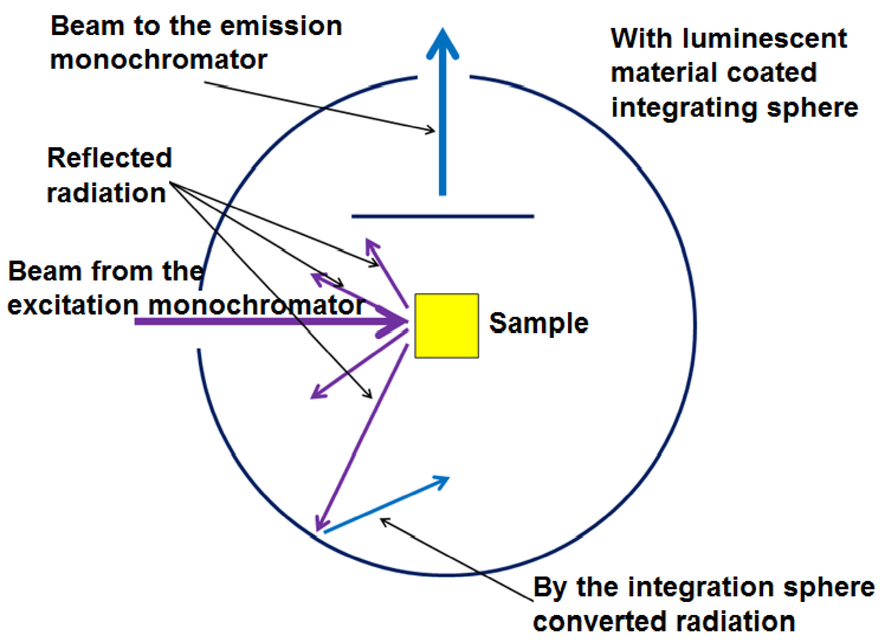

Fig. 2 Simplified sketch of the coated integration sphere showing the measurement principle .

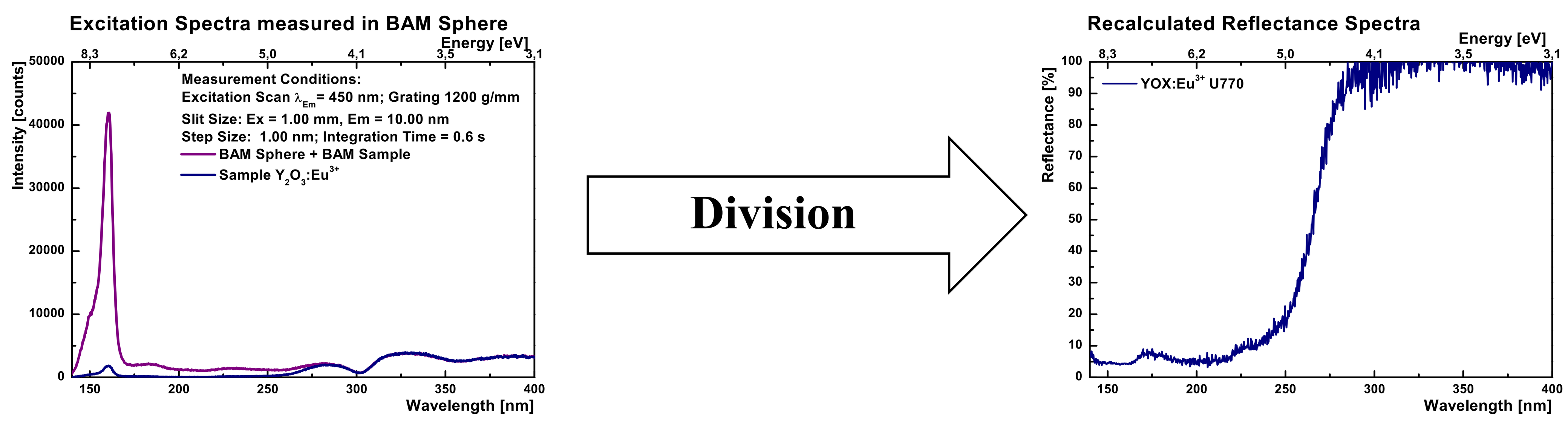

Fig. 3 Excitation spectra of the sample $Y_2O_3:Eu^{3+}$ and of the reference BAM:Eu as obtained by using the BAM coated sphere and the derived reflection spectrum.

To obtain reliable reflection spectra, the light source, the excitation monochromator and the sample chamber must be suitable for measurements in the VUV range. By flushing the BAM:Eu coated integrating sphere with Nitrogen, it is guaranteed that the reflected radiation can be converted and collected by the integrating sphere.

The comparison of reflection spectra taken by a BAM:Eu or LAP:Ce coated sphere with the reflection spectra in the range between 230 and 400 nm as taken by a $BaSO_4$ coated sphere confirms that the VUV reflection spectra are in line with each other.

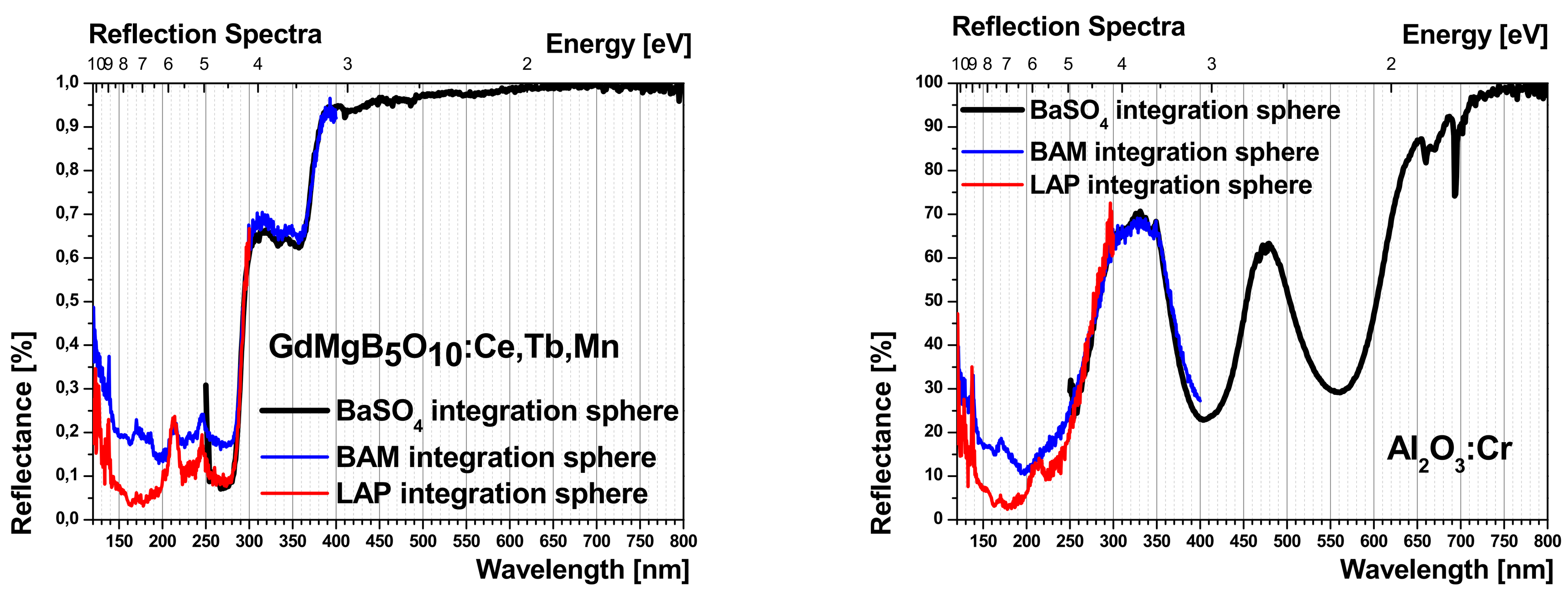

Fig. 4 Comparison of the reflection spectra of $GdMgB_5O_{10}:Ce,Tb,Mn$ and $Al_2O_3:Cr$ as obtained by a commercially available Ulbricht sphere and by a BAM:Eu and LAP:Ce coated integration sphere.

A limiting factor of the novel method is the position of the emission band or lines of the sample. From samples having an emission band at the emission wavelength of BAM:Eu (450 nm) or below, a VUV reflection spectrum cannot be recorded, since the radiation emitted by the sample is simultaneously interpreted as reflected radiation.

Therefore, only samples which an emission band beyond 450 nm can be measures. To record VUV emission spectra of blue or UV-A emitting samples, another integration sphere has been equipped by $LaPO_4:Ce^{3+}$ (LAP:Ce), that emits at 320 nm. In order to measure samples, which emits in the UV-B or UV-C range, one more integrating sphere will be coated by $YPO_4:Bi$, which emits at 240 nm.

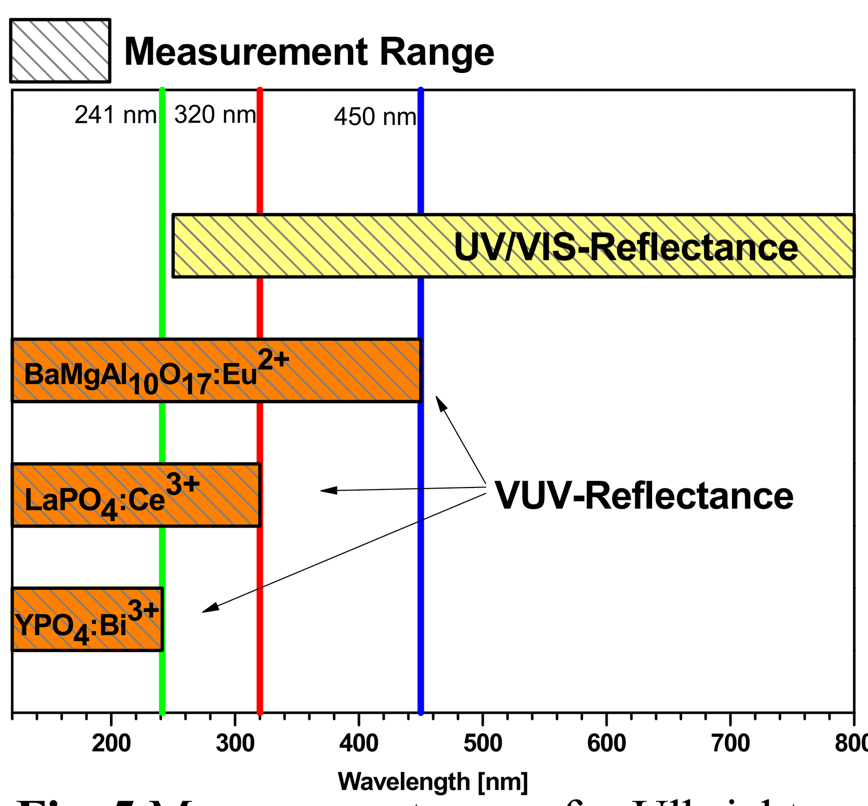

Fig. 5 Measurement range for Ulbricht spheres with different coatings

Conclusions

This work demonstrates a novel measurement technique to record reflection spectra in the VUV range without the necessity for a VUV monochromator and VUV detector for the emission branch. Since the knowledge of the reflectance is necessary to calculate the quantum efficiency of a sample at a given excitation wavelength, it will be possible to determine QE data upon VUV excitation in the future.

[1] T. Jüstel, J. Krupa, D. U. Wiechert, Journal of Luminescence 93 (2001) 179–189

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