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Analysis on stability and consistency of intensity measurement of White Light Emitting Diode phosphors

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ABSTRACT

This paper focuses on the stability and consistency of intensity measurements of WLED phosphors. The quality of phosphor products are determined by the measured intensities, but in practice it is often found that intensity measurements cannot be replicated. This problem is due to the instability of test conditions (fluctuating light source power, different paring of quartz lids, etc.) A Monte Carlo ray-tracing model is applied to illustrate the differences in faculae caused by tiny quartz lid slips. The research presented would be particularly beneficial for researchers and manufactures of phosphor.

1. Introduction

Since its invention, White Light Emitting Diodes (WLED) have been widely used in modern society [1]. In the near future, traditional fluorescence lamps will be replaced by WLED devices as the next generation light source [2]. Generally, phosphor powder and semiconductor GaN chips are fabricated together to emit white light under direct current drive [3], and therefore high quality phosphors are indispensable. Currently, the WLED phosphors are covering the full range of visible light colors. For example, Green WLED phosphors are mainly alkaline earth silicates [4,5]. Ce^{3+} doped Yttrium Aluminum Garnet (YAG) yields yellow WLED phosphor [6], while YAG:Ce^{3+} doped with Lu could serve as green-yellow phosphor. Orange and red WLED phosphors are composed of oxy-nitride or pure nitride [7–9]. The quality of phosphor is an important factor for WLED devices. Therefore, rigorous testing of phosphor is necessary in order to choose the most pertinent product.

A series of measurements, such as luminescent intensity, quantum efficiency, powder mobility, crystal form, and size distribution, should be performed to judge the quality of WLED phosphors. Among the above factors, the most important factor is photoluminescent (PL) intensity, which is directly linked to the output power of the WLED device and decides the quality of phosphor. However, in practical operations, some problems exist in testing PL intensity. For example, the output power of the light source will change after working for a few hours, resulting in a lack of credibility when comparing intensities of different samples measured within a longer time interval. Moreover, the consistency of intensity comparison is minimal. During testing, the intensity rank might change for a series of samples. Aforementioned pitfalls create obstacles in testing and evaluation of WLED phosphor.

In this paper, we analyze the abovementioned issues and provide several solutions. The spectrometer used is FLS920 (Edinburgh Instruments), which is widely used for phosphor measurement by researchers all over the world. This discussion also provides a helpful reference for other spectrometers.

2. Experimental procedure

The phosphor chosen for test is commercial WLED phosphor powders. Photoluminescence spectra are measured on FLS920 spectrometer (Edinburgh Instruments). It is equipped with double excitation monochromators in order to reduce stray light. A 450 W Xenon arc lamp working in continuous mode is employed as a light source for steady state measurement. The photomultiplier used is Hamamatsu R928P, which provides a very low dark noise level. The emission and excitation spectra are all corrected according to the spectral instrumental response and the spectral output of the light source, respectively.

3. Results and discussion

3.1. Influence of fluctuation of light source power on measurement of intensity

Most spectrometers are equipped with Xenon lamps as the light source. However, current fluctuations affect the power output of

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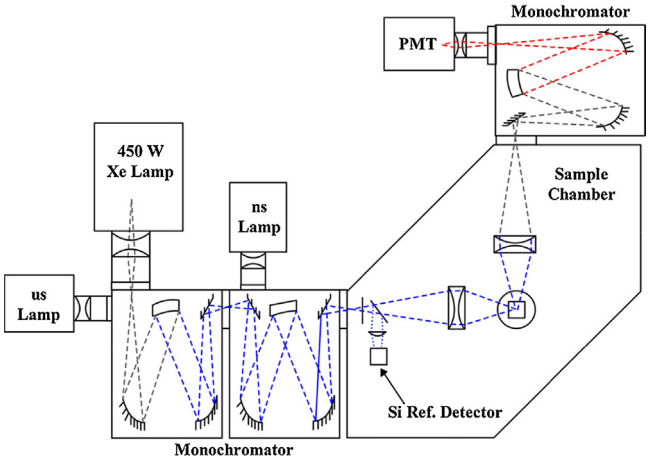

Fig. 1. Schematic optical path of FLS920 spectrometer. Redrawn from FLS920 brochure with modification.

Xenon lamps, which cause errors in the comparison of phosphor intensities. A feasible way to resolve this issue is to simultaneously record the light source power fluctuations and PL spectrum data and to correct the PL spectrum according to the output power change. Fig. 1 illustrates the schematic optical path of FLS920 spectrometer. A Silicon reference detector is present in the sample chamber, as indicated by the arrow in Fig. 1. About 10% of the photons exciting the excitation monochromator will be detected by the Si reference detector via spectroscope. Therefore, real time corrections employing Si reference detectors provide a possible solution.

Initially, in order to study the effectiveness of real time correction, a kinetic scan is employed to investigate the relationship between counts of the light source and the sample. In a kinetic scan, the excitation and emission wavelengths are fixed, and the detectors record the number of photons arriving at different times. The result is a "counts versus time" graph. In this case, the kinetic scan commences as soon as the Xenon lamps are turned on, and both detectors – PMT and Si reference detector – record photon counts for a period of time. When the shutter is closed, photons cannot enter the detectors, and the photon counts will drop to dark levels until the scan is complete. Kinetic scan on the left side of Fig. 2 is performed without real time correction. It is observed that starting from zero time, the Si reference detector counts begin to increase, which implies that the output power of the Xenon lamp is not stable when it is started. The PMT counts also increase, which reflects the change of light source output power. During real time correction, as

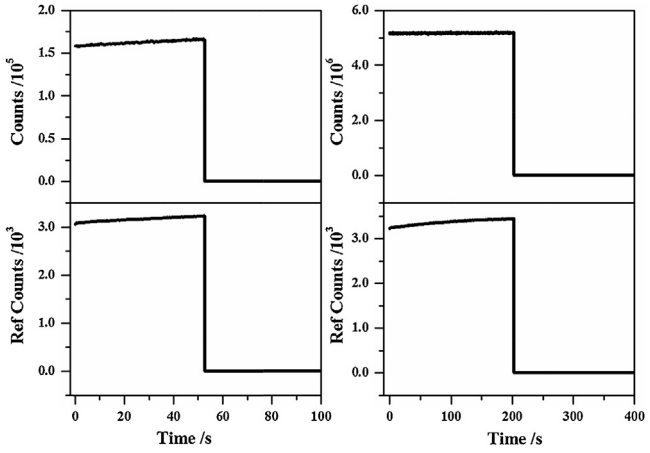

Fig. 2. Kinetic Scan of YAG:Ce^{3+}, with E_x = 450 nm, E_m = 550 nm. Left: real time correction off; Right: real time correction on.

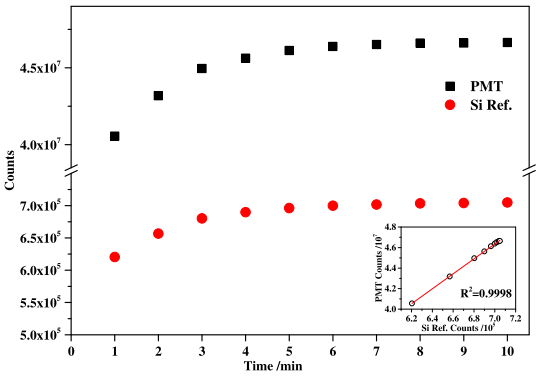

Fig. 3. Kinetic scan of YAG:Ce^{3+}, E_x = 450 nm, E_m = 550 nm with real time correction off, time = 60 s. The data point stands for integrated counts over 60 s; Inset graph: linear interpolation of PMT counts and Si Ref. Detector counts.

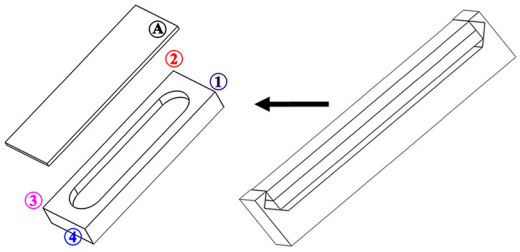

Fig. 4. Configuration of top and bottom quartz lids. The pair of lids is mounted onto the clamp apparatus for measurement.

shown on the right side of Fig. 2, the PMT counts are stable throughout the test even with the increasing levels of photons from the light source. Therefore, the real time correction of Si reference detector could effectively eliminate intensity errors caused by output power fluctuations from the light source.

The real time correction of the Si reference detector should accurately reflect the relationship between light source power and spectrum intensity. Specifically, the counts of PMT and reference detector should be linearly correlated. Kinetic scans with real time correction turned off are measured successively every 60 s. The integrated counts for the measurements are plotted in a graph, shown in Fig. 3. The trend of counts of PMT and reference detector are almost consistent. The linear interpolation of the two groups of data returns R^2 = 0.9998, as shown in the insert graph on Fig. 3, which confirms the linear relationship. Therefore, it is inferred that real time correction is a reliable solution to intensity errors caused by power fluctuations of the light source.

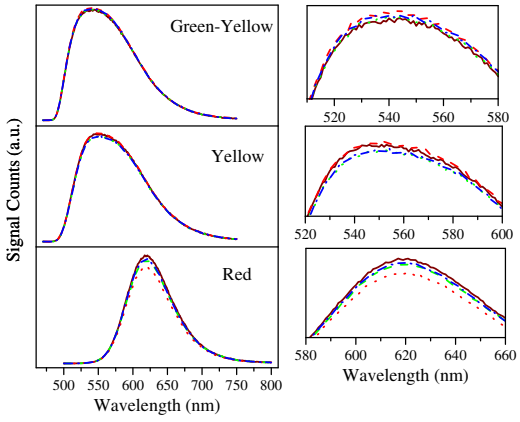

Fig. 5. Left: PL spectra of three groups of phosphors measured at different quartz lids paring configuration; Right: partial enlarged view.