Spectral emission properties of some blue light- emitting diodes

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The emission spectrum of light-emitting diodes used for stimulation of luminescence is important because of the need to separate the luminescence from scattered stimulating light by use of optical filters (for example as discussed by Huntley *et al.*, 1985; Galloway *et al.*, 1997; Bøtter-Jensen, 1997) and also because the efficiency of stimulation of luminescence is wavelength dependent (Spooner, 1994; Bøtter-Jensen *et al.*, 1994; Huntley *et al.*, 1996). We report here on the properties of three blue light-emitting diodes (LEDs) which have peak emission at wavelengths of 430, 450, and 470 nm (table 1) and which show contrasting behaviour in their emission spectra. The Nichia NSPB500S with peak emission at 470 nm is the brightest of the three and is in use for luminescence stimulation in this laboratory and elsewhere (Bøtter-Jensen, 1997). Optical spectra were measured with the same spectrophotometer as used by Galloway and Neal (1998) in the study of green LEDs. The spectrometer is based on a 700 lines/mm holographic grating with the diffraction spectrum captured by a CCD camera and displayed by a PC microcomputer; the wavelength range covered is 393 - 830 nm.

The results from spectral measurements on the blue LEDs are summarised in table 1, in terms of both the wavelength of the emitted light and the corresponding photon energy. Otherwise the results are presented and discussed in terms of emitted wavelength for ease of comparison with the data provided by manufacturers of optical filters. At a current of 20 mA, the 430 nm LED showed an emission peak with a width at half maximum of 65 nm, the 450 nm LED width was 78 nm, while the 470 nm LED had the narrowest width at half maximum, 28 nm. The mean wavelength of maximum emission for 7 of the 430 nm LEDs was 430 ± 2 nm while that for 6 of the 470 nm LEDs was 467 ± 7 nm, i.e. the wavelength of maximum emission varied more from diode to diode for the 470 nm LEDs. (Only one 450 nm LED was available for testing.) For all the LEDs, the shape of the emission spectrum was unchanged over the current range 10 - 30 mA. Indeed for the 430 and 450 nm LEDs the shape remained unchanged down to 4 mA, while for the 470 nm LED the wavelength of maximum emission moved upwards by about 4 nm as the current was reduced from 10 mA to 2 mA.

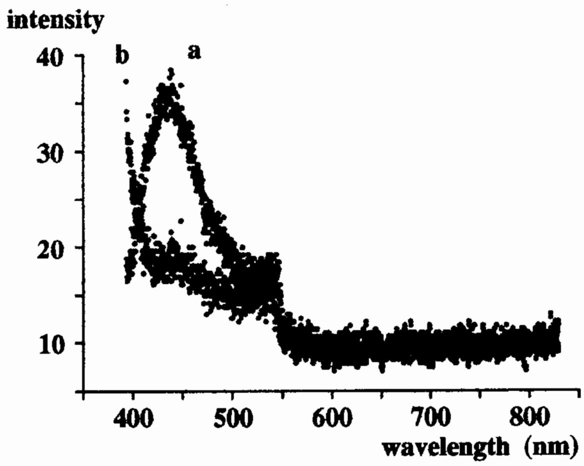

Figure 1.
Spectra from a 430 nm LED with the current in pulses of 50 ms duration at a repetition rate of 1 kHZ, (a) for 20 mA pulses and (b) for 400 mA pulses. (The intensity is in photons s^{-1} nm^{-1} on an arbitrary scale.)

Constancy of emission with time is also important for luminescence stimulation. Spectra were collected for all three types of diode, operated at 20 mA, at switch on and at frequent intervals over a 30 minute period without any detectable change in shape of the emission band. Commonly the intensity of light from an LED shows an overshoot at switch on (Poolton and Bailiff, 1989; Galloway *et al.*, 1997; Galloway and Neal, 1998). The brightest of the three types of LED (470 nm) was investigated in this regard by using a photomultiplier (preceded by neutral density filters) to count the number of photons detected in

250 successive 1 s intervals from switch on of a constant current supply. After the initial overshoot of intensity, which depends on the current as detailed in table 2, the intensity was constant within better than ± 1%.

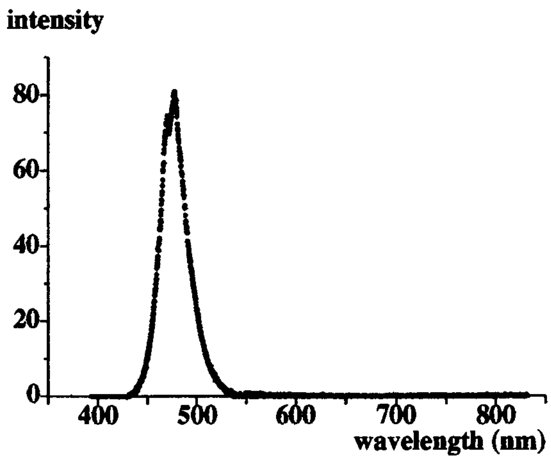

Figure 2.
The spectrum from a 470 nm LED with 50 mA current pulsed at 5% duty cycle. (The intensity is in photons s^{-1} nm^{-1} on an arbitrary scale.)

The behaviour of the 430 nm and 470 nm LEDs was also investigated when the maximum recommended current (30 mA dc or 100 mA pulsed at 10% duty cycle) was exceeded. For the 430 nm LED, increasing the current beyond the recommended maximum of 30 mA up to 50 mA produced no noticeable change in the emitted spectrum. Pulsing the LED on for 50 ms at a repetition rate of 1 kHz (5% duty cycle) showed for current pulses above 100 mA, a reduction in the 430 nm emission and the occurrence of significant emission at wavelengths shorter than 400 nm. Fig. 1 compares the emission spectra for current pulses of 20 mA and 400mA; this change of emission from a peak at 430 nm to a peak in the ultraviolet has been reported for a Nichia type NLPB500 LED by Sato *et al.* (1996). A typical spectrum for a 470 nm LED is shown in fig. 2; however, increasing the dc current above the recommended maximum of 30 mA introduced emission at the long wavelength end of the spectrum, as exemplified in fig. 3. The magnitude of this effect (< 2% of the main 470 nm peak) and the range of wavelengths of the emitted photons varied with current and from diode to diode of the same type. Once induced by exceeding 30 mA dc current, the effect persisted to a lesser extent even if the current was reduced well below 30 mA; it remained detectable down to 10 mA with one diode. However if the diode is pulsed at 50 mA at 5% duty cycle, the spectrum, fig. 2, is no different from the spectra associated with dc currents of less than 30 mA. Indeed pulsing the LED at currents up to 400 mA at 5% duty cycle does not introduce the long wavelength emission, but simply broadens the 470 nm peak (to 46 nm full width at half maximum). The long wavelength emission thus appears to be associated with overheating the diode rather than with the magnitude of the current passing through it. However, the shape of the spectrum in fig. 2 is not that of incandescence. All the diodes tested recovered their normal behaviour, that is no long wavelength emission for dc currents less than 30 mA, after being switched off. No such effect of long wavelength emission could be observed for the 525 nm (2.37 eV) green LED (Nichia type NSPG500) discussed by Galloway and Neal (1998) by increasing the dc current to 50 mA or by pulsing at 400 mA (5% duty cycle). The effect of pulsing at 400 mA was to increase the full width at half maximum to 64 nm (from 42 nm at 20 mA dc) and to reduce the wavelength of the peak in the emission spectrum by 10 nm.

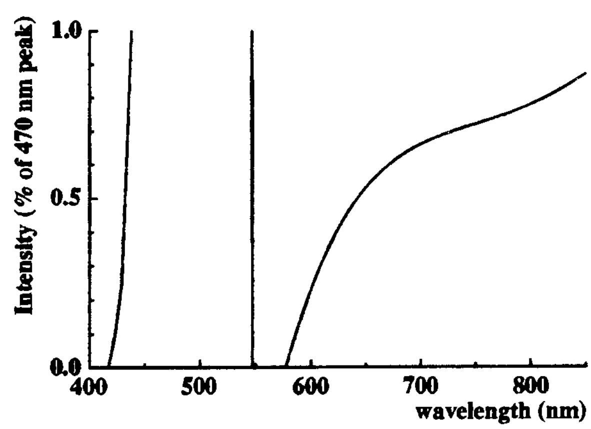

Figure 3.
An example of long wavelength emission from a 470 nm LED operated at a current greater than recommended maximum of 30 mA. The current was 50 mA and the intensity is a percentage of the amplitude of the 470 nm peak.

The 470 nm Nichia type NSPB500S LED shows a constancy of emission spectrum and light intensity when the recommended maximum current (30 mA dc) is not exceded, which makes it suitable for luminescence stimulation. However exceeding the maximum current may induce unexpected emission at long wavelengths, in the region of the resonance in the photostimulation of potassium feldspars (Hutt *et al.*, 1988).

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Reviewer

D.J. Huntley

Comments

It is very useful to know the properties of the blue LED's available. I had expected that they would not be particularly useful for dating because a significant fraction of the blue photons would be Raman scattered into the UV measurement window. Apparently I was wrong. I would caution those planning to use blue LED's particularly those of the shorter wavelengths, that this may yet be a problem in some instances, and will become more so if measurements are performed above room temperature.

Table 1

Properties of the blue LEDs measured.

Type no.	110121*	110039*	NSPB500S**
Specification:			
Peak wavelength (nm)	430	450	470
(photon energy eV)	*(2.89)*	*(2.76)*	*(2.64)*
Mcd at 20 mA	~300	500 – 1000	2000
Max. current (mA)	30	30	30
Measured (for 20 mA):			
One LED as example of type, peak wavelength (nm)	430 ± 2	449 ± 2	461 ± 2, 489 ± 2
(photon energy eV)	*(2.89 ± 0.01)*	*(2.75 ± 0.01)*	*(2.70, 2.54)*
50% of peak intensity (nm)	402 ± 2, 467 ± 2	419 ± 2, 497 ± 2	450 ± 2, 511 ± 2
(eV ± 0.01 eV)	*(3.09 , 2.66)*	*(2.97, 2.50)*	*(2.76, 2.43)*
10% of peak intensity (nm)	<390, 512 ± 2	398 ± 2, 550 ± 2	438 ± 2, 530 ± 2
(eV ± 0.01 eV)	*(>3.19, 2.43)*	*(3.12, 2.26)*	*(2.76, 2.43)*
1% of peak intensity (nm)	< 390, 550 ± 2	< 390, 596 ± 2	438 ± 2, 530 ± 2
(eV ± 0.01 eV)	*(> 3.19, 2.26)*	*(>3.19, 2.09)*	*(2.84, 2.35)*
mean of several LEDs,			
mean peak wavelength (nm)	430 ± 2		467 ± 7
(photon energy eV)	*(2.89 ± 0.01)*		*(2.66 ± 0.04)*
number of LEDs measured	7	1	6

** Nichia Chemical Company, Japan

* M.I. Cables Ltd., Inverness IV3 6EX, Scotland.

Table 2.

The initial overshoot in photon counting rate from one 470 nm Nichia type NSPB500S LED at switch on of a constant current power supply.

current (mA)	10	20	30	40	50
amplitude (%)	0 ± 0.8	0.9 ± 0.6	1.6 ± 0.5	2.4 ± 0.5	4.1 ± 0.5
duration at half amplitude (s)	0 ± 2	2 ± 2	8 ± 3	8 ± 3	8 ± 3