Practical Hints and Tips [on use of light-emitting diodes in research]

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Methods
Practical hints and tips

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The cost of UV LEDs continues to decrease

Finally, "high-power" UV-B LEDs are becoming affordable. They are not yet a commodity and are mostly available through specialized distributors like Roithner Lasertechnik although a few medium power LED types have appeared also in the catalogues of major electronic component distributors such as Mouser and Digikey. There are also a few (re)sellers in China, selling UV-B LEDs even cheaper. However, there are a few things to keep in mind when buying LEDs: 1) within a given part designation there are usually bins or sub-types available. These are not equivalent in performance, so a cheaper LED with the same designation, is likely to be one with a lower radiation output. Reliable sellers will provide the part designation in whole, rather than only the first part of it. 2) When LEDs are produced there is variation in the wavelength of the radiation emitted by individual LEDs. This means both that there are sometimes broad tolerances (e.g. ±5 nm or even ±10 nm) in the specifications, and that LEDs are also classified or binned by manufacturers based on wavelength of emission. Bins are usually also denoted by some digits or letters in the trailing part of the part code.

How much have prices changed? I will do the comparison based on UV radiation output, not on electrical power. Part of the reduction in cost is due to increased efficiency in the conversion of electrical power into optical radiation. This also reduces ancillary costs, and the improved life further reduces the effective cost of using UV-B LEDs. If we take LEDs available from Roithner Lasertechnik as example, in December 2014 I bought LEDs emitting 15 mW at 1180 € per piece, while this October 2019 I bought LEDs emitting 58 mW at 310 nm for 178 € per piece (current price 146 €). The cost per watt of emitted UV-B has decreased from 76 500 € down to 3070 €, or 25 times in 5 years! The LEDs I bought this year were expensive ones, incorporating a quartz lens. Cheapest available from a, reliable in my experience, Chinese supplier (`https://www.leds-global.com/`) emit 18 mW at 310 nm and cost 16.90 €, which makes their cost 940 € per watt, or 1.2% of what I paid in 2014!

UV flashlights

During the past few months I have been asked about UV-A flashlights and I have been using one of them for some time and recently acquired a second one. I also borrowed a third one for testing. I give here some hints on which flashlights are worthwhile buying and which ones are not. Good-quality UV-flashlights can be useful as radiation sources for photography and short term experiments

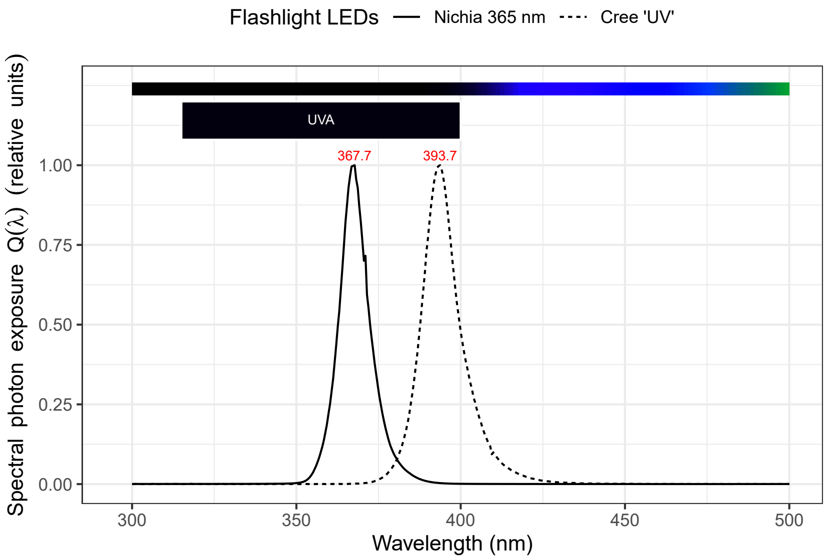

Figure 4.1: Comparison of two different "UV" flashlights. The output of both flashlights was normalized for this figure, in reality the radiation output of the flashlight with the Cree LED was only a fraction of that of the one with the Nichia LED. The flashlight with the Nichia LED had an unspecified UV-pass and VIS-blocking filter, while the one with the Cree LED had a clear glass. The spectrum for the Jaxman U1c flood is not shown as it overlaps the one for the Convoy 2+. (Emission spectra measured by the author. Data to be included in the next release of R package 'photobiologyLamps'.)

Figure 4.2: A Convoy 2+ flashlight next to a Jaxman U1c flood flashlight, both equipped with UV-pass/VIS-block filters.

Figure 4.3: The Convoy 2+ flashlight and the Jaxman U1c flood flashlight have similar bodies, and the same generic "remote cable switch" works with both.

but many of those being sold are unsuitable. These flashlights are rather widely available as they have various uses: checking the fluorescent safety threads and patterns in bank notes, identifying minerals in stones, looking for various types of contaminants both in households and commercial settings and even finding scorpions. Most if not all these flashlights use UV-A or violet LEDs, and almost all of them are sold with a clear glass window. First thing to be aware of is that many of these UV flashlights are based on LEDs with peak of emission at 385 to 410 nm. The ones that are useful as UV-A sources are those with LEDs with peak of emission at 365 nm as the others emit too much visible light (Fig. 4.1). Look for those using LEDs manufactured by the Japanese company Nichia,

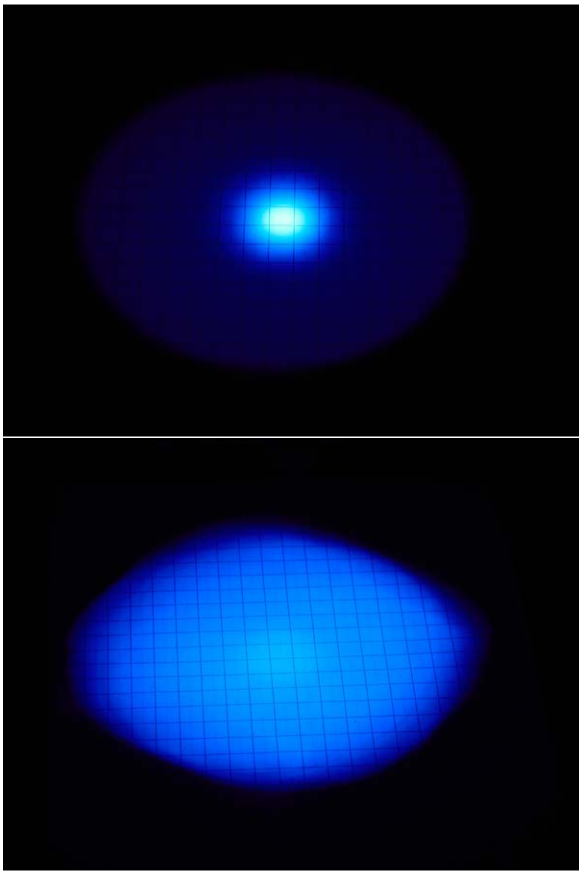

Figure 4.4: Light fields of a Convoy 2+ flashlight (top) and a Jaxman U1c flood flashlight. The photographs are of the UV-induced fluorescence of a white sheet of paper with rulings 10 mm apart.

Figure 4.5: A granite boulder at night. Top: illuminated with a white LED light source, exposure time 0.2 s; bottom illuminated with the Convoy 2+ flashlight by "light painting" and photographed through UV-blocking filters, exposure time 55 s. The yellow-fluorescing lichen on the boulder and the red fluorescence from the moss at the base of the stone are both clearly visible.

as these have strong output and less VIS contamination. In all cases the clear glass should be replaced with a good quality UV-pass VIS-blocking filter.

At this time, my recommendation is to buy a Convoy 2+ flashlight with a Nichia LED at 365 nm (ca. 25 €) or a Jaxman U1c flood flashlight, also with a Nichia LED at 365 nm (ca. 60 €) (Fig. 4.2, 4.3). As we will see below these flashlights are different and suitable for different purposes. Both are readily available through many different sellers in eBay and Aliexpress. As always there is a risk when buying from such on-line sellers, so it is important to check that the flashlight you have received matches the description and works as expected before the time for complaints and refunds is over. Buying filters is trickier than buying the flashlights unless you are willing to pay good money for them. Safest is to buy a filter made of Hoya glass already cut to size, buy this may cost you more than the flashlight. Filters 20.5 mm in diameter and 2 mm-thick, made from generic filter glass under the denomination ZWB2 can be good enough, but quality seems to vary a lot (they are sold for anything between 0.45 to 5 €). It is also important to consider both type, quality, and thickness of the glass filters in addition to their diameter. One eBay seller (uviroptics) sells these Convoy 2+ flashlights with a Hoya U-340 filter already installed at a price of ca. 90 € and the filter by itself for ca. 30 euro. The quality of the filters pre-installed by other sellers can vary greatly and will be type ZWB2 or inferior.

The Convoy 2+ Nichia 365 nm flashlights emit UV-A radiation in a concentrated beam, which can be a drawback for some applications. At close distance, at the centre of the beam UV-A irradiance is a few times more than in full sunlight at midday on a summer day (e.g. at 200 mm distance I have measured in the hot-spot of the UV-A illuminated field a photon irradiance of 1370 $\mu mol\,m^{-2}\,s^{-1}$). However, the area irradiated is mall and irradiance uneven (Fig. 4.4, top). The Convoy 2+ uses a LED rated at about 3 W of electrical power. The Convoy 2+ is good for spotting fluorescent object at night at distance. For photography of UV-A-induced visible fluorescence one usually needs to "paint" the area been photographed as is rarely possible to illuminate the whole area photographed simultaneously with such a narrow beam (Fig. 4.5).

Recently similar flashlights have appeared under a different brand name: Jaxman. These are readily available with pre-installed filters. Price and quality wise the Convoy 2+ is a good choice if one needs a concentrated UV-A radiation beam. Jaxman has a variant under the denomination of "U1C flood" which provides a much broader and even UV-A radiation field (Fig. 4.4, bottom). Even though the Jaxman is of the same small size as the Convoy, it has a LED rated at 6 W of electrical power. Still as the UV-A radiation is projected evenly over the illuminated area, the maximum irradiance is lower than for the Convoy 2+ (e.g. at 200 mm distance I have measured in the hot-spot of the UV-A illuminated field a photon irradiance of 117 $\mu mol\,m^{-2}\,s^{-1}$). I have used the Jaxman very little but spectral measurements indicate that both have an almost identical emission spectrum and leakage of VIS light. While the Convoy 2+ has only and on-off switch, the Jaxman, has low and high power settings. Although one could expect the Jaxman to heat up quickly because of the higher power rating, the metal body seems to dissipate heat well enough.

Both flashlights are externally very similar, with the bodies so similar as to be interchangeable. They measure 25 mm in diameter and 117 mm in length. The heads are different in the electronics, LED and optics. They both use one rechargeable Li-ion battery of type 18650. These batteries are fairly common, but not something you will get in the nearest supermarket. You need a charger or a battery with a USB charger circuit built in.

The Jaxman U1c flashlight comes in multiple versions, the "flood" version I have and a normal or non-flood version which I haven't tested. This version with normal optics can be expected to be similar to the Convoy 2+ in its 3W version, but I have no proof of this. This non-flood version at the moment sells for around 40 € for the 3 W version and 55 € for the 6 W version. They also have the two step power switch that the Convoy 2+ lacks, as well as the pre-installed UV-pass filter.

Although these flashlights emit in the UV-A, given the very strong and concentrated radiation output, it is advisable to use eye protection especially when using them in darkness or in weak visible light.

LEDs for horticulture and museums

Nichia (`nichia.jp`) has recently released LEDs chips designed for use in horticulture production. What is special about them? Primarily two features: very high energy conversion efficiency (About 2 or 2.5 times as efficient as Valoya B50 luminaires) and an emission spectrum unusual for grow lamps as it contains a good deal of radiation emission in the green range (Fig. 4.6 top). According to my tests photon irradiance can reach nearly 2 500 in a growth chamber (Aphalo and Belevich, unpublished).

Both Nichia and Toshiba/Seoul Semiconductor have released new series of LEDs

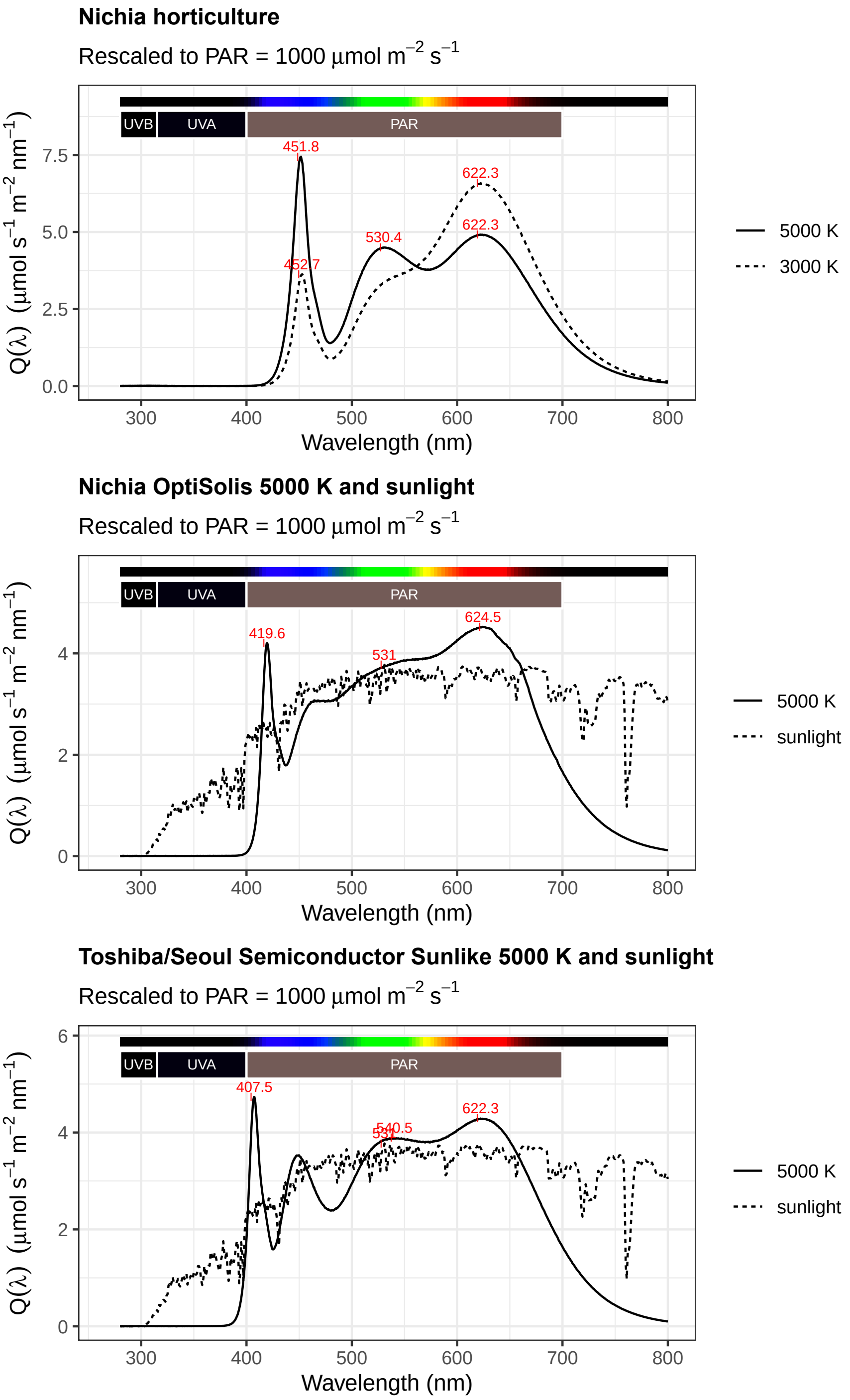

Figure 4.6: Emission spectra of white LEDs from Nichia and Seoul Semiconductor (LEDs' emission spectra measured by the author. Data to be included in the next release of R package 'photobiologyLEDs'.)

advertised as having an emission spectrum similar to that of sunlight (Fig. 4.6 middle). These LEDs are mainly aimed at achieving extremely good colour reproduction. Those from Nichia, sold under the name of *Optisolis*, do not emit UV and are advertised as ideal for use in museums. Those from Toshiba/Seoul Semiconductor are sold under the name *Sunlike* and emit to some extent at 390 nm (Fig. 4.6 bottom) (more information at `https://www.nichia.co.jp/en/product/led_sp_optisolis.html` and `http://www.seoulsemicon.com/en/technology/SunLike/`). Both series include versions emitting warmer and cooler white light. Energy conversion efficiency is slightly lower than that of the LEDs described in the previous paragraph. These LEDs emitting sun-like light would still need to be combined with UV-B, UV-A and far-red-emitting LEDs to achieve an spectrum that could considered a simulation of sunlight relevant to plants. Ready-assembled modules using these different LED chips are available from Lumitronix (`https://www.leds.de`).