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`photobiologyLEDs-package`

photobiologyLEDs: Spectral Data for Light-Emitting-Diodes

Description

Spectral emission data for some frequently used light emitting diodes available as electronic components. Part of the 'r4photobiology' suite, Aphalo P. J. (2015) doi:10.19232/uv4pb.2015.1.14.

Details

Data for emission spectra of different types of LEDs and LED arrays.

The package contains one main collection of spectra for different LEDs available as electronic components through hole (th), surface mount devices (SMD) and chip-on-board (COB) packages with no built-in driver circuitry to limit the current, `leds.mspct`. Data for LED bulbs and LED luminaires/lamps are included in package `photobiologyLamps-package`. Two smaller collections, provide spectra for a COB LED driven with varying current or constant-current (CC) dimming, `COB_dimming.mspct`, and at fixed current but in combination with different reflectors, `COB_reflectors.mspct`.

In addition to the spectra the package provides character vectors of names to be used as indexes to subset groups of spectra from `leds.mspct`. In all cases spectral data are normalized to spectral energy irradiance equal to one at the wavelength of maximum spectral energy irradiance (strongest emission peak). In most cases the multiplier used for normalization can be obtained by quering the object. However, this is useful only in those cases where the distance from source to entrance optics of the spectrometer and alignment were recorded.

All LEDs have been measured at room temperature mounted on passive heatsinks and usually driven near their maximum current rating. Precision power supplies or LED drivers were used to drive them at constant current.

The number of different LED types available is enormous, and this collection attempts only to provide examples for some of them. Which types are included is the result of what has been bought for specific uses at my lab or out of curiosity since 1995 to the present. Which brands and LED types are included, should not be interpreted as endorsement of any supplier.

Warning!

None of the spectral data included in this package are based on supplier's specifications and are only for information. The exact emission spectrum of a LED depends to some extent on testing conditions, but more importantly among individual LED dies. Spectral specifications are usually given by typical and boundary values. Furthermore, most manufacturers classify LEDs of a given type into "bins" with slightly different colour and electrical characteristics. In addition, the performance of LEDs deteriorates with use, with light output decreasing faster if driven with high current or if they overheat as a consequence of insufficient cooling. **In other words, the data provided here are not a substitute for actual measurements of radiation emission and spectrum of the LEDs actually used in a given piece of scientific research or other important work.** For less demanding situations, such as planning of experiments or testing the sanity of independent measurements, the data are in most cases reliable enough but perfect agreement with measurements on other LEDs of the same exact type should not be expected.

Note

Some of the LEDs were bought from AliExpress sellers while others were sourced from major electronic component distributors like Farnell, RS components, Digi-Key, Mouser, TME, Roithner-Lasertechnik, and Lumitronix/LedRise. In the case of some AliExpress sellers or smaller webstores sometimes the exact type specifications are not available. Some of the Chinese sellers package the LEDs they sell using LED dies (= chips) from major brands and provide this brand name. In very recent times this seems to have expanded in some cases to include high density COB packages. Be aware that in recent times the word COB is being used by AliExpress, Bangood and eBay sellers to describe old-style arrays where the LED chips are not directly attached to a board to maximize thermal conductance. In this package, we use COB in its more restricted meaning and name other packages simply LED array.

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References

Aphalo, Pedro J. (2015) The r4photobiology suite. UV4Plants Bulletin, 2015:1, 21-29. doi:10.19232/uv4pb.2015.1.14.

See Also

Useful links:

- https://docs.r4photobiology.info/photobiologyLEDs/
- https://github.com/aphalo/photobiologyLEDs
- Report bugs at https://github.com/aphalo/photobiologyLEDs/issues

Examples

```
library(photobiology)

names(leds.mspct)

led_brands

white_leds

qe_ratio(leds.mspct$Nichia_NS6L183AT_H1_sw) * 1e6 # umol / J

is_normalized(leds.mspct$Nichia_NS6L183AT_H1_sw)

cat(comment(leds.mspct$Nichia_NS6L183AT_H1_sw))

when_measured(leds.mspct$Nichia_NS6L183AT_H1_sw)

how_measured(leds.mspct$Nichia_NS6L183AT_H1_sw)
```

COB_dimming.mspct *Constant-current dimming of LEDs*

Description

A collection of emission spectra of a light-emitting-diode driven at different constant current.

Usage

```
COB_dimming.mspct

COB_dimming.tb
```

Format

A "source_mspct" object containing 8 "source_spct" objects.

In each of the member spectra, the variables are as follows:

- w.length (nm)
- s.e.irrad (W m-2 nm-1)

An object of class tbl_df (inherits from tbl, data.frame) with 8 rows and 6 columns.

Details

The "COB_dimming.mspct" object contains "source_spct" objects with spectral irradiance data with the same Optisolis COB LED from Nichia driven at different values of constant current. Distance from LED to cosine diffuser was 159 mm; a reflector was attached to the LED to make the light beam narrower. Spectra are not normalized. The position for the LED with respect to the entrace optics did not vary among measurements.

The COB LED used is the chip-on-board (COB) Optisolis type NFCWL036B-V3-Rfcb0 from Nichia with CRI > 95. Nominal electrical power of 10.3 W at nominal current of 270 mA. So, two spectra are for the COB over-driven, which is possible with enough cooling, but not recommended.

The spectral data are not expressed at constant wavelength intervals. Not only the intervals vary in the raw data from the array spectrometer, but in addition function thin_wl has been applied to reduce the storage space needed. In brief the wavelength interval has been increased as much as possible in those regions of the spectrum that lack detailed features (such as linear slopes and wavelength regions with zero light emission).

Note

Please see the metadata in each spectrum. These metadata are stored as attributes of the individual source_spct objects and can accessed with functions comment, getWhatMeasured, getWhenMeasured, getHowMeasured, getInstrDesc and getInstrSettings. See also the comment attribute of the COB_dimming.mspct object.

References

https://www.ledil.com/ https://www.nichia.co.jp/en/

Examples

```
library(photobiology)

names(COB_dimming.mspct)

# photon irradiance in umol m-2 s-1, and relative to maximum
q_irrad(COB_dimming.mspct, scale.factor = 1e6)

# precomputed values and measured supply current
COB_dimming.tb
```

COB_reflectors.mspct *LEDs with reflectors*

Description

A collection of emission spectra of a light-emitting-diode when combined with different reflectors.

Usage

```
COB_reflectors.mspct
```

Format

A "source_mspct" object containing 4 "source_spct" objects.

In each of the member spectra, the variables are as follows:

- w.length (nm)
- s.e.irrad (W m-2 nm-1)

Details

The "COB_reflectors.mspct" object contains "source_spct" objects with spectral irradiance data with the same Optisolis COB LED from Nichia, and different reflectors from the Mirella-G2 series from LEDiL . Distance from LED to cosine diffuser was 159 mm. Spectra are not normalized. It needs to be taken into account than even in these cases measurements have not been done in an optical bench, so values of spectral irradiance are subject to errors due to possible misalignment.

The COB LED used is the chip-on-board (COB) Optisolis type NFCWL036B-V3-Rfcb0 from Nichia with CRI > 95. Nominal electrical power of 10.3 W at nominal current of 270 mA. Spectra are for the COB over-driven at 350 mA, which is possible with enough cooling, but not recommended.

The spectral data are not expressed at constant wavelength intervals. Not only the intervals vary in the raw data from the array spectrometer, but in addition function thin_wl has been applied to reduce the storage space needed. In brief the wavelength interval has been increased as much as possible in those regions of the spectrum that lack detailed features (such as linear slopes and wavelength regions with zero light emission).

Note

Please see the metadata in each spectrum. These metadata are stored as attributes of the individual source_spct objects and can accessed with functions comment, getWhatMeasured, getWhenMeasured, getHowMeasured, getInstrDesc and getInstrSettings. See also the comment attribute of the COB_reflectors.mspct object.

References

https://www.ledil.com/ https://www.nichia.co.jp/en/

Examples

```
library(photobiology)

names(COB_reflectors.mspct)

# calculate photon irradiances in umol m-2 s-2 and relative to no reflector
irrads <- q_irrad(COB_reflectors.mspct, scale.factor = 1e6)
irrads$Q_Total_rel <- irrads$Q_Total / min(irrads$Q_Total)
irrads
```

led_brands *Spectral data for LEDs from different suppliers*

Description

The collection of spectra `leds.mspct` contains spectra for light emitting diodes (LEDs) from several different suppliers. The character vectors described here contain the names of the spectra for LEDs from each supplier/brand to facilitate their extraction from the collection. One additional vector, `led_brands` contains the names of the brands as used in the names of the spectra in the collection.

Usage

```
led_brands

Agilent_leds

HueyJann_leds

LedEngin_leds

Ledguhon_leds

LCFOCUS_leds

Marktech_leds

CREE_leds

Epileds_leds

Epistar_leds

SeoulSemicon_leds

Bridgelux_leds

Nichia_leds

Norlux_leds

Osram_leds

QuantumDevices_leds

Roithner_leds
```

`Weili_leds`

`TaoYuan_leds`

`Luminus_leds`

`Samsung_leds`

`HotRed_leds`

Format

A vector of character strings.

An object of class `character` of length 7.

An object of class `character` of length 2.

An object of class `character` of length 14.

An object of class `character` of length 2.

An object of class `character` of length 4.

An object of class `character` of length 1.

An object of class `character` of length 1.

An object of class `character` of length 12.

An object of class `character` of length 1.

An object of class `character` of length 3.

An object of class `character` of length 2.

An object of class `character` of length 9.

An object of class `character` of length 3.

An object of class `character` of length 3.

An object of class `character` of length 4.

An object of class `character` of length 15.

An object of class `character` of length 5.

An object of class `character` of length 1.

An object of class `character` of length 1.

An object of class `character` of length 1.

An object of class `character` of length 4.

Details

As described for the individual brands, ownership of brands and companies has changed over the years through take-overs, mergers and sales of company divisions. Even when brand names have changed it has been the norm for electronic components that component type codes are maintained

unchanged. In contrast to some integrated circuits, exact replacement types from multiple suppliers are not available for LEDs.

Some small suppliers sell under their own brand names, rarely with type codes, LEDs that seem to be based on out-of-specifications LED chips. Some are plain bad, such with low output, but others emit at wavelengths that are not otherwise available, at least in small numbers.

Agilent/Hewlett Packard

Hewlett Packard (HP) manufactured sold LEDs in the 1990's. This division later became part of Agilent, during its spin-off HP. Later the electronic components division of Agilent operated as Avago Technologies for some time. Currently, BROADCOM supplies some of these LEDs or similar improved types.

Huey Jann

Huey Jann was a Taiwanese supplier of high power LED arrays. The arrays measured were bought from their European distributors. Huey Jann is no longer in business.

LED Engin

Led Engin was an independent supplier of power LEDs in low thermal resistance ceramic substrate packages. It is now part of Osram.

LEDGUHON

LEDGUHON (AliExpress seller) advertised the LEDs measured as assembled using Bridgelux chips by Guangzhou Juhong Optoelectronics Co., Ltd., China.

LCFOCUS

LCFOCUS TECH (Shenzhen, China) sell LEDs and LED arrays. The ones measured where bought from LCFOCUS official store at AliExpress. The suppliers of LED chips are not allways informed.

Marktech

Marktech Optoelectronics is a distributor and supplier of LEDs from the U.S.A. that sells VIS and UV emitting LEDs.

CREE

The former LED products group of Cree is now Cree LED (U.S.A.) and a part of SGH.

Epileds

EPI LEDS Co., Ltd. (Taiwan) is devoted to the R & D, design, manufacture and sales of blue, green, red, and white light LED wafers and chips.

Epistar

EPISTAR Corporation (Taiwan).

Seoul Semiconductors

Seoul Semiconductor (Korea) supplies LEDs, including SunLike white LEDs using 'phosphor' technology from Toshiba (Japan). Seoul Viosys supplies UV LEDs based on an agreement with SETi (U.S.A.).

Bridgelux

Bridgelux, Inc. (U.S.A.) is a supplier of LEDs partnering with Epistar and Kaistar for the manufacture of their LEDs.

Nichia

With 24 in the world and inventor of the blue (and also white) light emitting diodes. The company was already an important supplier of 'phosphors' before the invention of the white LEDs based on blue-emitting LED chips.

Some of the Nichia LEDs we measured were assembled into arrays of the series names SmartArray and LinearZ from LUMITRONIX (Germany), and/or supplied by LEDRISE Ltd. (Hong Kong, Germany and Romania).

Norlux

Norlux is now part of Thomas Research Products. The LEDs we measured are some of the earliest COB designs from early 1990's. Each COB containing 90 LED chips. (Norlux is no longer in business.)

Osram

ams-OSRAM International GmbH (Germany) produces LEDS and various light and other sensors. Current trade name for LEDs is Osram Opto Semiconductors. Osram has recently become owner of Led Engin, whose LEDs are listed separately in this pacakge. LEDs supplied under the LED Engin brand differ mostly in the packages' thermal properties and contact layout.

Quantum Devices

Quantum Devices (U.S.A.) sold in the past both individual LEDs and luminaires. They were in the late 1980's and early 1990's the supplier of choice for LEDs emitting in the far-red region of the spectrum. The company still exists but no longer sells LEDs as components.

Roithner LaserTechnik

Roithner LaserTechnik is a distributor and reseller of LEDs, LED arrays and lasers. They have a very extensive catalogue covering almost all wavelengths for which LEDs are manufactured. Many of the LEDs are sold under new codes as they are retested and in some cases individual characterization data provided. For example some of short UV LEDs sold are from SETi.

Shenzhen Weili

Leds Global and Shenzhen Weili are trade names of the same supplier of LEDs and LED arrays. They sell both standard types and also assemble customized arrays upon request. Customized arrays may have up to twelve independent channels and vary in power output from 10 W to 300 W. The LED chips they use are from multiple suppliers, including Epileds, Epistar and Bridgelux.

Tao Yuan

TaoYuan Electron (Hong Kong and China) is a supplier of LEDs and LED arrays.

Luminus

Luminus Devices (USA) is a supplier of SMD LEDs and COB LEDs as components.

Samsung

Samsung LEDs (South Korea) is a supplier of SMD LEDs and COB LEDs as components.

Hot Red

Hot Red (AliExpress, China) is a seller of LEDs and LED arrays, most as components. Original manufacturers and item types in most cases are not published.

References

https://www.broadcom.com/products/leds-and-displays/

https://www.osram.us/ledengin/

https://www.ledguhon.com/

https://marktechopto.com/

https://www.cree-led.com/

https://www.epileds.com.tw/en/

https://www.epistar.com/

http://www.seoulsemicon.com/en/

https://www.bridgelux.com/bridgleux

https://www.nichia.co.jp/en/product/led.html

https://www.osram-os.com/

https://www.roithner-laser.com/ and http://www.s-et.com/en/

https://www.leds-global.com/

https://www.ledwv.com/en/

https://www.luminus.com/

https://led.samsung.com/

https://led.samsung.com/

See Also

leds.mspct

Examples

```
led_brands
Agilent_leds
```

---

led_colors *Spectral data for LEDs of different colours*

Description

Names of members of the collection of emission spectra leds.mspct grouped by the wavelength ranges or colors at which they predominantly emit energy.

Usage

```
led_colors

uv_leds

purple_leds

ir_leds

blue_leds

green_leds

yellow_leds

orange_leds

red_leds

amber_leds

white_leds

multi_channel_leds

single_channel_leds
```

Format

A vector of character strings.

An object of class `character` of length 18.

An object of class `character` of length 8.

An object of class `character` of length 10.

An object of class `character` of length 14.

An object of class `character` of length 11.

An object of class `character` of length 0.

An object of class `character` of length 4.

An object of class `character` of length 15.

An object of class `character` of length 4.

An object of class `character` of length 20.

An object of class `character` of length 6.

An object of class `character` of length 95.

Details

The character vectors `"uv_leds"`, `"purple_leds"`, `"blue_leds"`, `"green_leds"`, `"yellow_leds"`, `"orange_leds"` and `"red_leds"` contain the names of the members of `leds.mspct` with peaks of emission within the wavelength range corresponding to the light colours as defined by ISO standards. Vector `amber_leds` is the union of `"yellow_leds"` and `"orange_leds"`. Vector `white_leds` contains the names of spectra for LEDs with broad or multiple peaks of emission in the visible range. Vectors `"uv_leds"` and `"ir_leds"` contain the names for LEDs with peak emission at wavelengths < 400 nm and wavelengths > 700 nm, respectively. Vector `"multi_channel_leds"` contains names of spectra for LED arrays that contain LED chips of more than one colour grouped into channels that can be powered, and thus controlled, independently.

These vectors can be used to extract subsets of spectra from `leds.mspct`.

See Also

`leds.mspct`, `VIS_bands`, `UV_bands`.

Examples

```
uv_leds
blue_leds
red_leds
white_leds
multi_channel_leds

# select LEDs emitting in the amber (yellow to orange) region
leds.mspct[amber_leds]
```

led_uses *Spectral data for LEDs for different uses*

Description

The collection of spectra leds.mspct contains spectra for light emitting diodes (LEDs) designed for specific uses as well as for general illumination. The character vectors described here contain the names of the spectra for LEDs sold for specific uses to facilitate their extraction from the collection. One additional vector, led_use contains the wording of uses as in the names of the spectra in the collection.

Usage

```
led_uses

plant_grow_leds

high_CRI_leds
```

Format

A vector of character strings.

An object of class character of length 7.

An object of class character of length 9.

Details

Most LEDs can be useful in different situations individually or in combination with other types. The lists are thus not exclusive but rather indicate a typical use.

Plant grow

The character vector plant_grow_leds contains the names of the spectra to facilitate their extraction from the collection. This includes LEDs designed to be the only light sources as well as LEDs designed to be used together with other LEDs to assemble luminaires used for plant cultivation, either as only light source or to supplement natural light.

High color reproduction index

The character vector high_CRI_leds contains the names of the spectra to facilitate their extraction from the collection. This includes white LEDs with a high color reproduction index (CRI > 95) as computed from the actual measured spectra. Nowadays some of these types of LEDs are not only advertised as good from illumination in museums, exhibitions and as light sources for video and photography, but also as less stressful to human vision and in some cases as good for the entraining of the human circadian clock. In practice this means an emission spectrum covering most of visible light with only minor peaks and valleys.

See Also

leds.mspct

Examples

```
led_uses
plant_grow_leds
```

---

leds.mspct *Spectral irradiance for diverse LEDs*

Description

A collection of emission spectra of light-emitting-diodes from different suppliers.

Usage

```
leds.mspct

led_arrays.mspct
```

Format

A "source_mspct" object containing 74 "source_spct" objects.

In each of the member spectra, the variables are as follows:

- w.length (nm)
- s.e.irrad (W m-2 nm-1)

An object of class source_mspct (inherits from generic_mspct, list) with 6 rows and 1 columns.

Details

The leds.mspct and led_arrays.mspct objects contain "source_spct" objects with spectral irradiance data, for single channel and multichannel LEDs, respectively. As the exact distance from LED to cosine diffuser and/or the driving current vary among spectra for different LEDs, members of leds.mspct have been all normalized to the wavelength of maximum spectral energy irradiance. In contrast, spectra in led_arrays.mspct have not been normalised as comparisons among channels of each array are meaningful, even if approximate.

When the details of the measurement conditions are know, these are stored as metadata attributes. In any case, it needs to be taken into account than even in these cases measurements have not been done in an optical bench, so values of spectral irradiance are subject to errors due to possible misalignment. The shape of the spectra, in contrast can be relied upon as measurements were done with well calibrated instruments.

The output of LEDs at a given current decreases as their temperature increases. The wavelength at the peak of emission can depend on the temperature and current, but shifts tend to be only a couple

of nanometres. In LED arrays with heterogeneous LED chips or white LEDs based on secondary emission from phosphor the shape of the spectrum can slightly change depending on the drive current and temperature.

There is variation among LEDs of the same type, specially with respect wavelength and light output. The data included are for individual LEDs and can be expected to differ to some extent from the typical values in the manufacturers specifications. Some of the LEDs for which data are included are only of historical interest as their production has been discontinued, usually replaced by new types with enhanced performance. When known, the approximate "vintage" is provided in the metadata.

Some LEDs are "generic" ones which lacked detailed data sheets at the time of purchase, or even lacked a manufacturer's type denomination code. For them, the metadata is necessarily less detailed.

The spectral data are not expressed at constant wavelength intervals. Not only the intervals vary in the raw data from the array spectrometer, but in addition function `thin_wl` has been applied to reduce the storage space needed. In brief the wavelength interval has been increased as much as possible in those regions of the spectrum that lack detailed features (such as linear slopes and wavelength regions with zero light emission). The algorithm used preserved the location and height of significant energy emission peaks, i.e., the global peak and clear local peaks.

Note

Please see the help page for `led_brands` for LED suppliers' contact information. Please see the metadata in each spectrum for other information. These metadata are stored as attributes of the individual `source_spct` objects and can accessed with functions `comment`, `getWhatMeasured`, `getWhenMeasured` and `getHowMeasured`. Many of the spectra also contain information on the measurement procedure accessible with `getInstrDesc` and `getInstrSettings`.

See Also

`oo_maya_leds`

Examples

```
library(photobiology)

names(leds.mspct)

names(led_arrays.mspct)

leds.mspct$Nichia_NS6L183AT_H1_sw

cat(getWhatMeasured(leds.mspct$Nichia_NS6L183AT_H1_sw))

peaks(leds.mspct$Nichia_NS6L183AT_H1_sw, span = 100)

wl_range(leds.mspct$Nichia_NS6L183AT_H1_sw)

wl_stepsize(leds.mspct$Nichia_NS6L183AT_H1_sw)

intersect(LedEngin_leds, blue_leds)

leds.mspct[intersect(LedEngin_leds, blue_leds)]
```

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UV_bands, *13*

uv_leds *(*led_colors*)*, 12

VIS_bands, *13*

Weili_leds *(*led_brands*)*, 7
white_leds *(*led_colors*)*, 12

yellow_leds *(*led_colors*)*, 12