VALOYA SPECTRA SPECIFICATIONS

CONTENTS

FLUCTUATIONS IN LIGHT SPECTRA

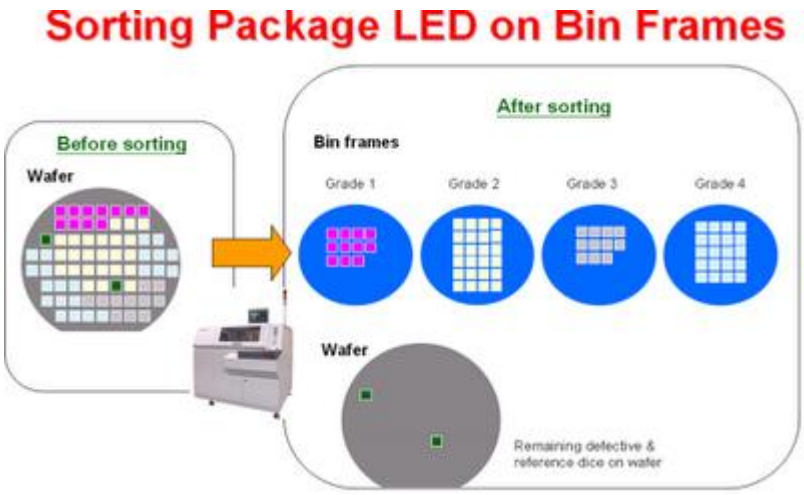
Valoya's light spectra are based on over 400 plant light trials, with more than 60 light spectra tested on over 150 plant species or varieties. The research started in 2009 and continues today in tens of ongoing plant trials.

Valoya is heavily committed to replicating the benchmark light spectrum in each fixture produced and technical R&D continuously develops ways to secure this in current and future products. However, due to reasons out of Valoya's reasonable economical control there are sometimes variations in the spectra. The spectral variation is due to variation in the LEDs. The variation on an LED level is mostly negligible, and small variations are also effectively evened out when combining multiple LEDs. Some variations are larger and require releasing a new version of the spectra. In general, the changes are insignificant. When larger changes occur Valoya will inform customers and partners about these. This document presents the reasons for the variations, as well as the process for avoiding them and how Valoya informs about the changes.

Reasons for changes in the light spectra

Valoya uses high quality LEDs in its fixtures. Most LEDs used by Valoya are proprietary for Valoya. They compose of a blue (about 450 nm peak wavelength) or ultra-violet/near UV (about 405 nm peak wavelength) chip and phosphor. The "chip" lights up when electricity passes through and converts part of the blue or UV light into one of Valoya's signature spectrum, as the phosphorus material absorbs the blue/UV light and converts it to a longer wavelength pinkish color. Each fixture consists of tens or hundreds of phosphor coated LEDs. These are either one kind of single spectrum LEDs or a combination of two or several single spectrum LEDs. Together they make up the complete AP67, AP673L or NS1 spectrum for example.

The challenges in maintaining perfect spectral uniformity across fixtures of the same product series stem from the very core of the LED chip making process. The LED chips are made from semi-conductor wafers. The process to make the semi-conductor metallic alloy mix is still not perfectly mastered and as a result of this the wafer will have slightly different metallic mixes on different parts of the wafer. Lack of material uniformity across the wafer results in different kinds chips, when the wafer is cut into chips. The differences are in peak wave-length (for example some 450 nm, some 447, some 453 nm etc.) and in efficiency (which is presented as differences in the threshold voltage (the DC voltage needed to make the LED radiate light). In order to enable LED buyers to know that they are getting a uniform light output from the LED batch they buy, the chips have to be sorted (binned) into sufficient uniform groups (grades).



The grading also has impacts on the pricing of the chips, the most efficient ones being more expensive than the less expensive ones, and narrow bins (for example 449-451 nm) are more expensive than wider bands (445-455 nm). The development in LED chip manufacturing is reducing these differences, but sometimes it also leads to situations where some bins become unavailable or economically unviable to use.

The phosphor coating of the LED may also lead to minor variations over time. As Valoya uses almost exclusively LED epi chips at ~450 nm, which are very stable in different temperatures, the phosphor related variation risk is mostly from the potential decay of the phosphors, which may slightly change the spectrum after a long use time.

For Valoya the differences in the chips cause only minor manageable issues, but occasional disappearance of a certain type of chip is a big challenge and leads to a situation where a blue peak of a spectrum will slightly change. These are major changes and will be duly informed. Smaller variations, such as normal variation within a certain bin, even out, as Valoya fixtures always comprise of tens or hundreds of LEDs.

Valoya is also now implementing a quality monitoring system to its production, where each assembled printed circuit board (PCB) is tested for efficiency and spectrum. This enables securing spectral and light output quality before PCBs are assembled into fixtures (where they are further quality tested).

Another source for slight spectral variance is between the different product series of Valoya. As different fixture designs do not all have equal numbers of LEDs or are equally divisible, they will be matched as closely as possible, meaning that some variance between different product ranges can occur.

Measuring the spectrum of light must be done with a professional spectrometer. The human eye sees light in a skewed way, detecting very small variations in the green-yellow area and having poor sensing of the blue and red area, not to mention UV-A and far red (700-750nm) which are on the outer limits of the eye's visual detection capability. More information on human vision can be found, for example, here:
https://www.handprint.com/HP/WCL/color1.html

Benchmark spectra and spectral variation bands

In order to balance strict spectral uniformity, commercial viability and have the least impact on plants with the variation, Valoya has introduced the following metrics in judging acceptance or rejection of a spectrum in production, as well as for the threshold of when a new spectrum version needs to be launched.

The variation will be benchmarked to the Official "Golden Sample" of a certain spectrum. This spectrum will be the reference in Valoya marketing materials and the current Spectrum Guide (Available to resellers and customers under non-disclosure agreement).

Changes to the benchmark will be informed to resellers in the reseller newsletter as soon as possible, and also informed to customer's.

Spectrum Safe Variation Intervals (SAVI)

1. Spectrum graph with Normal distribution assumed
2. Spectral bands (380-399, 400-499, 500-599, 600-699, 700-780 nm)
3. Red/Far Red (defined by Sellaro 2010; R 650-670 / FR 720-740)
4. B:G (defined by Sellaro 2010; B 420–490 / G 500–570 nm)

The specified variation values within these SAVI intervals simultaneously (i.e. criteria 1-4 apply at the same time) are accepted. Values of all four categories have to be met.

The LEDs meeting these criteria can and will be used in production or specially notified to customers.

Valoya will keep the spectral test data stored for future reference (see spectrum testing process below).

Spectral variations of LEDs assembled on a PCB (printed circuit board, the unit being tested spectrally), which are outside the variation intervals will be rejected in production and these PCBs will not be in the fixture assembly.

When there are major variations from the benchmark, which are highly likely to lead to systematic/permanent out of SAVI, Valoya will analyze options for keeping the current benchmark and variation interval. If there is no economically viable way of keeping the current benchmark, Valoya will set a new spectral benchmark for the spectrum with issues and release this as a new benchmark. When possible, Valoya will inform resellers about this as soon as possible in advance, and also update the Spectrum Guide and marketing materials. Ideally a change in benchmark would be identified early enough to enable plant trials, ensuring the new benchmark provides equal results, but in practice the changes can be out of Valoya's control and there may only be a short or no time for preparing for it.

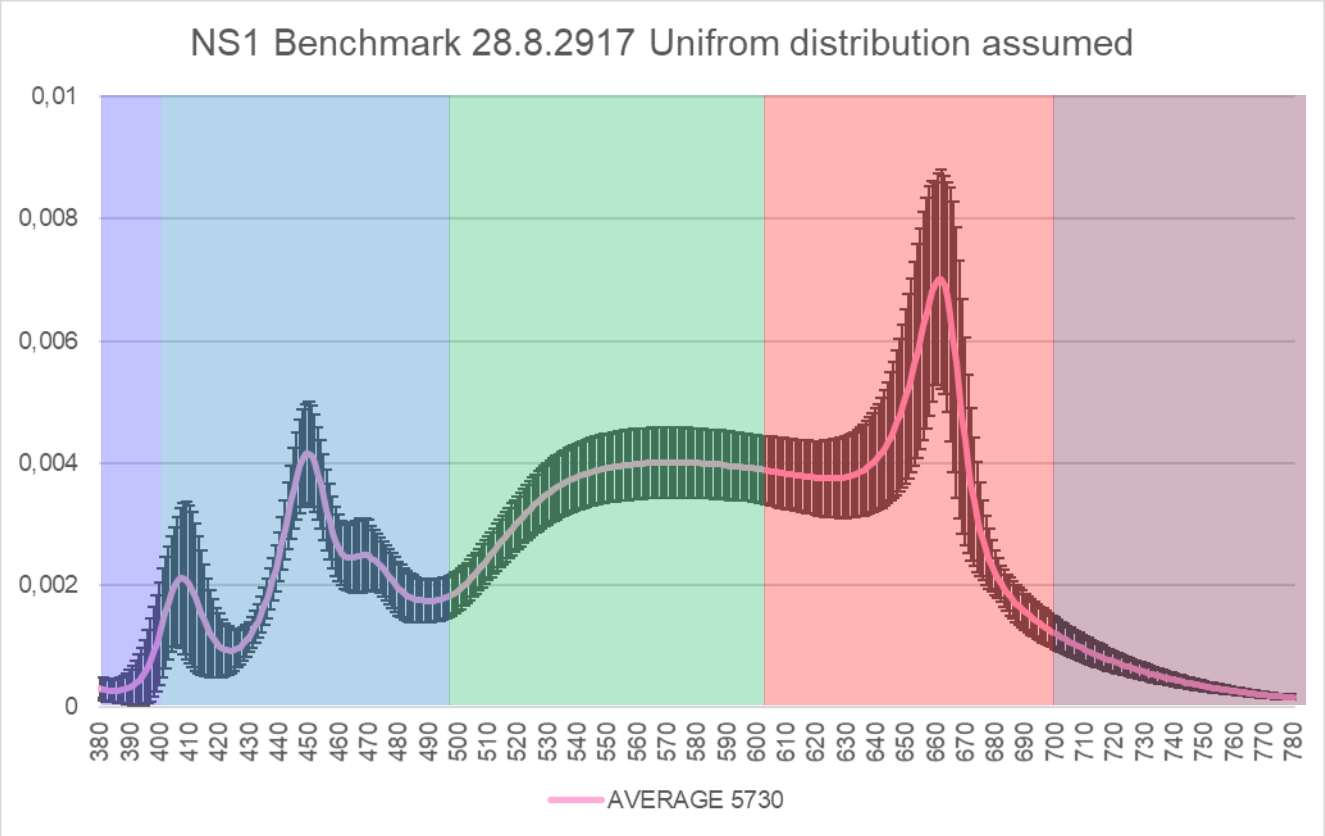
BENCHMARK SPECTRA

Valoya uses a benchmark spectrum, to which it targets to match all subsequent versions of the spectra. The benchmark spectra for all LED types used with each spectrum is listed below with SAVI.

SAVI includes the spectrum graph, with standard deviation (uniform distribution assumed). All spectra will be compared to the benchmark spectrum graph (graph test); the light distribution needs to fit the standard deviation area.

In addition to the graph test, a spectrum needs to meet the specifications given in the table of ranges and ratios (range and ratio test) for the benchmark of the LED type. The table of ranges and ratios defines the spectral distribution in 100 nm intervals for each spectrum and LED type and the ranges for acceptable R:FR and B:G ratios, defined by Sellaro et al 2010.

Spectrum graph is presented as photons (µmol/m/s), the data is normalized to Area = 1.



NS1

CURRENT BENCHMARK NS1 (BASED ON 5730 LED)

The current benchmark spectrum is based on 5730 LED.

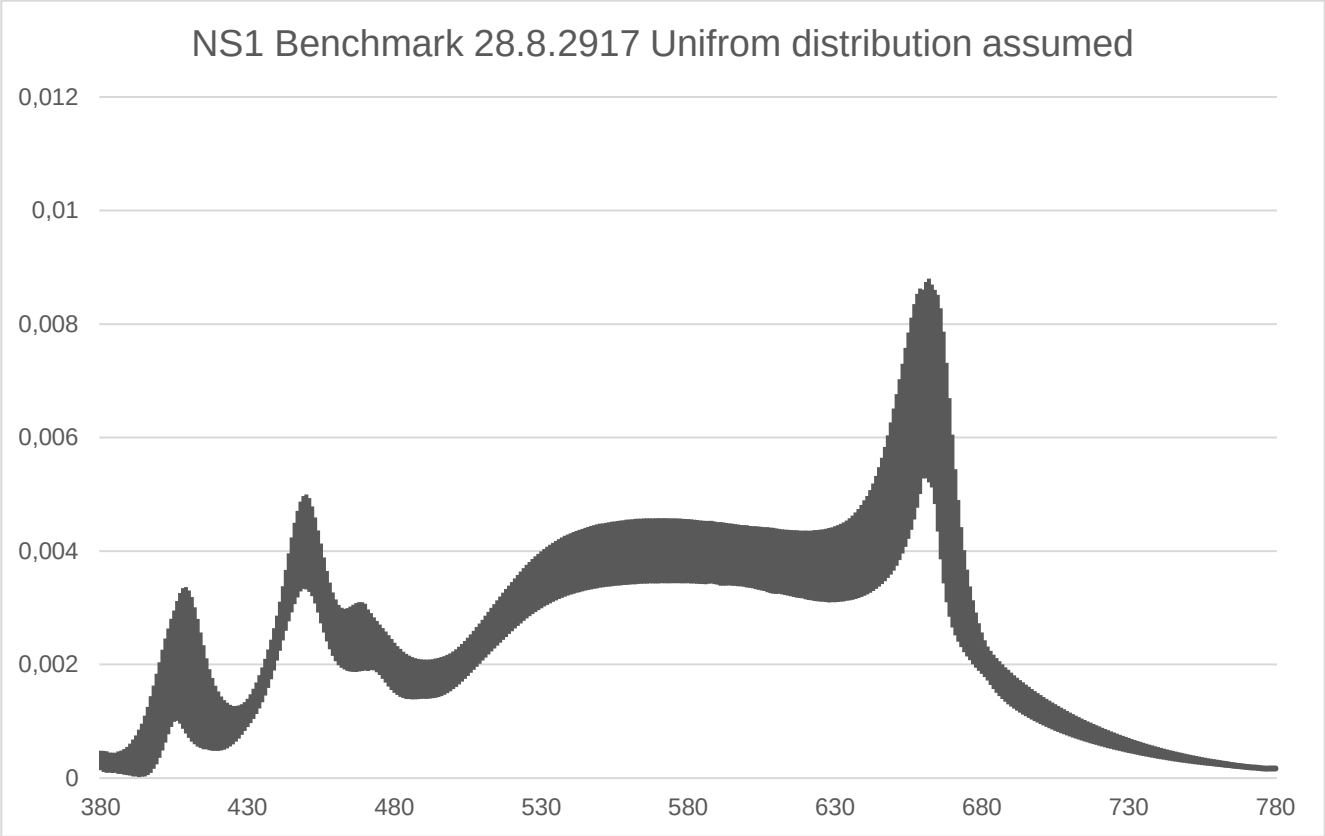


Table 1 Table of ranges and ratios of Current Benchmark Spectrum NS1.

	Range	Valoya NS1 Benchmark 28.8.2017	Allowed MIN	Allowed MAX
	300-400	0.9%	**0.4%**	**1.4%**
	400-500	21.2%	**19.5%**	**22.3%**
	500-600	35.4%	**34.8%**	**36.4%**
	600-700	38.3%	**36.1%**	**39.5%**
	700-800	4.2%	**3.9%**	**4.7%**
	TOTAL	100.0%	**100.0%**	**100.0%**
	PAR 400-700	94.9%	**94.4%**	**95.3%**
Sellaro 2010	R:FR	10.4	9.4	12.0
Sellaro 2010	B:G	0.7	0.6	0.8
Smith 1982	R:FR	11.6	10.5	13.5

PREVIOUS AND CURRENT BENCHMARK SPECTRA NS1

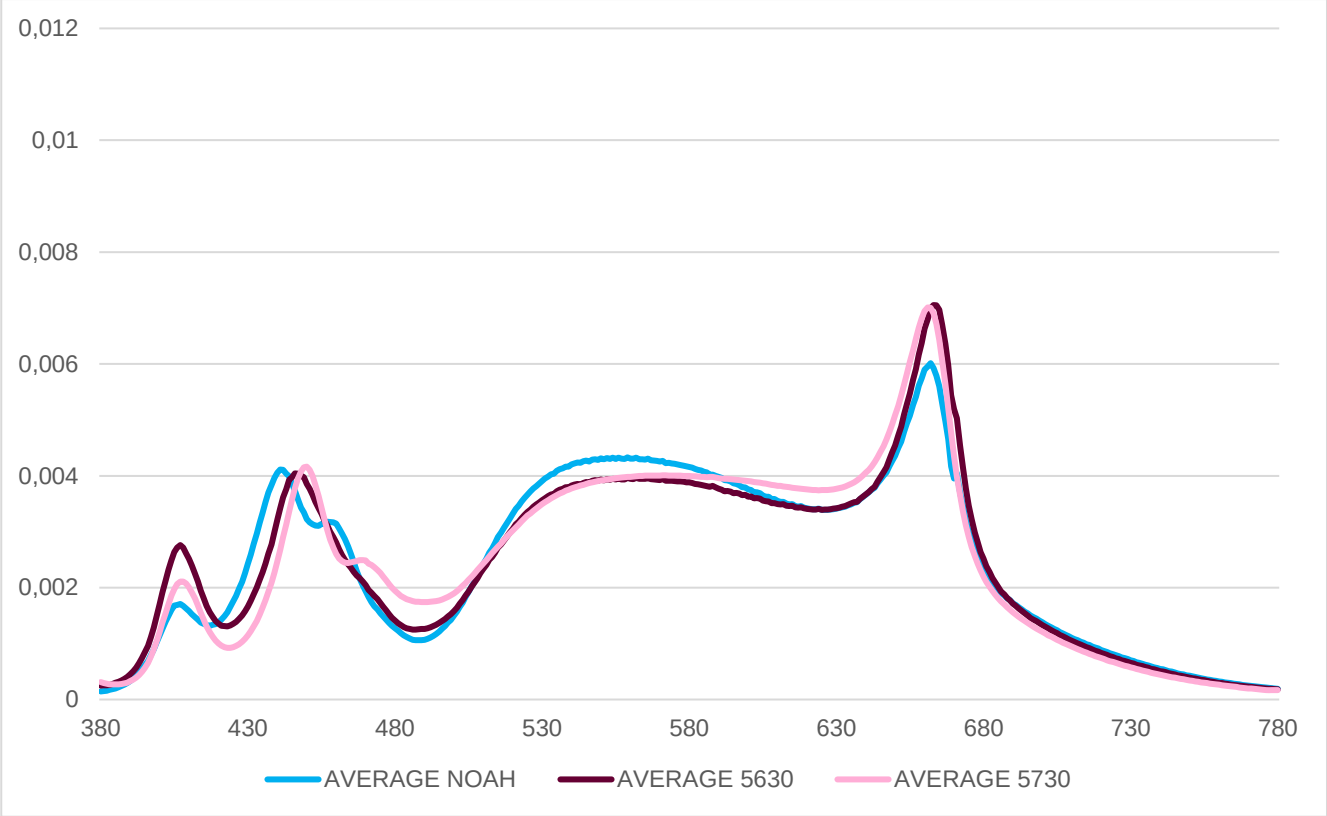


Table 2 Current and past NS1 benchmark spectra data.

		NOAH	5630	5730	STDEV	MIN	MAX
	300-400	0.8%	0.9%	1.2%	0.2%	0.8%	1.2%
	400-500	21.5%	21.2%	22.0%	0.4%	21.2%	22.0%
	500-600	37.4%	35.4%	34.8%	1.4%	34.8%	37.4%
	600-700	35.2%	38.3%	37.3%	1.6%	35.2%	38.3%
	700-800	5.1%	4.2%	4.8%	0.4%	4.2%	5.1%
	TOTAL	100.0%	100.0%	100.0%	0.0%	100.0%	100.0%
	PAR 400-700	94.1%	94.9%	94.1%	0.5%	94.1%	94.9%
Sellaro 2010	R:FR	7.3	10.4	9.0	2.2	7.3	10.4
Sellaro 2010	B:G	0.7	0.7	0.7	0.0	0.7	0.7
(Smith 1971)	(R:FR)	8.0	9.9	11.6	1.3	8.0	11.6

AP67

CURRENT BENCHMARK AP67 (BASED ON 5730 LED)

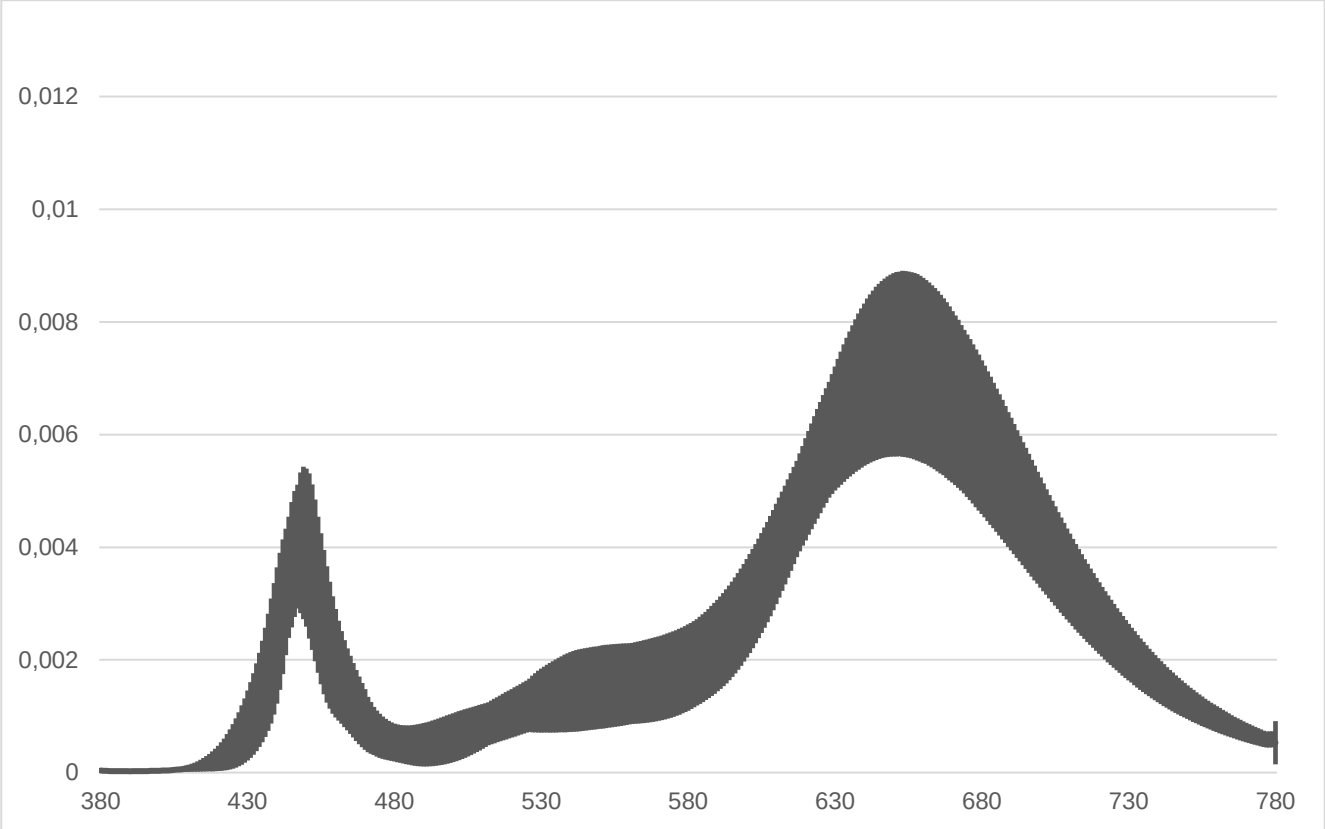


Table 2 Table of ranges and ratios of Current Benchmark Spectrum AP67 (based on 5630 + 5730 LED).

	Range	Average 5730	Allowed MIN	Allowed MAX
	300-400	0.1%	**0.0%**	**0.1%**
	400-500	11.7%	**10.4%**	**13.7%**
	500-600	15.1%	**9.9%**	**17.6%**
	600-700	57.7%	**54.5%**	**62.0%**
	700-800	15.5%	**14.6%**	**17.7%**
	TOTAL	100.0%	**100.0%**	**100.0%**
	PAR 400-700	84.5%	**82.3%**	**85.3%**
Sellaro 2010	R:FR	3.3	**2.9**	**3.4**
Sellaro 2010	B:G	1.2	**1.0**	**1.8**
Smith 1982	R:FR	3.3	**2.9**	**3.4**

PREVIOUS AND CURRENT BENCHMARK SPECTRA AP67

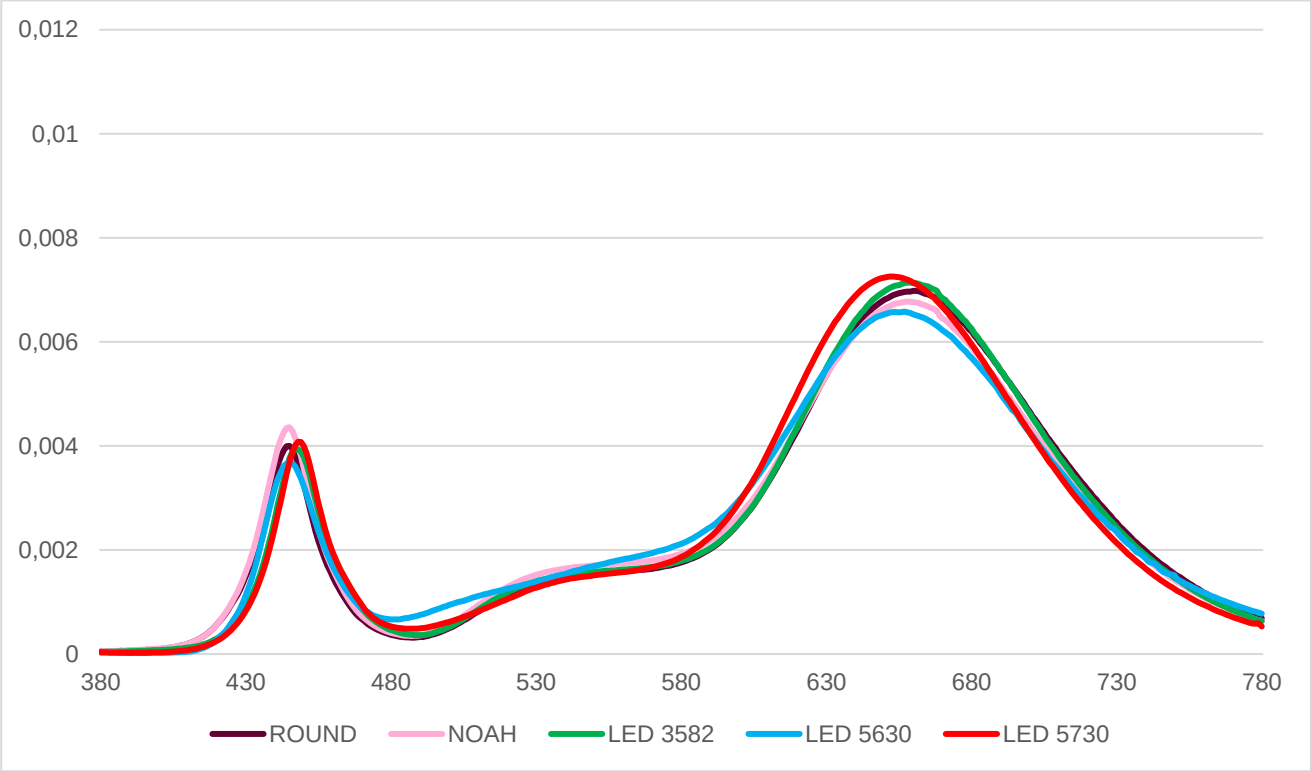


Table 3 Current and past AP67 benchmark spectra data.

	Ranges	ROUND	NOAH	LED 3582	LED 5630	LED 5730	STDEV	MIN	MAX
	300-400	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
	400-500	12.1%	13.1%	11.5%	12.3%	11.7%	1.5%	11.5%	13.1%
	500-600	14.7%	16.2%	15.0%	17.1%	15.1%	2.6%	14.7%	17.1%
	600-700	55.0%	53.8%	55.9%	53.6%	57.7%	4.4%	53.6%	57.7%
	700-800	18.1%	16.8%	17.5%	16.9%	15.5%	2.5%	15.5%	18.1%
	TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	100.0%	100.0%
	PAR 400-700	81.8%	83.1%	82.4%	83.0%	84.5%	2.6%	81.8%	84.5%
Sellaro 2010	R:FR	2.7	2.8	2.9	2.8	3.3	0.58	2.7	3.3
Sellaro 2010	B:G	1.2	1.2	1.2	1.1	1.2	0.16	1.1	1.2
Smith 1982	R:FR	2.7	2.9	2.9	2.8	2.9	0.16	2.7	2.9

NS12

CURRENT BENCHMARK NS12 (BASED ON 5630+5730 LED)

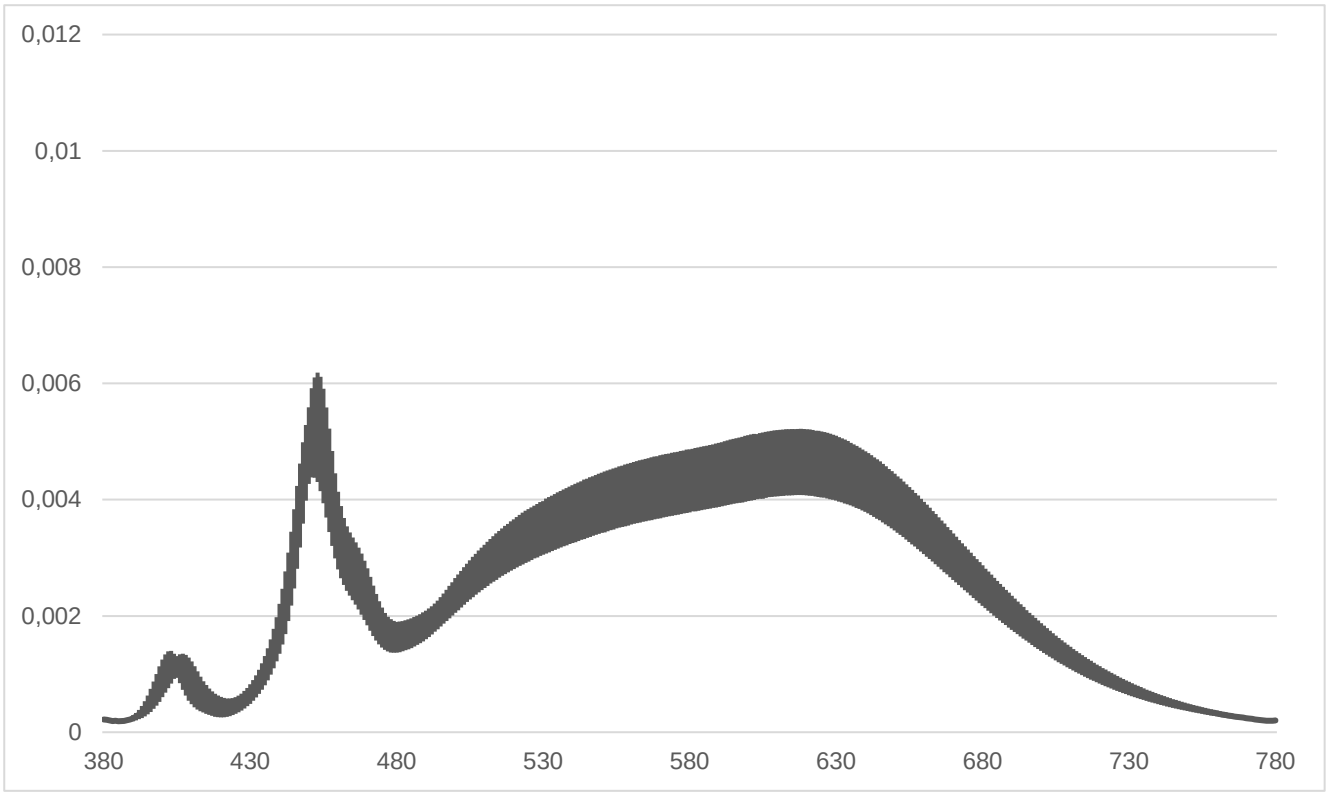


Table 4 Table of ranges and ratios of Current Benchmark Spectrum NS12 (based on 5630 + 5730 LED).

		Average 5630+5730	Allowed MIN	Allowed MAX
	300-400	0.7%	0.6%	0.7%
	400-500	19.5%	19.4%	19.7%
	500-600	37.8%	37.4%	38.2%
	600-700	36.5%	36.3%	36.7%
	700-800	5.6%	5.4%	5.7%
	TOTAL	100.0%	100.0%	100.0%
	PAR 400-700	93.8%	93.5%	94.1%
Sellaro 2010	R:FR	4.6	4.5	4.7
Sellaro 2010	B:G	0.6	0.6	0.7
Smith 1982	R:FR	4.7	4.6	4.8

PREVIOUS AND CURRENT BENCHMARK SPECTRA NS12

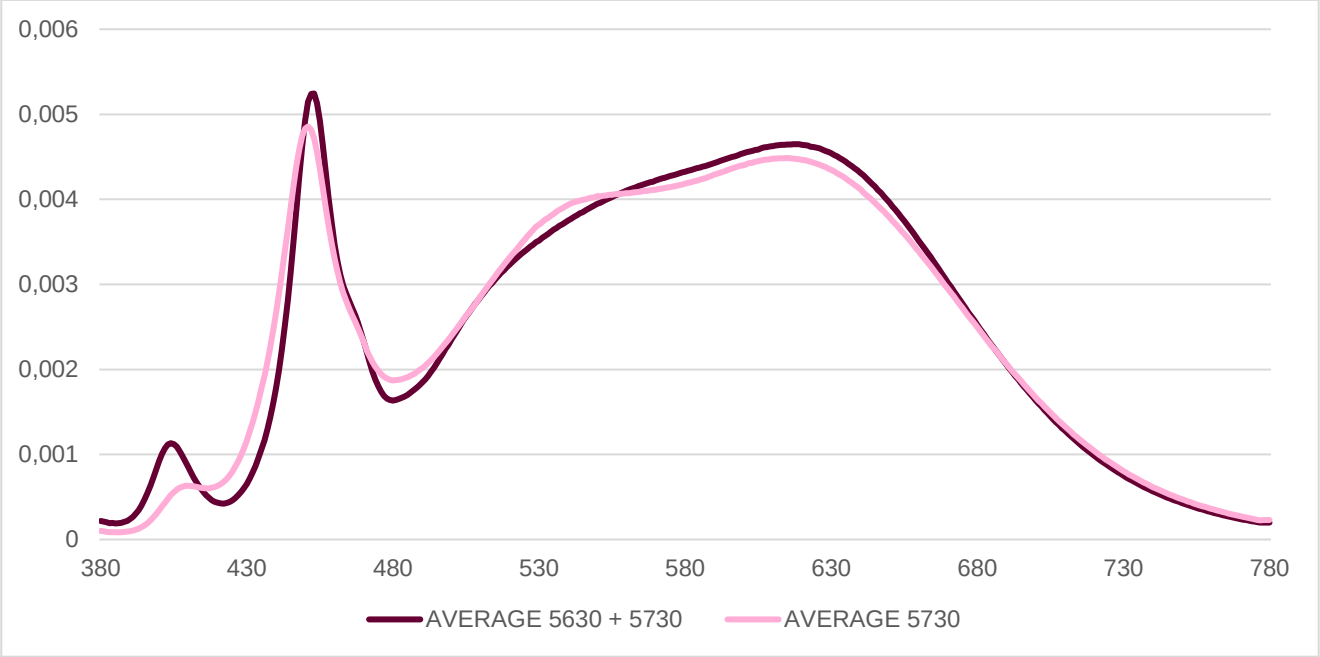


Table 5 Current and past NS12 benchmark spectra data.

	AVERAGE 5630 + 5730	AVERAGE 5730	STDEV	MIN	MAX
300-400	0.7%	0.3%	0.8%	0.3%	0.7%
400-500	19.5%	20.7%	2.1%	19.5%	20.7%
500-600	37.8%	37.8%	0.1%	37.8%	37.8%
600-700	36.5%	35.3%	2.2%	35.3%	36.5%
700-800	5.5%	5.9%	0.7%	5.5%	5.9%
TOTAL	100.0%	100.0%	0.0%	100.0%	100.0%
PAR 400-700	93.8%	93.8%	0.1%	93.8%	93.8%
R:FR	4.6	4.1	0.9	4.1	4.6
B:G	0.6	0.7	0.1	0.6	0.7
R:FR	4.7	4.2	0.9	4.2	4.7

AP673L

CURRENT BENCHMARK AP673L (BASED ON 5730 LED)

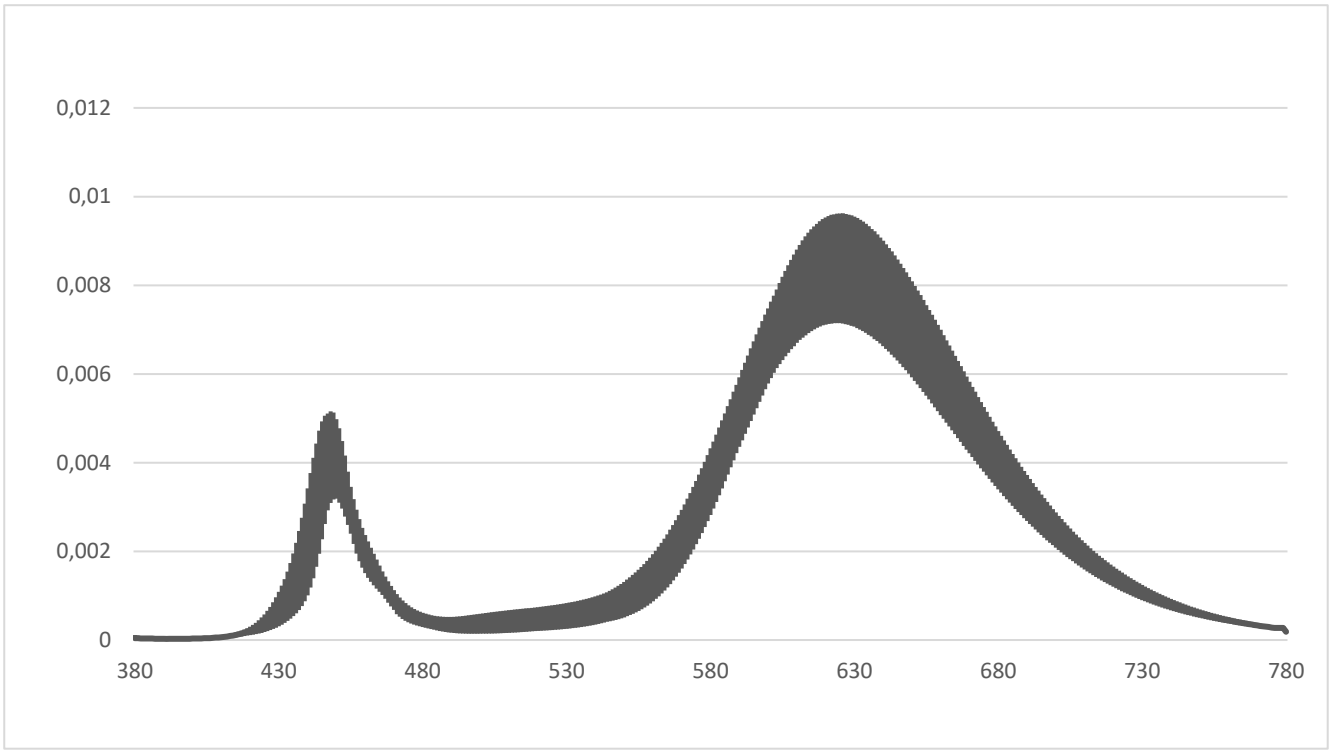


Table 6 Table of ranges and ratios of Current Benchmark Spectrum AP673L (based on 5730 LED).

		AVERAGE	Allowed MIN	Allowed MAX
	300-400	0.1%	0.0%	0.1%
	400-500	11.0%	9.3%	12.5%
	500-600	18.5%	16.3%	20.1%
	600-700	62.4%	59.7%	65.9%
	700-800	8.0%	7.6%	8.5%
	TOTAL	100.0%	100.0%	100.0%
	PAR 400-700	91.9%	91.4%	92.4%
Sellaro 2010	R:FR	5.5	5.3	5.6
Sellaro 2011	B:G	1.8	1.5	2.2
Smith 1982	R:FR	5.6	5.4	5.7

PREVIOUS AND CURRENT BENCHMARK SPECTRA AP673L

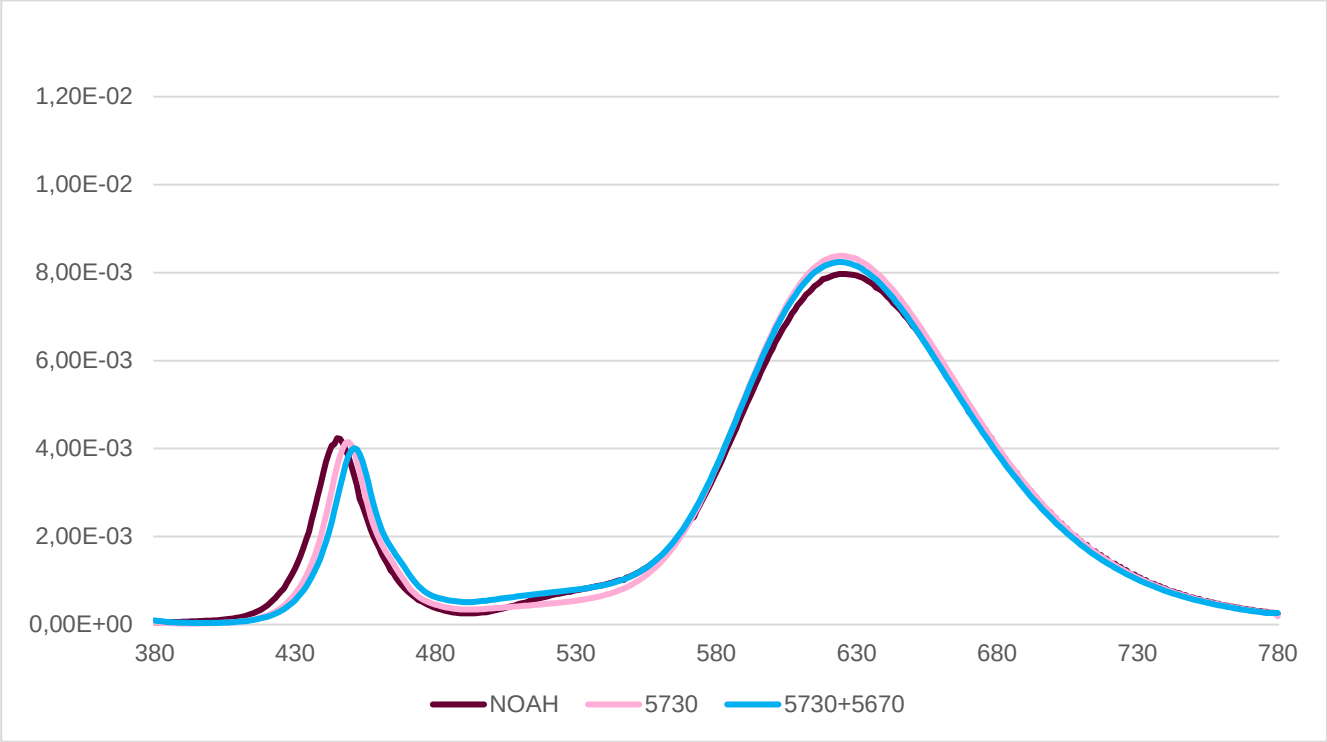


Table 7 Current and past AP673L benchmark spectra data.

	Range	NOAH	5730	5730+5670	STDEV	MIN	MAX
	300-400	0.1%	0.1%	0.1%	0.0%	0.1%	0.1%
	400-500	12.2%	11.0%	11.3%	0.6%	11.0%	12.2%
	500-600	19.0%	18.5%	19.9%	0.7%	18.5%	19.9%
	600-700	60.2%	62.4%	61.0%	1.1%	60.2%	62.4%
	700-800	8.1%	8.0%	7.7%	0.2%	7.7%	8.1%
	TOTAL	99.6%	100.0%	100.0%	0.2%	99.6%	100.0%
	PAR 400-700	91.4%	91.9%	92.2%	0.4%	91.4%	92.2%
Sellaro 2010	R:FR	5.4	5.5	5.6	0.1	5.4	5.6
Sellaro 2010	B:G	1.7	1.8	1.5	0.2	1.5	1.8
Smith 1982	R:FR	5.4	5.6	5.7	0.2	5.4	5.7

G2

CURRENT BENCHMARK G2 (BASED ON 5730 LED)

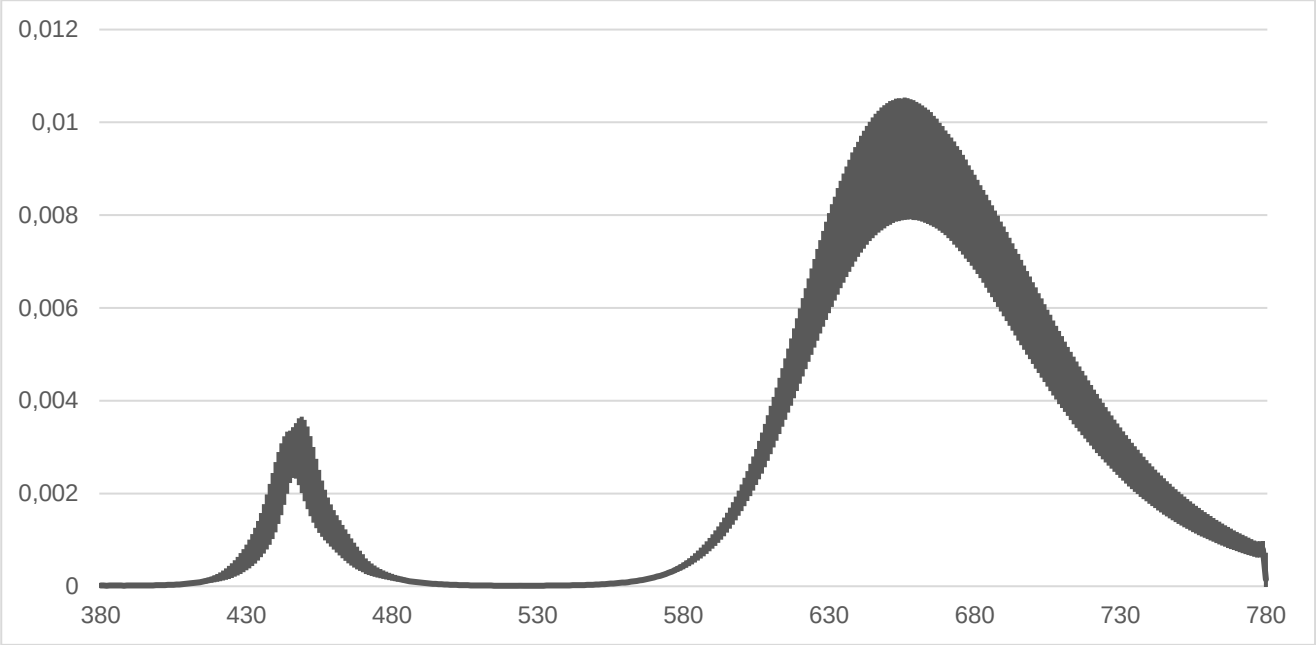


Table 8 Table of ranges and ratios of Current Benchmark Spectrum G2 (based on 5730 LED).

		AVERAGE 5730	Allowed MIN	Allowed MAX
	300-400	0.0%	0.0%	0.0%
	400-500	7.5%	7.1%	8.0%
	500-600	2.5%	2.5%	2.7%
	600-700	69.2%	67.7%	69.9%
	700-800	20.7%	19.9%	22.4%
	TOTAL	100.0%	100.0%	100.0%
	PAR 400-700	79.2%	77.6%	80.0%
Sellaro 2010	R:FR	3.1	2.8	3.2
Sellaro 2010	B:G	25.9	23.7	27.3
Smith 1982	R:FR	3.2	2.9	3.3

PREVIOUS AND CURRENT BENCHMARK SPECTRA G2

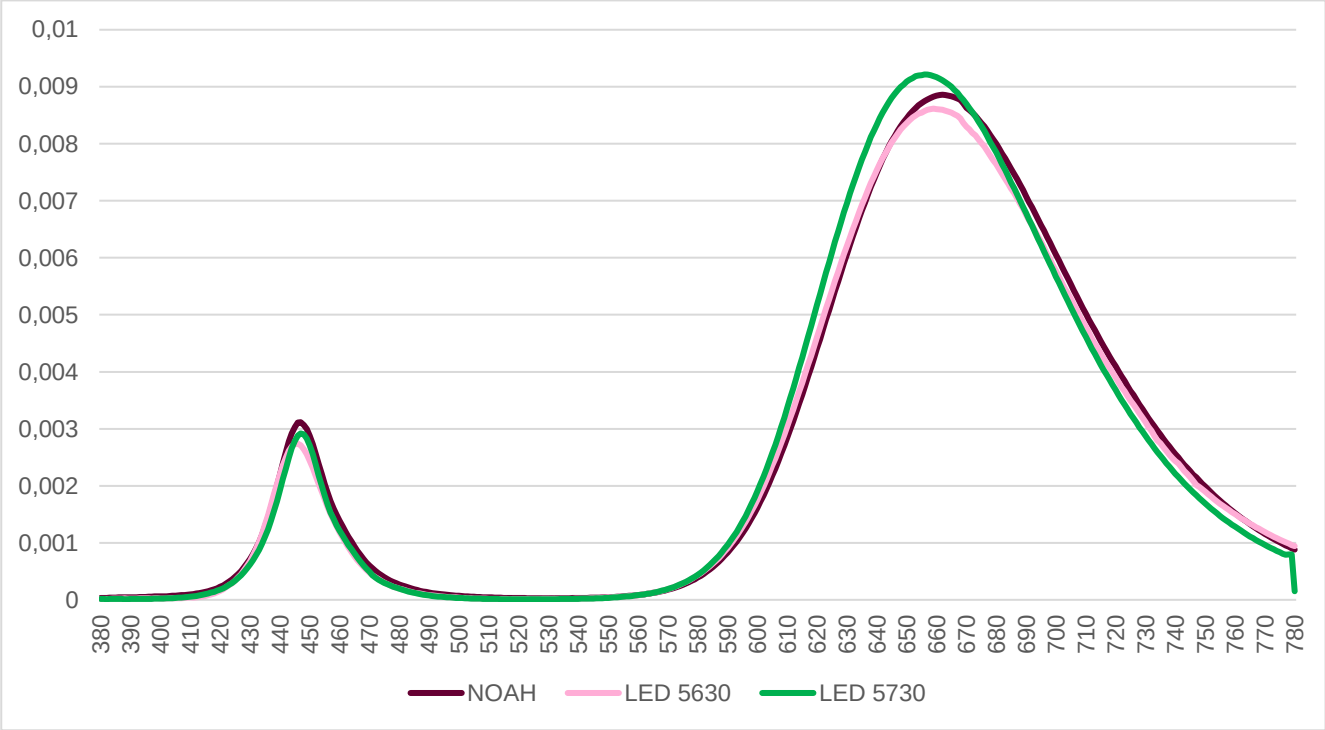
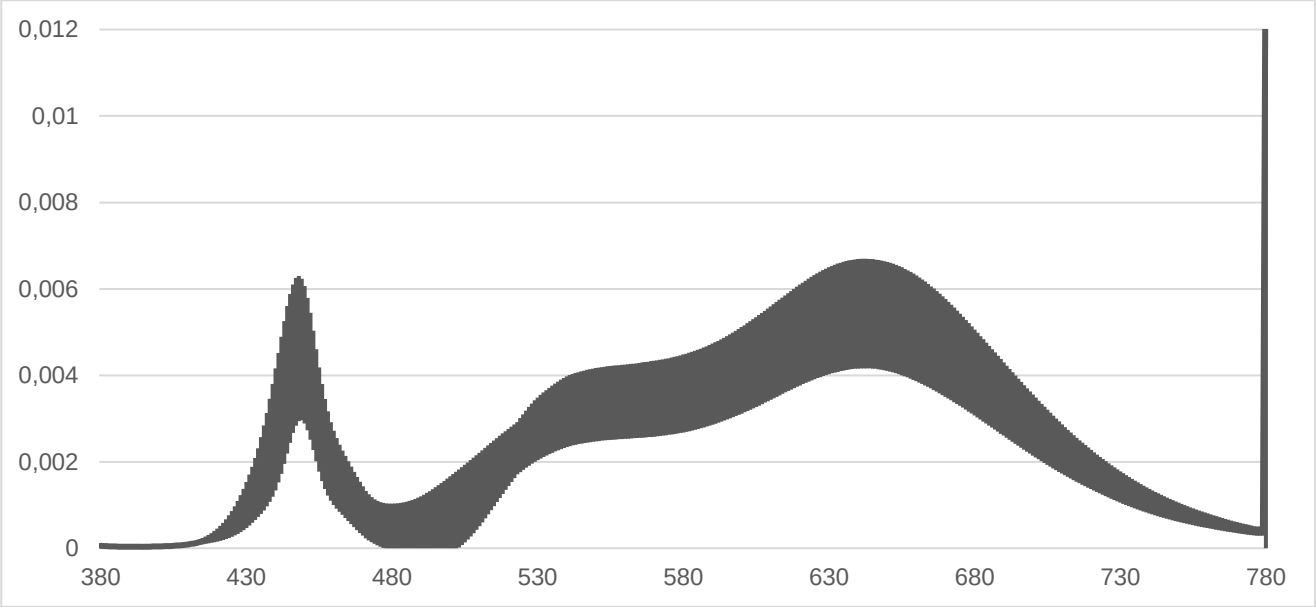


Table 9 Current and past G2 benchmark spectra data.

	Range	NOAH	5630	5730	STDEV	MIN	MAX
	300-400	0.1%	0.0%	0.0%	0.1%	0.0%	0.1%
	400-500	8.6%	7.5%	7.5%	1.6%	7.5%	8.6%
	500-600	2.3%	2.4%	2.5%	0.3%	2.3%	2.5%
	600-700	65.6%	64.8%	69.2%	6.1%	64.8%	69.2%
	700-800	23.4%	22.4%	20.7%	3.5%	20.7%	23.4%
	TOTAL	100.0%	97.3%	100.0%	4.1%	97.3%	100.0%
	PAR 400-700	76.6%	74.8%	79.2%	5.9%	74.8%	79.2%
Sellaro 2010	R:FR	2.7	2.7	3.1	0.7	2.7	3.1
Sellaro 2010	B:G	21.4	24.6	25.9	6.1	21.4	25.9
Smith 1982	R:FR	2.7	2.8	3.2	0.7	2.7	3.2

SARCH

CURRENT BENCHMARK SARCH (BASED ON 5730 LED)



	Range	Average 5730	Allowed MIN	Allowed MAX
	300-400	0.1%	0.0%	0.1%
	400-500	12.6%	9.9%	18.8%
	500-600	29.2%	23.4%	30.8%
	600-700	46.4%	37.4%	47.8%
	700-800	11.8%	10.1%	29.3%
	TOTAL	100.0%	100.0%	100.0%
	PAR 400-700	88.1%	70.7%	89.9%
Sellaro 2010	R:FR	3.5	3.1	3.6
Sellaro 2010	B:G	0.6	0.6	0.9
Smith 1982	R:FR	3.6	3.2	3.7

PREVIOUS AND CURRENT BENCHMARK SPECTRA

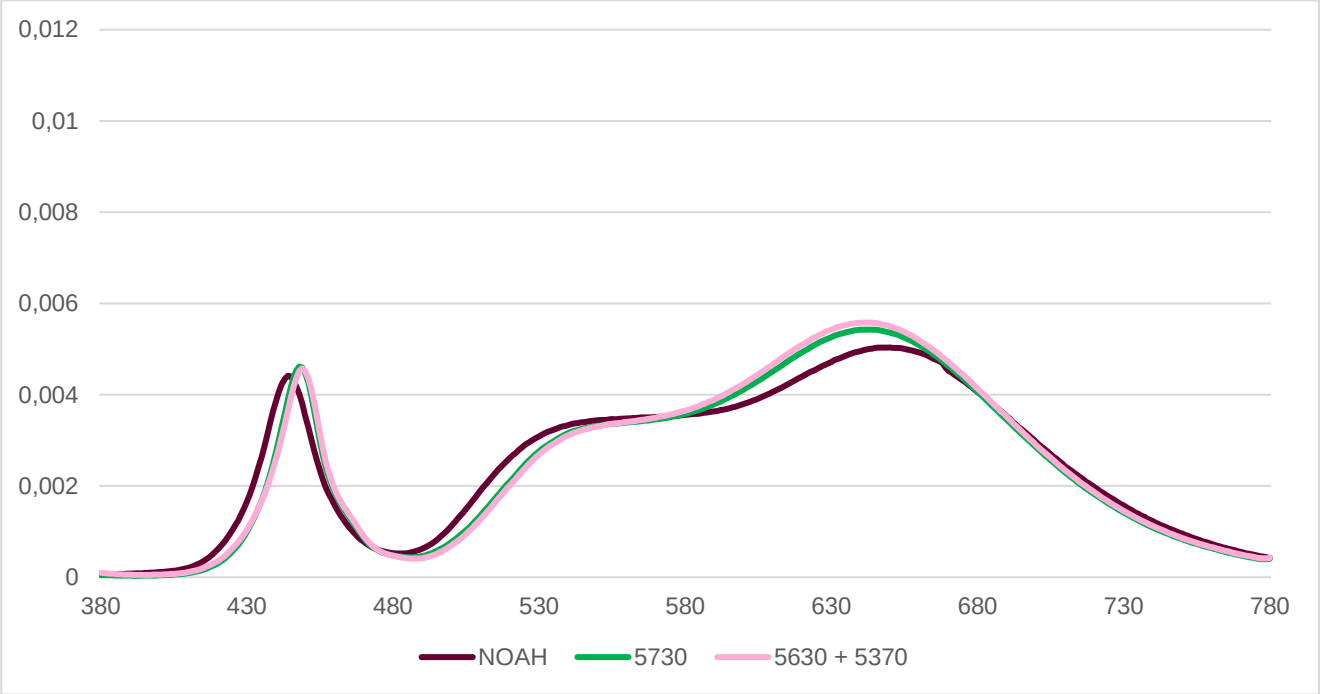


Table 10 Current and past SARCH benchmark spectra data.

	Range	NOAH	5730	5630+5730	STDEV	MIN	MAX
	300-400	0.2%	0.1%	0.1%	0.1%	0.1%	0.2%
	400-500	13.9%	12.6%	12.6%	2.0%	12.6%	13.9%
	500-600	30.9%	29.2%	29.1%	2.7%	29.1%	30.9%
	600-700	43.7%	46.4%	47.6%	5.1%	43.7%	47.6%
	700-800	11.3%	11.8%	10.6%	1.6%	10.6%	11.8%
	TOTAL	100.0%	100.0%	100.0%	0.0%	100.0%	100.0%
	PAR 400-700	88.6%	88.1%	89.3%	1.6%	88.1%	89.3%
Sellaro 2010	R:FR	3.1	3.5	3.5	0.3	3.1	3.5
Sellaro 2011	B:G	0.6	0.6	0.7	0.0	0.6	0.7
Smith 1982	R:FR	3.1	3.6	3.6	0.3	3.1	3.6