Northern Illinois University

Experimental Evaluation of Optical Filters for Reduction of Blue Light Hazard and Circadian Stimulus

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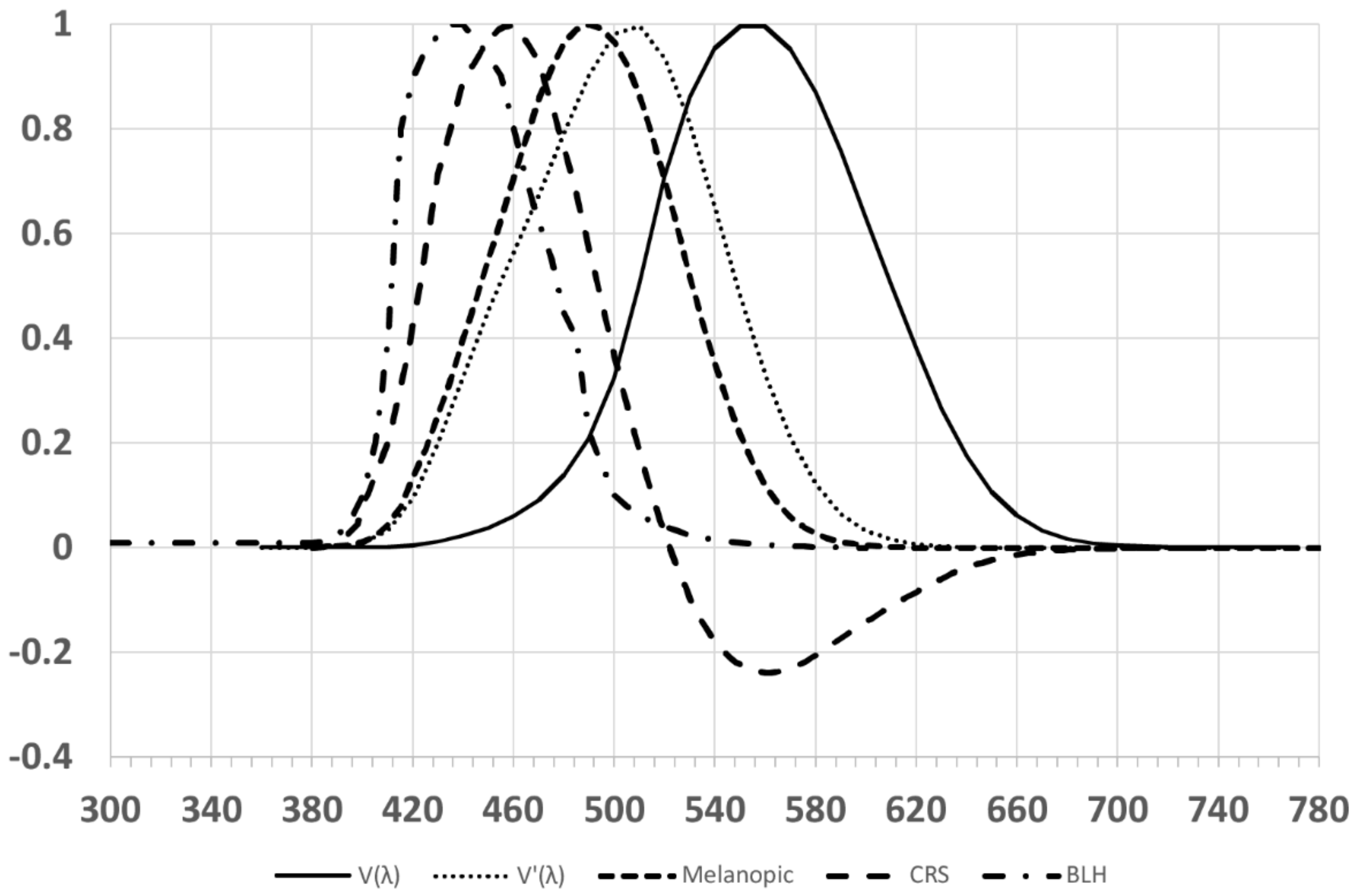
Background

- High radiant energy light sources (in particular 400-500 nm) can cause photochemical damage and affect physiology
  - lesions in the human eye formed from exposure to short VLS wavelengths (T. Ham et al., 1976)
  - retinal damage and cell death (Lougheed, 2014)
  - photoreceptors in children are 2.8 times more sensitive to blue light than an adults (Point, 2018)
  - Suppressing the blue light spectrum is also known to help with sleep quality, insomnia, and depression (Burkhart et al., 2009; Esaki et al., 2016; Esaki et al., 2017; Micic et al., 2015; Ostrin et al., 2017

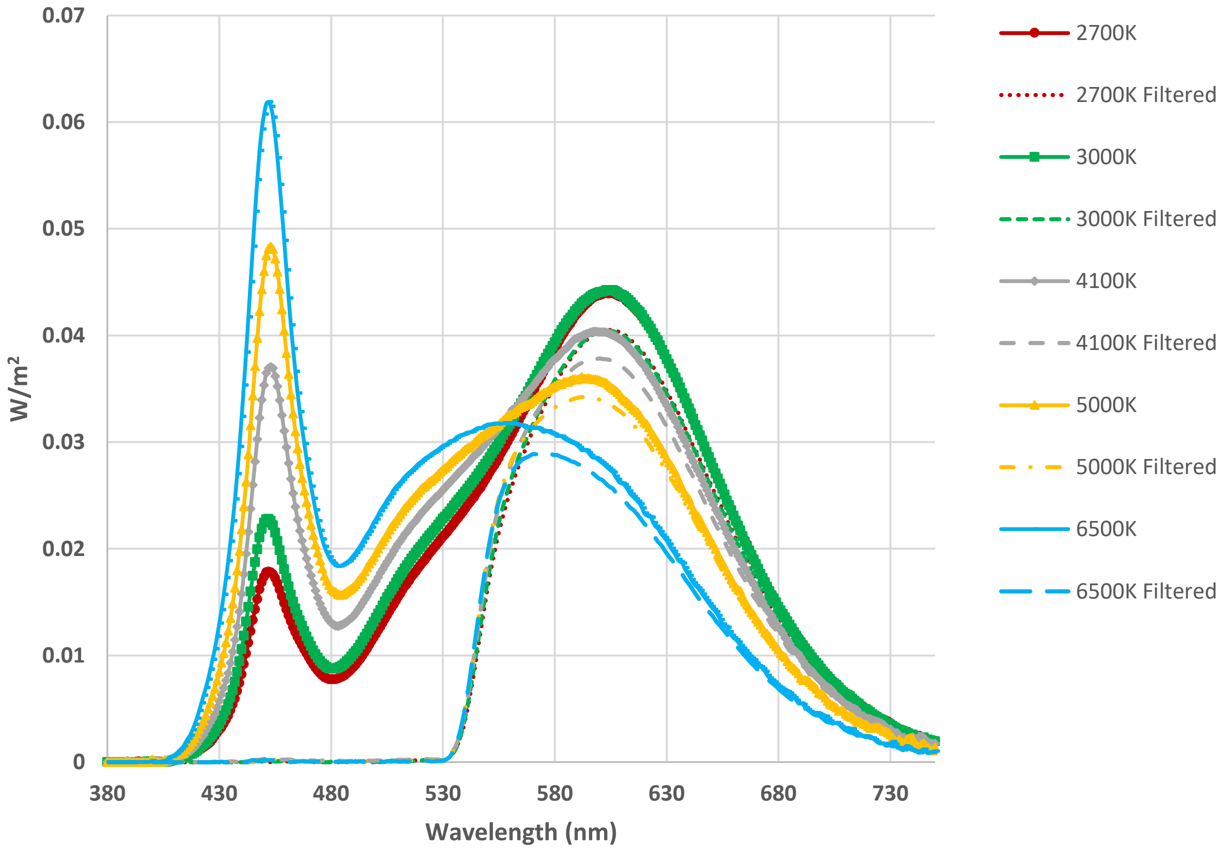
Background

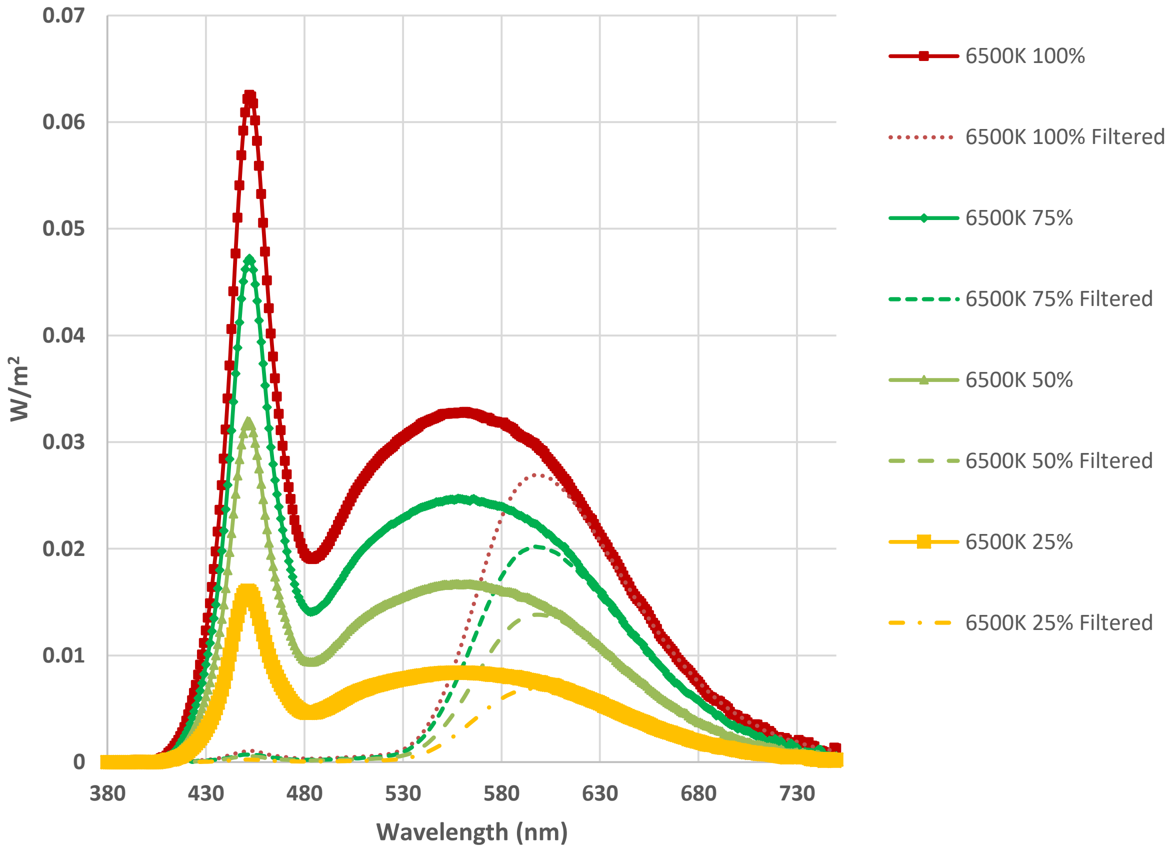
- Retinal photochemical injury weighting functions (435-440 nm peaks) developed to protect against BLH (ACGIH, 2001)
- Intrinsically photosensitive retinal ganglion cells (iPRGC), are directly tied to the operation of the SCN (Berson et al., 2002)
- Melanopsin in the iPRGC relates to the circadian phototransduction response, peaks at 480 nm (Lucas et al., 2014)
  - the SCN peak sensitivity response is at 460 nm
  - Melanopic lux based on the action spectrum of melanopsin
- The eye's rods and cones also play a role in how the SCN responds to light by broadening and shift its spectral sensitivity (Figueiro, 2017)
  - The circadian light (CL_A) and circadian simulant (CS) metrics were developed

Spectral Weighting Functions



SPD and Intensity



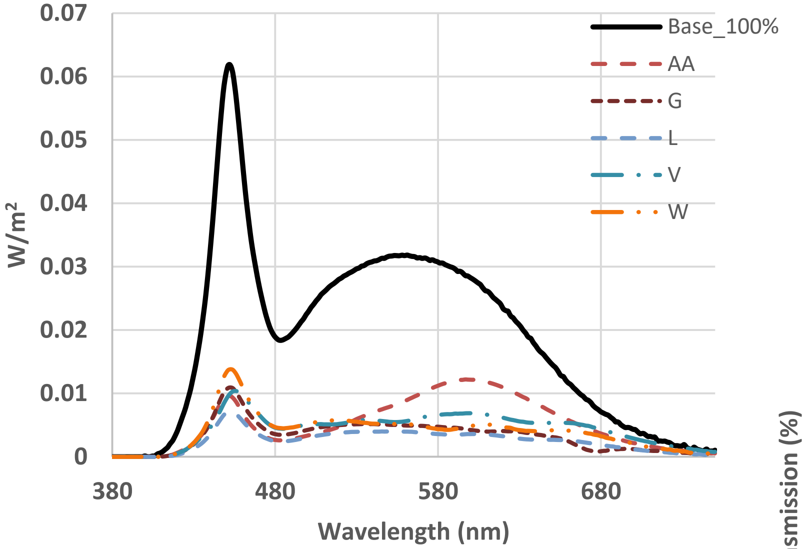


Tested Glasses

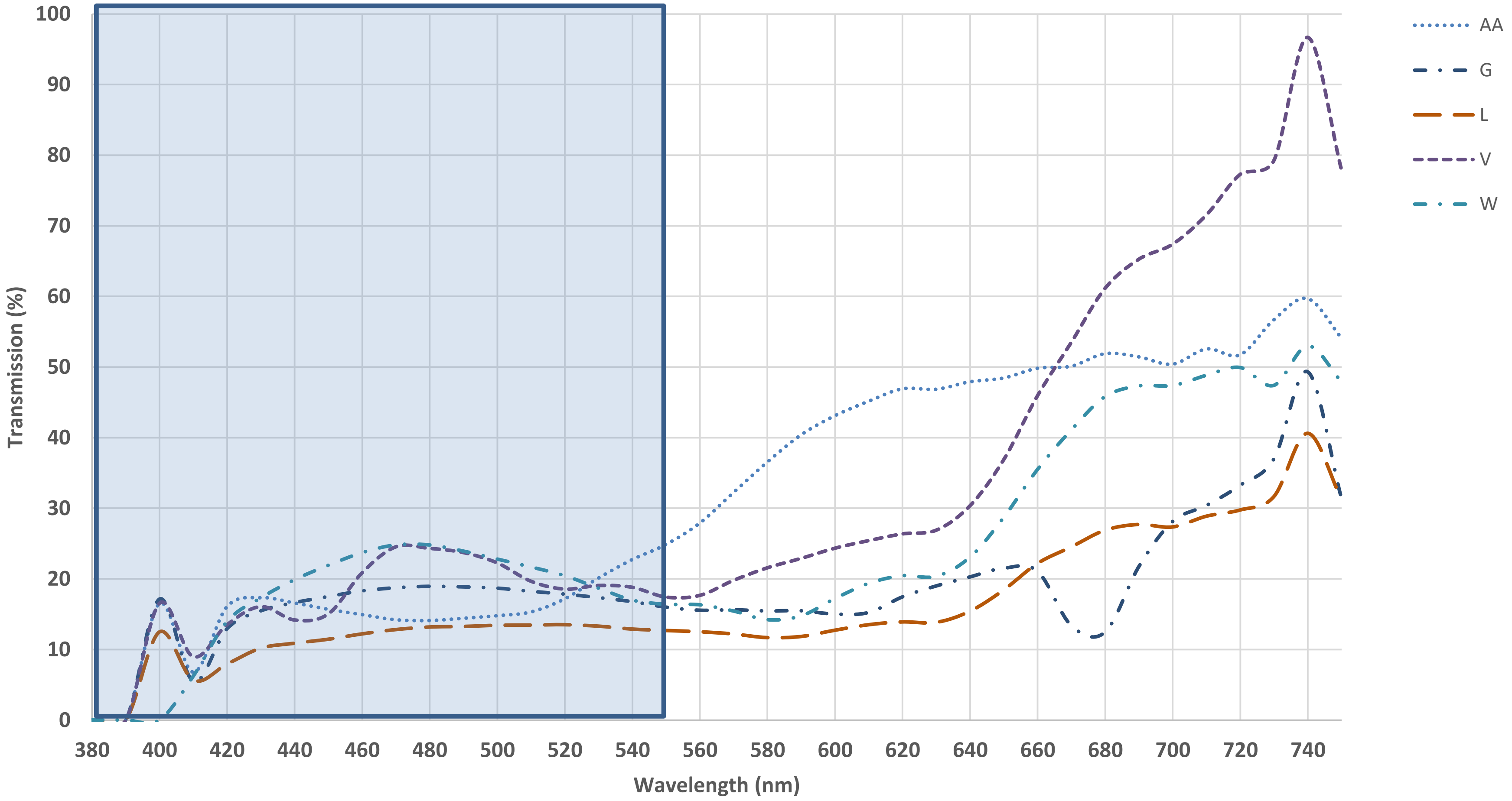
General Trends

- Group A $1-12
  - measurable transmittance below 540nm with approx. linear increases at larger wavelengths
- Group B $7-80
  - exhibit minimal changes in spectral transmittance once 80% is reached at 600 nm or below
- Group C $7-30
  - have a spectral transmittance of less than 5% at shorter wavelengths until a step change in the 530 - 580 nm range

Group A

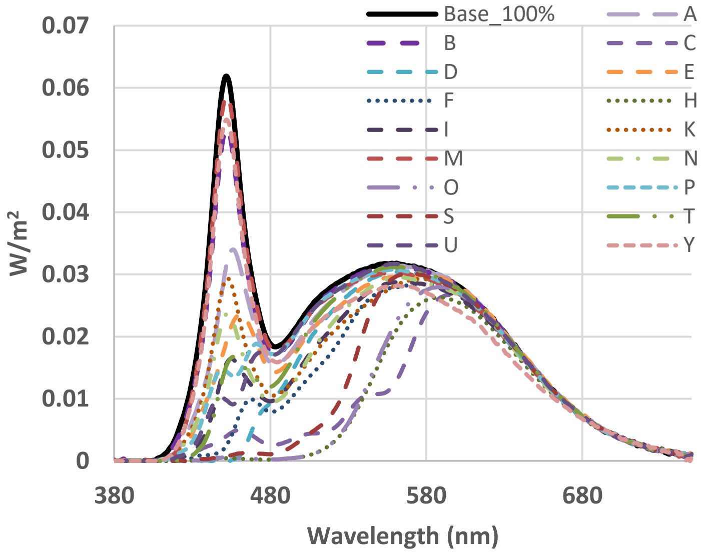


W/m²
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
380
480
580
680
Wavelength (nm)
Base_100%
AA
G
L
V
W

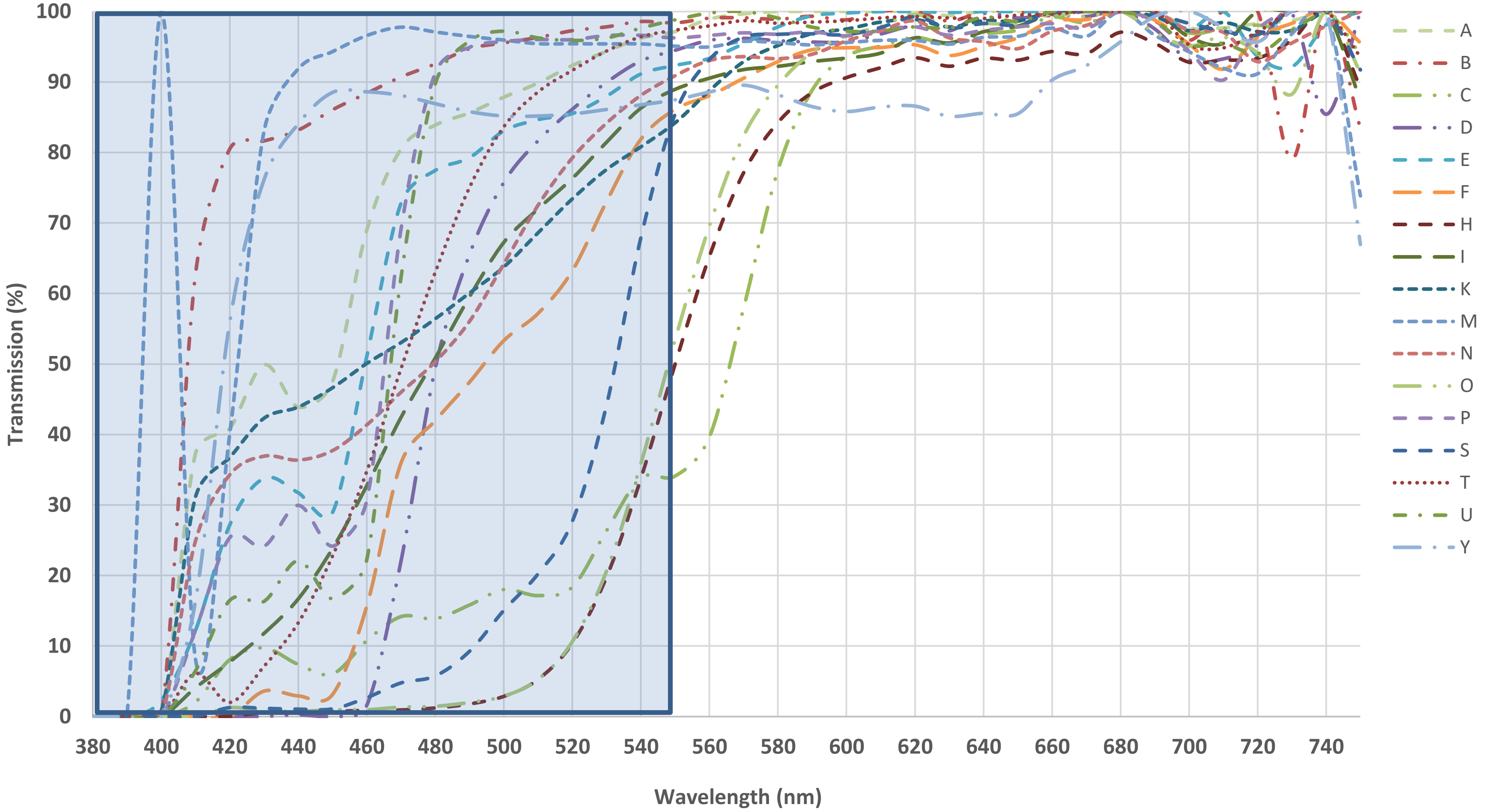


Transmission (%)
100
90
80
70
60
50
40
30
20
10
0
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
Wavelength (nm)
AA
G
L
V
W

Group B



W/m²
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
380
480
580
680
Wavelength (nm)
Base_100%
A
B
C
D
E
F
H
I
K
M
N
O
P
S
T
U
Y



Transmission (%)
100
90
80
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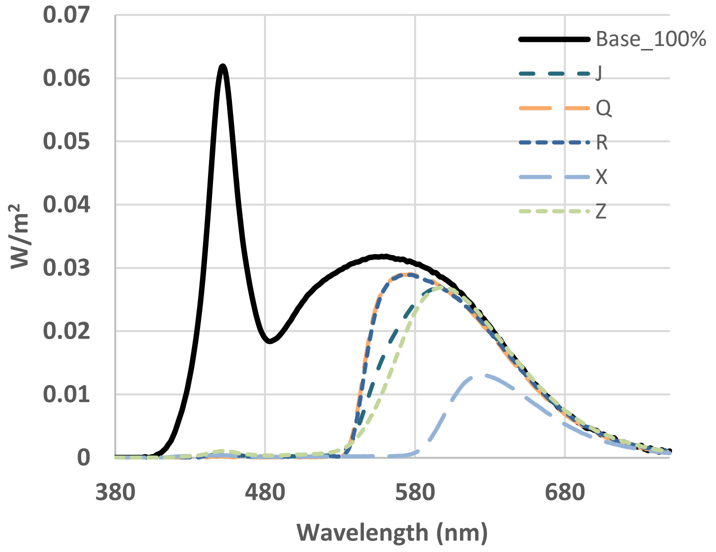
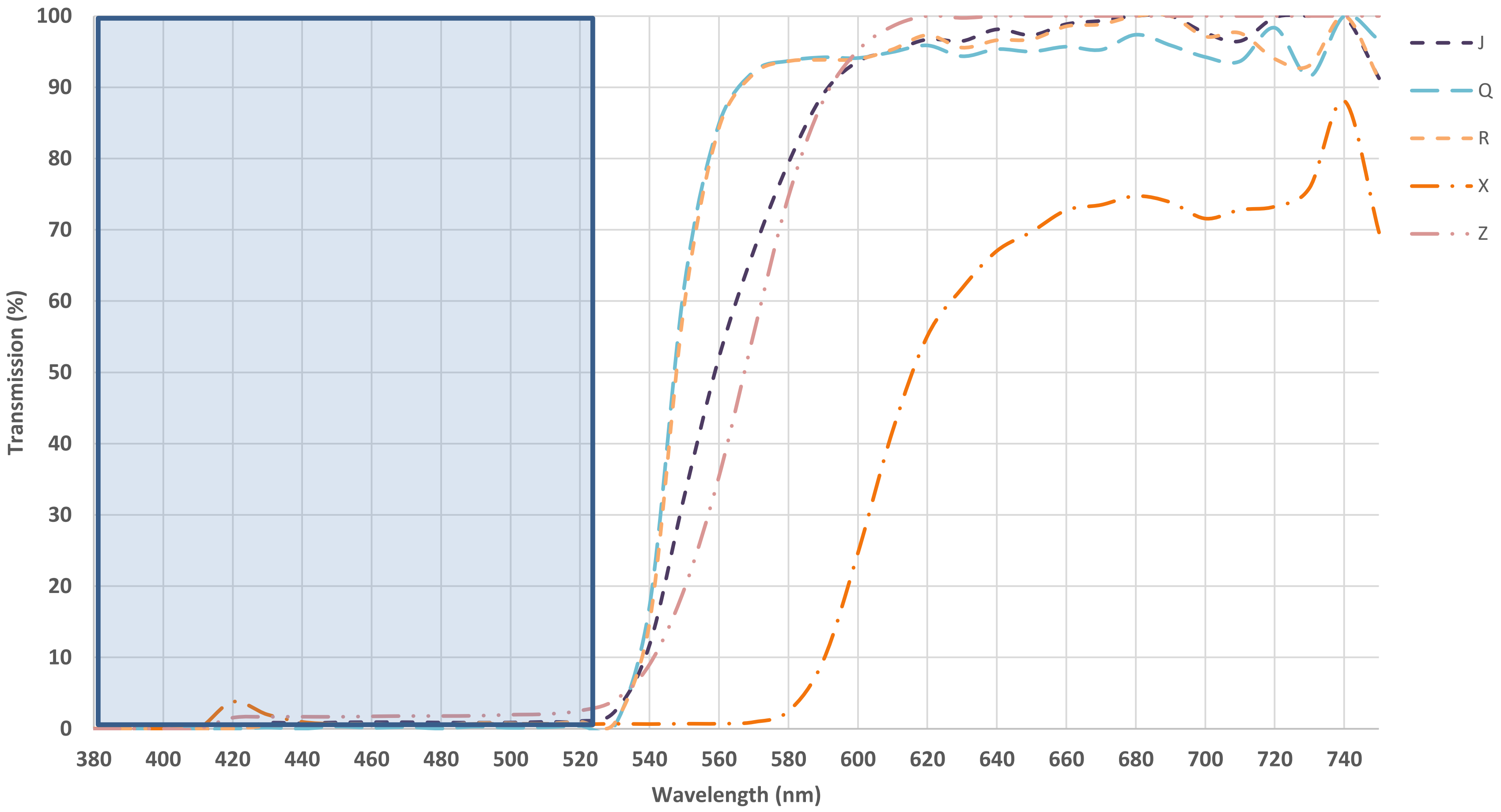
40
30
20
10
0
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
Wavelength (nm)
A
B
C
D
E
F
H
I
K
M
N
O
P
S
T
U
Y

Group C



0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
W/m²
380
480
580
680
Wavelength (nm)
Base_100%
J
Q
R
X
Z



100
90
80
70
60
50
40
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20
10
0
Transmission (%)
380
400
420
440
460
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520
540
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740
Wavelength (nm)
J
Q
R
X
Z

Single Metric?

Key	CS_{rel} / P_{rel}	P_{rel}	S_{rel}	S/P	CLA_{rel}	CS_{rel}	M_{rel}	LBL %	EBL %
Base 100%	1.00	1.00	1.00	2.25	1.00	1.00	1.00	0.00	0.00
A	0.96	0.96	0.82	1.93	0.54	0.93	0.78	55.06	25.37
B	1.00	0.98	0.94	2.15	0.85	0.98	0.92	16.19	8.39
C	1.38	0.51	0.21	0.94	0.19	0.70	0.16	92.88	84.10
D	1.02	0.90	0.59	1.47	0.51	0.92	0.47	99.84	56.67
E	0.94	0.92	0.74	1.81	0.38	0.87	0.68	69.82	35.82
F	1.10	0.82	0.50	1.39	0.45	0.90	0.41	97.12	61.82
G	4.03	0.16	0.18	2.41	0.16	0.66	0.18	83.54	82.37
H	0.87	0.55	0.16	0.65	0.09	0.48	0.08	99.32	91.66
I	1.10	0.86	0.61	1.61	0.61	0.95	0.53	82.40	49.34
J	0.64	0.47	0.09	0.46	0.04	0.30	0.04	99.23	96.81
K	1.02	0.86	0.66	1.74	0.39	0.87	0.61	55.92	40.33
L	4.15	0.13	0.13	2.24	0.10	0.53	0.13	89.25	87.60
M	1.04	0.95	0.95	2.25	0.94	0.99	0.95	11.77	5.71
N	0.94	0.88	0.65	1.68	0.31	0.82	0.58	63.31	42.56
O	0.85	0.58	0.17	0.65	0.09	0.50	0.09	99.23	91.15
P	1.03	0.95	0.77	1.83	0.81	0.98	0.70	73.29	34.79
Q	0.61	0.57	0.13	0.51	0.05	0.35	0.05	99.81	95.80
R	0.64	0.57	0.13	0.51	0.06	0.36	0.05	99.47	95.75
S	0.96	0.74	0.29	0.90	0.19	0.71	0.18	98.97	81.02
T	1.02	0.94	0.71	1.69	0.70	0.96	0.62	85.26	42.32
U	1.01	0.96	0.76	1.77	0.76	0.97	0.67	81.04	38.34
V	3.22	0.21	0.20	2.16	0.17	0.67	0.20	85.52	80.95
W	4.26	0.18	0.21	2.63	0.23	0.76	0.22	80.27	78.84
X	0.77	0.09	0.01	0.26	0.01	0.07	0.01	98.89	99.26
Y	1.13	0.87	0.87	2.23	0.85	0.98	0.87	17.54	14.07
Z	0.73	0.42	0.08	0.45	0.05	0.31	0.04	98.36	96.68
AA	1.74	0.29	0.18	1.42	0.10	0.51	0.17	83.70	83.16

Group A

Group B

Group C

High CS

Low P

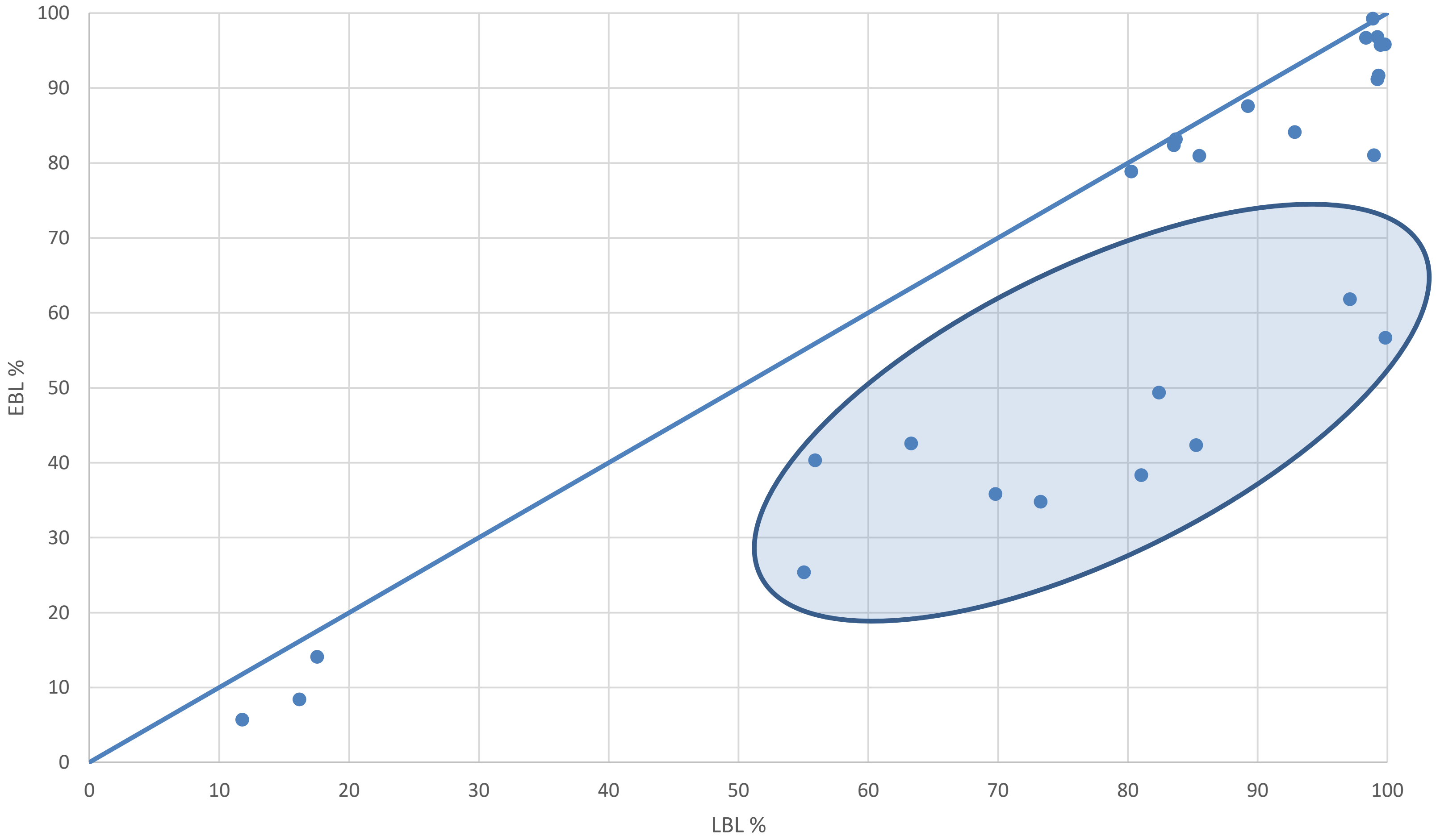
No Agreement

Confusing Terminology

LBL_{rel} 380-450 nm
EBL_{rel} 380-550 nm

% blocked light on an energy basis

0.5 - 43% deviation between EBL & LBL



Conclusions

- Performance of "Blue Light Blocking" varies greatly
- Identify parameter(s) which could be used for regulation
  - Clarify terminology for consumer benefit
- Protection ranges needs to incorporate entire/extended sections of response curves not just 380 nm to peak response wavelength
- At a minimum the spectral transmittance for any filter marketed as having blue light blocking capabilities should be available for review