



# Robotika

Počítačové vidění – vznik digitálního obrazu

Vladimír Smutný

Centrum strojového vnímání

Český institut informatiky, robotiky a kybernetiky (CIIRC)

České vysoké učení technické v Praze

1

2

3

4

5

6

7

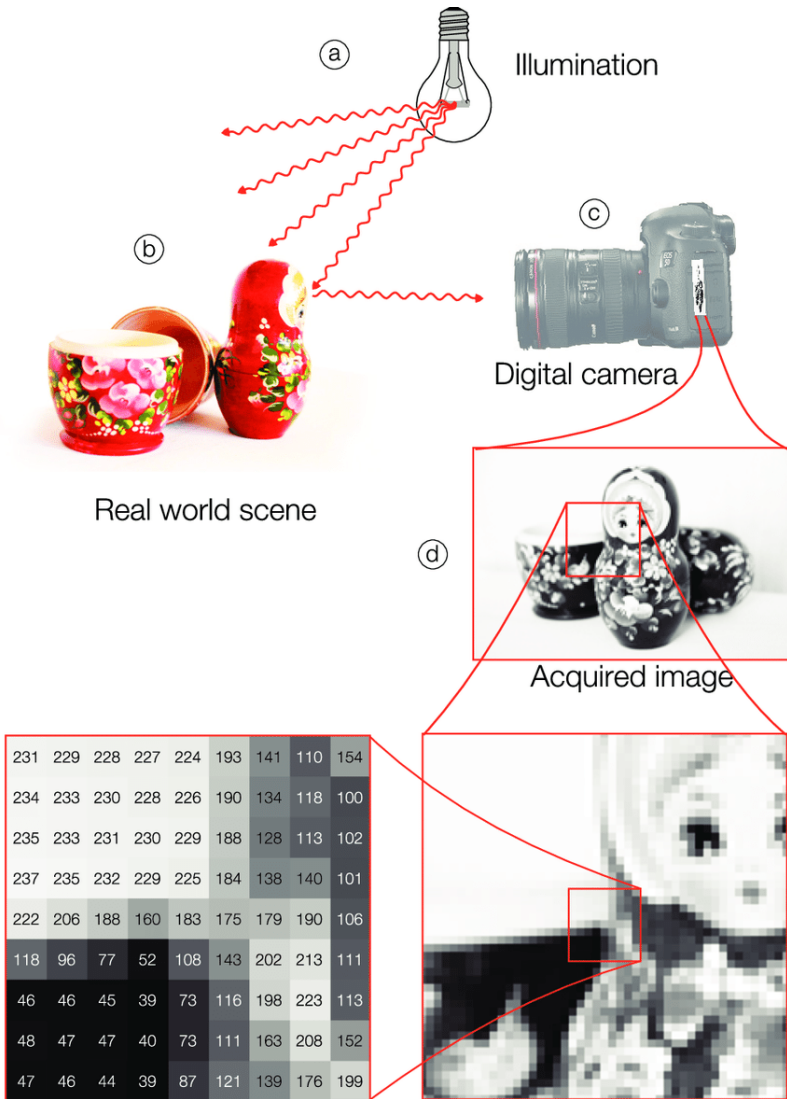
8

9

10

11

12



- ◆ zdroj světla
- ◆ odraz
- ◆ prostředí (není na obrázku)
- ◆ optika
- ◆ snímač

1

2

3

4

5

6

7

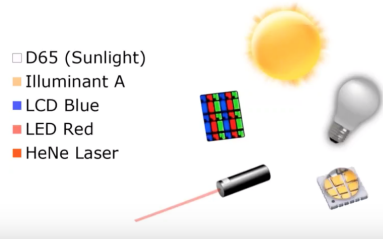
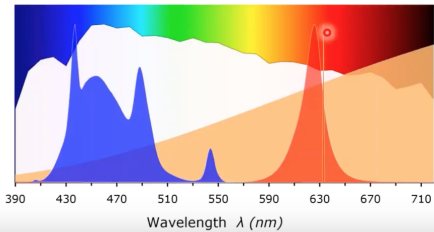
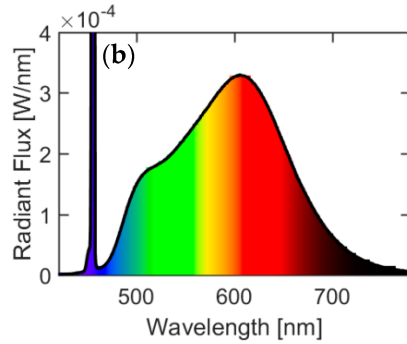
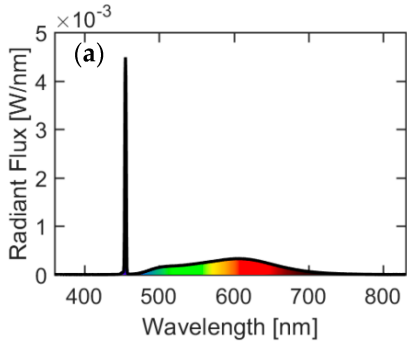
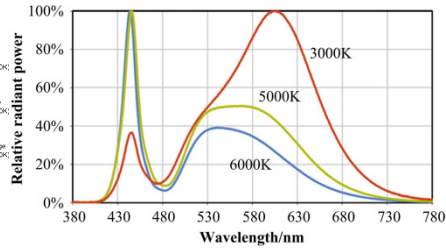
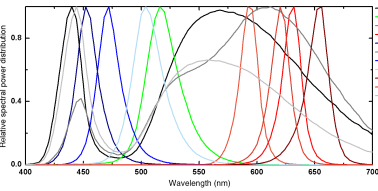
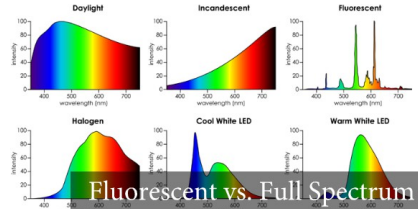
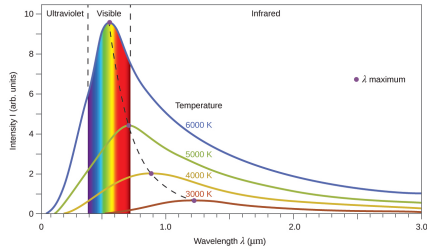
8

9

10

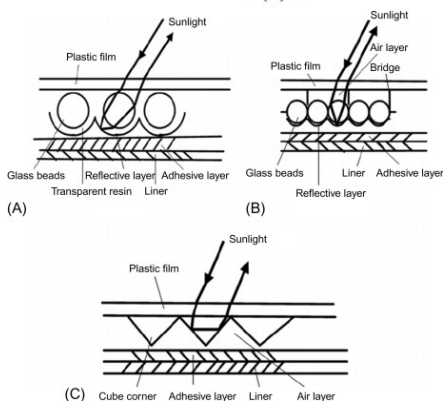
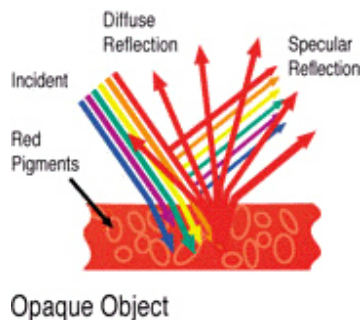
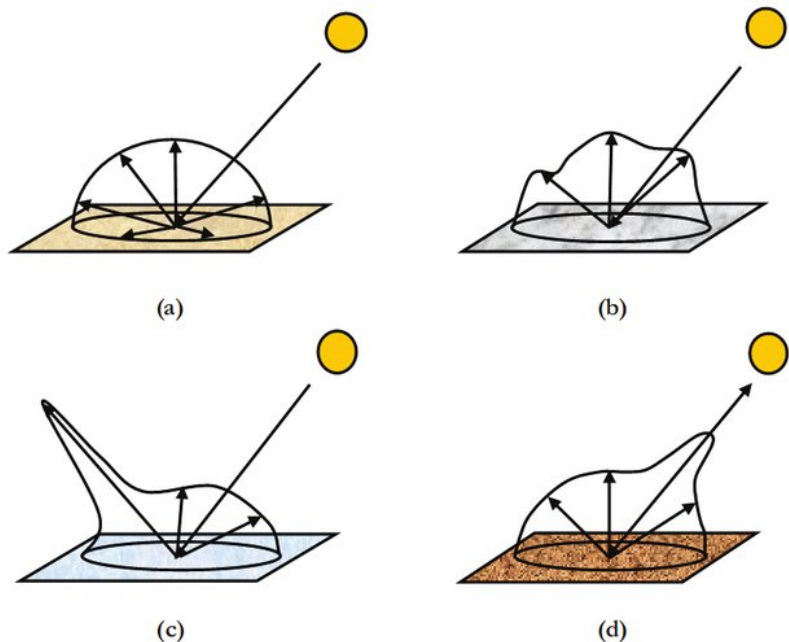
11

12



- ◆ Vyzařování černého tělesa – slunce, žárovka (obyčejná/halogenová), svíčka,...
- ◆ Výboj v plynech – zářivka (má lumino-for!!!), doutnavka, výbojka
- ◆ LED – barevné nebo s luminoforem
- ◆ Laser
- ◆ Luminofor

1
2
3
4
5
6
7
8
9
10
11
12



- ◆ Zrcadlový, např. vyleštěný nebo napařený kov
- ◆ Matný, drsný povrch
- ◆ Průhledný lesklý povrch s pigmenty
- ◆ Retroreflektivní povrch
- ◆ Luminiscenční, fosforescenční materiál



1

2

3

4

5

6

7

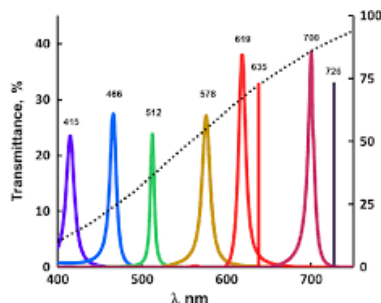
8

9

10

11

12



- ◆ Mlha, déšť, sněžení, smog, prach,...
- ◆ Optické barevné filtry, sluneční brýle,...
- ◆ Interferenční filtry
- ◆ Polarizační filtry,...
- ◆ Mřížky, efektové filtry,...

Mohou měnit směr chodu paprsků (déšť), zeslabovat intenzitu (prach) i spektrální složení (barevné filtry).

1

2

3

4

5

6

7

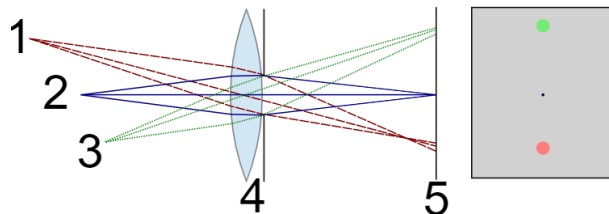
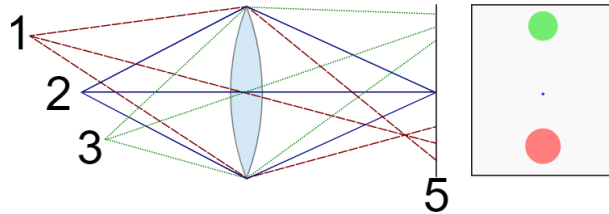
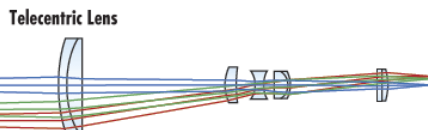
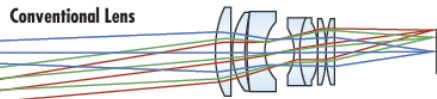
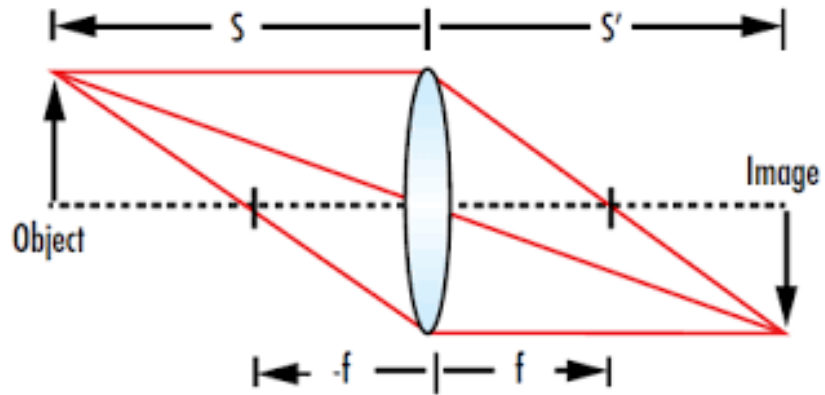
8

9

10

11

12



- ◆ Objektivy s centrálním promítáním
- ◆ Telecentrické objektivy (střed promítání v nekonečnu)
- ◆ Dalekohledy
- ◆ Mikroskopy
- ◆ Zoom

1
2
3
4
5
6
7
8
9
10
11
12



- ◆ Ohnisková vzdálenost (teleobjektiv, rybí oko)
- ◆ Clona
- ◆ Rovina ostrosti, pracovní vzdálenost
- ◆ Hloubka ostrosti (clona, difrakční limit)
- ◆ Velikost senzoru
- ◆ Rozlišení (circle of confusion)
- ◆ Závit

1

2

3

4

5

6

7

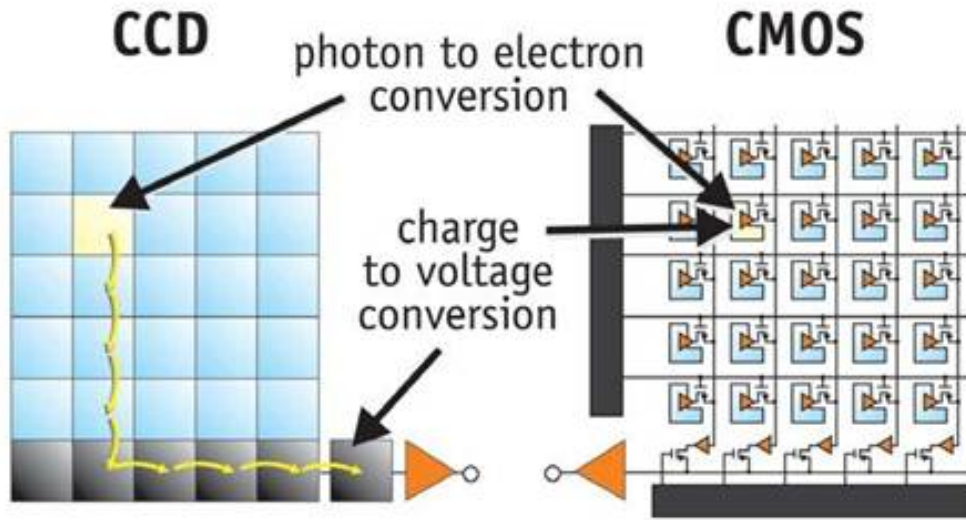
8

9

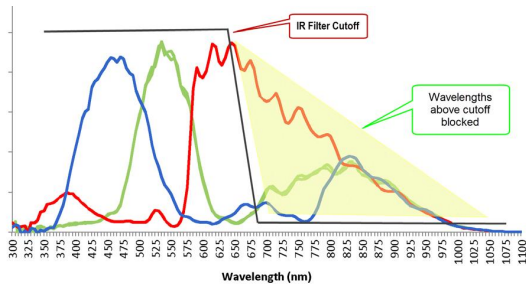
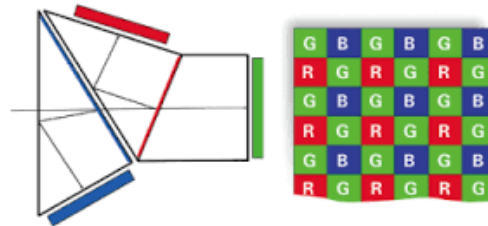
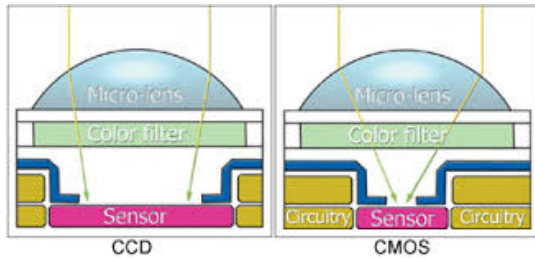
10

11

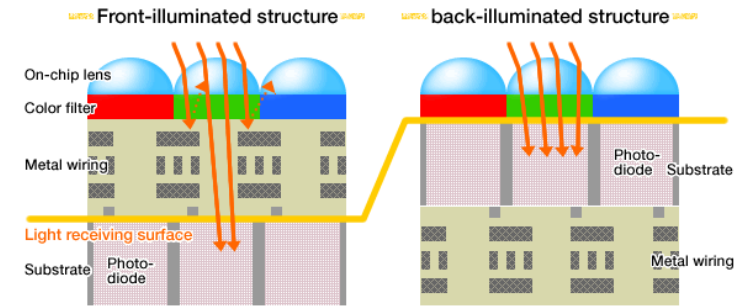
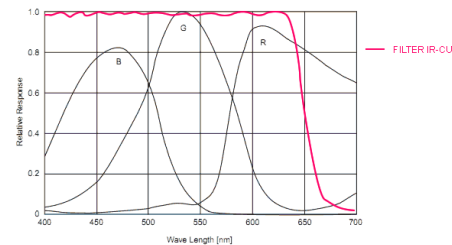
12



- ◆ CCD, CMOS, mikrobolometr (termokamery),...
- ◆ Černobílý, barevný, multispektrální



Spectral Sensitivity Characteristics (Excludes lens characteristics and light source characteristics)



1

2

3

4

5

6

7

8

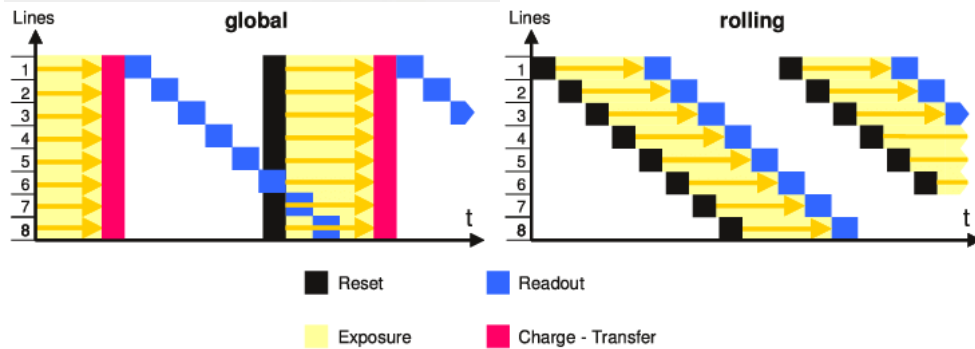
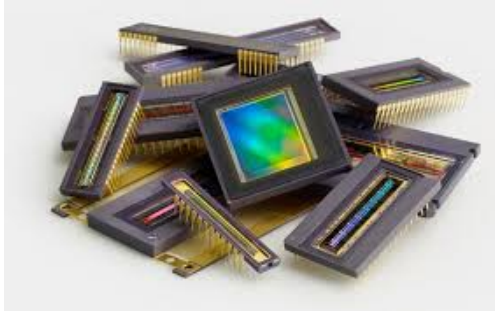
9

10

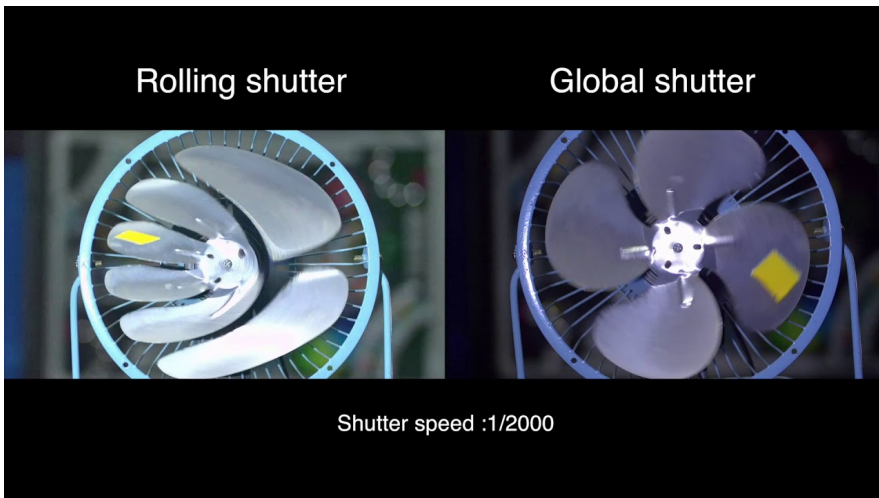
11

12

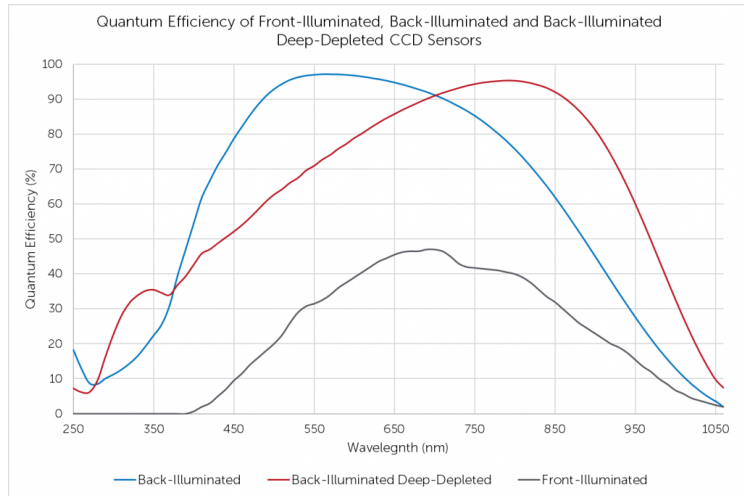




- ◆ Plošné, řádkové
- ◆ Rolling vs. global shutter



1
2
3
4
5
6
7
8
9
10
11
12



- ◆ Počet pixelů, velikost pixelu, velikost čipu
- ◆ Přenosová kapacita (bandwidth) rozhraní
- ◆ Maximální snímková frekvence
- ◆ Kapacita pixelu (full-well capacity)
- ◆ Šum (SNR)

1

2

3

4

5

6

7

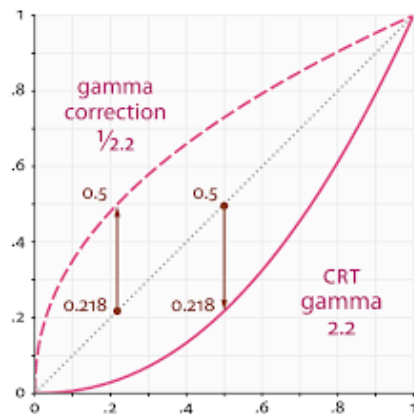
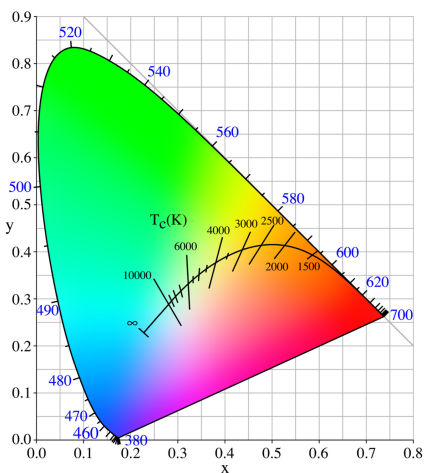
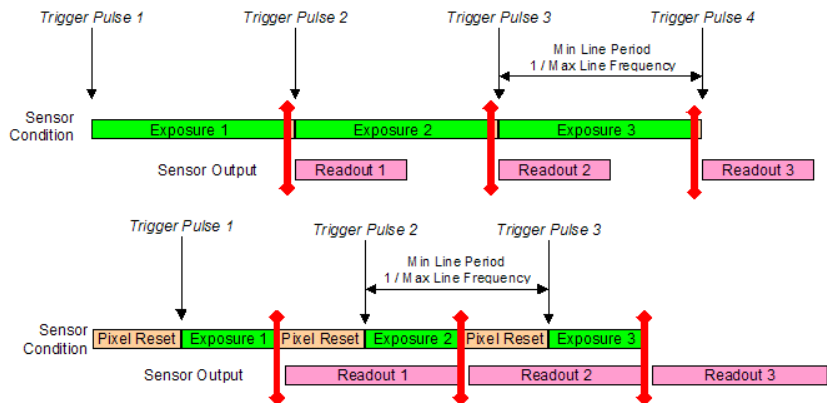
8

9

10

11

12



- ◆ Expoziční čas
- ◆ Zesílení, AGC
- ◆ Vyvážení bílé, AWB
- ◆ Gamma korekce
- ◆ Oblast zájmu

1

2

3

4

5

6

7

8

9

10

11

12



$$U = \int I(\lambda)\rho(\lambda)f(\lambda)s(\lambda)d\lambda$$

$$U_i = \int I(\lambda)\rho(\lambda)f_i(\lambda)s(\lambda)d\lambda \quad i \in \{R, G, B\}$$

1

2

3

4

5

6

7

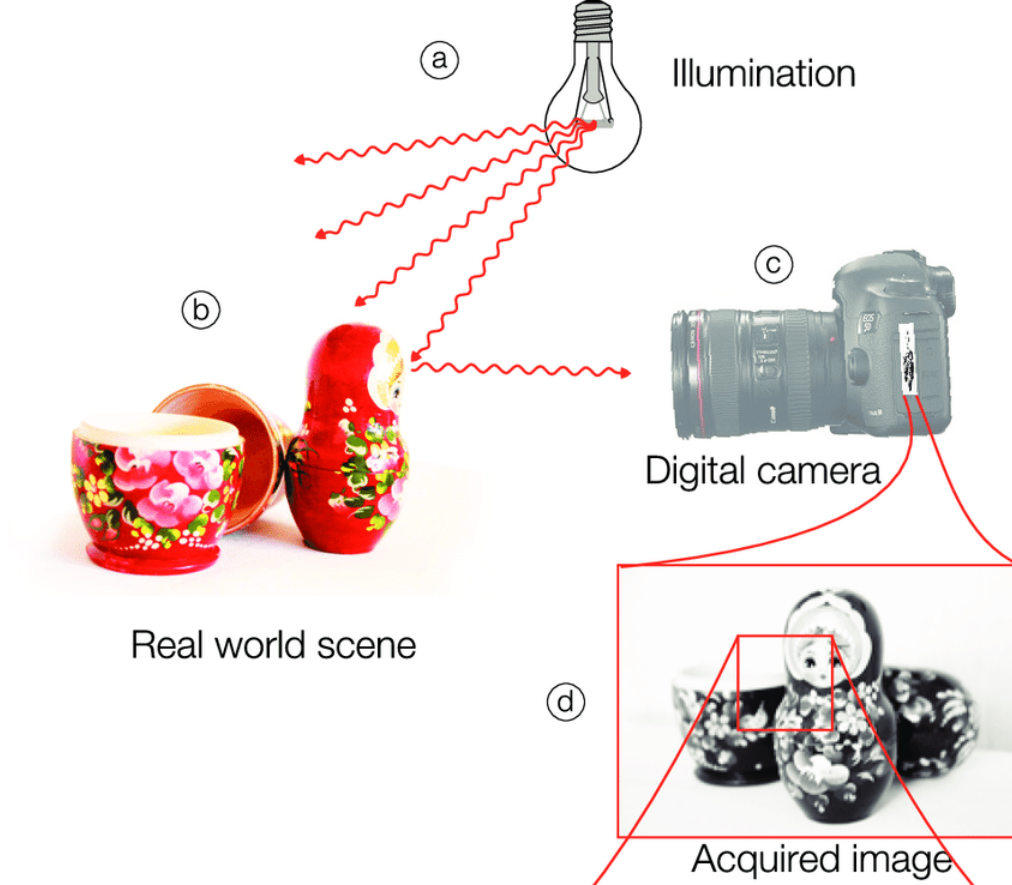
8

9

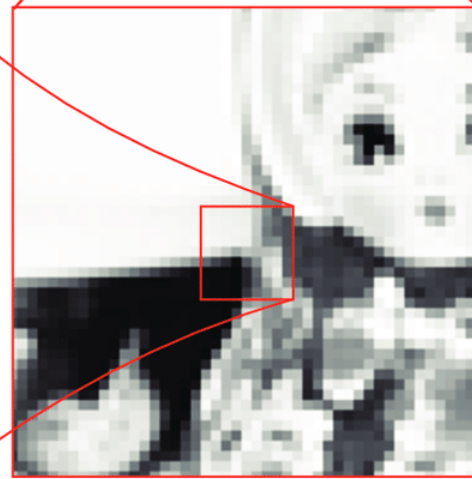
10

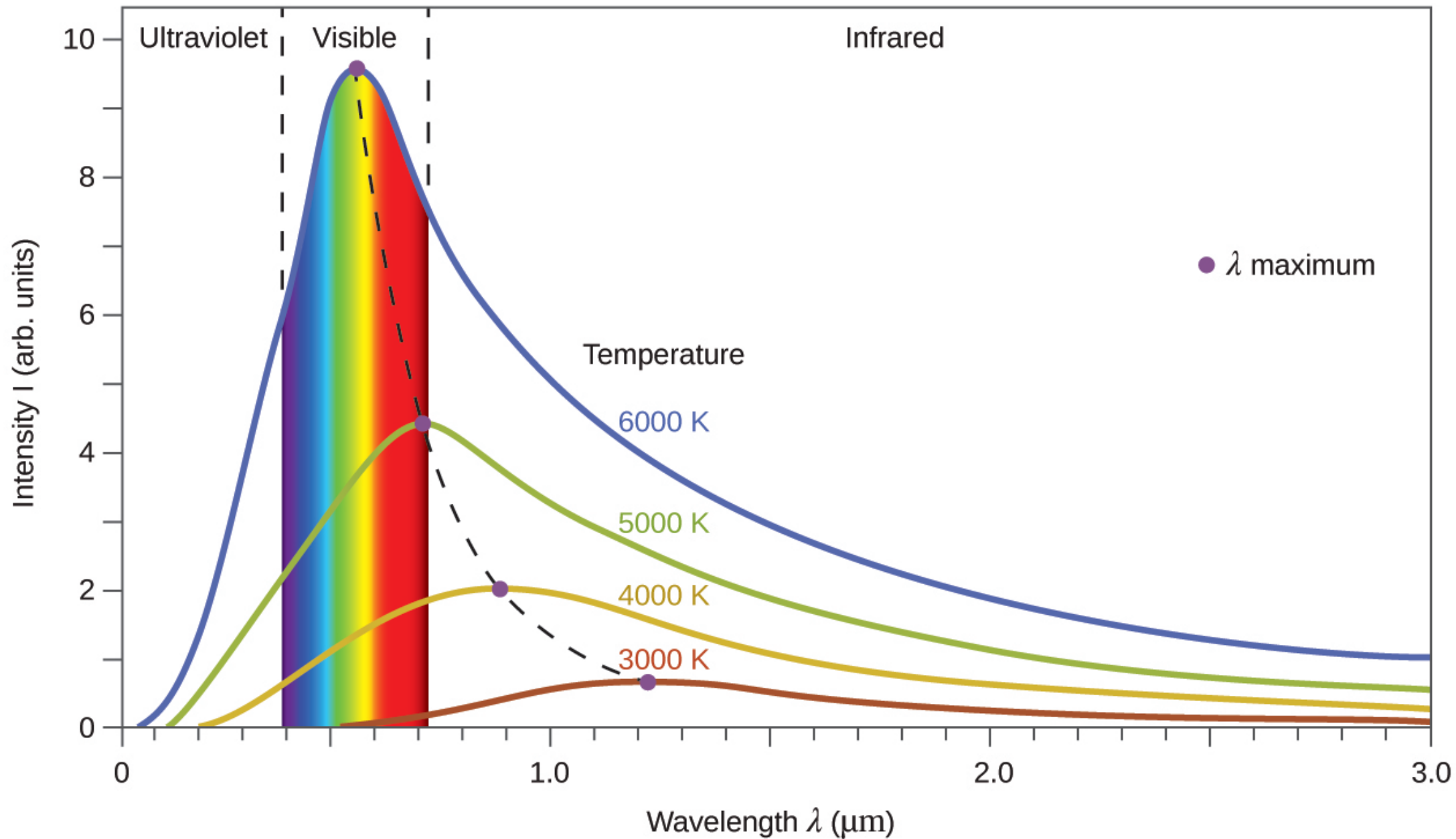
11

12

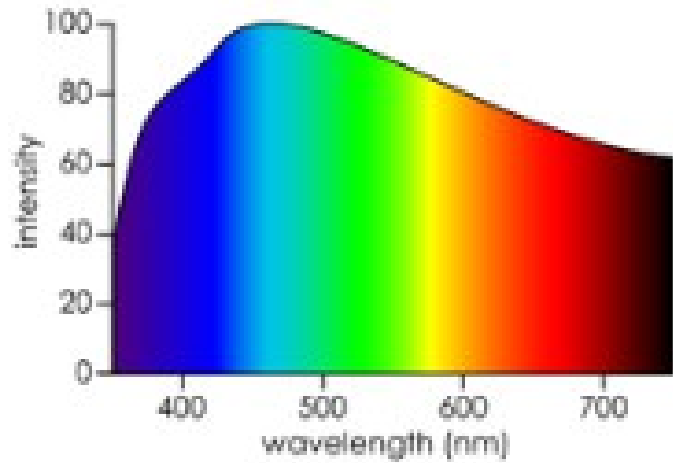


231	229	228	227	224	193	141	110	154
234	233	230	228	226	190	134	118	100
235	233	231	230	229	188	128	113	102
237	235	232	229	225	184	138	140	101
222	206	188	160	183	175	179	190	106
118	96	77	52	108	143	202	213	111
46	46	45	39	73	116	198	223	113
48	47	47	40	73	111	163	208	152
47	46	44	39	87	121	139	176	199

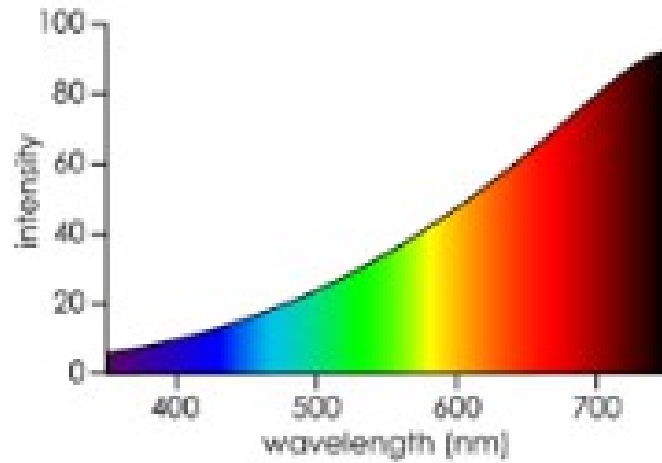




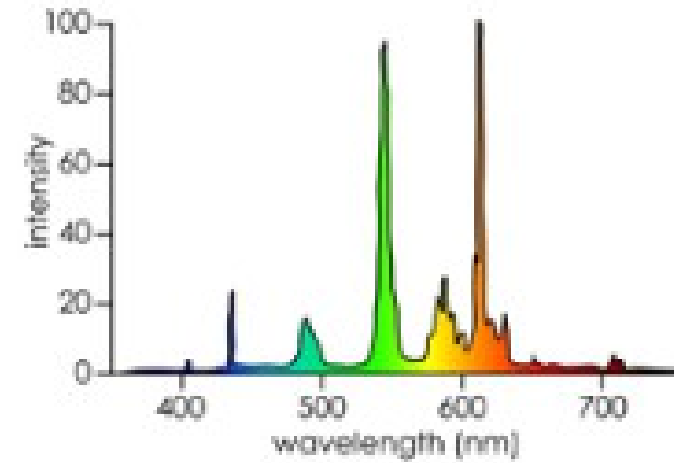
**Daylight**



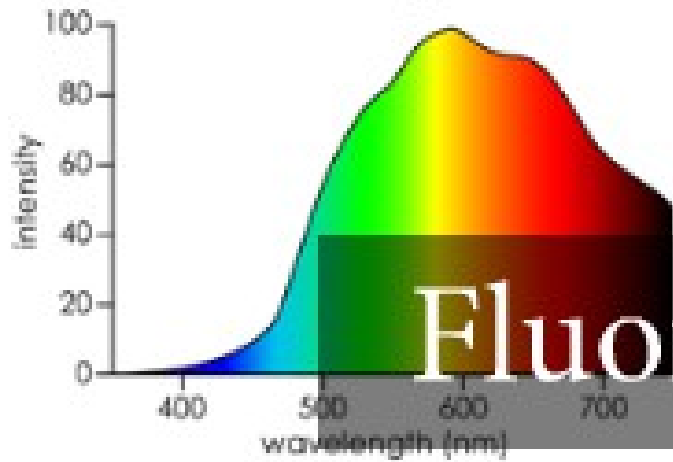
**Incandescent**



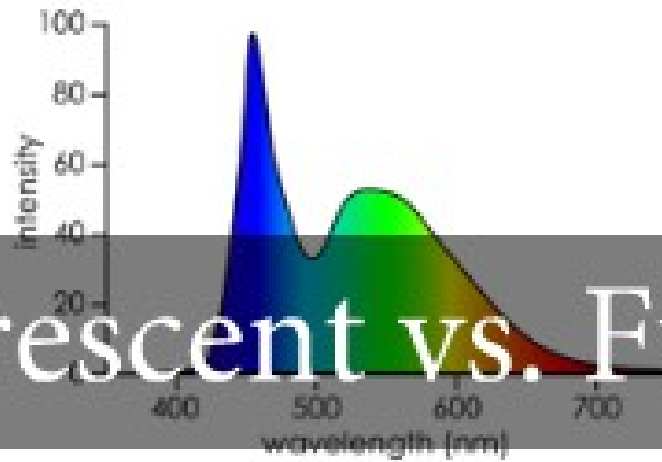
**Fluorescent**



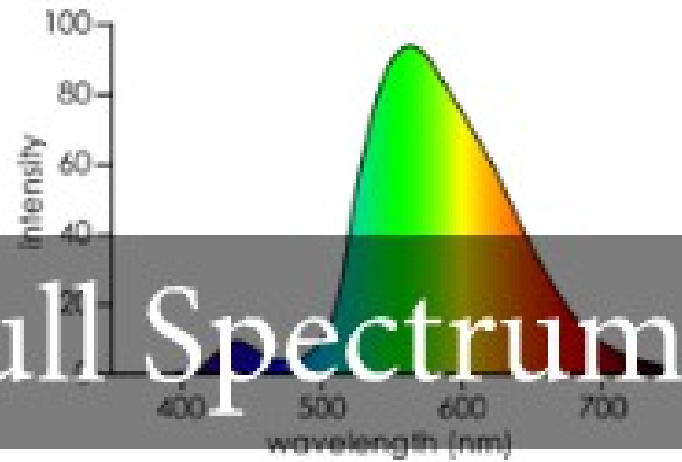
**Halogen**



**Cool White LED**

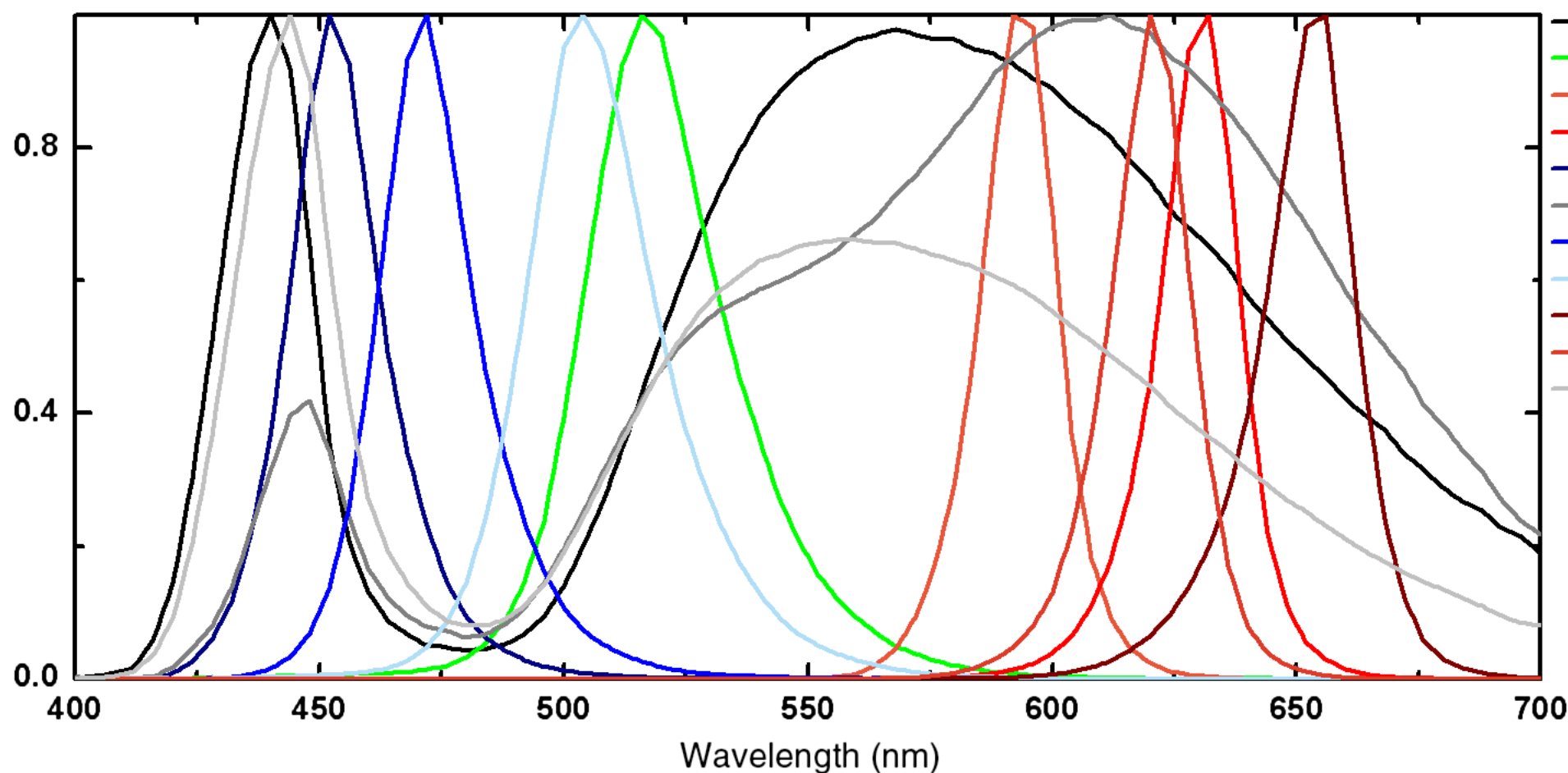


**Warm White LED**



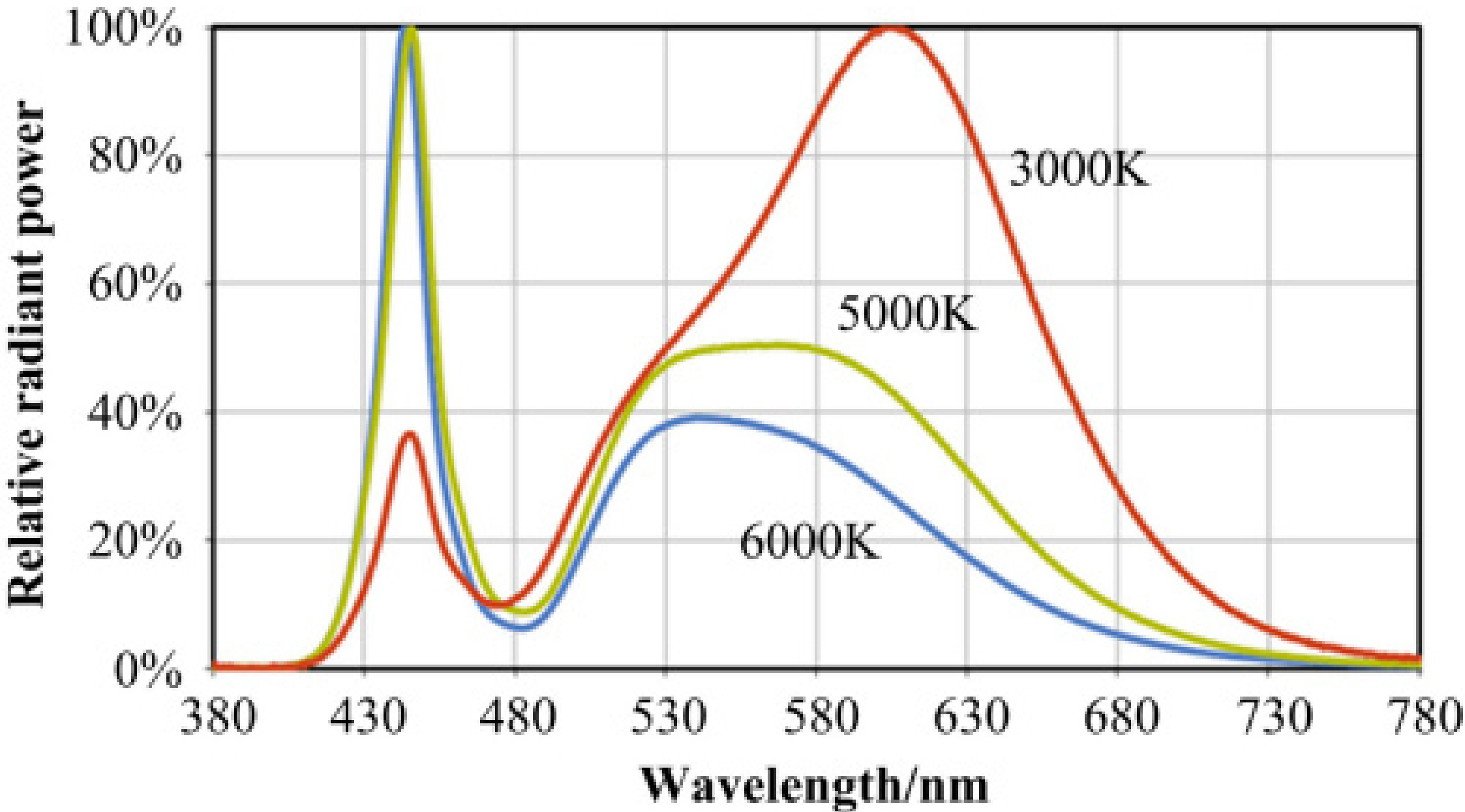
Fluorescent vs. Full Spectrum

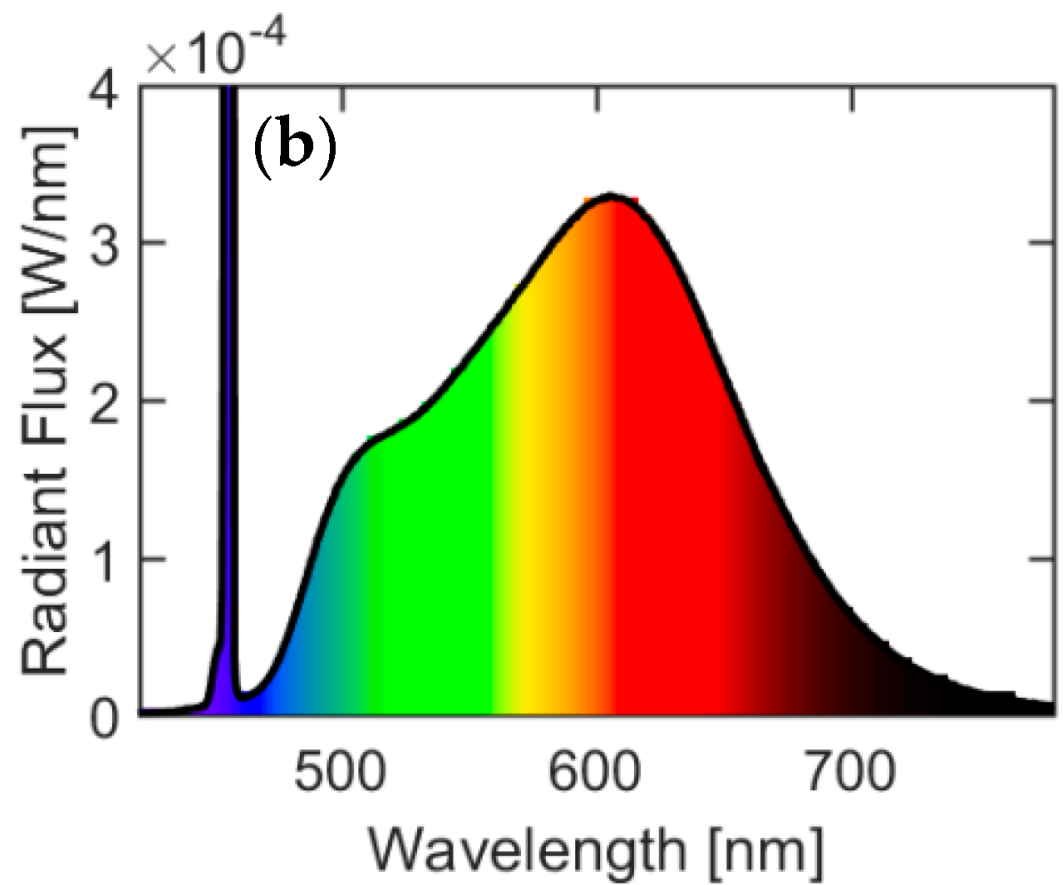
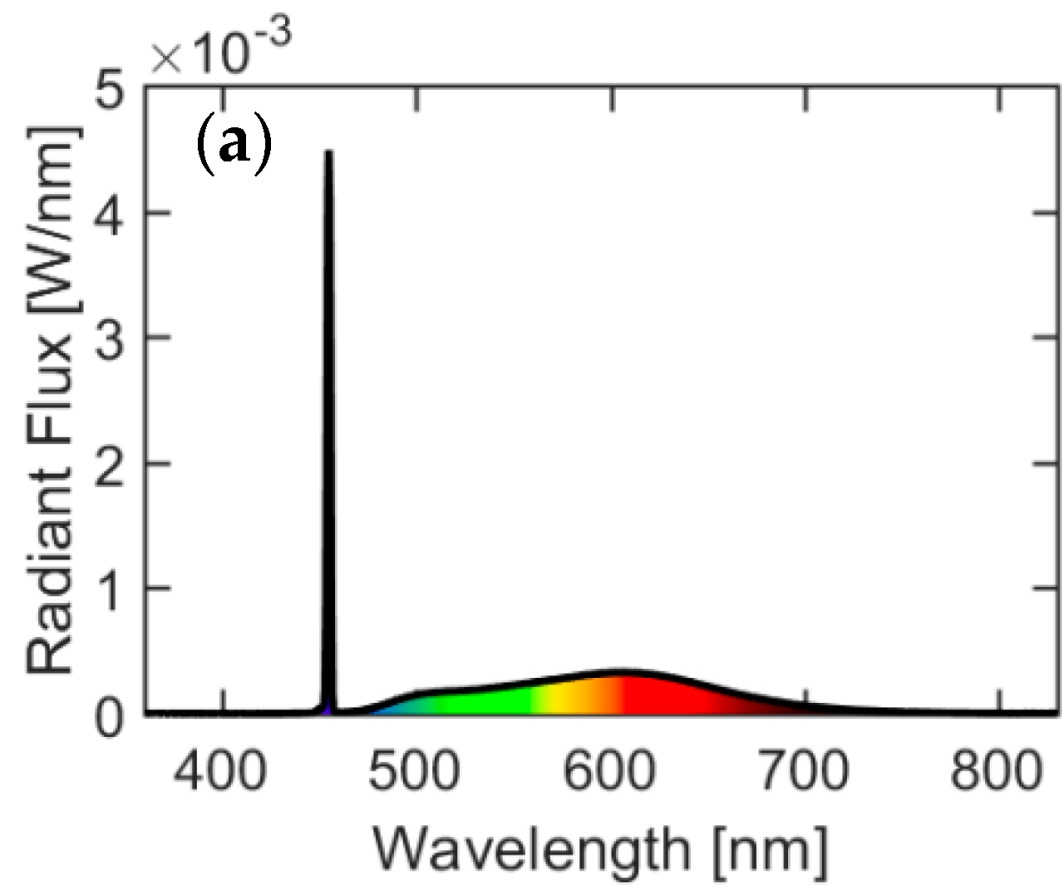
Relative spectral power distribution

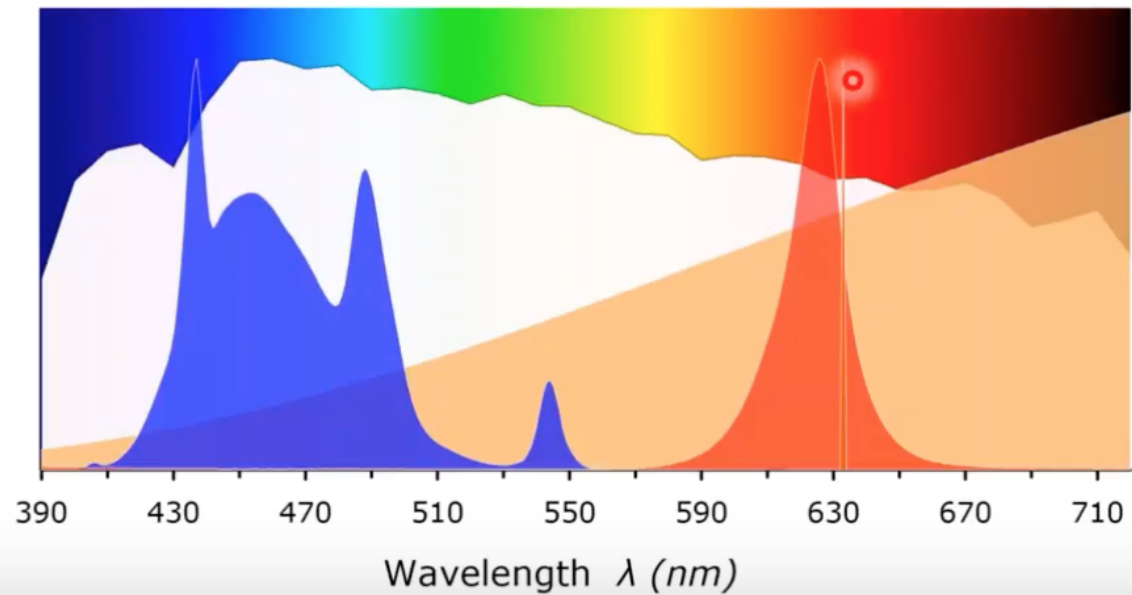


- White(4000K)
- Green
- Amber
- Red
- Royal-Blue
- White(3000K)
- Blue
- Cyan
- Deep Red
- Red-Orange
- White(5500K)

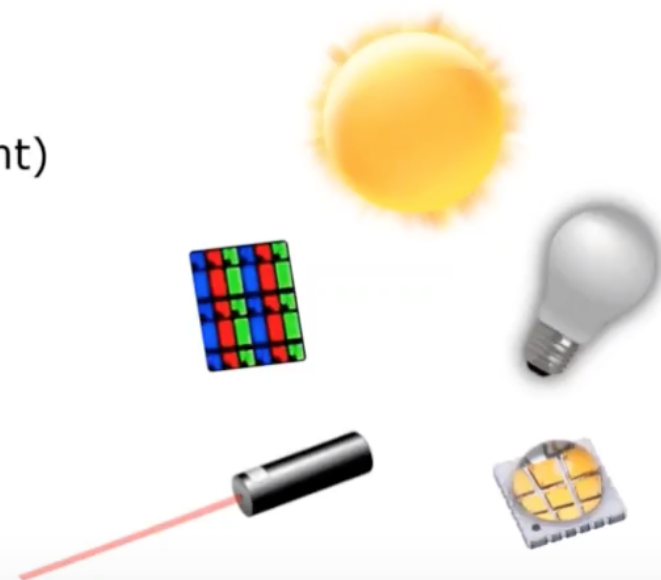


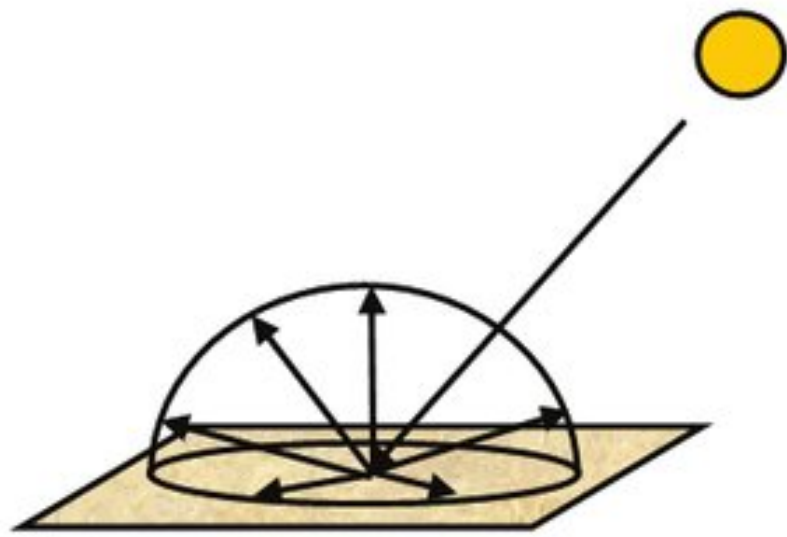




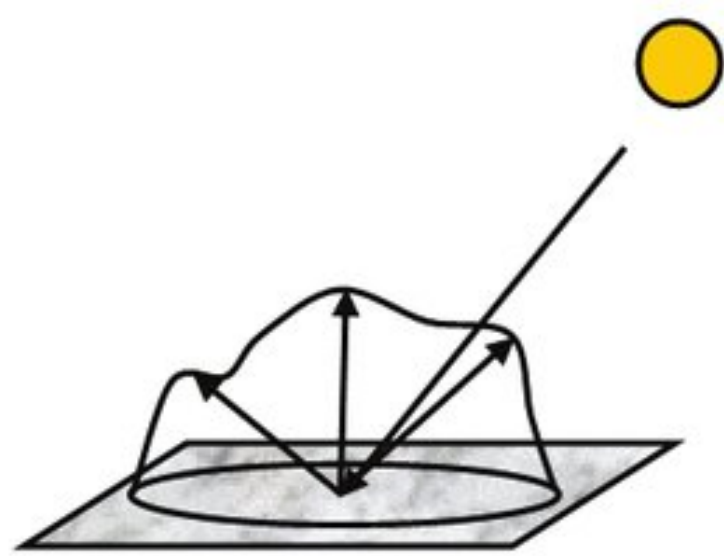


- D65 (Sunlight)
- Illuminant A
- LCD Blue
- LED Red
- HeNe Laser

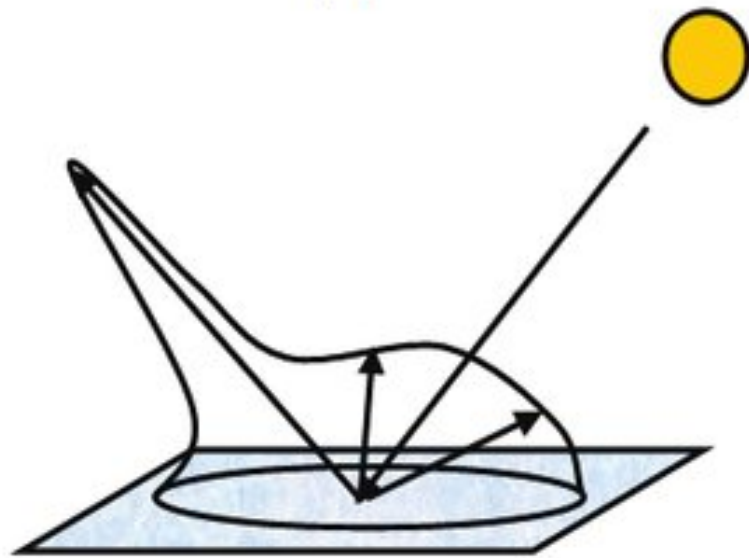




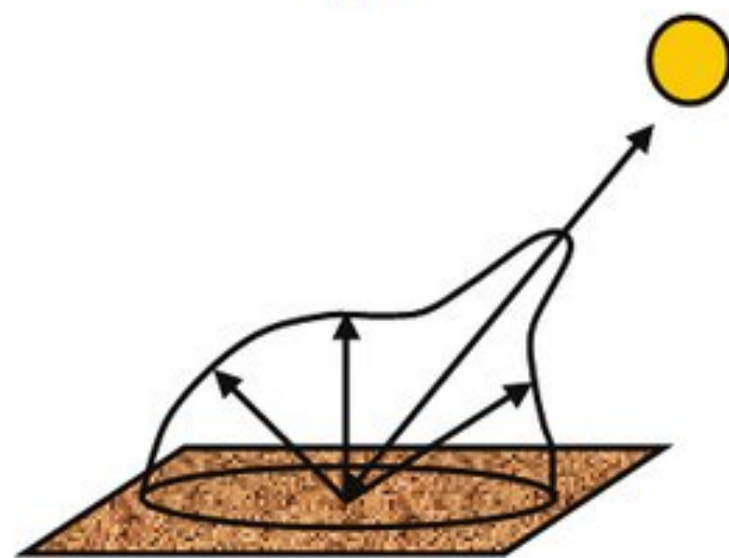
(a)



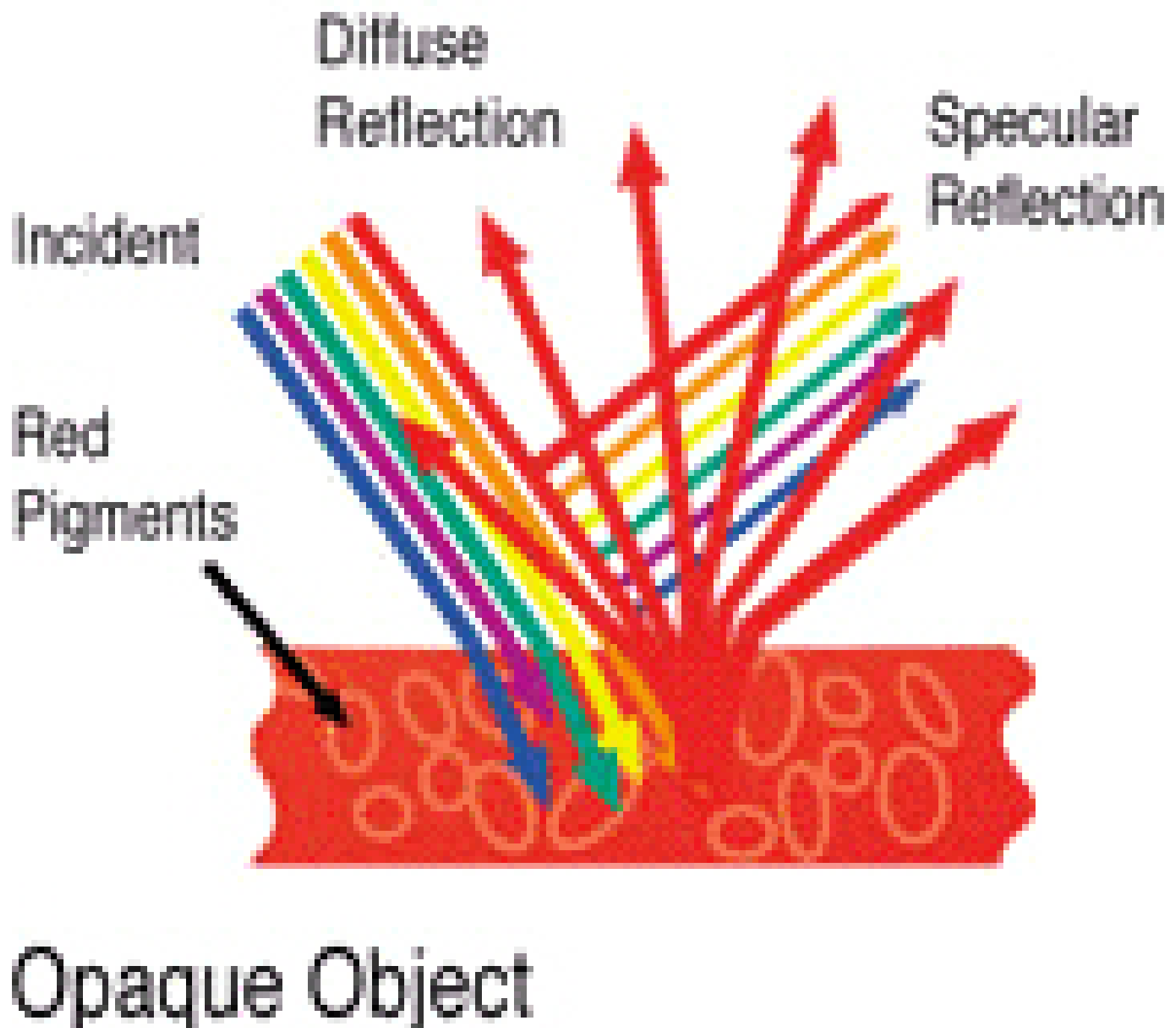
(b)

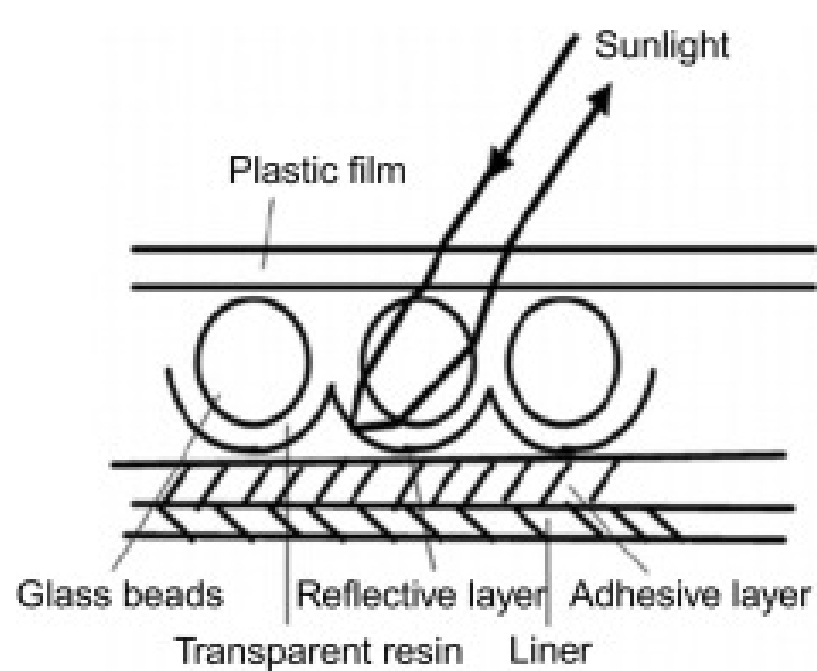


(c)

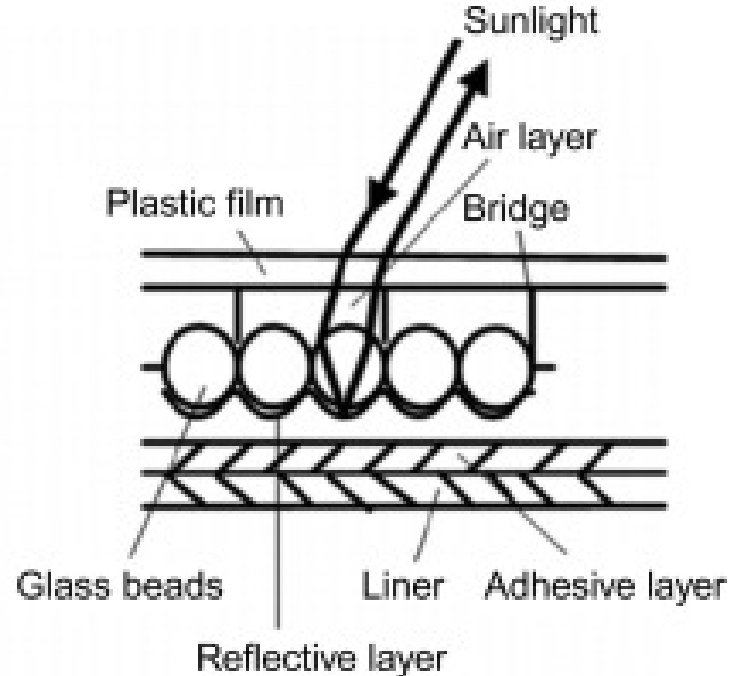


(d)

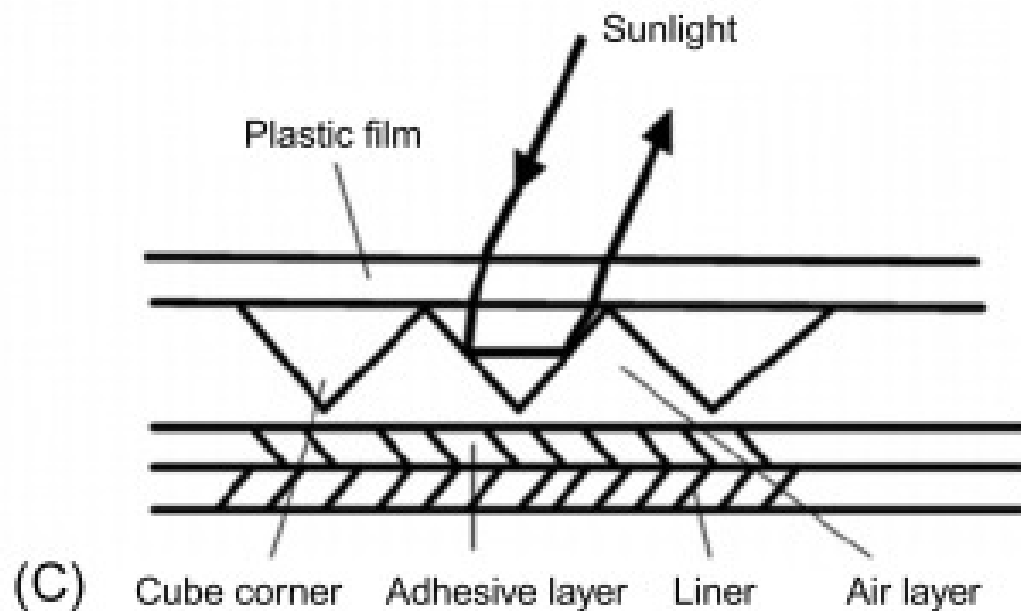




(A)



(B)



(C)

SFvest®

SFTC07









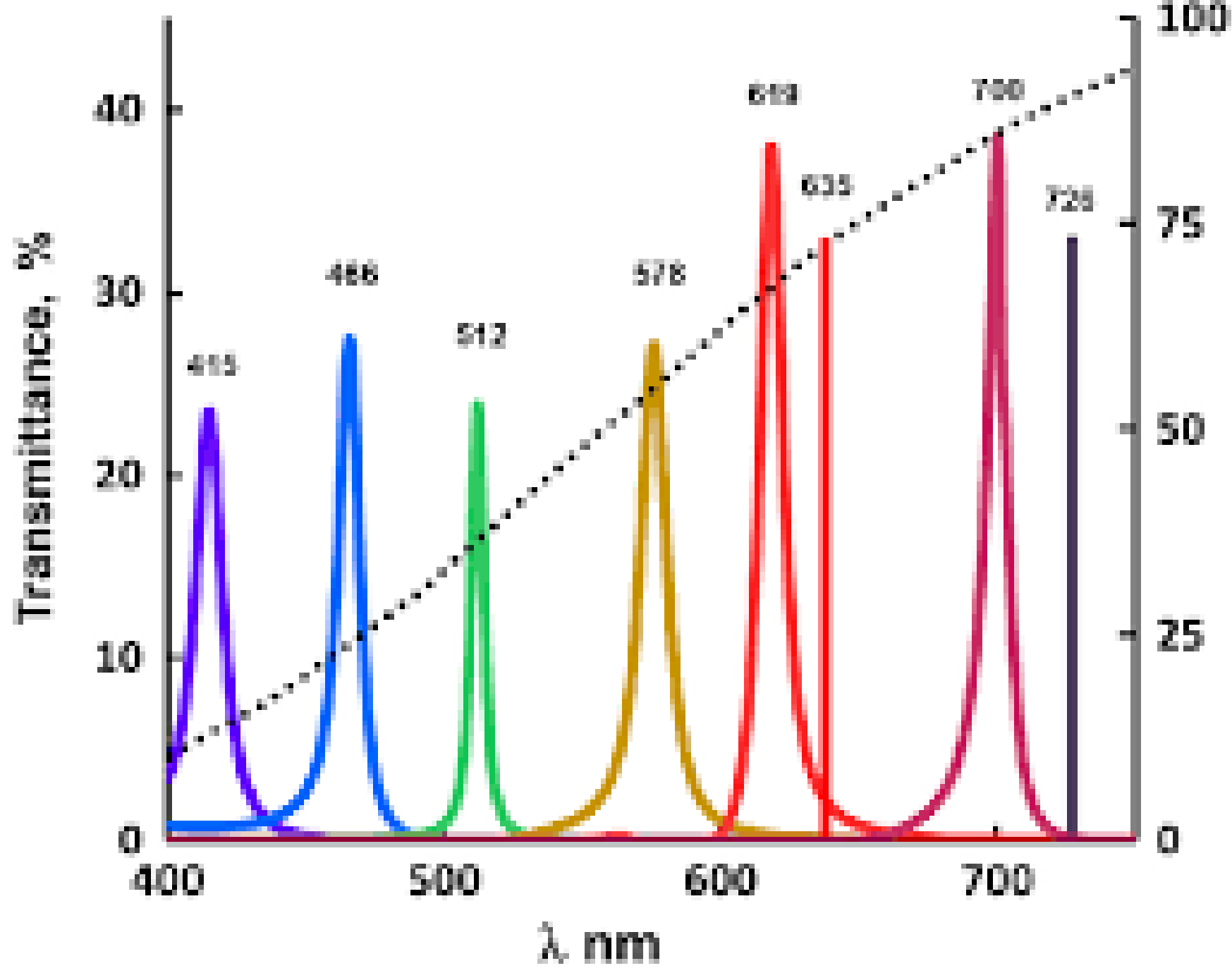
Parkview

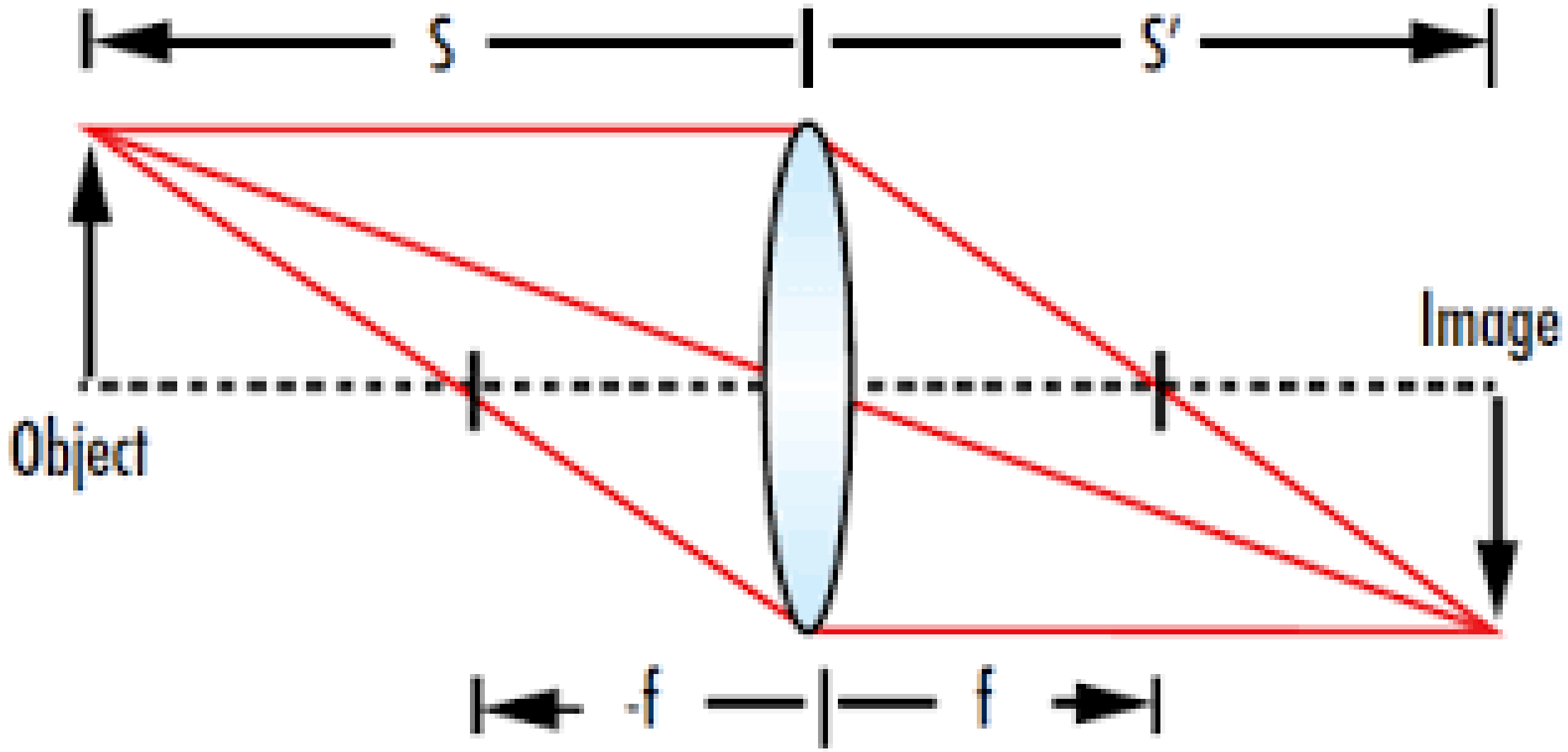
11th Blvd East

DELAYED GREEN

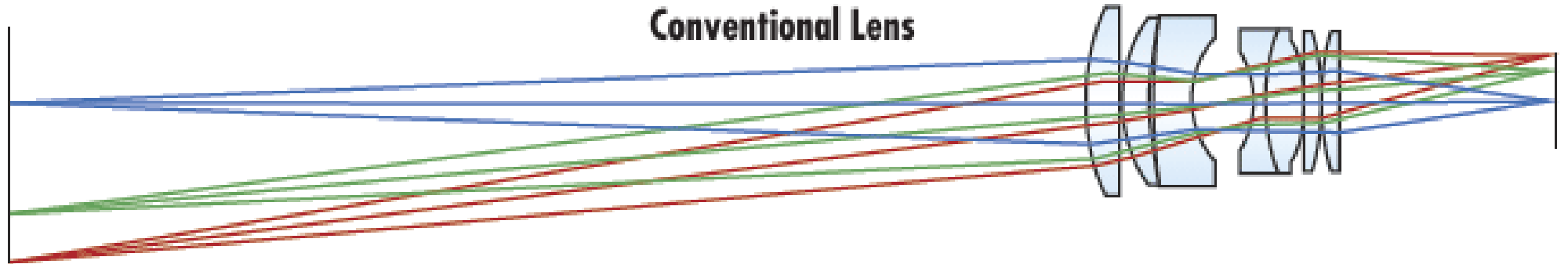
Parkview



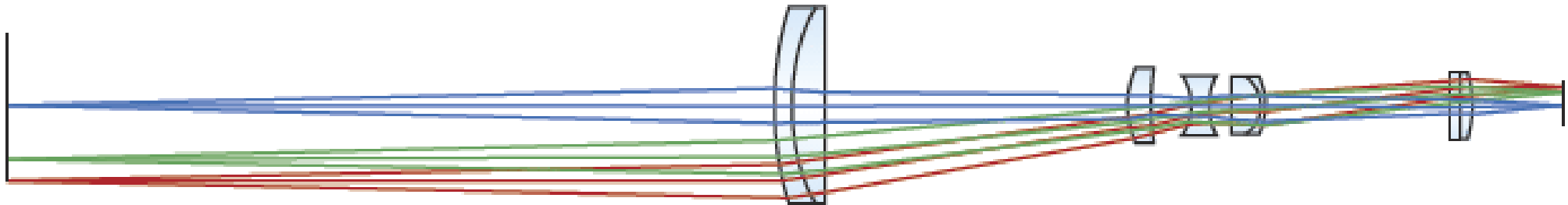


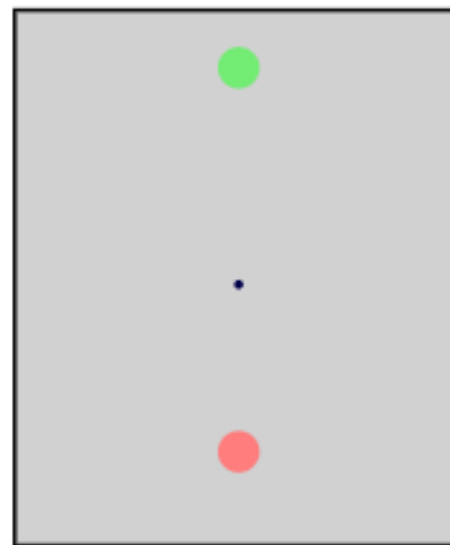
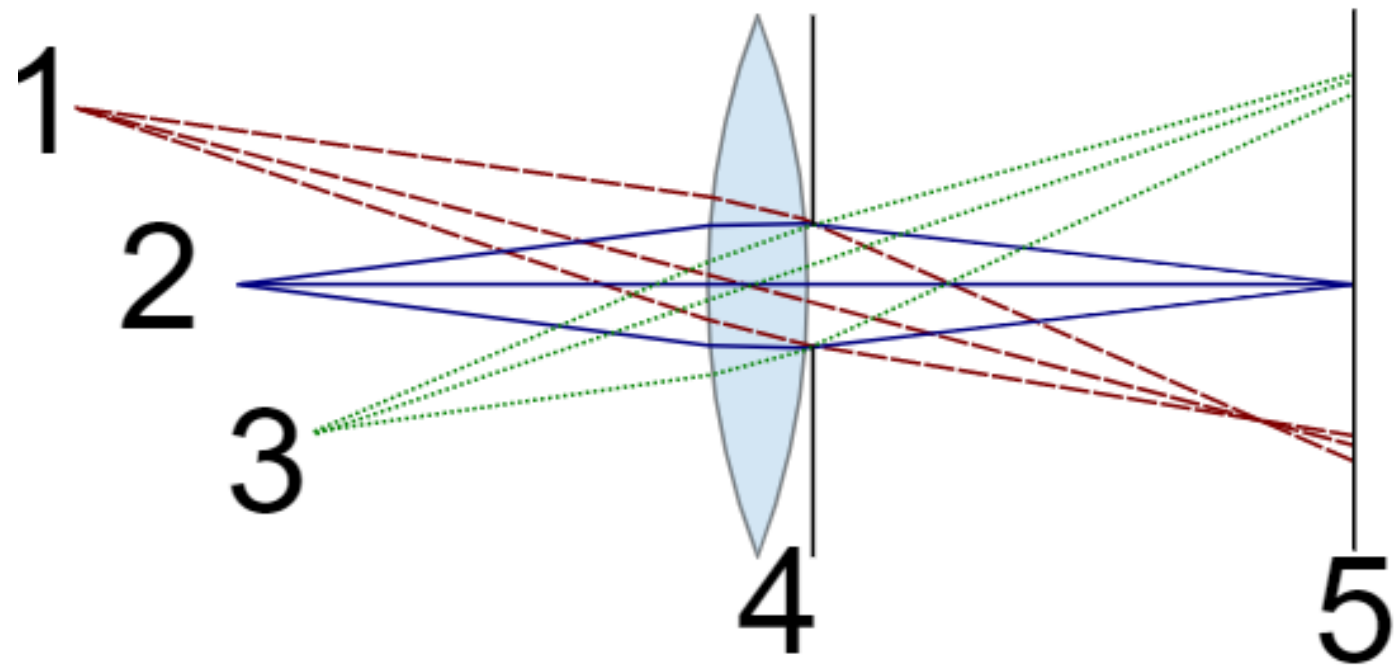
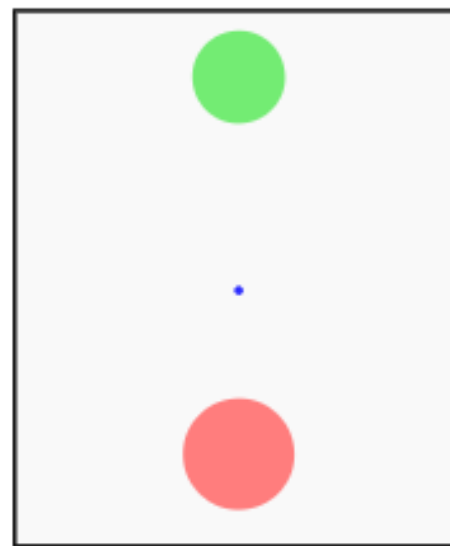
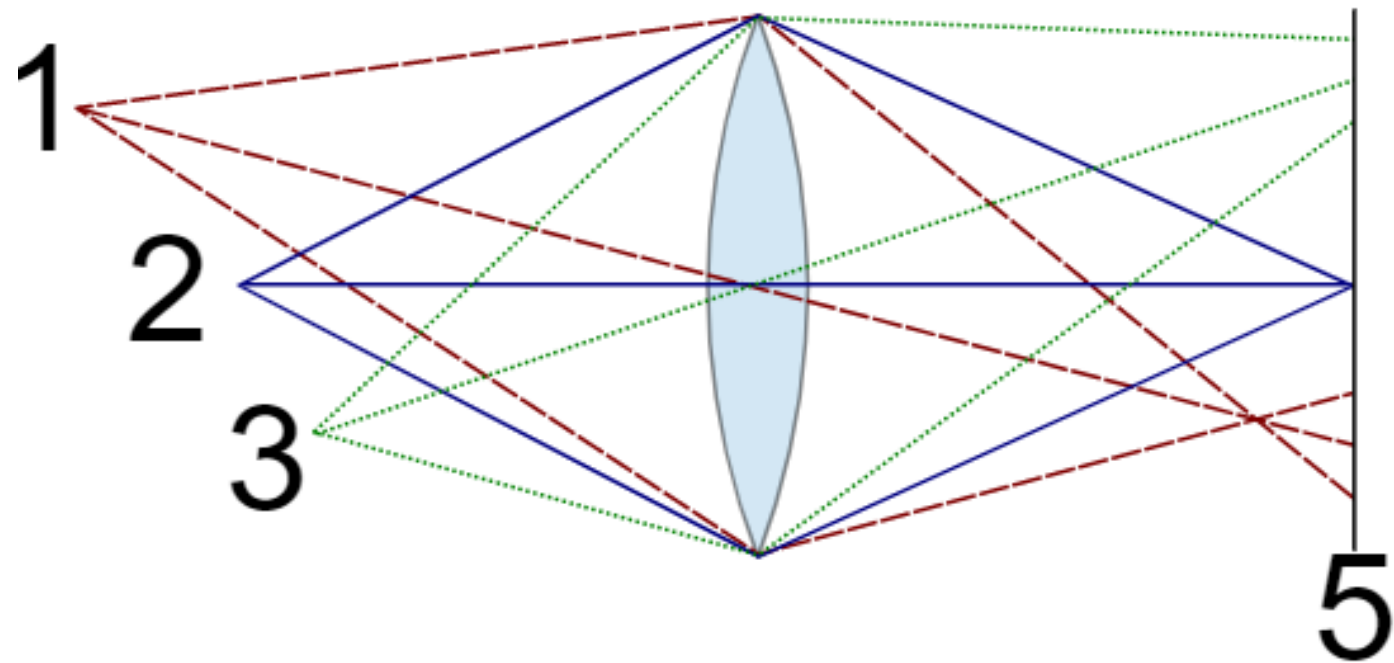


**Conventional Lens**



**Telecentric Lens**



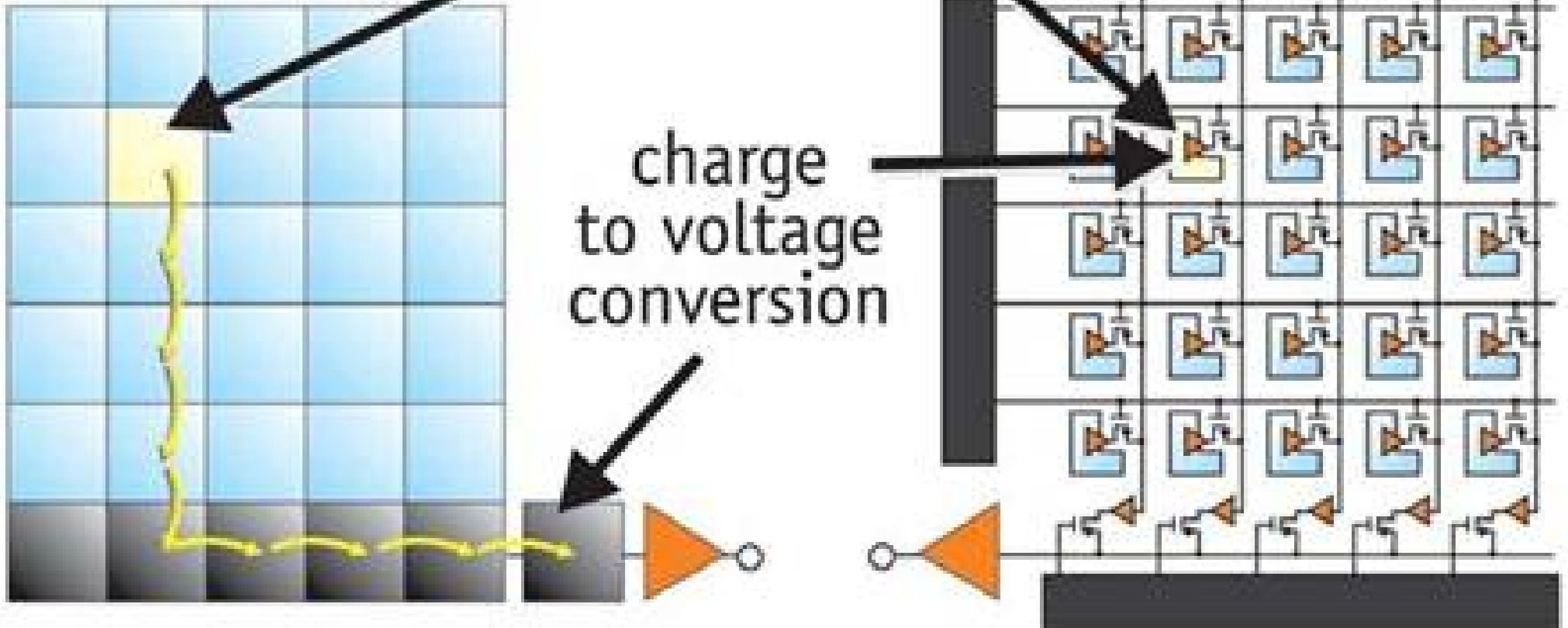


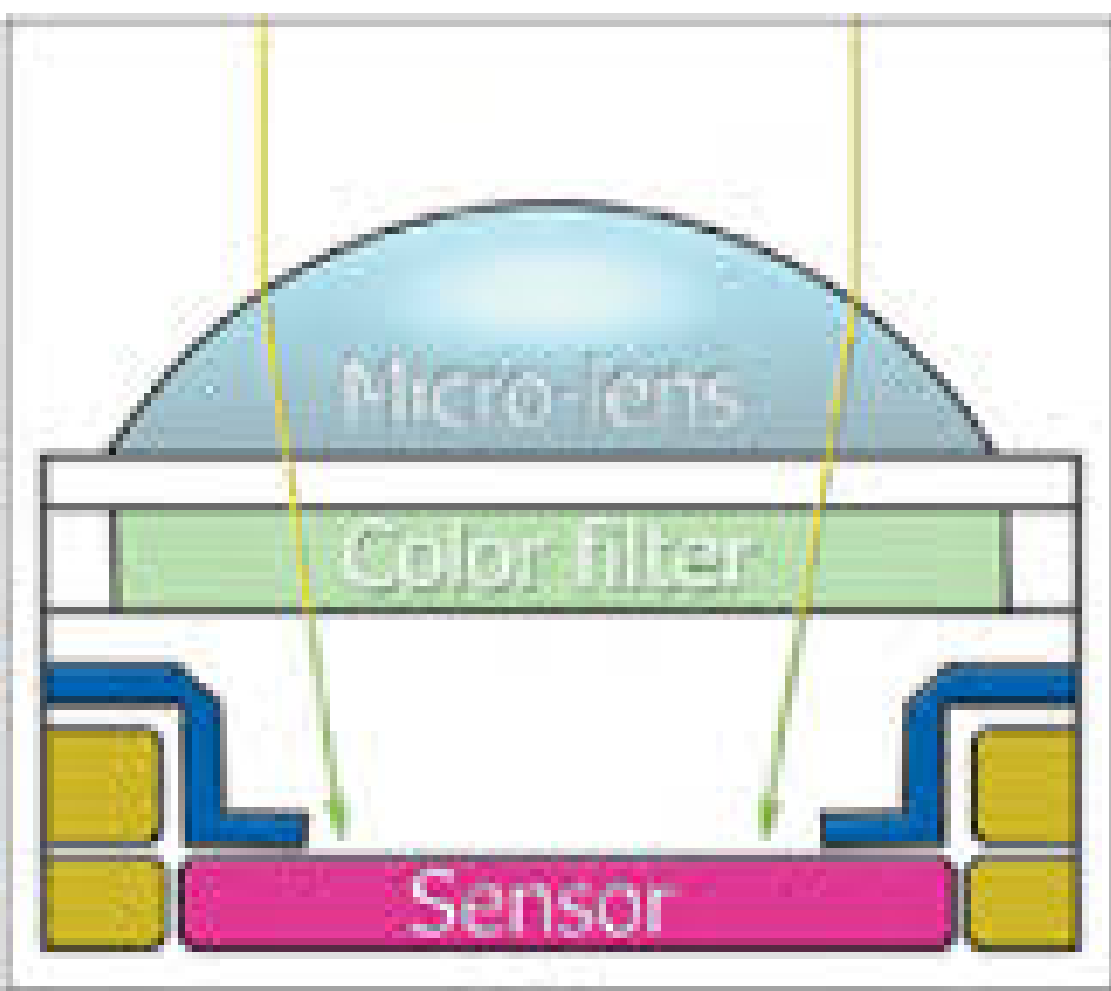
# CCD

photon to electron  
conversion

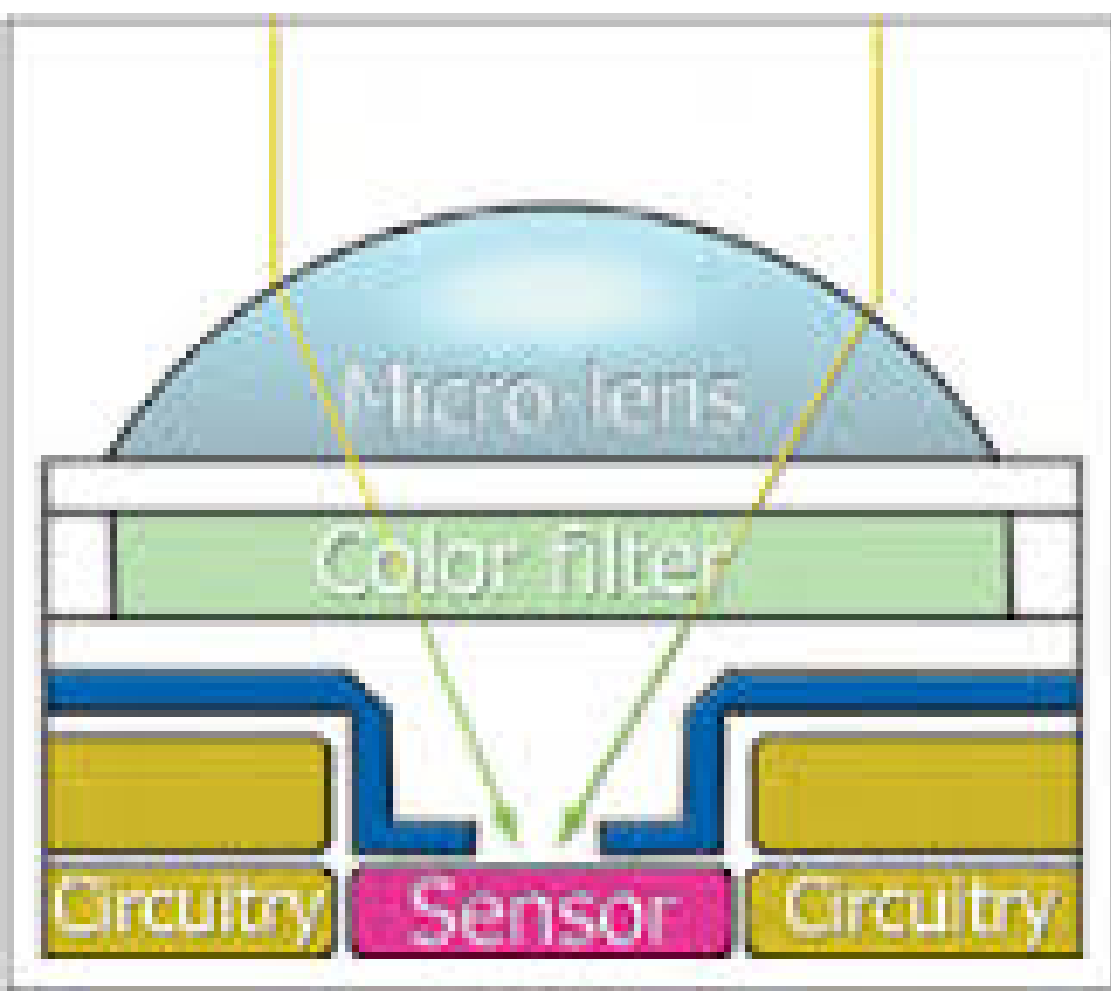
# CMOS

charge  
to voltage  
conversion



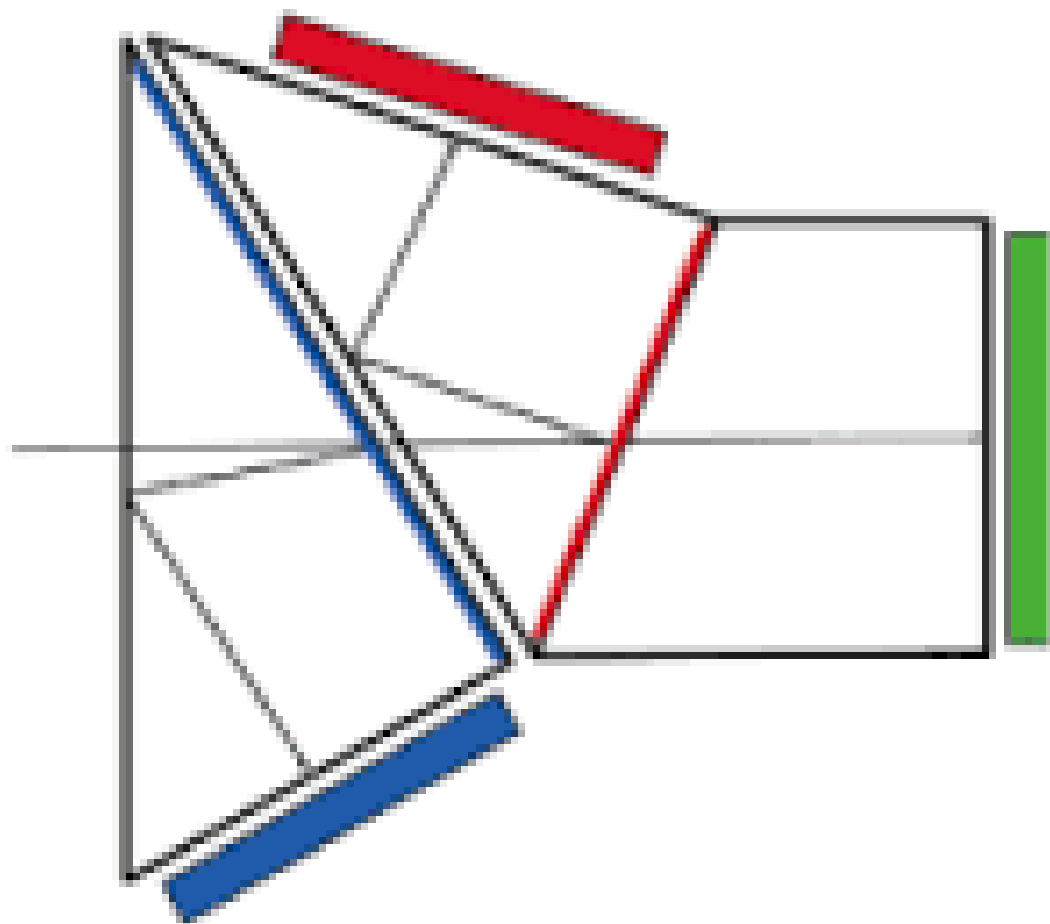


CCD

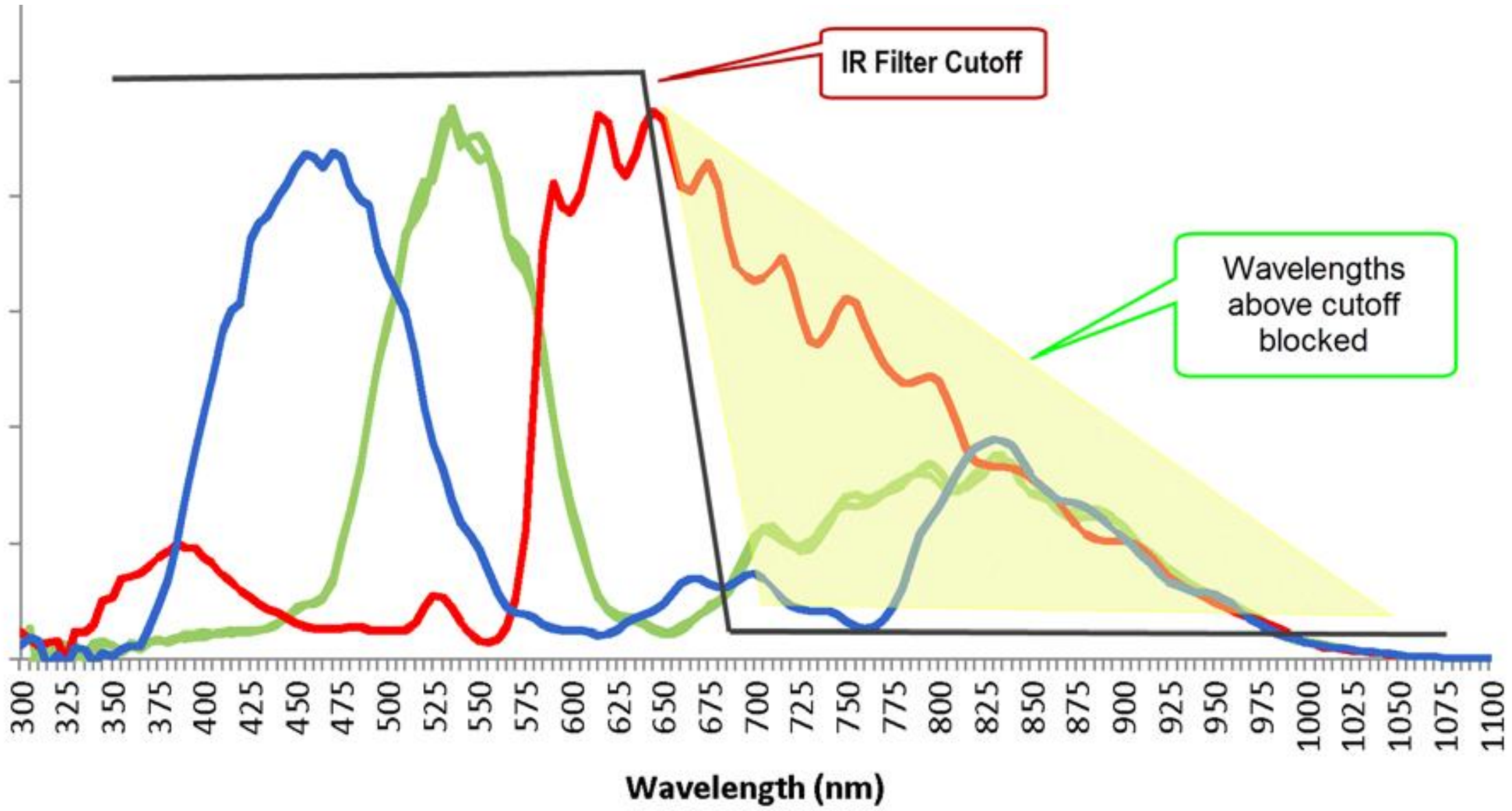


CMOS

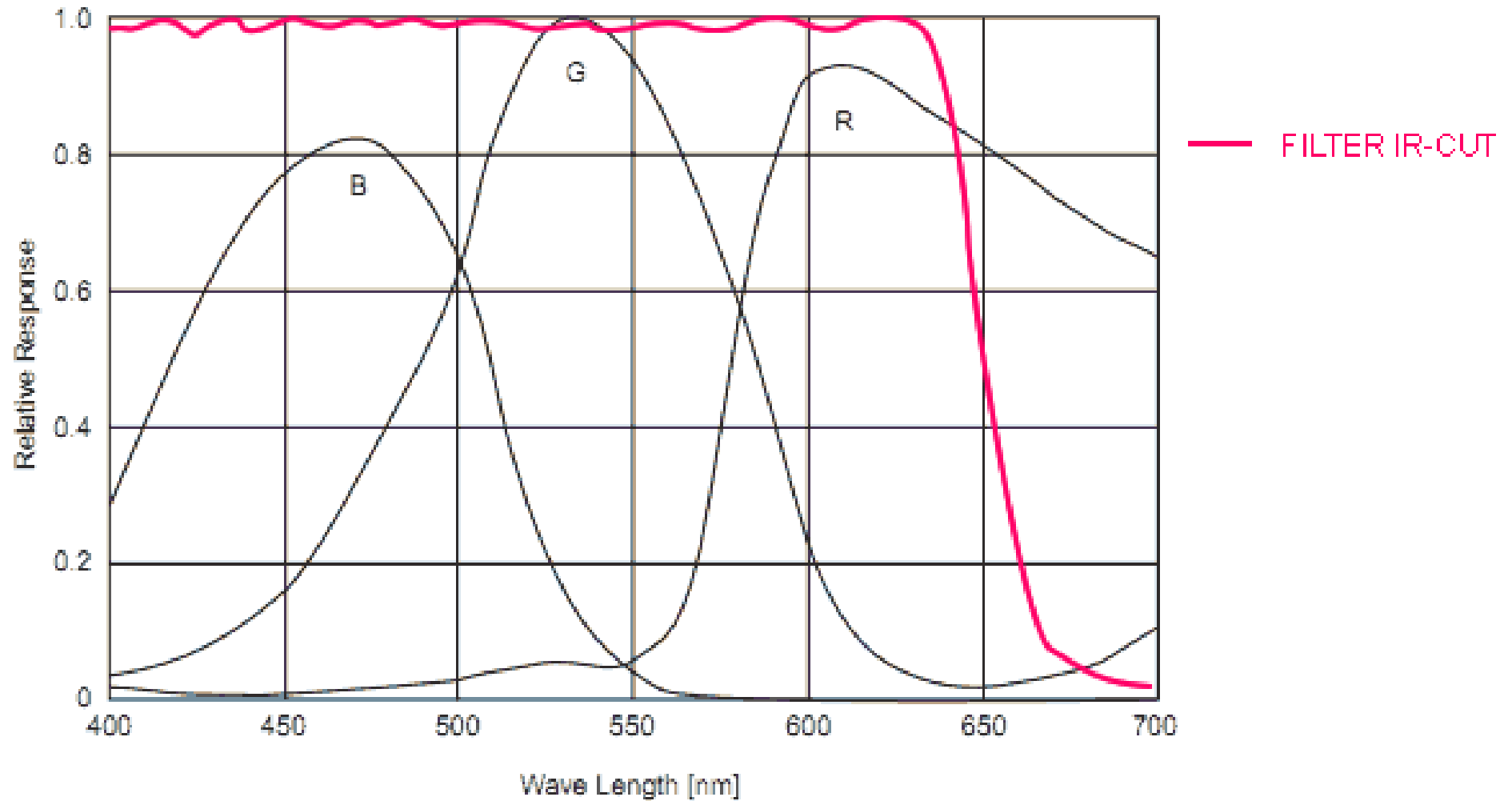




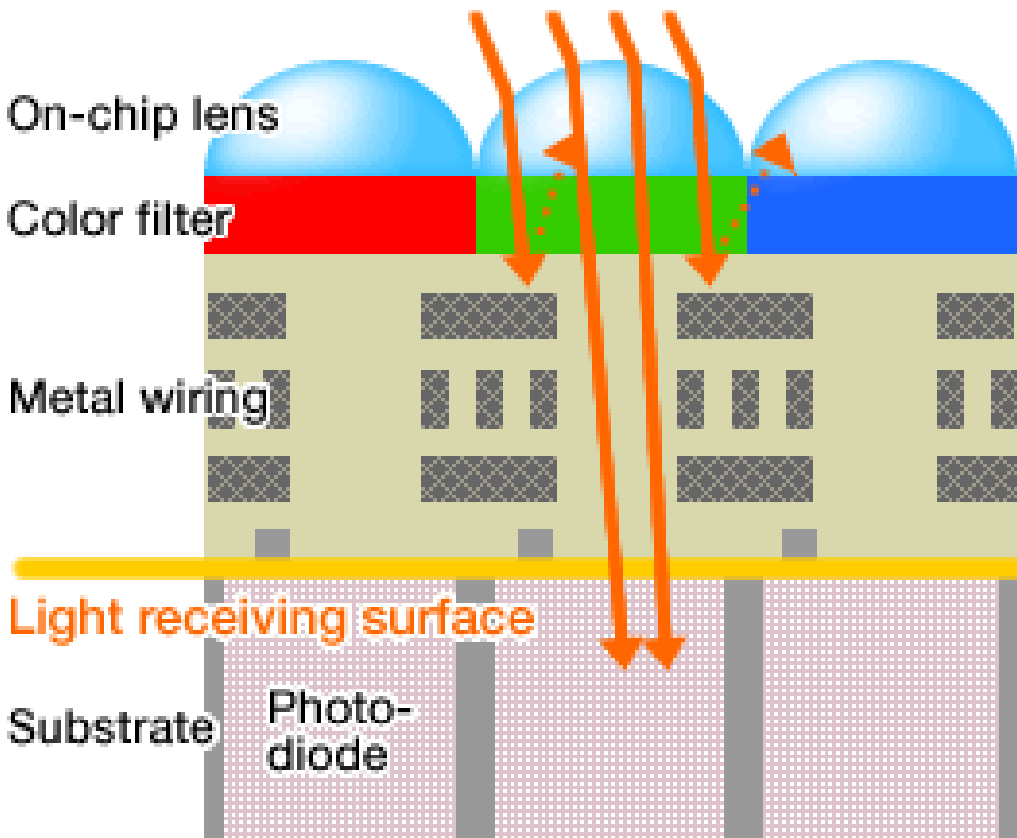
G	B	G	B	G	B
R	G	R	G	R	G
G	B	G	B	G	B
R	G	R	G	R	G
G	B	G	B	G	B
R	G	R	G	R	G



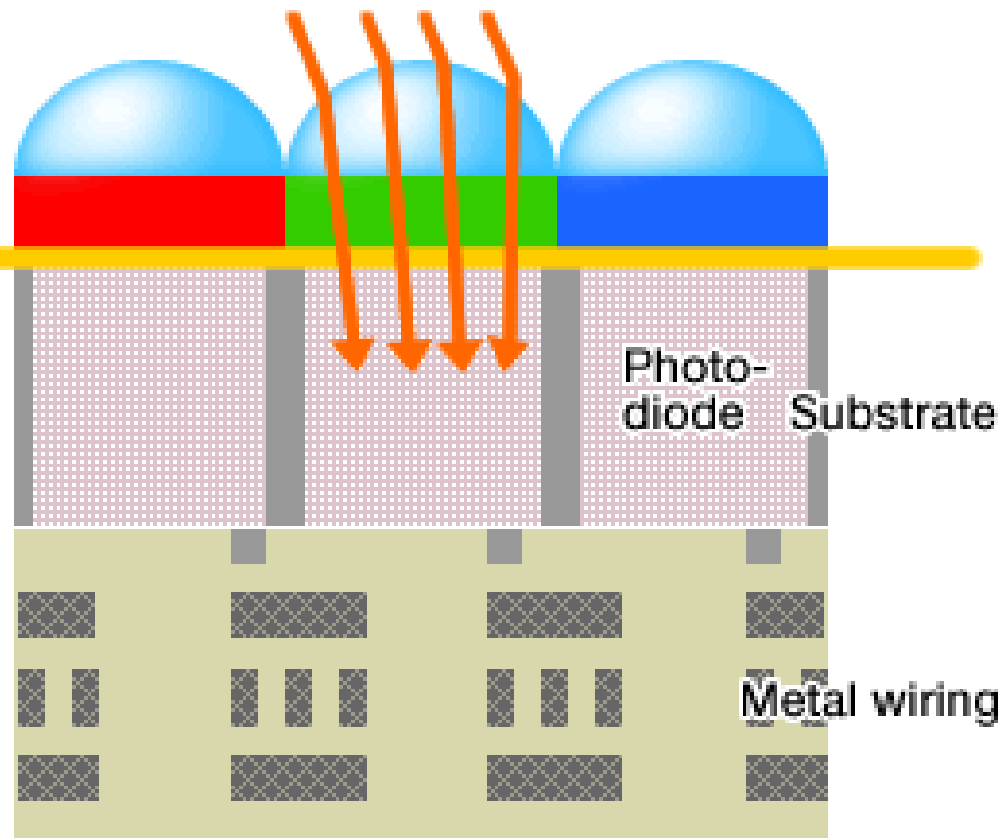
## Spectral Sensitivity Characteristics (Excludes lens characteristics and light source characteristics)

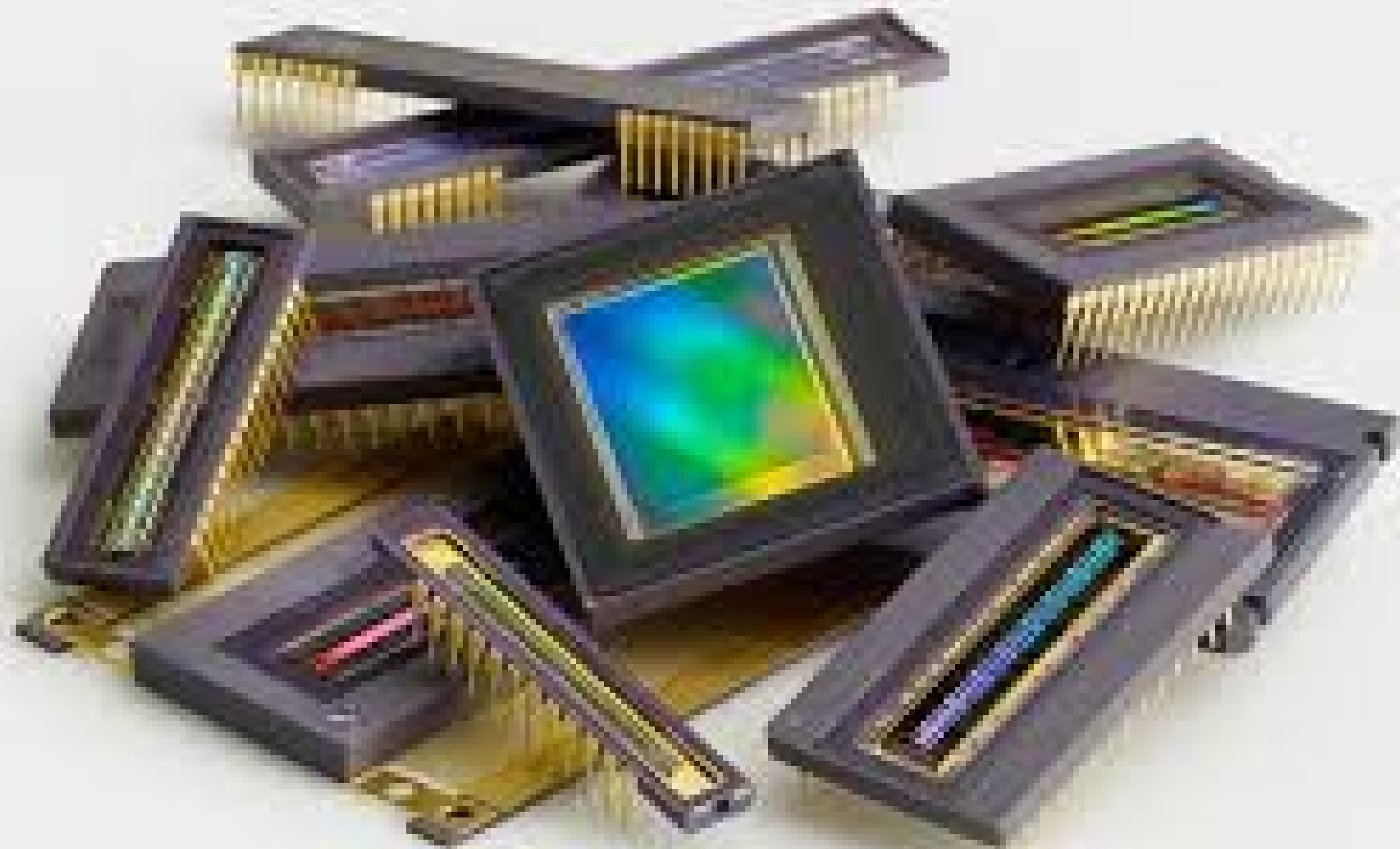


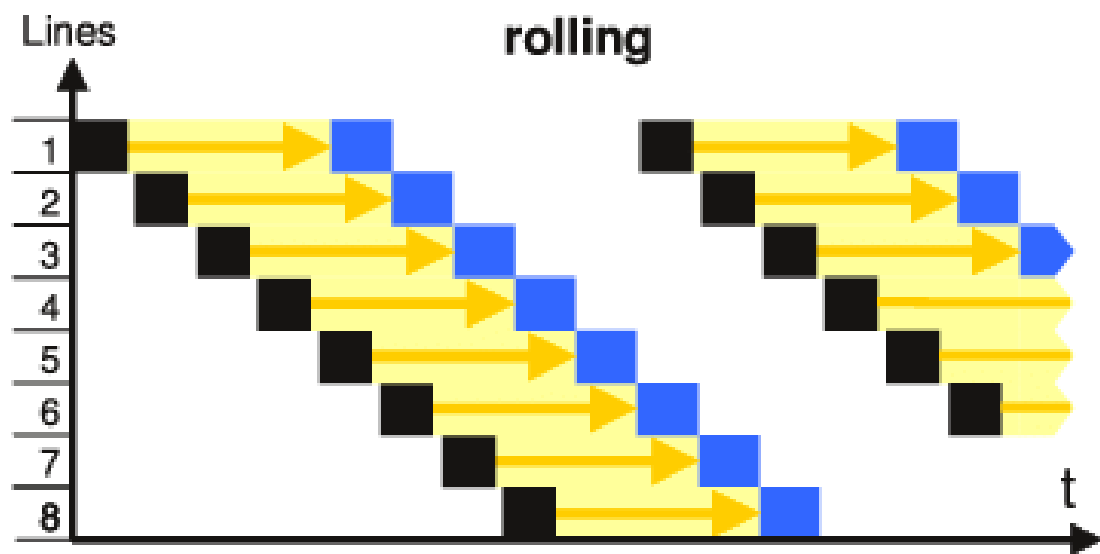
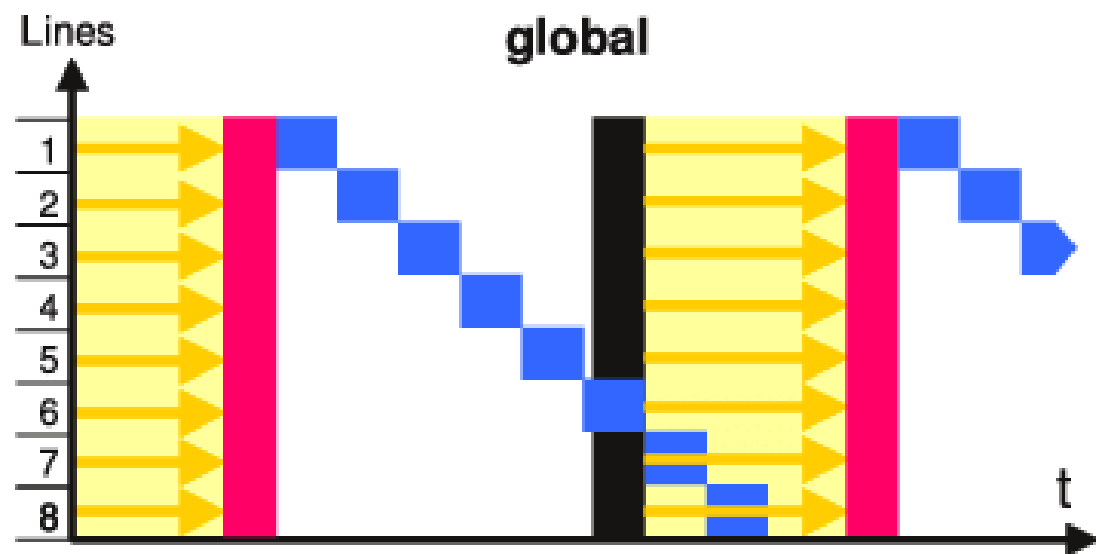
Front-illuminated structure



back-illuminated structure







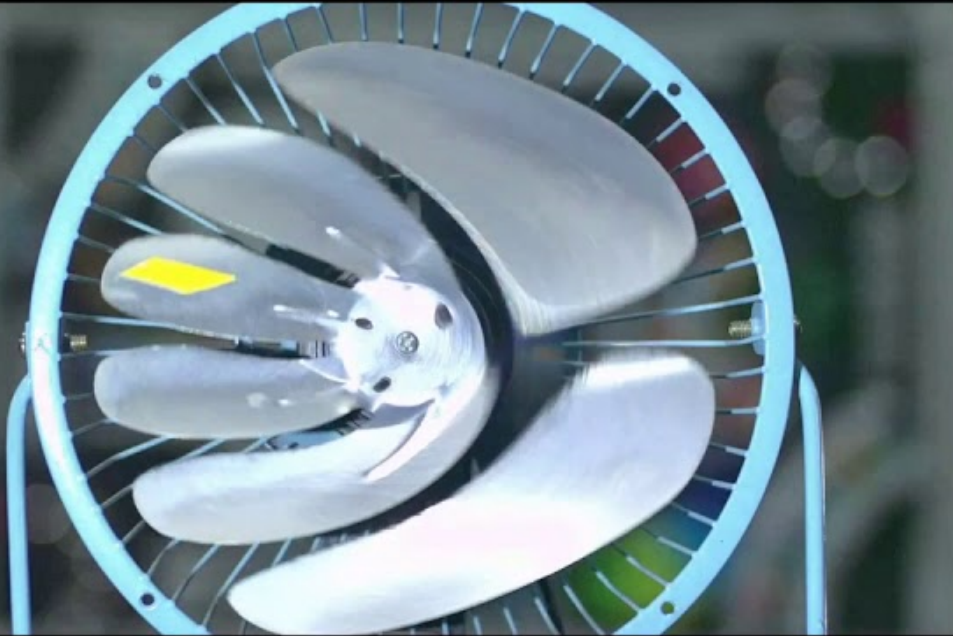
Reset

Readout

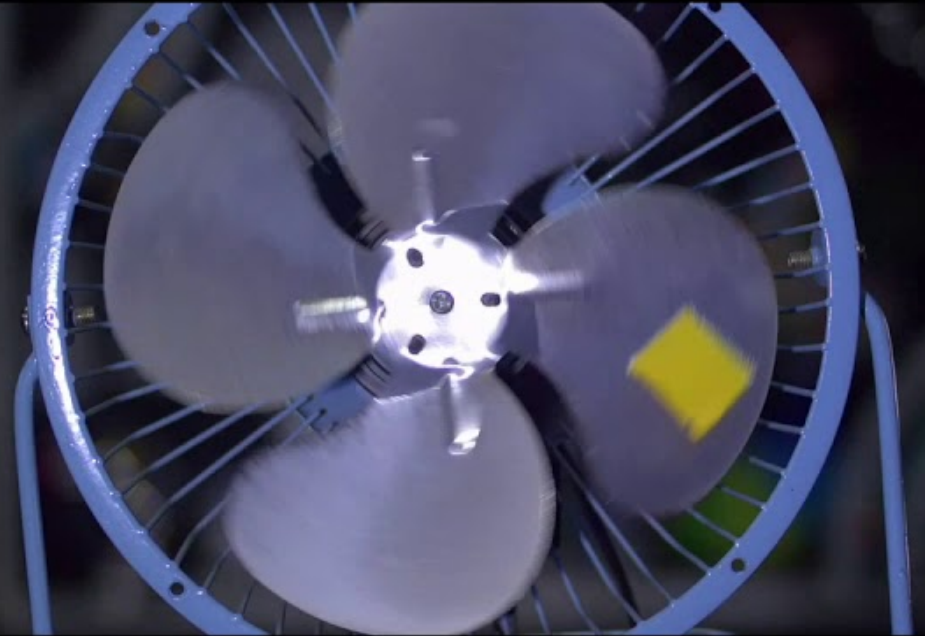
Exposure

Charge - Transfer

Rolling shutter



Global shutter



Shutter speed :1/2000

Quantum Efficiency of Front-Illuminated, Back-Illuminated and Back-Illuminated Deep-Depleted CCD Sensors

