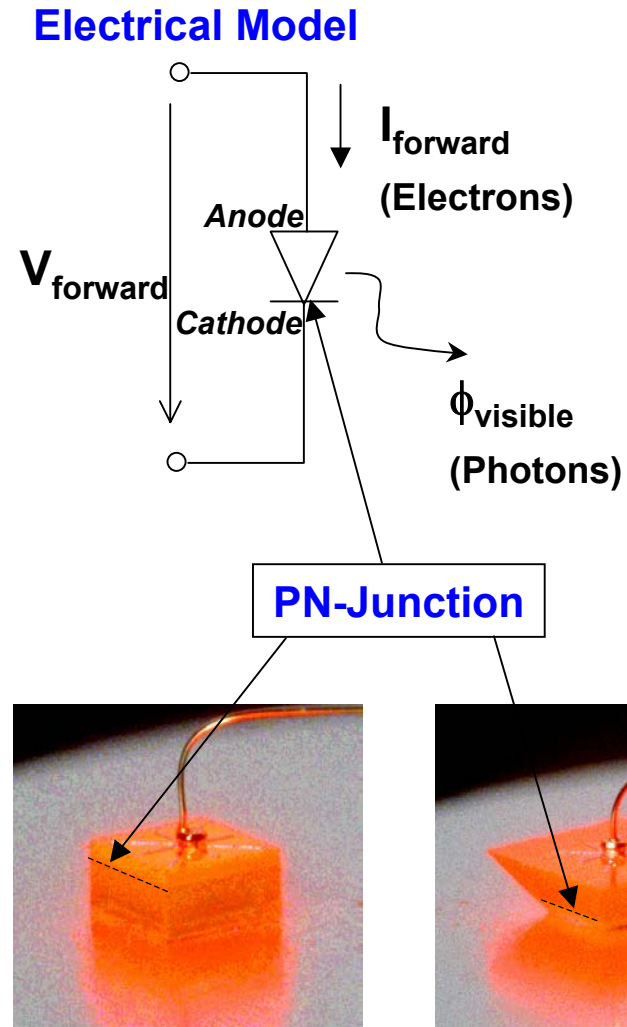


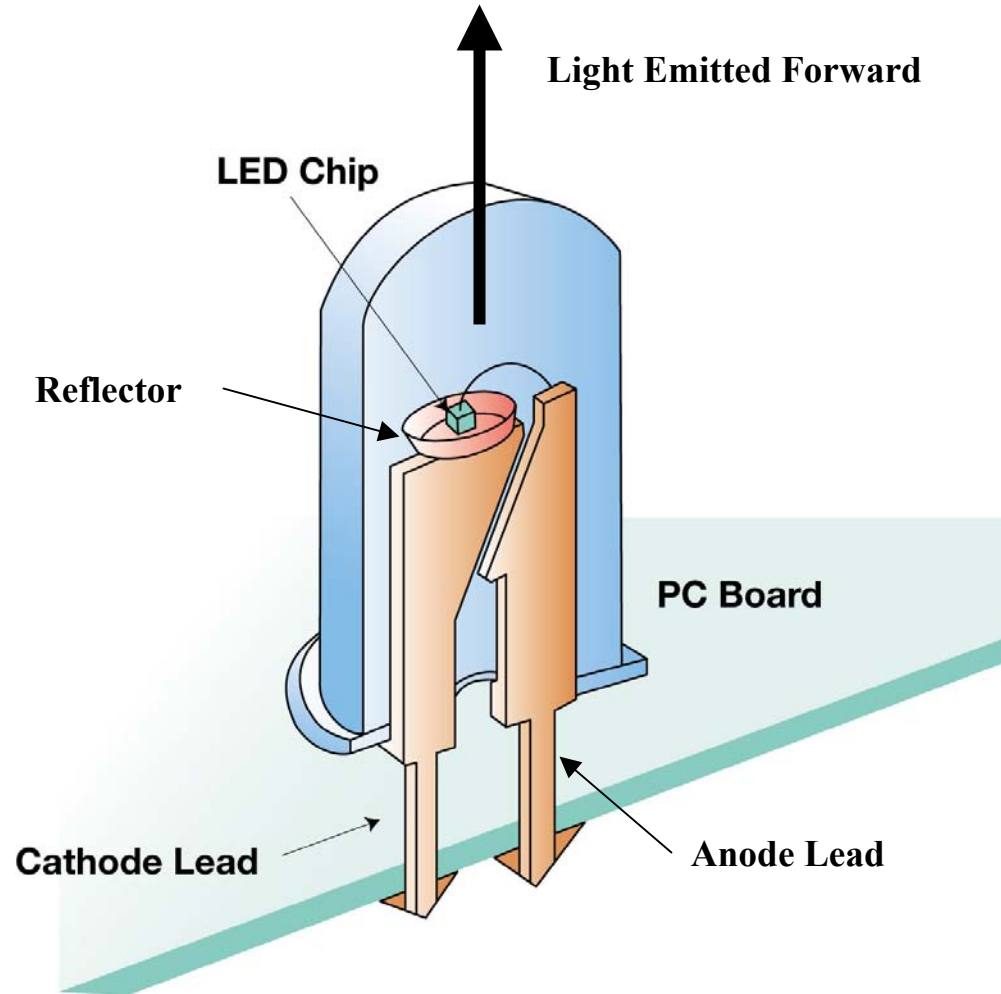
Language

- **Die = chip: heart of the LED**
- **LED - chip in a package**
- **PN Junction - where the light is created in the chip**
- **AllnGaP & AlGaS: red - yellow technology**
- **InGaN - green – blue +white technology**
- **Level 1 – the chip or die**
- **Level 2 – the LED**
- **Level 3 – a LED array; may include optics, heat sink and/or power supply**
- **Level 4 – LED luminaire**
- **Driver = ballast**
- **Thermal Resistance (C/W) - a measure of the heat transfer capacity of the LED - lower is better**
- **Binning - subdivision of the manufactured “distribution” into common operating parts (color, flux, forward voltage)**



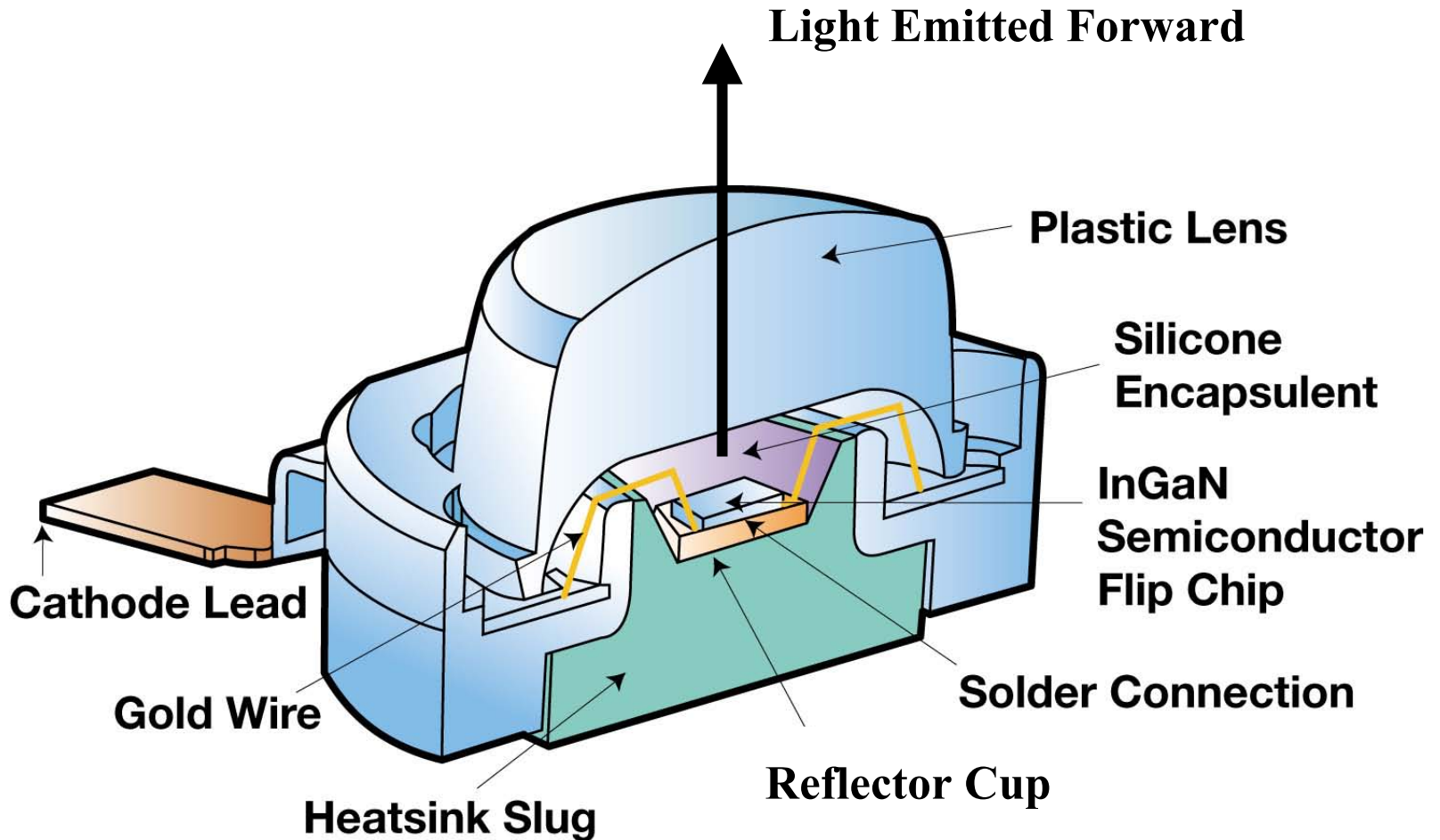
What is a LED?

Low Flux LED



What is a LED?

High Flux LED



What is a LED?

LED's Defined

- The exchange of positive and negative charges between these materials results in the emission of photons.

The image shows a standard periodic table of elements. A legend in the upper left identifies the color coding: red for Metals, green for Semimetals, and yellow for Nonmetals. A black circle highlights a region in the upper right quadrant, encompassing elements from Boron (B) to Xenon (Xe). The table includes atomic numbers, symbols, and atomic weights for each element. The legend also includes labels for 'Atomic number', 'Symbol', and 'Atomic weight' with arrows pointing to the corresponding fields in the Carbon (C) element box.

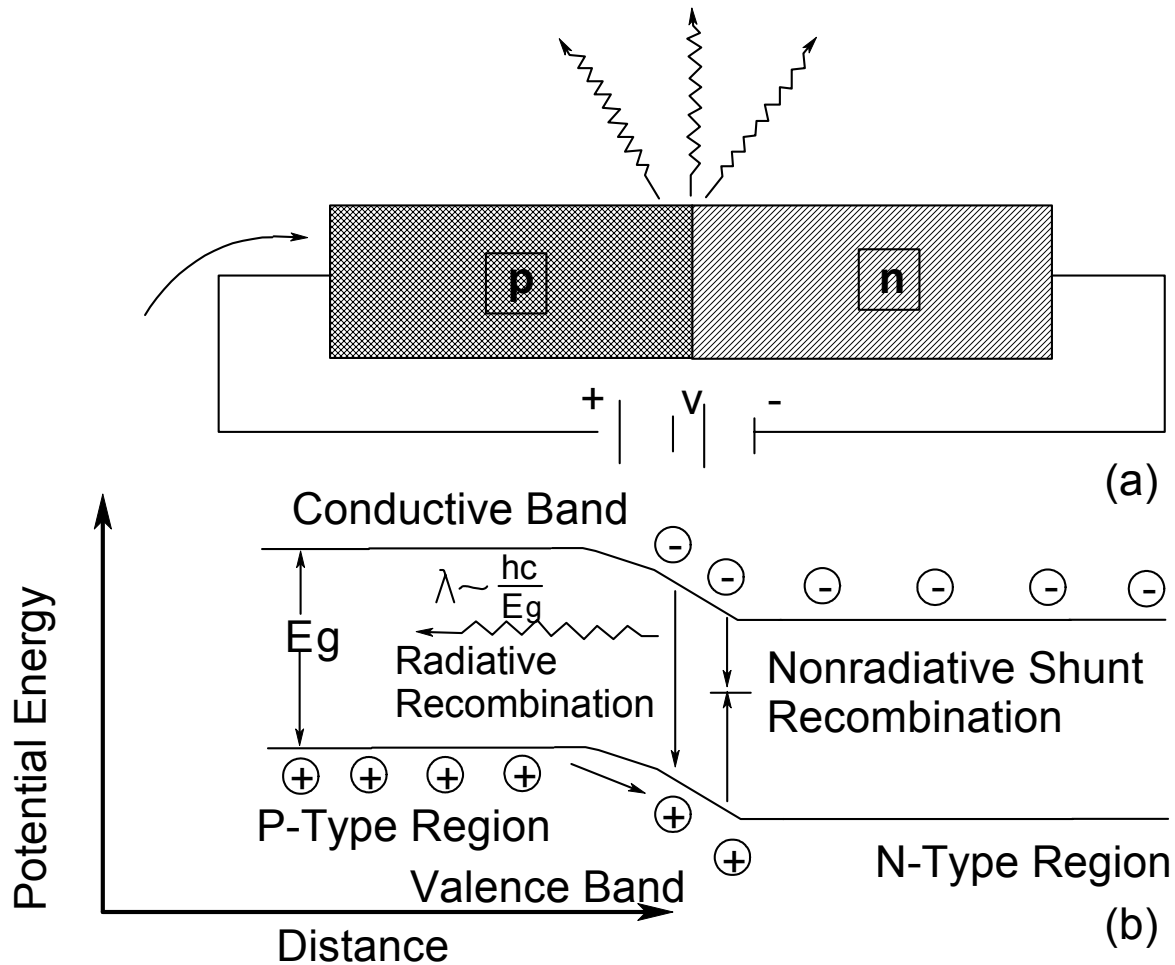
1																	18					
1	H																	He				
2	Li	Be															B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar				
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr				
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe				
6	Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn				
7	Fr	Ra	Lr	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub	Uut	Uuq	Uup	Uuh	Uus	Uuo				
			57	58	59	60	61	62	63	64	65	66	67	68	69	70						
			La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb						
			89	90	91	92	93	94	95	96	97	98	99	100	101	102						
			Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No						

(c) 1998
Kromer Paul

The Periodic Table

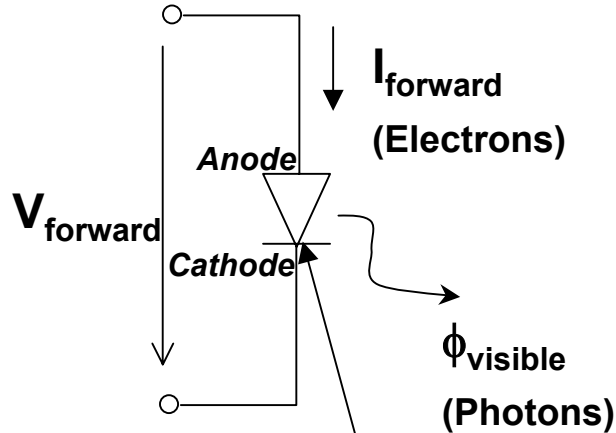
Courtesy io Lighting

What is a LED – How does it work?

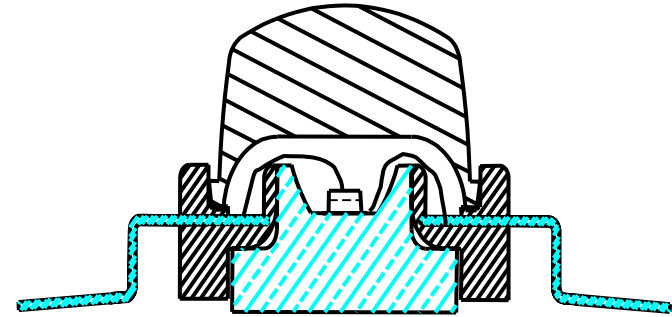
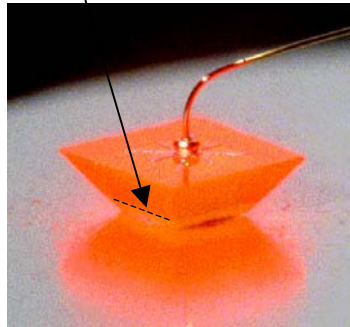
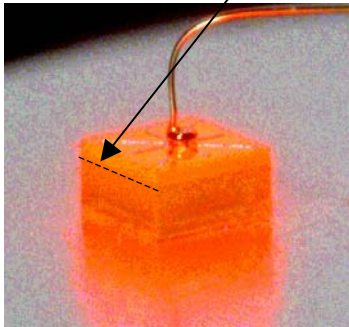


Working Principle of an LED

Electrical Model



PN-Junction

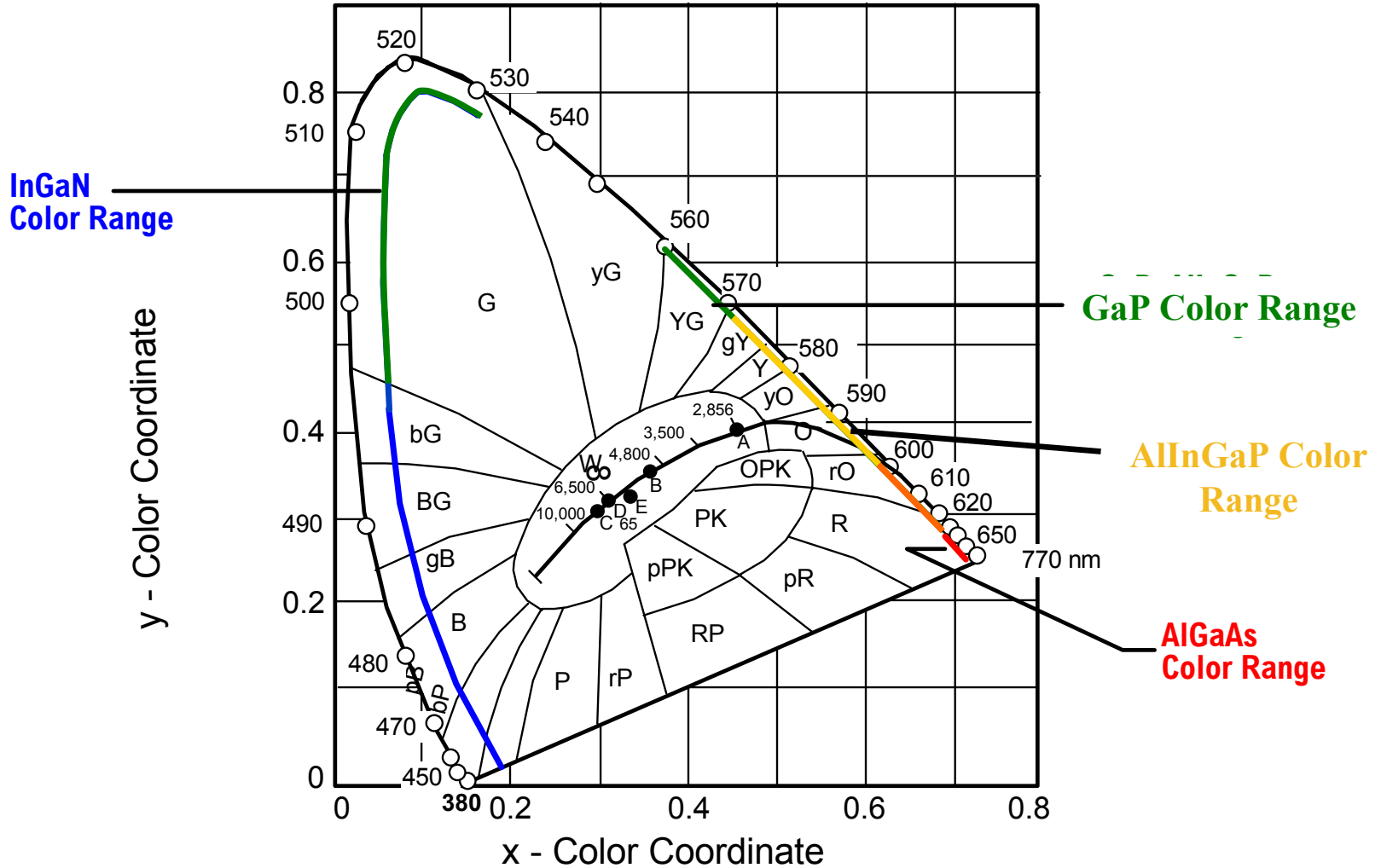


- Same principle for all colors (AlInGaP & InGaN)
- Power dissipation: 1-5 Watt
- Package Extraction Efficiency: >95%

• Maximum Ratings

- $T_{\text{junction-max}} = 120^{\circ}\text{C}$
- $I_{\text{forward-max}} = \text{Product dependent}$

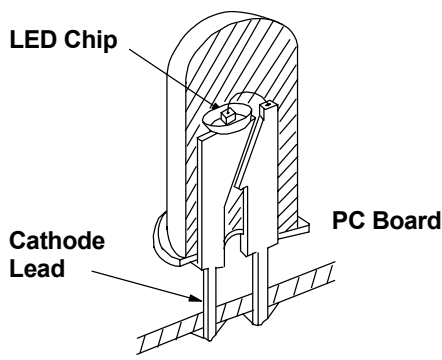
LED Color Ranges



Historical Development of LEDs

- **1962 – first LED, a novelty in the lab**
- **Late 60s – low output red LEDs (< 1 mcd) find commercial applications as indicator lamps**
- **mid 70s – Green LEDs**
- **Early 90s – Blue (Nakamura), completing spectrum**
- **Late 90s + - commercialization of high brightness LEDs**

Historical Development - Design Evolution of LED Packages

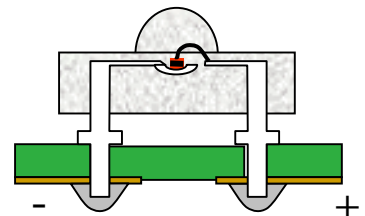


LED Chip

Cathode Lead

PC Board

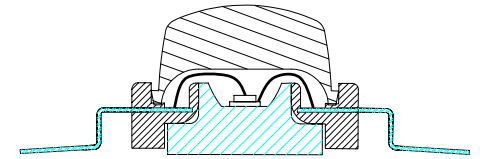
5mm Lamp
Circa 1970
2-3 lumens
 $I_f = 30$ mA



-

+

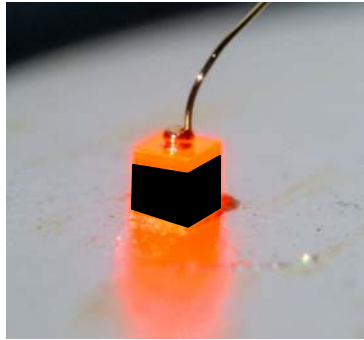
SuperFlux
Circa 1992
4-8 lumens
 $I_f = 70$ mA



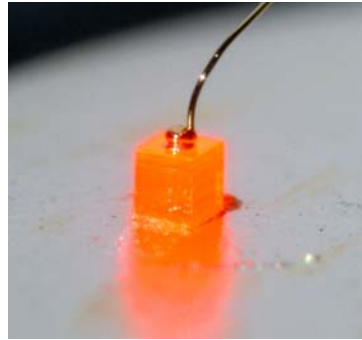
Luxeon
Circa 1997
20-40 lumens
 $I_f = 350$ mA

Historical Development - Better Light Extraction

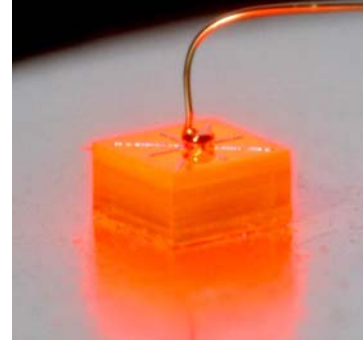
Absorbing Substrate (1991)



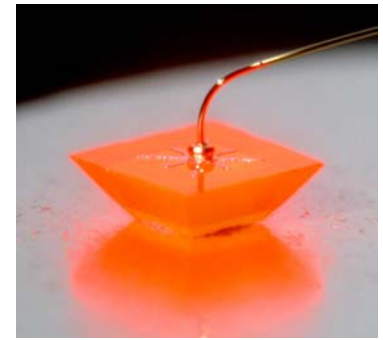
Transparent Substrate (1994)



Batwing (1998)

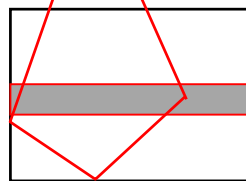
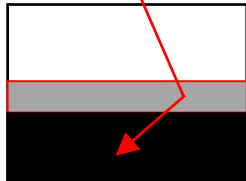


Lambertian (mid 2001)

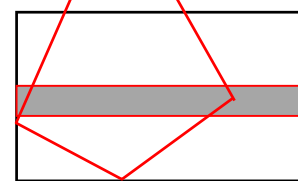


Increase surface area

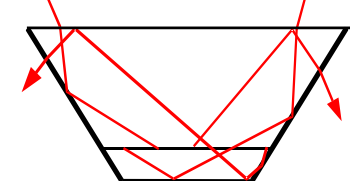
Re-shape Chip



~ 3x flux improvement



~ 15x flux improvement



~ 30x flux improvement