Light Emitting Diodes

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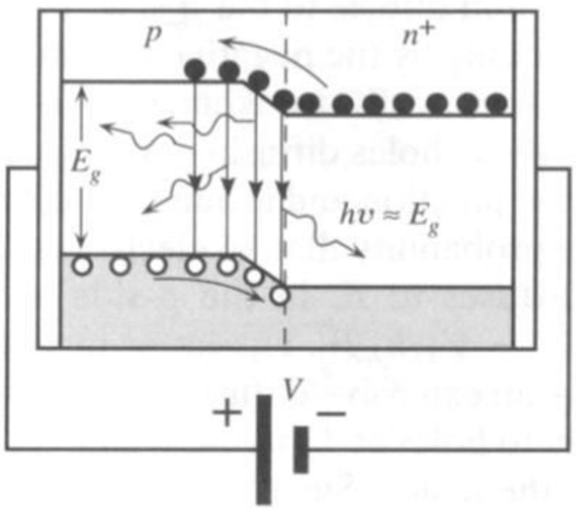
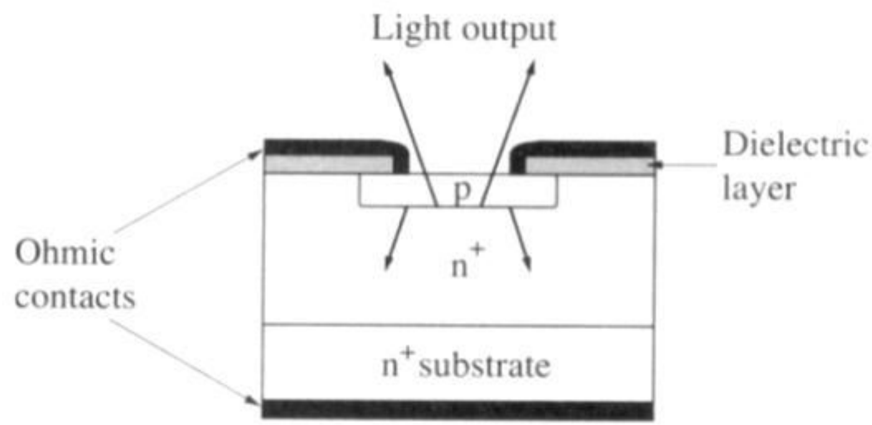
- **LED light output generated by strongly forward biasing a pn junction formed across the LED**
  - **Light generated by recombination of electrons and holes across junction**
  - **Wavelength controlled by band gap energy of the device**
  - **Plastic dome commonly used to minimize total internal reflection**
- **LED characteristics**
  - **Turn on voltage increases with increasing energy of emission**
  - **Light output linearly proportional to LED current**

Light Emitting Diodes





Energy diagram of heavily forward injected p – n⁺ junction showing carrier recombination (left) and cross section of planar surface emitting LED (right).

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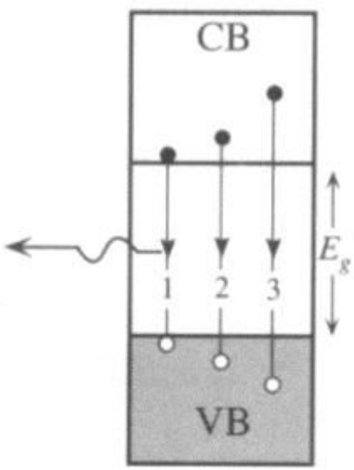
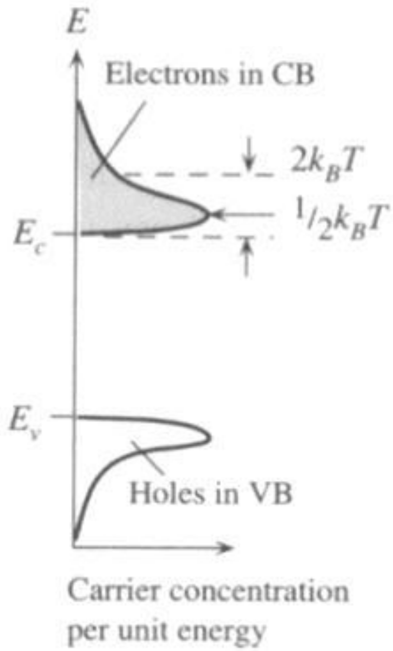
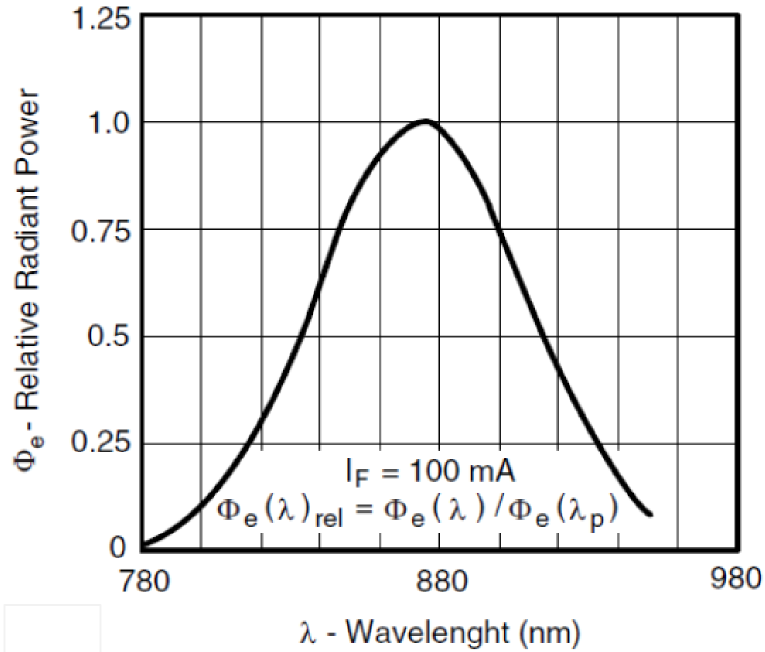


$\lambda(\mathrm{nm}) \approx 1240 / E_g(eV)$





Energy band diagram with possible recombination paths (left), energy distribution of electrons and holes (center), and output spectra of infrared LED (right).

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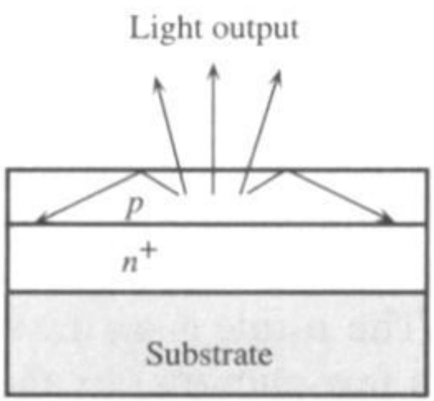

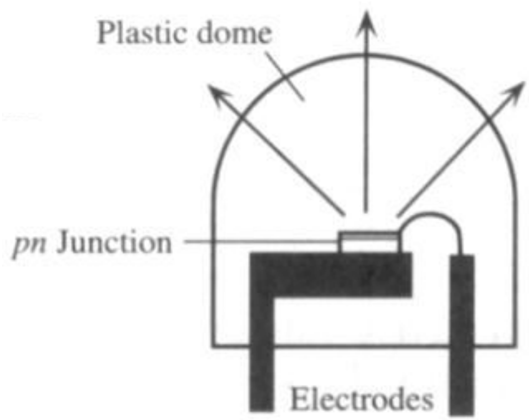

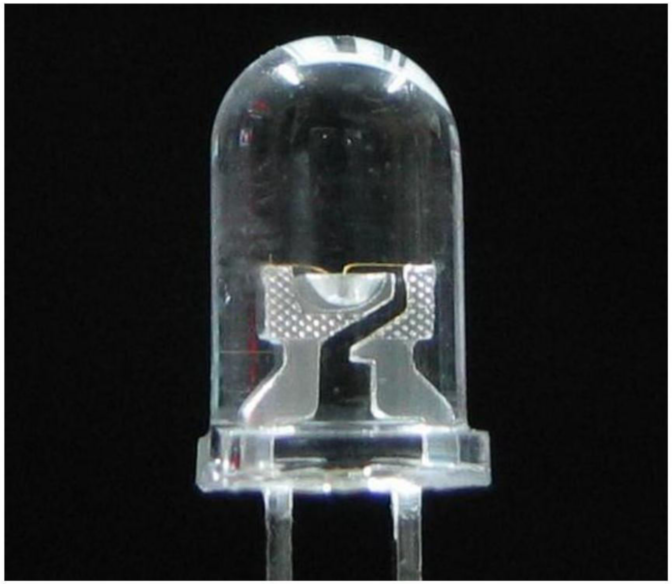

Planar light emitting diode showing total internal reflection (left), LED encapsulated in a transparent plastic dome (center), and actual LED (right).

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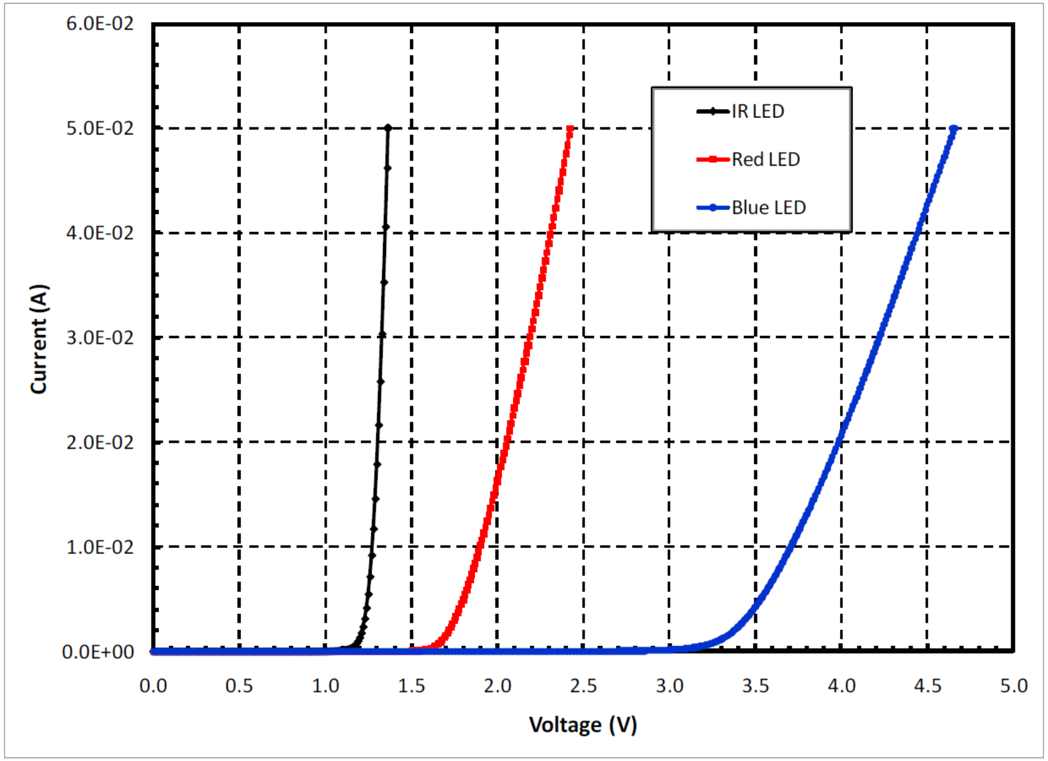
Table 1. Specifications of LEDs.

Color	V_{fwd} @ 20 mA	Light Intensity	Peak Wavelength (nm)	Composition
Infrared	1.5 V	20 mW/sr	875	GaAlAs
Red	2.0 V	10 mcd	635	GaAsP on GaP
Blue	3.9 V	15 mcd	428	GaN on SiC



Specifications for LEDs (top) and LED I-V characteristics (bottom).

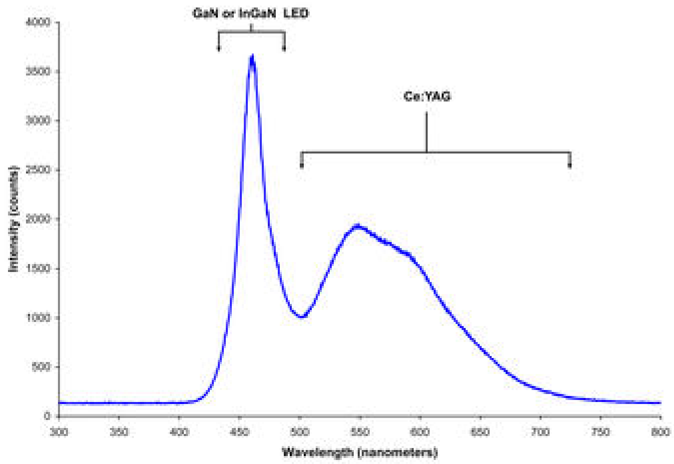
White LED

White LEDs are created by coating LEDs of one color (mostly blue LEDs made of InGaN) with phosphors of different colors to form white light;

the resultant LEDs are called phosphor-based or phosphor-converted white LEDs (pcLEDs).

A fraction of the blue light undergoes the Stokes shift, which transforms it from shorter wavelengths to longer. Depending on the original LED's color, various color phosphors are used. Using several phosphor layers of distinct colors broadens the emitted spectrum.

Most commonly employed Phosphor : YaG



More Information:

https://youtu.be/15CTEn0Uaew

https://youtu.be/No8PZsLnjZU

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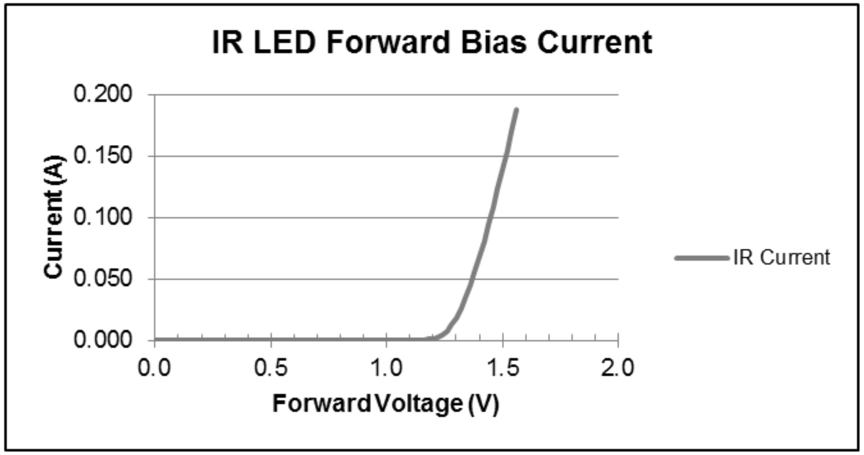
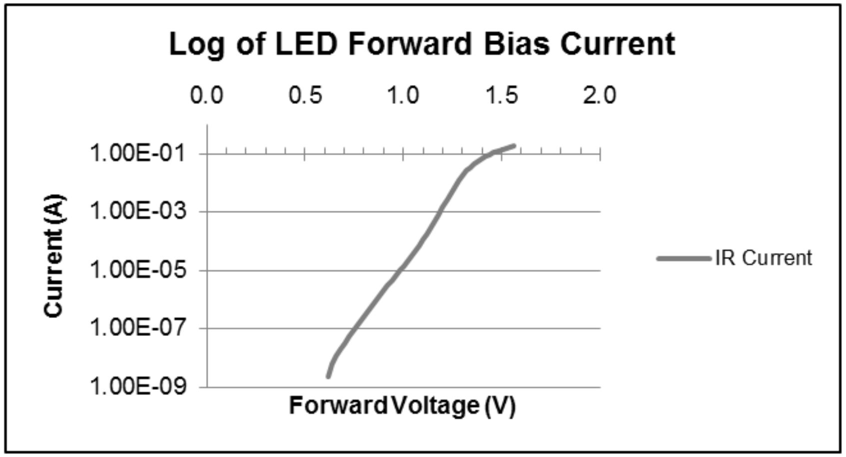
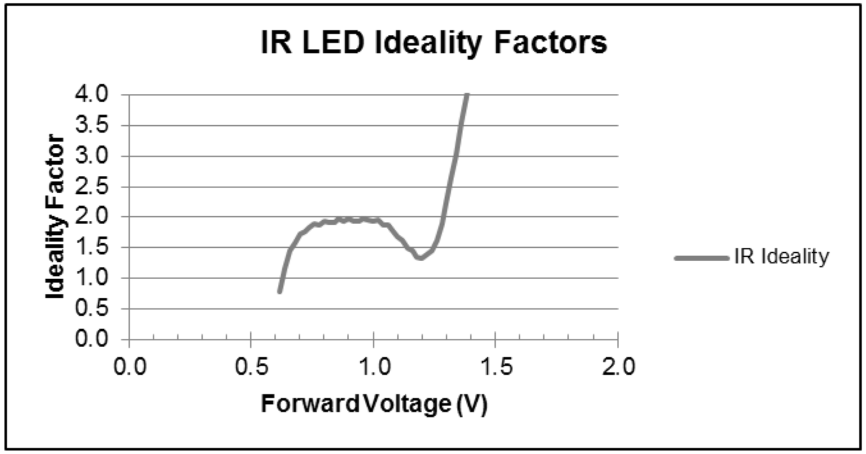
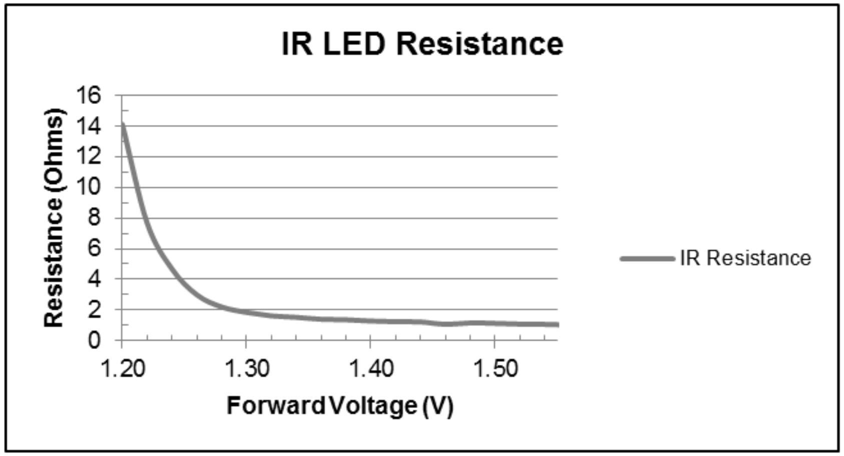


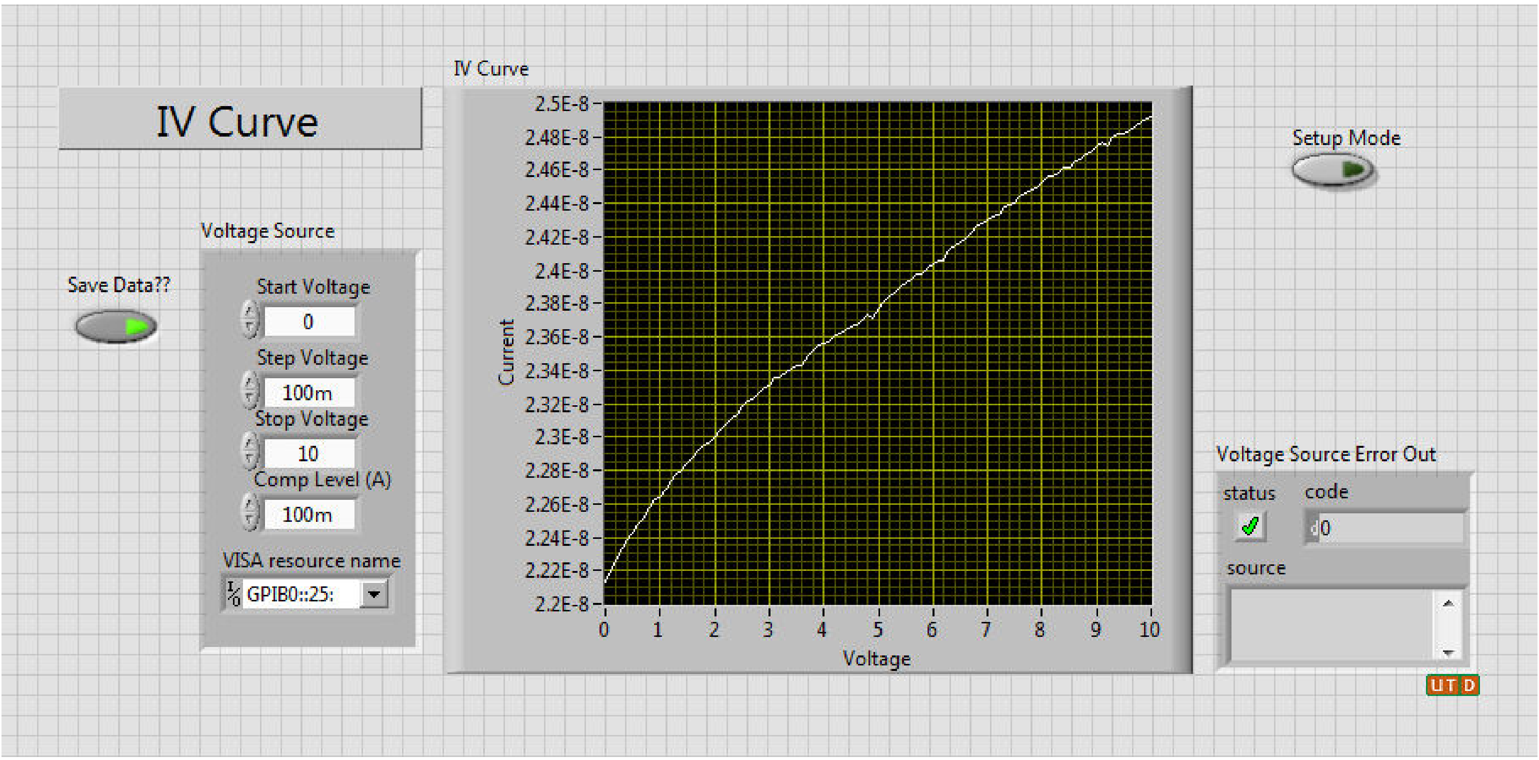






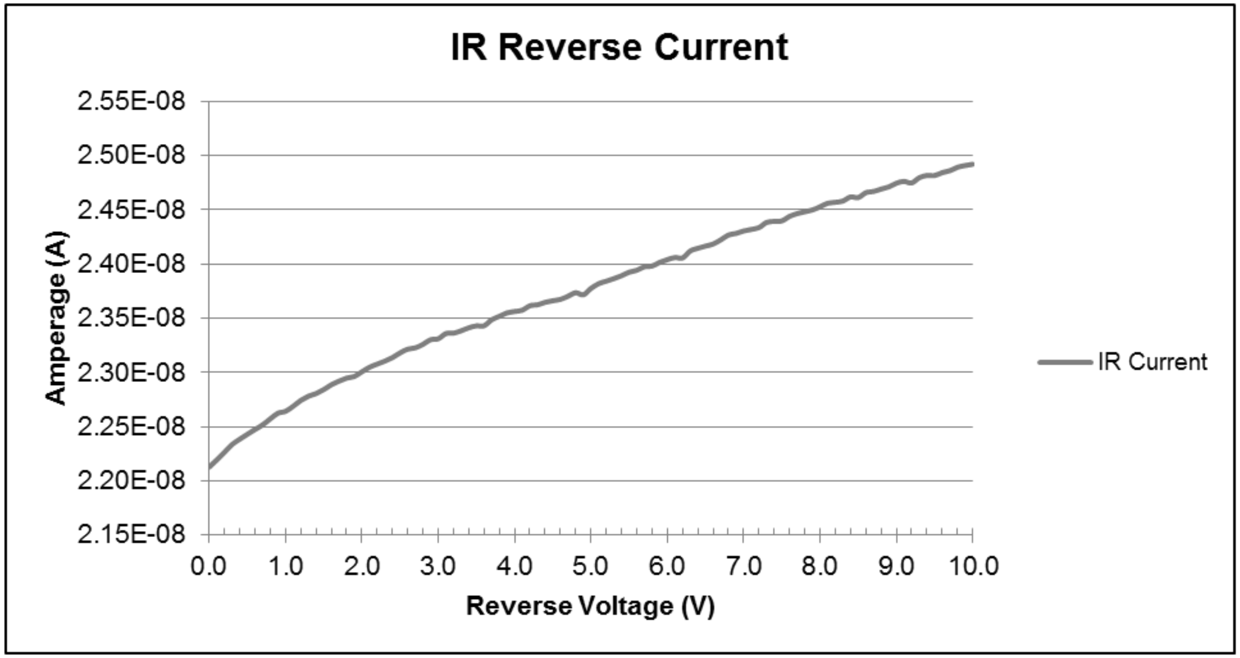
Forward I-V characteristics, ideality factor, and resistance for infrared LED.

Light Emitting Diodes

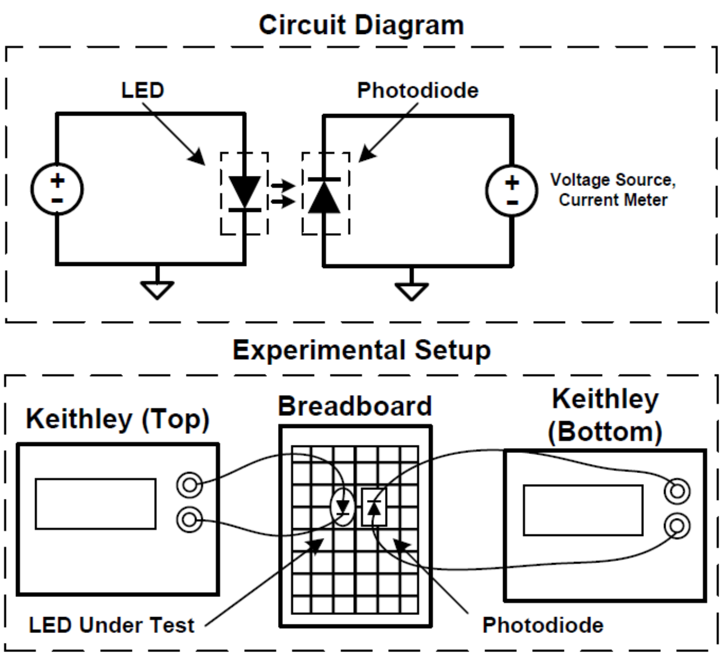


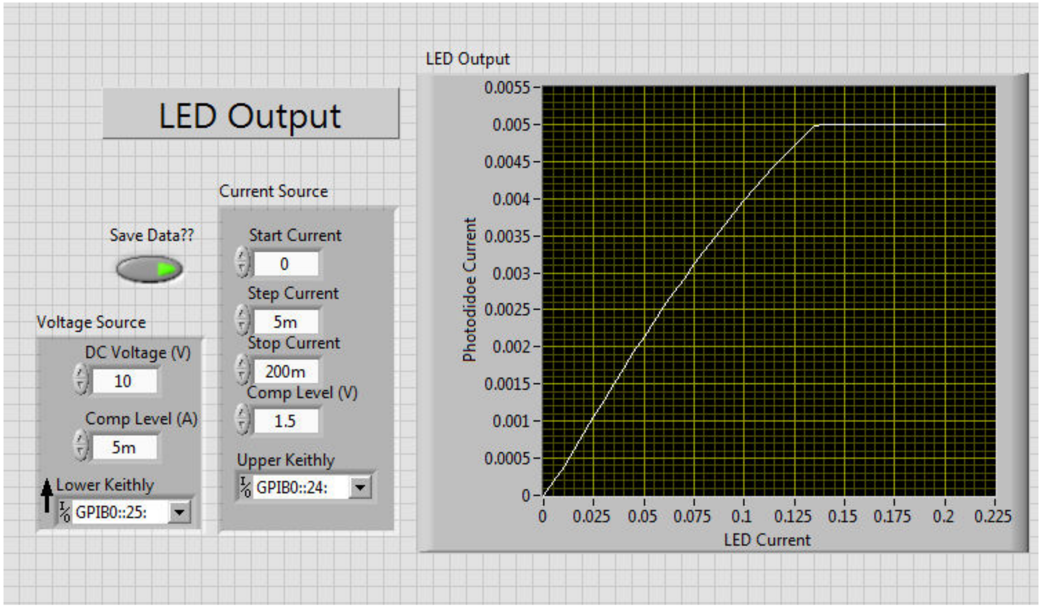
Reverse biased test configuration for infrared LED.

Light Emitting Diodes



Reverse biased diode characteristic for infrared LED.





Circuit diagram and experimental setup (left) and LabView test configuration (right) used to generate light output for infrared LED.

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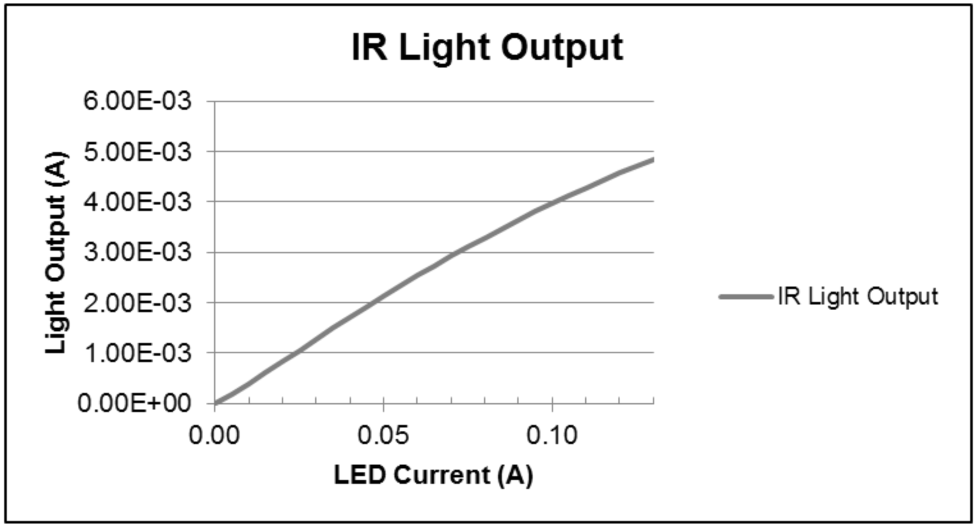
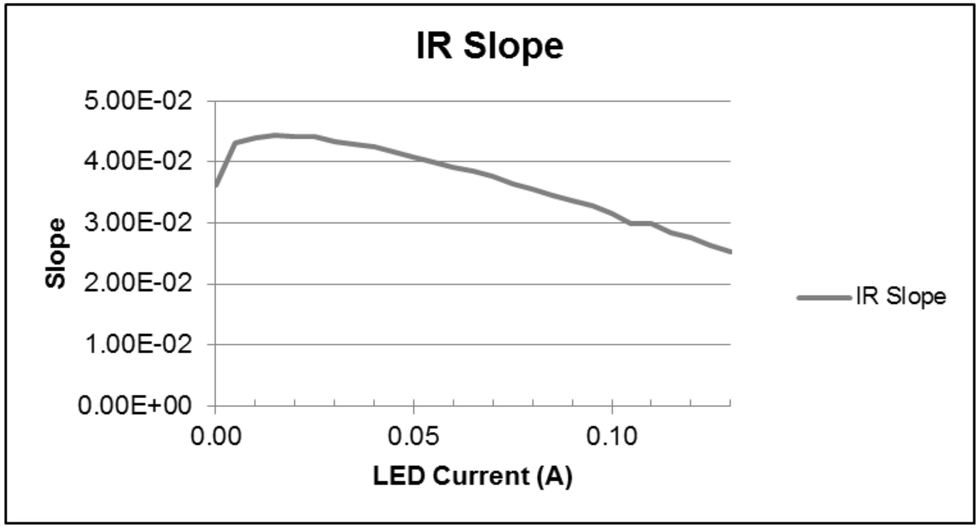
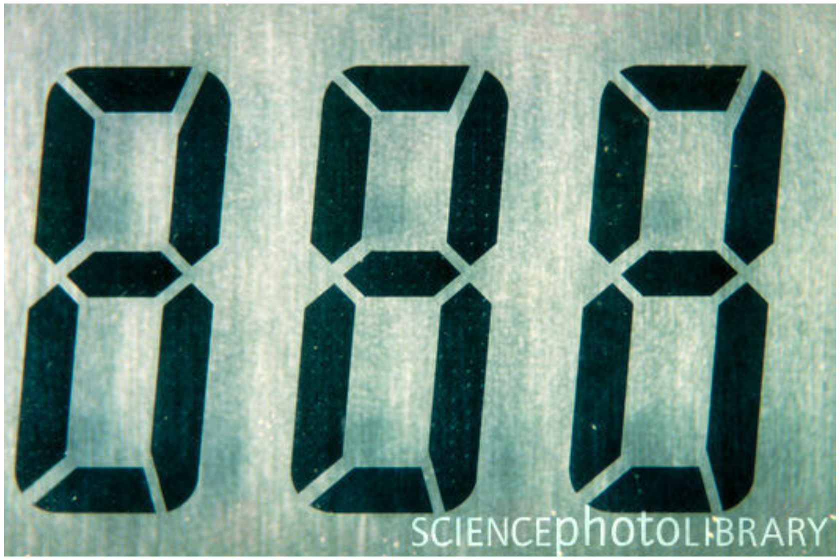




Light output and slope of light output versus LED current for infrared LED.

Liquid Crystals

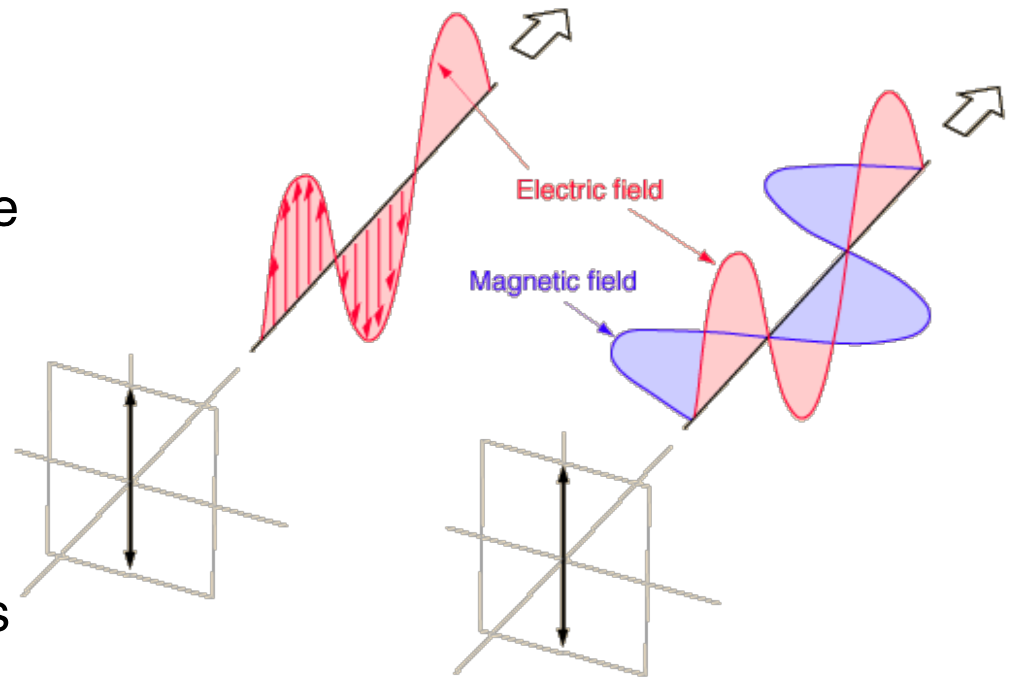


Key things

- Liquid crystals do NOT emit light!
- Liquid crystals should NOT be run on DC

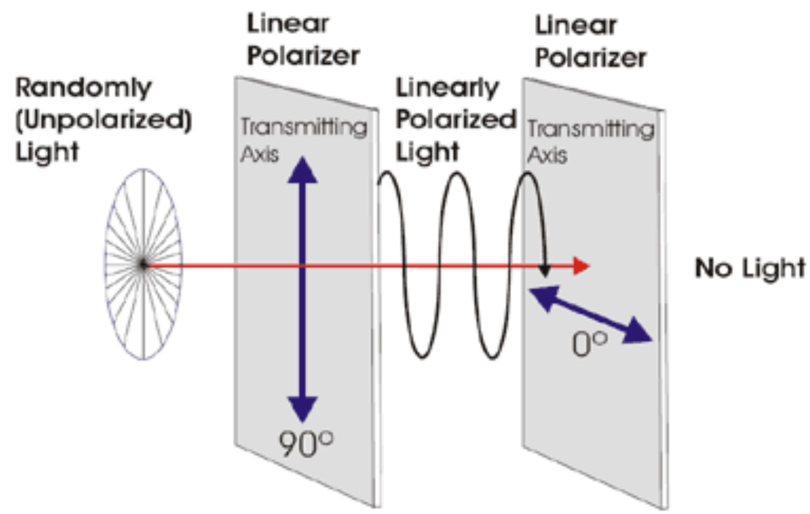
How do they work?

- They use polarization
- Light is a wave
  - An electromagnetic wave
    - Has an electric field
    - And a magnetic field
  - The polarization is the direction of the electric field
  - In this picture, the light is polarized vertically



Suppose light is polarized already?

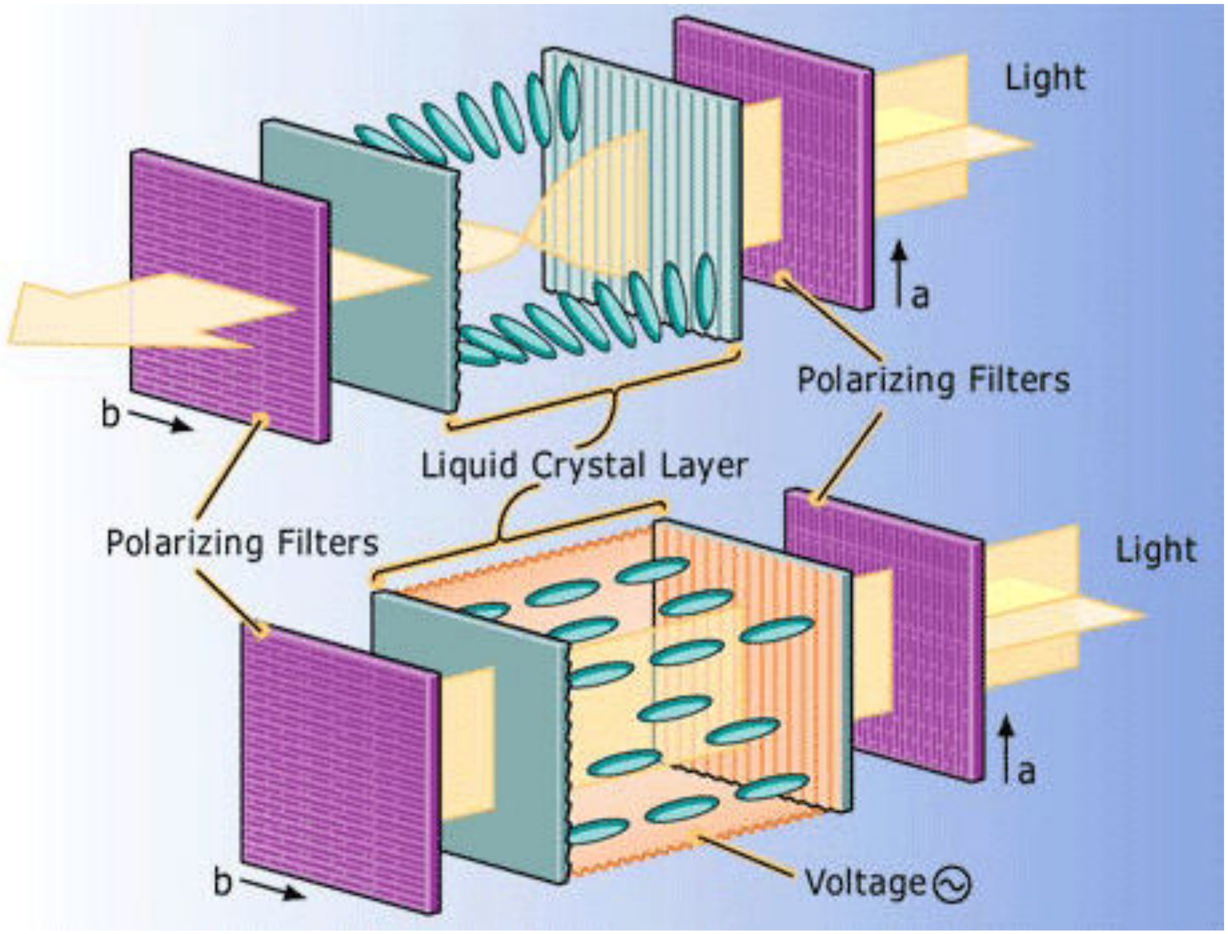
- What if light is polarized vertically?
- What if you try to pass it through a horizontal polarizer?



It won't go through!

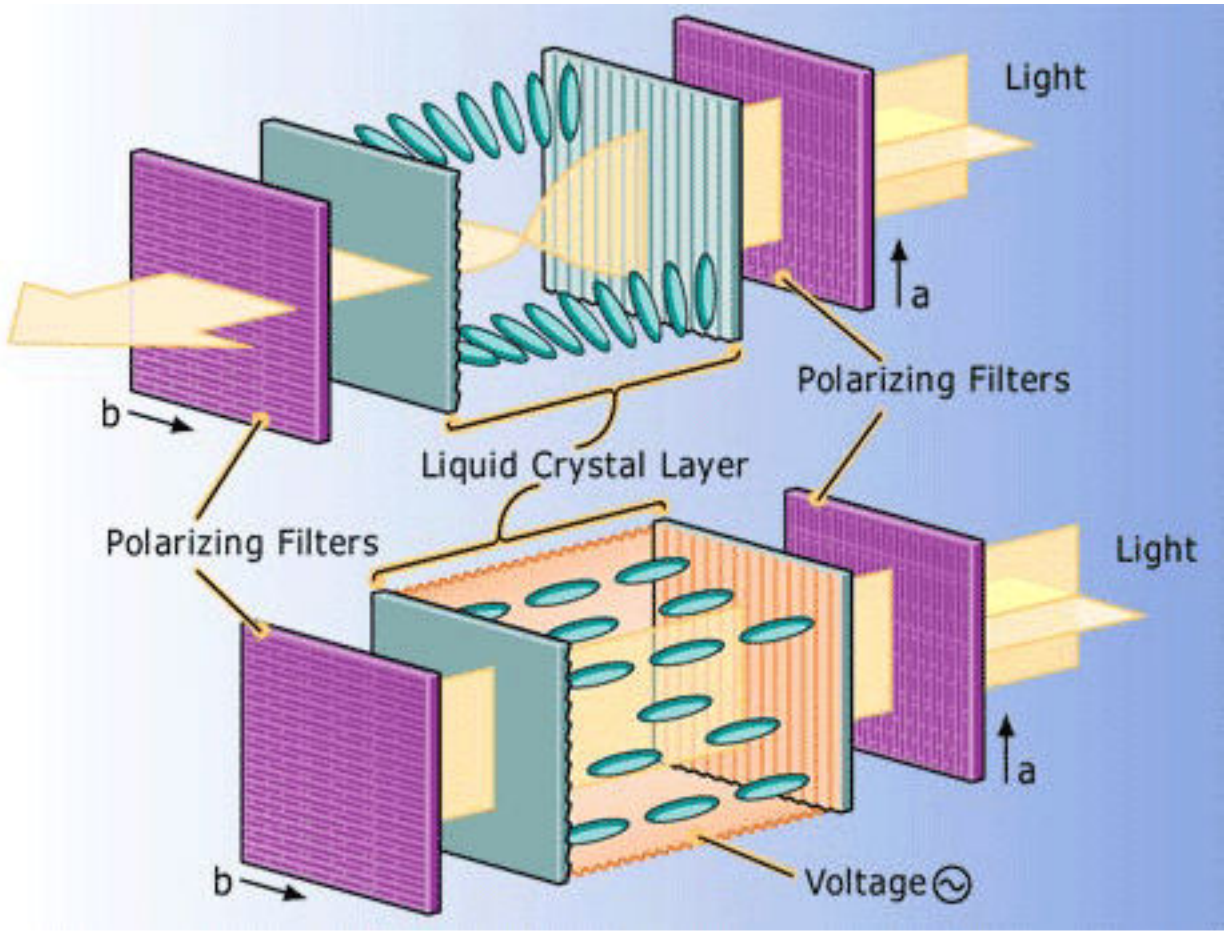
How do liquid crystals work?

- They change the polarization of the light
- Put a polarizer on the front and back
- The molecules are arranged in a twist
- They twist the polarization so it passes through the back
  - With no voltage applied



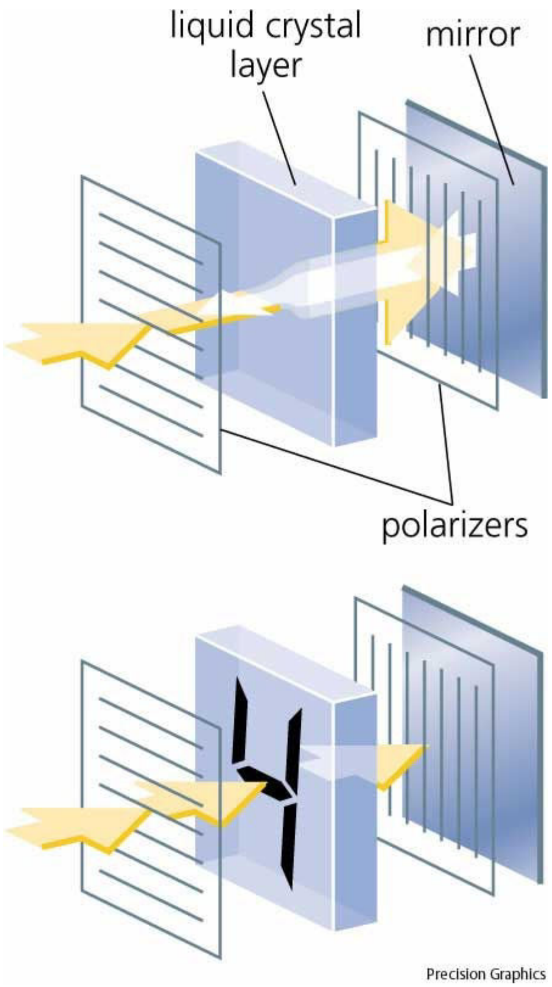
When you apply the voltage

- The molecules turn end-on so the light doesn't get twisted
- Light can't pass through the second polarizer
- Looks black
- This is a transmissive display
  - It's lighted from the back



Reflective LCD

- Mirror on the back
- Light comes from front



More Information:

https://youtu.be/tUGJlBB2qK0

https://youtu.be/F0aeFniieB8