Georgia Institute of Technology

Computational Photography

Dr. Irfan Essa
Professor
School of Interactive Computing

Study the basics of computation and its impact on the entire workflow of photography, from capturing, manipulating and collaborating on, and sharing photographs.

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Cameras, Optics, Lenses, and Sensors

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Cameras: Sensors (and Film), where Rays of Light become Pixels

Lesson Objectives

- ★ Describe in your own words the Photographic Processes for Digital and Film Capture
- ★ Recall all Eight (8) layers of Color Film
- ★ Recall all Five (5) layers of a CCD
- ★ Describe in your own words at least one (1) difference between a CCD and CMOS Sensor
- ★ Explain two (2) benefits of using the Camera Raw Format

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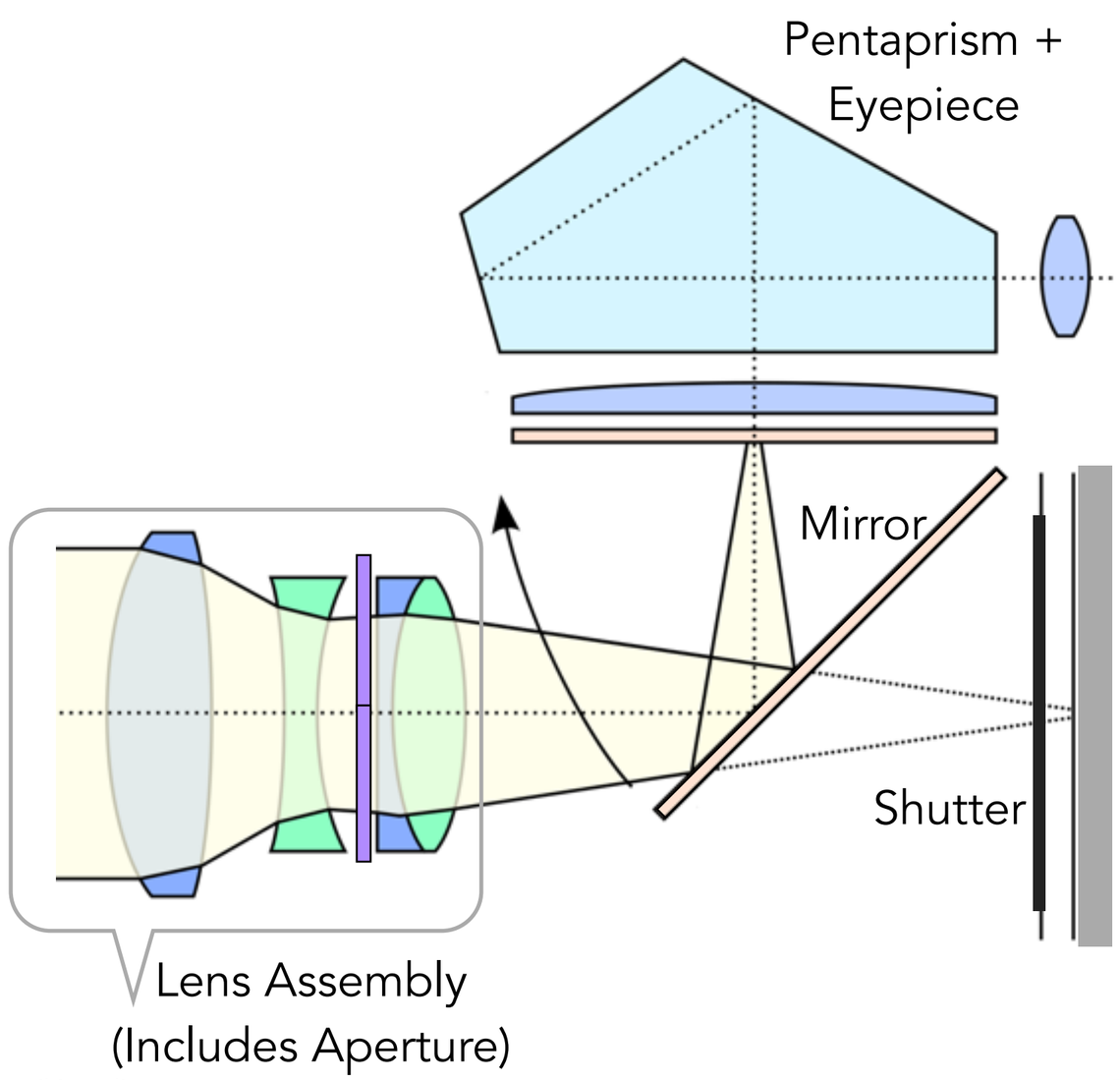
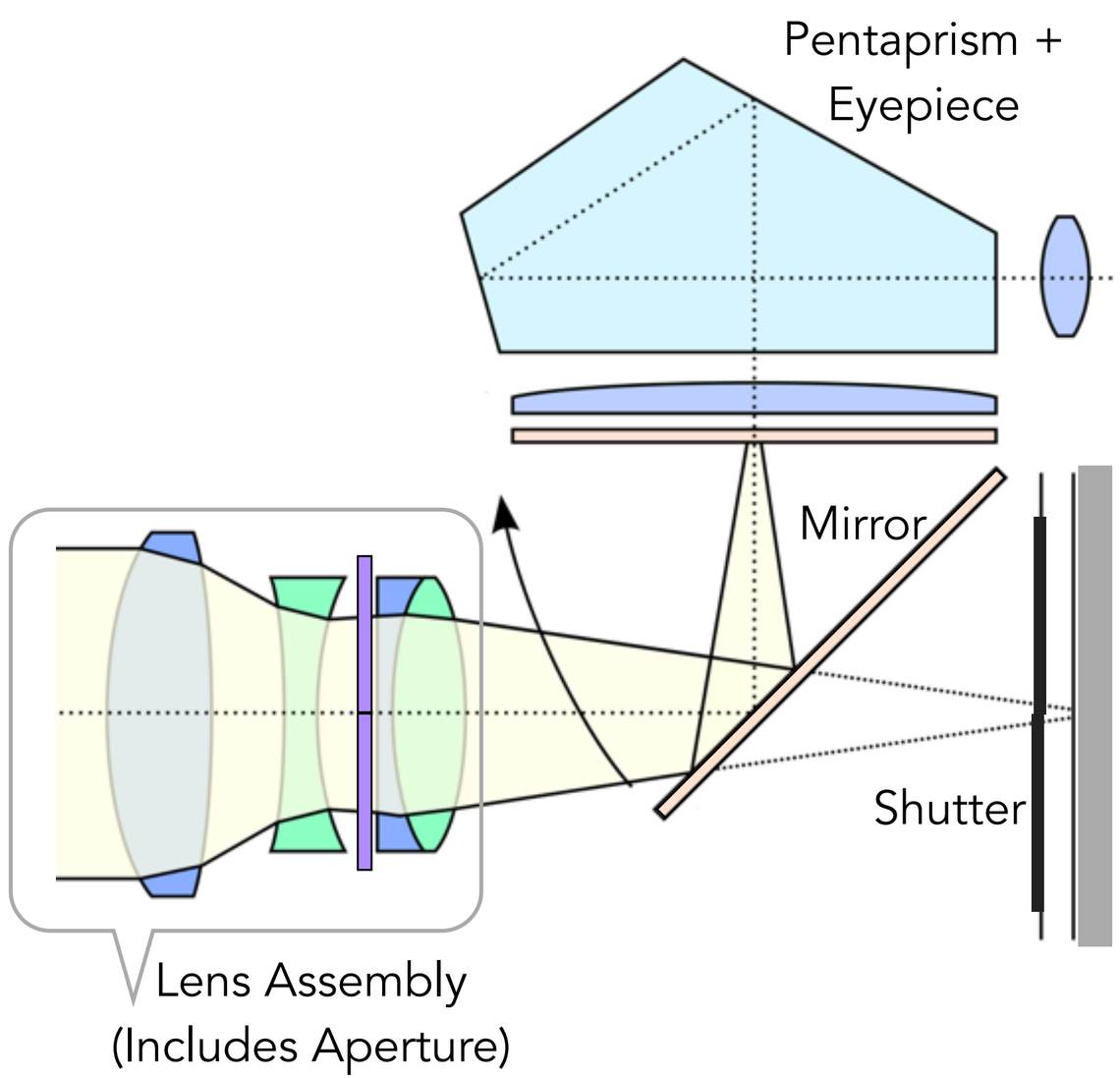
Inside a Camera (an SLR)



Adapted from commons.wikimedia.org/

1. Lens assembly
   a. Includes Aperture
2. Shutter
3. Sensor/Film
4. Mirror
5. Pentaprism or Pentamirror and Eyepiece

Inside a Camera (an SLR)



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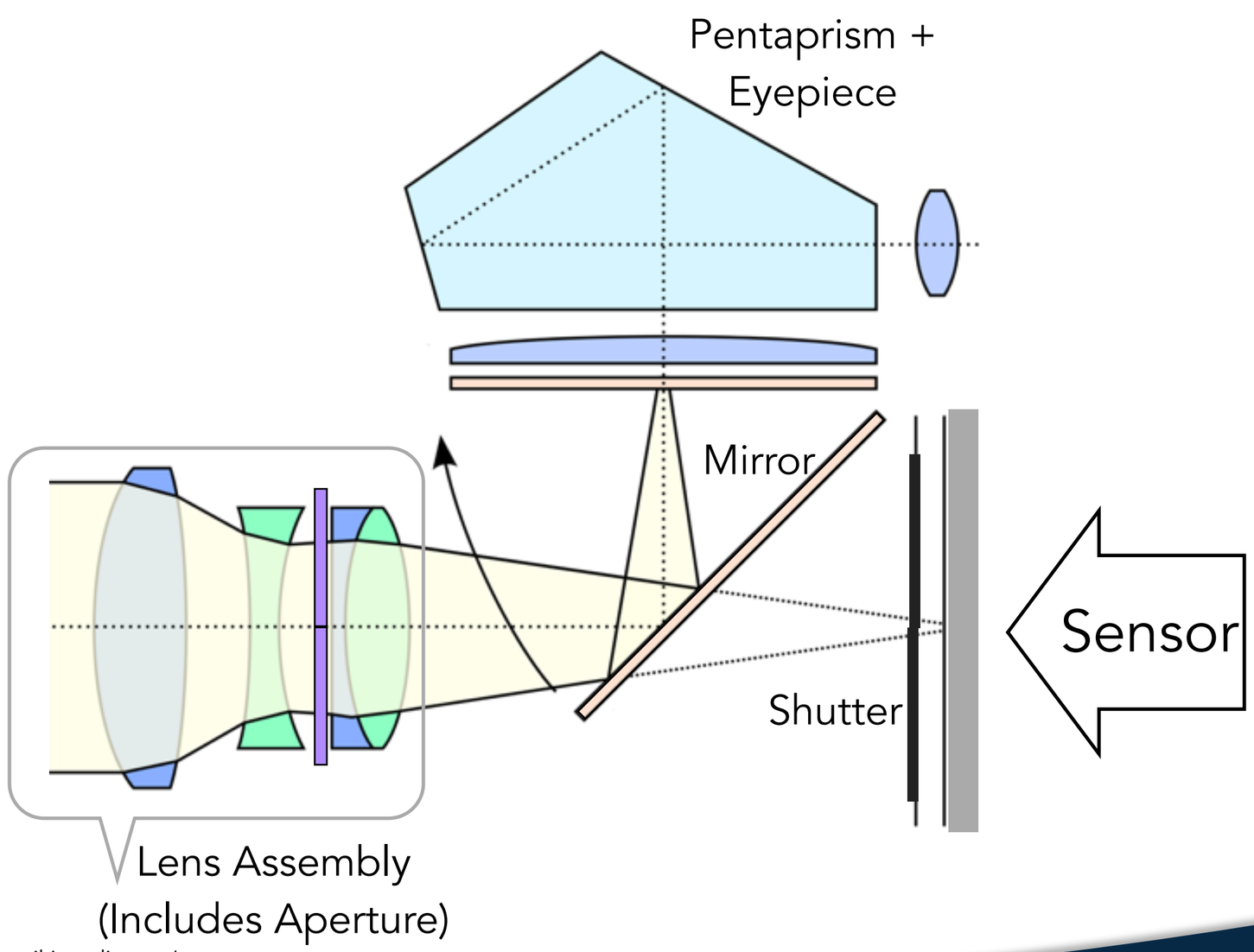

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Film vs. Digital

- ★ Film and Digital Cameras are essentially (say 80-90%) the same.
  - Optics, Aperture, Shutters are almost the same (though there have been significant improvements in actuators, and lenses).
- ★ Difference is how light is "trapped and preserved" for later use.
- ★ Chemical process for Film, and Electronics for Digital "capture the moment" in Time and Space and make it "cherish-able."

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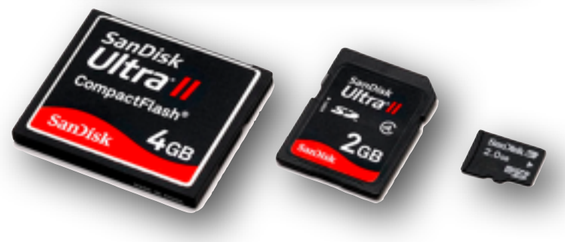

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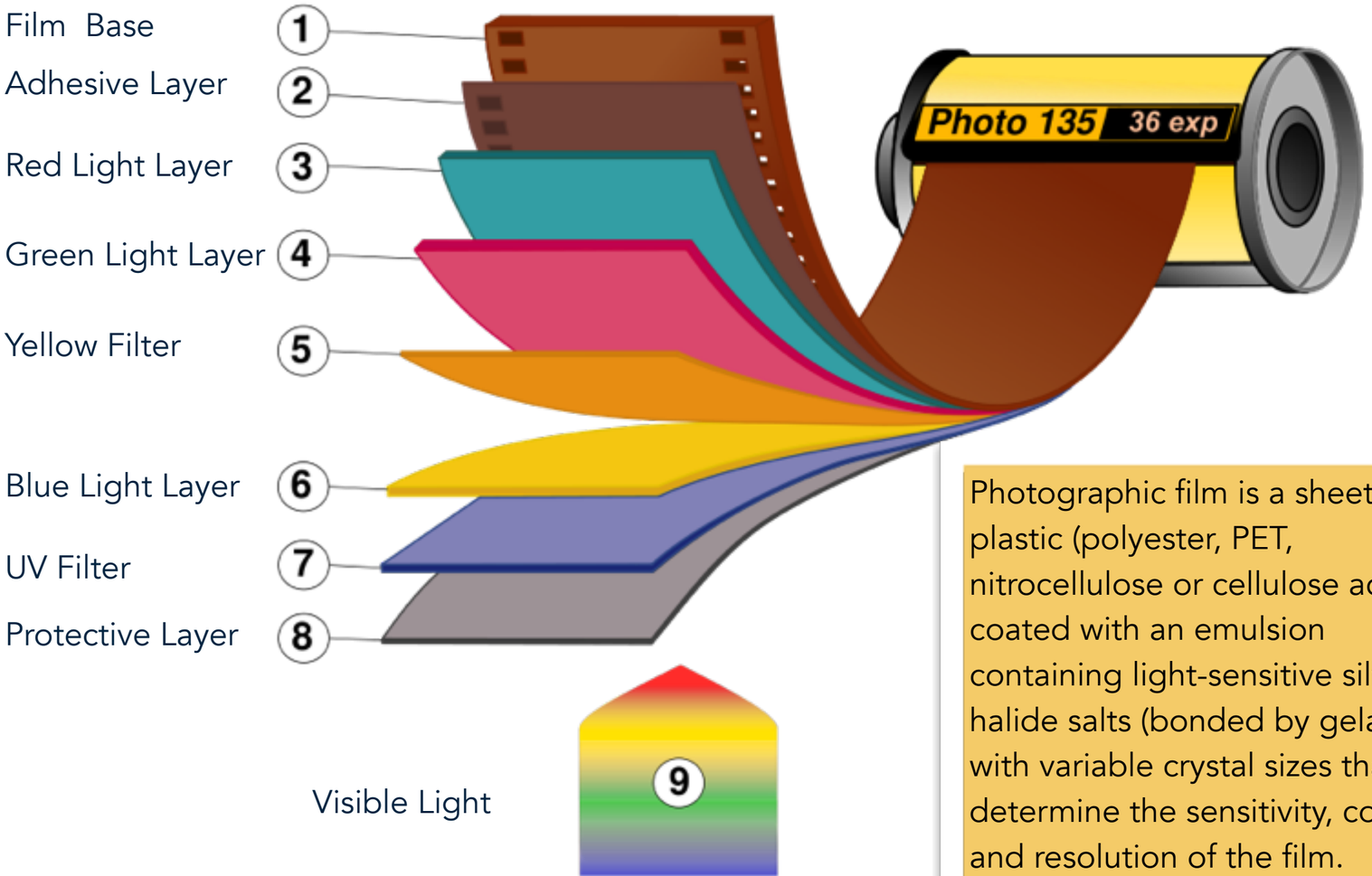
Film: Reaction between Light and Chemicals



http://commons.wikimedia.org/wiki/File:Photographic_Film_135.svg

1. Film base + Antihalation Coating
2. Adhesive layer
3. Red light sensitive layer;
4. Green light sensitive layer;
5. Yellow filter;
6. Blue light sensitive layer;
7. UV Filter;
8. Protective Layer;
9. Visible Light.

Photographic film is a sheet of plastic (polyester, PET, nitrocellulose or cellulose acetate) coated with an emulsion containing light-sensitive silver halide salts (bonded by gelatin) with variable crystal sizes that determine the sensitivity, contrast and resolution of the film.

wikipedia.org/wiki/Photographic_film

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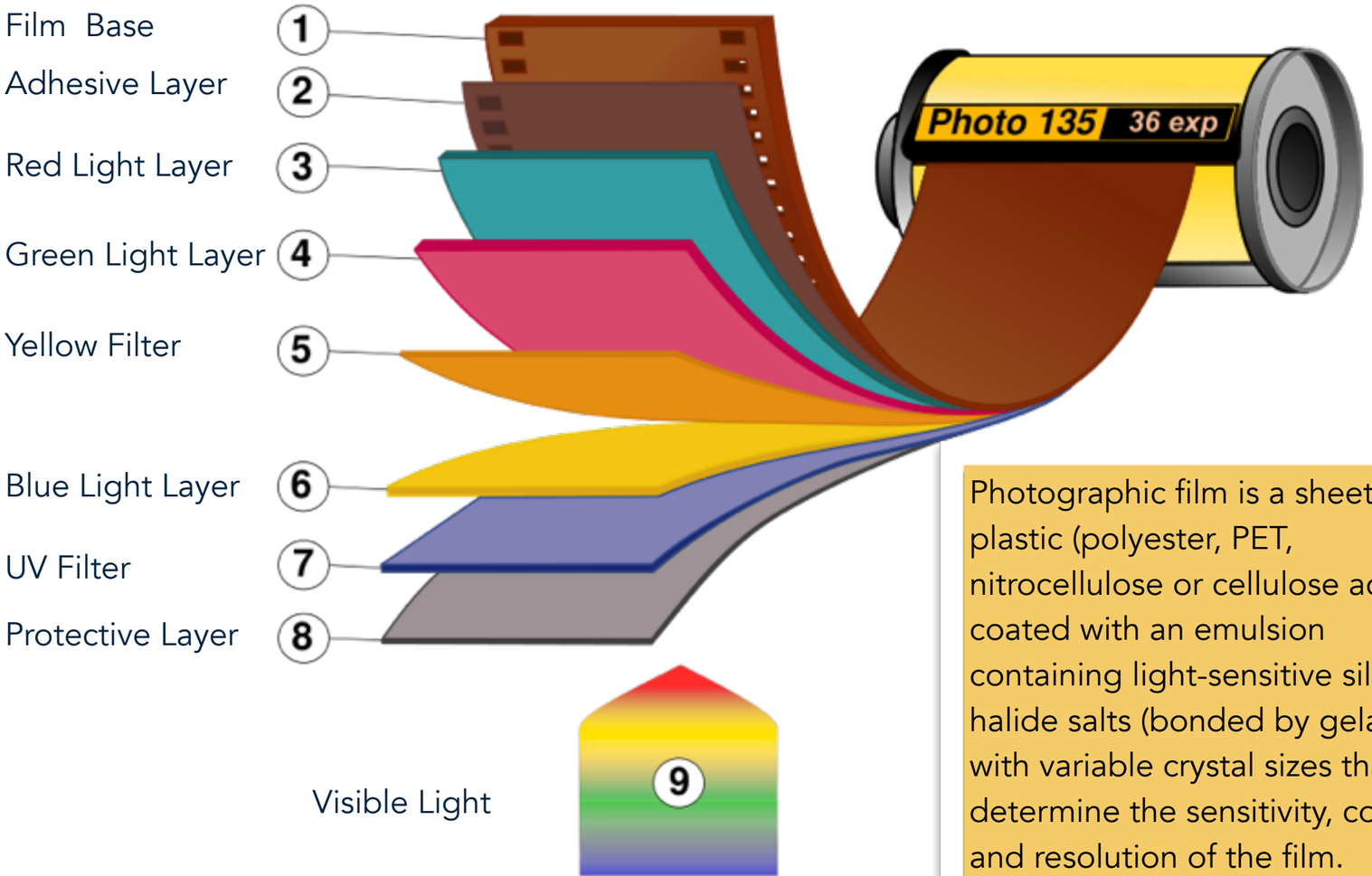

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Emulsion

1. Film base + Antihalation Coating
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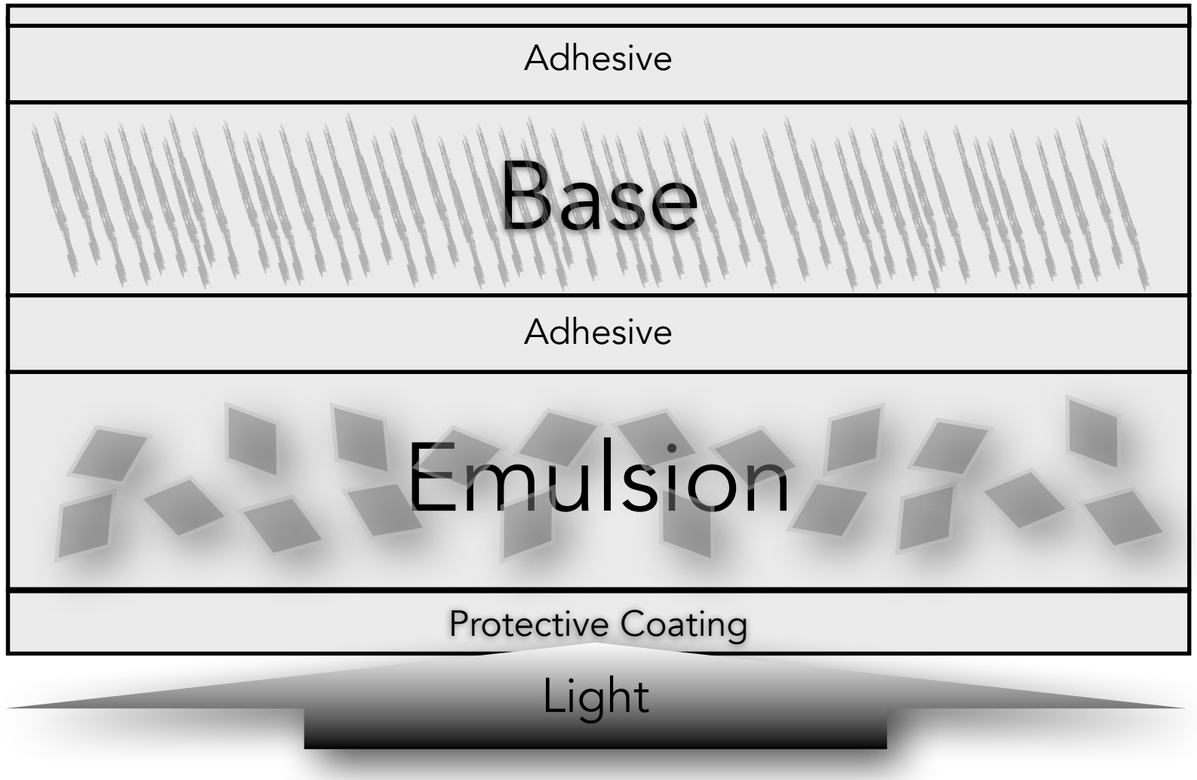
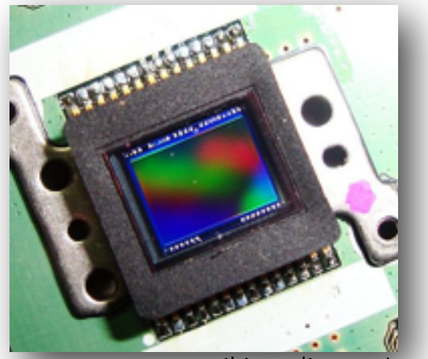


- ★ **Emulsion**: Where image is formed, consists of light sensitive crystal halide crystals. For Color image, dye couplers are also added
- ★ **Base**: Support and Stability
- ★ **Antihalation Coating**: Prevents light from reflecting back.

Digital: Converting Light to Data



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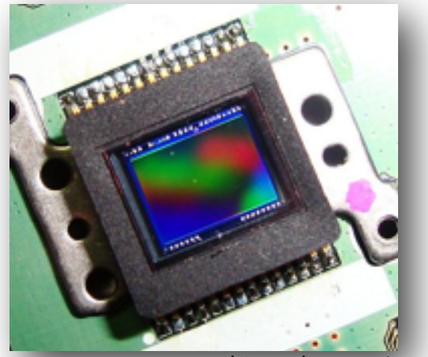

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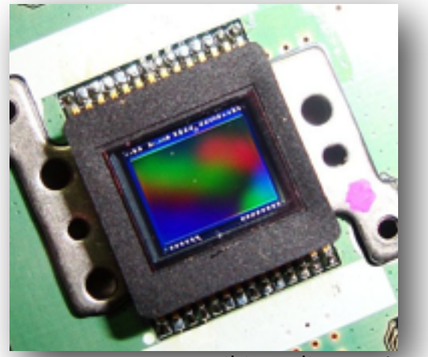
- ★ CCD: Charge-Coupled Device, a device for movement of electrical charge, within the device to an area where the charge can be converted into a digital value.

8

Digital: Converting Light to Data



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- CCD: Charge-Coupled Device, a device for movement of electrical charge, within the device to an area where the charge can be converted into a digital value.
- In a CCD image sensor, pixels are represented by capacitors. These capacitors convert and then store incoming photons as electron charges.

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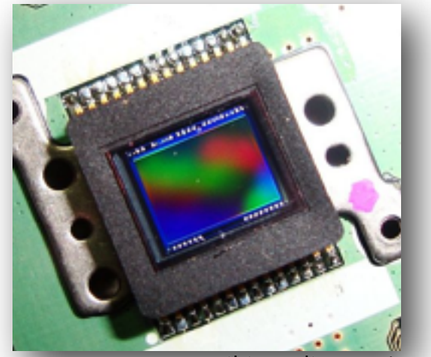

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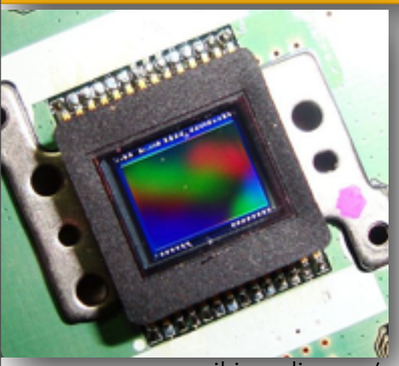
- In a CCD image sensor, pixels are represented by capacitors. These capacitors convert and then store incoming photons as electron charges.
- Invented in 1969 at AT&T Bell Labs by Willard Boyle and George E. Smith (Won a Noble Prize in Physics in 2009).

en.wikipedia.org



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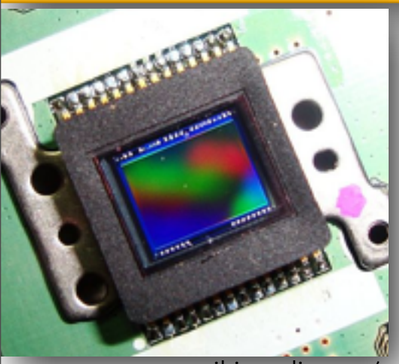

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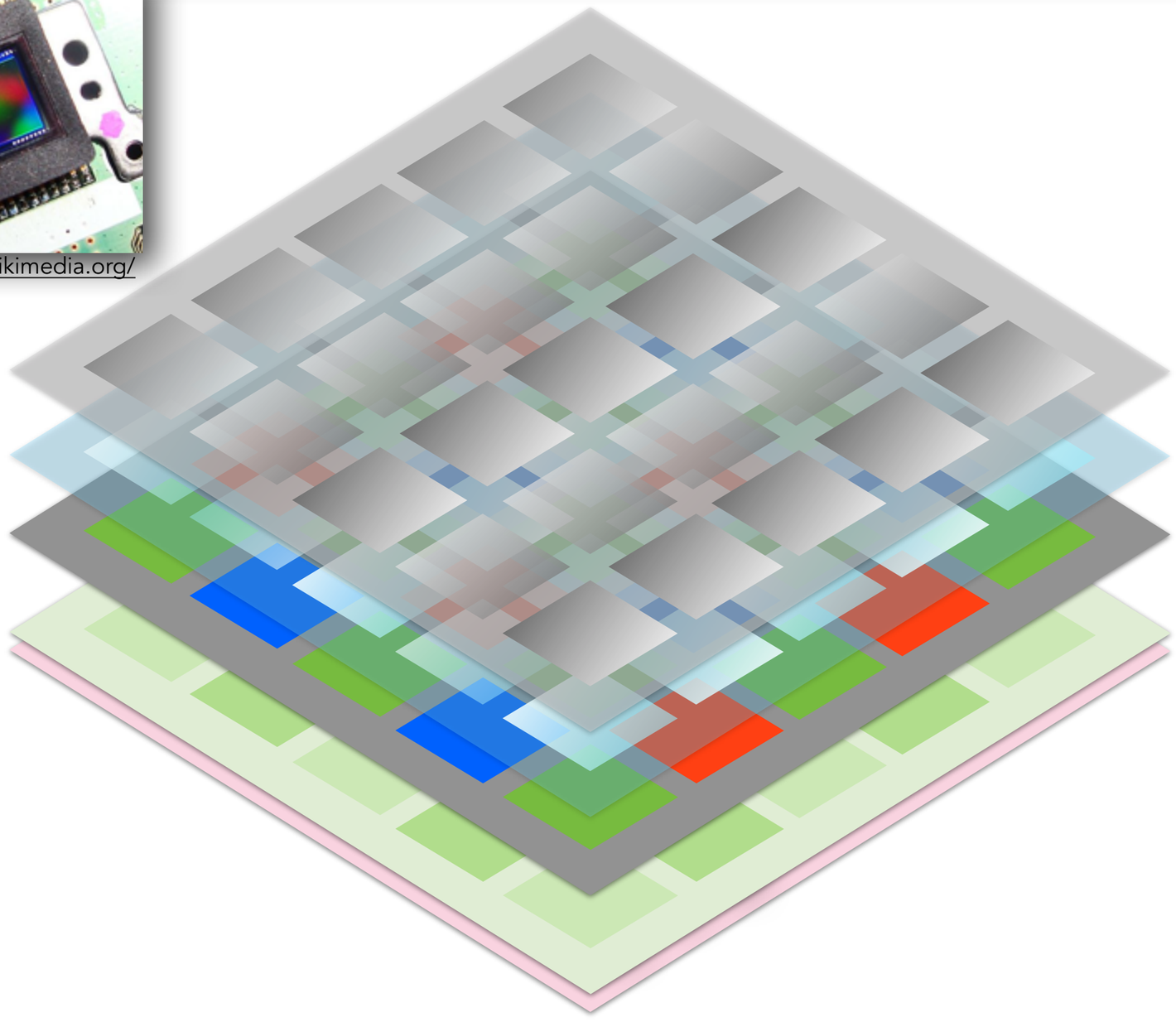

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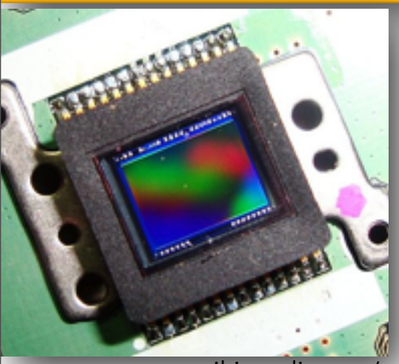

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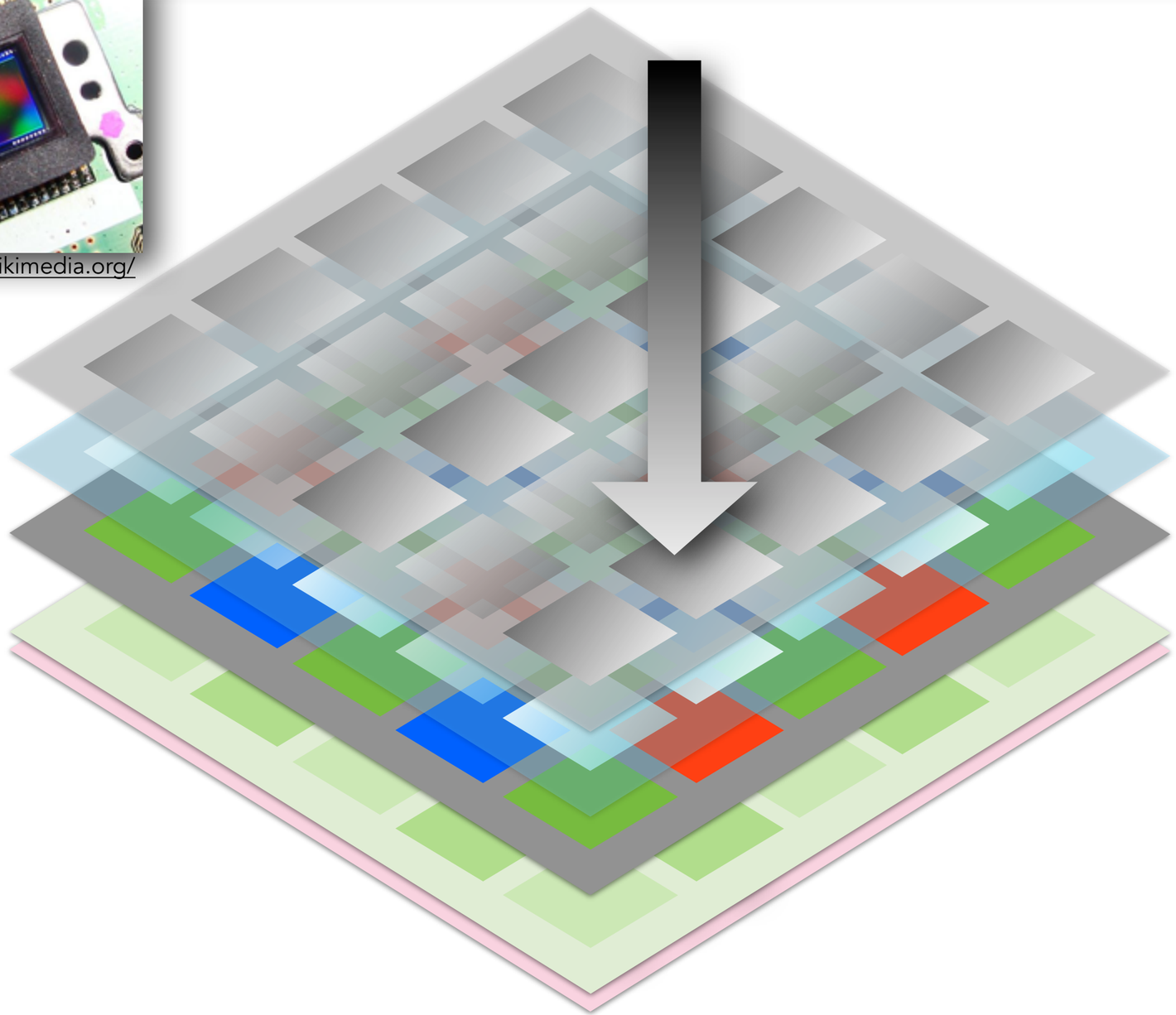

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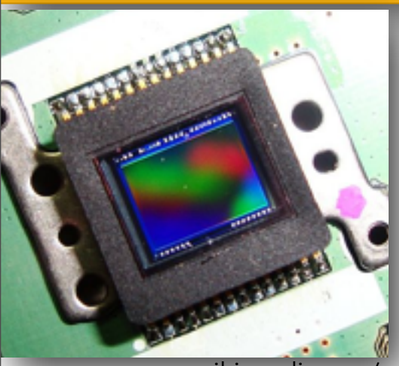

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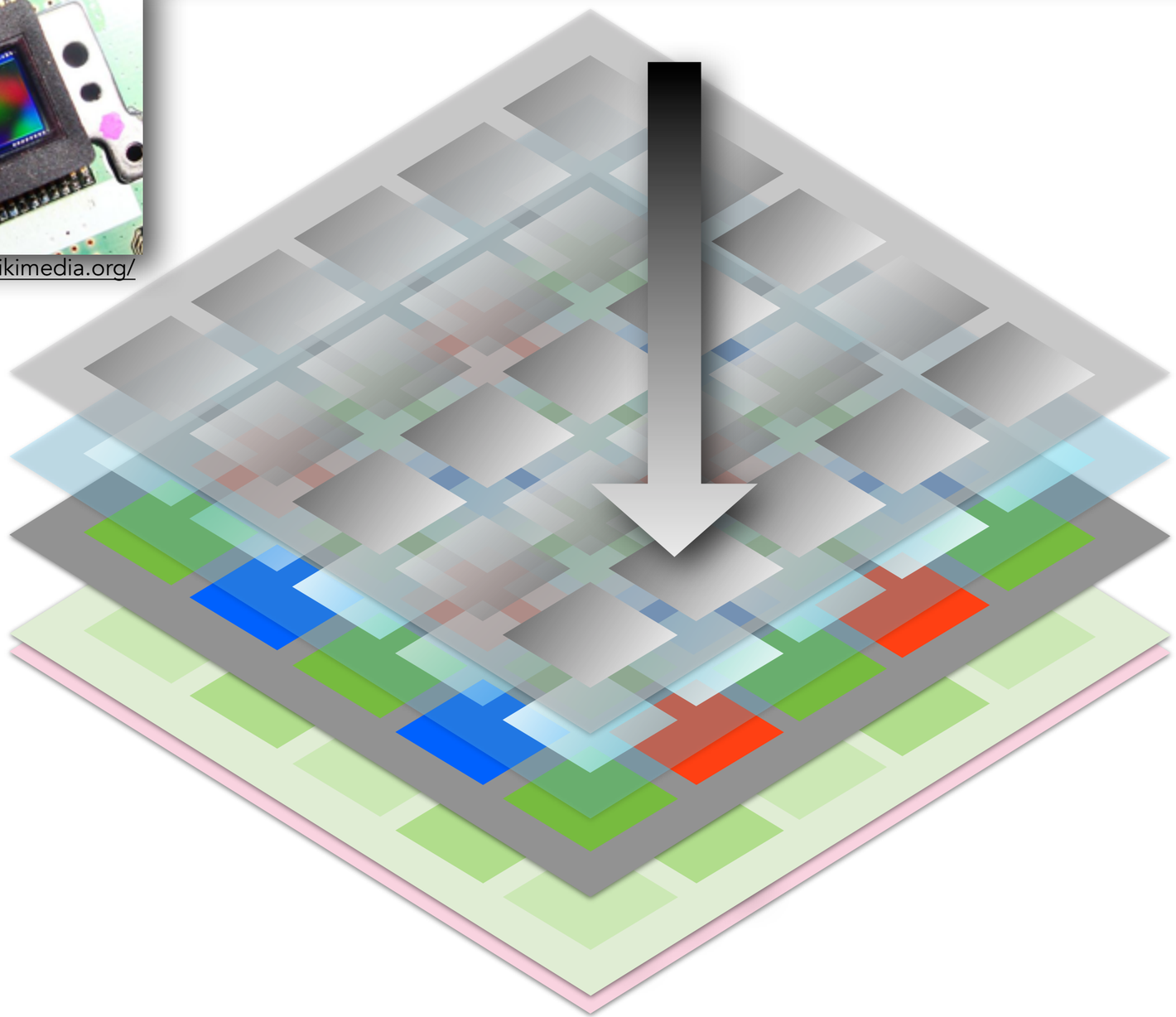

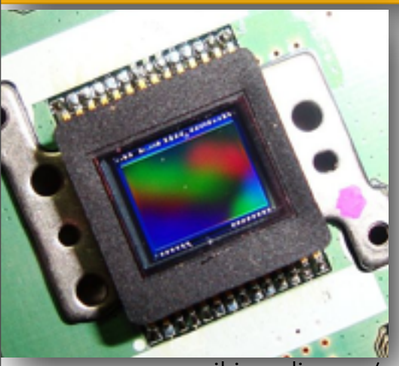

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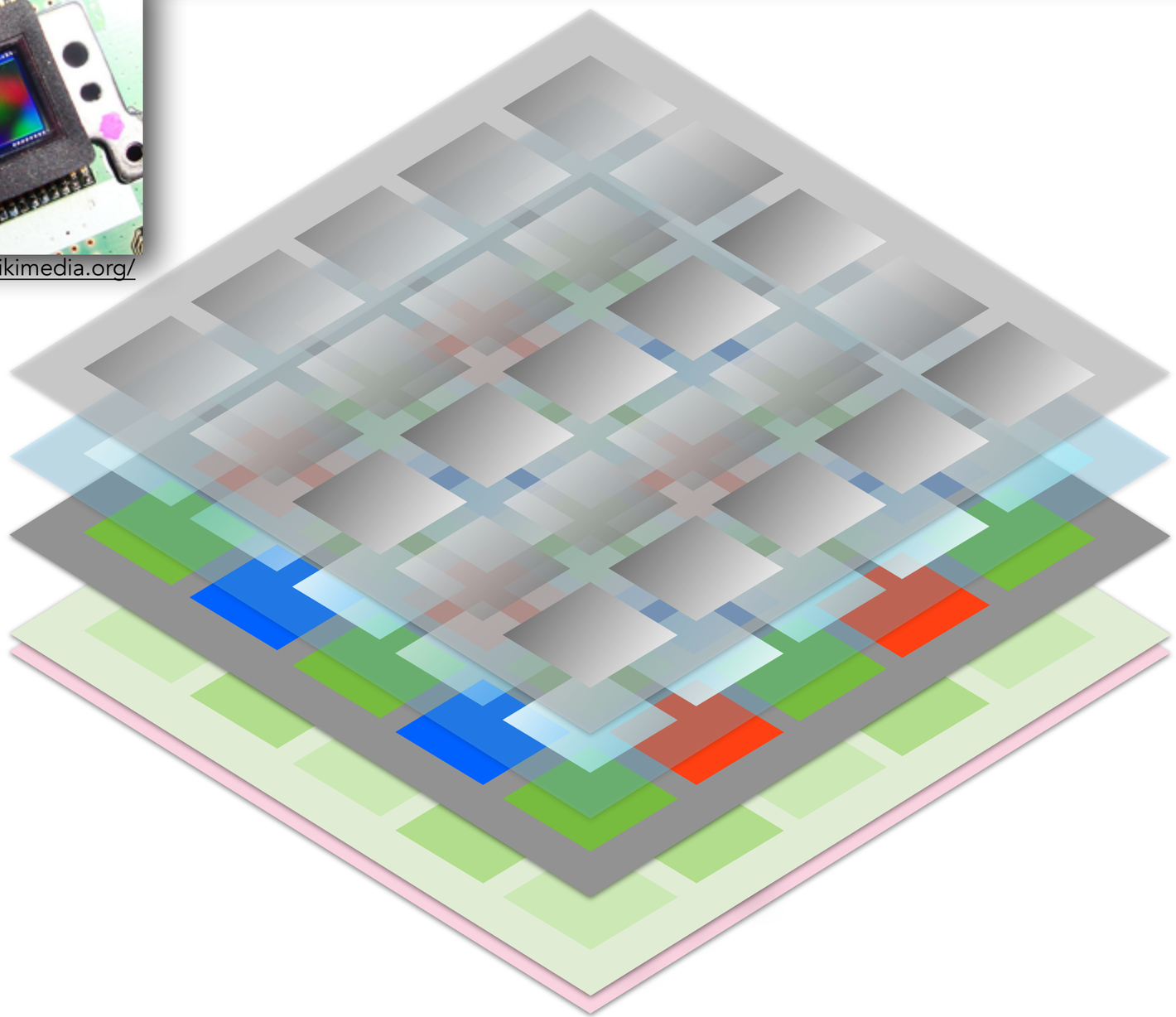

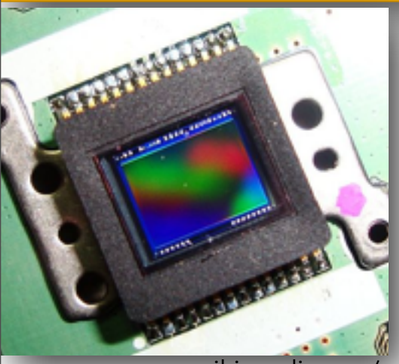

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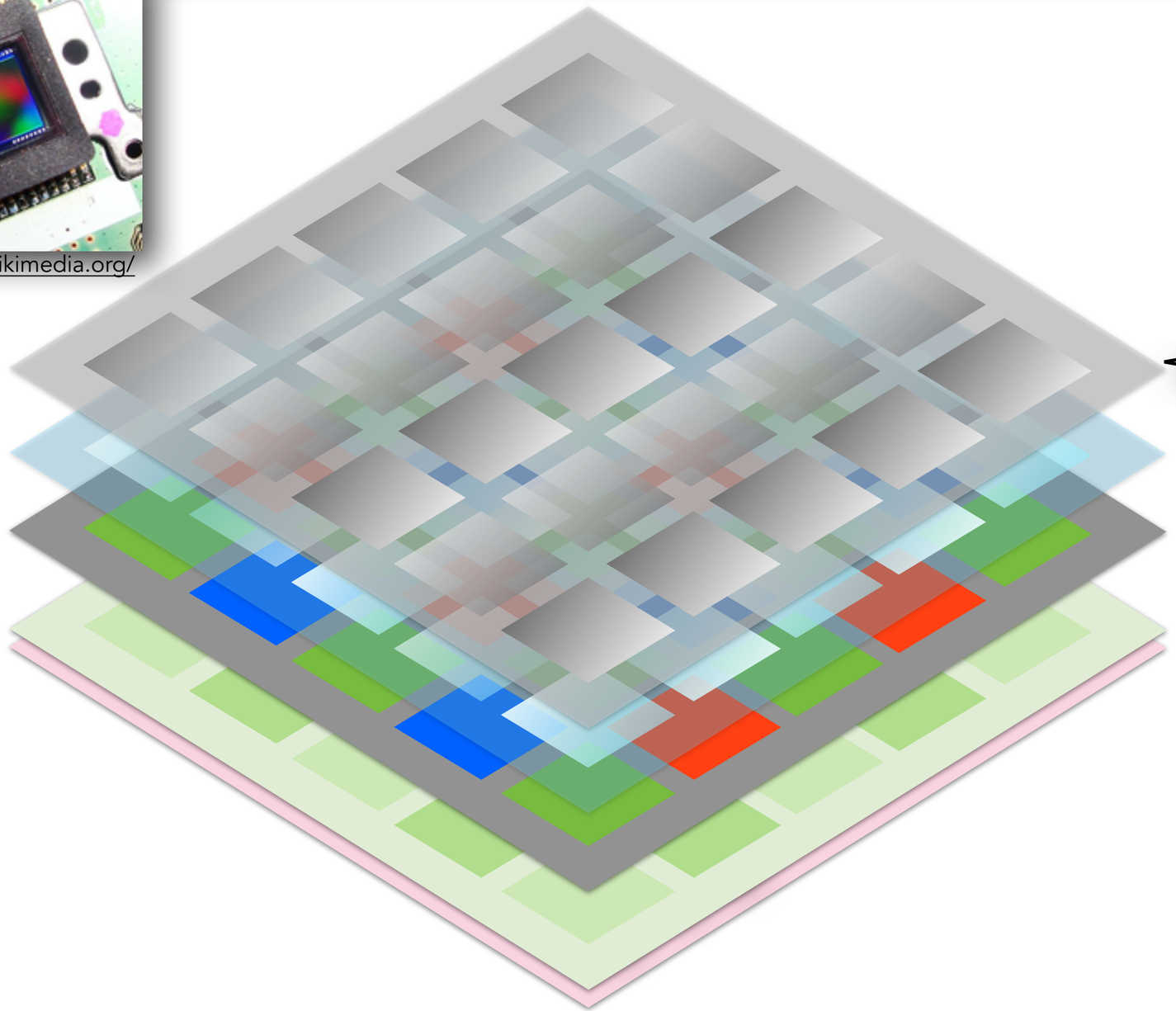
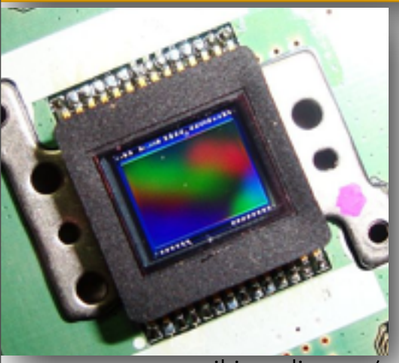


Micro Lenses

Capture the light and direct it towards light-sensitive areas.



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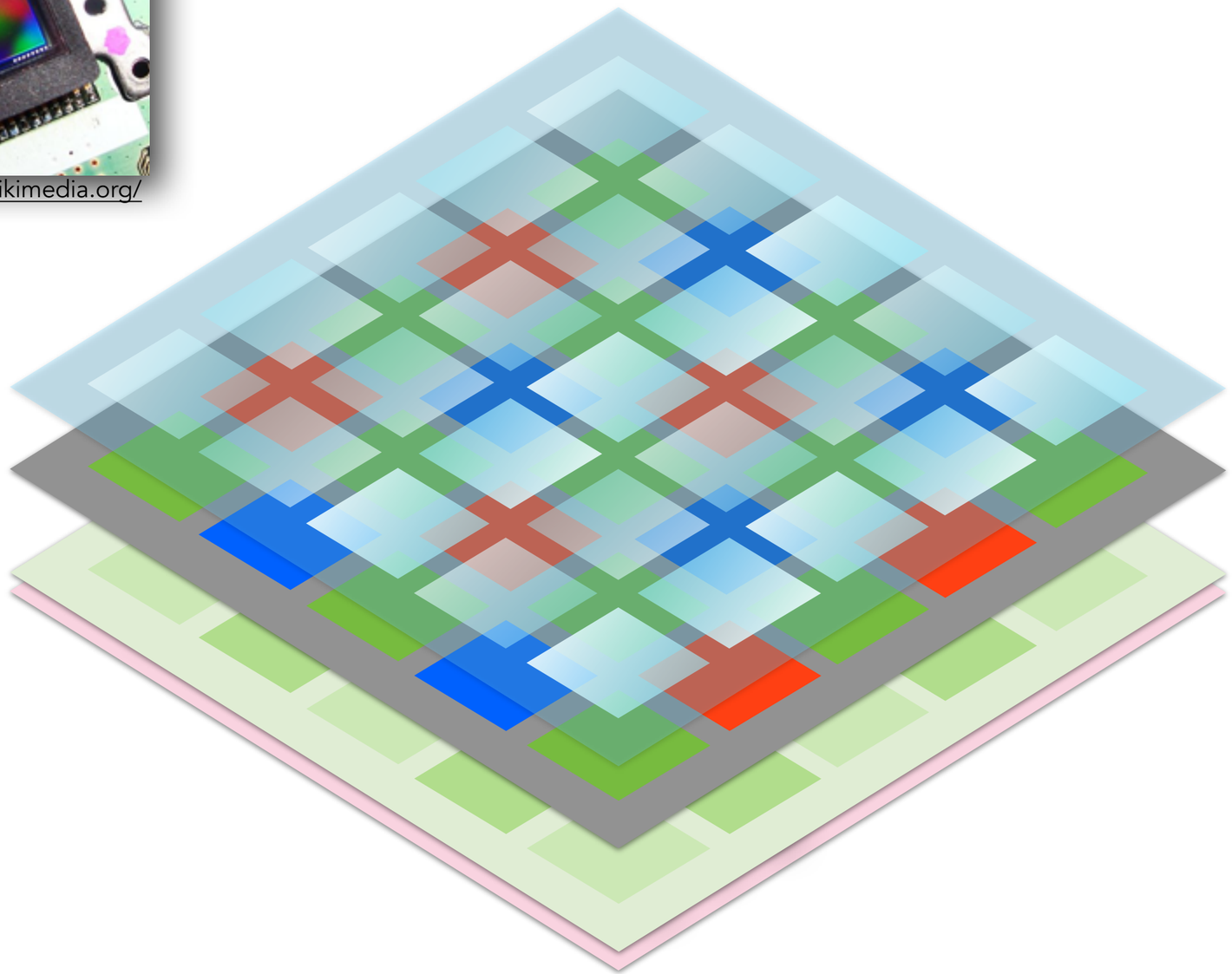

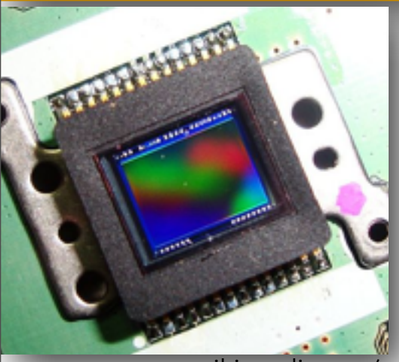

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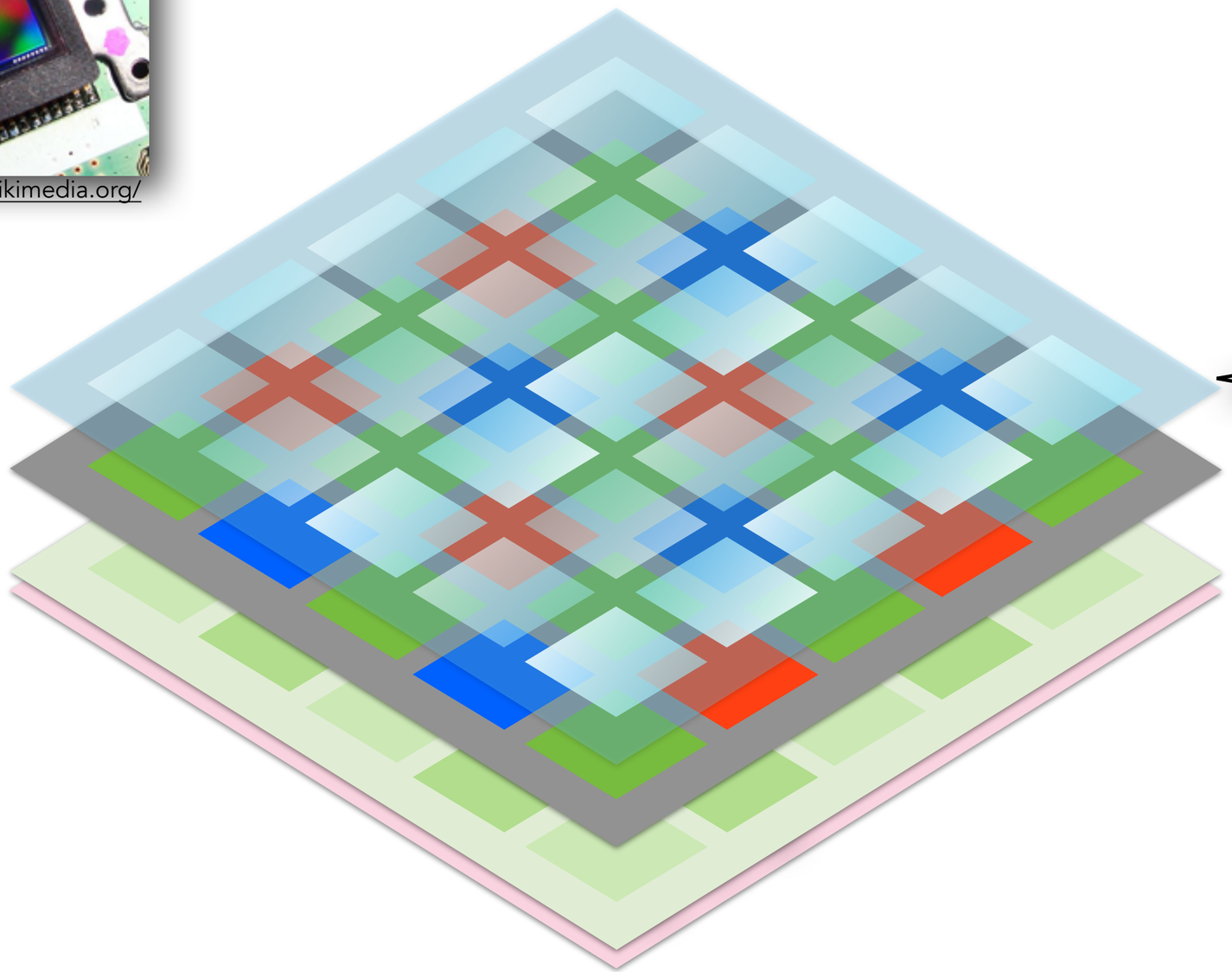
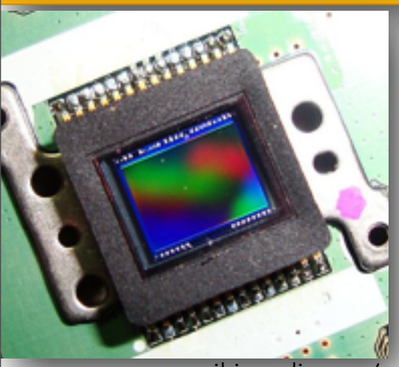


Hot Mirror

Lets visible light pass, but reflects lights invisible part of the spectrum (depends on what kind of light to capture)



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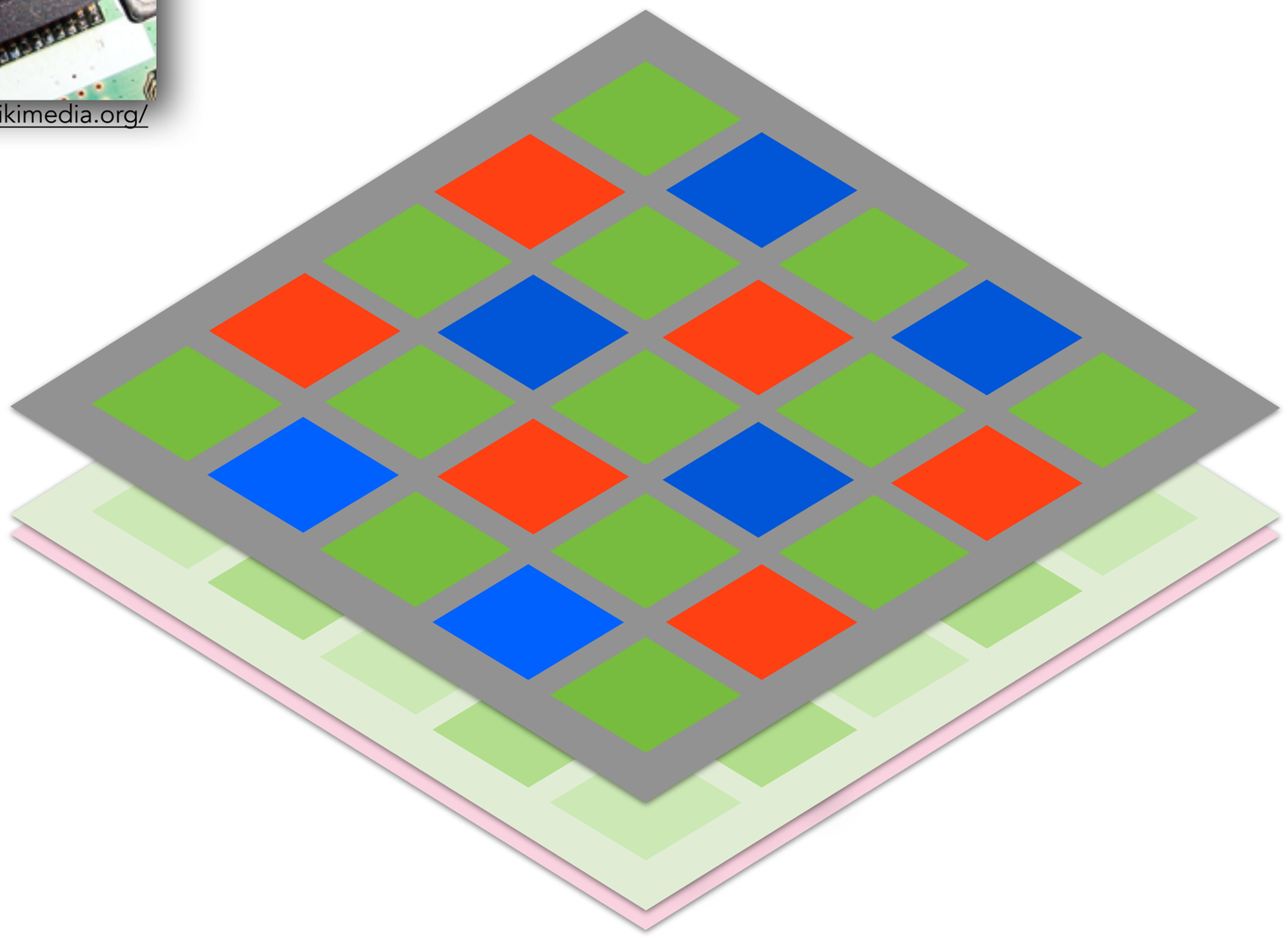

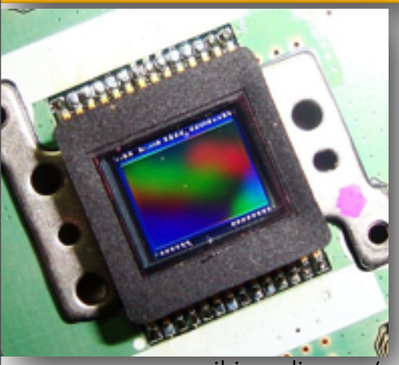

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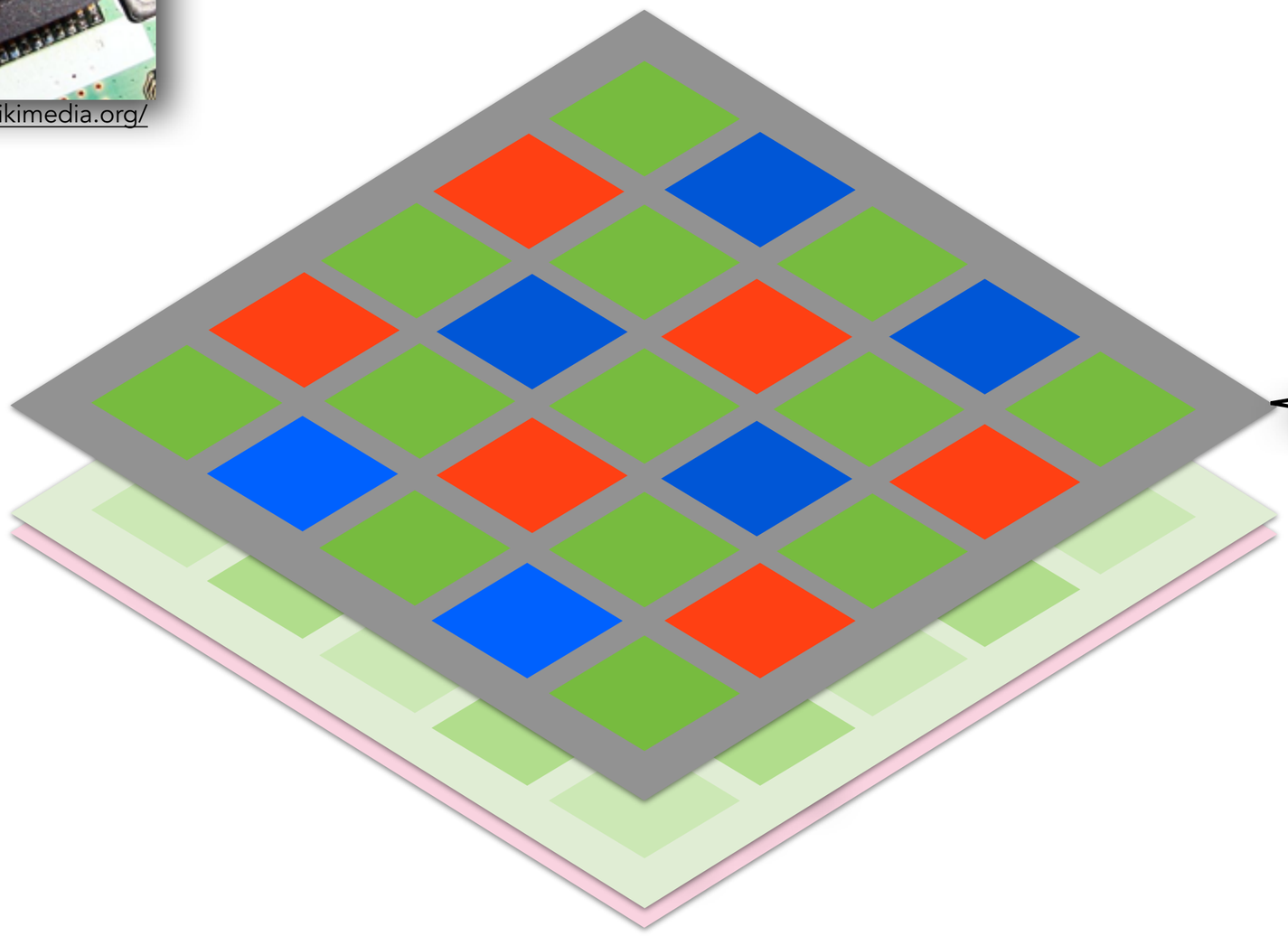
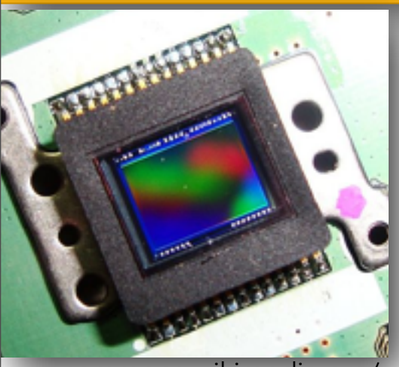


Color Filter

Photodiodes (below) are color blind. A color filter matrix separates the light into Red, Green, Blue. Usually referred to as Bayer Array.



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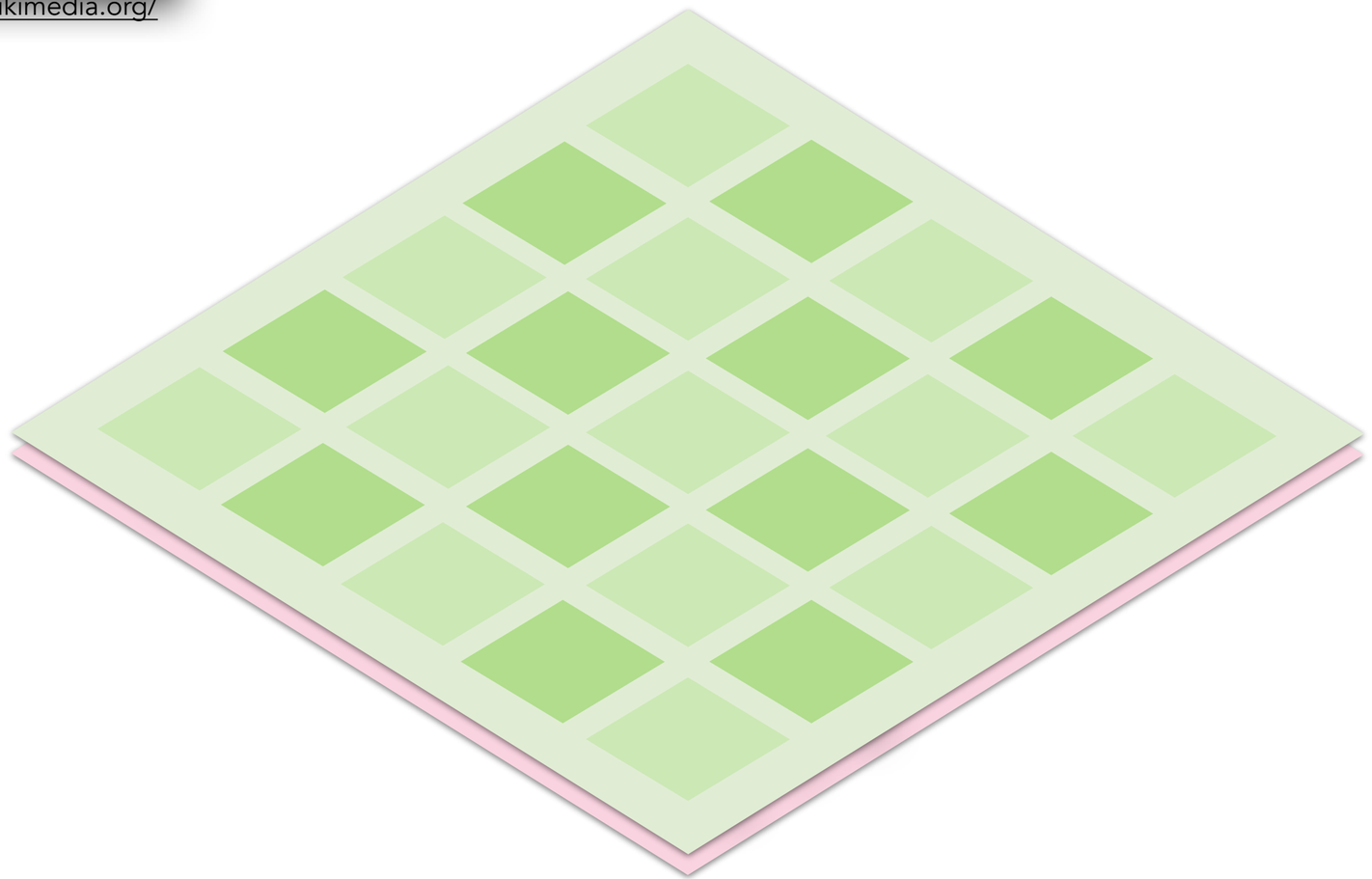

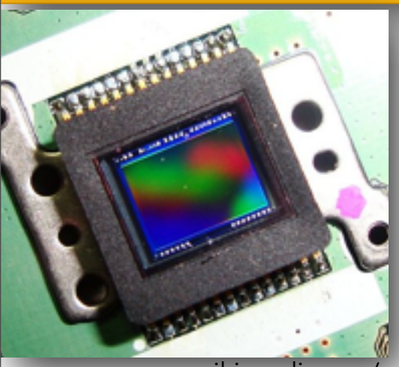

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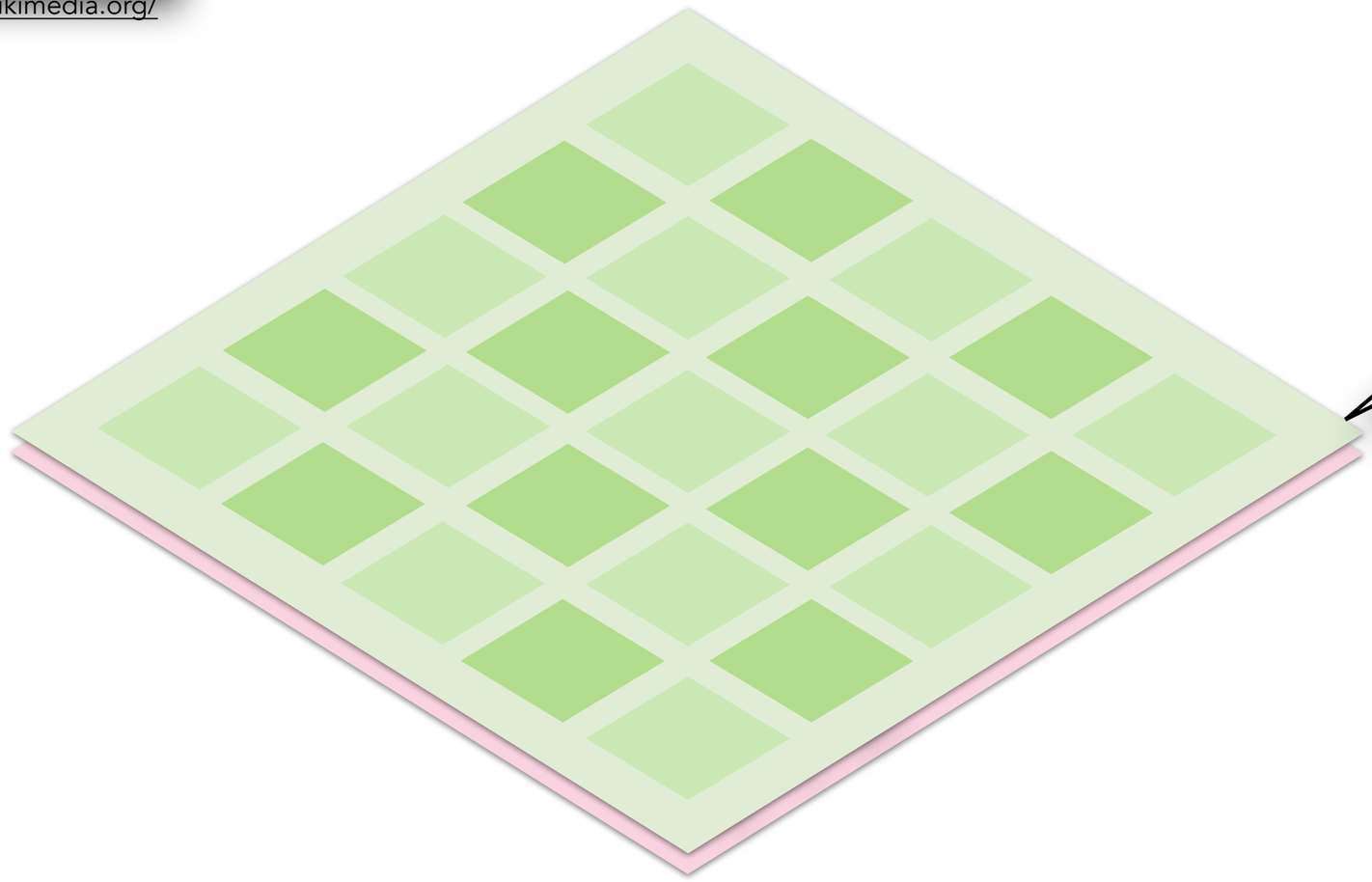
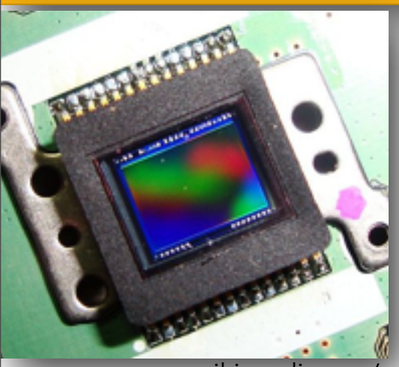


Photodiodes

This is where light energy is converted to Electrons, creating a negative charge.



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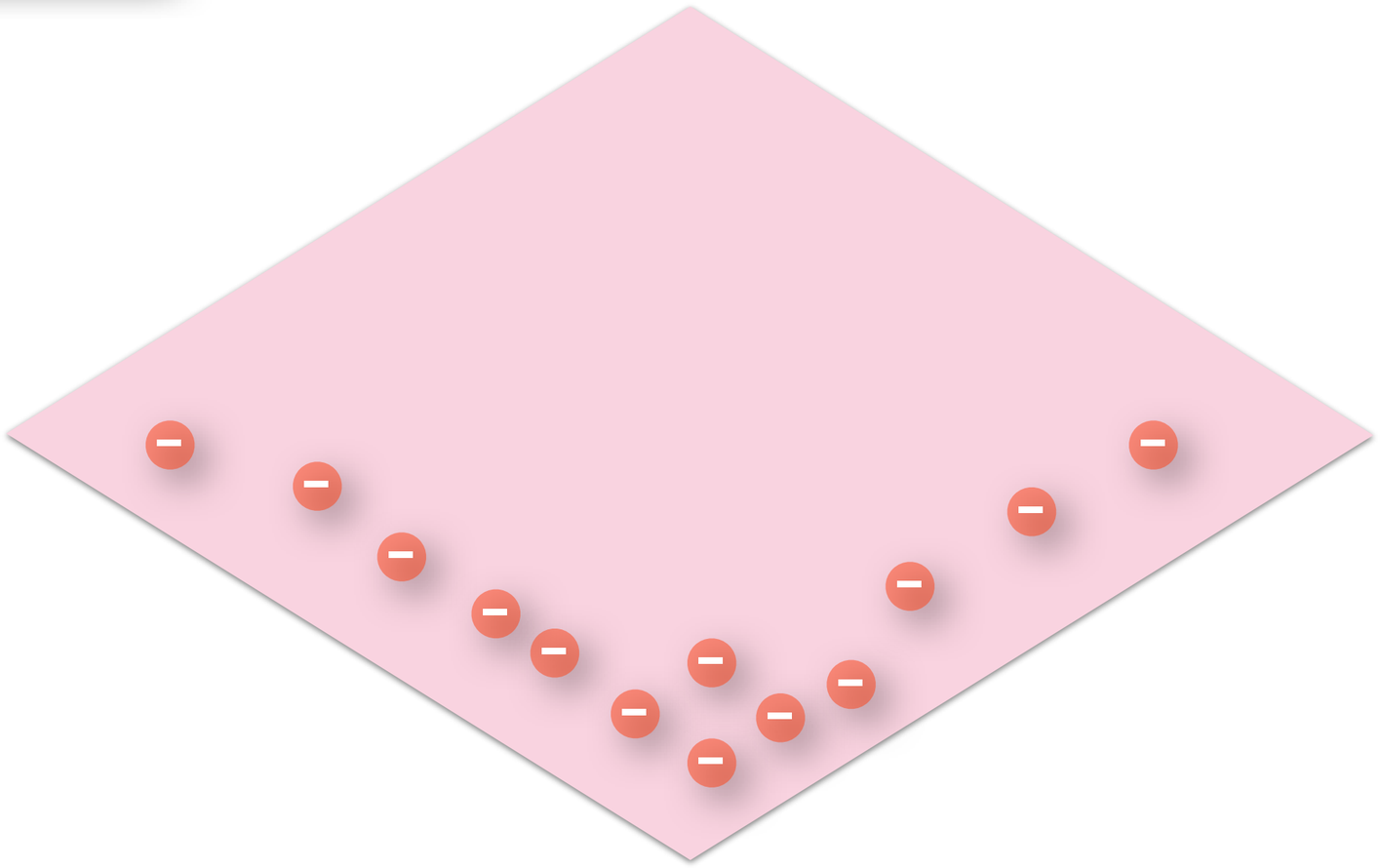

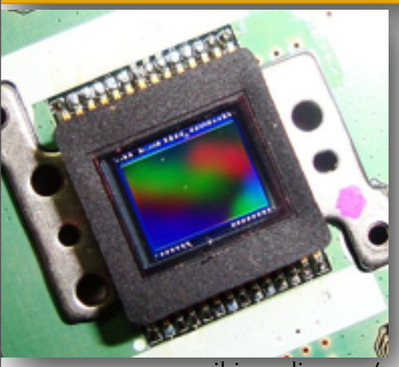

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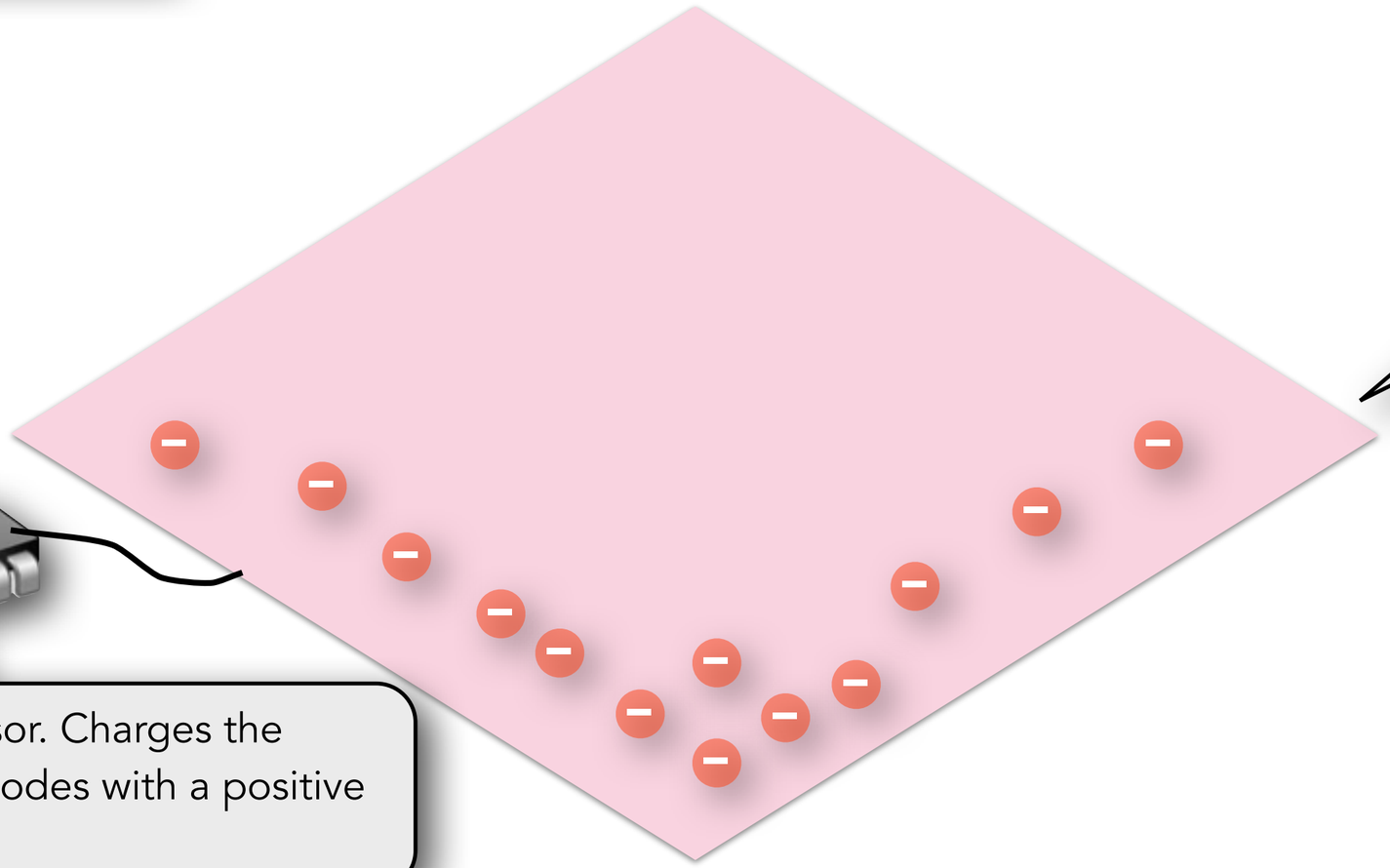
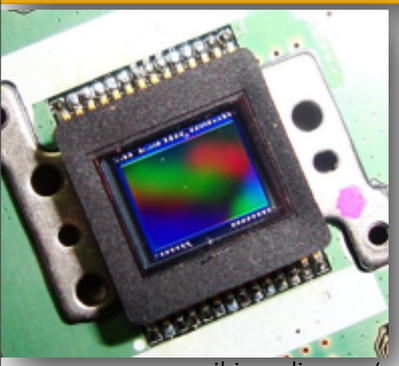
Well (Depletion Layer)
Where the electrons are collected.



Processor. Charges the photodiodes with a positive charge



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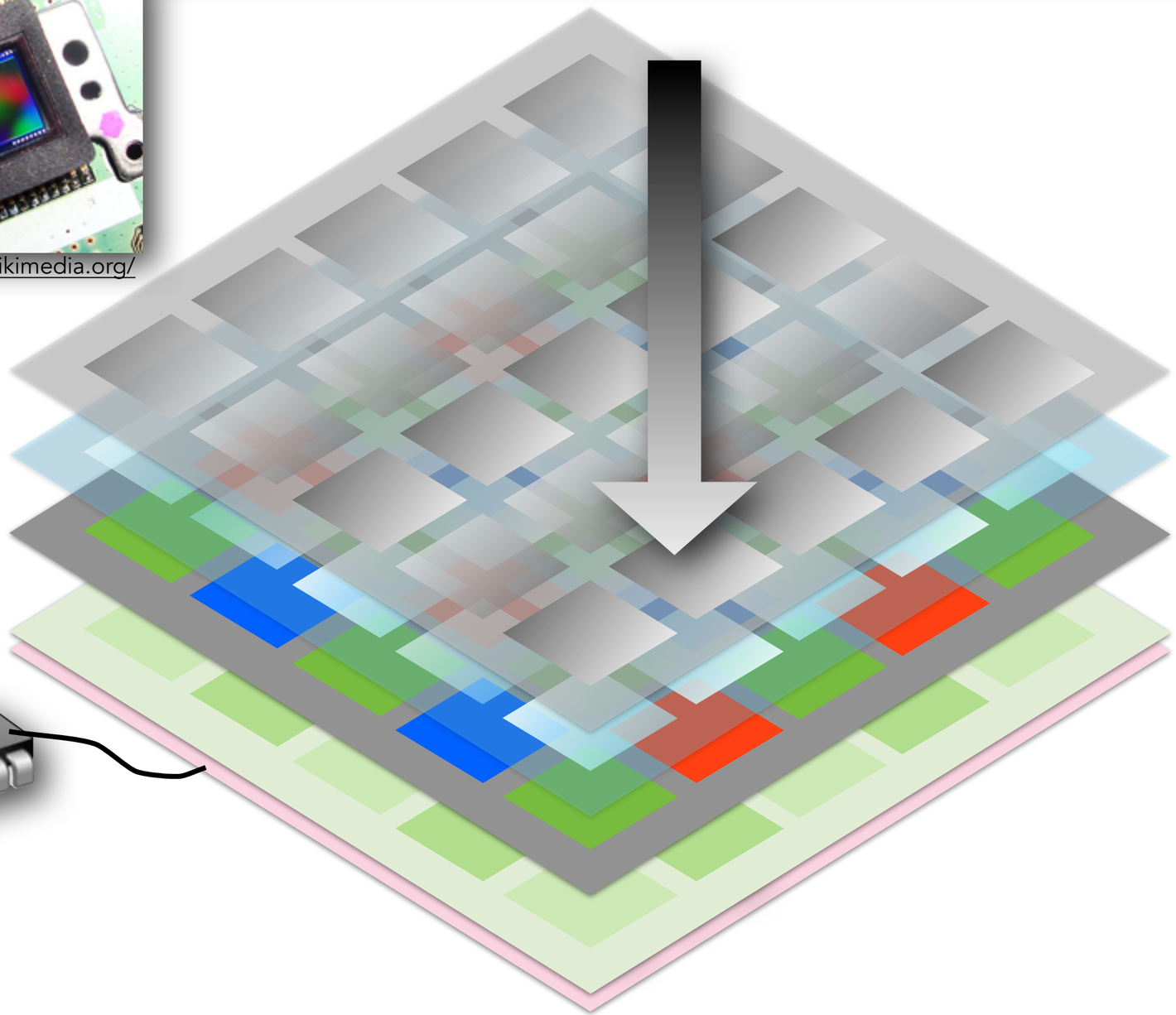
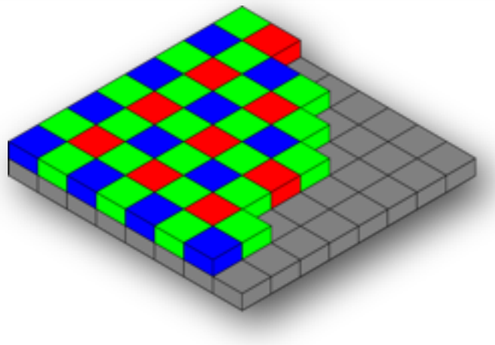


Digital: Converting Light to Data



Color Filter Layer

http://en.wikipedia.org/wiki/File:Normal_and_Bayer_Filter_(120px-Colorful_spring_garden).png
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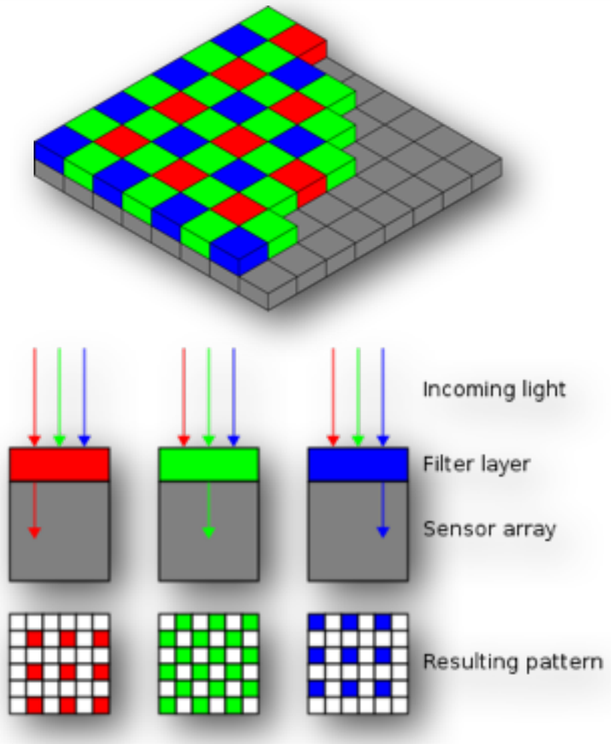

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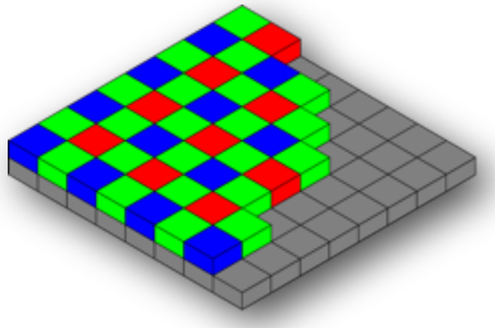

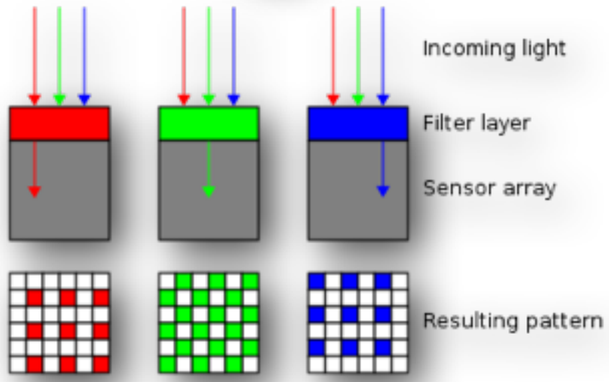

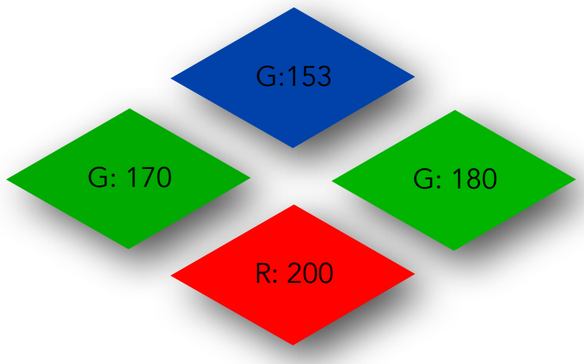

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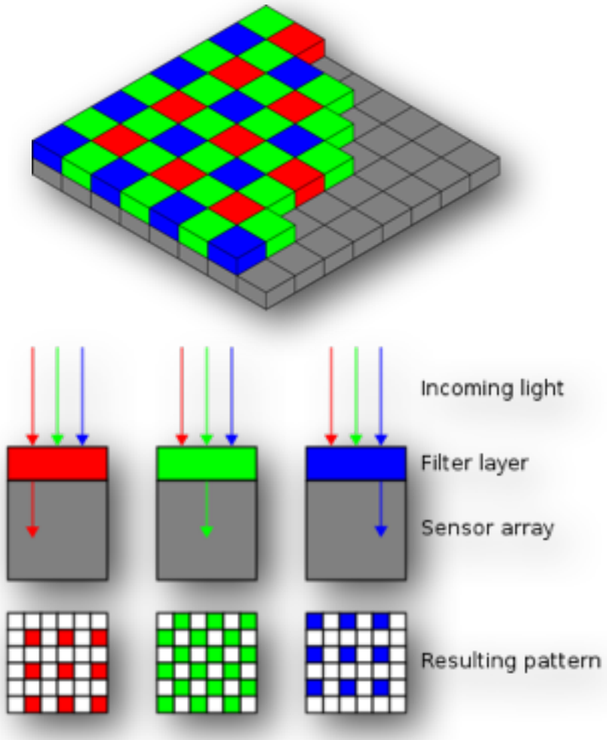

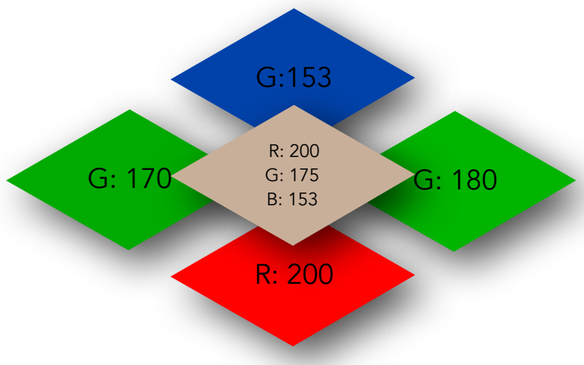

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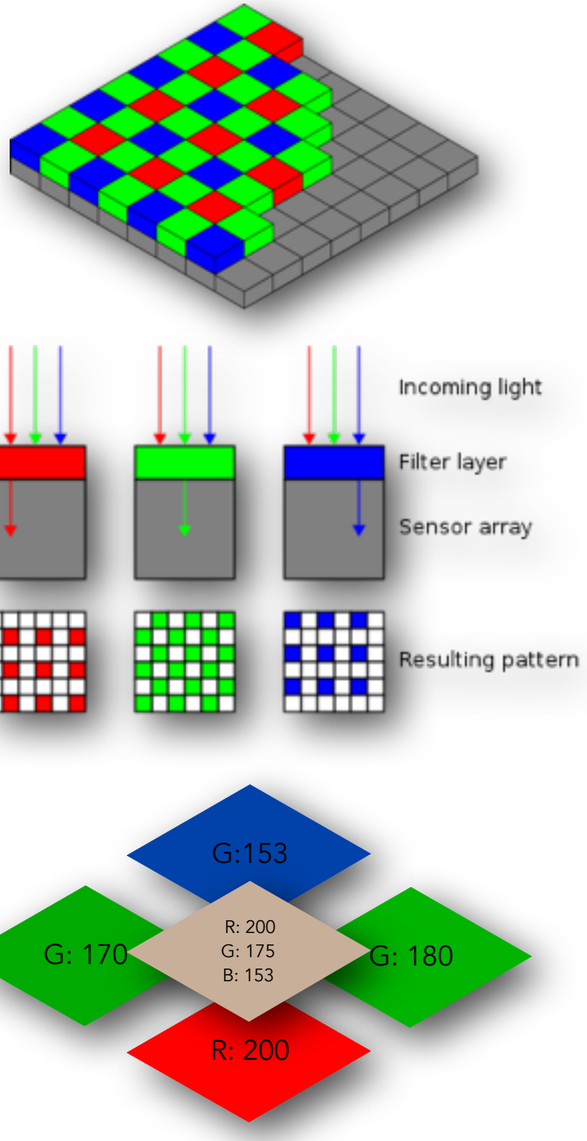
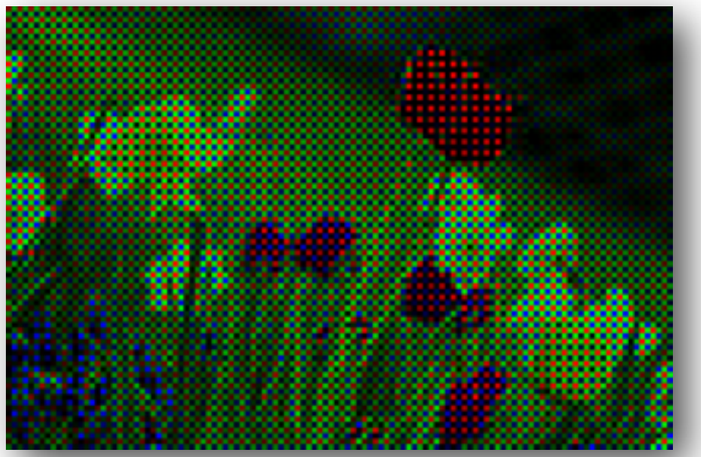
Color Filter Layer

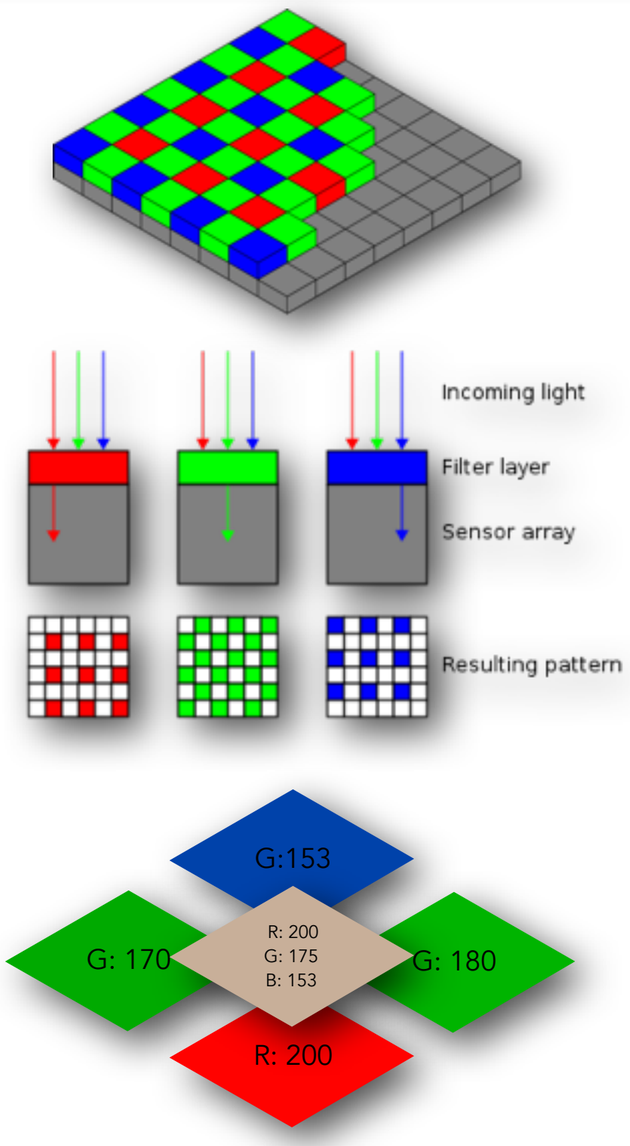




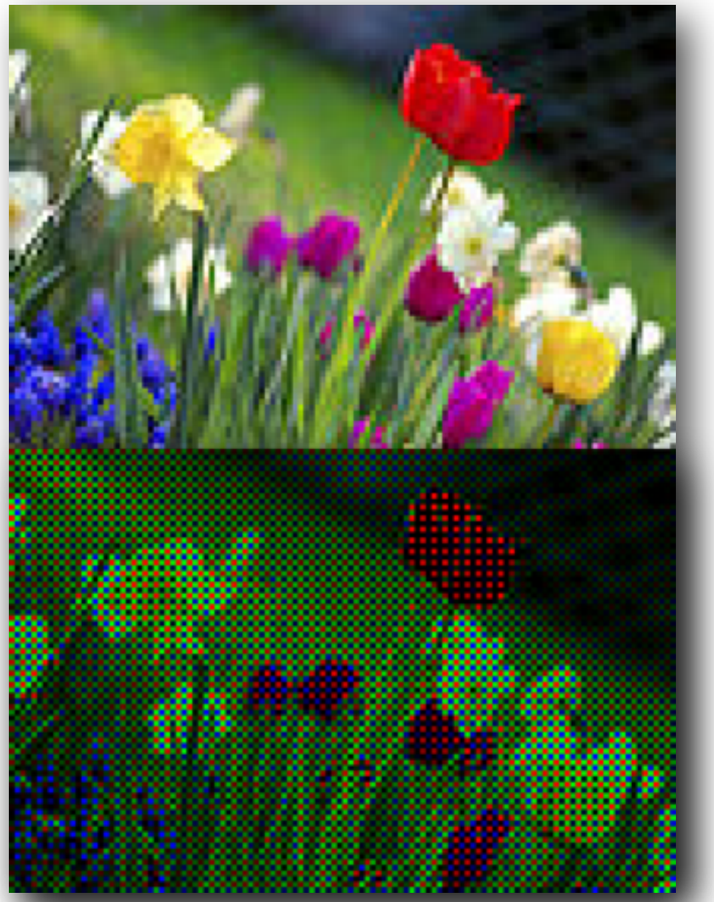
Actual Sensor Information with Bayer Filter

http://en.wikipedia.org/wiki/File:Normal_and_Bayer_Filter_(120px-Colorful_spring_garden).png
http://en.wikipedia.org/wiki/File:Bayer_pattern_on_sensor.svg
http://en.wikipedia.org/wiki/File:Bayer_pattern_on_sensor_profile.svg

Color Filter Layer



Reconstructed Image after Interpolation



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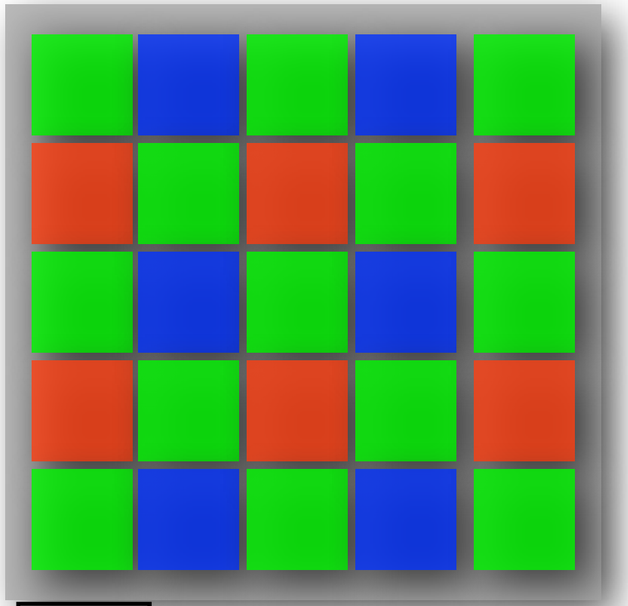
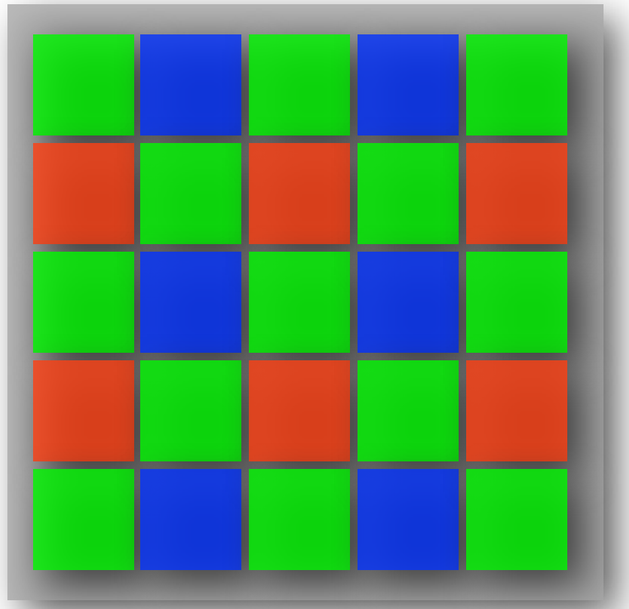
CCD vs. CMOS Sensors





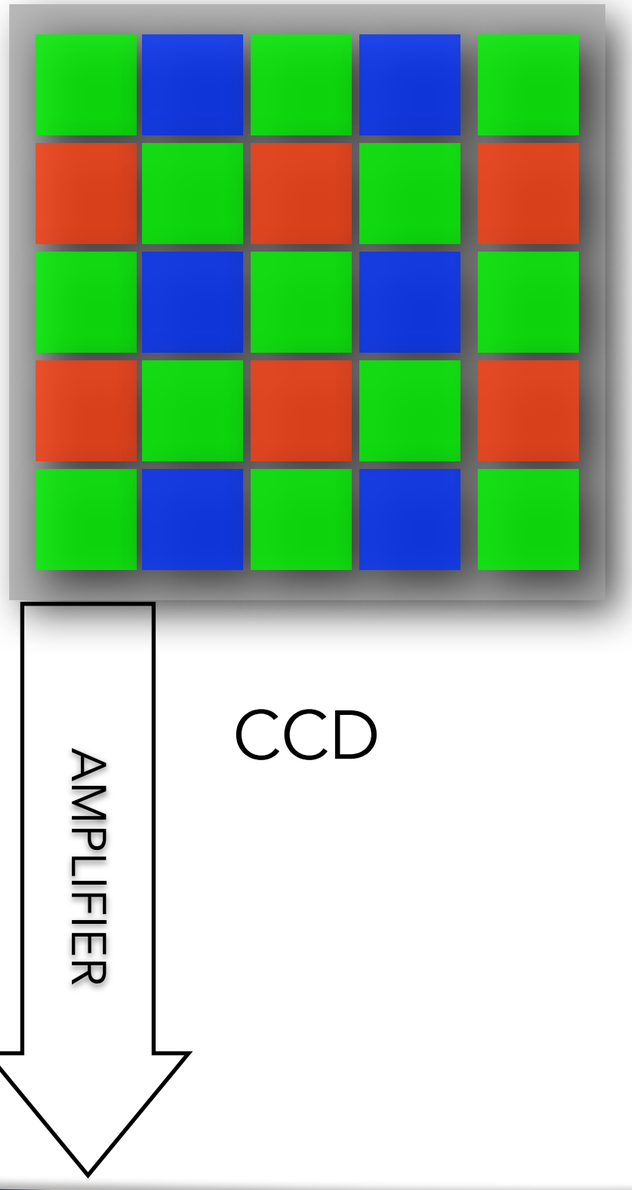
CCD

CMOS

AMPLIFIER

CCD vs. CMOS Sensors

- CMOS: Complementary Metal Oxide Semiconductor



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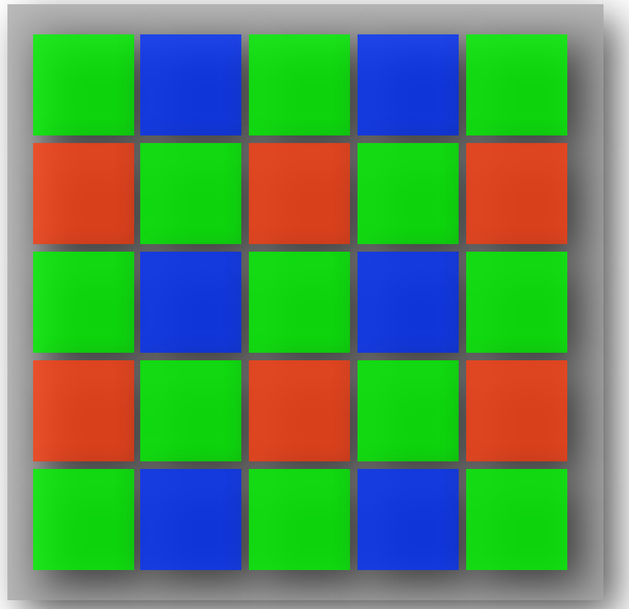

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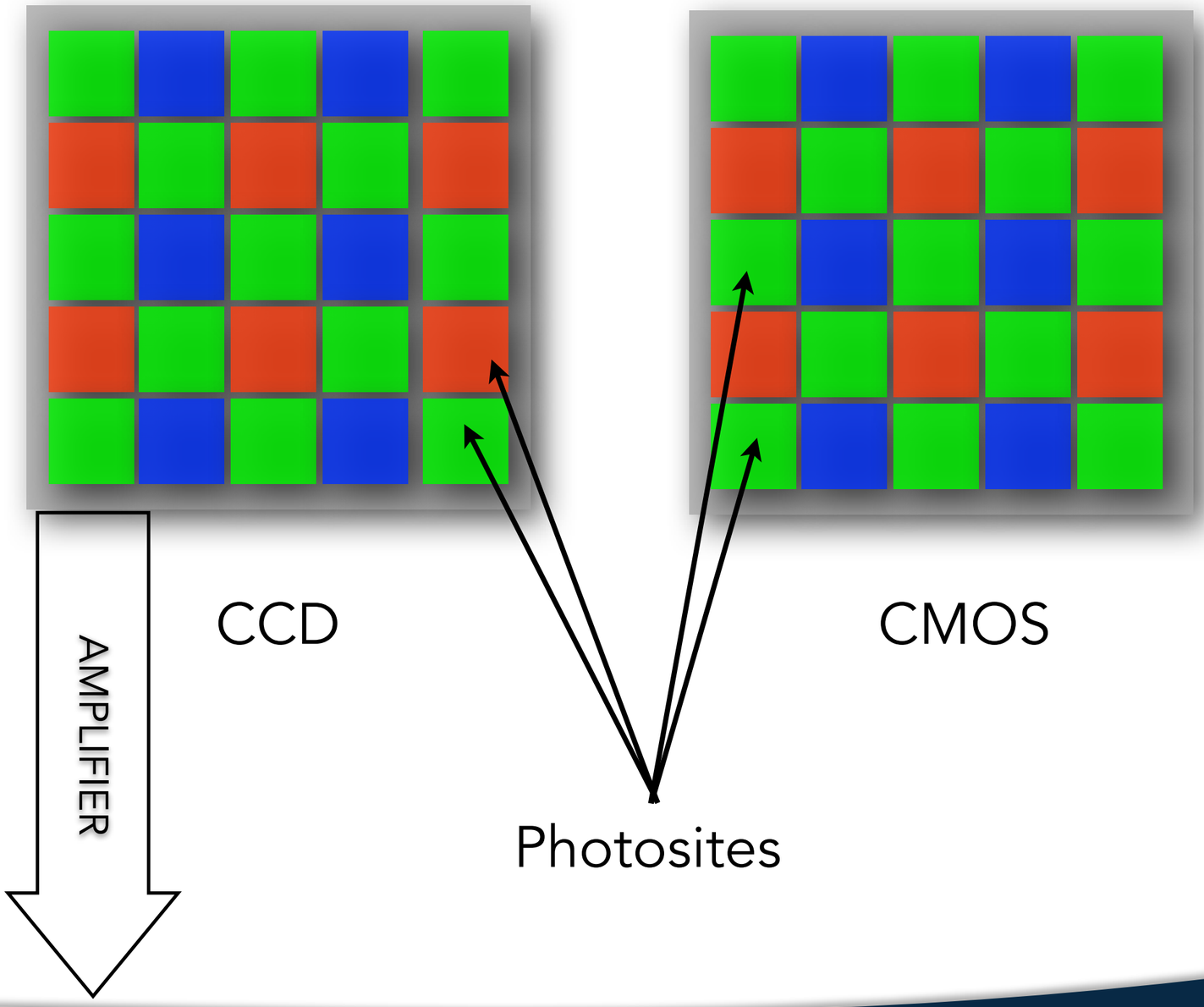

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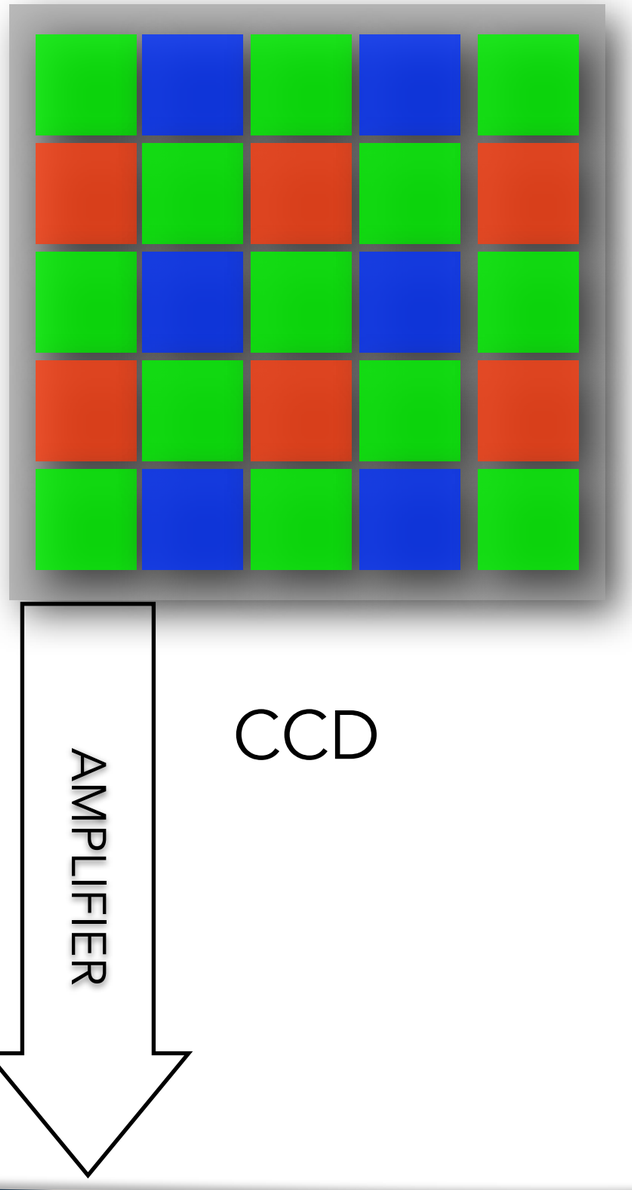

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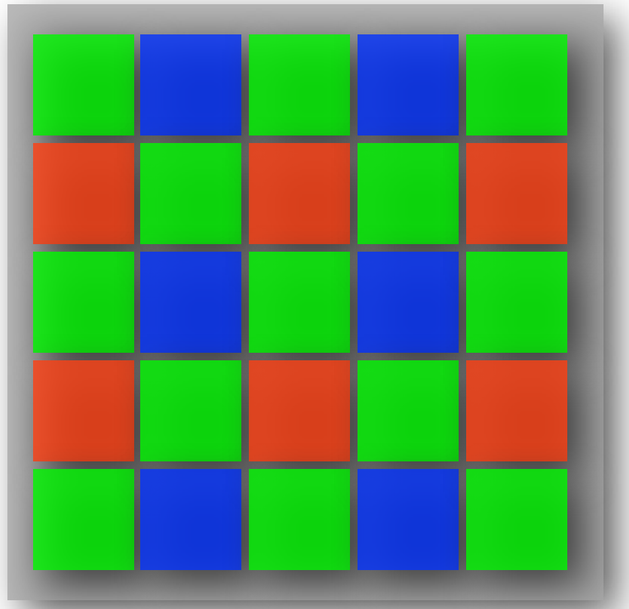

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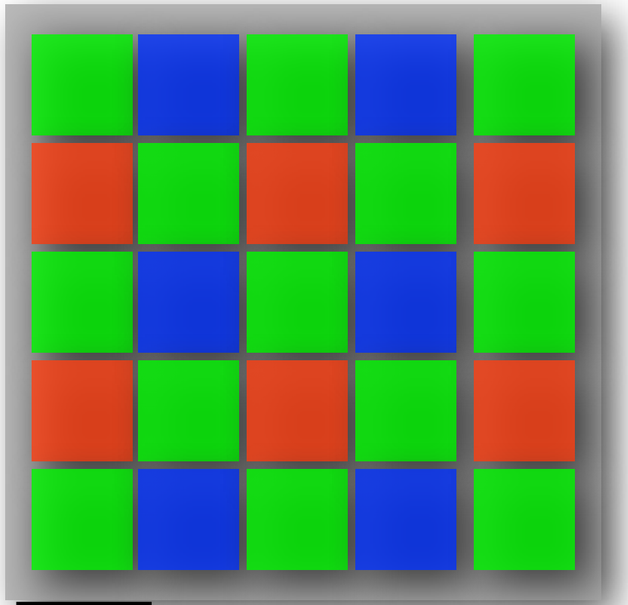

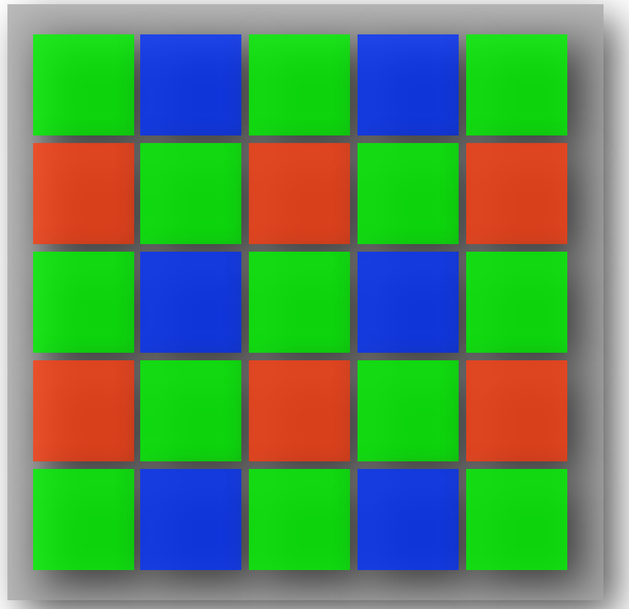

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- ★ CMOS: Complementary Metal Oxide Semiconductor
- ★ Photosites in CCD are passive and do no “work”

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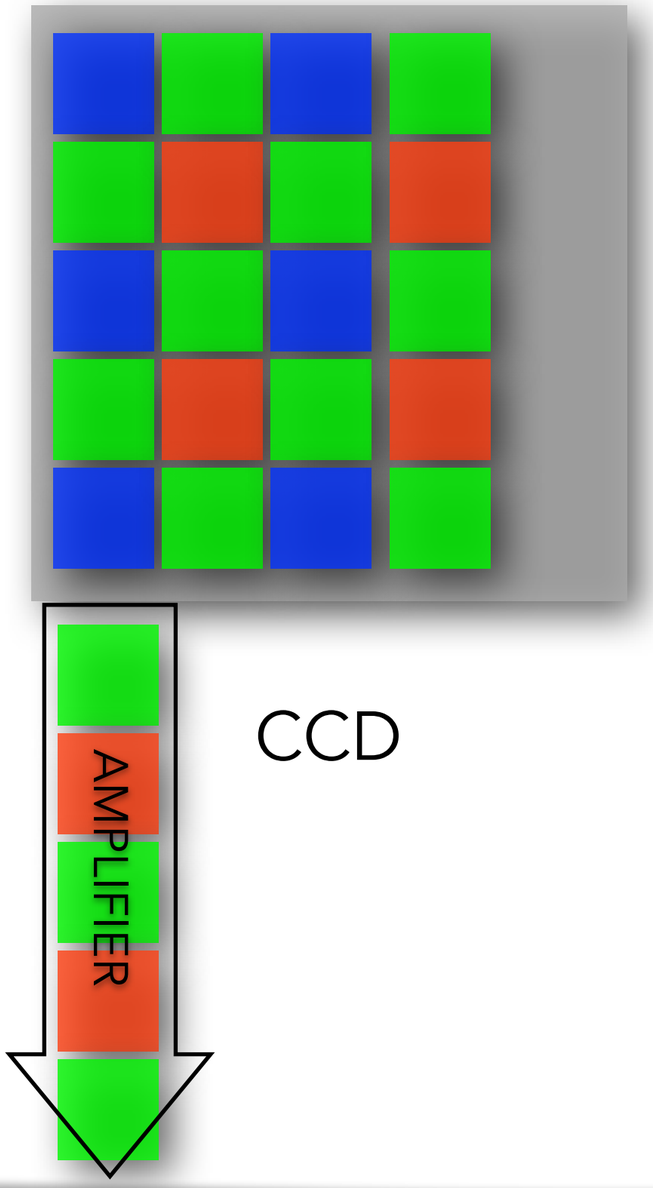

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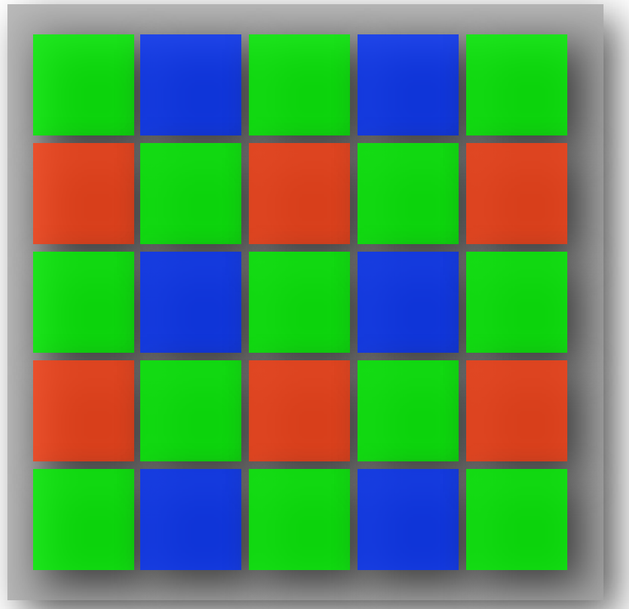

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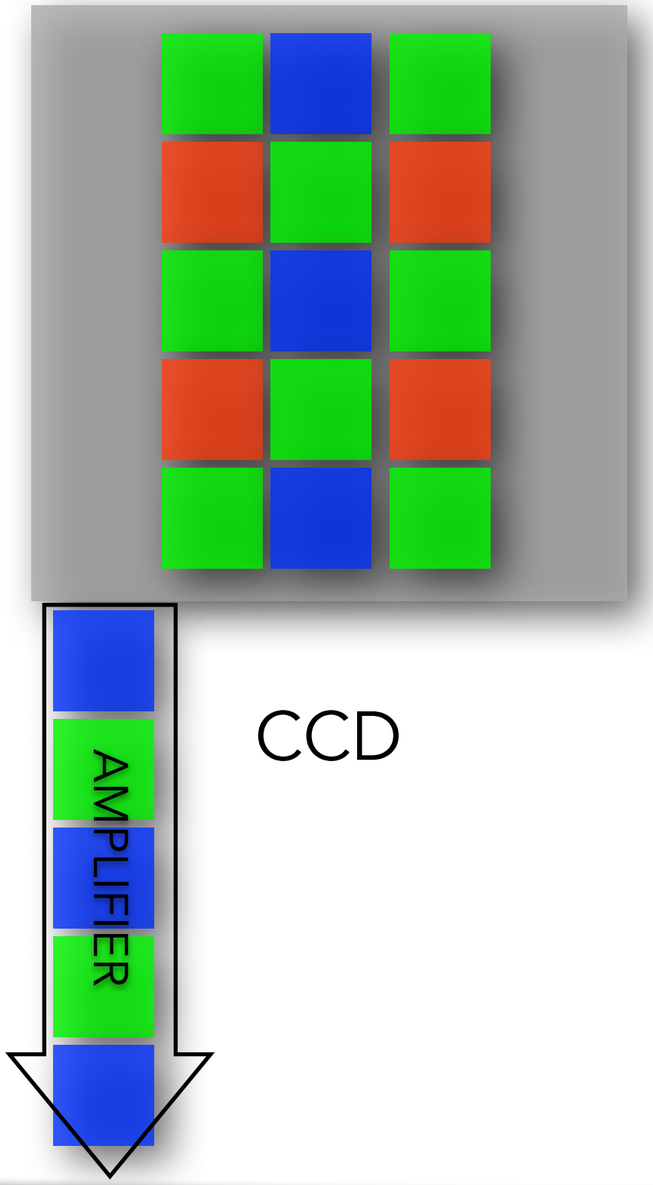

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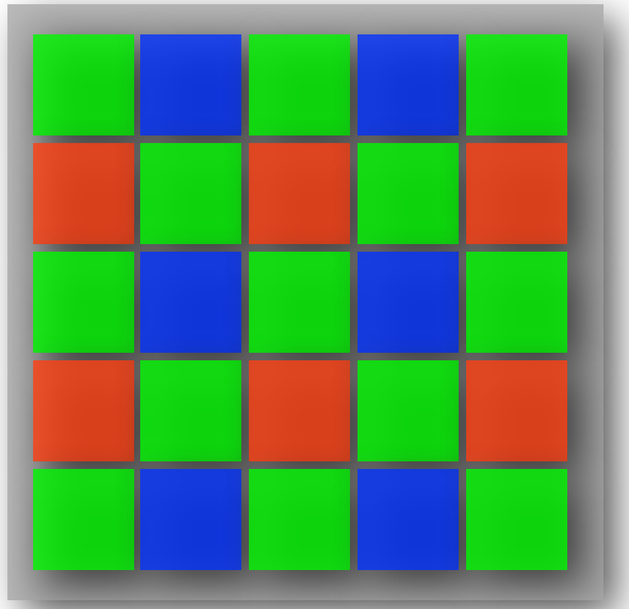

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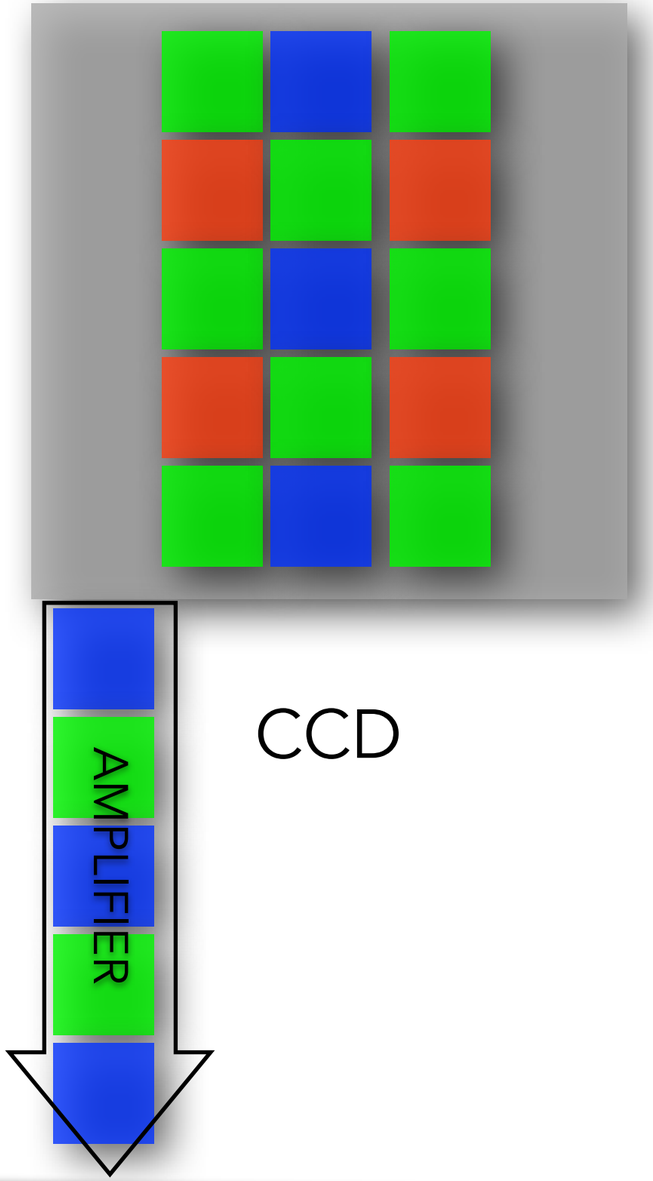

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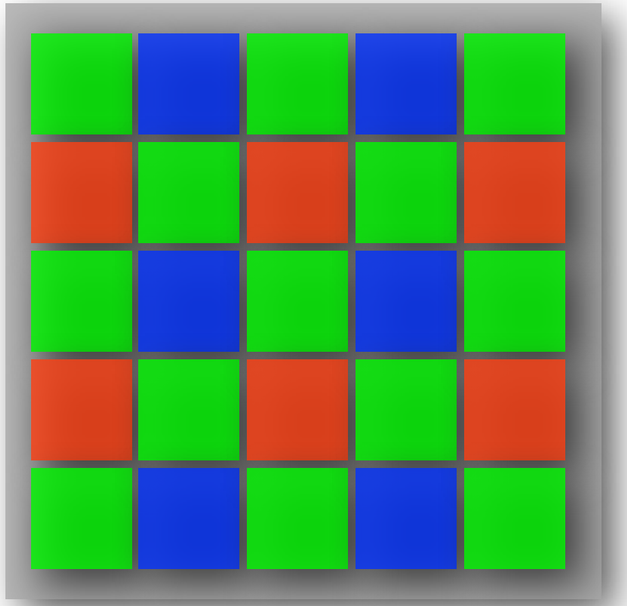

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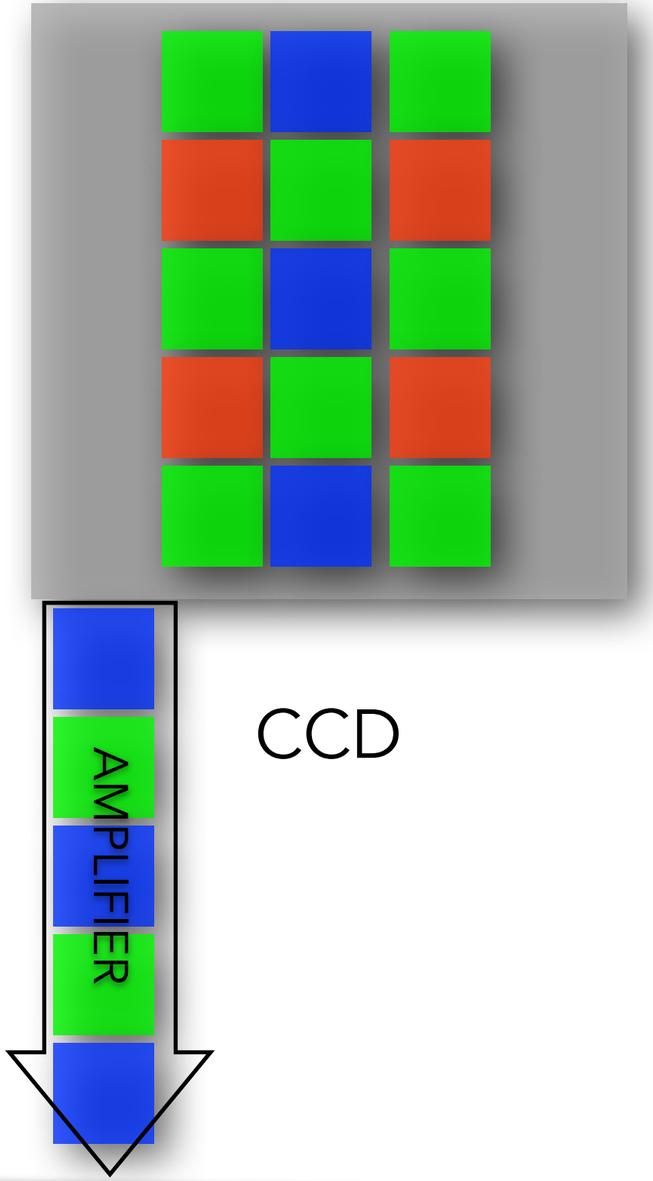

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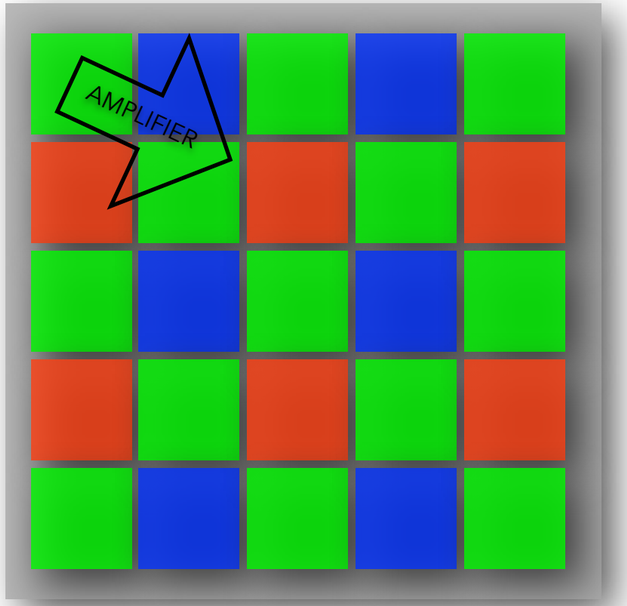

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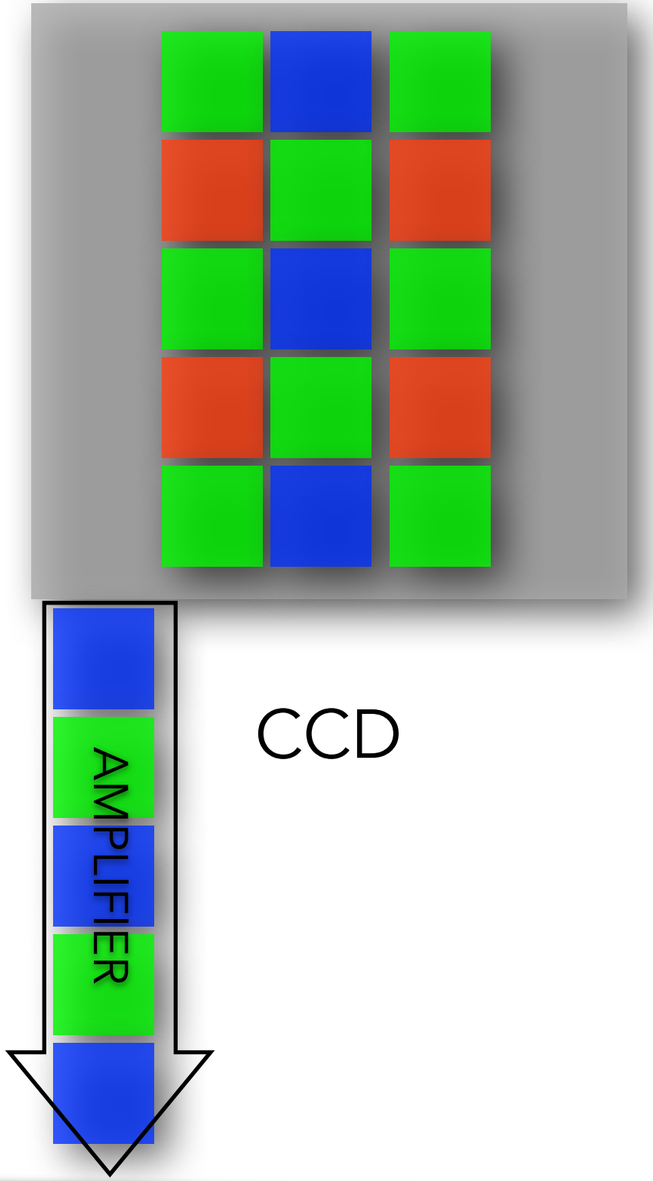

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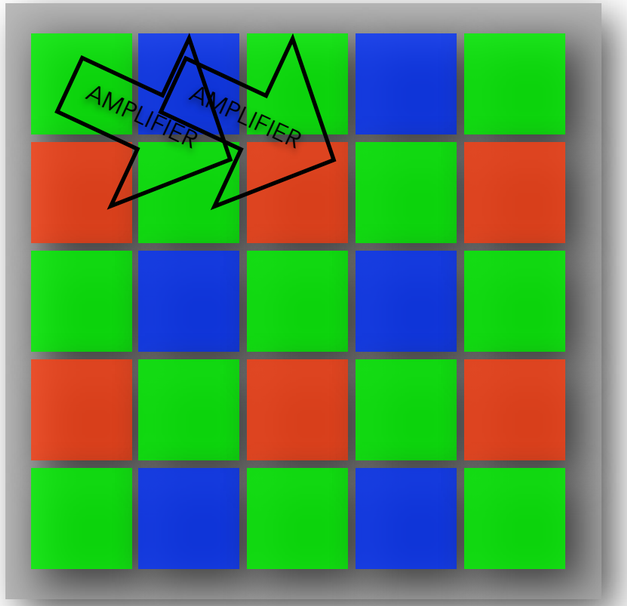

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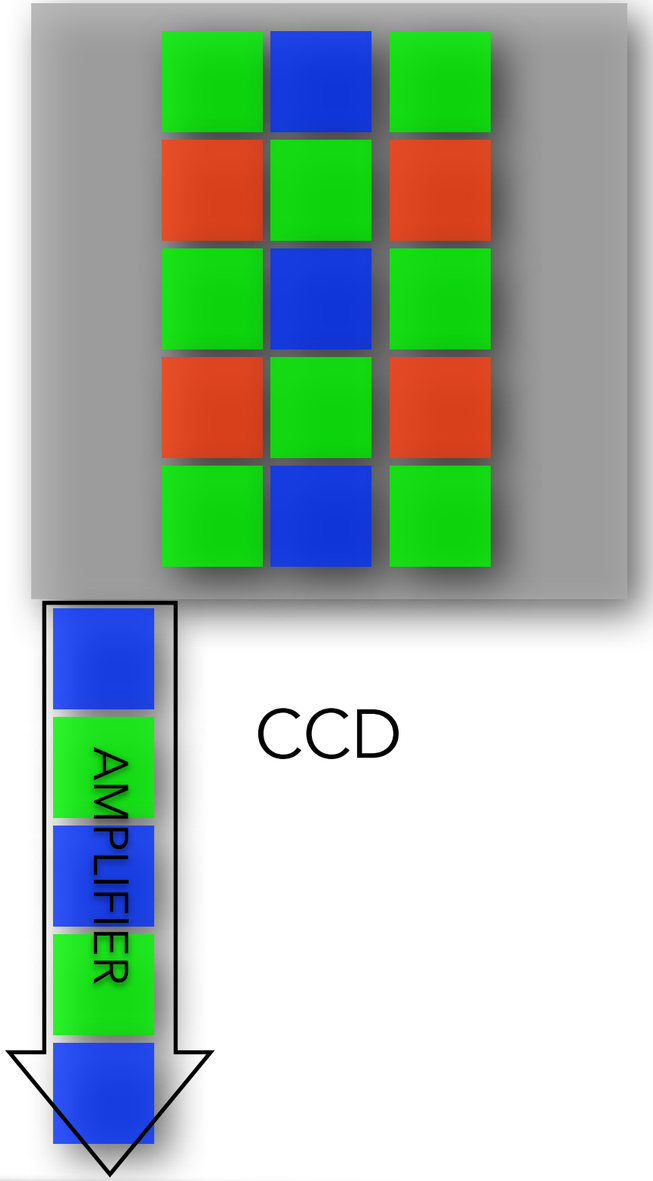

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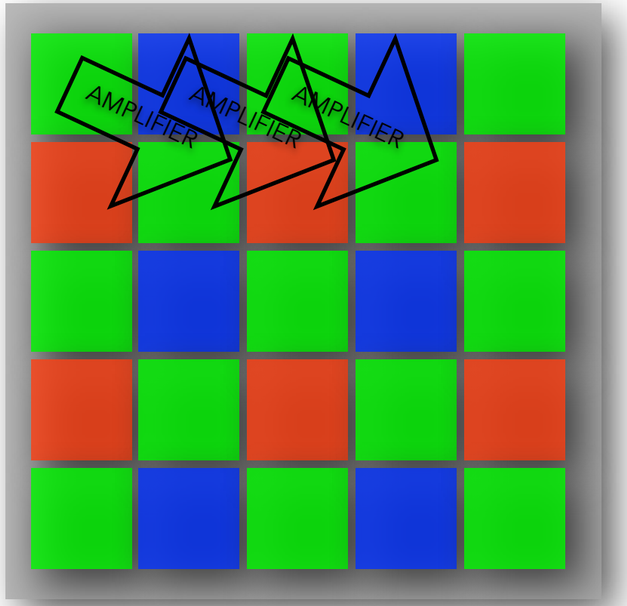

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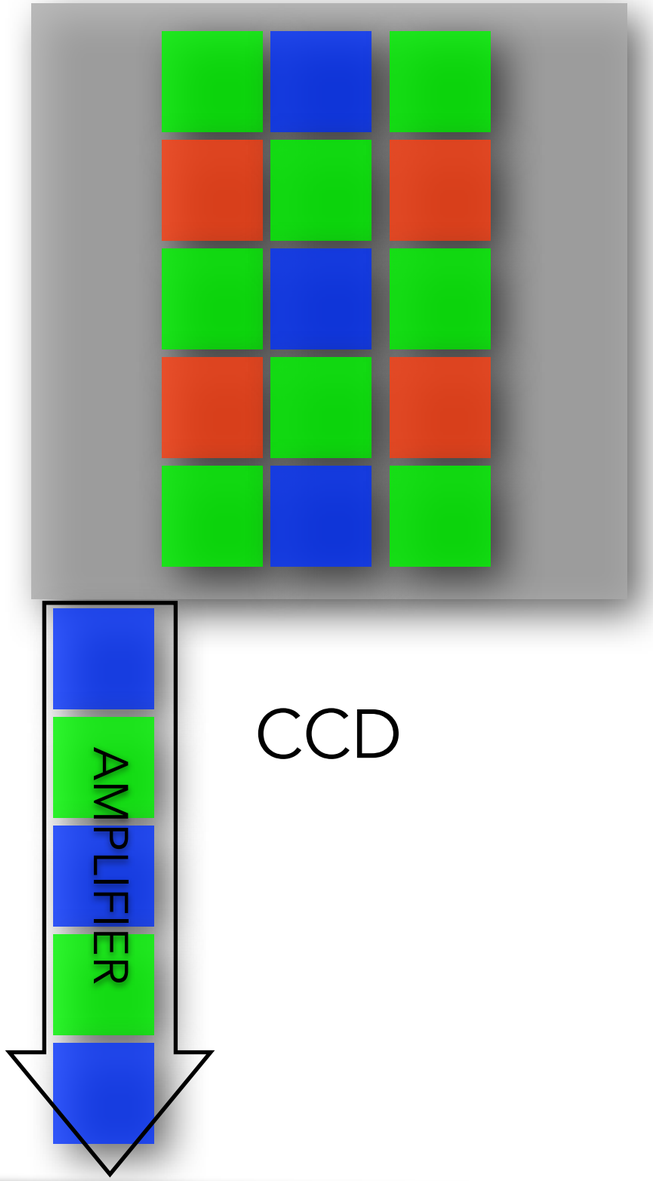

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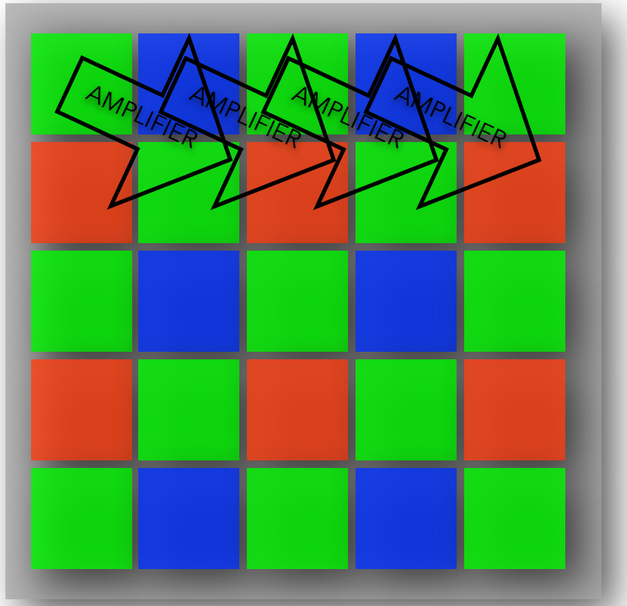

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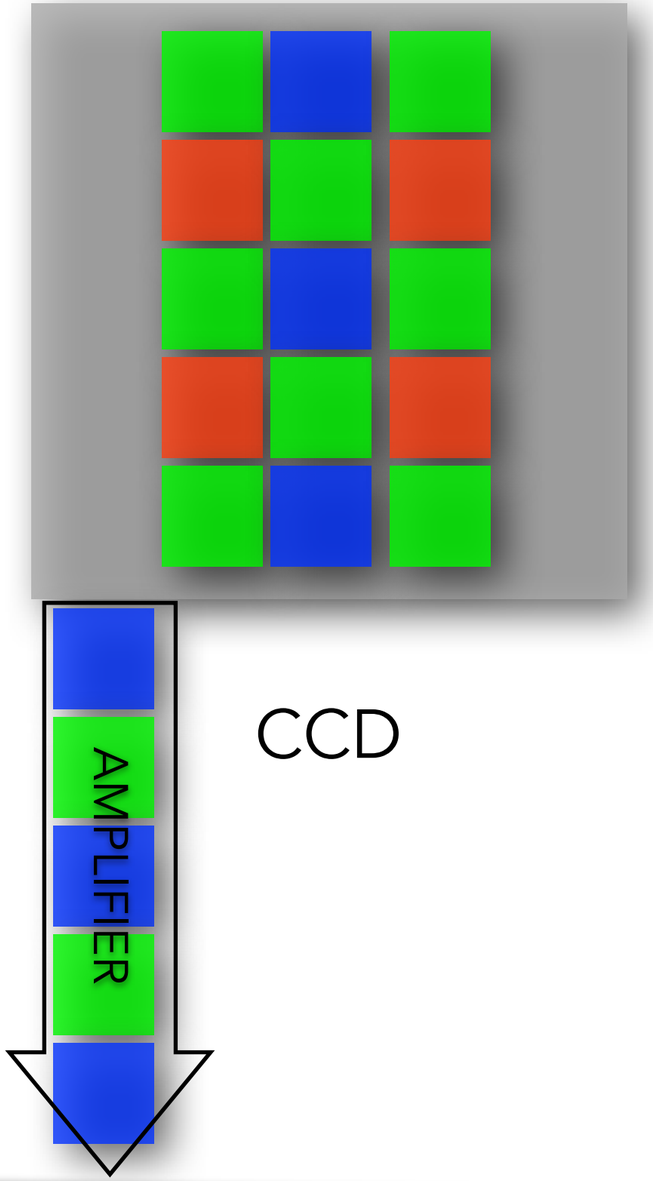

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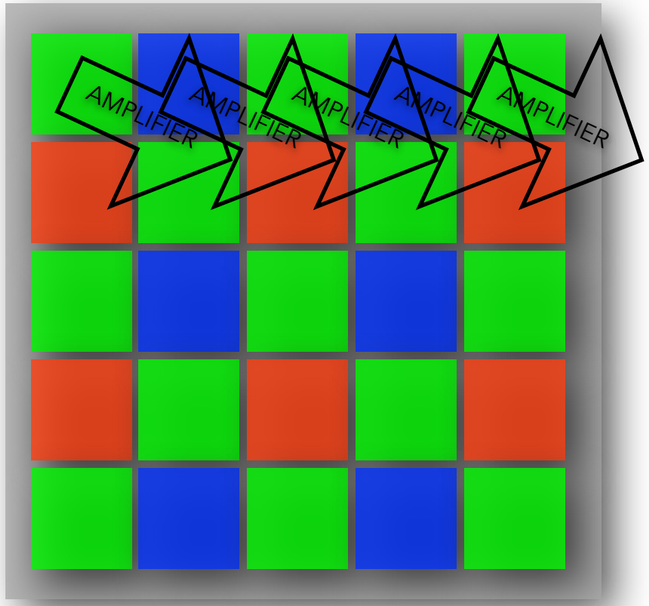

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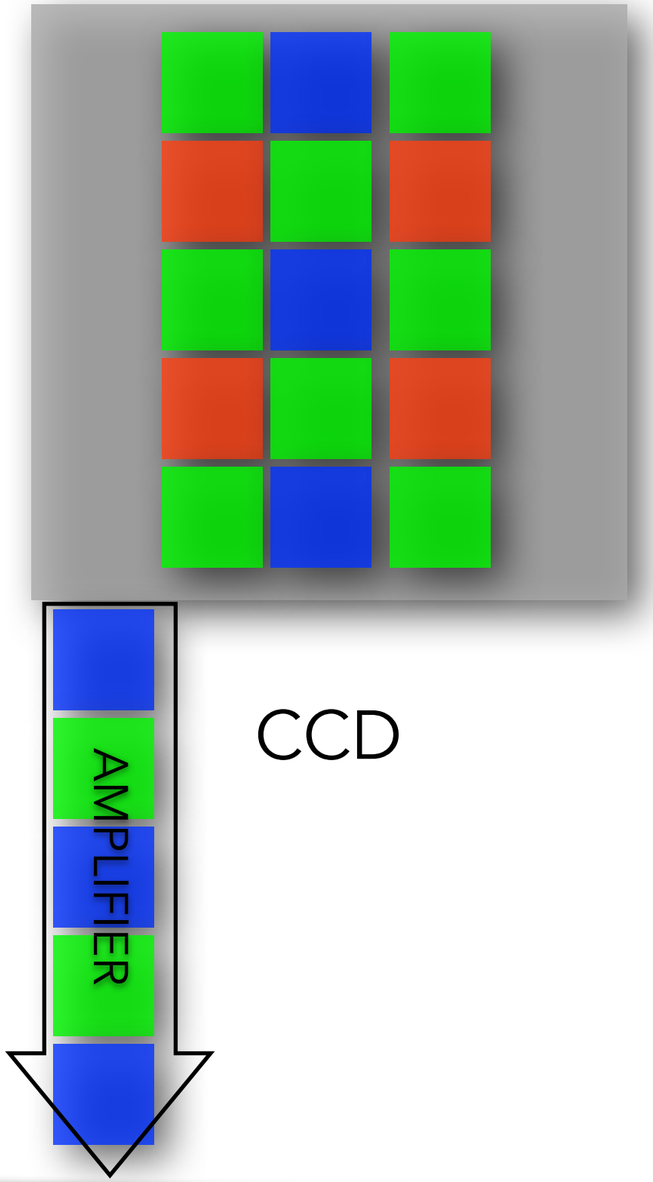

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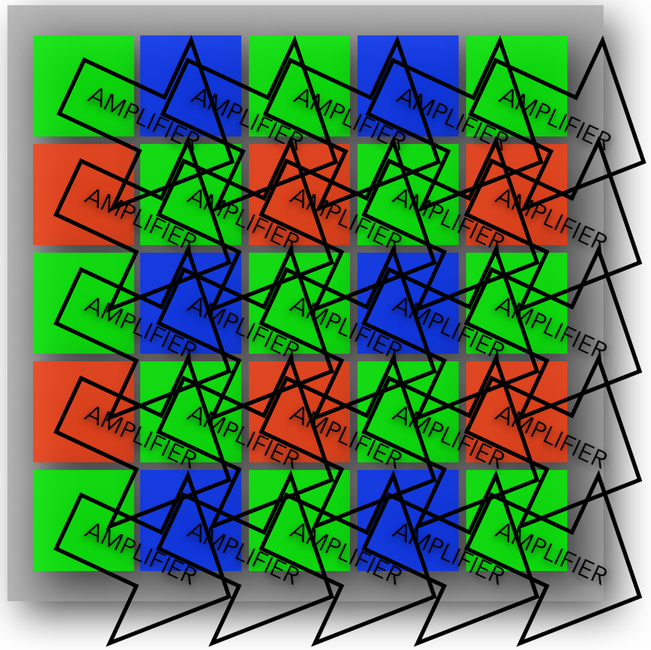

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Camera RAW File Format

- Contains minimally processed data from the image sensor of a digital camera.
- Encodes the image in a device-dependent colorspace.
- Intended to capture as closely as possible the radiometric characteristics of the scene.
- Files contains the information required to produce a viewable image from the camera's sensor data.
- Like a photographic negative, a raw digital image has a wider dynamic range or color; preserves most of the information of the captured image.

14

Summary

- ★ Described the Photographic Processes for Digital and Film Capture.
- ★ Presented how sensors work in Cameras
- ★ Discussed how a Color filter works in a sensor
- ★ Presented CCD and CMOS sensors
- ★ Discussed the benefits of the Camera Raw Format

Next Class

★ Doing Computational Photography.

- Blending/Fading
- Panoramas
- High-Dynamic Range Imaging.

16

Credits

- For more information, see
  - Hecht, E. (2002). *Optics*, 4th ed. Reading, MA: Addison-Wesley,
  - London, B., Stone, J., & Upton, J. (2011), *Photography*, 10th ed. Upper Saddle River, NJ: Prentice Hall, and
  - White, R. (2006), *How DIgital Photography Works, Que Publishers.*
- Some images retrieved from
  - http://commons.wikimedia.org/.
  - List will be available on website.

www.flickr.com/photos/neneonline/231886965/

Georgia Institute of Technology

Computational Photography

Dr. Irfan Essa
Professor
School of Interactive Computing

Study the basics of computation and its impact on the entire workflow of photography, from capturing, manipulating and collaborating on, and sharing photographs.