In Search of Sensors

Prof. Hank Dietz

University of Kentucky
Electrical & Computer Engineering

Things You Already Know

- The sensor is some kind of chip
- Most can't distinguish colors
- They have lots of pixels (sensels)
- They're pretty good & getting better

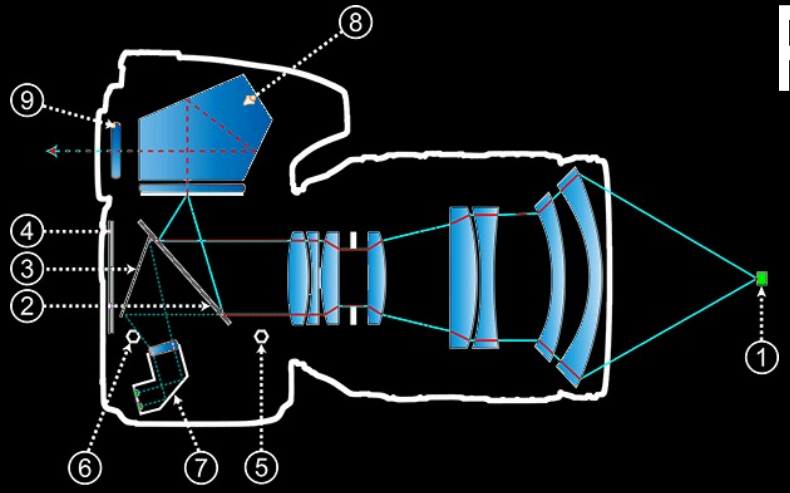
Where Is The Sensor?

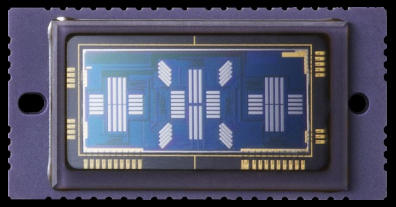
- Sensor
- Shutter
- Microlens array
- CFA
- Mirror
- NIR-blocking filter
- IBIS
- PDAF
- AA filter
- Dust...?

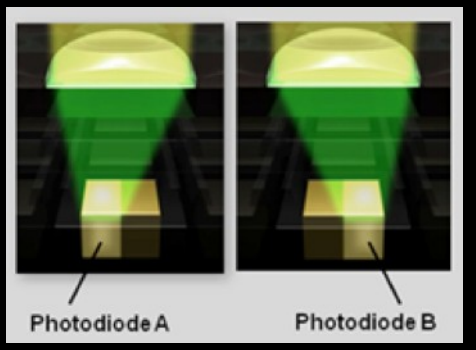
Mirror

- Reflects light to OVF (Optical ViewFinder):
  - In “mirror box” of SLR (Single Lens Reflex)
  - TLR (Twin Lens Reflex)
- Reflects light to secondary sensors
- Moving conventional front surface mirror
- Fixed pellical (thin semi-transparent) mirror (Sony's SLT – Single Lens Translucent)

PDAF?







- Phase Detect AutoFocus – estimate defocus direction and distance by measuring feature Separation between left/right views
- Traditionally done with separate line sensors, now can be done on main sensor using the microlens offset to separate left/right views

Anti-Dust Stuff

- Often, top layer of sensor is just glass
- Usually has an anti-static coating
- Glass far in front to diffuse dust shadows (even “Dust-Shield” user-installable plastic)
- Sometimes, an ultrasonic filter – camera can shake glass to repel dust
- Often over a sticky tape to catch dust...

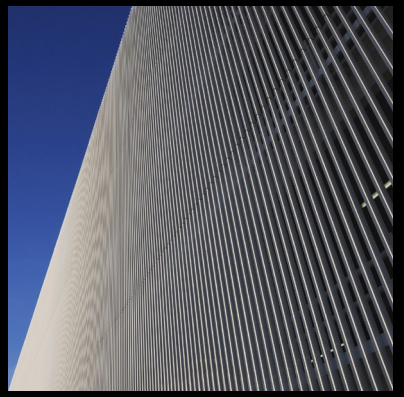
Shutter

- Leaf – aperture iris, but closes completely
- Focal Plane – a moving slit
  - 1st curtain opens
  - 2nd curtain follows closing
- Electronic shuttering methods:
  - Solid state optical / LC – no moving parts
  - Global – all sensels sampled at once
  - Rolling – sensels sampled in scan order

NIR-Blocking Filter

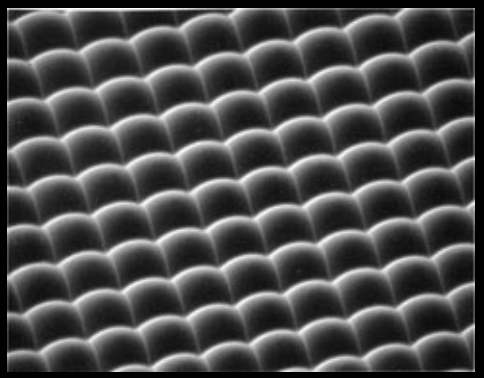
- Most image sensors strongly detect NIR
- Wavelengths from ~850nm to ~1100nm (IR is from ~8000nm to ~13000nm)
- Hot Mirror – dichroic mirror or interference filter that passes visible light, not (N)IR (a Cold Mirror is the opposite)
- Many camera NIR filters are *coatings*... which leak and often have visible color tints

Anti-Aliasing (AA) Filter



- Aka, Optical Low-Pass / Blur Filter
- Used to avoid Moire' Patterns caused by regular spacing of sensels below Nyquist
- Sensors using CFAs interpolate wrong colors
- Above Nyquist if lens resolution is poor – a 5um sensel is ~Nyquist for 50lppmm

Microlens Array



- Fill Factor – fraction of sensel area sensing
- Low fill factors are bad:
  - Leave gaps, breaking sampling (Nyquist)
  - Waste photons, reducing sensitivity
- Microlens Array – literally, a lens over each sensel area to focus light on active area
- Hard to make, simple plano-convex lenses (don't focus all light where you want it)

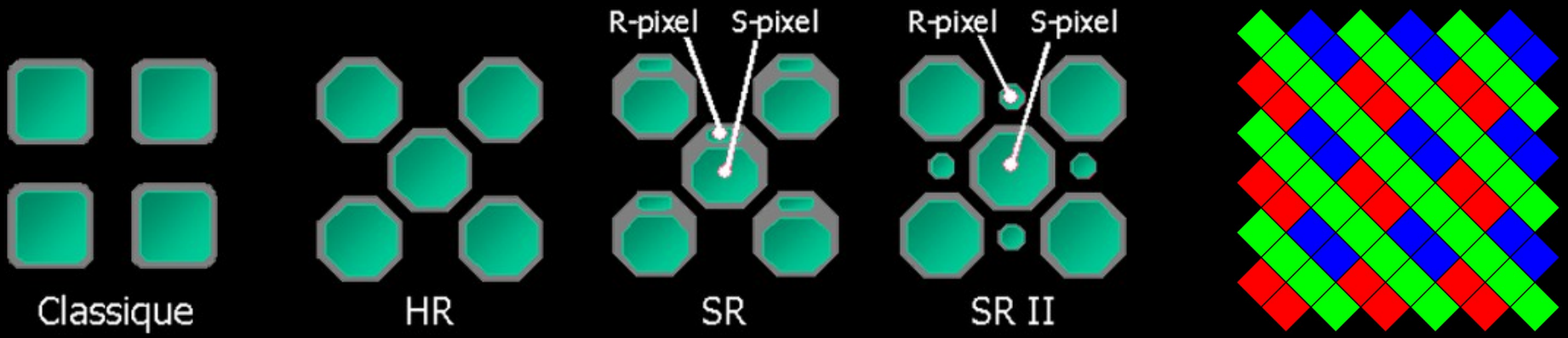
Color Filter Array (CFA)

- Color choices:
  - Bayer – [[Red, Green], [Green, Blue]]
  - Cyan, Magenta, Yellow, Green
  - Red, Green, Blue, Clear
  - Deliberately randomized, etc.
- Pattern choices:
  - Rectangular array of square sensels
  - Diagonal array of hexagonal sensels (Fuji)
  - Large or randomized color patterns

The Main Sensor

- Various technologies:
  - CCD (Charge-Coupled Device)
  - CMOS – now most common in cameras
  - Foveon – color by depth, stacked pixels
  - Microbolometers for IR, etc.
- Can be front or back illuminated
- ISO is a function of quantum efficiency, fill factor, analog gain, etc.
- Higher sensitivity makes low ISOs hard...

Funny-Looking From Fuji



- Fuji is trying lots of unusual layouts...
  - Fuji SuperCCD SR sensor (in S3)
  - Fuji EXR sensor (in X10)
- No other company has followed this path

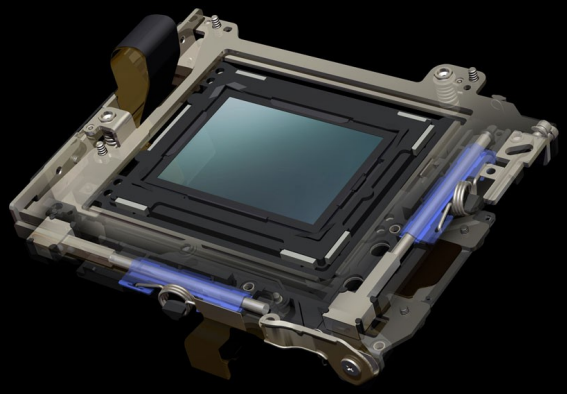
My TDCI Sensor Concept

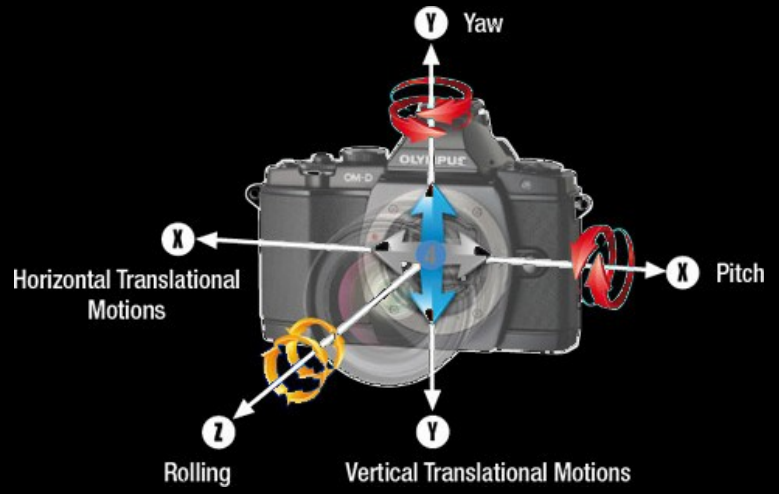
- TDCI (Time Domain Continuous Imaging) – sensor doesn't actually capture images
- Each sensel has a processor *under* it (or could use compressed sensing)
- Asynchronously measure time for each sensel to reach a threshold (then reset)
- Sensor returns smooth waveform per sensel giving sensed EV as a function of time
- Images computed from waveforms

The Main Sensor

- Sensels are linear photon counters
- Analog values converted to 8-14 bit digital
- Interpolation of colors
  - Various algorithms... not a trivial issue
  - Color vs. resolution; handling of noise
  - Pixel/dust mapping; dark frame subtraction
- Determine & correct for black point, color (CMS – color management system)

IBIS?





- In Body Image Stabilization – anti-shake by moving the sensor inside the body
- Movement to compensate computed from motion and lens focal length
- Can have from 2 to 5 axis of motion for the plate on which the sensor is mounted

Conclusion

- The sensor isn't as exposed as you think
  - Sensor cleaning not as scary as you think
  - Can change sensor stack (`maxmax.com`)
- Mechanical complexity is high
- Lots of differences even with same sensor – e.g., Sony sensors in Nikon cameras