

The physics of photography

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About me

....

BSc at Sydney University

Then a PhD at Trinity College Dublin

Post Doctoral Fellowship in Paris

Lectureship in Dublin

Research Fellow at Sydney University

Now research manager with Canon, in North Ryde

And Adjunct As/Prof here in Physics...

This is actually a circular story, because

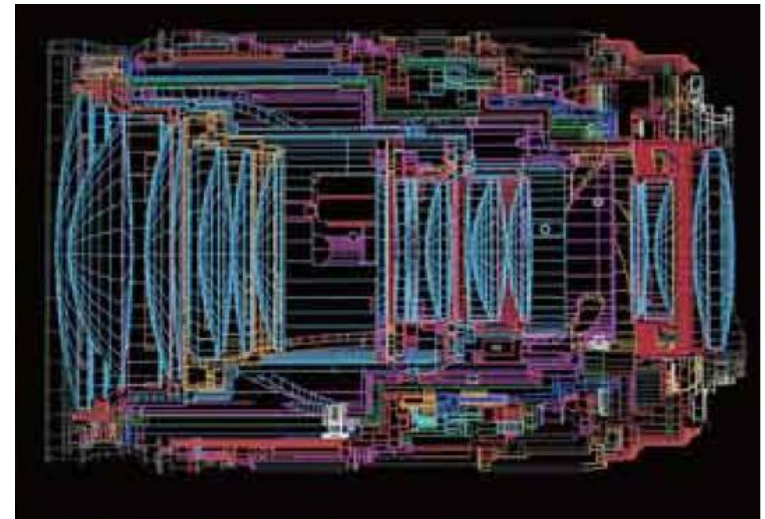
- ❖ What got me into physics in the first place was photography
- ❖ After a brief flirtation with being a paparazzi ...



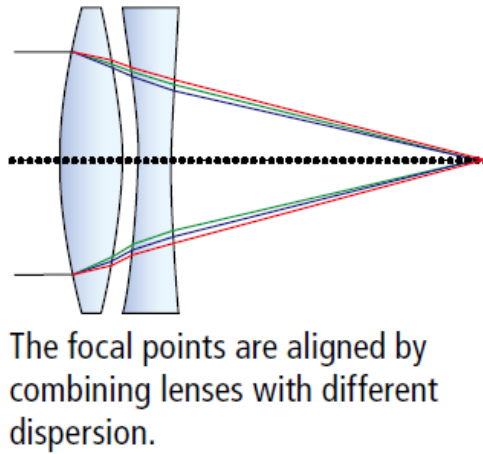
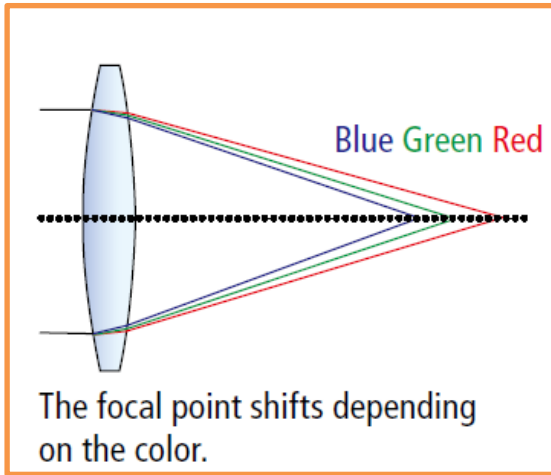
- ❖ I decided on optics research...

Lots of optics in photography

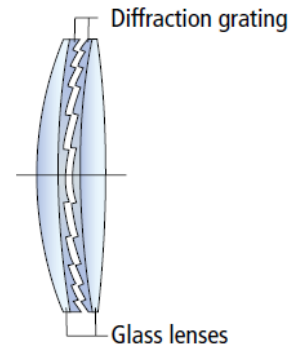
- Lots of physics involved in lens design (depends on the application):
 - Reducing aberrations
 - Producing a bright image, good low light performance
 - Miniaturization



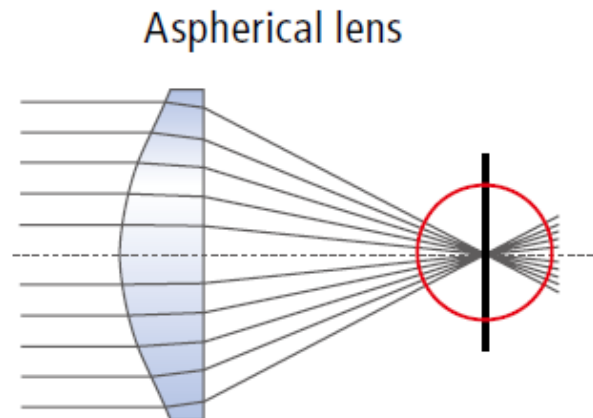
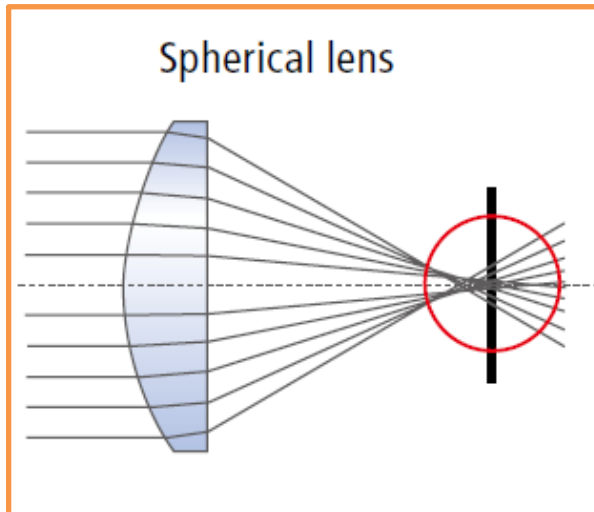
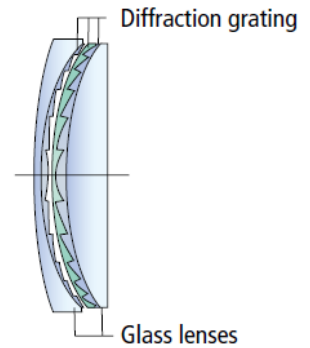
chromatic and spherical aberration



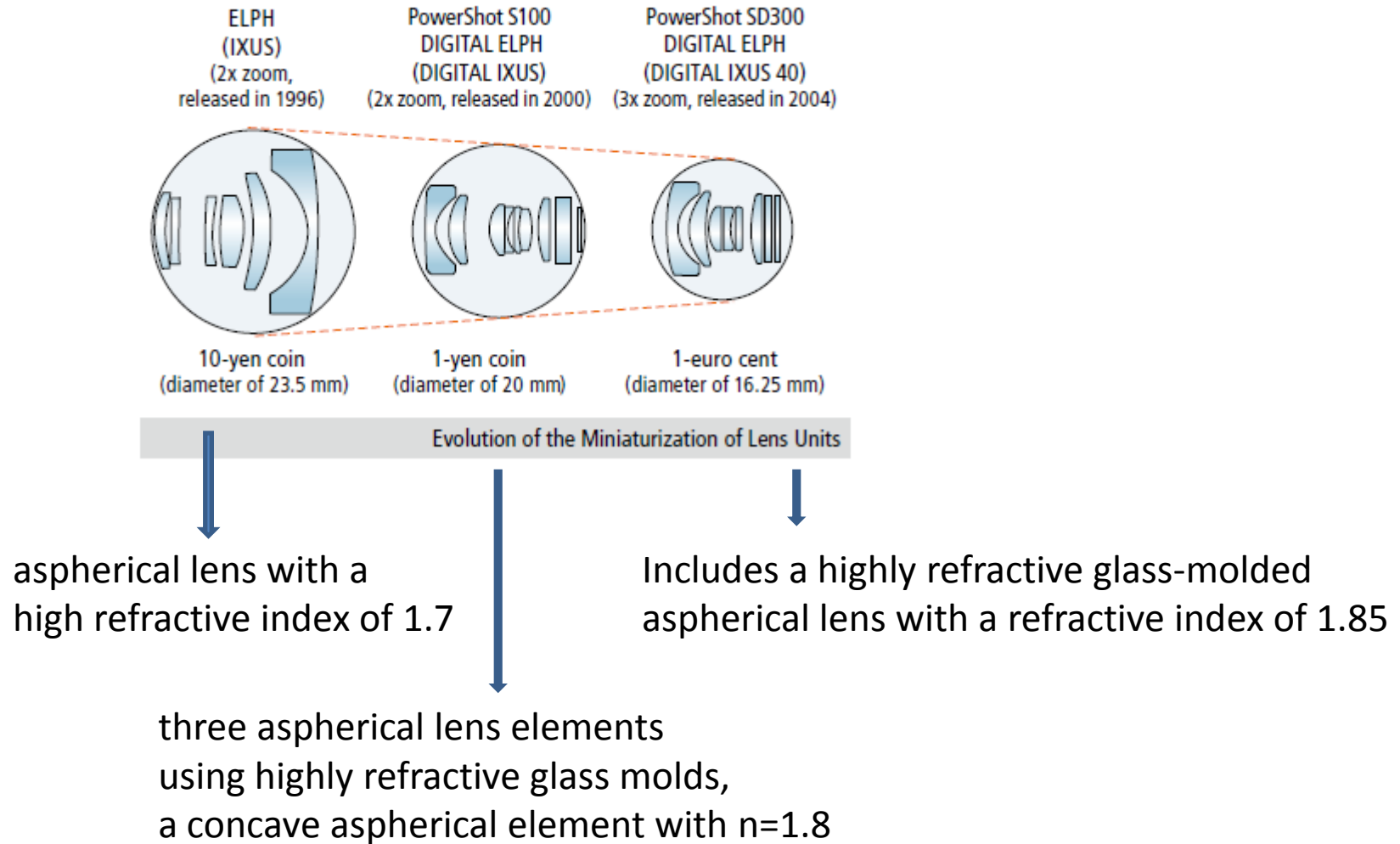
Two-layer DO lens



Three-layer DO lens

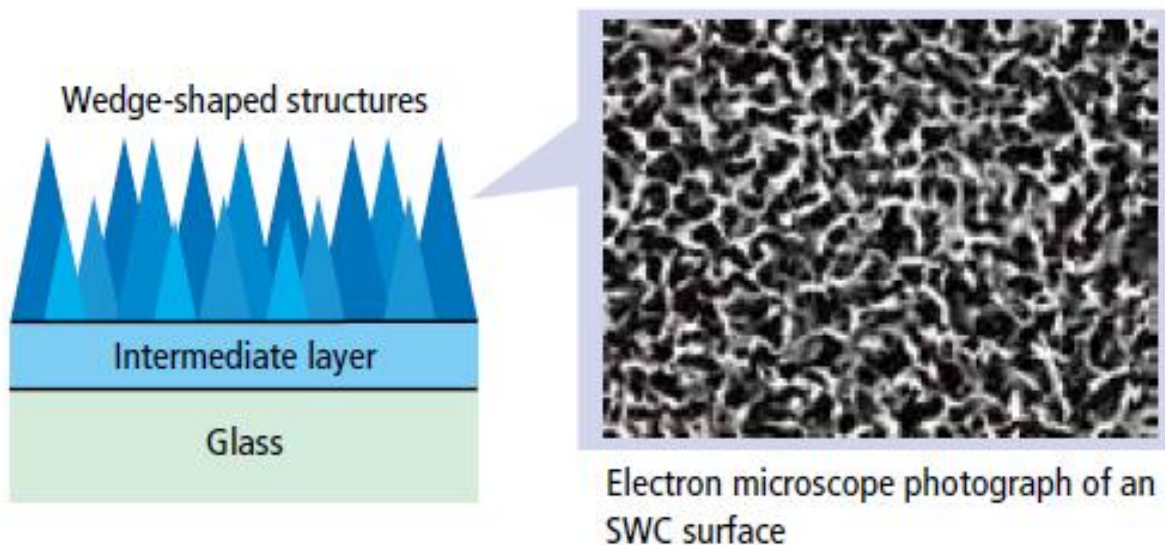


Optics: Lens miniaturization



Anti-reflection optics

- Lots of high refractive index surfaces..
- Lots of reflection ($\sim 4\%$ per surface for normal glass, see Fresnel reflection coefficients)
- How do we reduce it? Subwavelength structure coating to gradually change in



But not ONLY optics...

Digital cameras are pretty complicated

Overview of SLR Cameras

Digital SLR cameras feature an interchangeable lens system and use an image sensor that converts light into electrical signals to record images.

Focusing Screen

The image of the subject to be photographed is displayed on this screen

Shutter Release Switch

Memory Card

Main Mirror

Flips up during exposure to open a path for light to reach the image sensor

Secondary Image-Formation Lens

Two pairs of integrated aspherical lenses guide the image of the subject to the AF sensor

Imaging Processor

Processes the signals read from the image sensor at high speeds and generates image data
► DIGIC 4 (P.33)

Metering Sensor

63-zone metering sensor optimized for Area AF

Pentaprism

Converts the image on the focusing screen to an upright image

Low-Pass Filter

► Hybrid Infrared-Cut Low-Pass Filters

Image Sensor

Utilizes Canon's proprietary CMOS sensor. The image sensor converts light into an electric signal, and is equivalent to film used in a conventional film camera.
► Large Size CMOS Sensor

Shutter

Opens during exposure to allow light to reach the image sensor

Submirror

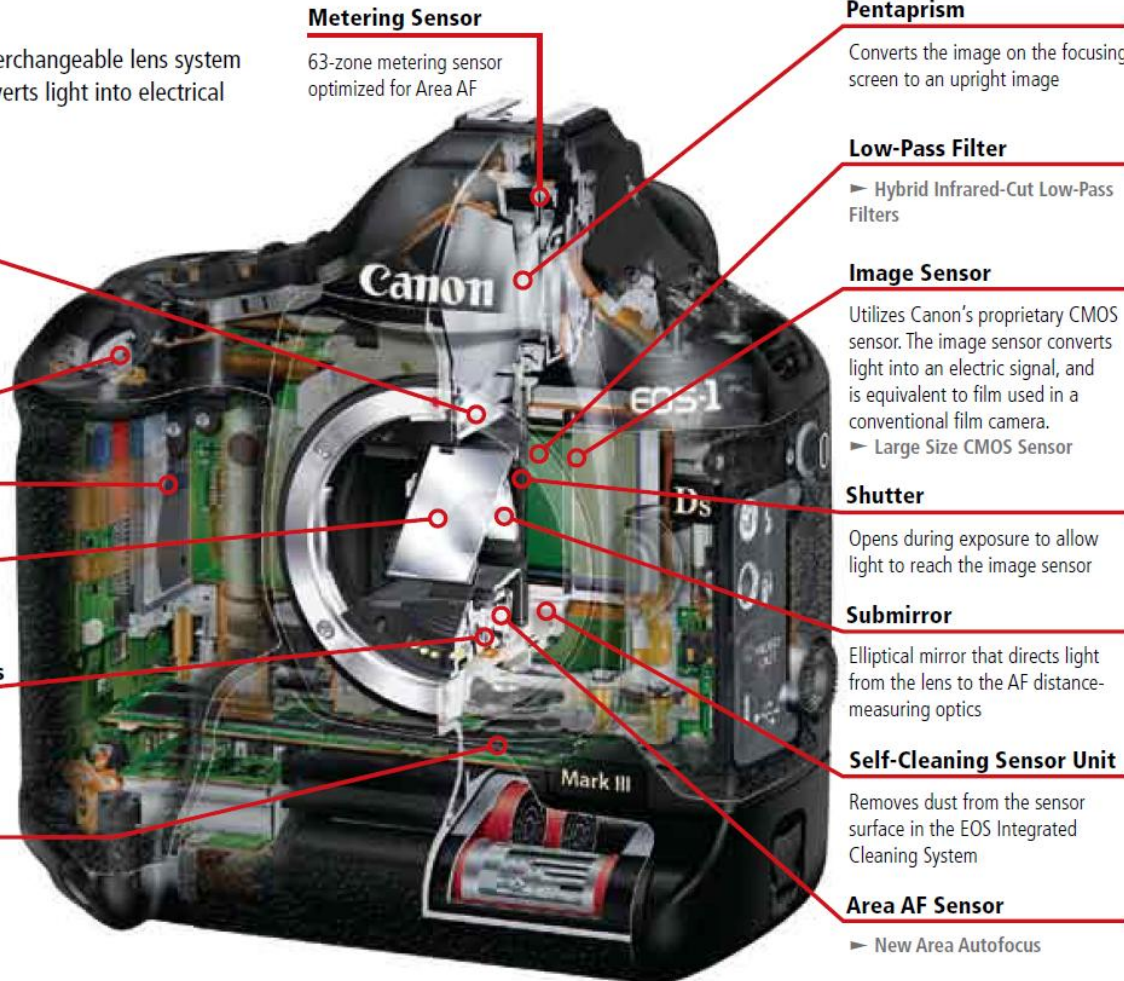
Elliptical mirror that directs light from the lens to the AF distance-measuring optics

Self-Cleaning Sensor Unit

Removes dust from the sensor surface in the EOS Integrated Cleaning System

Area AF Sensor

► New Area Autofocus



The first digital camera

invented at Kodak

- Film (and chemistry) replaced by solid state physics devices: **CCD** arrays or **CMOS** detectors
- CCD= Charge Coupled Device
- CMOS= Complementary metal–oxide–semiconductor



Steve Sasson with the first digital camera he created in 1975. *Photo: Andrew Wolf*

How does this work?

A rather simplified version

- Detectors (photodiodes) use the photo-electric effect in a semiconductor
- Photon hits the detector and knocks out an electron
- Electrons “stored” in electron well for reading
- The electron well is about 100 000 for a DSLR and ~5000 for a compact
- Photodiode arranged in arrays form sensor
- Read-out (geometries vary with design)

Getting colour

- Photodiodes basically respond to intensity. We need some tricks to get a colour image
- The most common is to use a Bayer filter

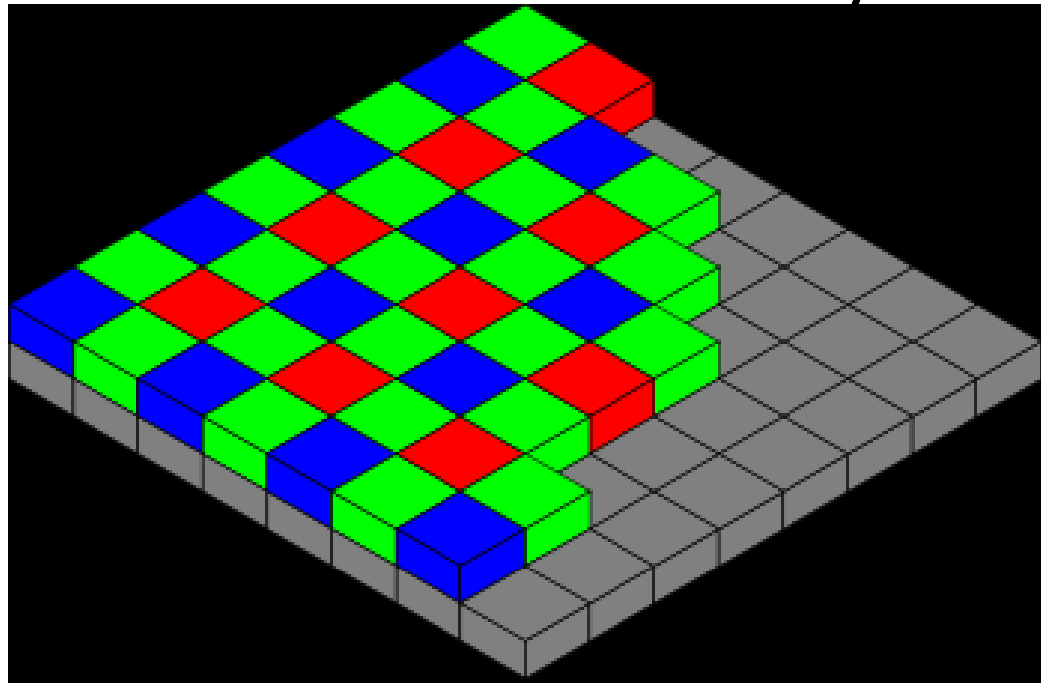


Image processing

- Digital cameras require image processing at the most basic level- getting a colour image
- Need interpolation of the colour from the Bayer filter
- Other processing done on camera includes: autofocus, correction of some aberrations, face detection- **These are non-trivial problems**
- New frontiers for photography?

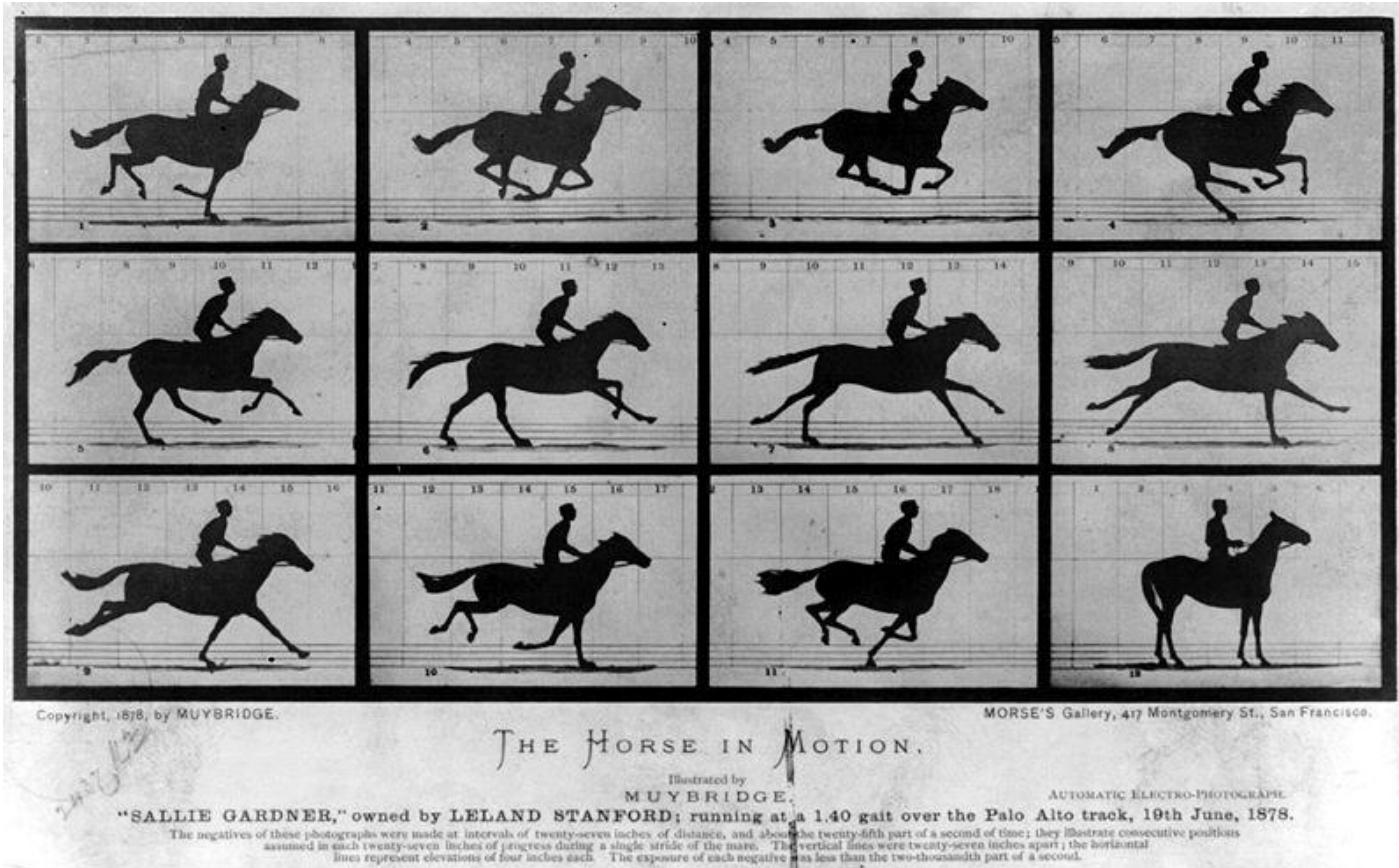
High speed photography

- There are now commercial cameras that take 100, 000 frames per second!
- Problems: shutter that is fast enough, getting enough light in, reading off the sensor fast enough, storage
- Benefits: can study extremely fast events: materials science- how breakages occur, how drops form, explosions: nature, how animals move, flight etc

How does high speed photography work?

- Very short exposure times means few photons
- Previously this meant we had to amplify the signal
- Now people use very efficient CMOS detectors, and CONTROL NOISE
- Can get away with electron wells of ~ 1000 electrons
- Use large areas detectors, very fast readout, sophisticated noise correction

Why? The uses of high speed photography



Until this 1878 study, people did not actually know **how** horses ran.

Even MORE high speed

some random interesting examples

- In **biology**: looking at [flight](#)
- This isn't *exactly* relevantbut it's very [beautiful](#)
- In **materials science**: Here is a gratuitous (but very cool) [explosion](#).
- Other examples include fluid dynamics, failure mechanisms, industrial processing etc
- We need a lot of physics to enable high speed photography, but when it works, it becomes a tool for new science

Other future directions

social media, photosharing, 3D

- Project of GRAIL
<http://grail.cs.washington.edu/rome/>
- In this example, combines 58,000 images of Dubrovnik on Flickr
- matches images to find common points, computes three dimensional structure
- [reconstruction of the Old City of Dubrovnik](#)

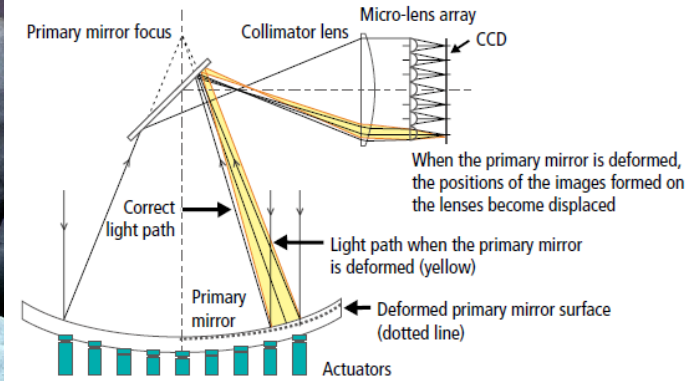
3 things you may not know about Canon



Image taken from:
http://en.wikipedia.org/wiki/Canon_%28company%29



<http://www.letsgodigital.org/en/14374/polar-bear>



Canon technology highlights 2010

1. It is named after the Buddhist goddess of mercy

2. It is one of the world's greenest companies:

<http://climatecounts.org/>

<http://www.canon.com/environment/>

3. It is **VERY BIG**.
~ 197, 300 employees,
Works in almost all areas of optics: cameras, medical imaging, robotics....

A new Canon Prize for Extreme Imaging

- The prize will be awarded for the best student research prize in the area of “extreme imaging”.
- \$5000 for student and \$5000 for supervisor
- Example topics would be: modifying a cheap camera to do something unusual, imaging at unusual wavelengths, ultra-fast photography, imaging in difficult environments, or “green” photography, imaging of very small, or very distant objects, imaging using unusual and innovative techniques.
- More details soon....