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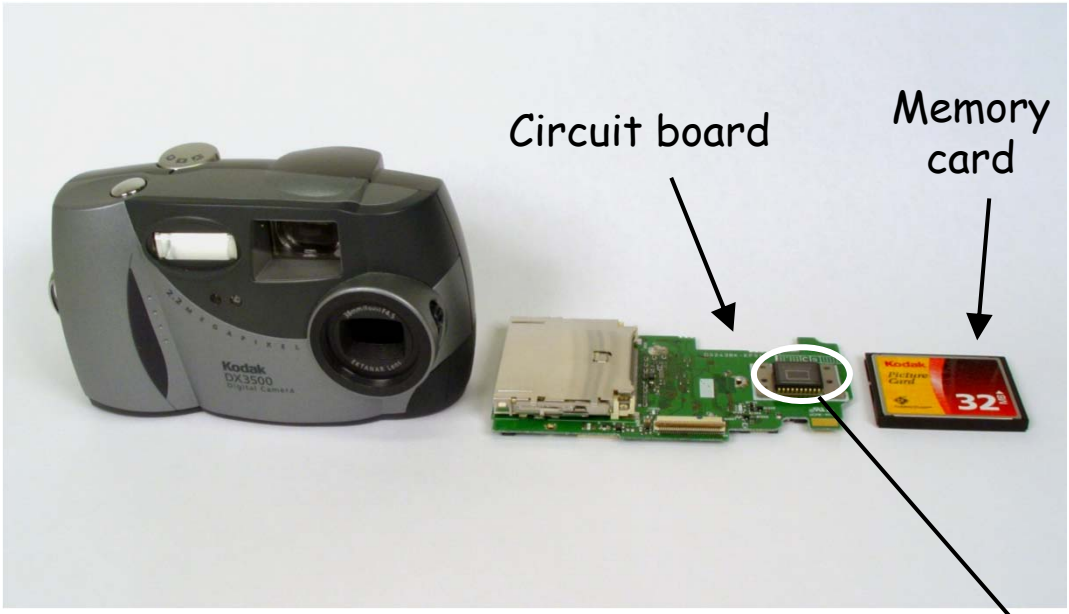
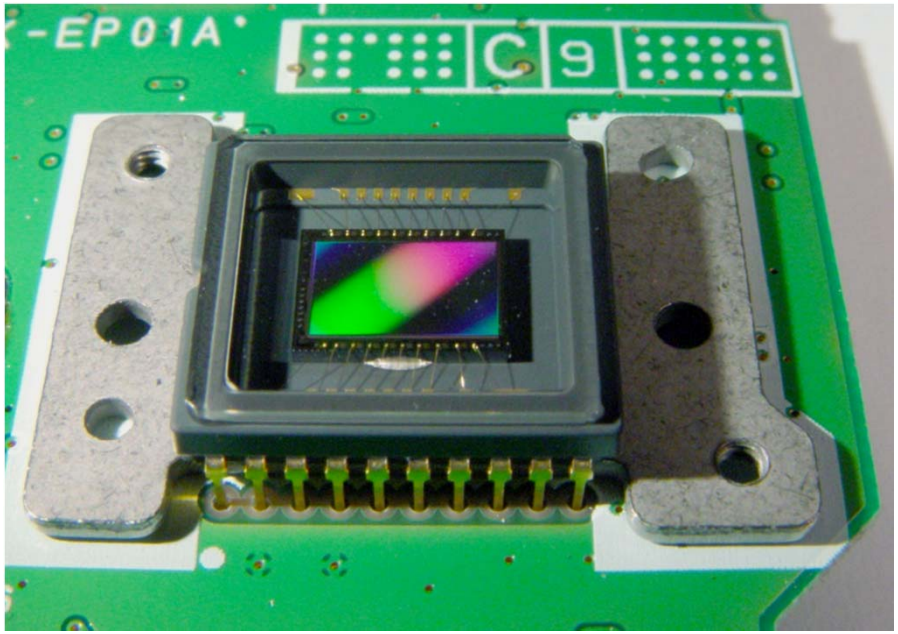
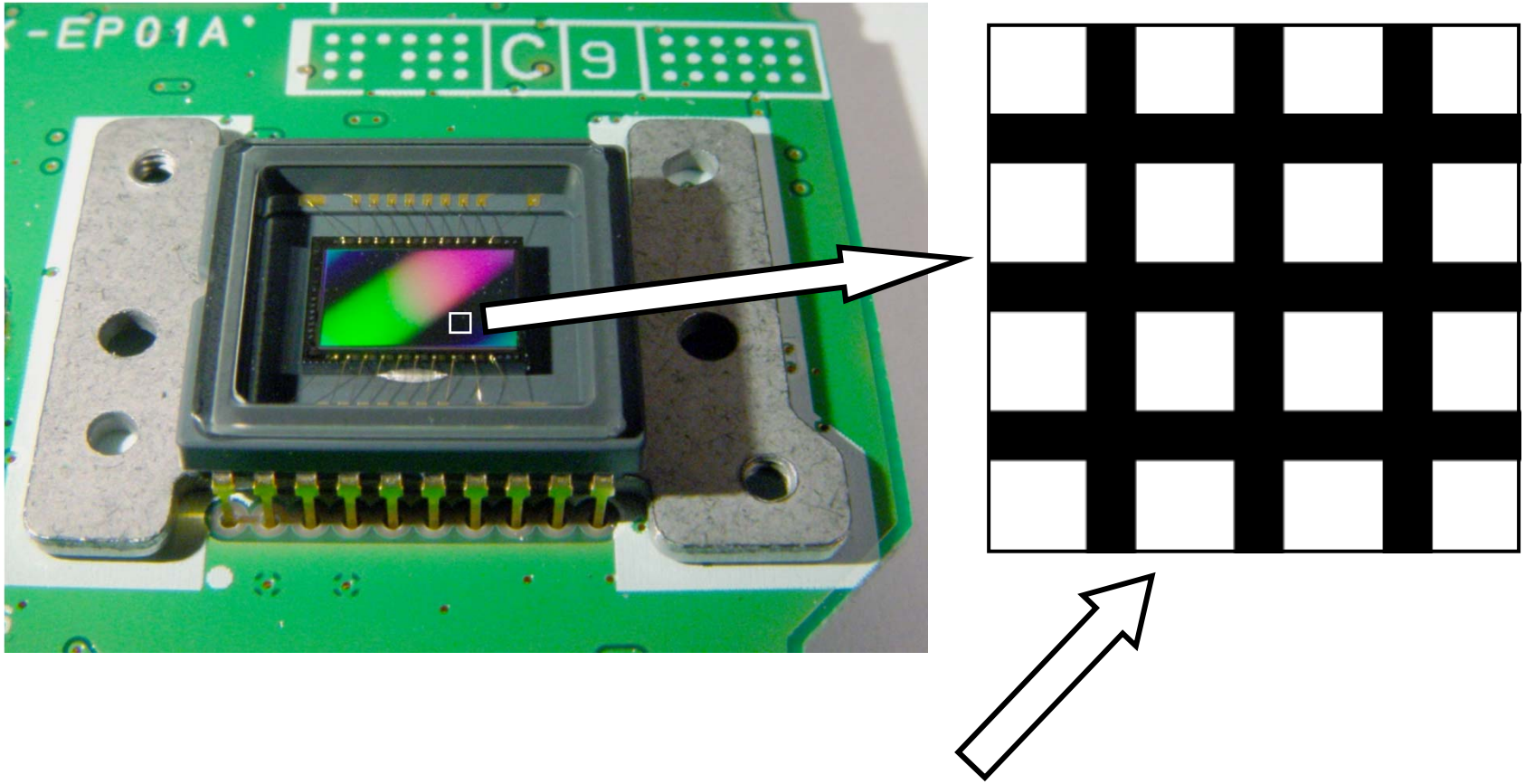
Digital camera



Sensor





Detector element (pixel).

Typical size: 2-5 μm square

Typical number: 5-20M

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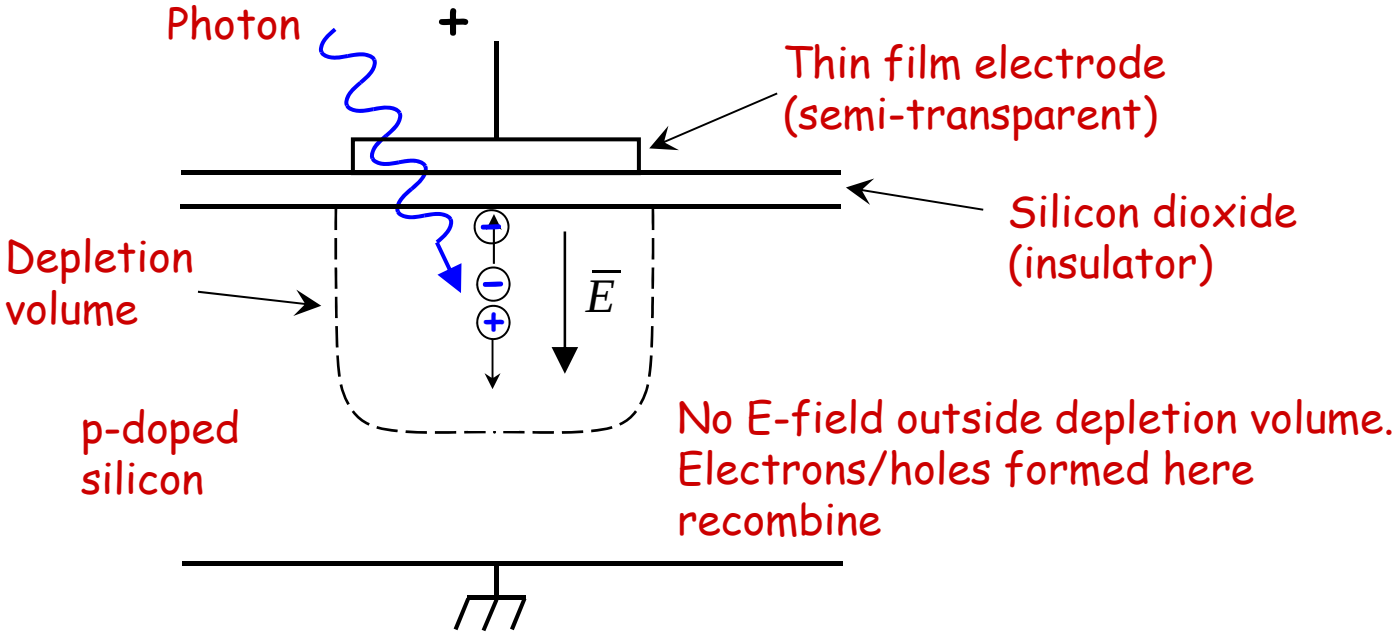
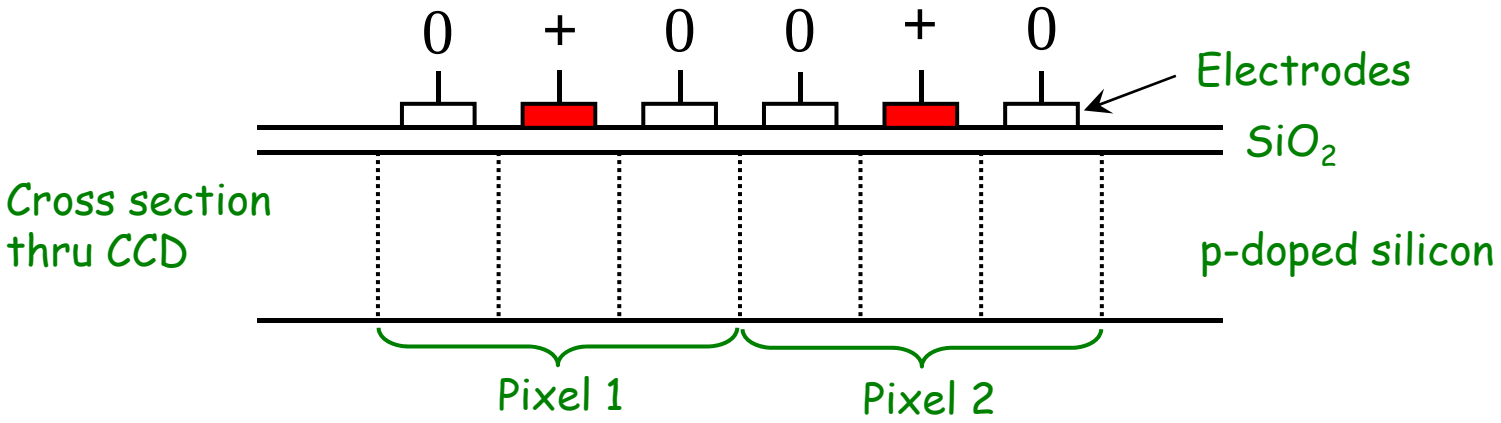
Pixel = Photogate





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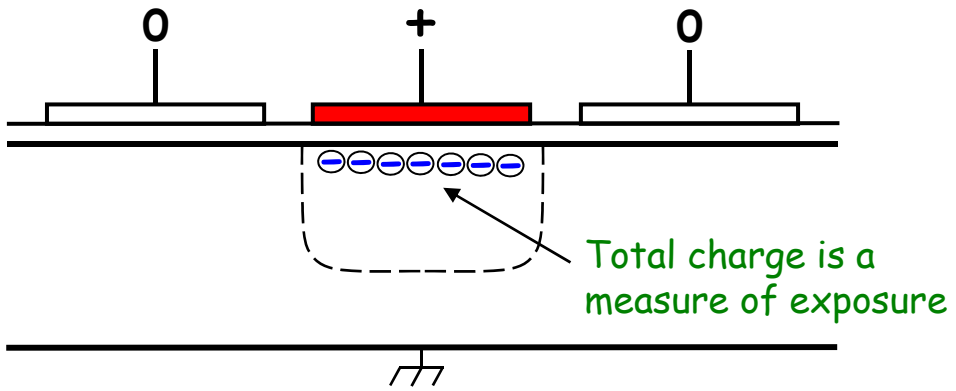
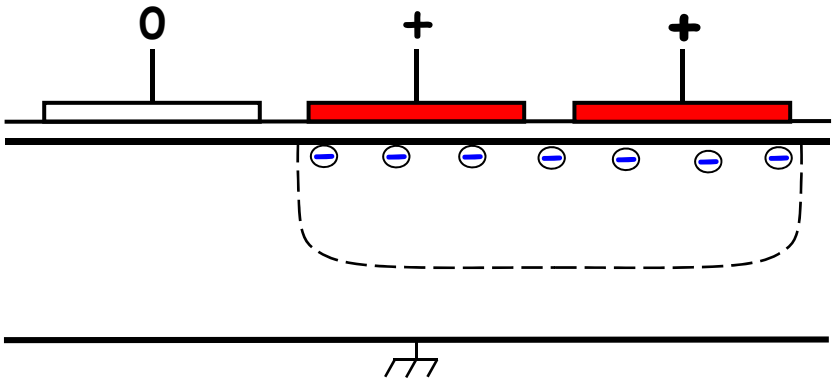
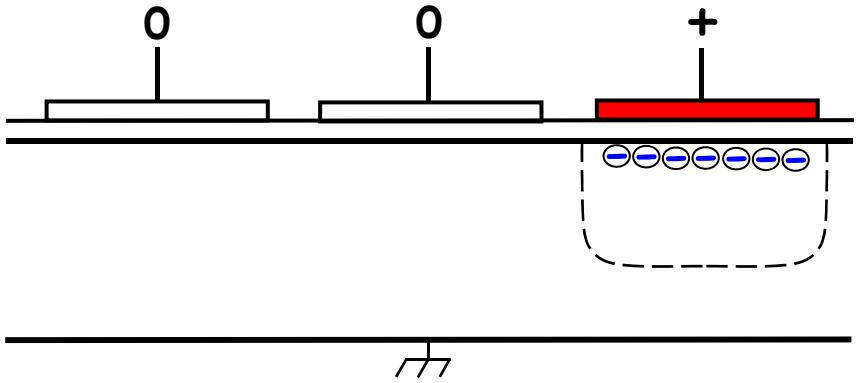
After exposure



Charge transfer





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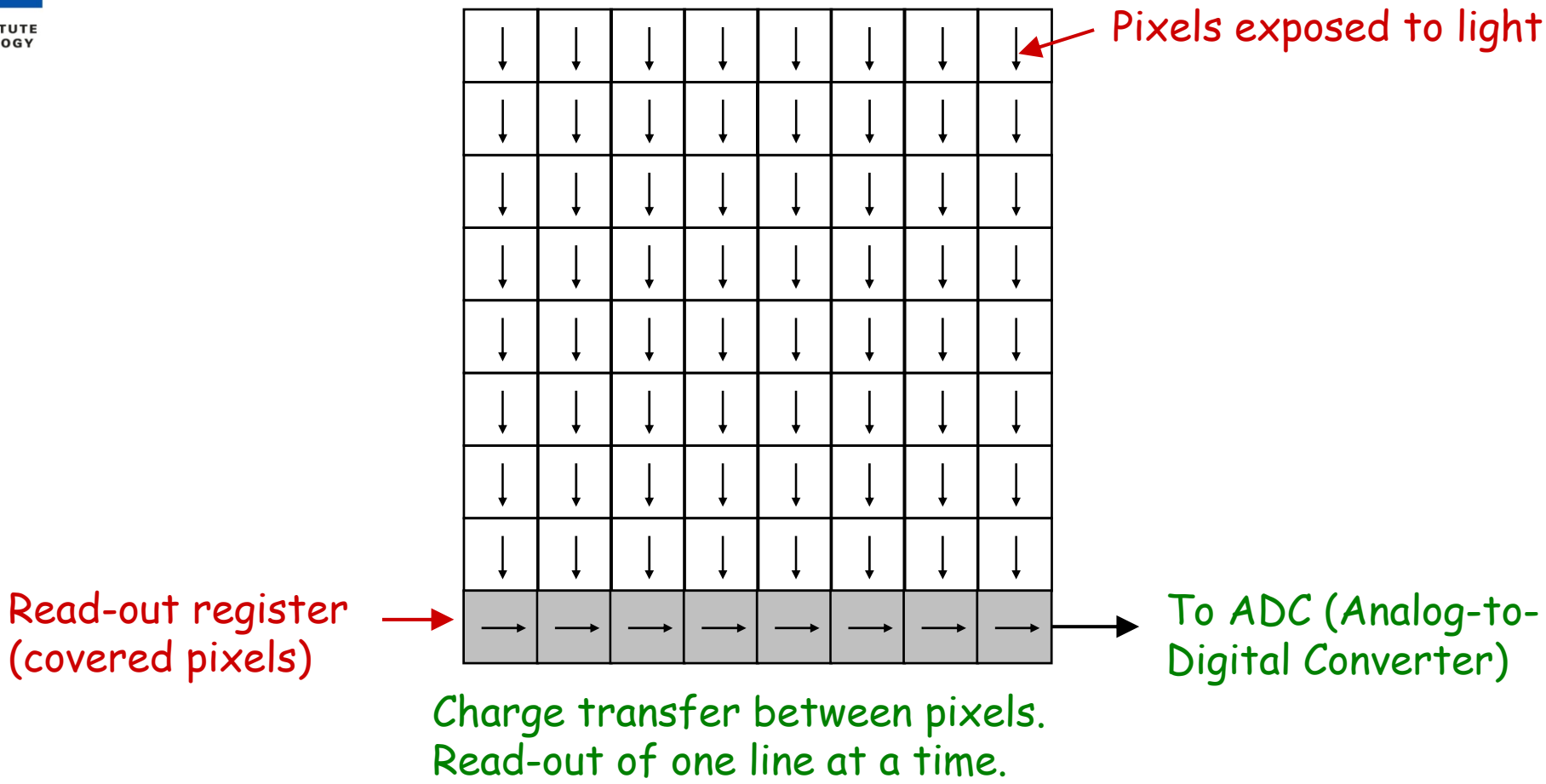
CCD (Charge Coupled Device)



Charge transfer efficiency typ. 0.999995

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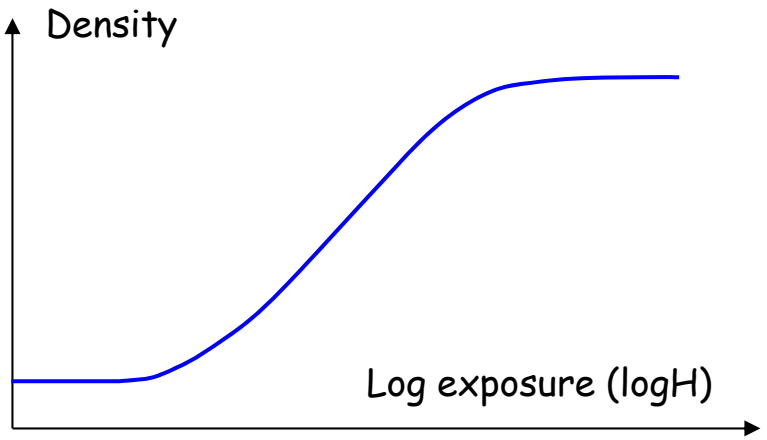
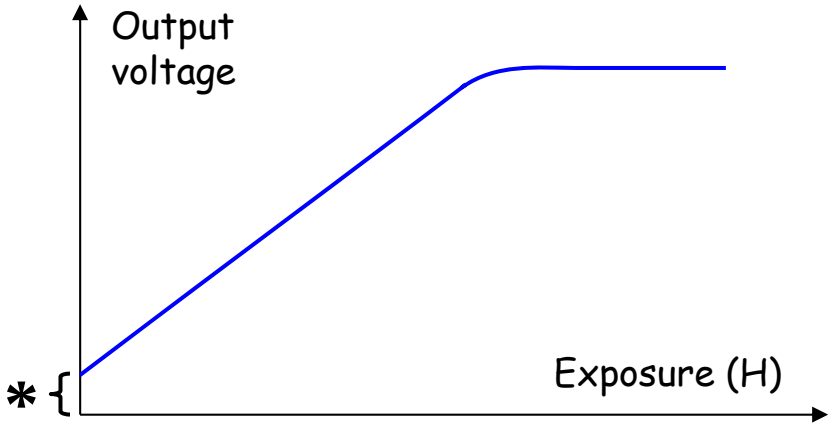
Response curves for film and CCD sensor

Film:



Non-linear response. Lowest acceptable exposure determined by curve slope

CCD:



Linear response. Lowest acceptable exposure determined by noise.

* Dark signal. Can be reduced by cooling.

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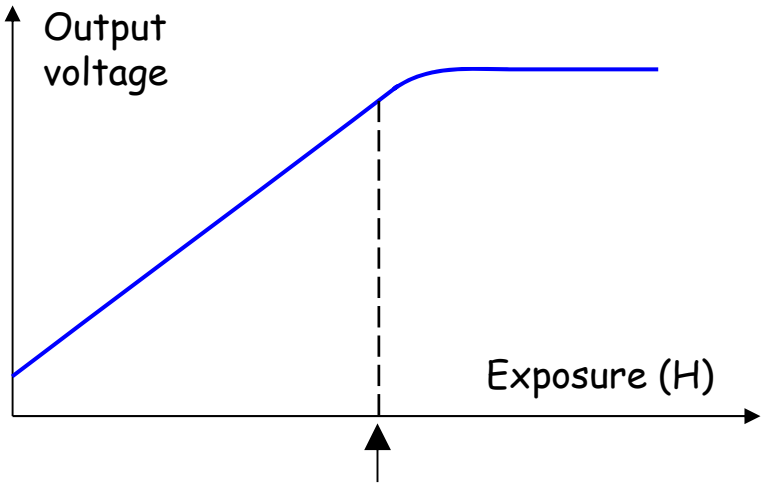
CCD:



Brightest part of object should give exposure close to saturation

This happens if lowest ISO-setting (typically 100-200) is used on camera.

Higher ISO settings = Underexposed sensor + extra amplification = More noise

ISO 100

ISO 10 000

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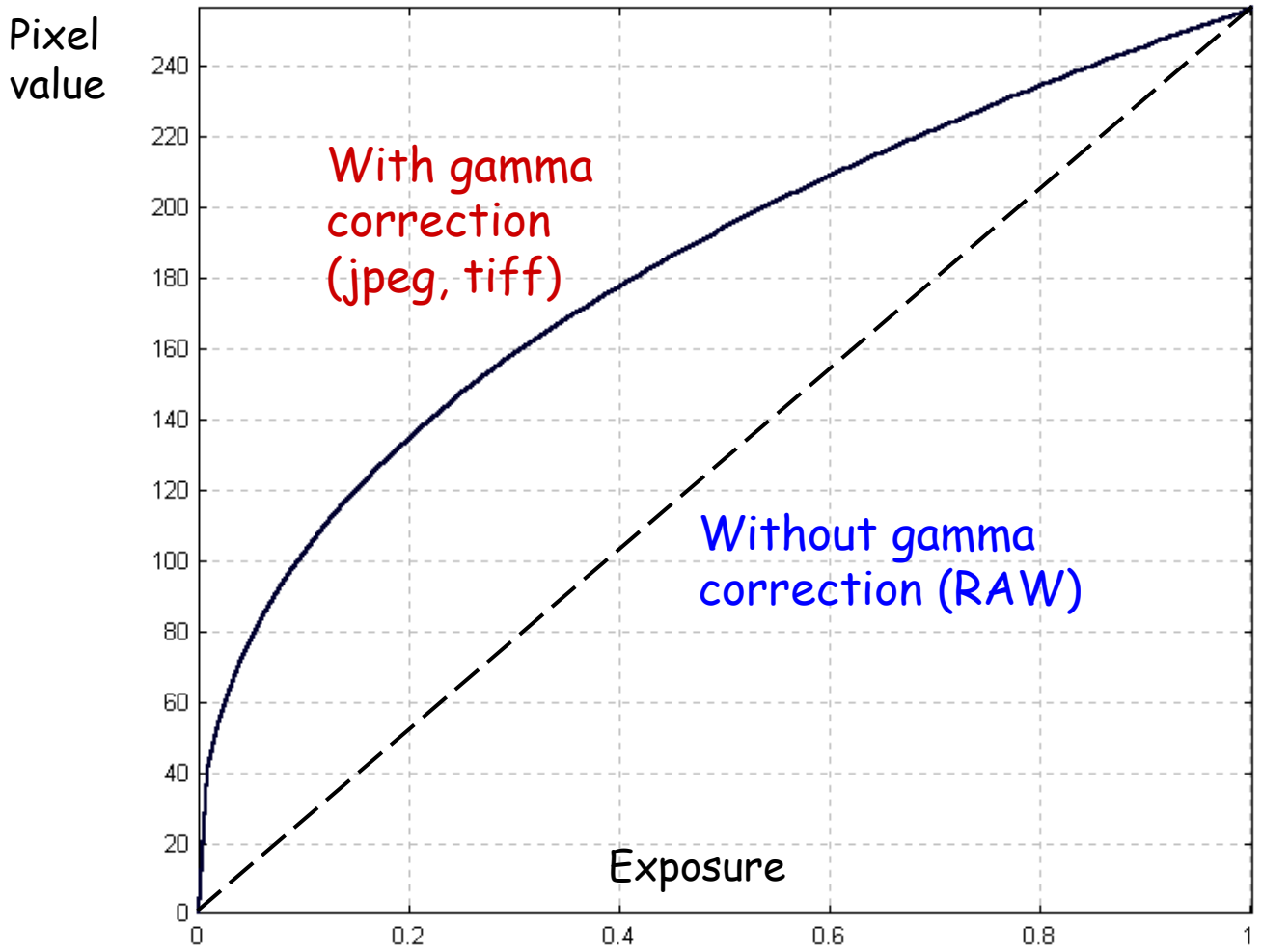
Gamma correction

The good linearity in CCD is "destroyed" by non-linear scaling.



Gamma correction makes it possible to use fewer bits in the digital signal (e.g. 8 bits instead of 12)

RAW format uses more bits and no gamma correction

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Spectral sensitivity

Typical performance

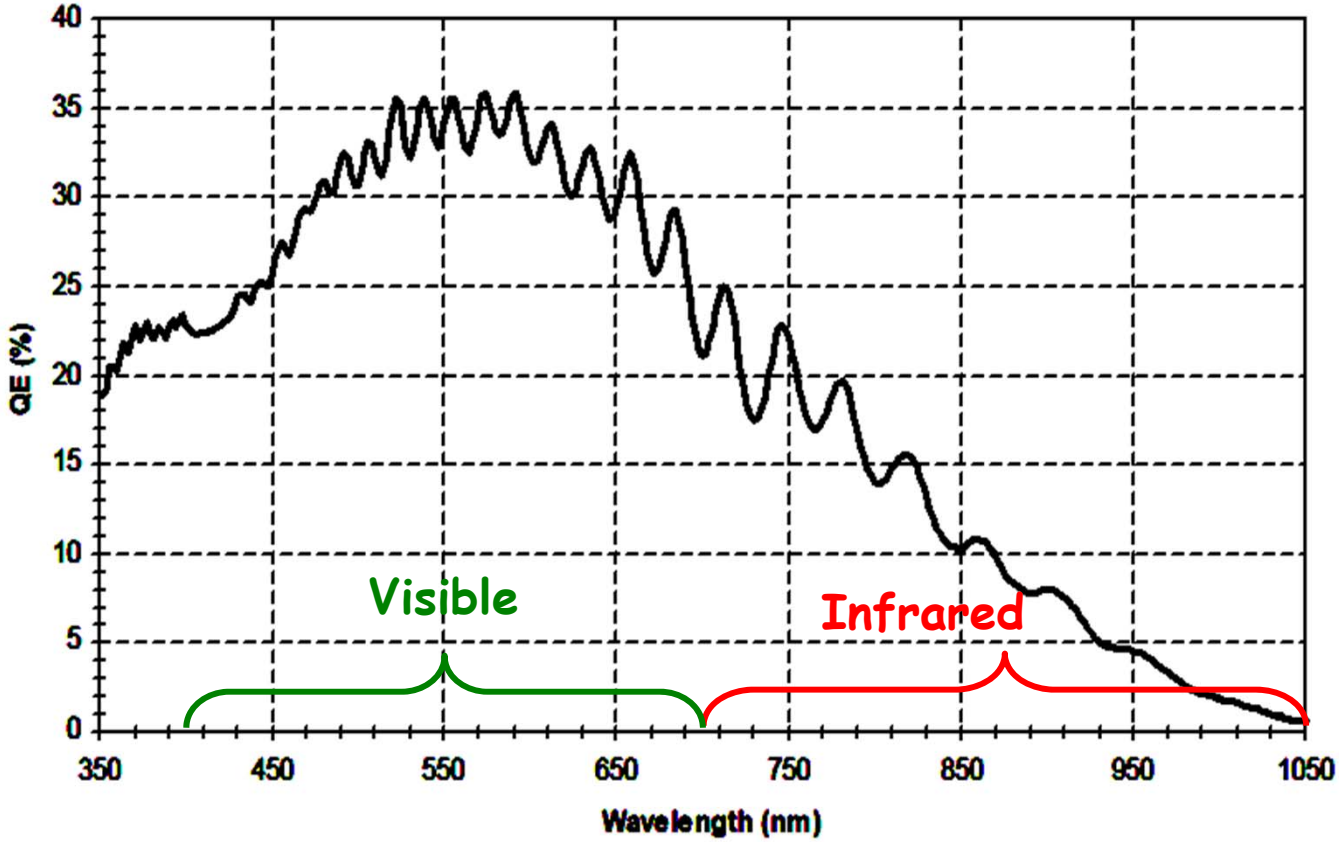

Figure 1: Spectral Response of a CMOS Image Sensor

Compare: Film quantum efficiency approx. 1%!

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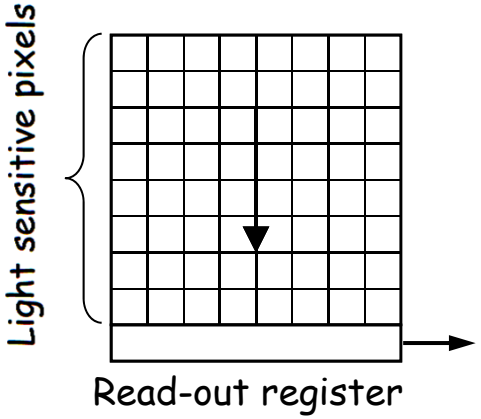
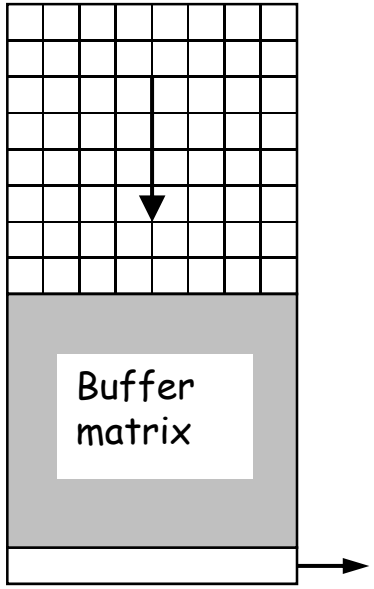
Different types of CCD

Full frame

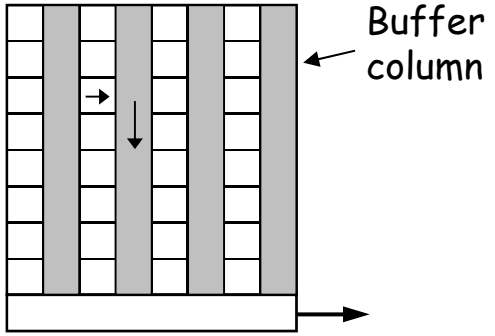


Frame transfer



Used mainly in scientific equipment

Interline transfer



Used in digital cameras and video cameras. Exposure and data readout can be done in parallel

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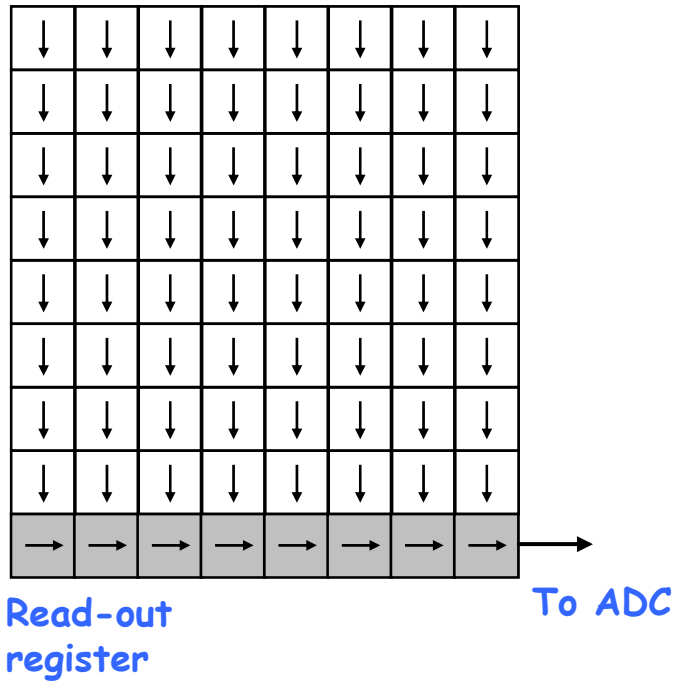
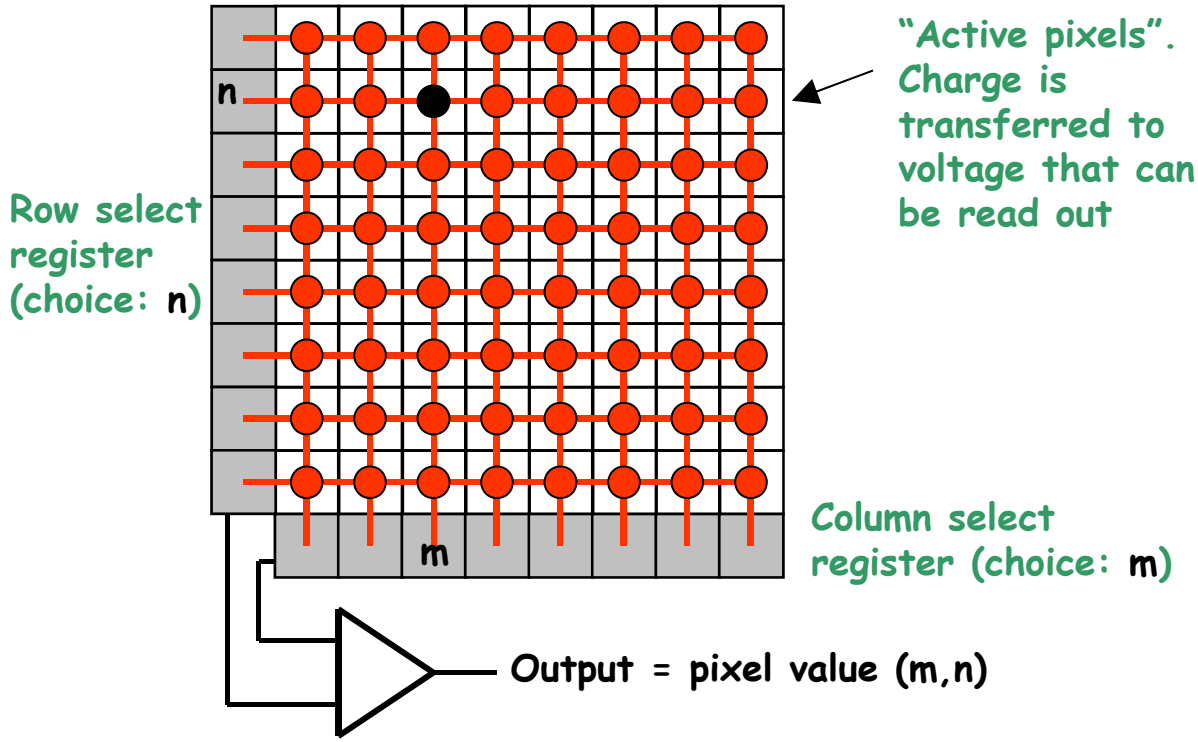
CCD:

Charge transfer between pixels.
Read-out of one line at a time via read-out register



CMOS:

Individually addressable pixels.
Full flexibility concerning which pixel values to read out.



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CCD versus CMOS

CMOS:

- Consume less power (batteries last a bit longer)
- Sensor + surrounding electronics (partly) on same chip
- Faster read-out (ca. 50-100 Mpix/s). (CCD ca. half of that)
- Allows video recording (24 or more frames/s with reduced number of pixels)

CCD:

- Somewhat higher image quality (but remember, size matters)
- Higher "fill factor" (light collection efficiency)

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Full frame sensors (24 mm x 36 mm) are commonly CMOS.

Large CCDs are more expensive and don't allow video recording

BUT!

Very expensive cameras (e.g. Hasselblad) use CCDs.

(typically 40 mm x 54 mm, 60 Mpixel)

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ALIASING

(sv. vikningsdistorsion)

MOIRÉ EFFECT

DEMO!!

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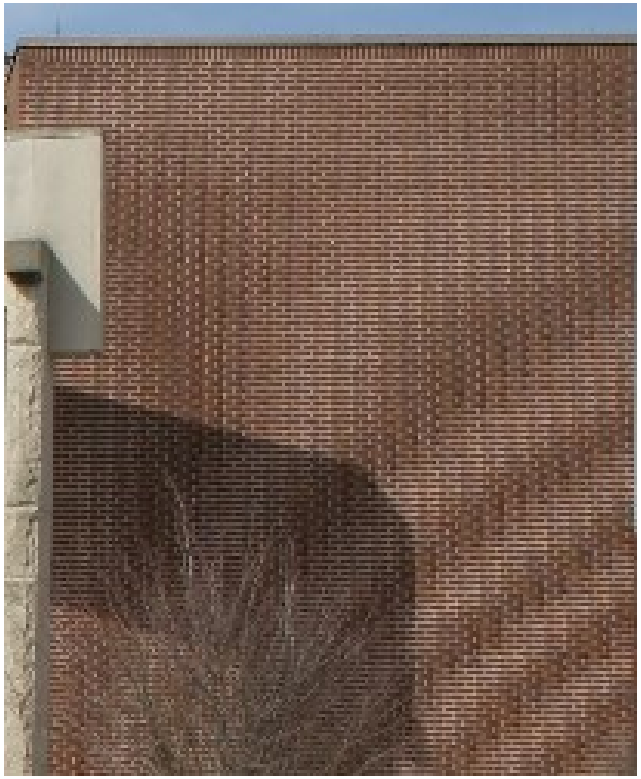
Example of aliasing

(From Wikipedia)

Proper sampling density



Violation of sampling criterion

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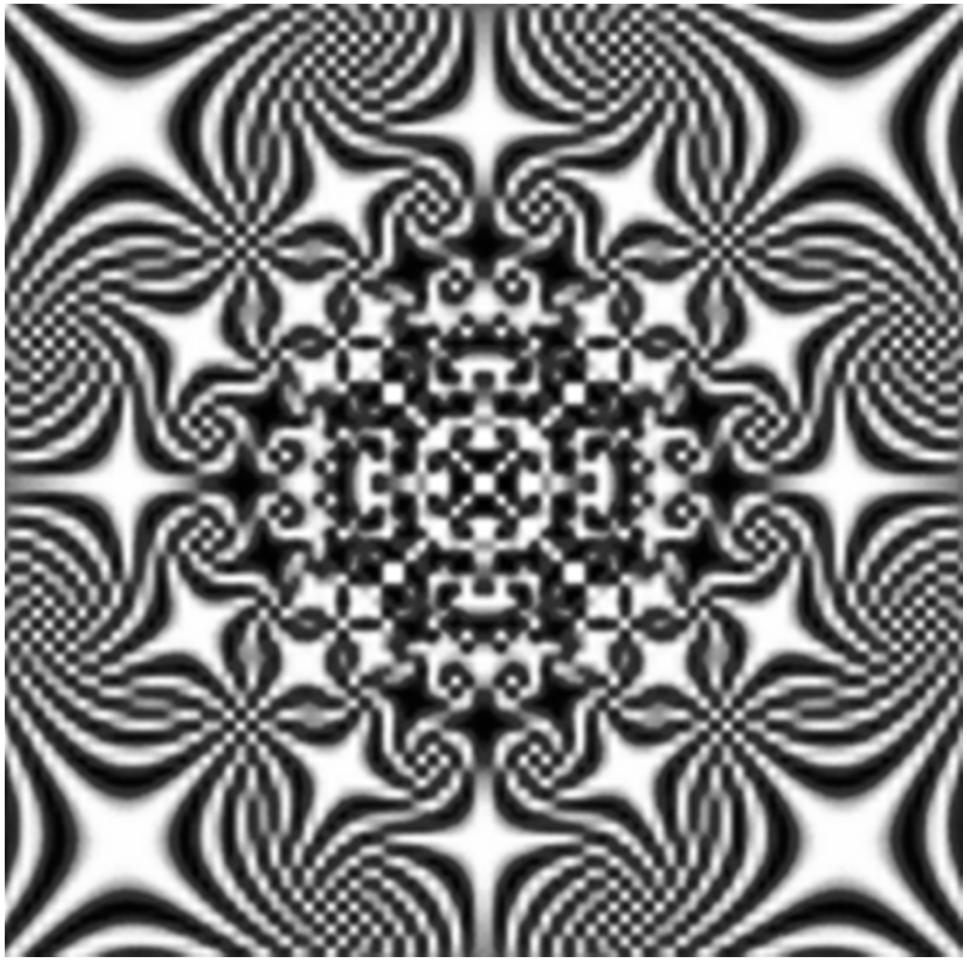
Aliasing patterns can be beautiful



Oriental carpet?

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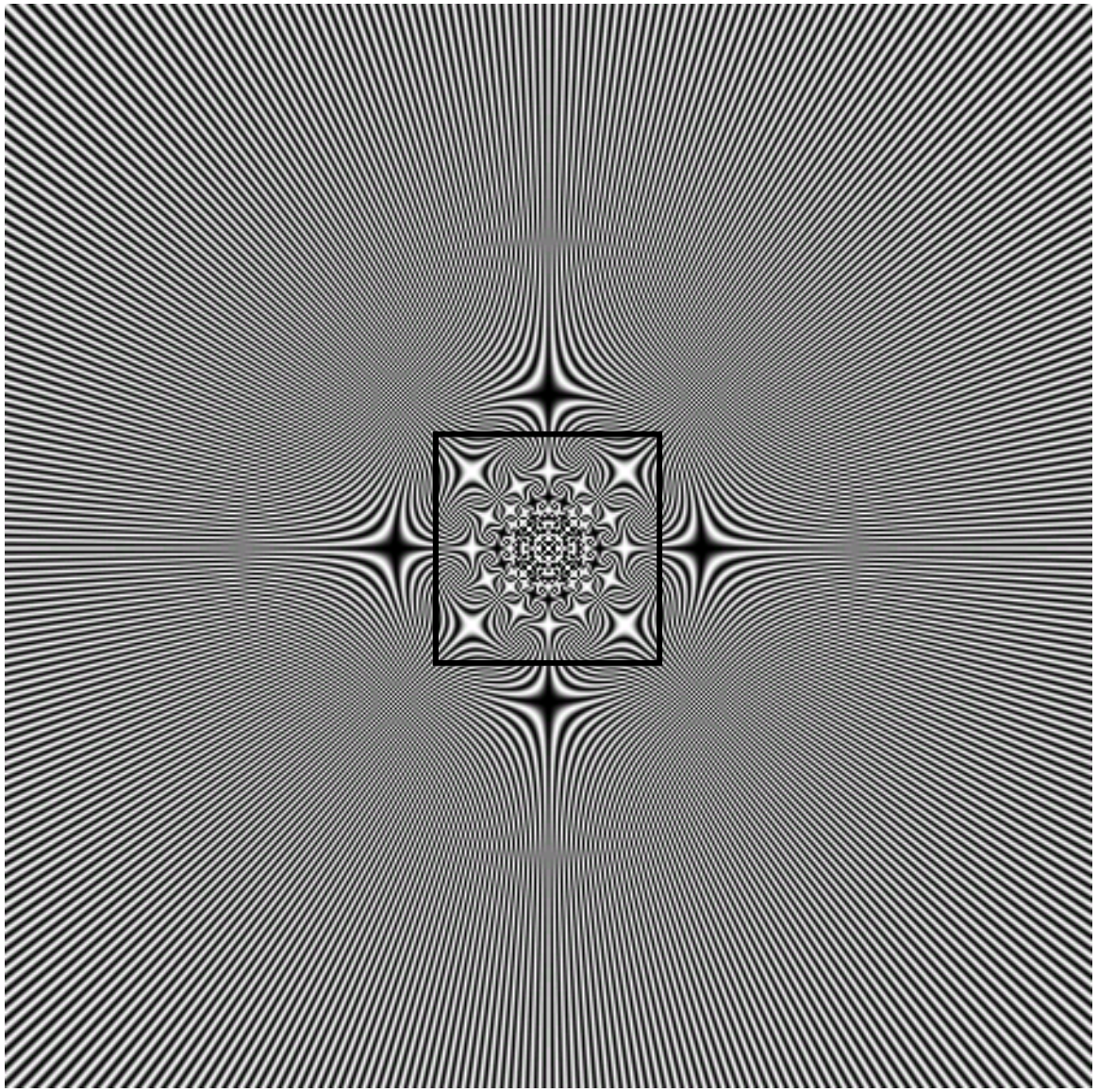
No, moiré because of pixellation

Line pattern is getting denser towards image center



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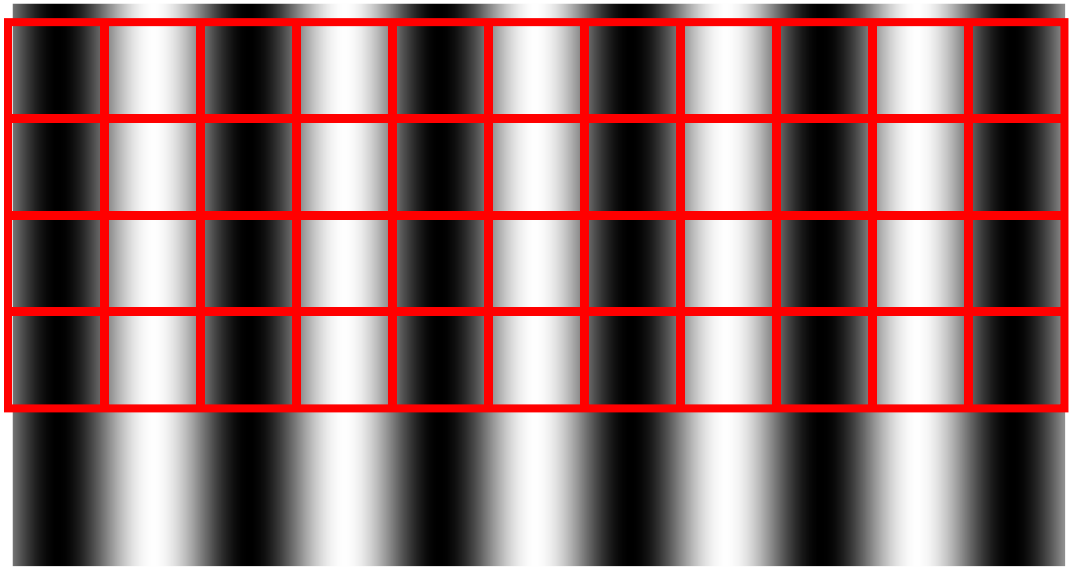
How to avoid moiré

At least two pixels per period

Just fulfilled here



ν = Spatial frequency (ortsfrekvens) of pattern (units m^{-1} or mm^{-1})

ν_s = Sampling frequency (number of pixels per m or mm)

The sampling criterion:

$$\nu_s > 2\nu$$

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Automatic features in digital cameras

- Autofocus
- Auto-exposure

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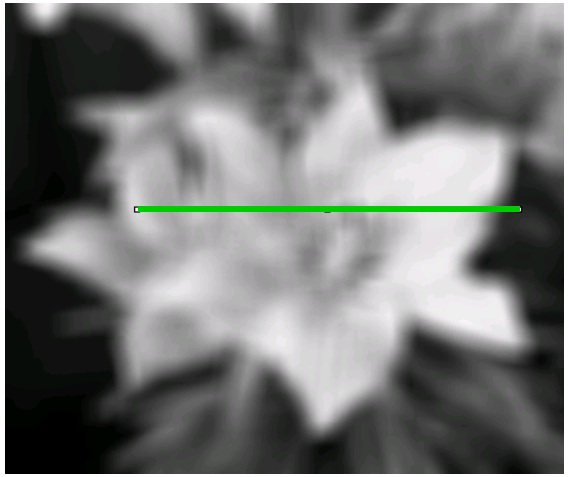
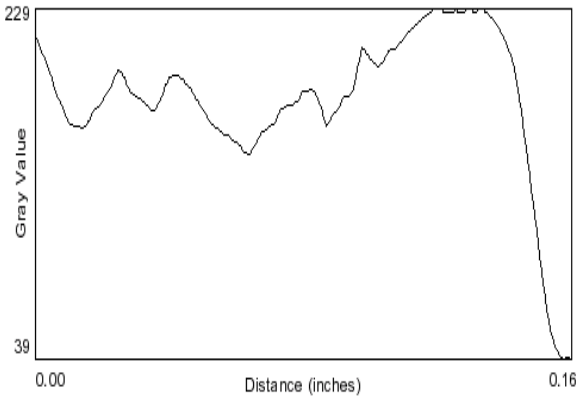
Autofocus

Idea: The lens is adjusted until adjacent pixels differ maximally in intensity

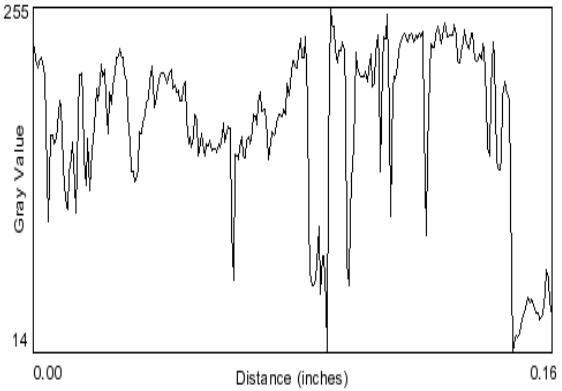


Out-of-focus scene



Intensity profile along green line

In-focus scene



Intensity profile along green line

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Auto-exposure

Idea: The camera automatically adjusts shutter speed and/or aperture to get correct exposure.

3 modes:

Aperture priority (A):

Desired aperture (for example 5.6) is manually selected. Camera selects shutter speed.

Good for: Optimum control of depth of field.

Shutter priority (S):

Desired shutter speed (for example 1/500 s) is manually selected. Camera selects aperture.

Good for: Shooting fast-moving objects.

Fully automatic:

Camera makes "intelligent" choice of both shutter speed and aperture.

Good for: Everyday "standard" photography.