



UPPSALA
UNIVERSITET

Centre for Image Analysis



Digital Imaging Systems

Digitala Bildalstrande System

Concluding discussion



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Aim of the course

- To give a unified perspective on the great variety of imaging technologies that have been developed the last decades.
- The imaging technologies have been discussed based on
 - what they are imaging,
 - how
 - with what quality
 - for which applications
- What have we learned?





Have we fulfilled the aim of the course:

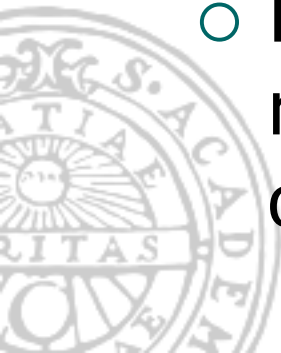
- After the course the participants will:
- Have a better understanding of the
 - possibilities and
 - limitations
 - of different imaging systems
 - Be able to evaluate the suitability of a particular technology for a particular task.





$$B = F(x, y, z, w, t)$$

- An image can be described as a 5D function
 - x, y, z – 3 spatial dimensions
 - w – wavelength, spectral dimension
 - can be generalized when not dealing with electromagnetic signals
 - t – time - temporal dimension
 - exposure time and repetition frequency
- Each dimension and the function value must be quantized into a limited range of discrete values





The spatial dimension

- How are the three spatial dimensions mapped into the image?
- Is the image a slice, a projection, a depth map or what?
- How correct is the image? Distortions?
- What is the geometric resolution?
- Is the technology capable of providing more than 2D?





Projection, distance image, slice image or tomographic reconstruction

- **Projection** gives a 2D image of visible surfaces in 3D or a transmission through the object
- **Distance images** give explicit depth information see from a point $2\frac{1}{2}D$
- A **slice image** images a selected thin volume
- **Tomographic reconstruction** computes information about internal density structure from measurements of numerous line integrals, gives slice or complete volume images





Projection images

- Gives a 2D image of visible surfaces in 3D or a transmission through the object
- Examples?





Projection images

- Normal photography
- Conventional X-ray imaging
- Conventional microscopy
- Most optical remote sensing techniques





Distance images

A way of representing 3D in 2D

- Measures the distance from the surface of the object to the sensor for each point in the image
- How?
- Examples?





Distance images

A way of representing 3D in 2D

- Measures the distance from the surface of the object to the sensor for each point in the image
- Passive sensor
 - Parallax camera – light source
 - Stereo images
- Active sensor
 - Time of flight (radar, ultrasound, laser)
 - Triangulation, structured light





Emission, excited emission transmission or reflection

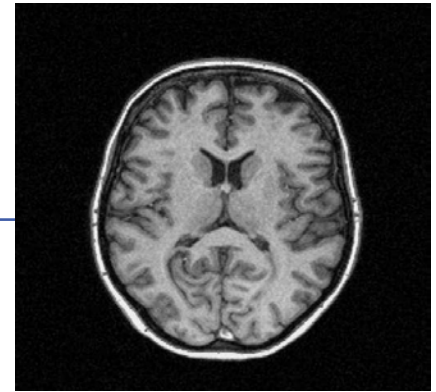
Where/what is the light source?

- Emission
 - PET
 - IR
- Excited emission
 - MR
 - Fluorescence microscopy
- Transmission
 - CT
 - Light microscopy





Reconstructed images



- Tomography
 - Transmitted X-rays, Computer Tomography
 - Radioactive decay, Emission Tomography
 - PET
 - SPECT
 - MRI, emitted excited radio frequency
 - Electron tomography

- Light microscopic, through DMD control





Reconstructed images

- Interferometric
 - Radio astronomy
 - Microwave tomography
- SAR - synthetic aperture radar





Active or passive sensor system

Can we control the illumination?

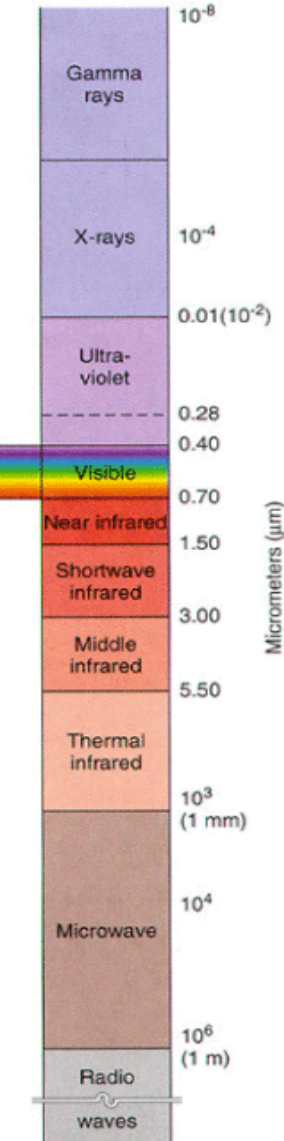
- Active = we can illuminate the scene
 - All at once
 - One or several lines
 - With pixelwise scanning
- Passive = we must cope with existing illumination





The spatial resolution

- A very important aspect, often determining the imaging modality
- Light imaging is (almost always) limited by diffraction to about $0.5 \mu\text{m}$
- Electrons down to nm, voltage dependent
- X-rays determined by illumination source size mm or sub μm
- Magnetic resonance down to 0.3 mm





The spectral dimension

- All imaging involves a choice of spectral range
- The image is a result of a convolution between
 - The spectral distribution of the illumination
 - The spectral absorption/reflection properties of the object
 - The spectral sensitivity function(s) of the sensor
- Different spectral ranges often give very different image contrast →





New imaging method presented last week – Magnetic Resonance Imaging

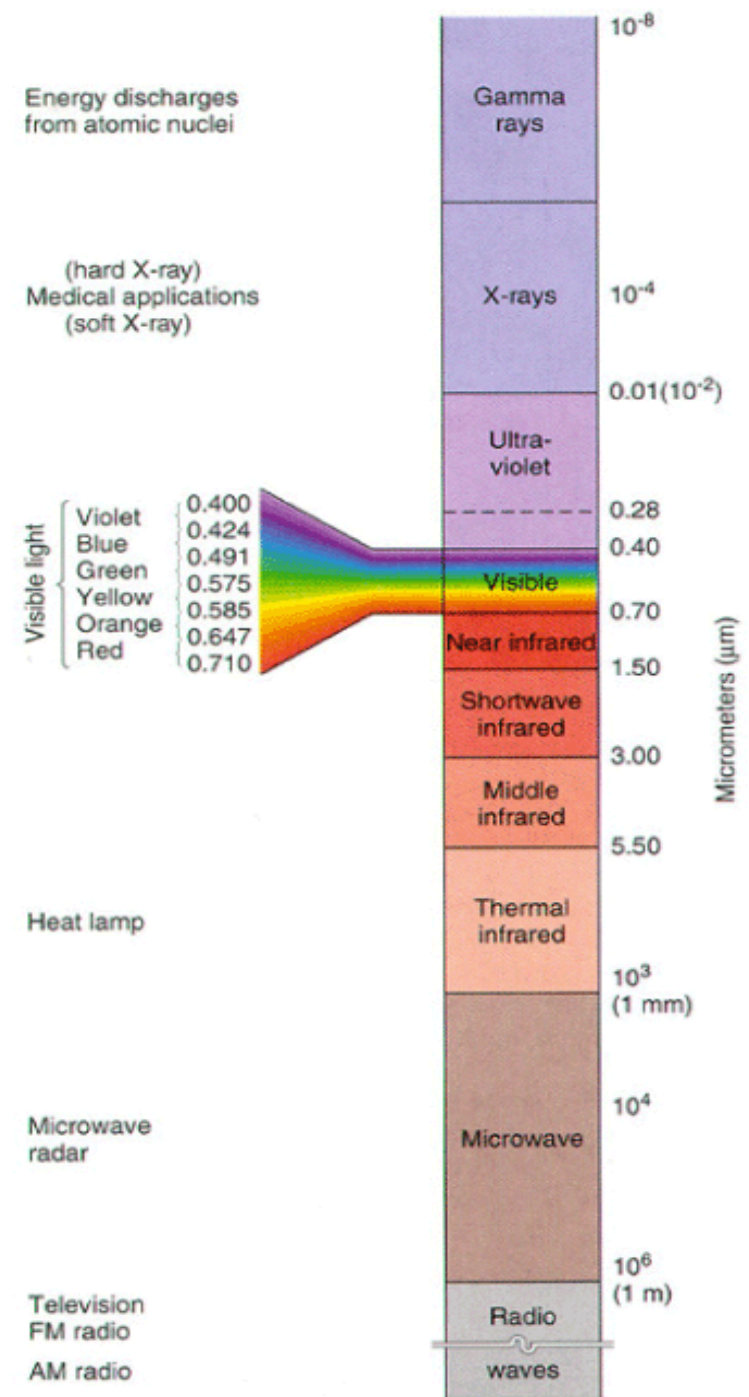
- Based on similar principles as atomic force and tunneling microscopy
 - A scanning probe
- A magnetic field which interacts with the object to be imaged creates a force which changes the resonance frequency of the probe which is detected
- Can create volume images at nm resolution
 - EMT could already do that but differently





Electromagnetic spectrum

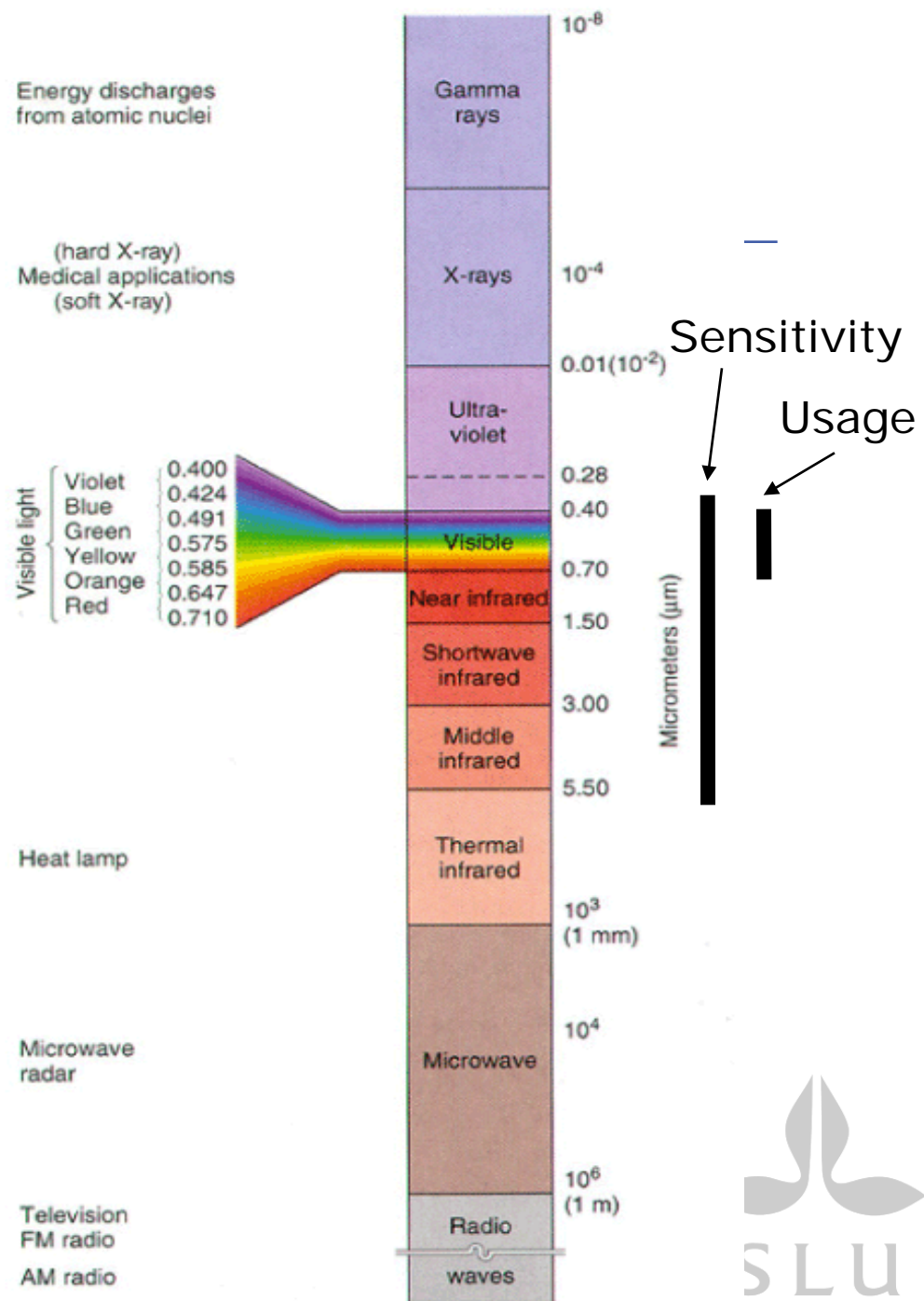
- All parts of the electromagnetic spectrum is used:
 - PET – hard gamma rays, 511keV
 - X-rays, CT
 - Visible light, photography
 - Infrared, Thermography
 - Radio waves, MRT
 - Imaging body electric activity, EEG





CCD/CMOS spectral range

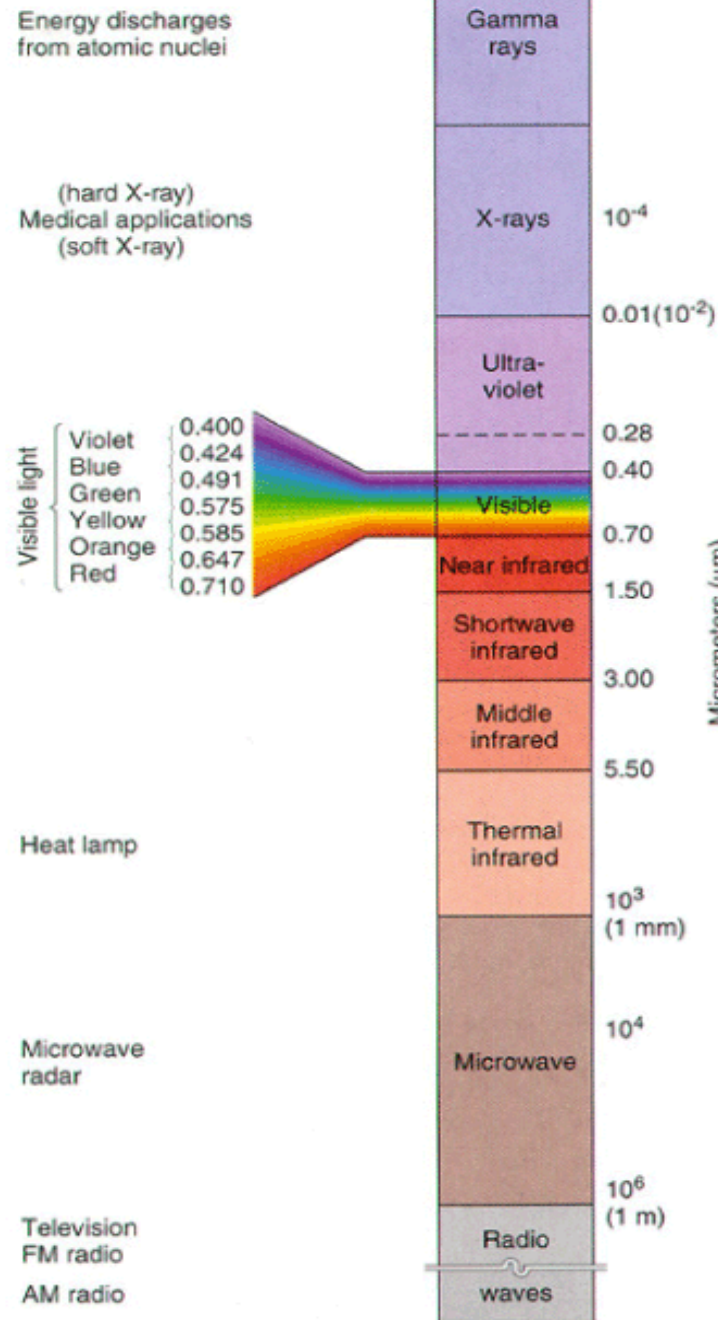
- CCD and CMOS sensors are normally used for visible light
- Have good natural sensitivity in near infrared, usually removes that by filters
- Can be specially adapted for other parts of the spectrum e.g. X-rays





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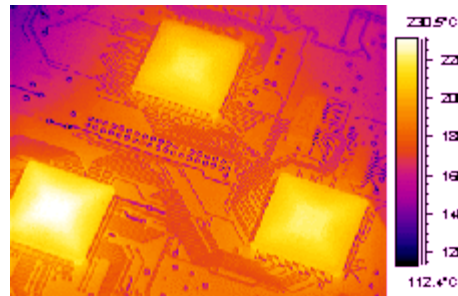
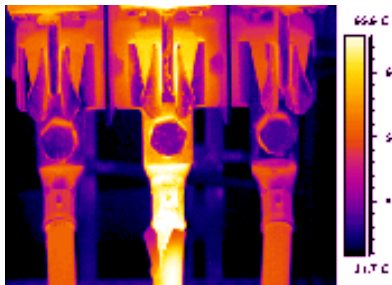
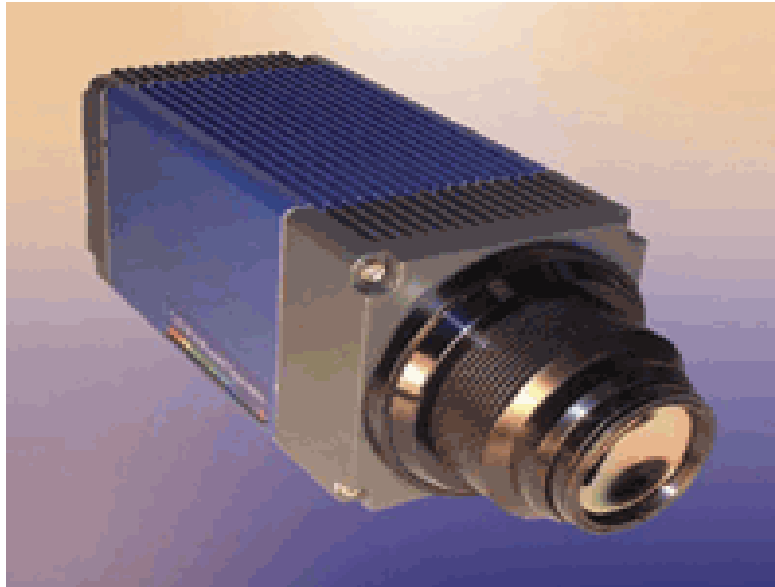


source: Christopherson (2000) Geosystems





IR cameras show emissive, heat images





IR thermal - sensing techniques

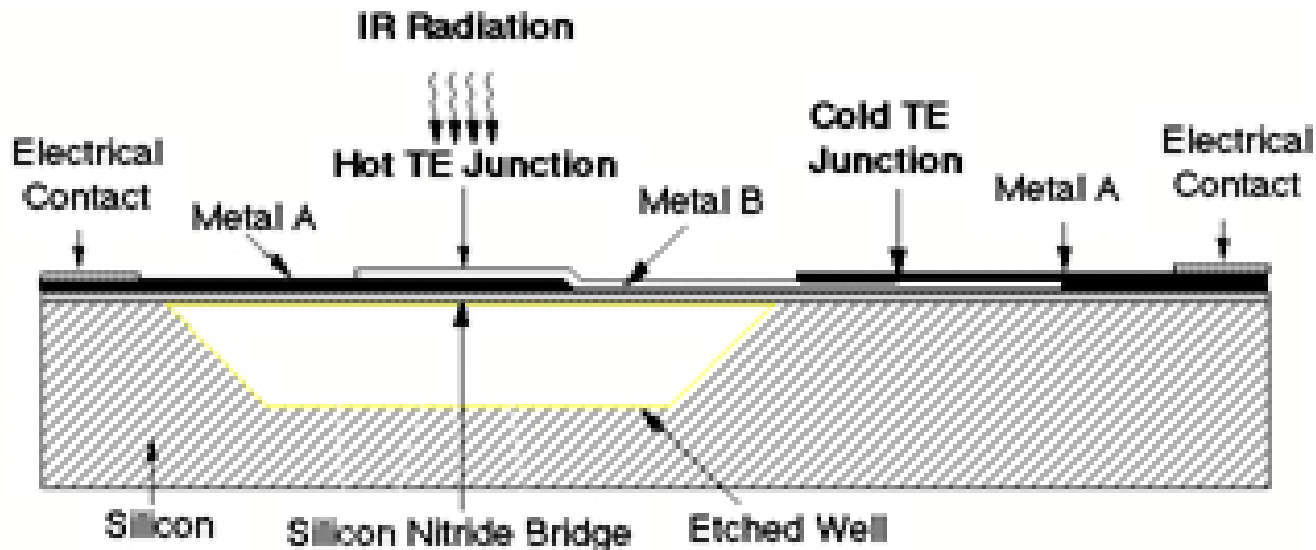
- Two approaches exist for making uncooled IR imaging devices.
 - One uses a two-dimensional array of detectors. This permits “seeing” the entire scene through a lens at once and can produce real-time pictures at TV rate
 - The second approach uses a single row of detectors that is moved across the image plane of the lens, creating two-dimensional, “snapshot,” images.





IR thermal - sensing techniques

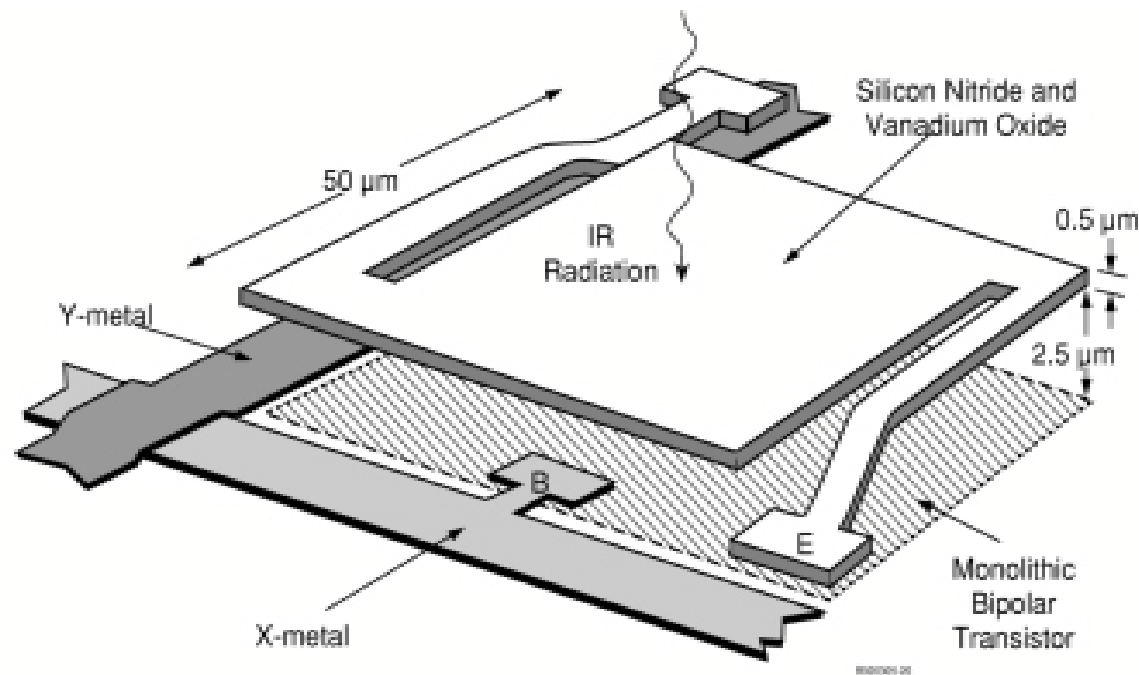
The sensing elements in a linear array:
Miniature thermoelectric elements causes small voltage changes that are detected





IR thermal - sensing techniques

The sensing elements in a 2D array: IR radiation causes a change in electrical resistance, which is readout by measuring the resulting change in bias current of a transistor





Multiplexing the spectral dimension

- In our 5D image model we sometimes wish to register in more than 2D, e.g. Multispectral 2D images or 3D images
- Sensors are seldom capable of registering in more than 2D
- We need to multiplex the additional dimension, usually by using the time dimension
 - Scanning linewise
 - Sequentially in spectra bands
- Can also spread spectral channels spatially





The spectral dimension

Imaging spectrometry

- The spectral dimension can be spread with a grating orthogonal to a sensor line
 - A 2D sensor will give a line camera with high spectral resolution
 - Motion in the other dimension yields imaging spectrometry
 - Easily leads to lack of sufficient light
 - Gives large amounts of data, needs effective compression
- Can also have a rotating filter wheel and an area sensor





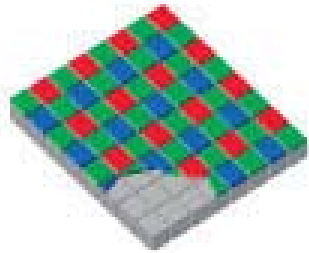
Temporal aspects

- Each image registers something for a defined time interval
 - Single temporal slice – still image
 - Multiple exposures – film, video
 - Continuous recording mode
- For each exposure we need to define the exposure time
 - Does it give motion blur?
 - Can it be varied freely?
 - How are the image quality aspects effected by the exposure time?

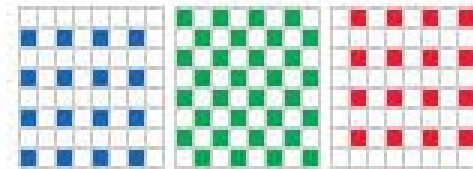
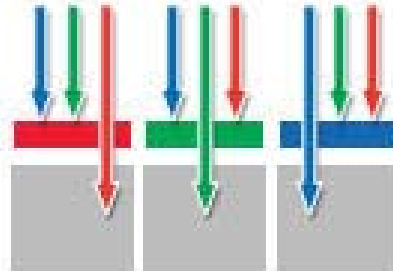




2D Mosaic vs vertical filtering



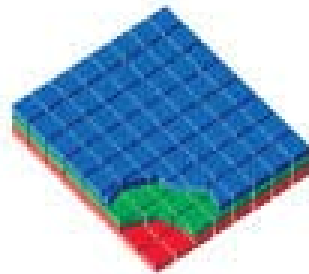
傳統 CCD & CMOS



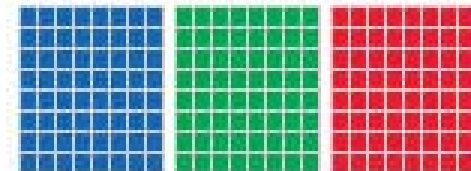
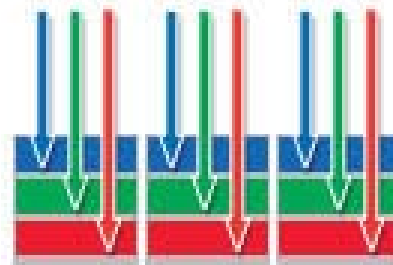
B25%

G50%

R25%



SIGMA SD9



B100%

G100%

R100%





The important temporal resolution

- CCD and CMOS sensors collect charge and integrate illumination. Can not resolve the exact time of an event. For some applications e.g. time of flight depth imaging, timing is essential. Used to require single PM-tube or photodiode. Now arrays of photodiodes are built. Makes new imaging principles possible, eg. high speed co-registered depth and intensity images.





Volume imaging methods

- How can we create truly 3D volume images?





Volume imaging methods

- Physical slicing of the object
 - “destructive imaging”
- Tomography
 - X-ray (CT)
 - Magnetic Resonance Imaging (MRI)
 - Emission (SPECT och PET)
 - Electron Tomography (ET)
- Confocal microscopy
- Ultrasound
- Magnetic Resonance Tomography →





Concluding questions: What is important for my image?

- Is geometry or photometry the most important aspect?
- What are the image matrix and resolution needs?
- What are the needs for contrast, dynamic range, signal/noise ratio
- What spectral properties are important?
- Need for speed, temporal resolution?
- Economical constraints?





Summary

- It is important to understand the limitation of the images that are to be analysed, caused by the imaging system
- This requires some understanding of the imaging technology
- This understanding can also be used when selecting an appropriate imaging solution for a particular problem

