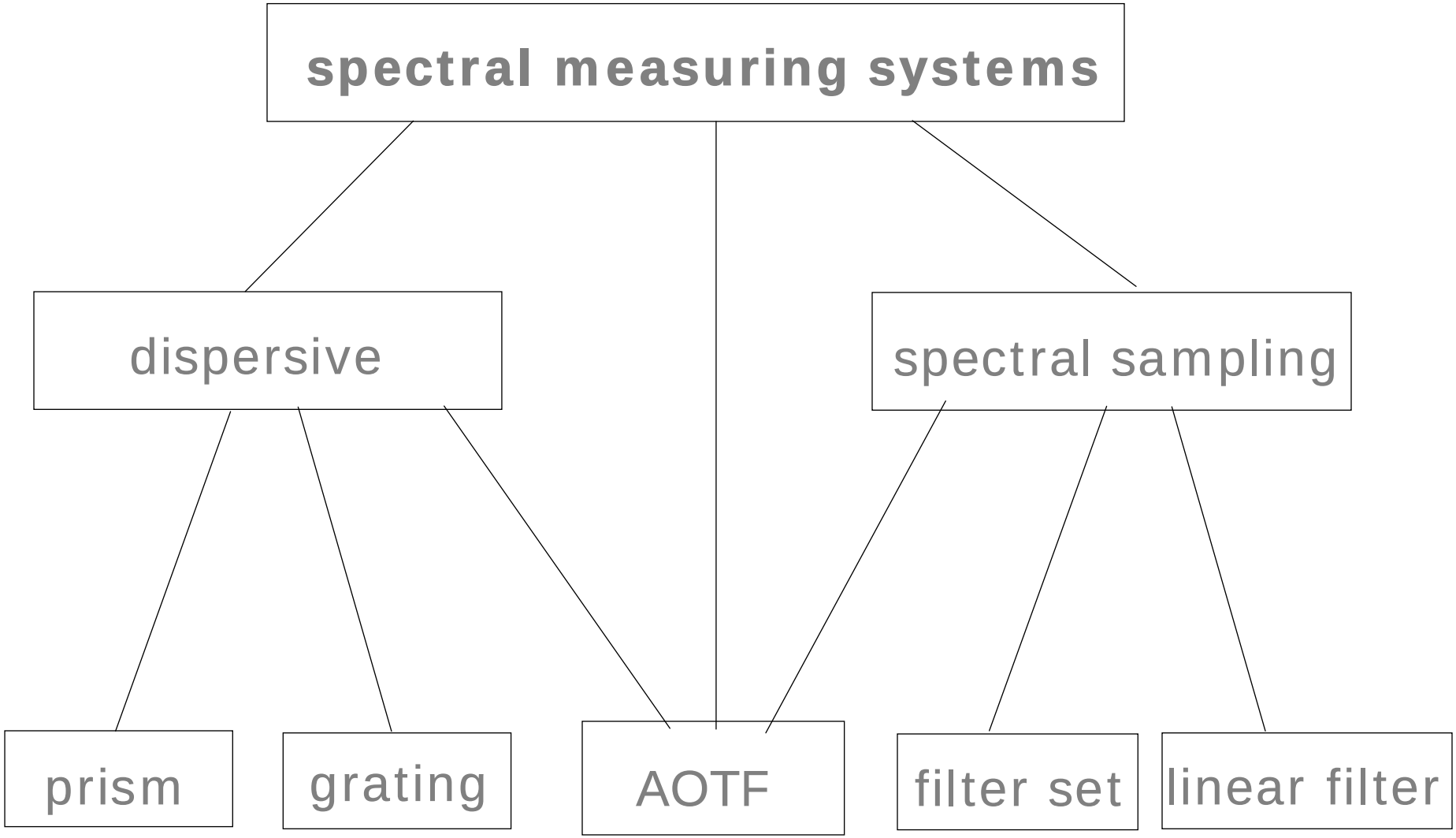
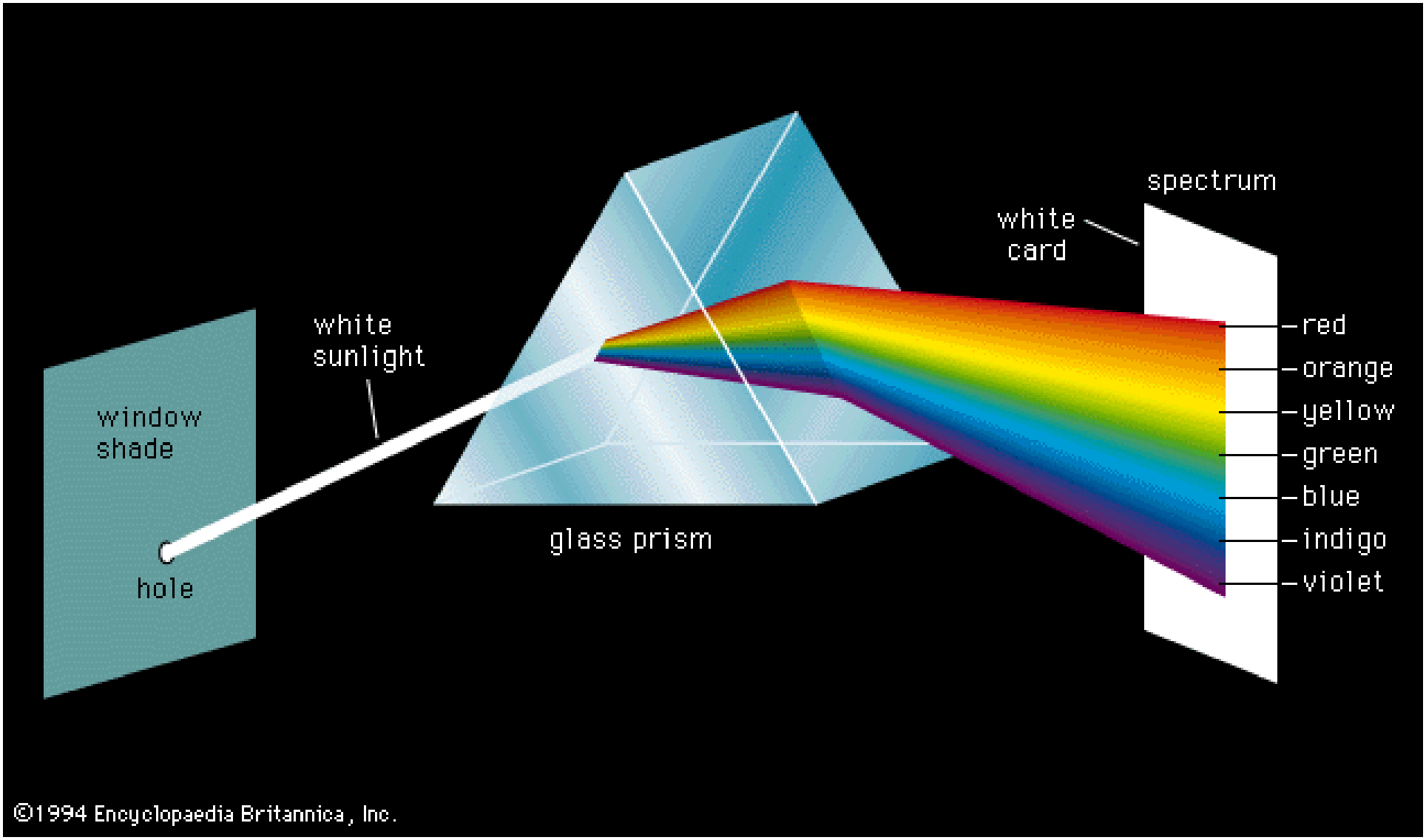
Color measuring and imaging

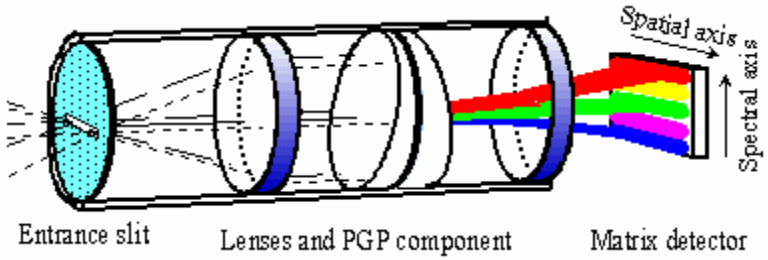

spectral measuring systems
dispersive
spectral sampling
prism
grating
AOTF
filter set
linear filter

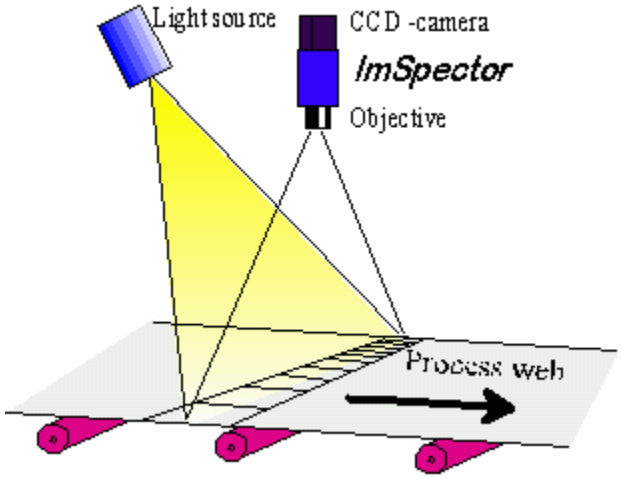
Multispectral cameras

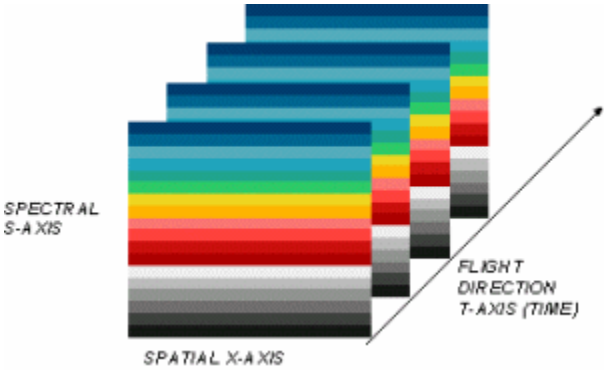
16-band multispectral camera
for still image


spectrum
white
card
white
sunlight
window
shade
hole
glass prism
red
orange
yellow
green
blue
indigo
violet
©1994 Encyclopaedia Britannica, Inc.

Spectral Line Camera







An example of spectral measuring system (from Avantes catalog)

Optical Bench Design

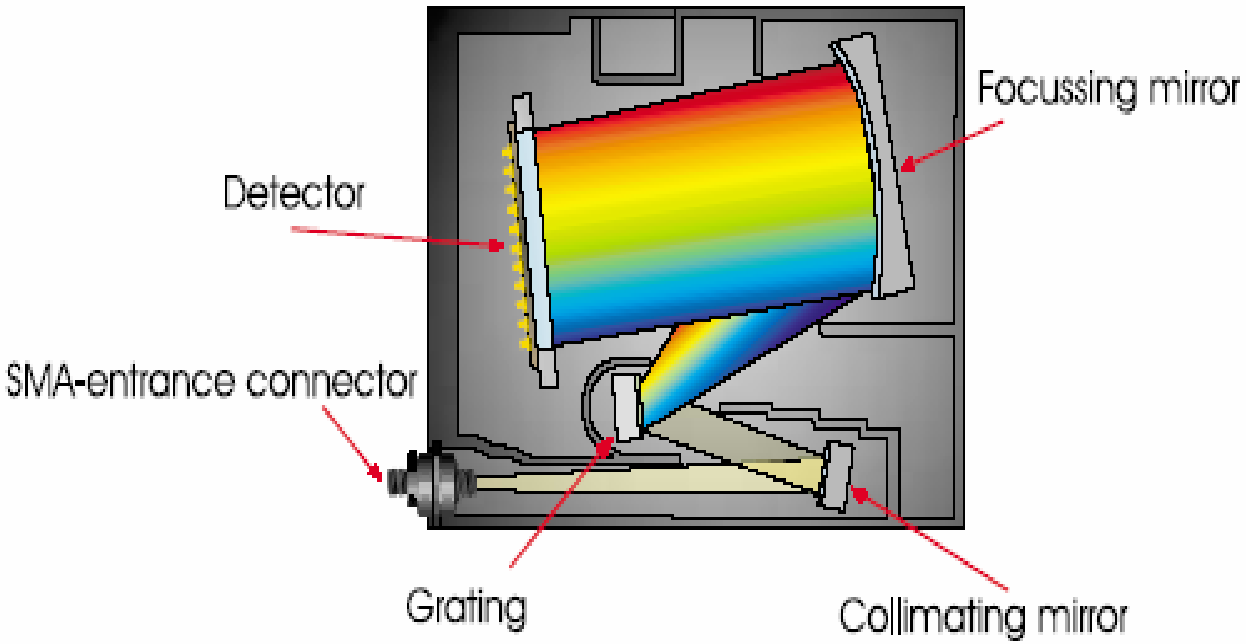
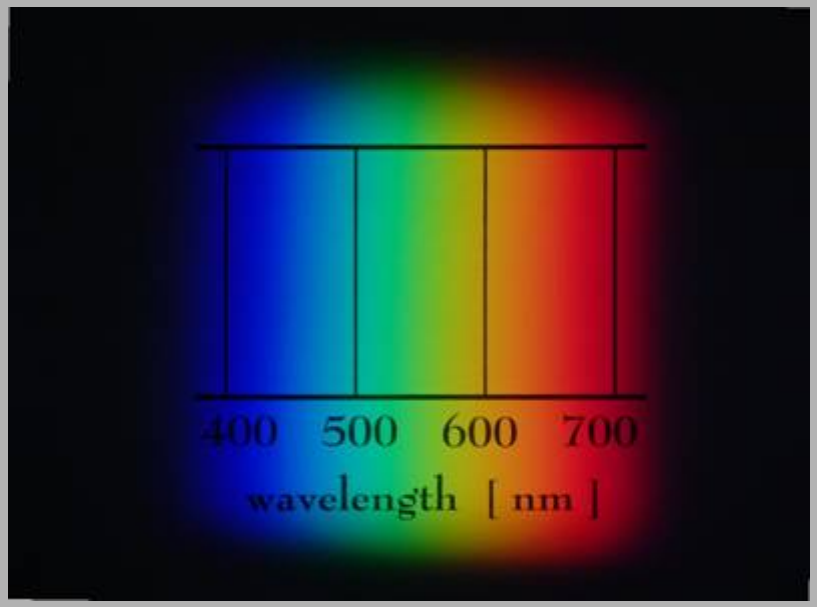


Figure 1 Optical bench design

Note: measures only one spectrum at a time

Spectral instruments

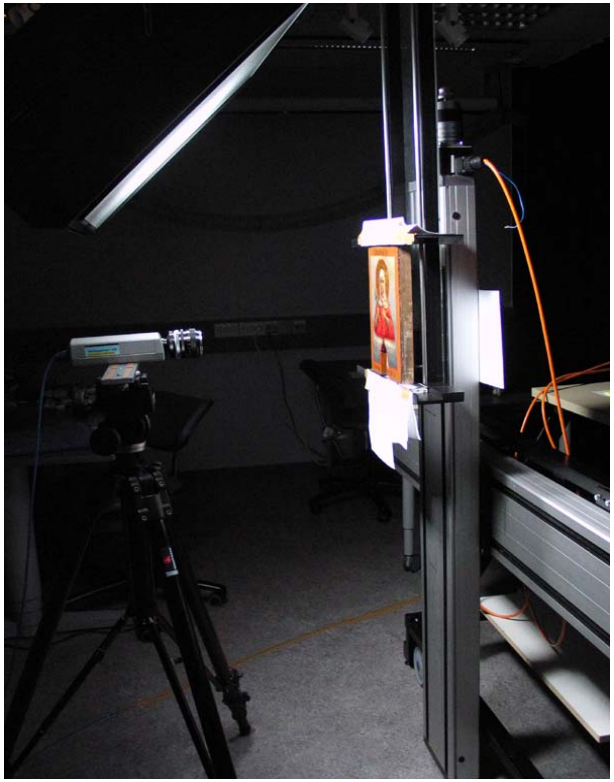
- spectrometers
  - Perkin Elmer λ 18
  - Perkin Elmert λ 9
  - Minolta CM-2002
  - Hamamatsu PMA-11 C7473
  - Avantes USB2000
  - Avantes Avamouse
- spectral cameras
  - ImSpector V8
  - ImSpector V10E
  - ImSpector N17E
  - Nuance LCTF (by CRI)
- spectroradiometer
  - Photo Research 705



ImSpector V8

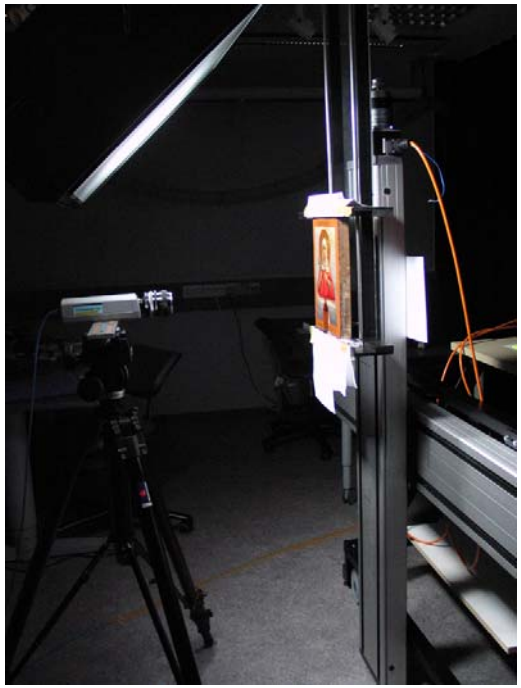
- spectral range: 380 – 780 nm
- spectral resolution: 4 nm
- spectral interval: avg. 0.46 nm
- slit width: 50 μm
- numerical aperture: F/2.8
- camera:
  - PCO PixelFly (12-bit)
  - CCD: 1280 x 1024

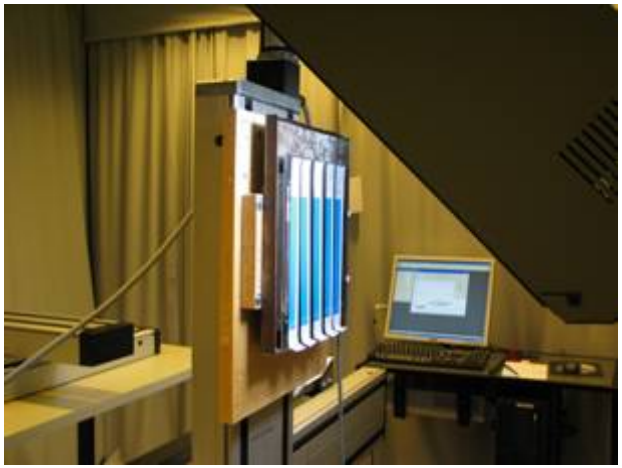
Spectral camera measurements

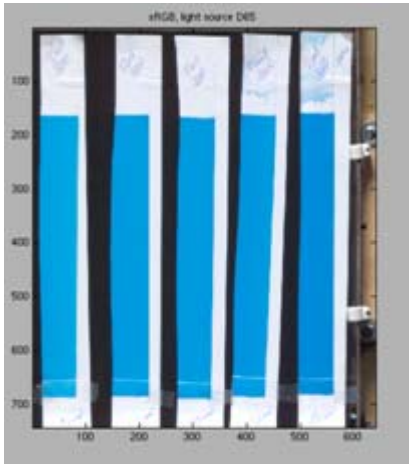


Spectral imaging from 380 nm to 1700nm

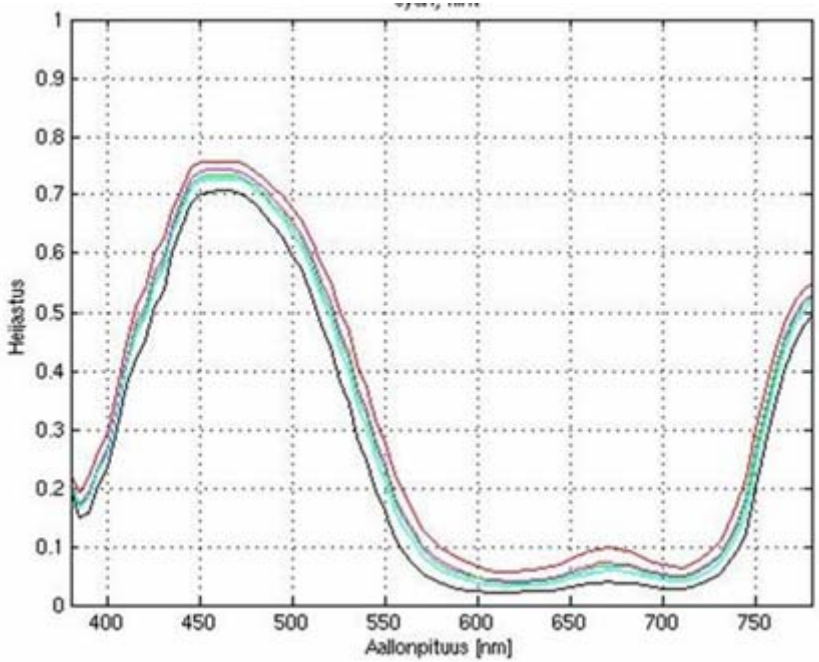
Example: spectral measurements

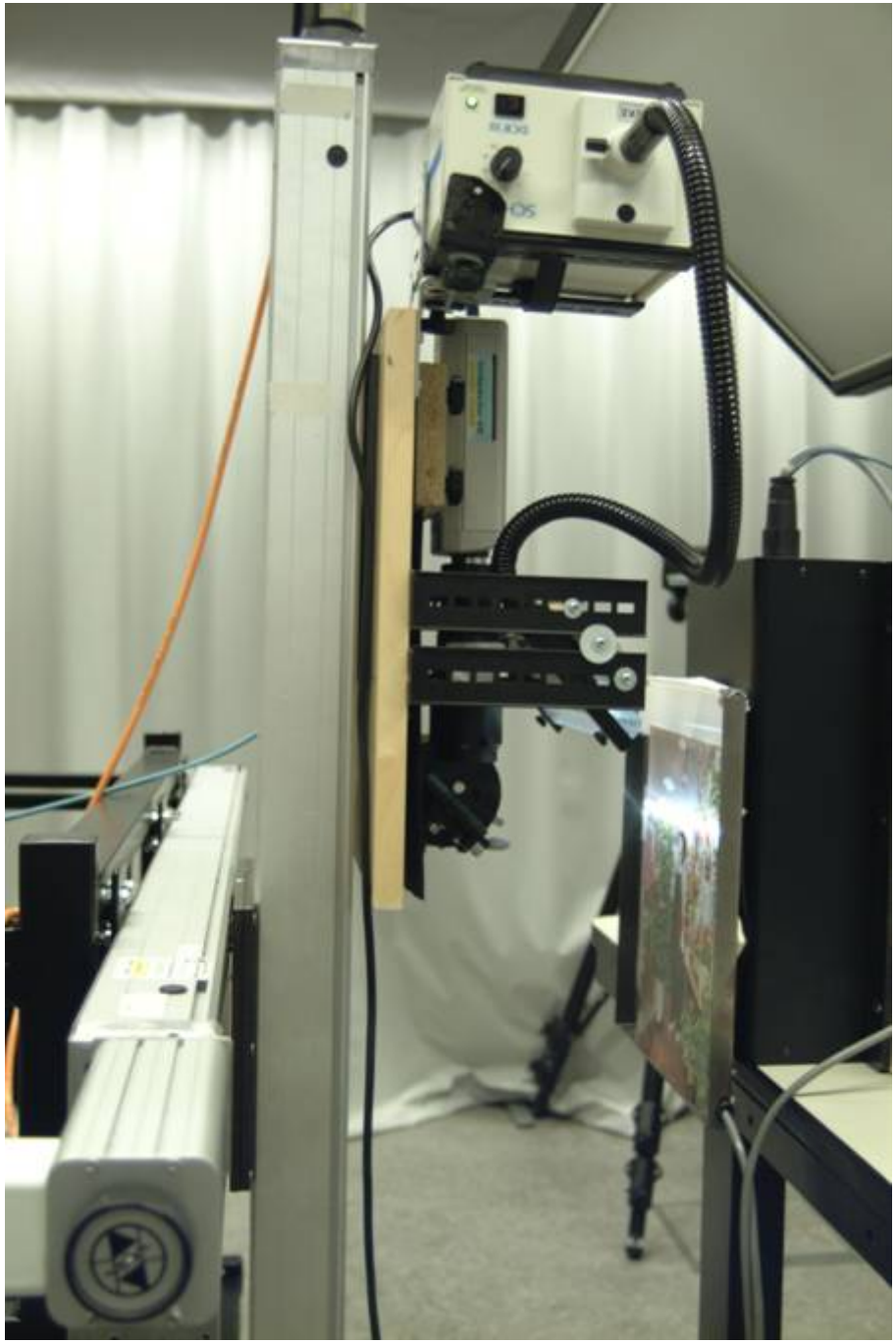


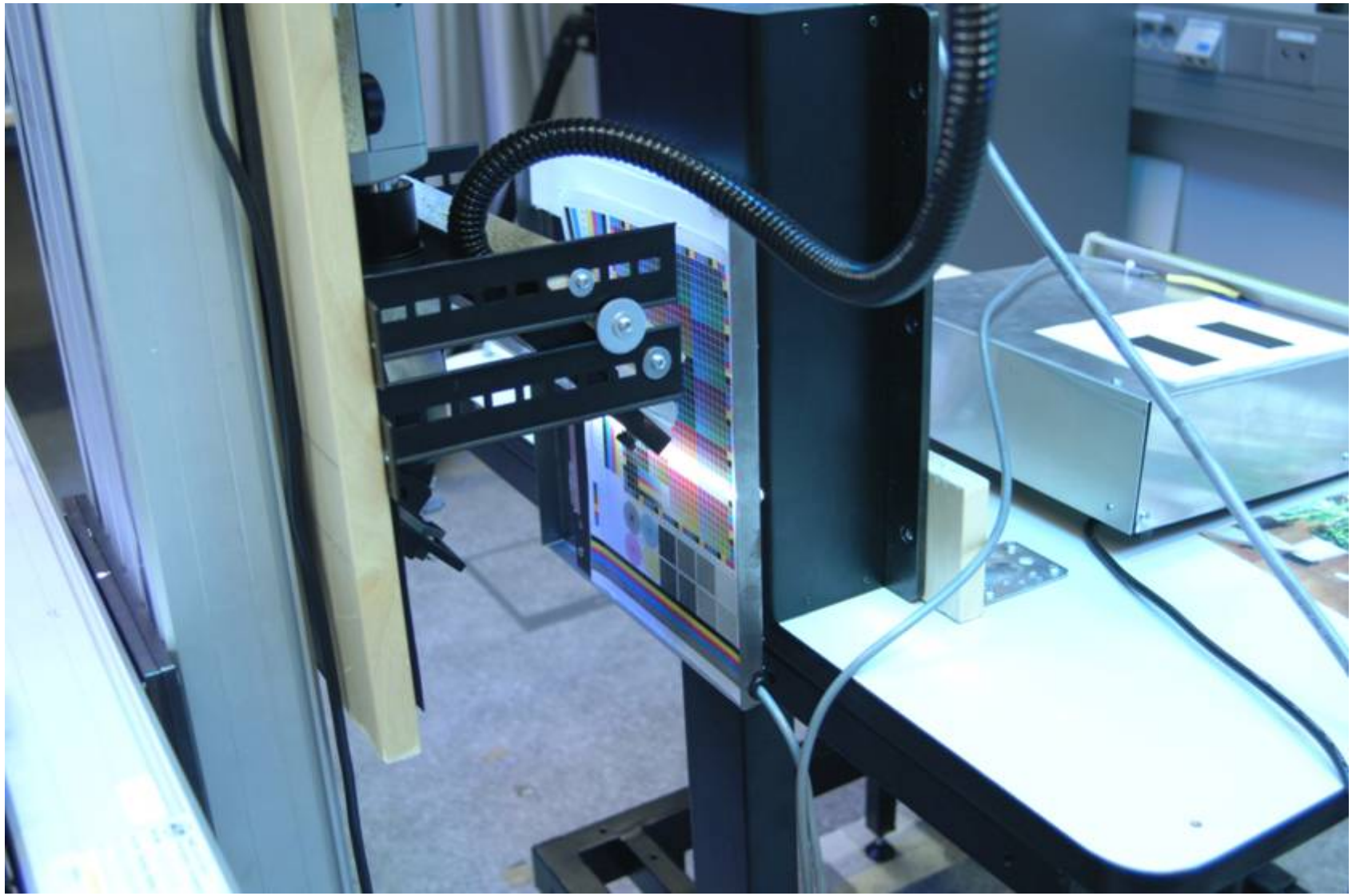




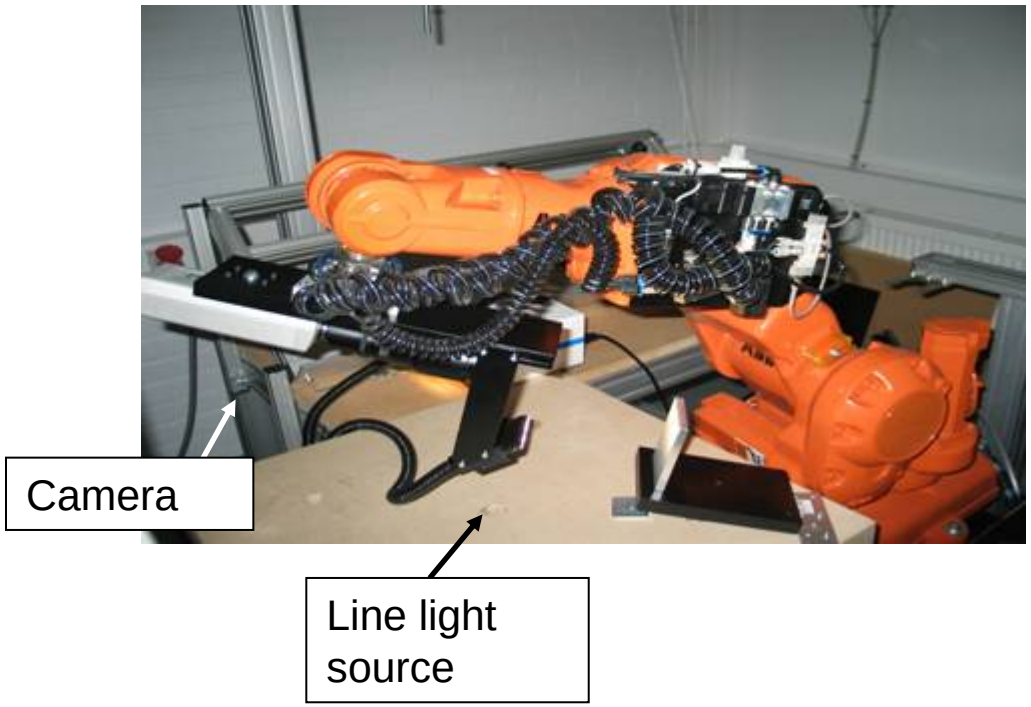
Same ink in same paper
(different amount of ink)

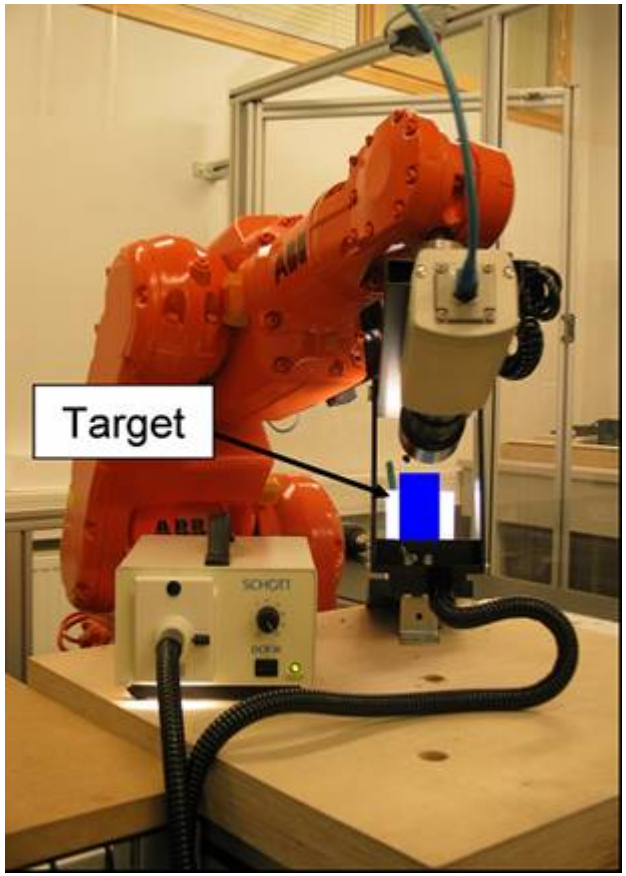






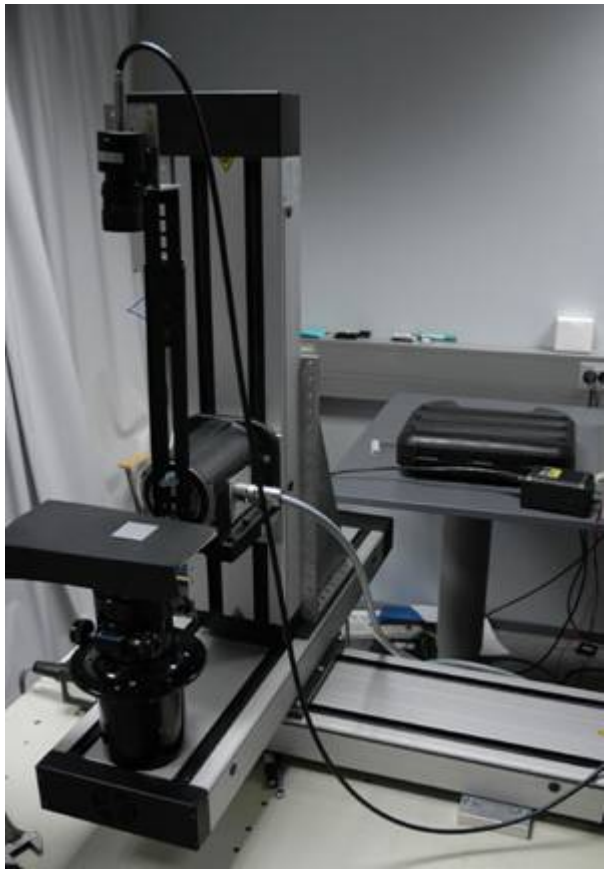
Spectral measurements with a robot





Linear stages

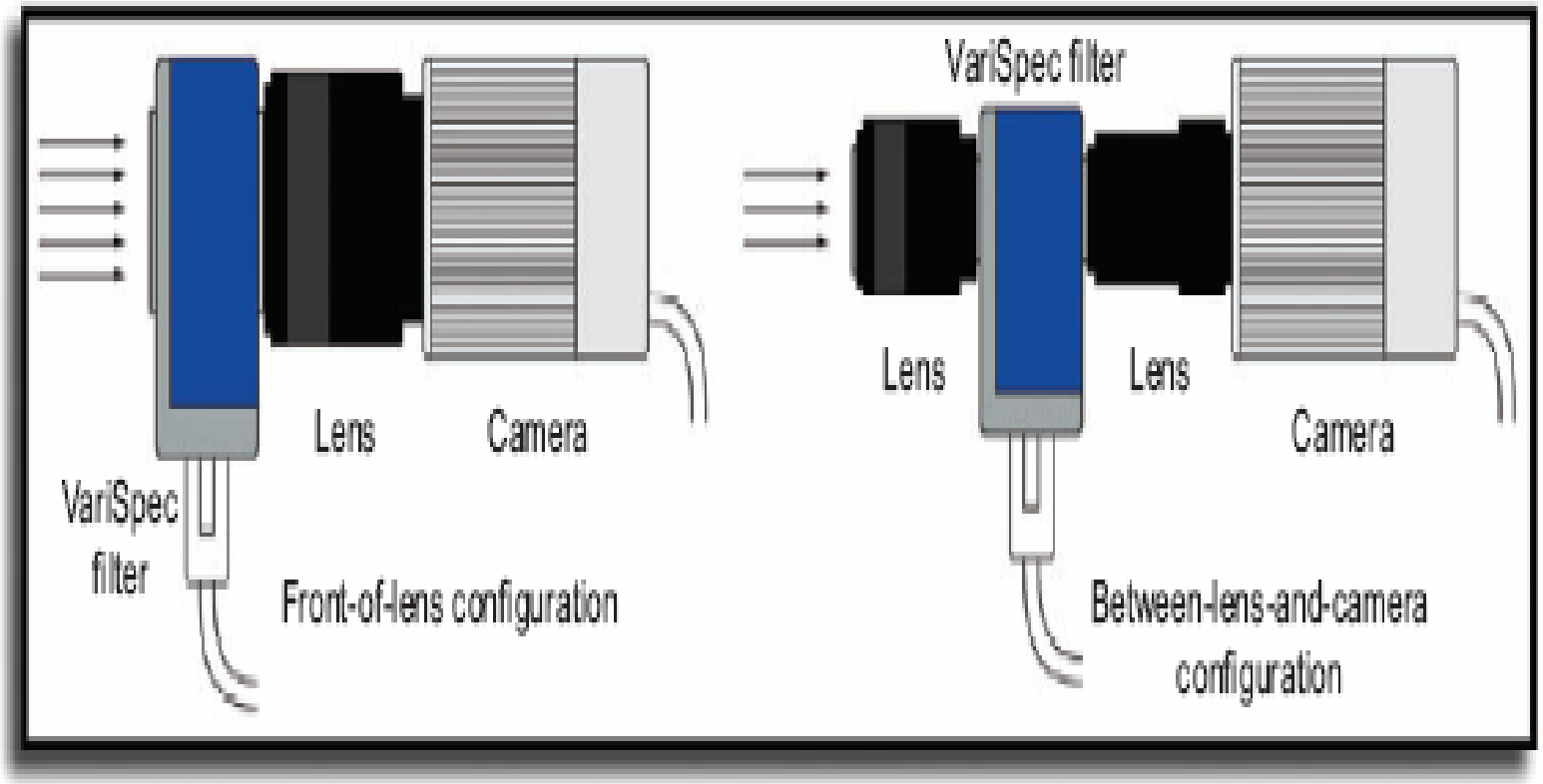
- totally 10 stages (Isel)
  - 1 xyz -system with a rotary unit
  - 3 xy -system
    1 additional linear stage
  - 1 additional rotary unit
- 4 driving controllers
  - possibility to drive
    3 or 4 unit / controller
- lengths of the stages from
  40 cm to 150 cm
- minimum step 10µm
- xyz with rotary can be used in goniometrical measurements
  for example with Hamamatsu
  or spectral camera



Light sources

- 2 Gretag MacBeth Spectralight III light booth
  - D65 and D50 filters
  - Cool White
  - horizon
  - lamp A
  - TL 84
  - UV
- Oriel 1000 W Xe
- 3 UV lamps (254nm, 302nm and 365nm)
- Schott Fostec Line light (halogen)
- calibrated QTH light source (250-2400nm)

LCTF



From CRI Varispec www-pages

LCTF

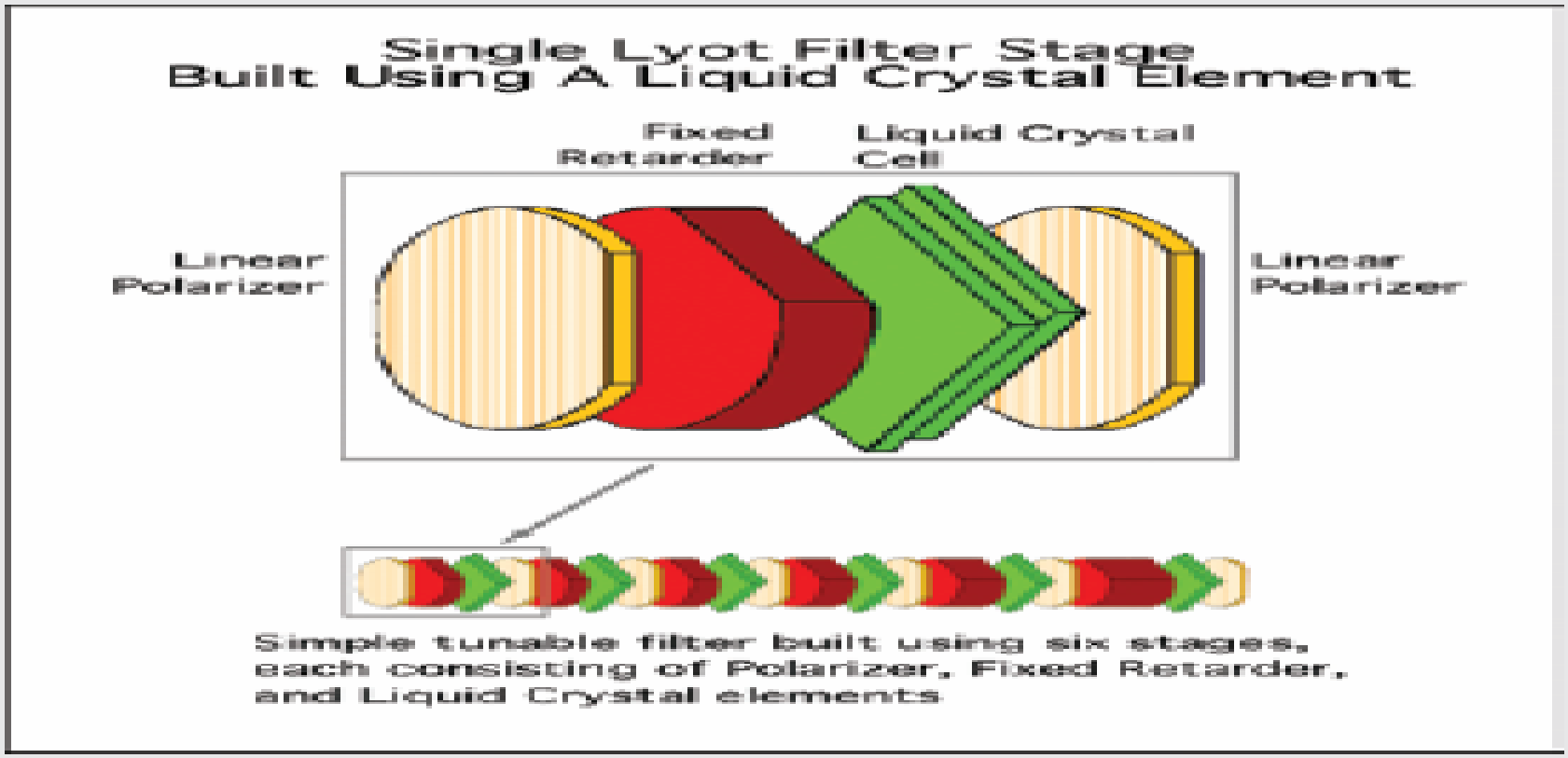
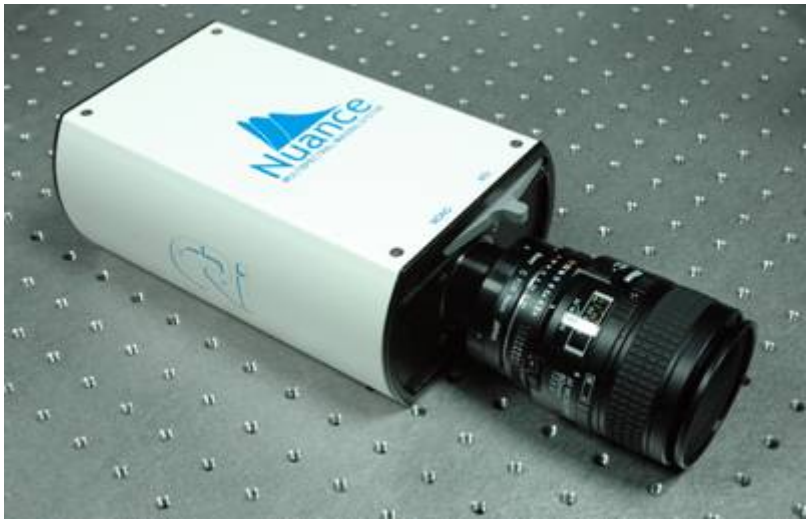


Figure 1. Lyot filter design with the addition of liquid crystal cells which can be precisely controlled.

From CRI Varispec www-pages

Nuance LCTF (by CRi)

- spectral range: 420 – 720 nm
- spectral bandwidth: 10 nm
- wavelength accuracy: 1.25 nm
- camera:
  - 1.3 M pixels (12-bit)



Spectral Imaging Approaches

• One approach: to measure the spectral data accurately

$\Rightarrow$ A large amount of data

• Other approach: to measure component images using a few optimally designed color filters

$\Rightarrow$ Data is convenient for storing and transmission

$\Rightarrow$ Spectral image can be reconstructed computationally

Color Filter Design

• One approach: to choose an optimized set of commercially available color filters (for example, interference filters, Kodak Wratten gelatin filters)

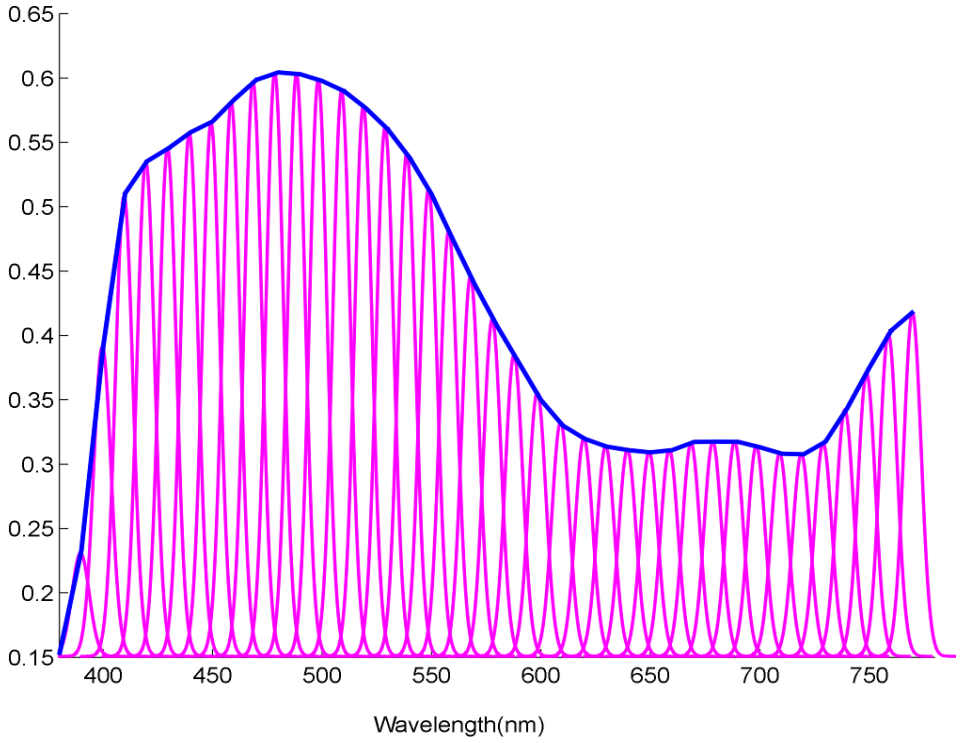
• Other approach: to design optimal color filters computationally (our approach)

$\Rightarrow$ adaptive to various application

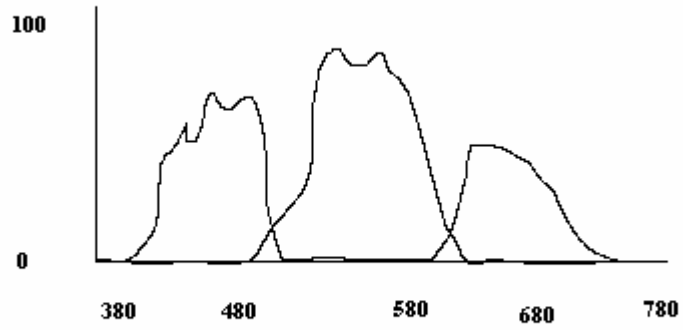
$\Rightarrow$ rewritable filter based imaging system needed

$\Rightarrow$ Spectral image can be reconstructed computationally, if needed

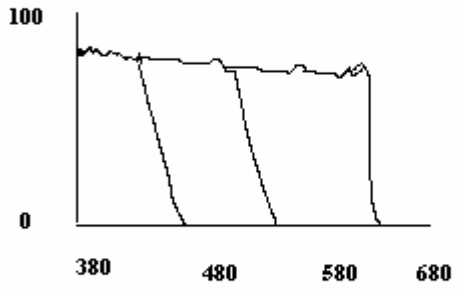
A spectrum sampled at 39 wavelengths

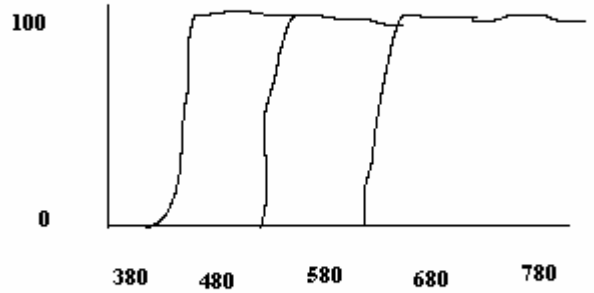


RGB-filters



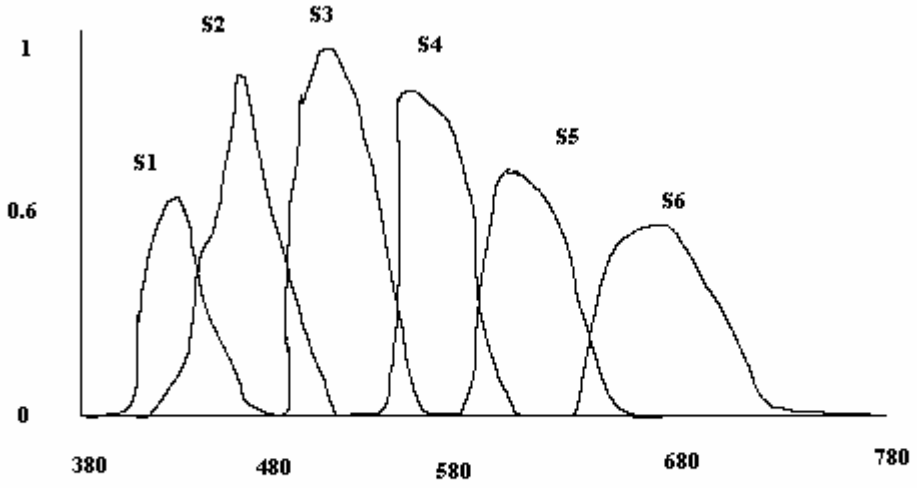
High and low pass filters

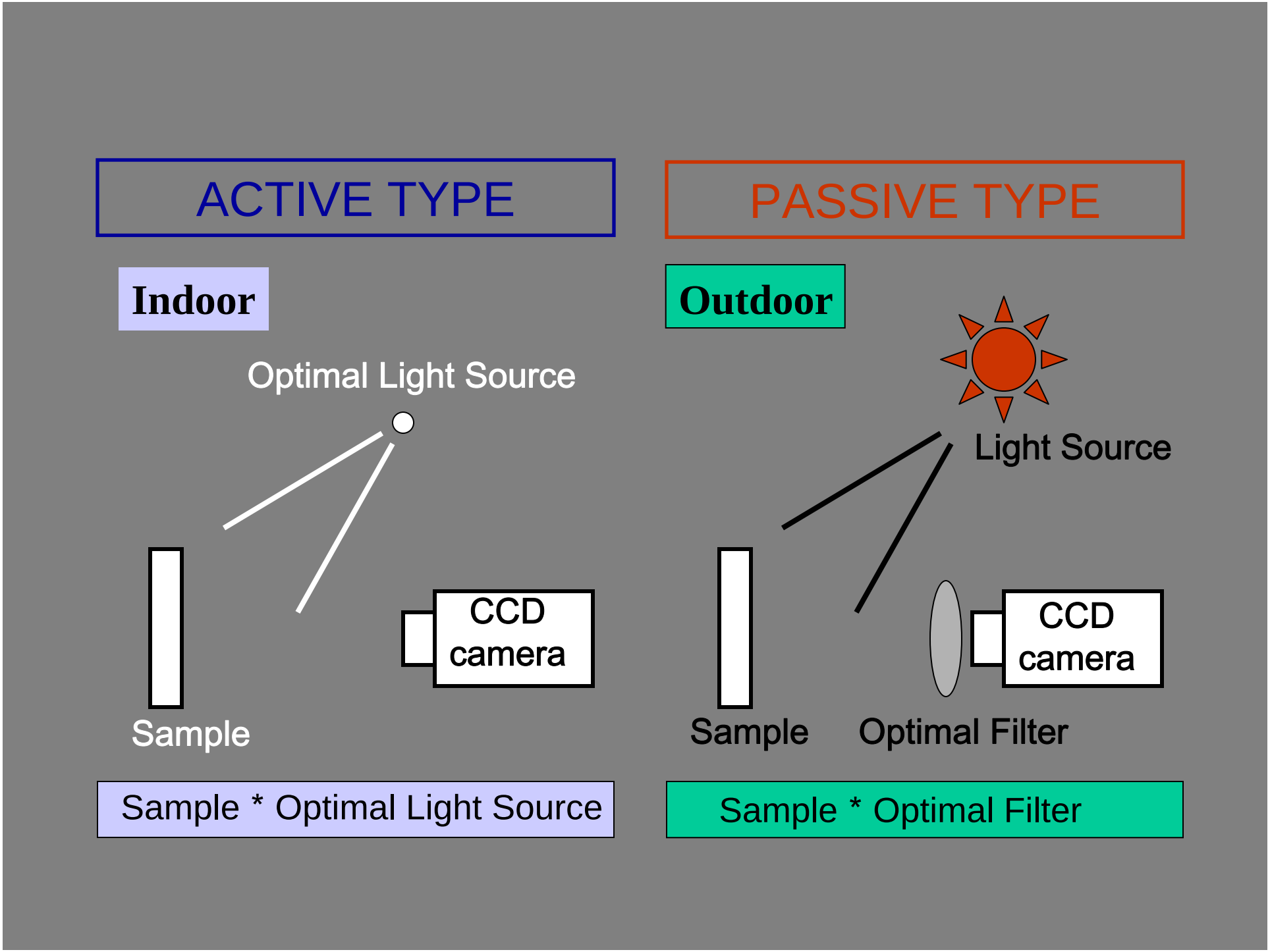




6 filters for

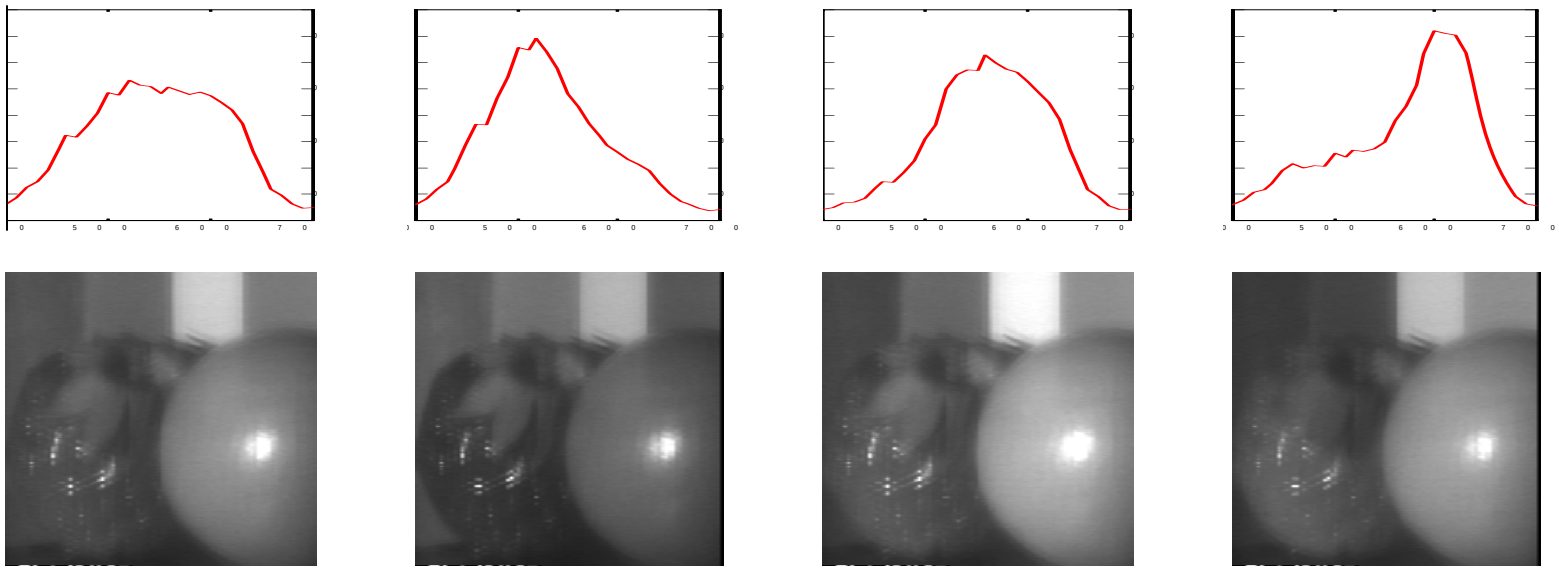
Multiprimary displ




ACTIVE TYPE
PASSIVE TYPE
Indoor
Outdoor
Optimal Light Source
Light Source
CCD camera
CCD camera
Sample
Sample
Optimal Filter
Sample * Optimal Light Source
Sample * Optimal Filter

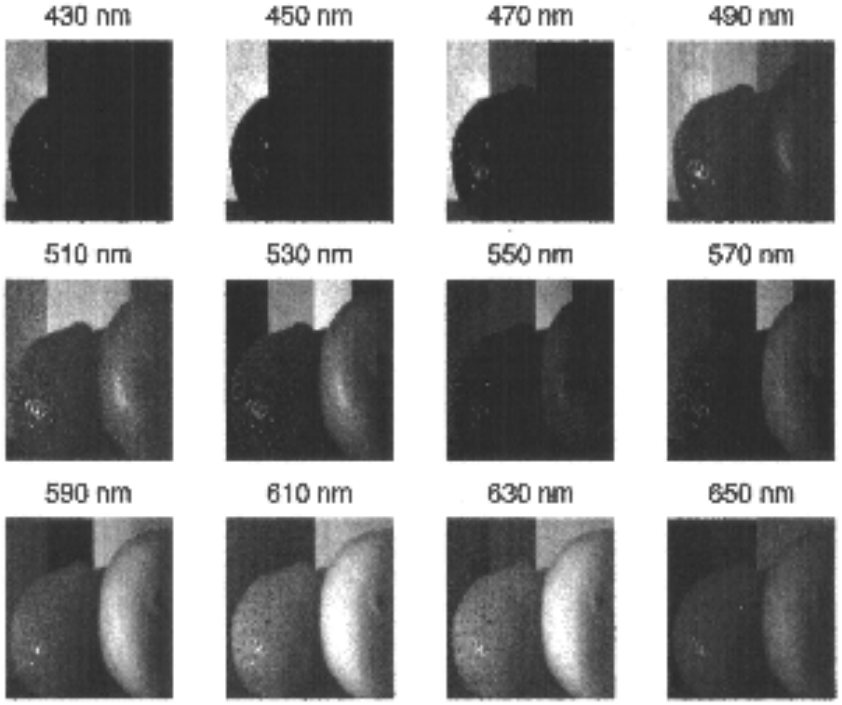
Experiments with Real World Object (indoor)

Filter No.1 Filter No.2 Filter No.3 Filter No.4



Detected intensity images of the object through the 4 filters.

Spectral image reconstructed from 4 inner-product images



Spectral image measured using 31 narrowband filters