Soil Spectroscopy: Principle and Applications

Novospec

THE REMOTE SENSING LABORATORIES

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Department of Geography and Human Environment

Brno Czech Republic, June 25-26

esf european social fund in the czech republic
EUROPEAN UNION
MINISTRY OF EDUCATION, YOUTH AND SPORTS
OP Education for Competitiveness
INVESTMENTS IN EDUCATION DEVELOPMENT

Soil Spectroscopy

Lesson 2

Special Working Group on Soil Spectroscopy

EUFAR European Facility For Airborne Research

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- Glossary
- Frequently Asked Questions
- Help
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Welcome to EUFAR

EUFAR is an 'Integrating Activity' funded by the European Commission under FP5/FP6/FP7.
EUFAR works to coordinate the operation of instrumented aircraft and hyperspectral imaging sensors, exploiting the skills of experts in airborne measurements in the fields of environmental and geo-sciences, in order to provide researchers with the infrastructure best suited to their needs.
Read More

To have an overview of the **FP7 achievements**, visit this page.

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What's nev

- The EUFAR book on 'Airborne Measurements for Environm available for purchase here!!!!
- XV congress of the Spanish Remote Sensing Association One-days workshops on UAV technologies and hyperspectral October 23rd.
- You can read the 9th EUFAR FP7 Newsletter (November 2012

- Specific measurement fields:

Working groups designation	Coordinator
Active remote sensing	Jacques Pelon
Cloud Microphysics	Manfred Wendisch
Gas phase chemistry	Jim Mcquaid
Hyperspectral Applications for Soil	Eyal Ben dor
Hyperspectral Applications for Vegetation	Michael Schaepman
Hyperspectral Applications for Water	Steve Groom
Imaging remote sensing	Jose-antonio Gomez-sanchez
In-Situ Aerosols	Paola Formenti
Polar Research	Tom Lachlan-cope
Radiation	Thomas Ruhtz
Stratospheric Measurements	Fred Stroh
Thermodynamics	Martin Zoger
Turbulence	Marco Esposito

Expert Working-Groups / **Hyperspectral Applicatio**

Description | Meetings | Documents | Mailing

Description:
Hyperspectral Applications for Soil

HYRESSA (Contract Number 026194), a Specific Sup the HYRESSA website.

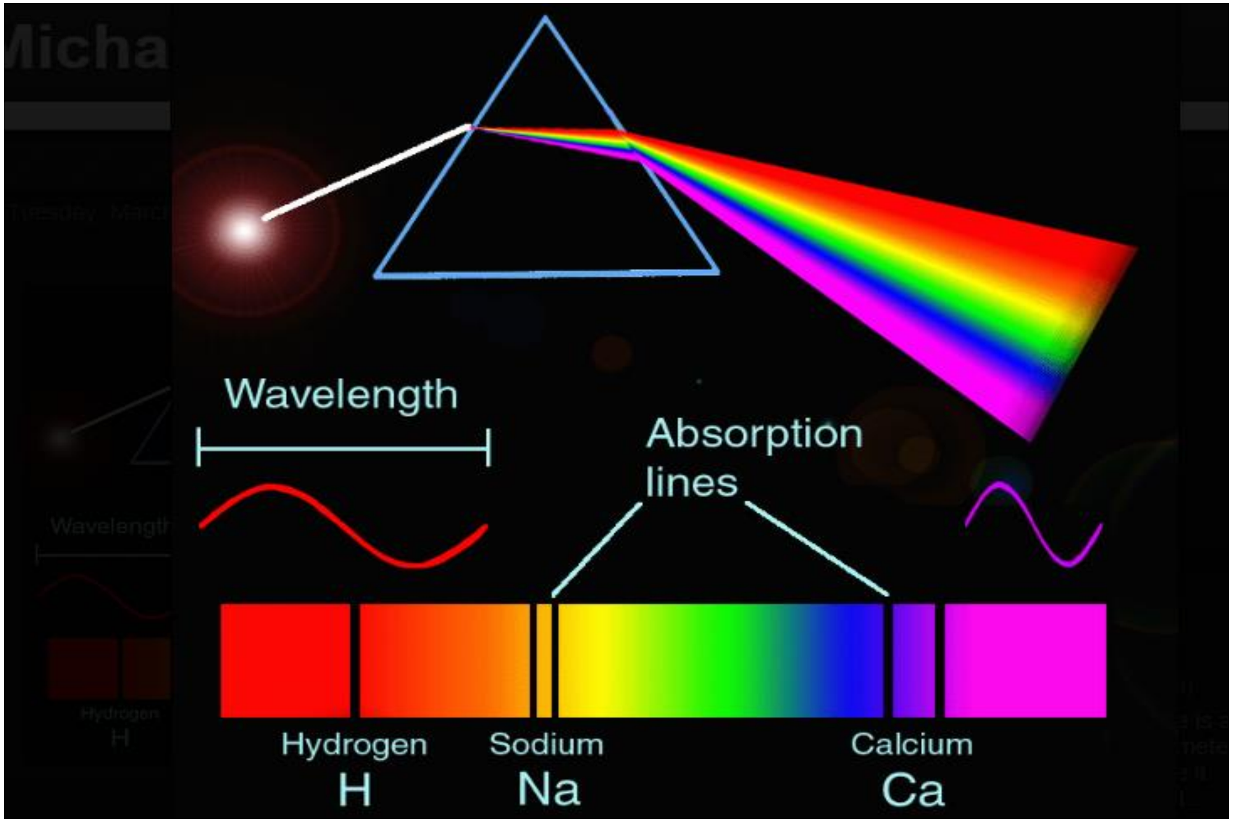
Coordinator of the Hyperspectral Applications for Soil working group :
Ben dor Eyal

If you are interested in this working group, please enter your login/password or subscribe.

253 members

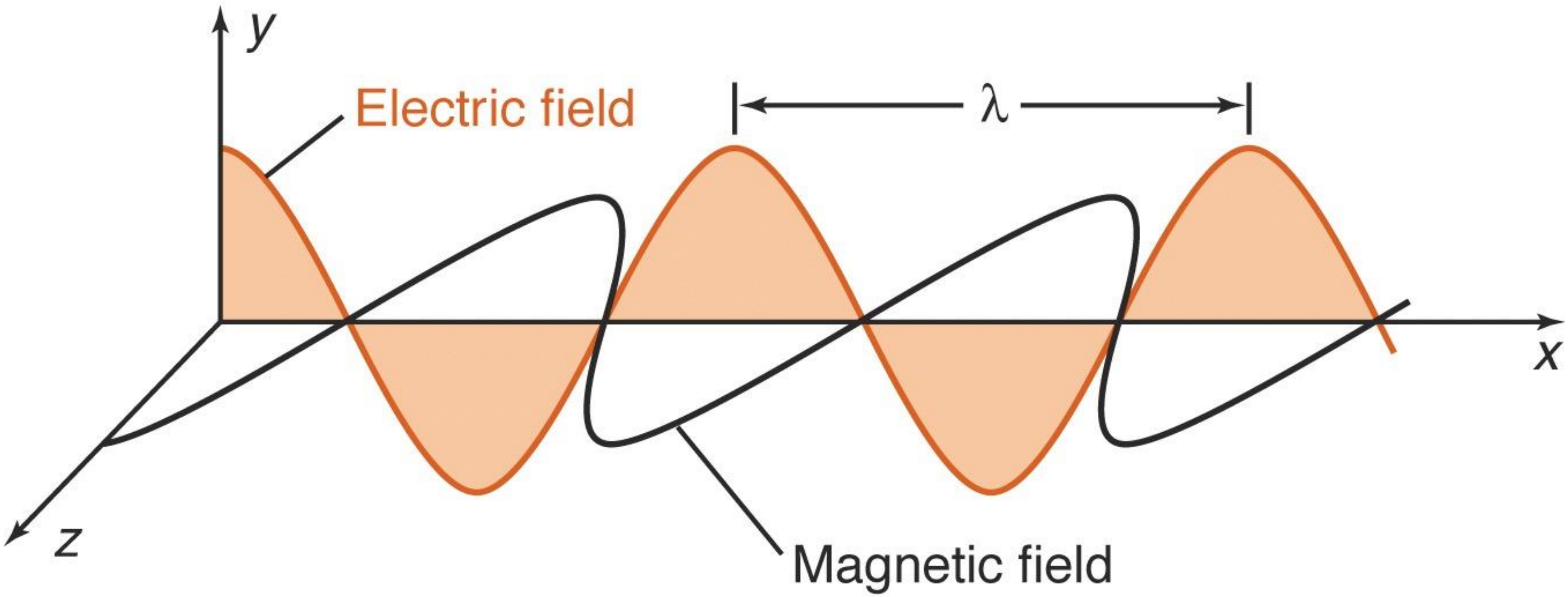
Spectroscopy

The science of tracking after the EM interaction with matter



Properties of Electromagnetic Radiation

”Plane-polarized electromagnetic radiation of wavelength λ, propagating along the x axis. The electric field of the plane-polarized light is confined to a single plane. Ordinary, unpolarized light has electric field components in all planes."



Properties of Light

Electromagnetic Radiation

- energy radiated in the form of a WAVE caused by an electric field interacting with a magnetic field
- result of the acceleration of a charged particle
- does not require a material medium and can travel through a vacuum

Properties of Electromagnetic Radiation

$v_i = \nu \lambda_i$

where v_i => velocity

ν => frequency

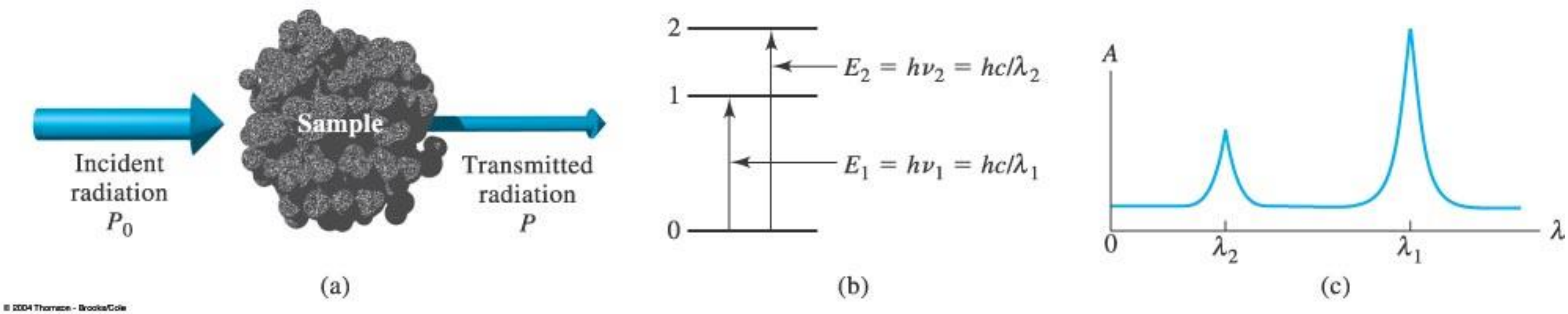
λ_i => wavelength

Properties of Electromagnetic Radiation

in vacuum, velocity is independent of frequency, maximum value

$$c = \nu\lambda = 2.998 \times 10^8 \text{ m/s}$$

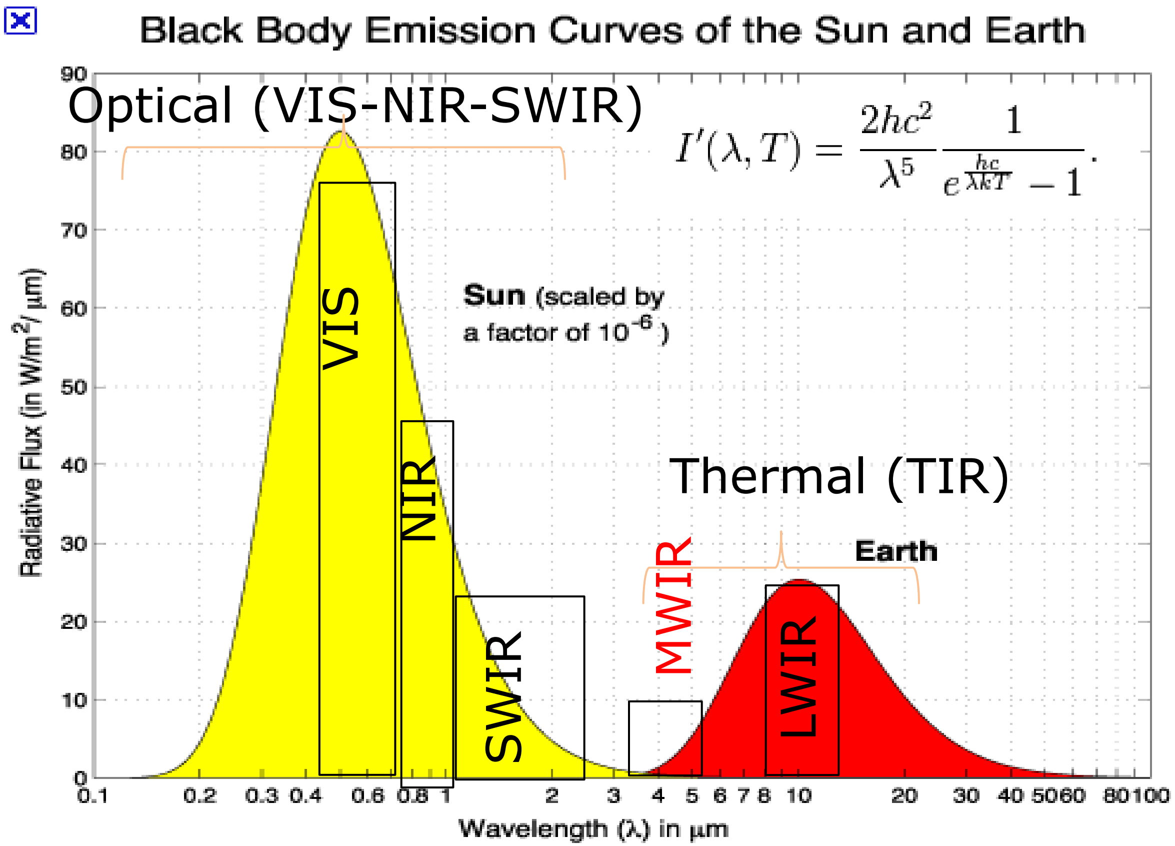
Spectrum: A plot of the interaction of EM with matter



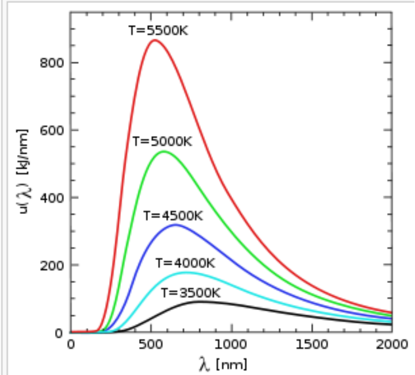
Interaction Theory Spectrum

Black Body and Plank Theory

Radiation Sources and Atmosphere windows (1)

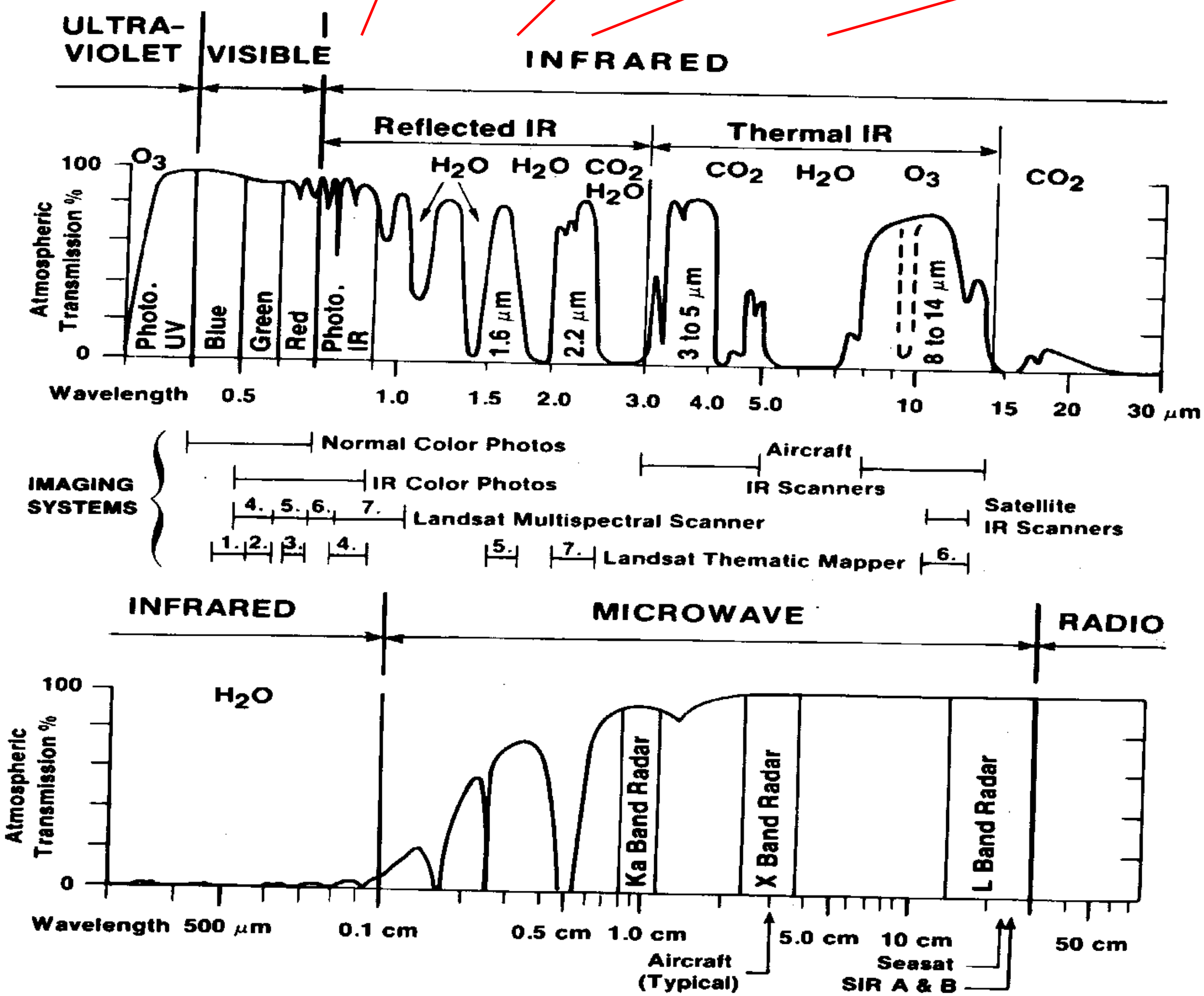


04-2.5 μm 3-5 μm 8-12 μm



Black body spectrum (spectral energy density **inside** a blackbody cavity). Indicated units are correctly kJ/m^4, or nJ/cm^3/μm. Scale by c/4π to achieve $I'(\lambda,T)$.

VIS NIR SWIR-1 SWIR-2 TIR



VIS-0.4-0.7µm

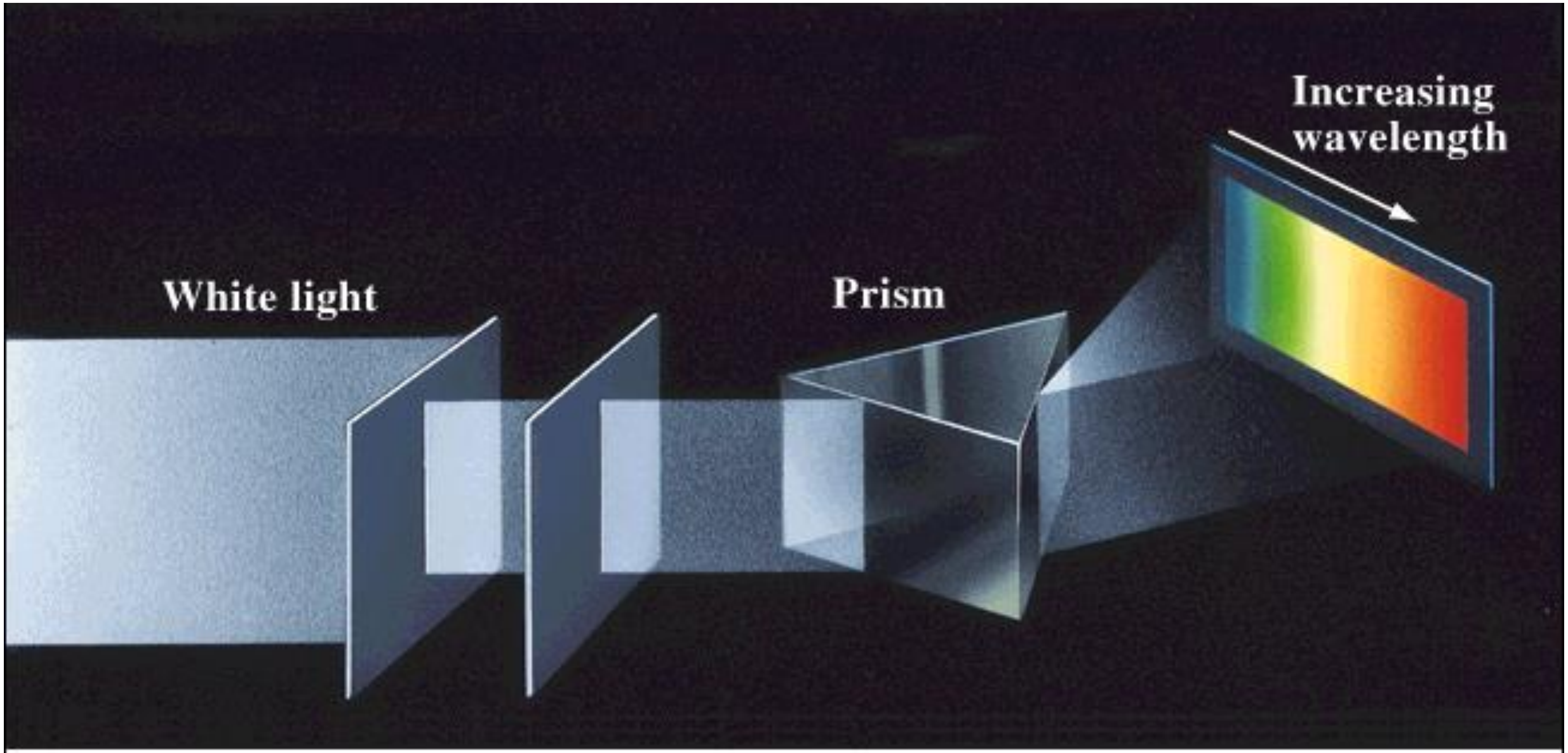
NIR 0.7-1.2µm

SWIR-1 1.2-2.0µm

SWIR-2 2.0-2.5µm

TIR – 2.5-14µm

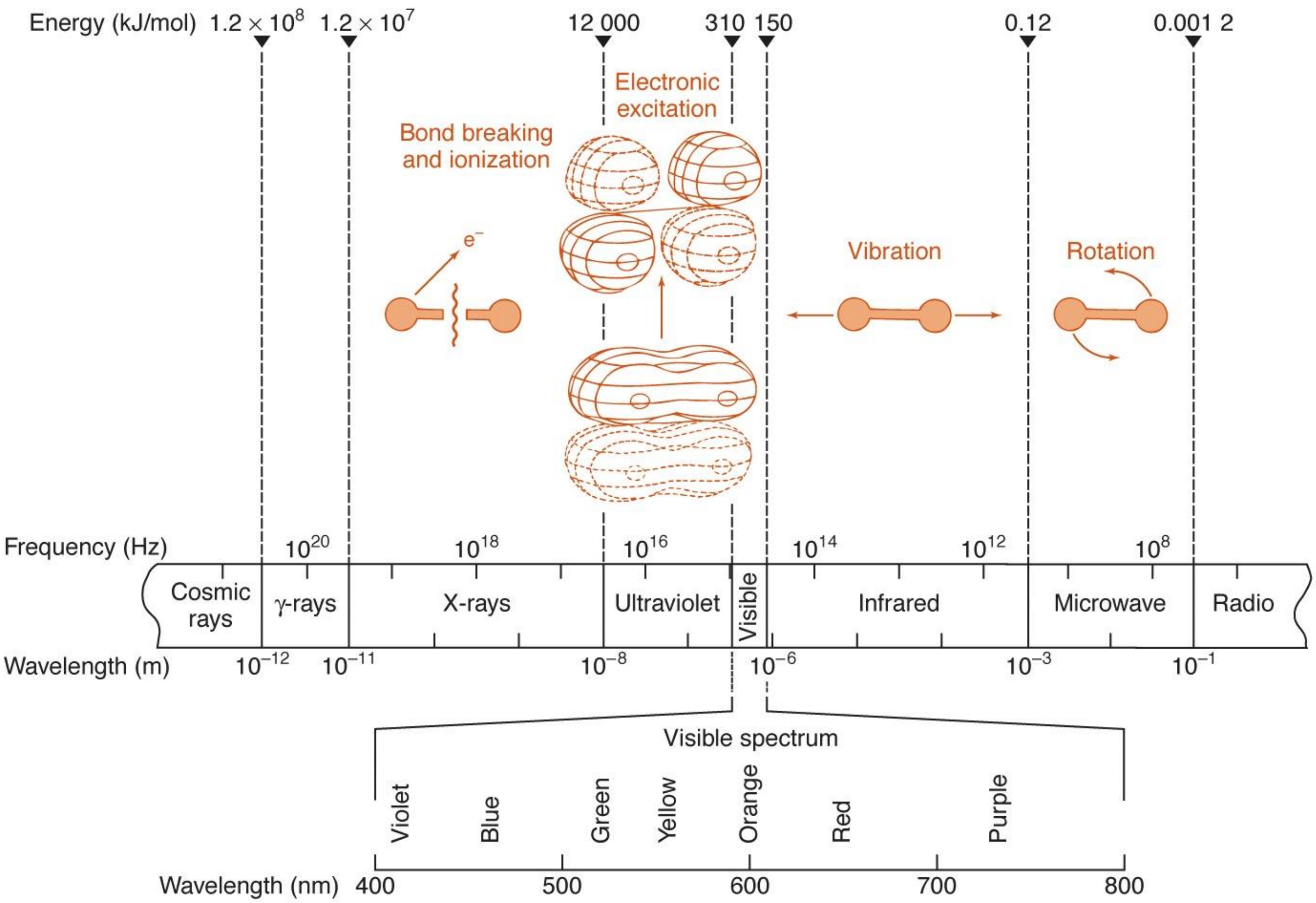
White Light consist of many wavelengths



Colors of Visible Light

Wavelength	Absorbed	Observed
380-420	violet	green-yellow
420-440	violet-blue	yellow
440-470	blue	orange
470-500	blue-green	red
500-520	green	purple
520-550	yellow-green	violet
550-580	yellow	violet-blue
580-620	orange	blue
620-680	red	blue-green
680-780	purple	green

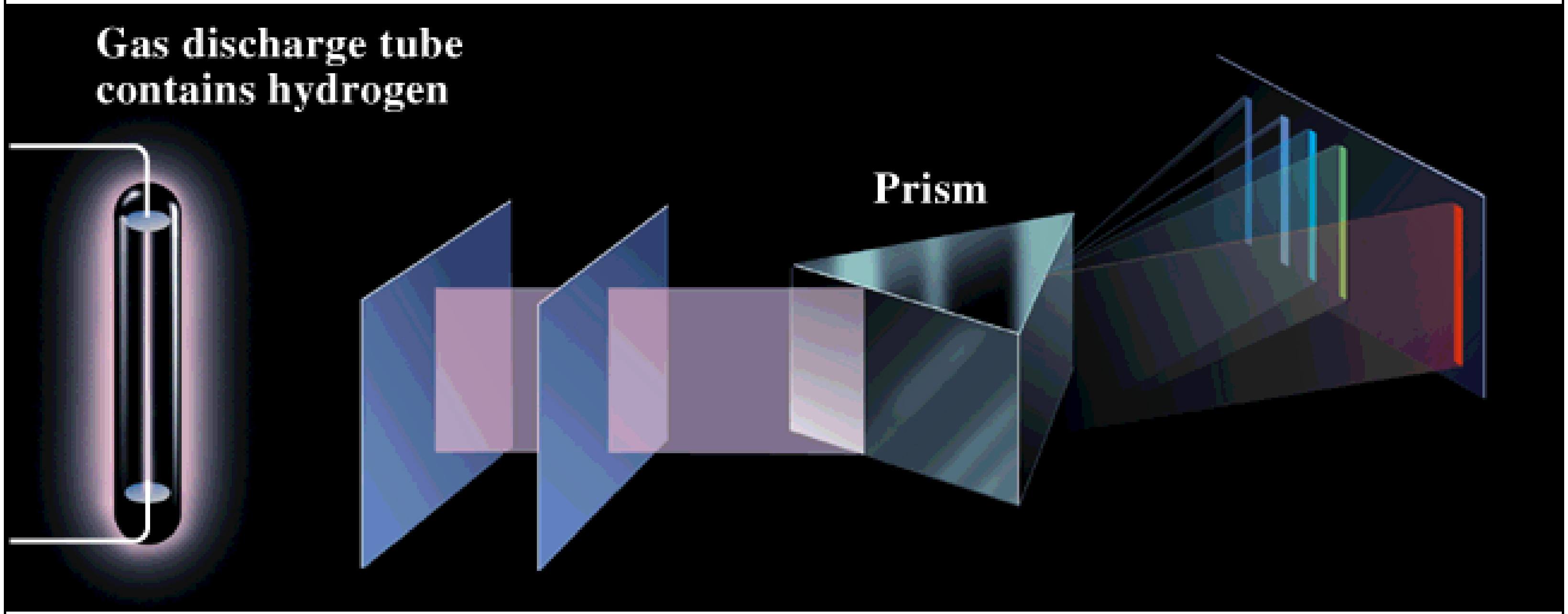
Energy and Processes at the Electromagnetic Spectrum



Line Spectrum

A spectrum produced by a luminous gas or vapor and appearing as distinct lines characteristic of the various elements constituting the gas.

Hydrogen line emission spectrum



Use to calibrate "spectrally" spectrometers

Ground State

The state of least possible energy in a physical system, as of elementary particles. Also called *ground level.*

Excited State

Being at an energy level higher than the ground state.

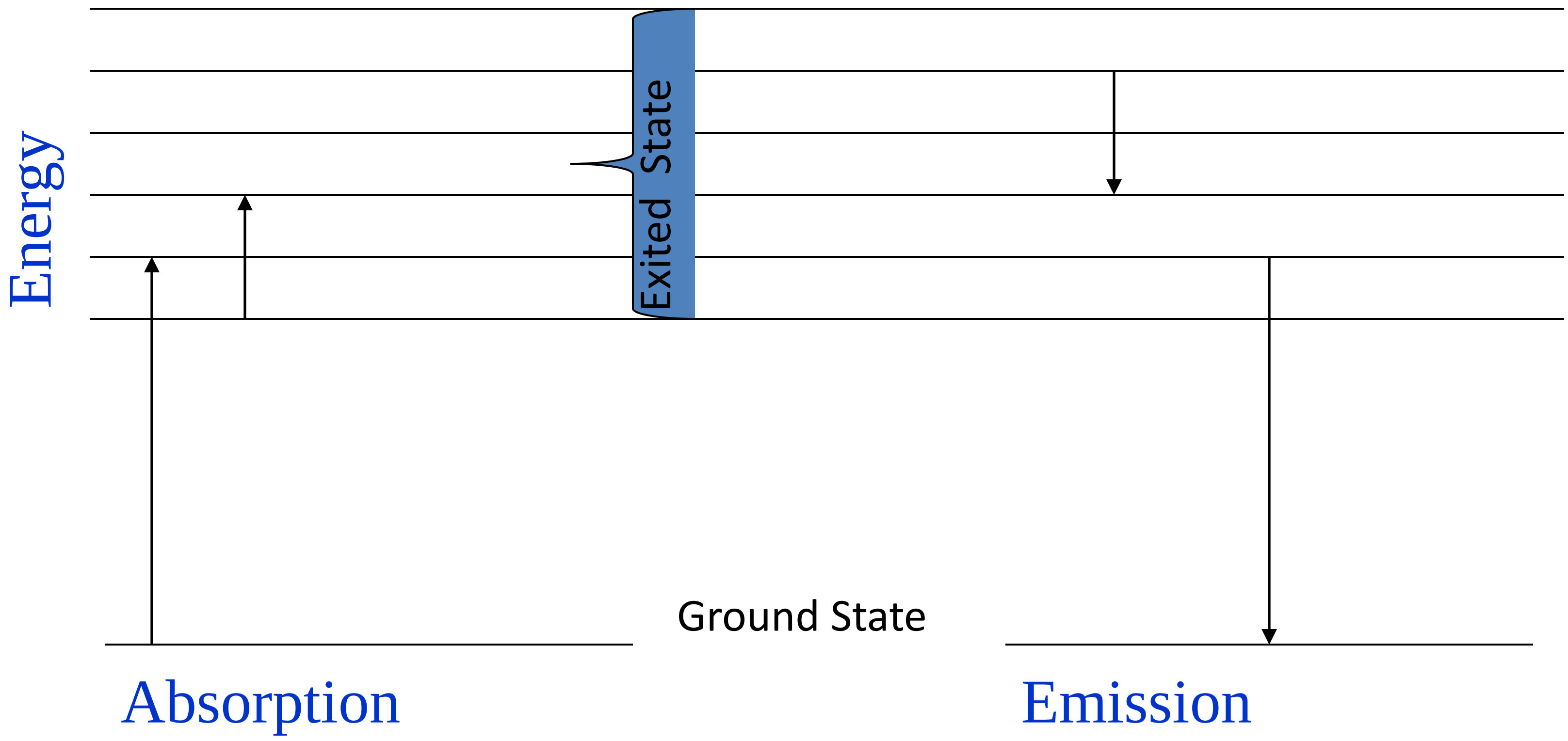
Emission Spectrum

- The spectrum of emitted energy from a specific emitting substance subjected to a specific kind of excitation.

Absorption Spectrum

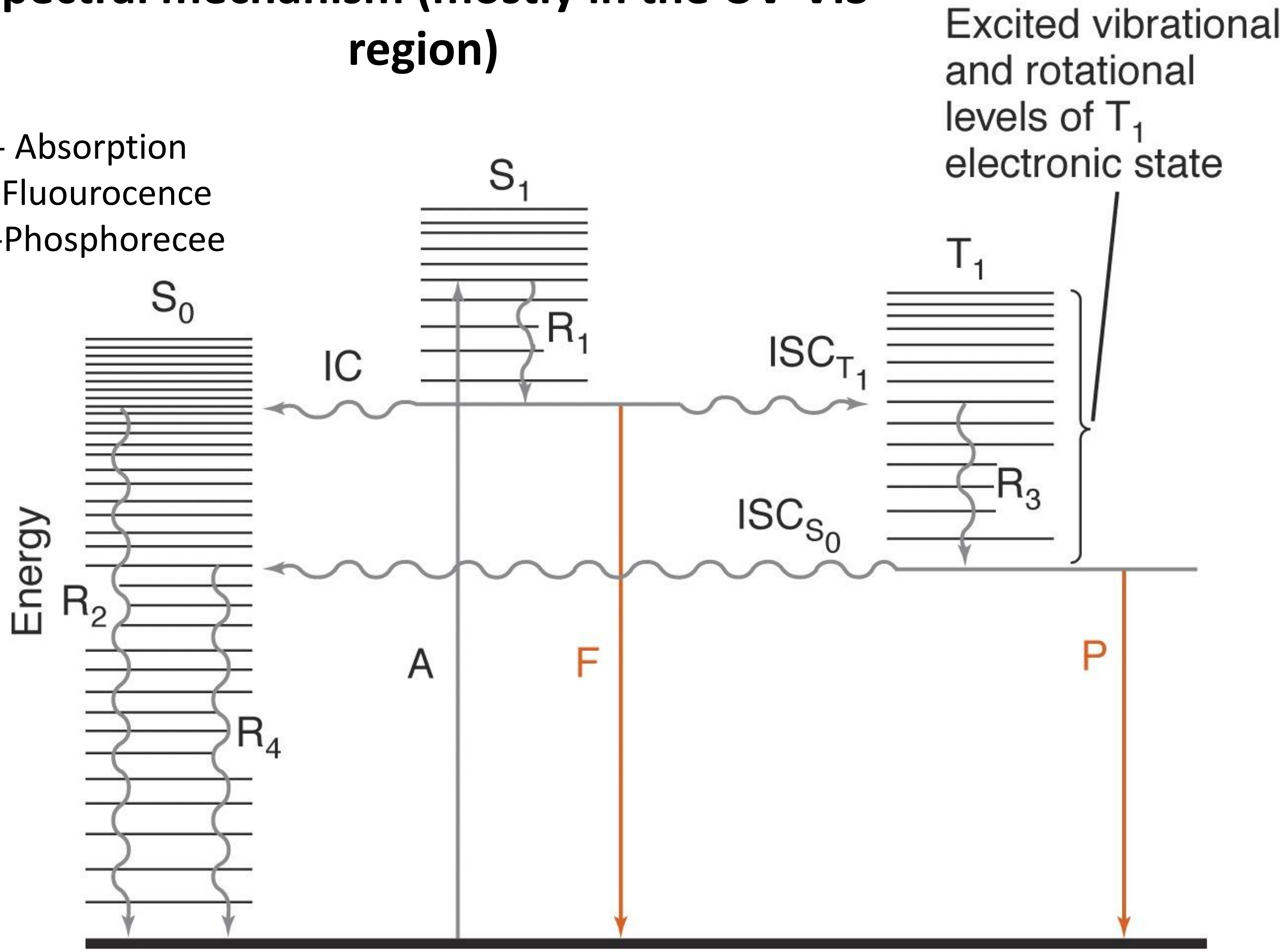
- Light shinning on a sample causes electrons to be excited from the ground state to an excited state or vibration levels to be changed
- wavelengths of that energy are removed from transmitted/reflectcted spectra

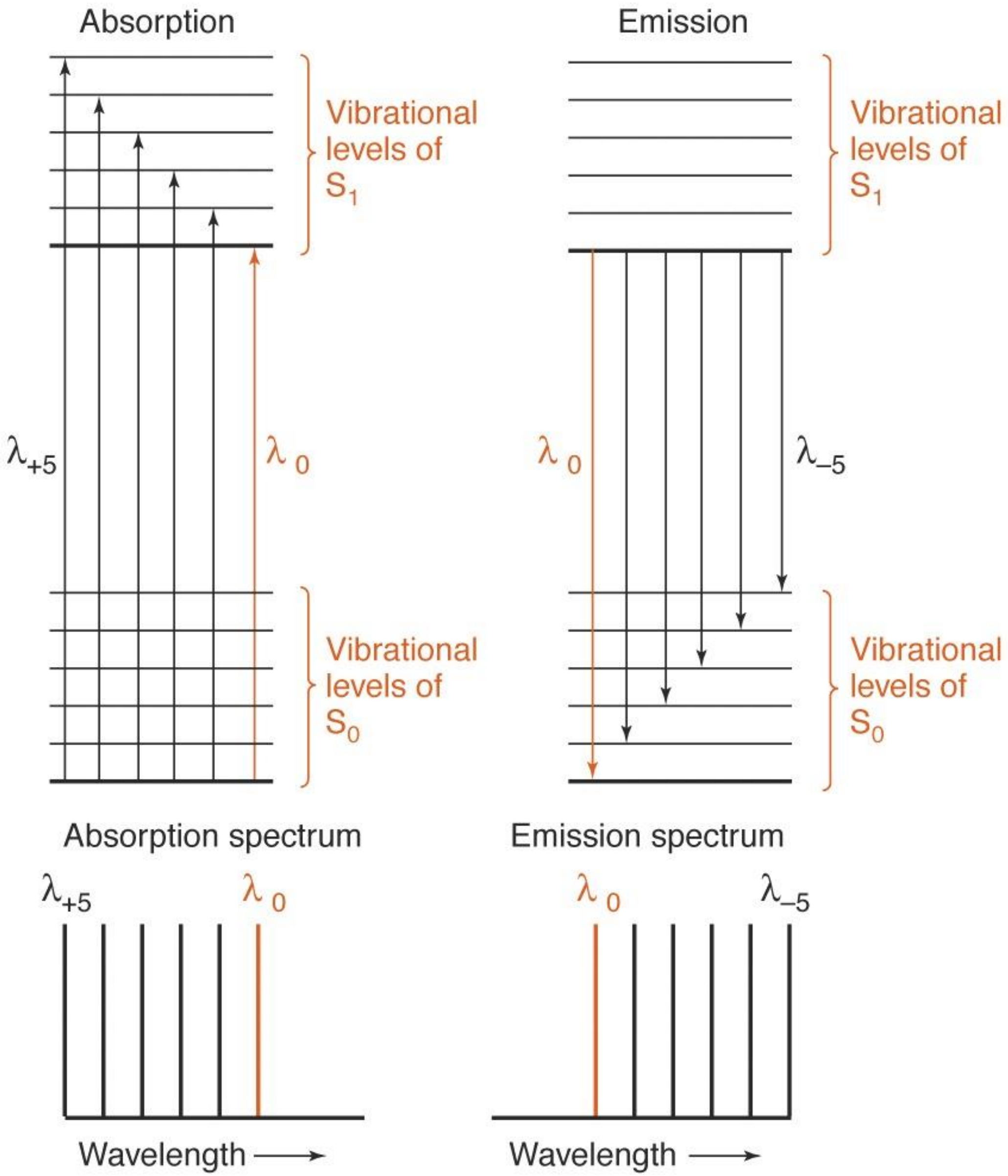
Absorption and Emission of Light



Spectral mechanism (mostly in the UV-VIS region)

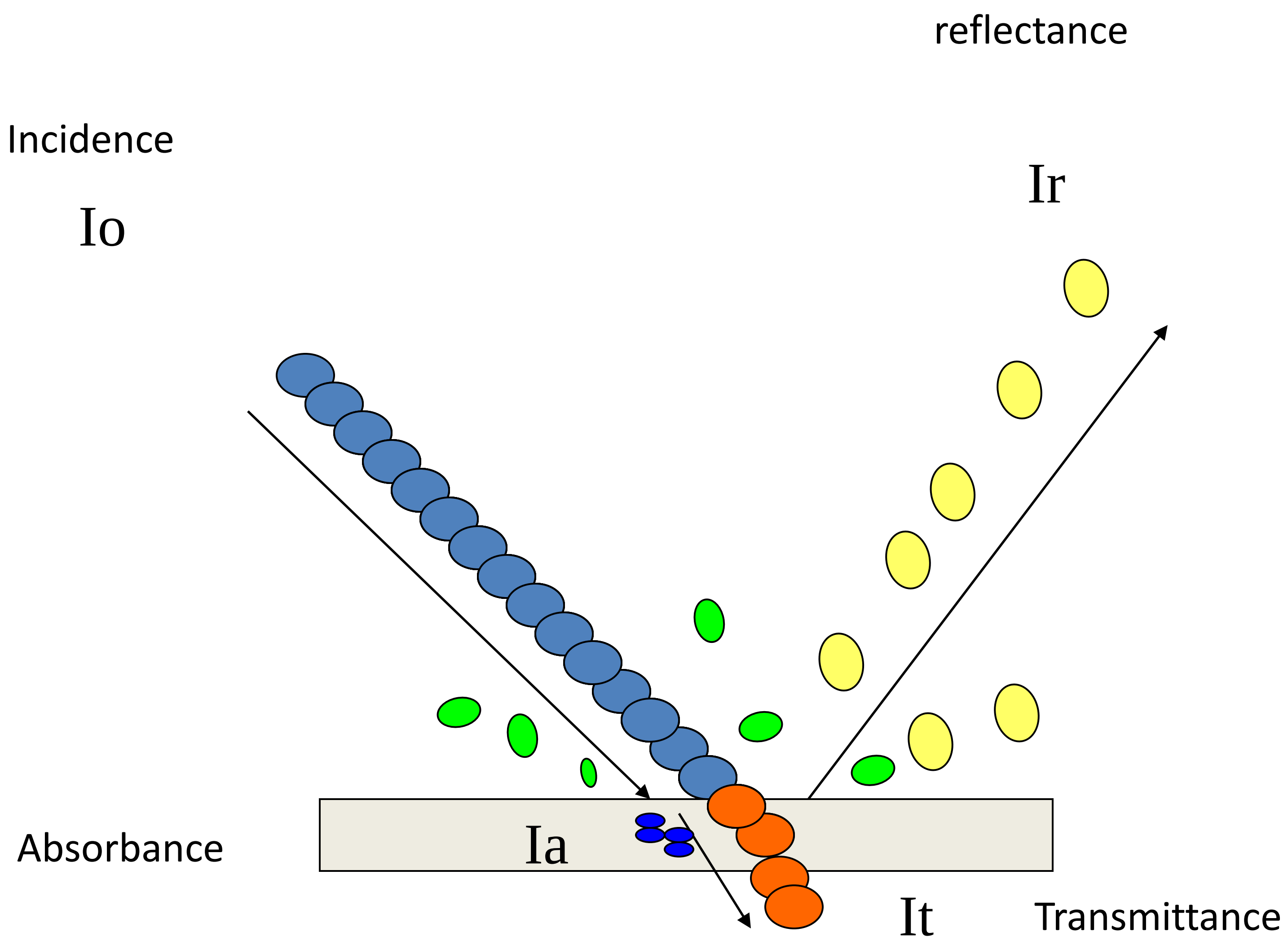
A- Absorption
F-Fluourocence
P-Phosphorecee



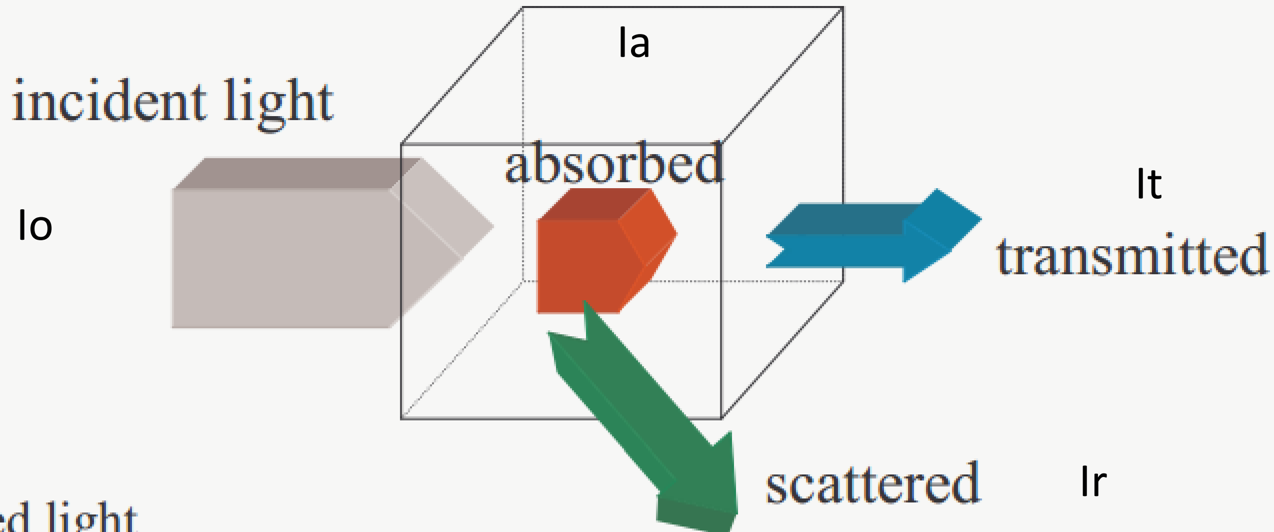


Absorption
Emission
Vibrational levels of S_1
Vibrational levels of S_1
λ_{+5}
λ_0
λ_0
λ_{-5}
Vibrational levels of S_0
Vibrational levels of S_0
Absorption spectrum
Emission spectrum
λ_{+5}
λ_0
λ_0
λ_{-5}
Wavelength →
Wavelength →

A Photon: a pack of energy with no mass traveling in the speed of light (and lower)



- Consider a beam of light on a material
  - It can be scattered, absorbed, or transmitted



- Transmitted light
  - Light emerges propagating in the same direction as the incident light
- Absorbed light
  - Energy from light is absorbed in the volume of the material
- Scattered light
  - Light emerges in a different direction from the incident light

$$I_o = I_a + I_t + I_r$$

$$Io = Ia + It + Ir \quad / \; Io$$

$$1 = \alpha + \tau + \rho$$

Absorptnace Transmittance Reflectance

Absorption Methods, Transmittance (Reflectance =0)

$T = I/I_o$

where T => transmittance

I => power of transmitted radiation

I_o => power of incident radiation

$\%T = (I/I_o)*100$

where %T => percent transmittance

Absorption Methods, Transmittance

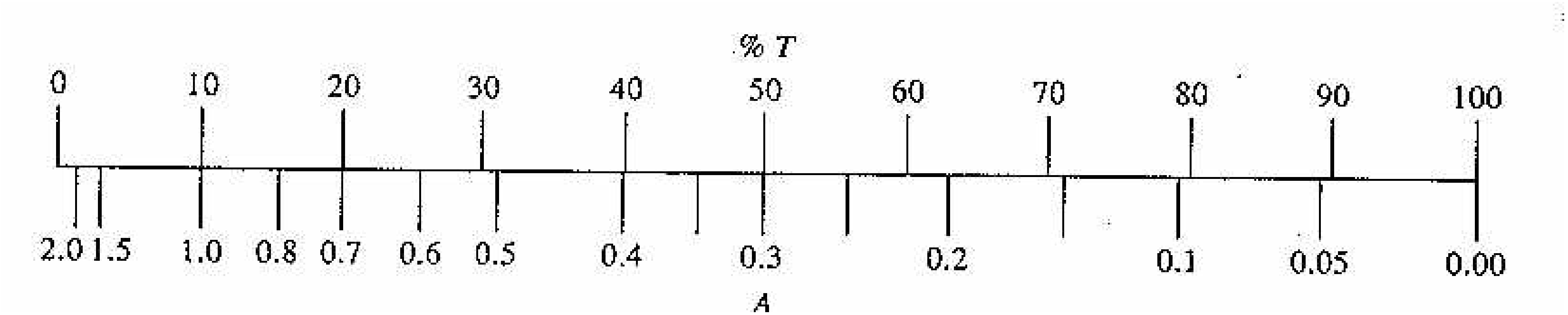
$$A = -\log_{10}T = -\log_{10}(I/I_o)$$

where A => absorbance

Relation Between Transmittance and Absorbance (Ref = 0)

I/I_o	%T	A
1	100	0
0.1	10	1
0.01	1	2

Relationship of Transmittance and Absorpbance



transmittance (reflectance) scale is linear

absorbance scale is exponential thus, read transmittance, then calculate absorbance

Absorption Methods, Reflectance (Transmittance =0)

$R = I/I_o$

where R => reflectance

I => power of reflectance radiation

I_o => power of incident radiation

$\% R = (I/I_o)*100$

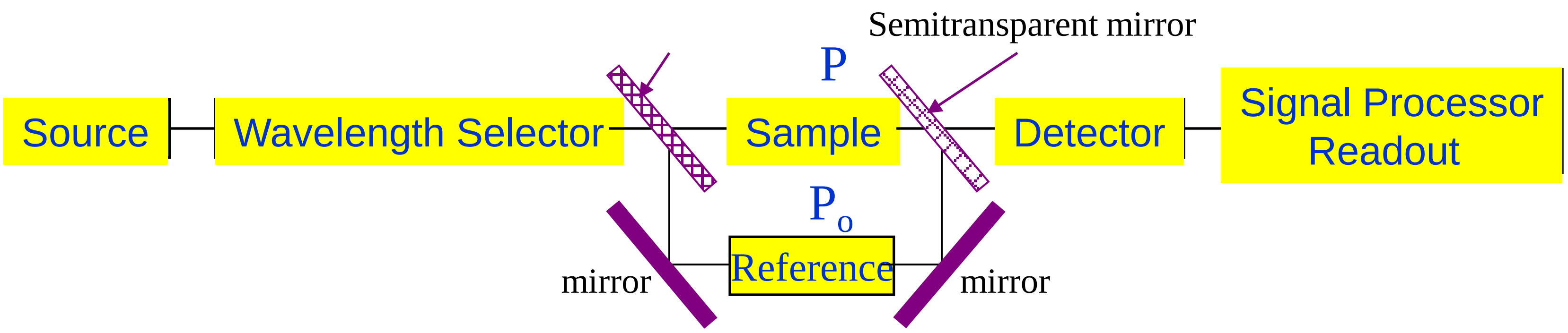
where %R => percent reflectance

Absorption Methods, Reflectance

$A = -\log_{10}R = -\log_{10}(I/I_o)$

where A => absorbance

Components of Optical Instruments to do the analysis



Transmittance Spectrometer

Reflectance Spectrometer

Emission Flame Photometer

Flame Atomic Absorption Spectrometer

Fluorescence and/or Scattering Spectrometer

Beer's Law $A = a\underline{b}c$

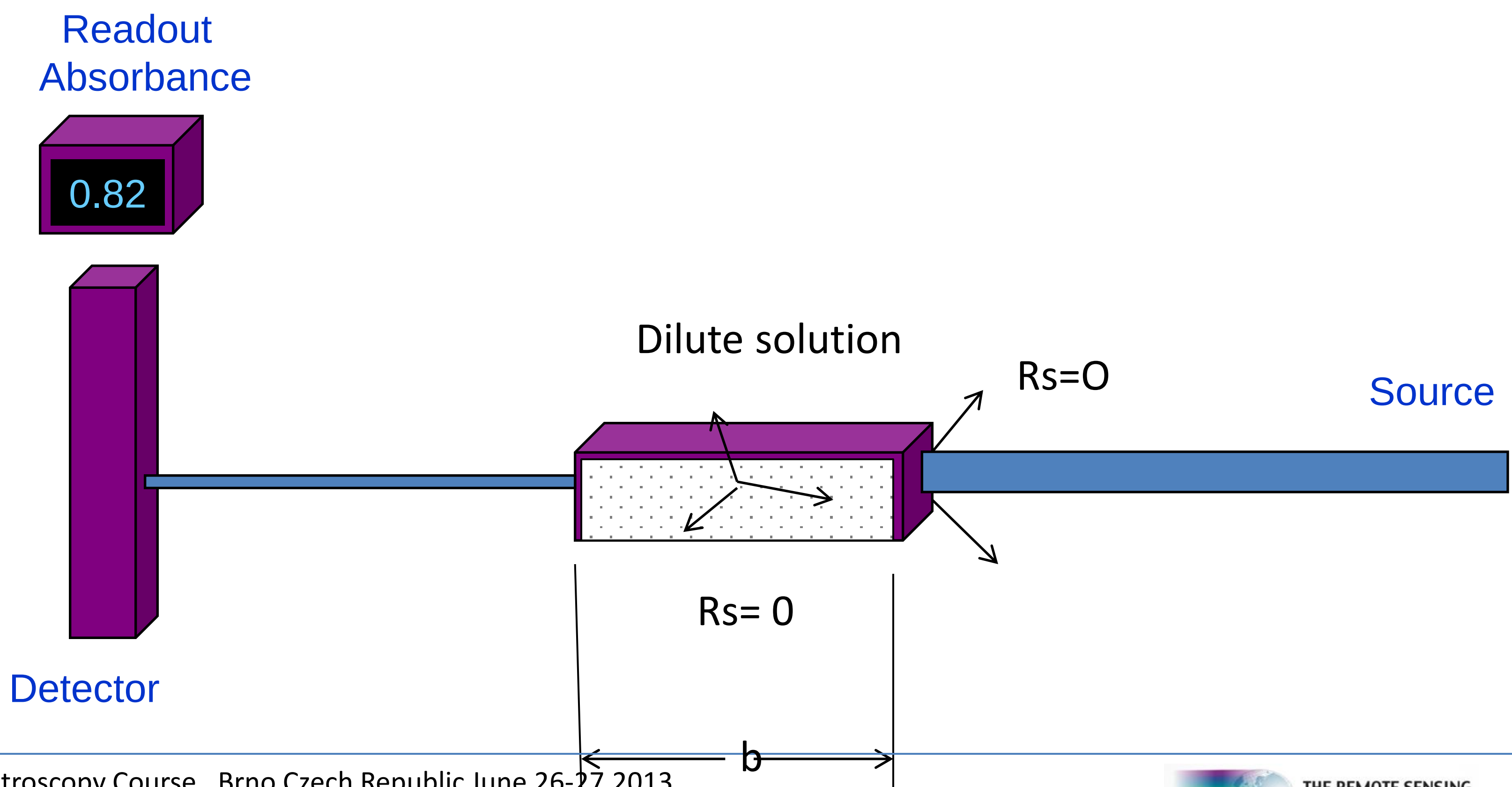
constant

Concentration

absorbance

Optical path

Path Length Dependence, b



Absorption Methods, Beer's Law

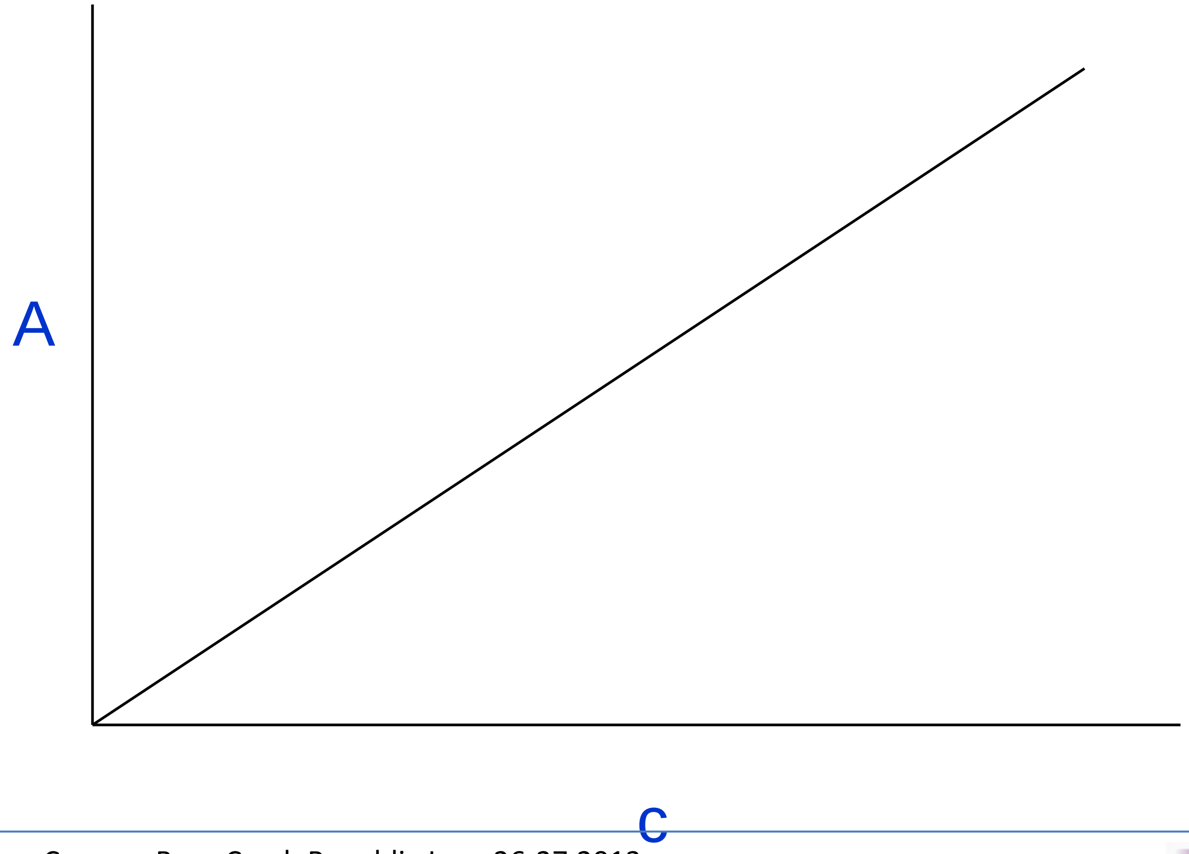
$A = abc = \varepsilon bc$

where

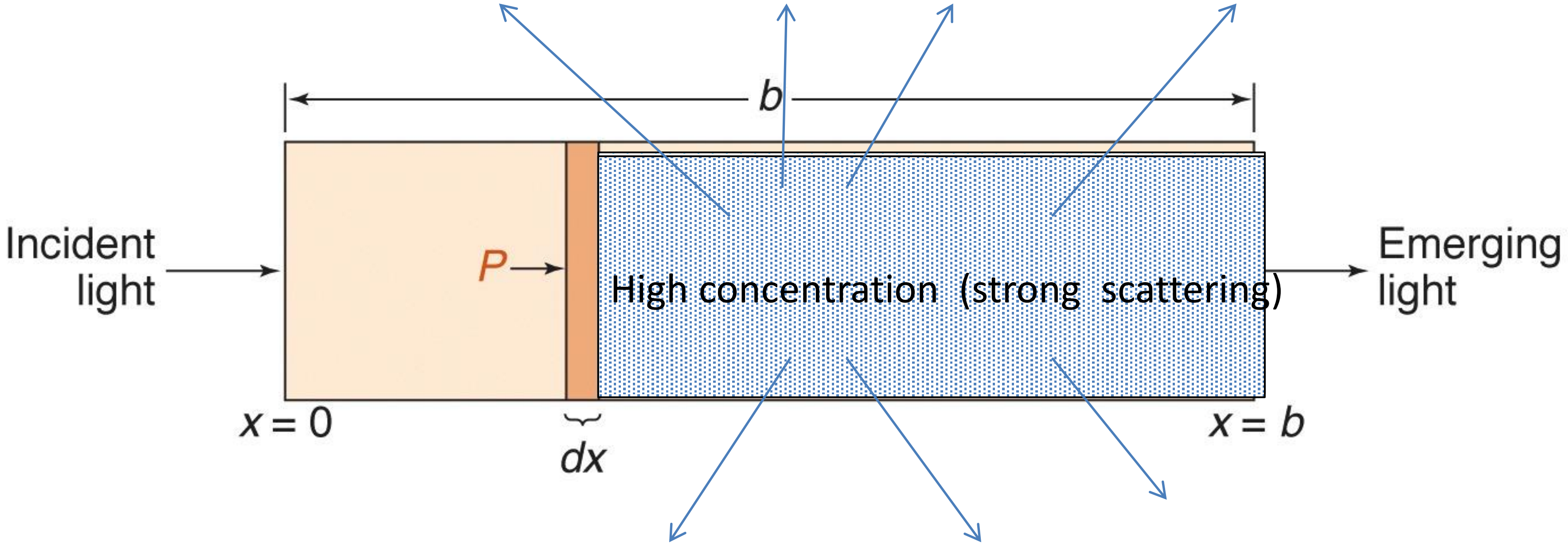
- a => absorptivity
- b => path length
- c => concentration
- ε => molar absorptivity

Beer's Law

A = abc = εbc



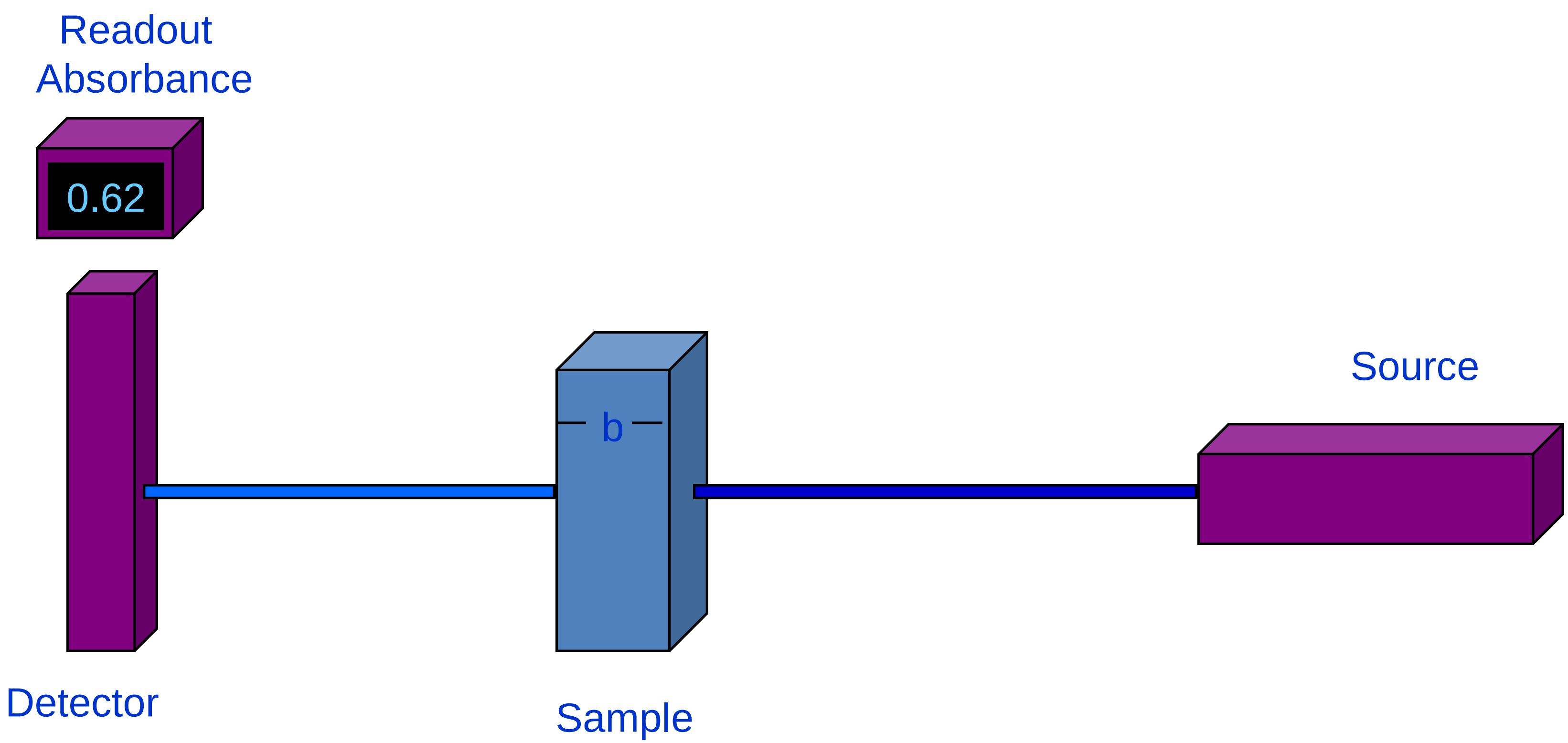
Attenuation of Light



Beers law does not work for High concentration as the scattering effect is significant

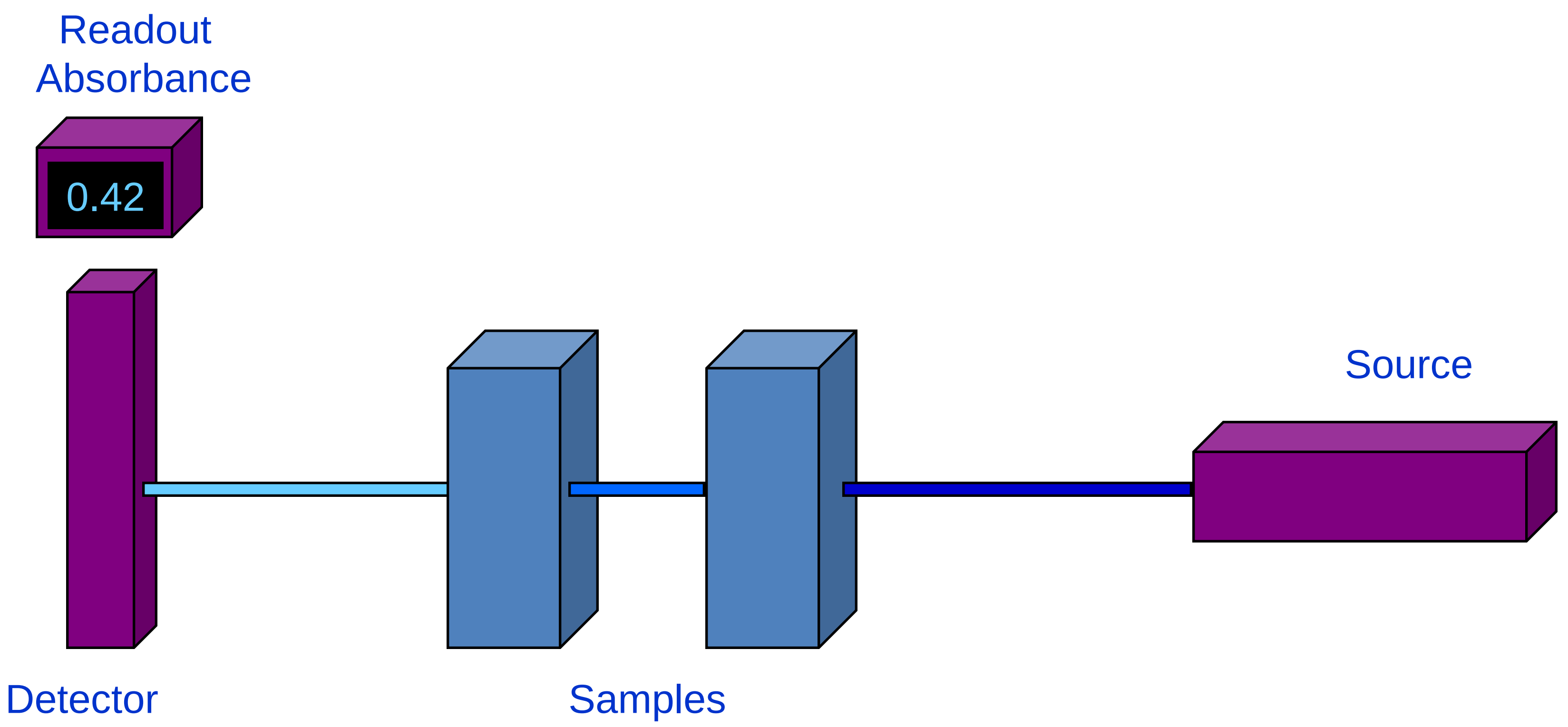
Beer’s Law $A = a\underline{b}c$

Path Length Dependence, b



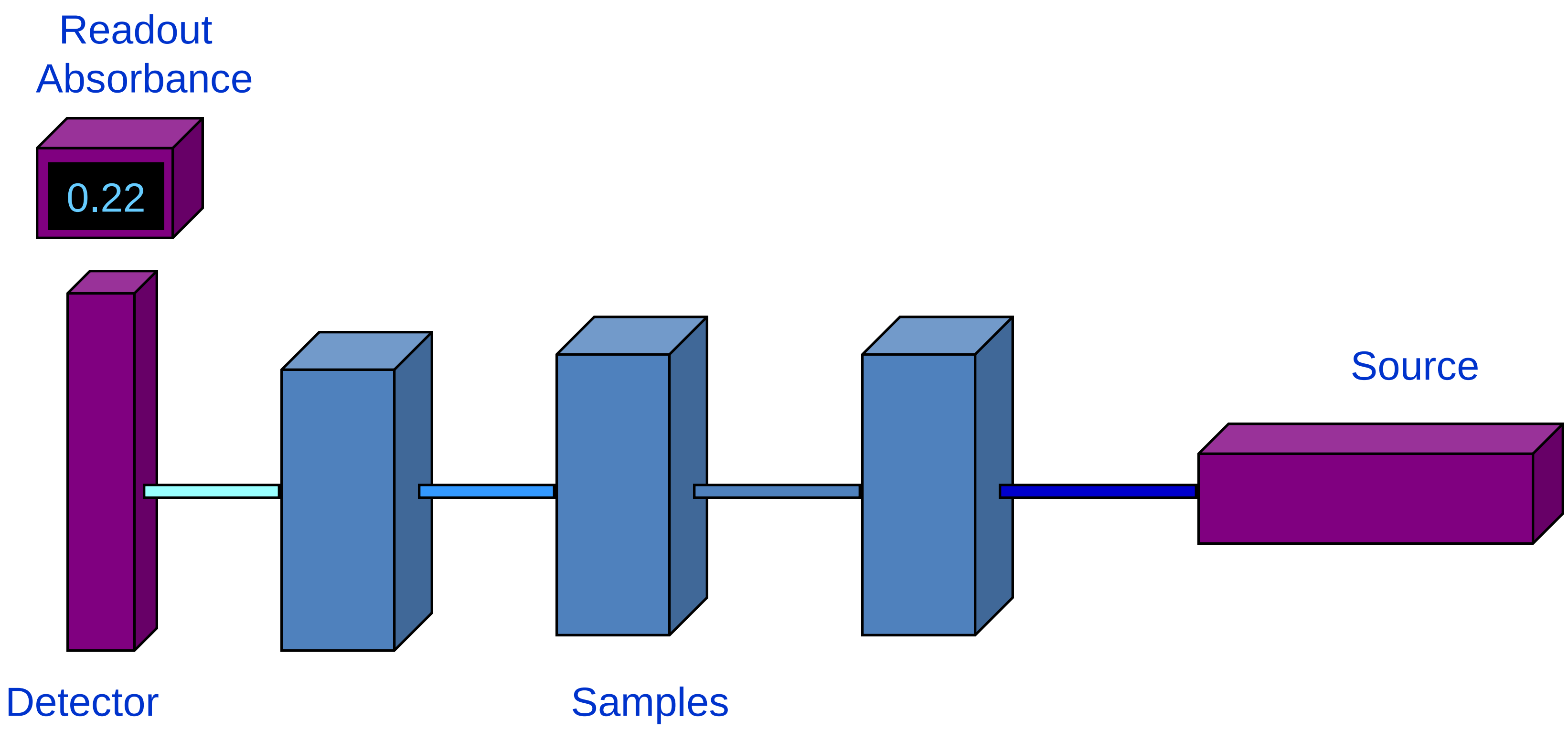
Beer's Law $A = a\underline{b}c$

Path Length Dependence, b



Beer's Law $A = a\underline{b}c$

Path Length Dependence, b

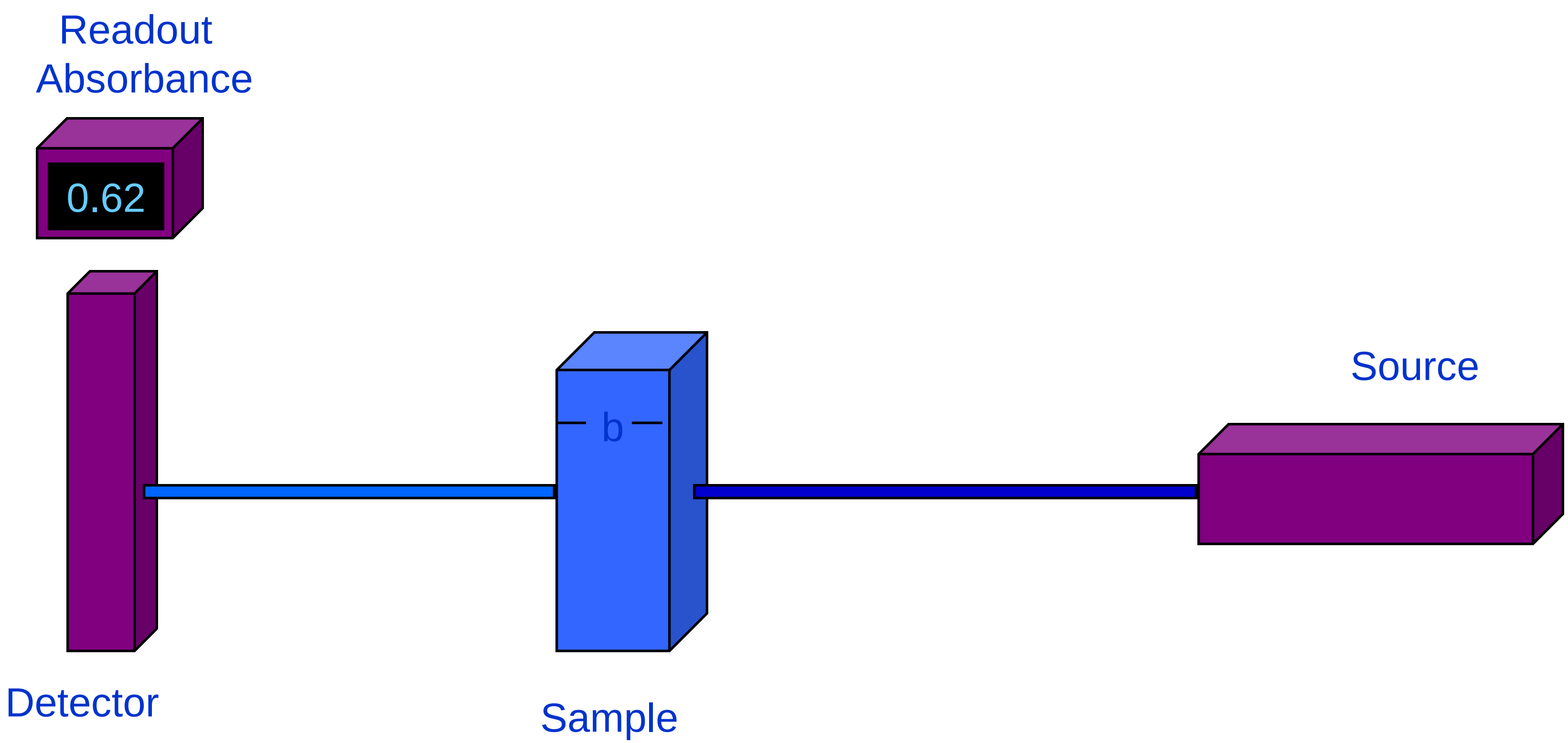


Beer's Law $A = ab\underline{c}$

Concentration Dependence, c

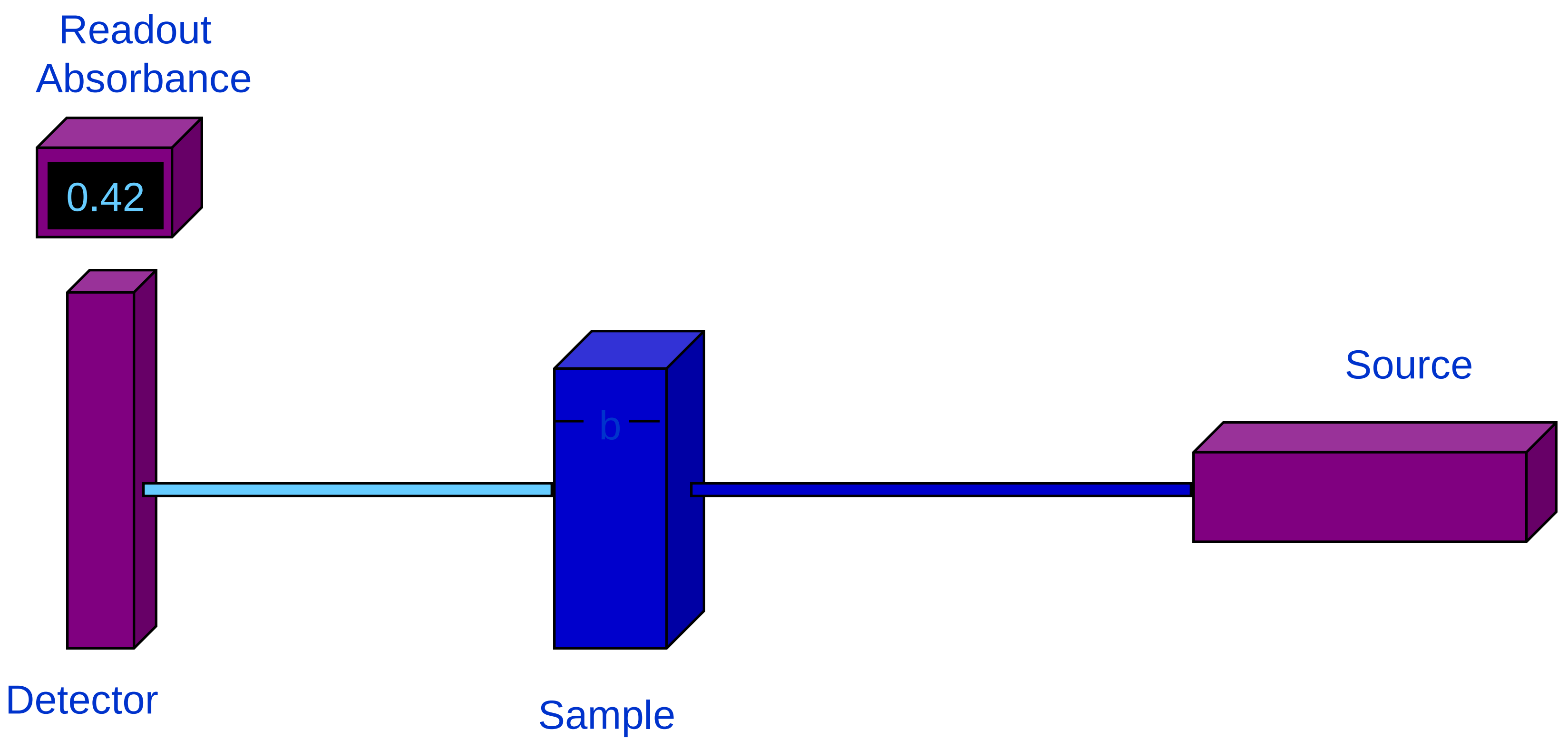
Beer's Law $A = ab\underline{c}$

Concentration Dependence, c



Beer's Law $A = ab\underline{c}$

Concentration Dependence, c

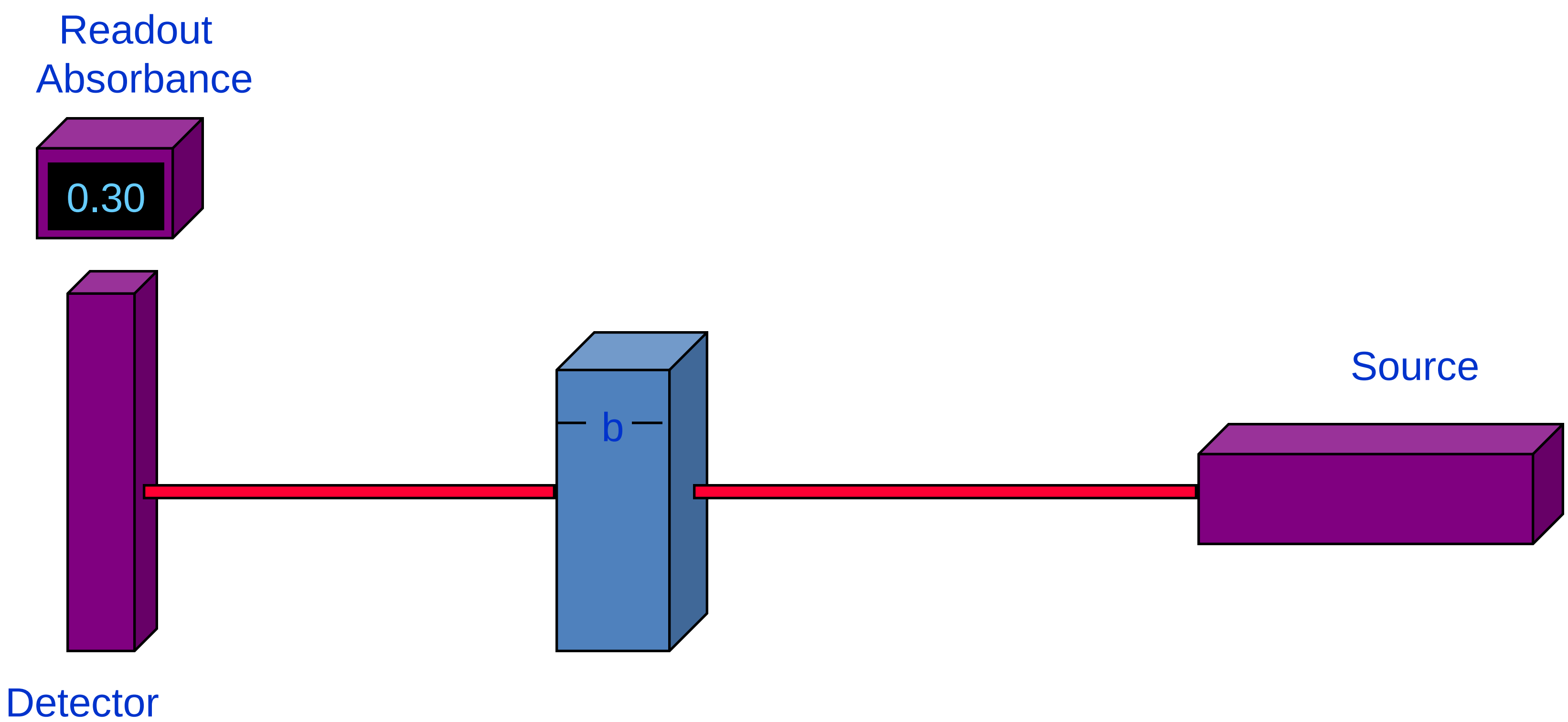


Beer's Law   A = *a*bc

Wavelength Dependence, a

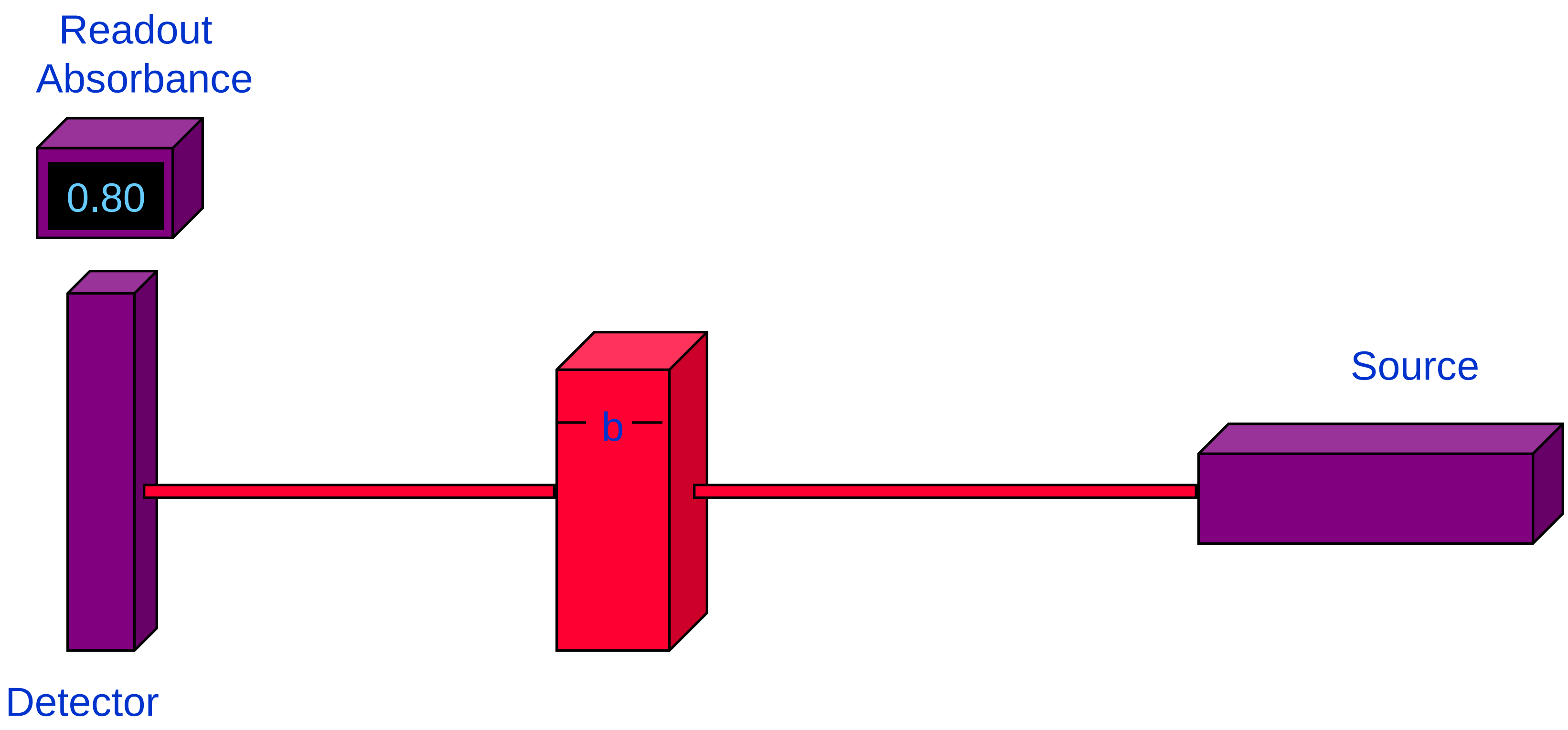
Beer's Law $A = \underline{a}bc$

Wavelength Dependence, a

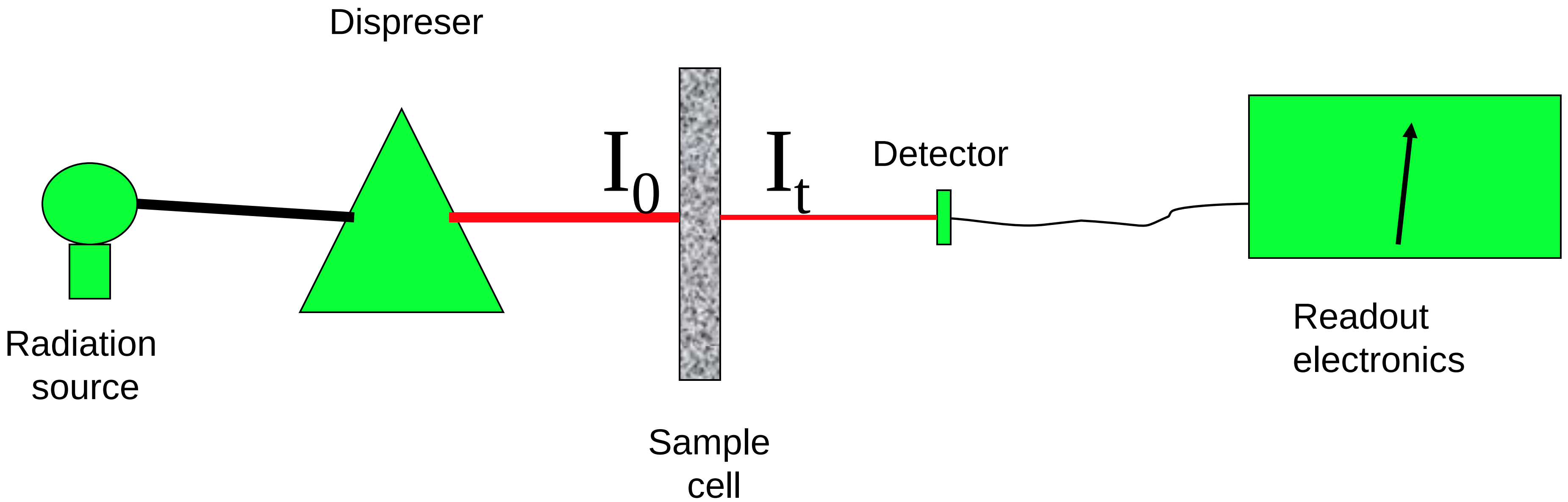


Beer's Law $A = \underline{a}bc$

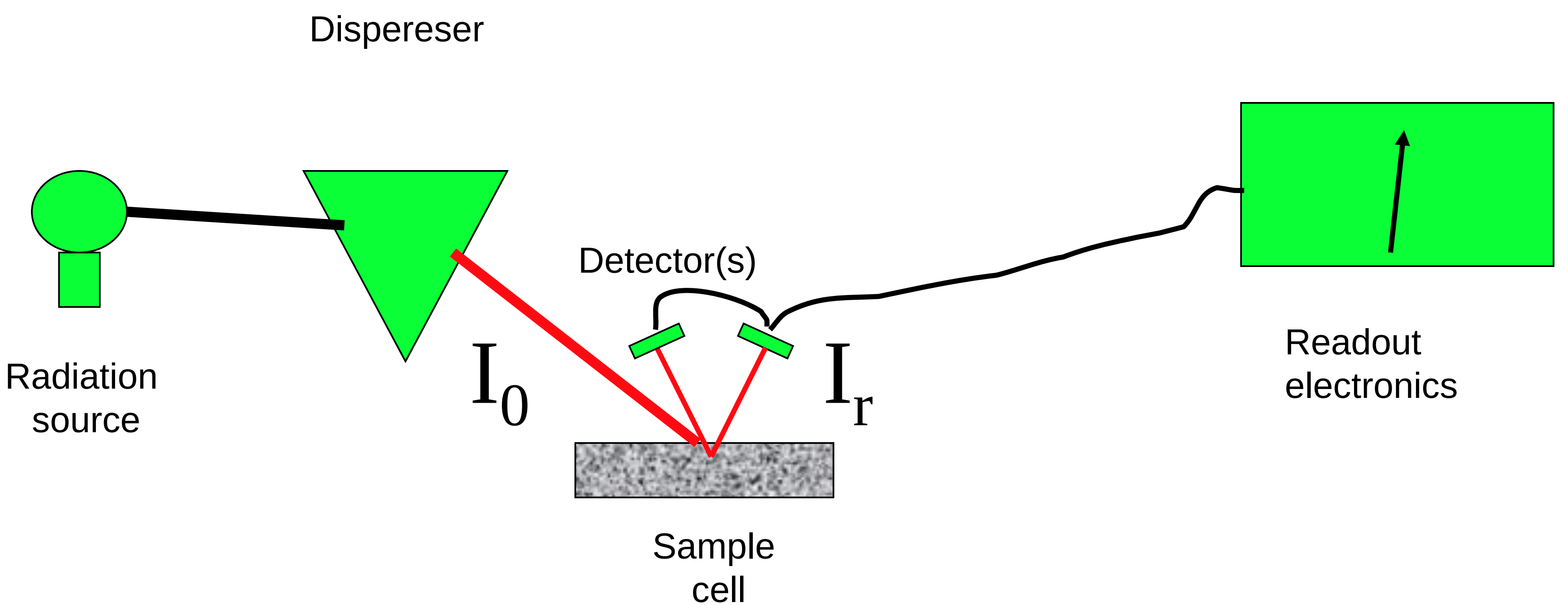
Wavelength Dependence, a



Transmission



Reflection


Dispereser
Detector(s)
Readout
electronics
Radiation
source
I_0
I_r
Sample
cell

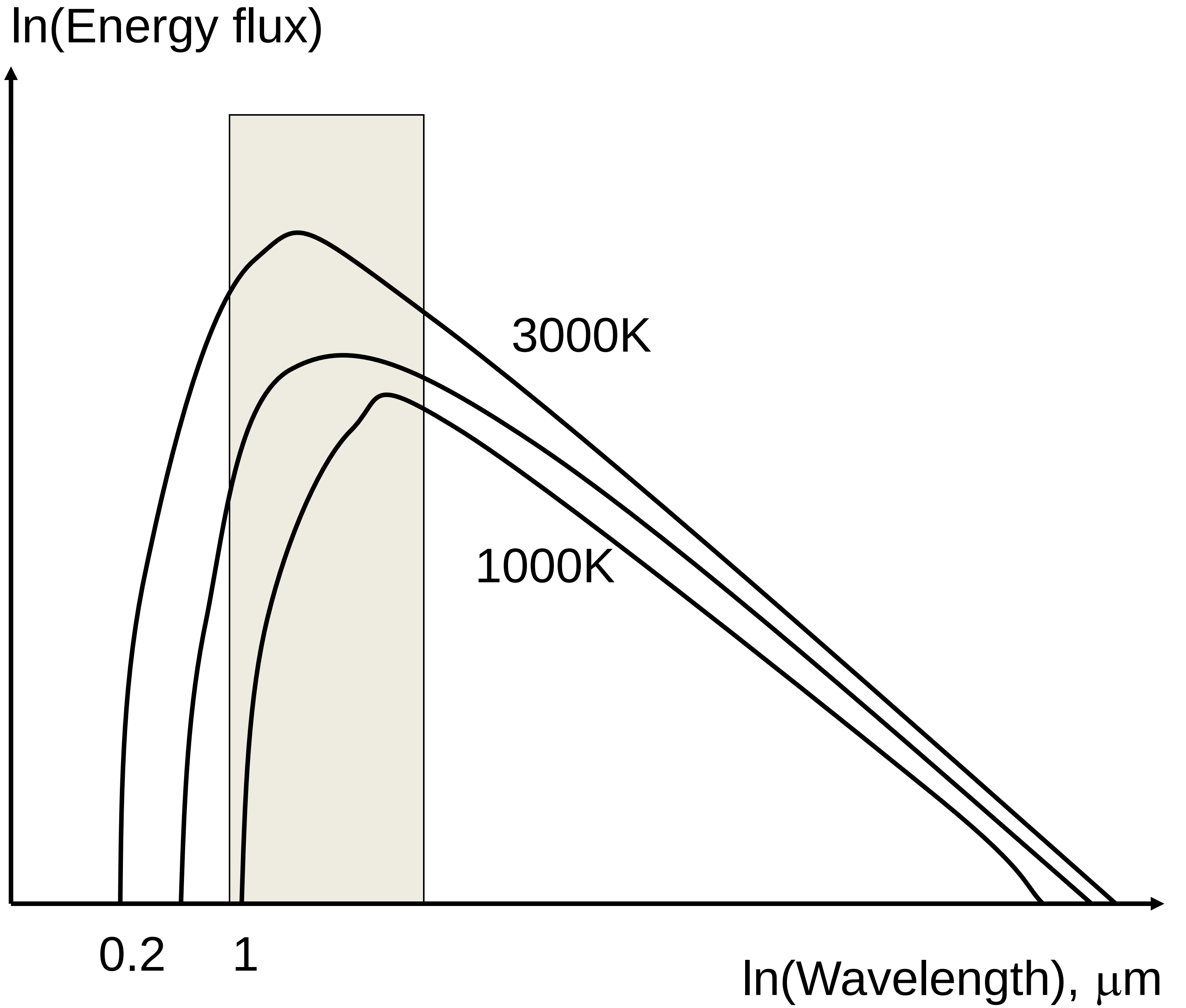
- Spectroscopy?
- Instrumentation
- Modes of measurement

What can be changed?

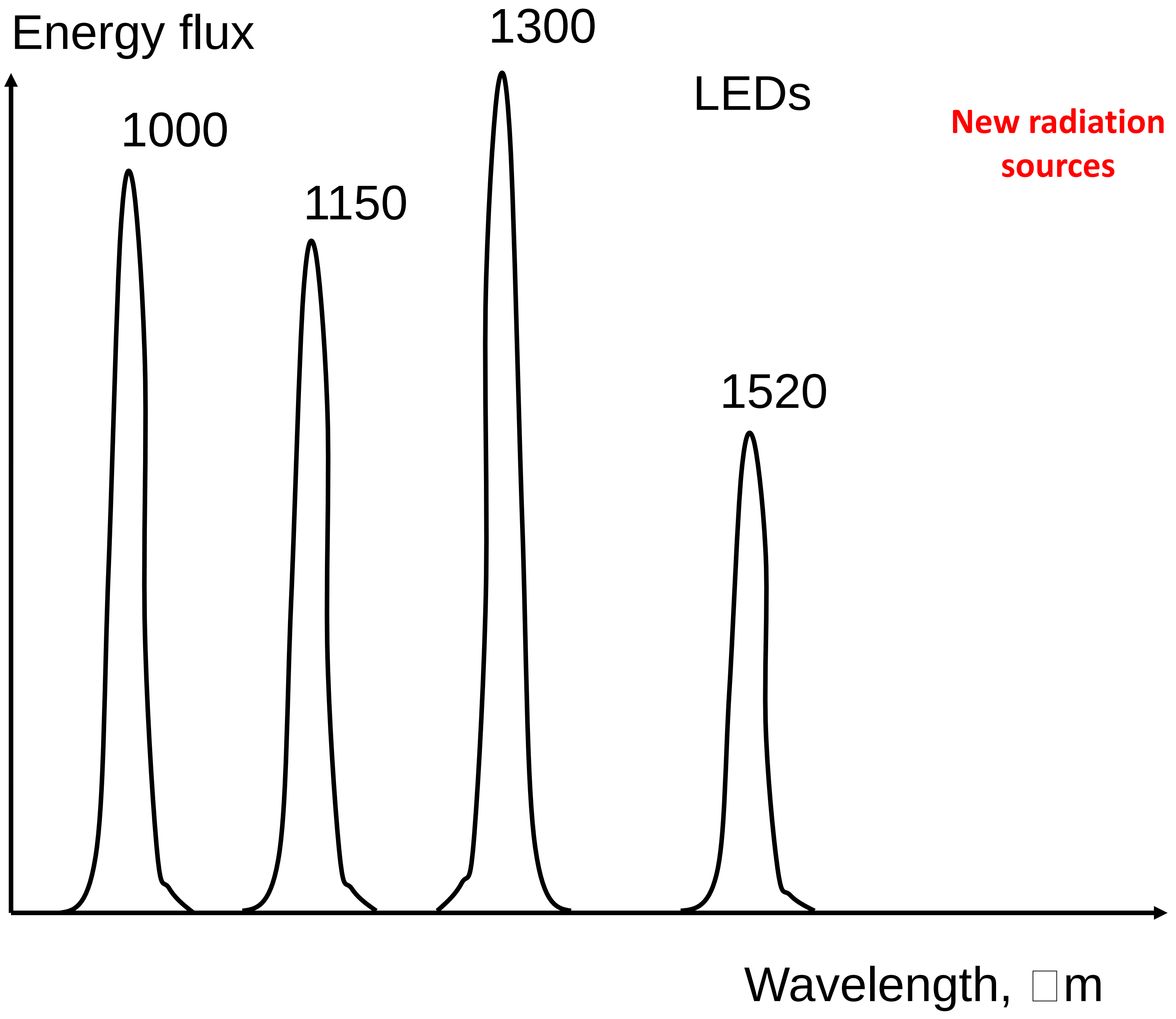
- Radiation source
- Dsipreser
- Sample cell
- Detector

Radiation source

- Tungsten-halogen lamp (Car type)
- Coated tungsten SiC
- Laser(s)
- LEDs
- LED arrays



ln(Energy flux)
3000K
1000K
0.2
1
ln(Wavelength), μm



Energy flux
1300
LEDs
New radiation
sources
1000
1150
1520
Wavelength, □m

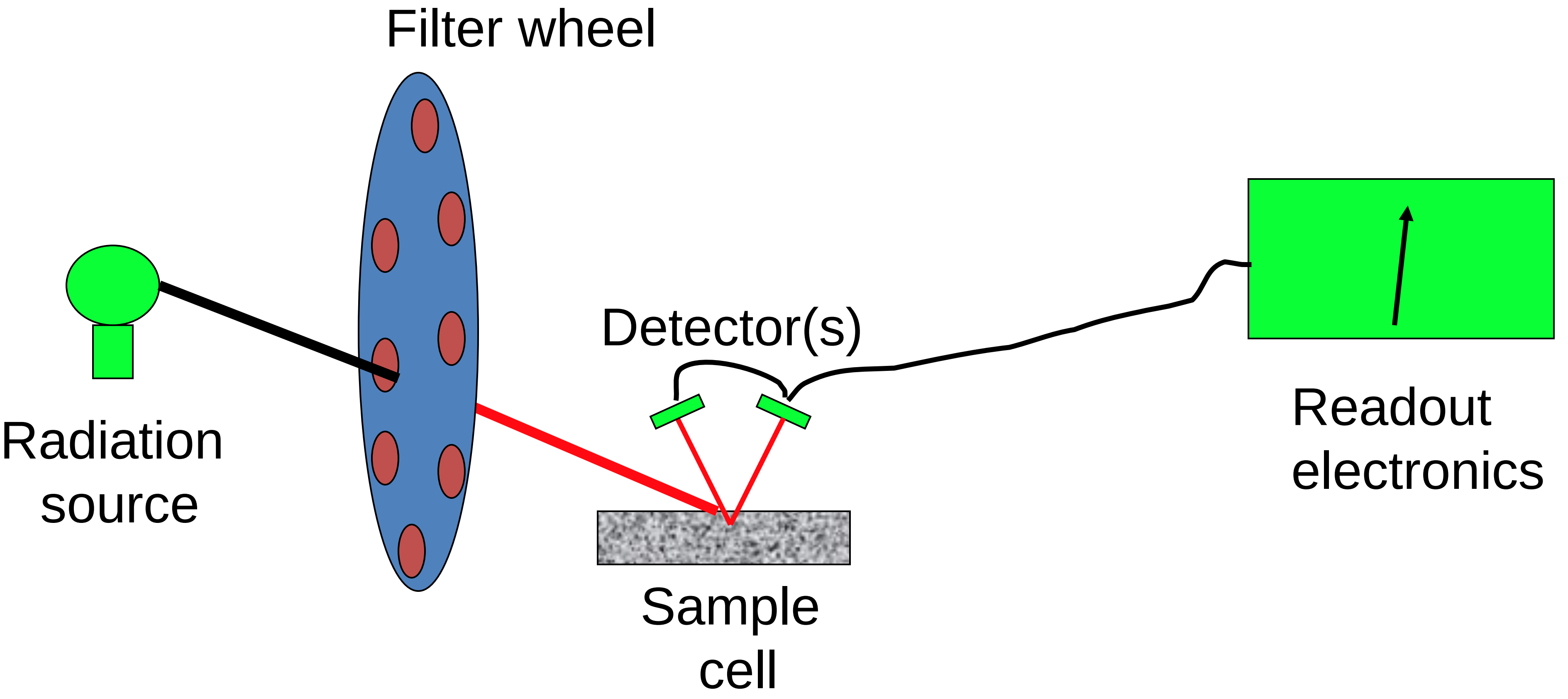
What can be changed?

- Radiation source
- Dispreser
- Sample cell
- Detector

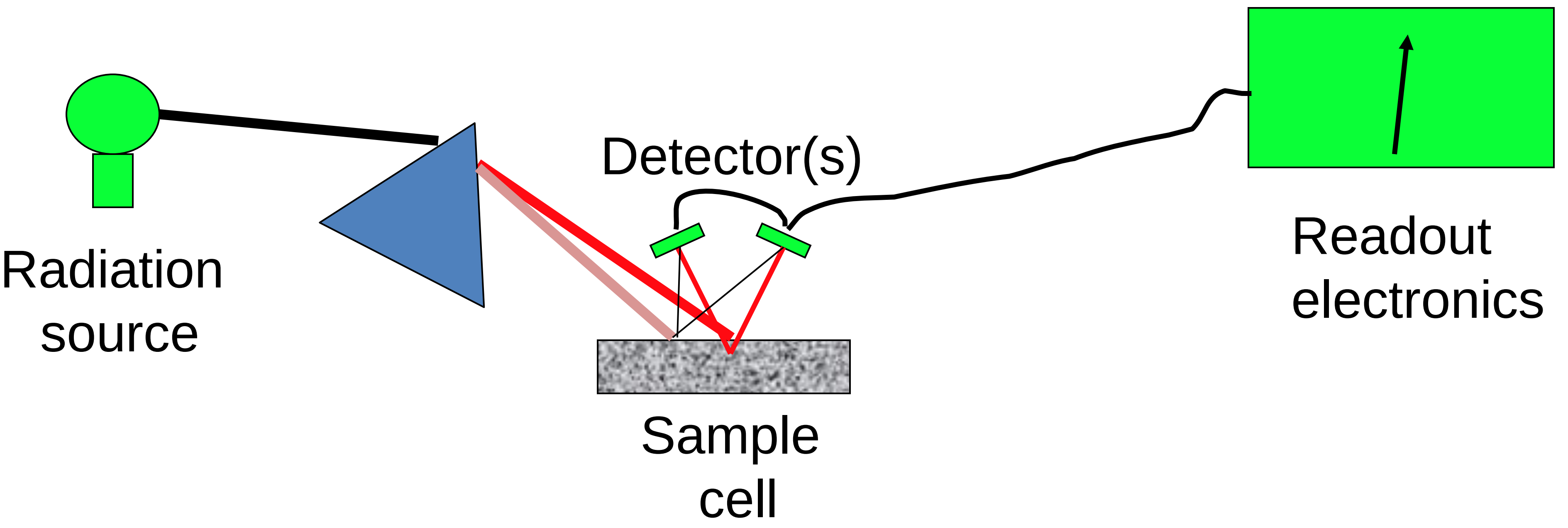
Dispreser

- ”Glass filter”
- Interference filters
- Prism
- Grating
- Interferometer
- Electrooptical

Filter wheel



Prism

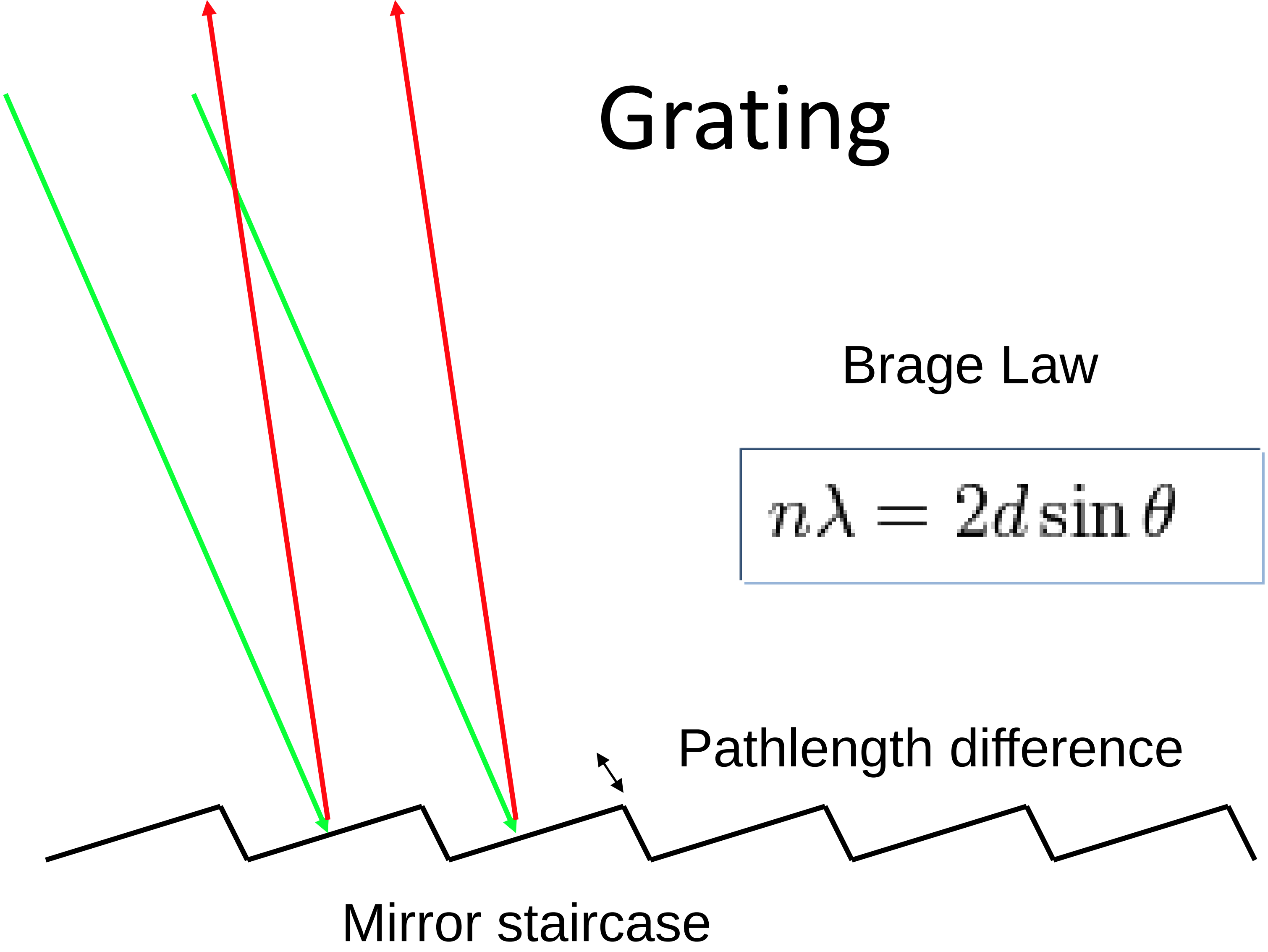


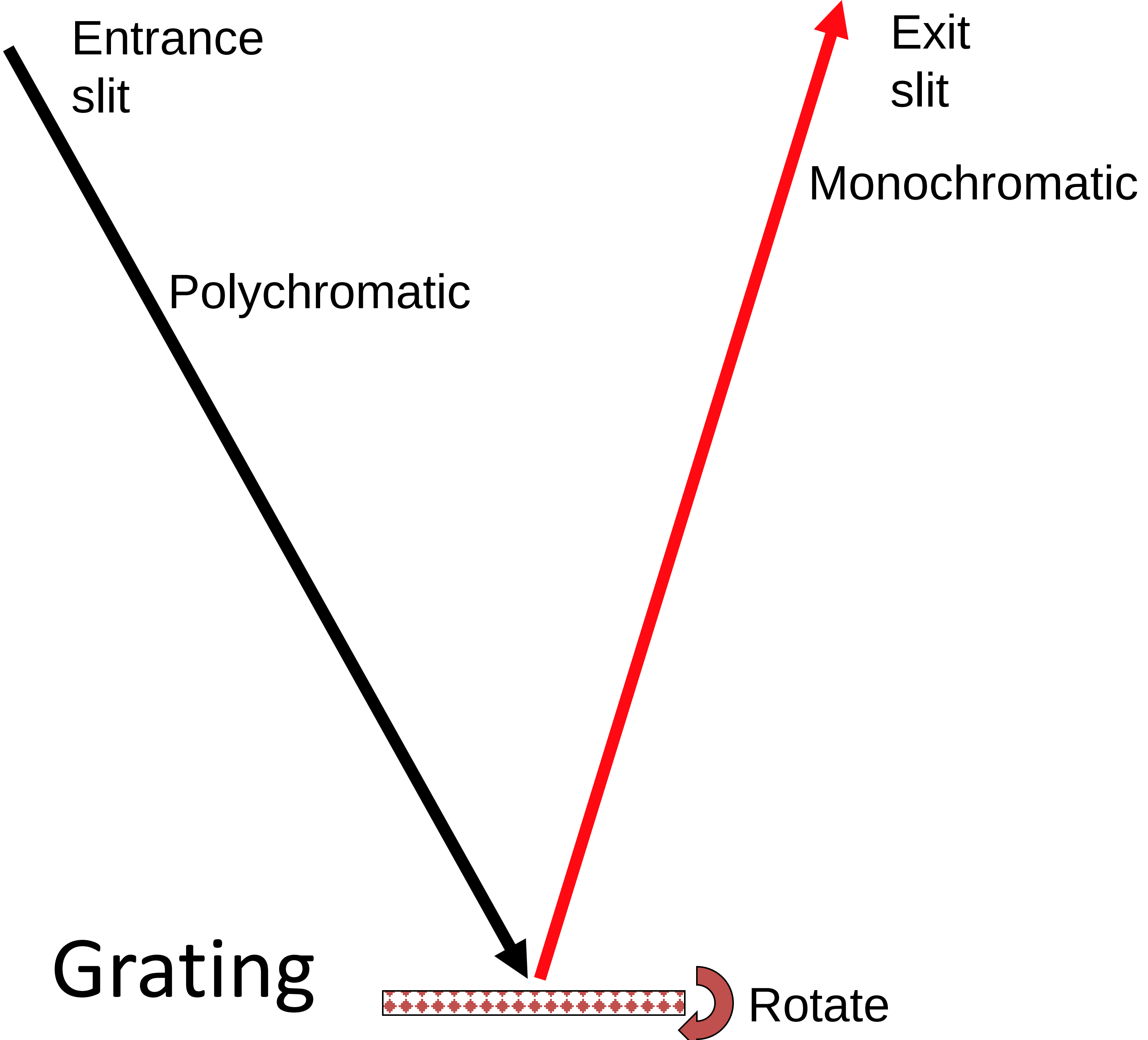
Detector(s)
Radiation source
Readout electronics
Sample cell

Grating

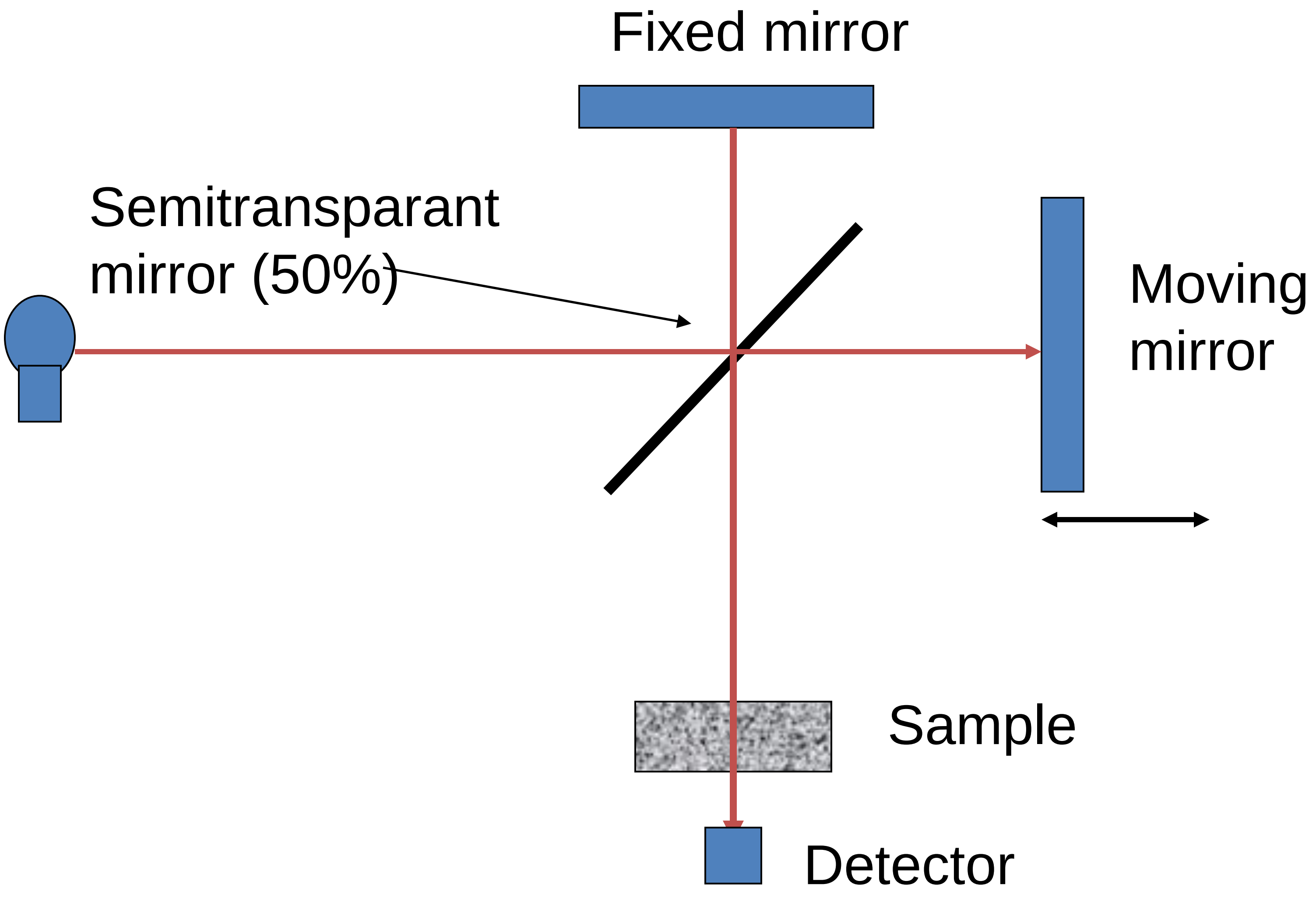
Brage Law

$$n\lambda = 2d\sin\theta$$

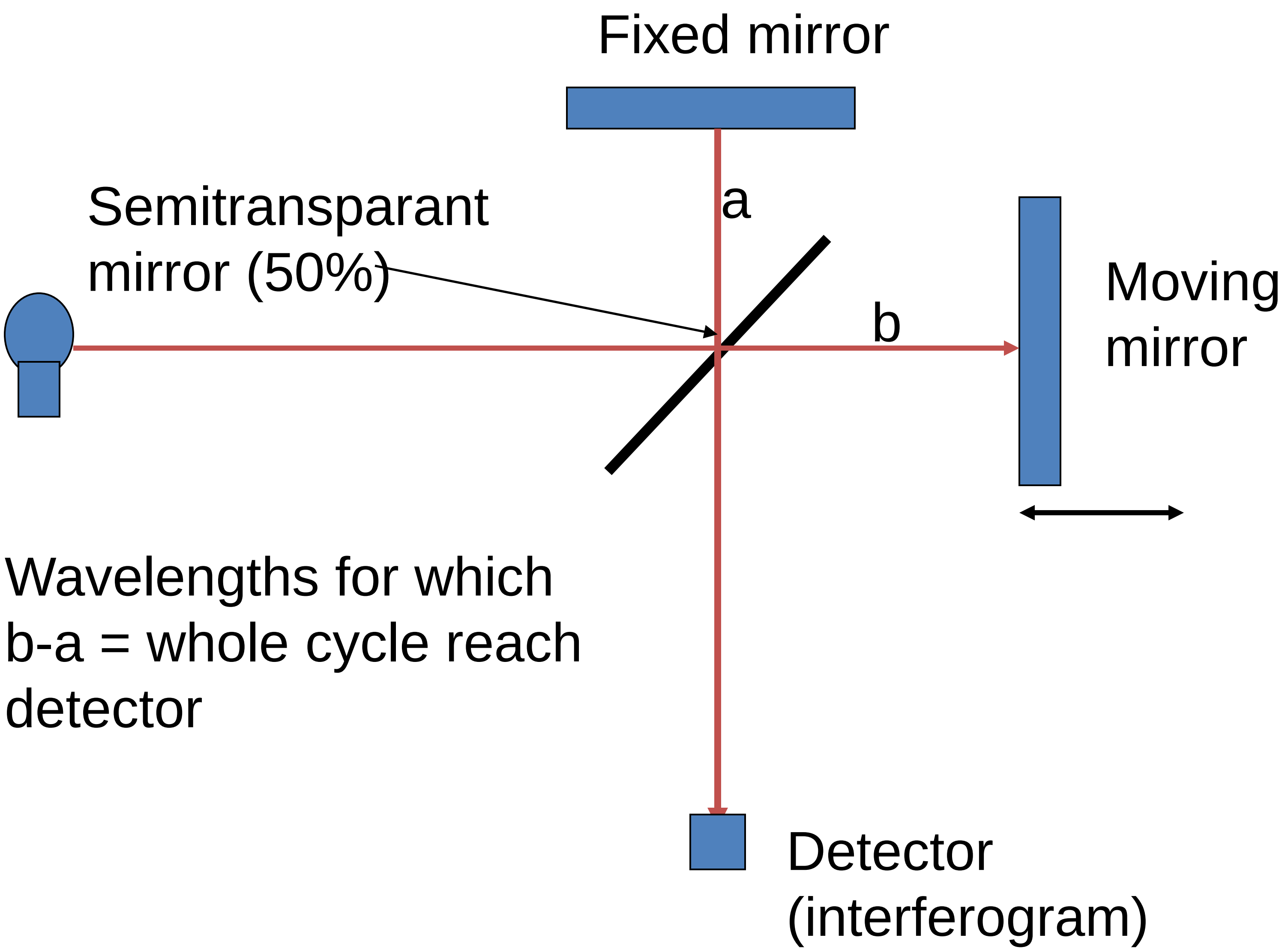



Entrance
slit
Exit
slit
Monochromatic
Polychromatic
Grating
Rotate

Interferometer



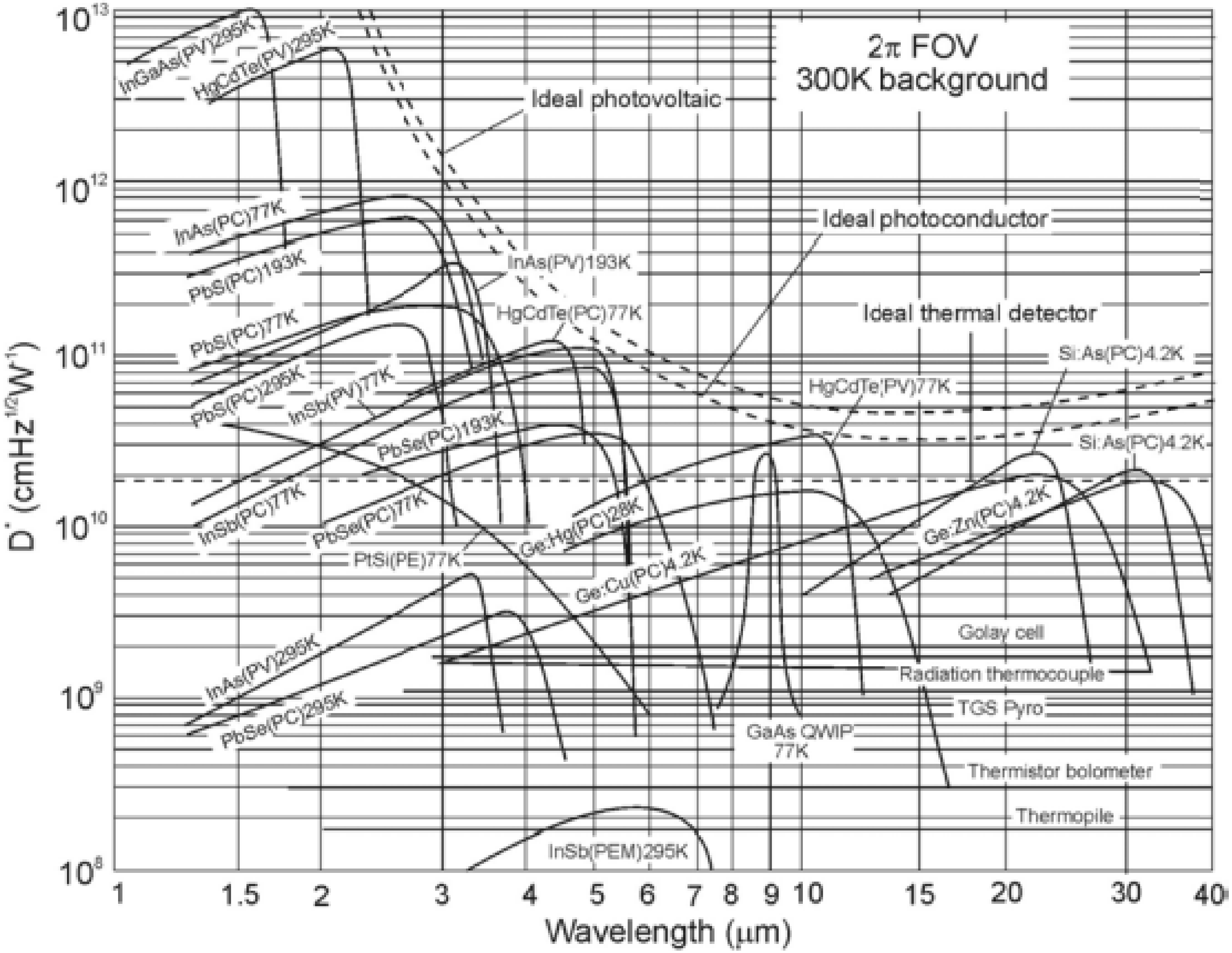
Interferometer



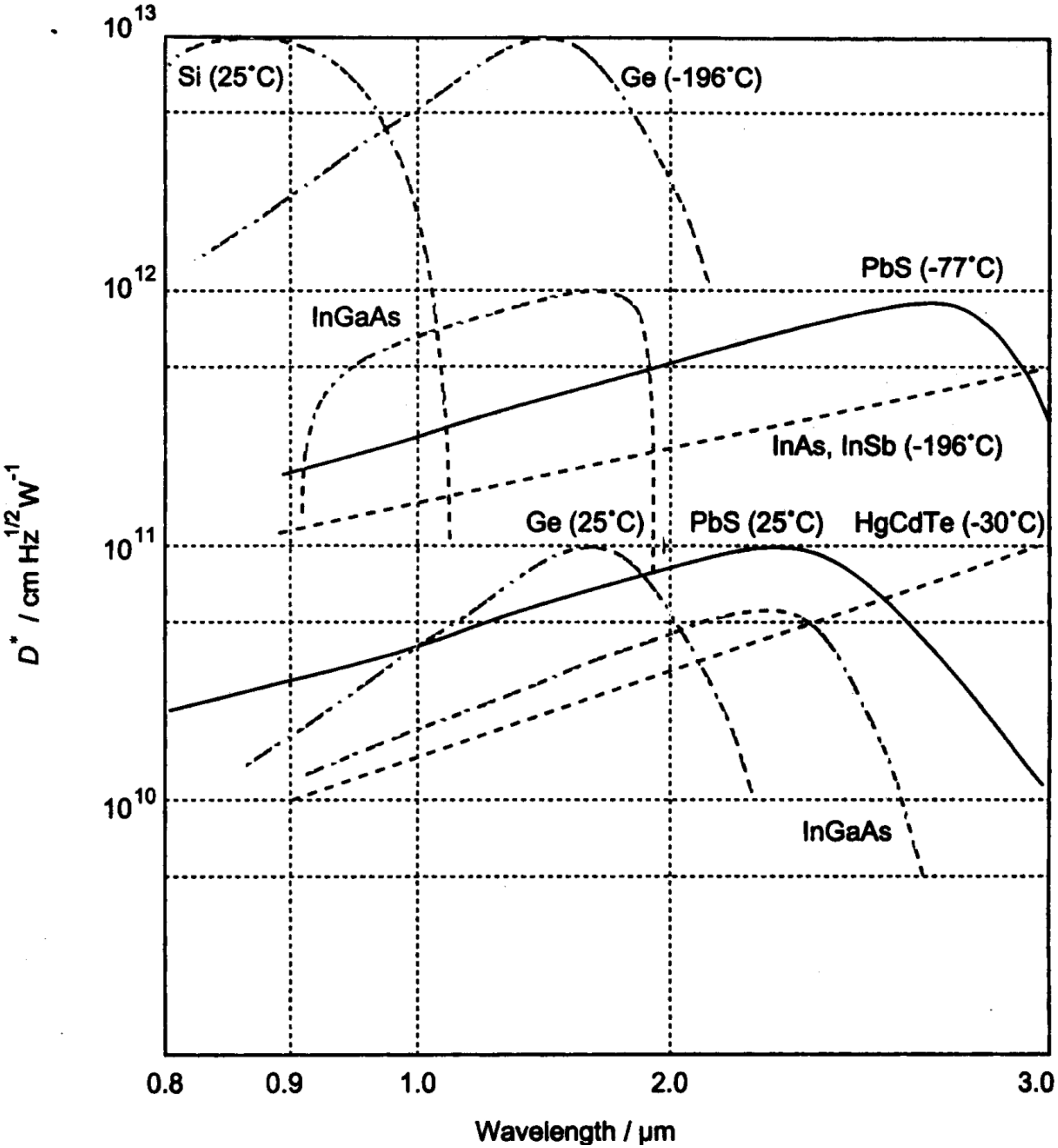
Wavelengths for which b-a = whole cycle reach detector

What can be changed?

- Radiation source
- Monochromator
- Sample cell
- Detector

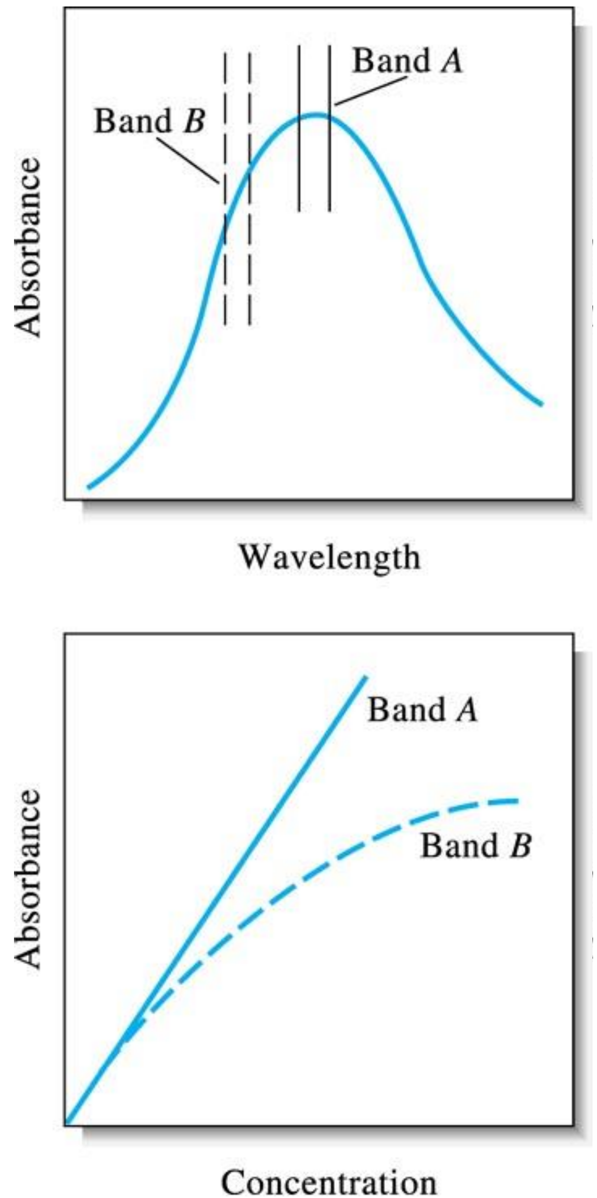


2π FOV
300K background
InGaAs(PV)295K
HgCdTe(PV)295K
Ideal photovoltaic
InAs(PC)77K
PbS(PC)193K
InAs(PV)193K
Ideal photoconductor
HgCdTe(PC)77K
Ideal thermal detector
PbS(PC)77K
Si:As(PC)4.2K
PbS(PC)295K
InSb(PV)77K
HgCdTe(PV)77K
PbSe(PC)193K
Si:As(PC)4.2K
InSb(PC)77K
PbSe(PC)77K
Ge:Hg(PC)28K
Ge:Zn(PC)4.2K
PtSi(PE)77K
Ge:Cu(PC)4.2K
Golay cell
InAs(PV)295K
Radiation thermocouple
TGS Pyro
PbSe(PC)295K
GaAs QWIP
77K
Thermistor bolometer
Thermopile
InSb(PEM)295K
D* (cmHz1/2W-1)
Wavelength (μm)

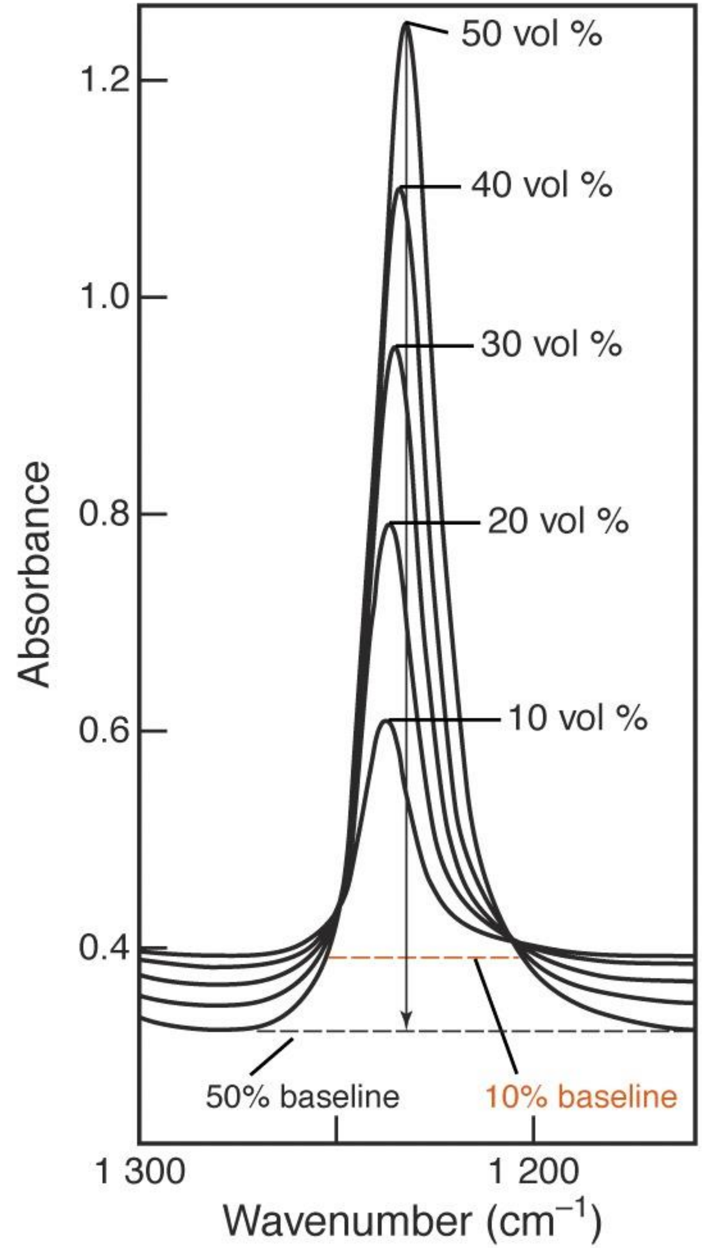


10^{13}
10^{12}
10^{11}
10^{10}
Si (25°C)
Ge (-196°C)
PbS (-77°C)
InGaAs
InAs, InSb (-196°C)
Ge (25°C)
PbS (25°C)
HgCdTe (-30°C)
InGaAs
D^* / cm $Hz^{1/2}$ W^{-1}
0.8
0.9
1.0
2.0
3.0
Wavelength / μm

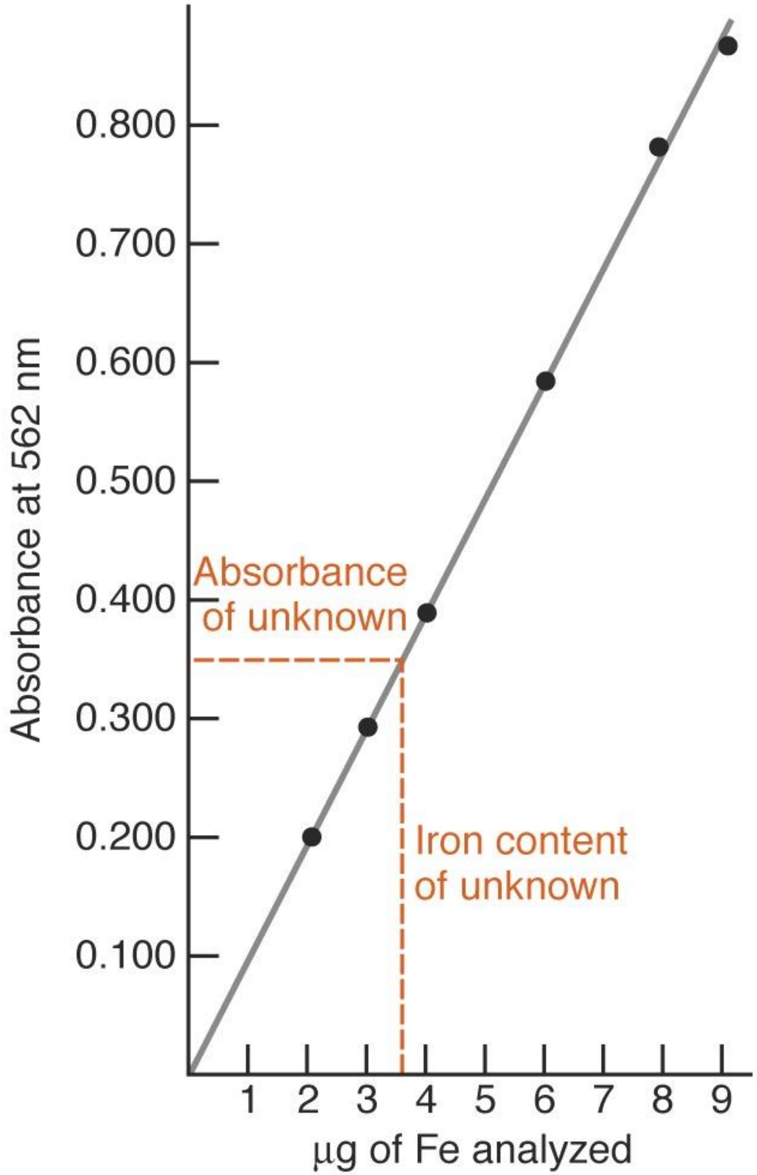
Quantitative Approach at Absorbance region

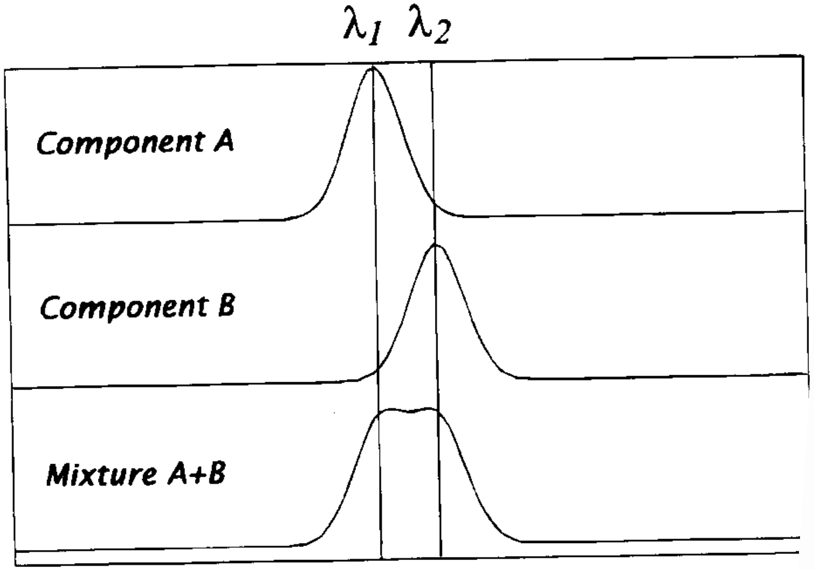


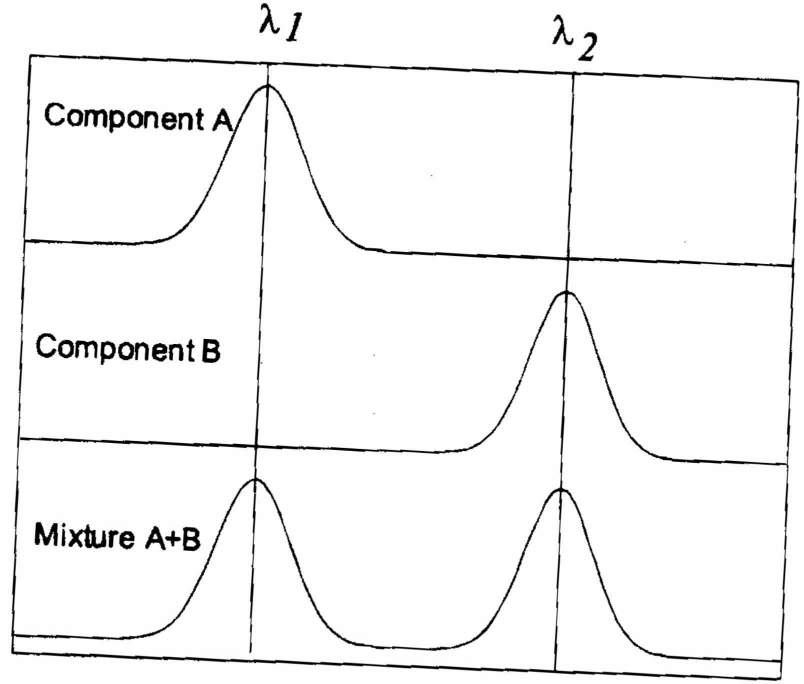
Position to account for the EM-Matter Interaction


50 vol %
40 vol %
30 vol %
20 vol %
10 vol %
1.2
1.0
0.8
0.6
0.4
Absorbance
50% baseline
10% baseline
1 300
1 200
Wavenumber (cm⁻¹)

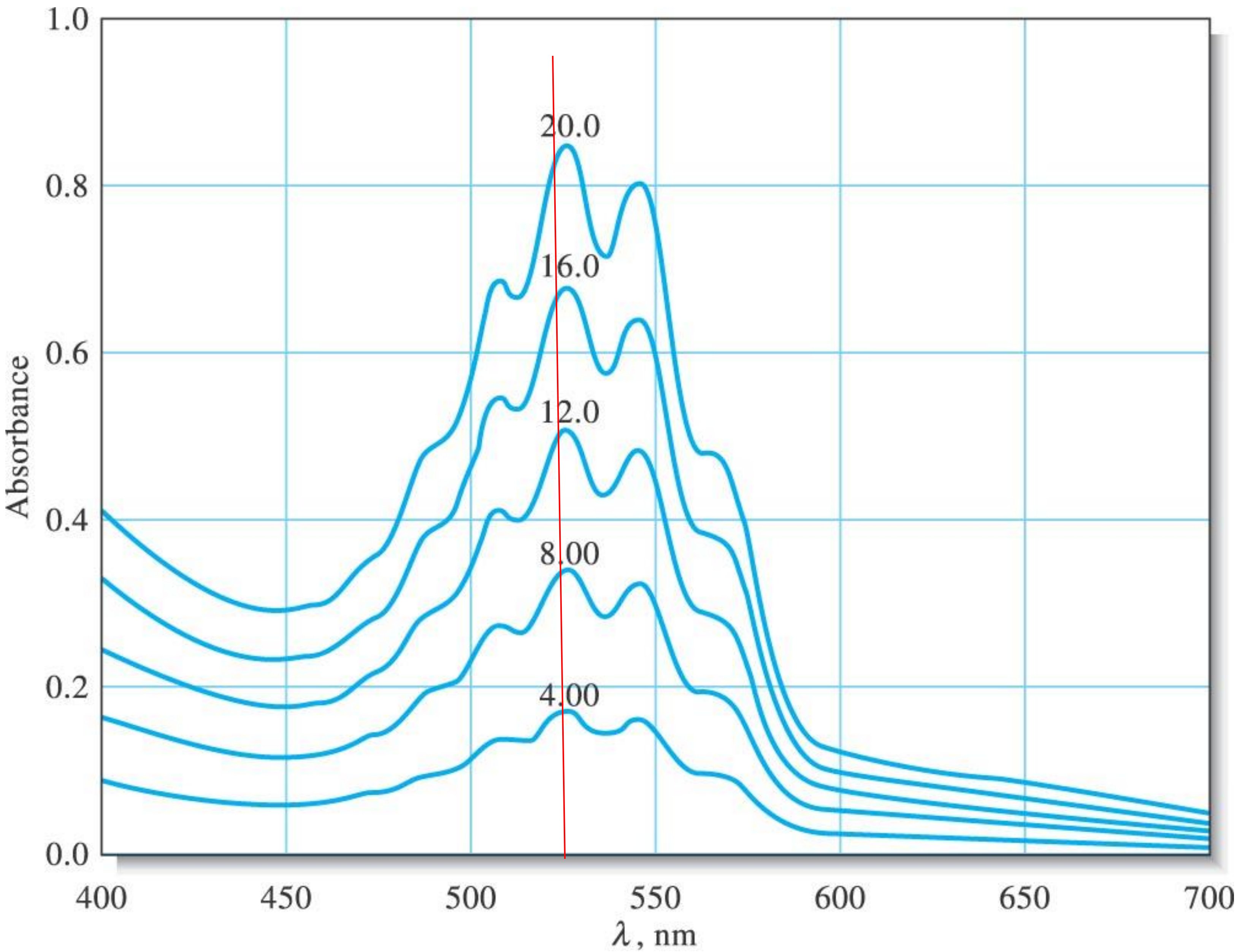
Calibration curve of absorption







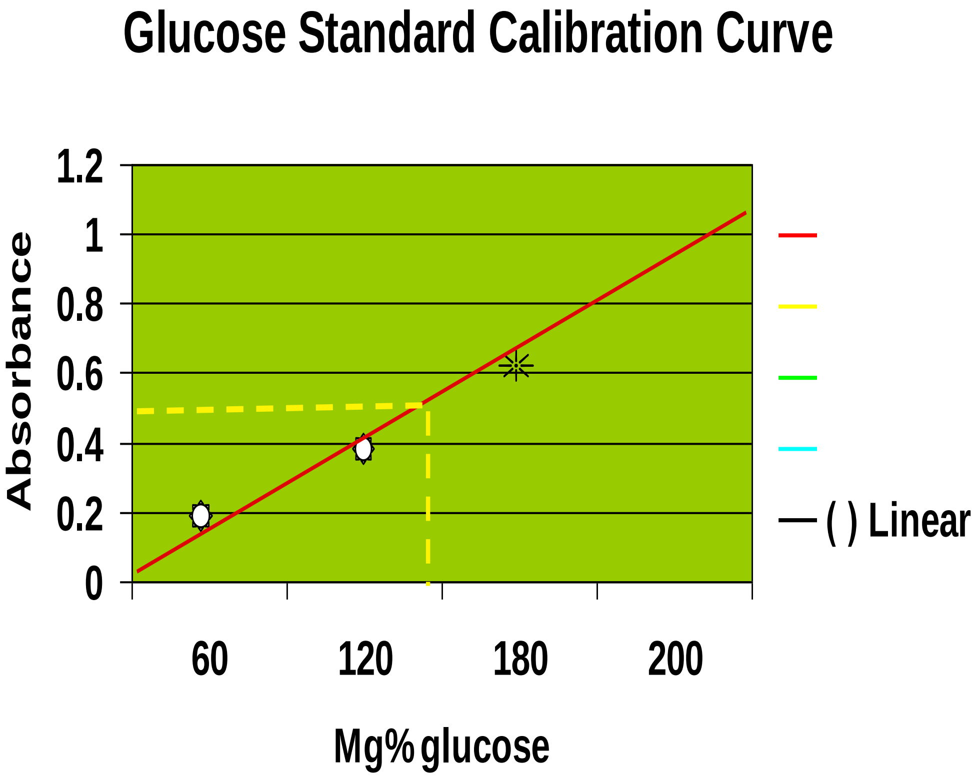
Peaks Orientation: Super - position or absorption features of two different component: A LINEAR MIXTUR



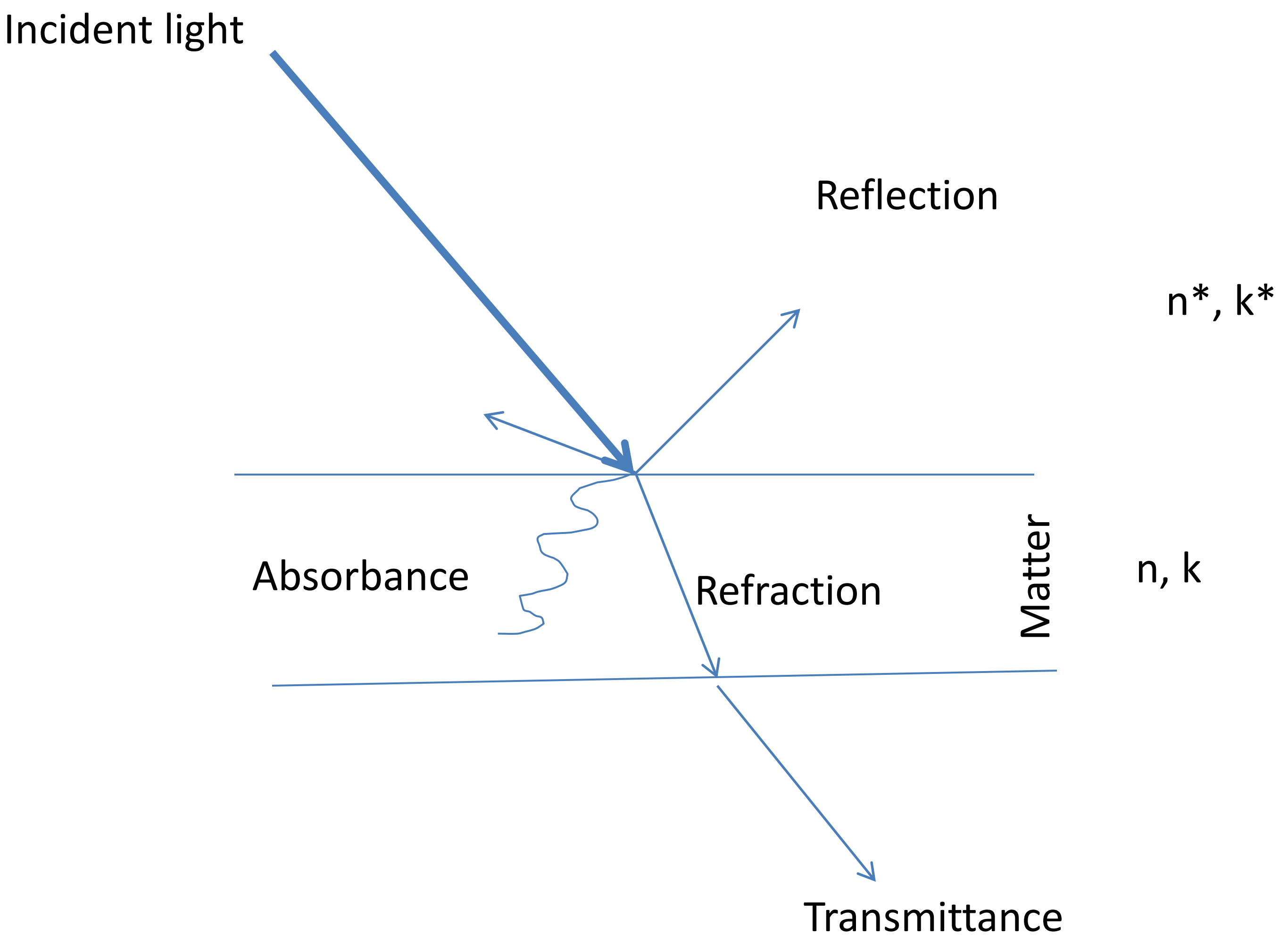
1.0
0.8
0.6
0.4
0.2
0.0
Absorbance
20.0
16.0
12.0
8.00
4.00
400
450
500
550
600
650
700
λ, nm

Calibration Curve at 525nm

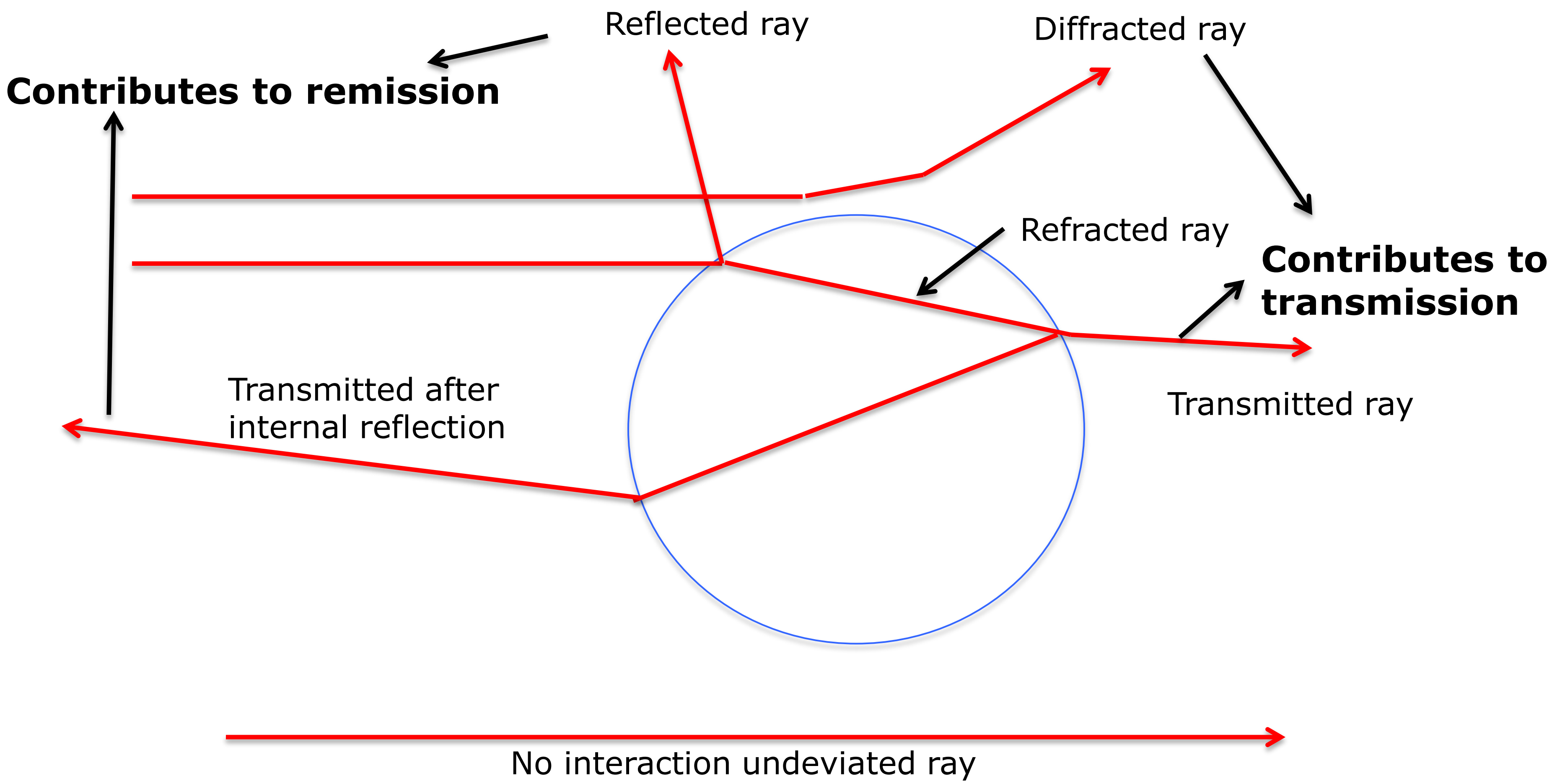
Glucose Std. Concn.	Absorbance
60 mg%	0.2
120 mg%	0.4
U	0.5
180 mg%	0.6



Refraction Theory

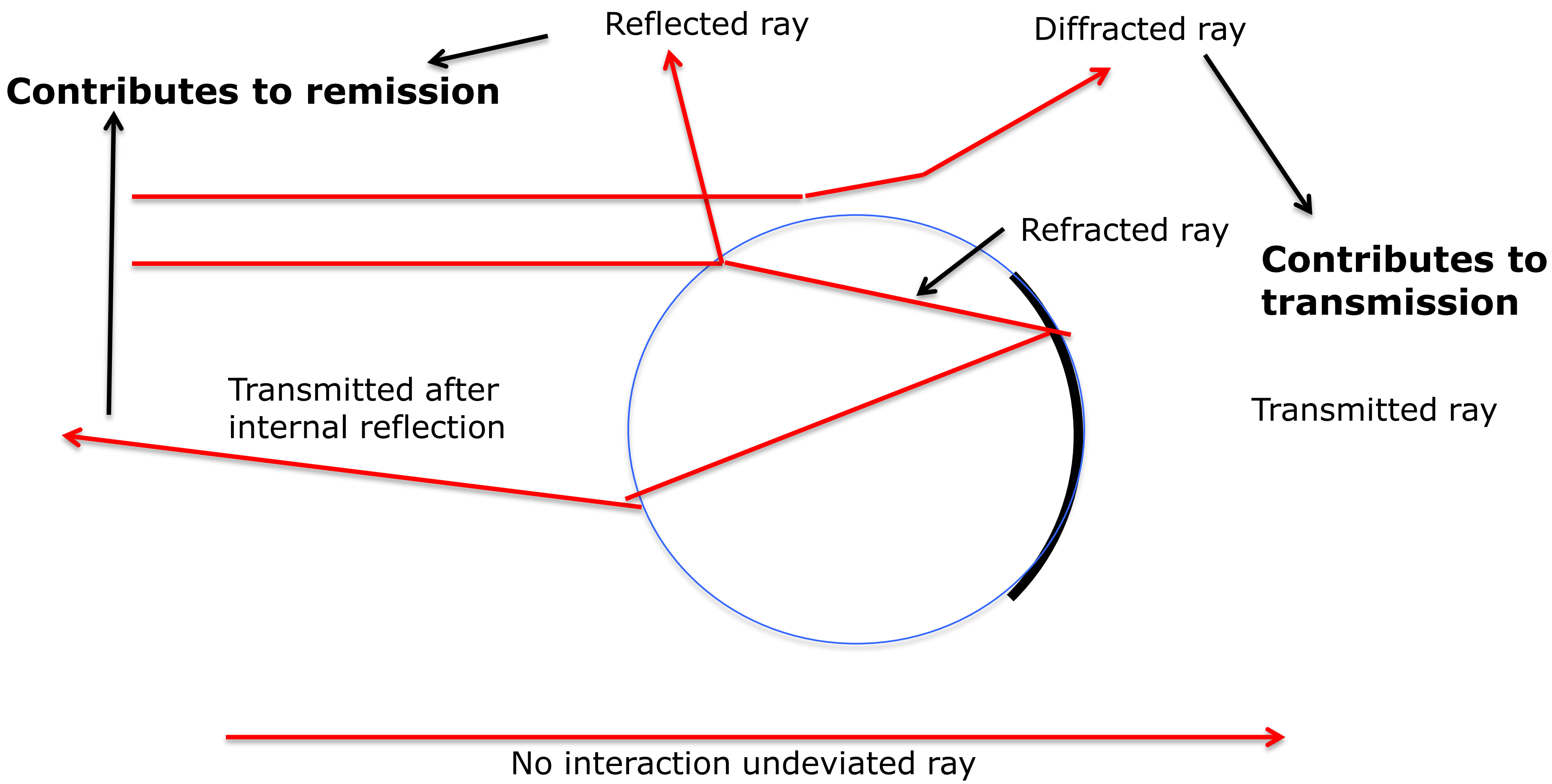


Particle interaction with radiation



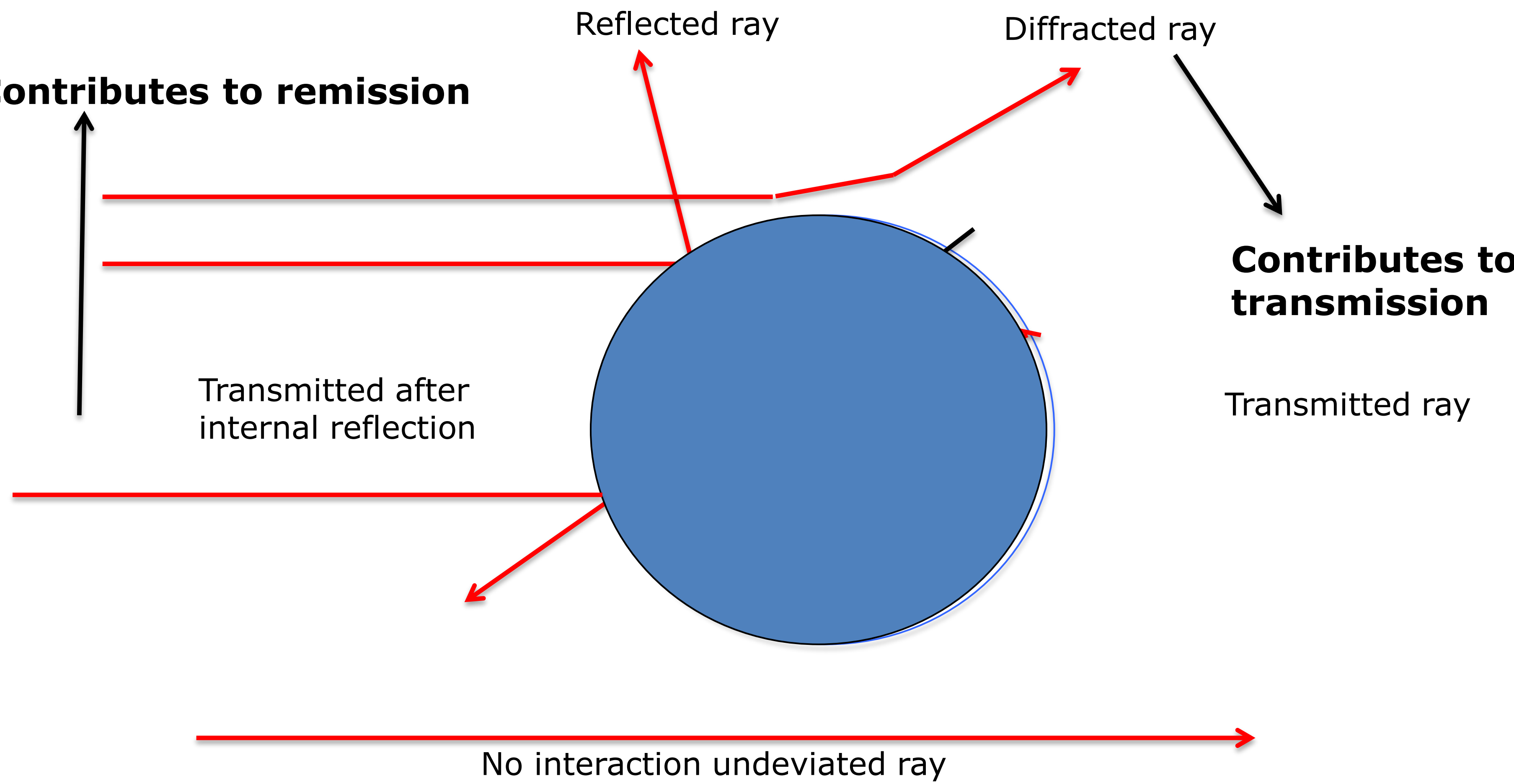
Transparent

Particle interaction with radiation



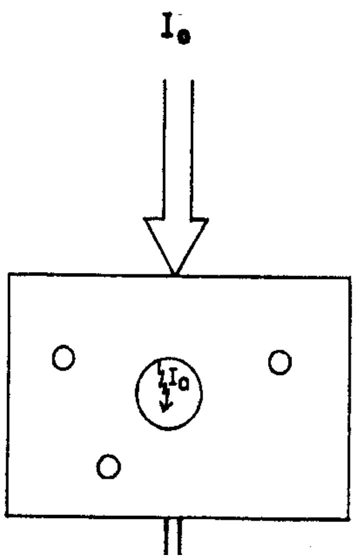
Semi Transparent

Particle interaction with radiation

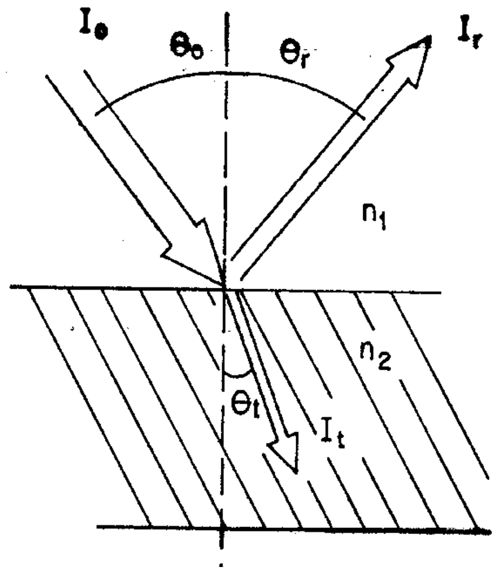


Opaque

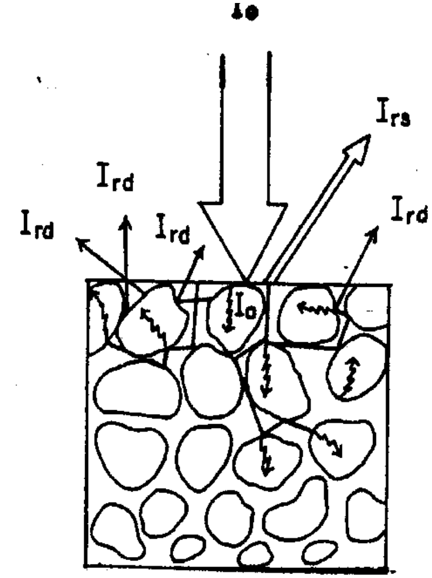
Transmittance



Refraction + Reflectance



Diffuse Reflectance



Beer lambert law

$$I = Io\ e^{-kx}$$

Fresnel law

$$R = [(n - 1)2 + K2] / [(n + 1)2 + K2$$

Hapke theory

$$r_\lambda = [[(w'/4\pi) \text{ x } (\mu / \mu + \mu_o)] \text{ x } [(1+B_g)P_g + H \mu H \mu_o^{-1}]$$

complex index of refraction (m)

$$m = n - jK$$

n is the real part of the index, $j = (-1)^{1/2}$ and K is the imaginary part of the index of refraction (extinction coefficient)

$$k = 4 \pi K/\lambda$$

$$\lambda K / 4 \pi = K$$

Fresnel Equation

The reflection of light, R, normally incident onto a plane surface is described by the Fresnel equation:

$$R = [(n - 1)^2 + K^2] / [(n + 1)^2 + K^2$$

If the real part of the refraction index n is constant then the imagery part k is changing.

In Beer law: concentration is low, the optical path is constant, and the incident light hit at 90o (no scattering nor reflection) → n is minimal and constant while k is correlated to the material interact with the radiation.

When photons enter an absorbing Beer medium, then :

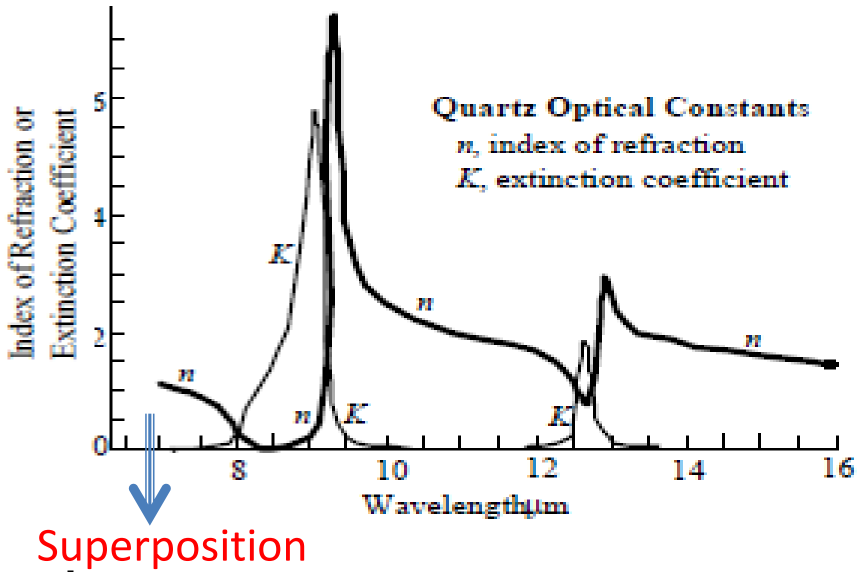
$$I = Io\ e^{-kb}$$

where I is the observed intensity, Io is the original light intensity, k is an absorption coefficient and b is the distance traveled through the medium.

The absorption (extinction) coefficient is related to the complex index of refraction by the equation:

$$k = 4\,\pi\,K/\lambda$$

Example index of refraction, n, and extinction coefficient, K are shown in quartz.



Index of refraction and extinction coefficient of quartz for the wavelength interval 6-16 mm

Hapke's Theory

Clark (1999) suggests that it is possible to model the reflectance from an exposed rock consisting of several minerals or a single mineral based on Hapke's (1993) equation:

$$r_\lambda = [[(w'/4\pi) \text{ x } (\mu / \mu + \mu_o)] \text{ x } [(1+B_g)P_g + H \mu H \mu_o^{-1}]$$

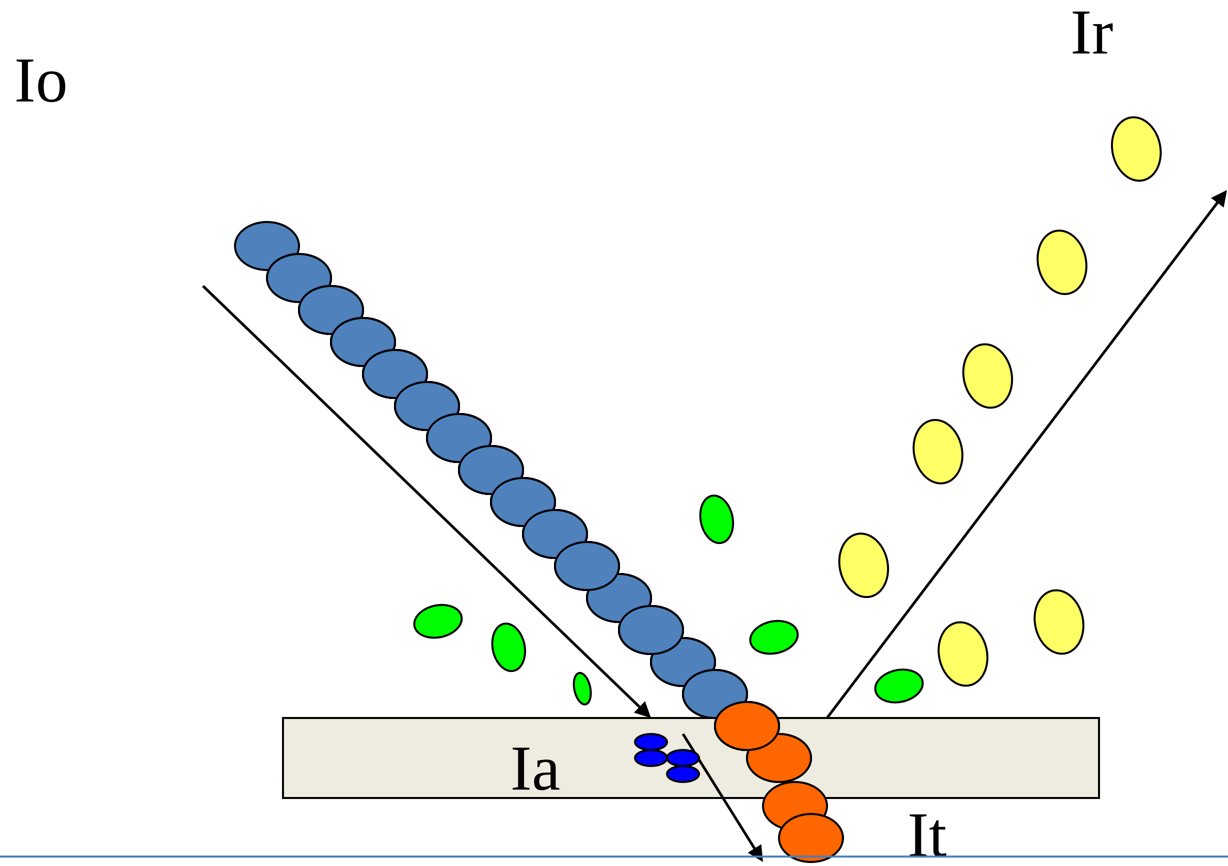
Where r_λ is the reflectance at wavelength λ,
w' is the average single scattering albedo from the rock or mineral of interest,
μ is the cosine of the angle of emitted light,
u_o is the cosine of the angle of incident light onto the rock or mineral of interest,
g is the phase angle,
B_g is a back-scattering function,
P_g is the average single particle phase function, and
H is a function for isotropic scatterers.

Hapke Theory: References to read

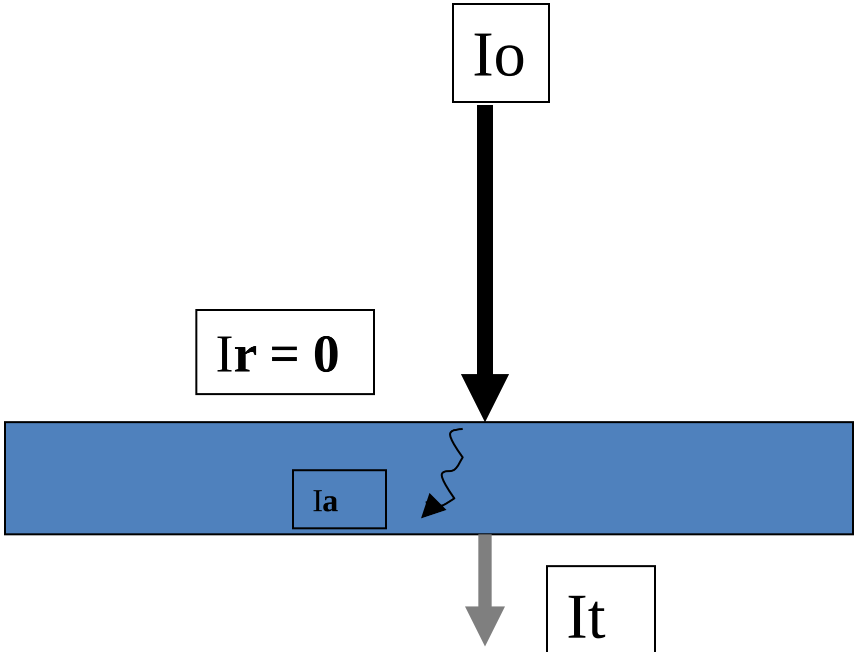
- Hapke B.W. 1981a Bidirectional reflectance spectroscopy I. Theory. *Journal of Geophysical Research* 86:3039-3054.
- Hapke B.W., 1981b Bidirectional reflectance spectroscopy: 2 Experiments and observation. *Journal of Geophysical Research* 86:3055-3060.
- Hapke B.W, 1984 Bidirectional reflectance spectroscopy: Correction for macroscopic roughens. *Icarus* 59:41-59.
- Hapke B.W. 1986, Bidirectional reflectance spectroscopy 4: The extinction coefficient and the opposition effect. *Icarus* 67:264-280
- Hapke B.W. 1993 *Theory of Reflectance and Emittance Spectroscopy*, Cambridge University Press, New-York.

The “particle” theory of light (photons)

$$E = h\,c / \lambda$$



A Leaf Model

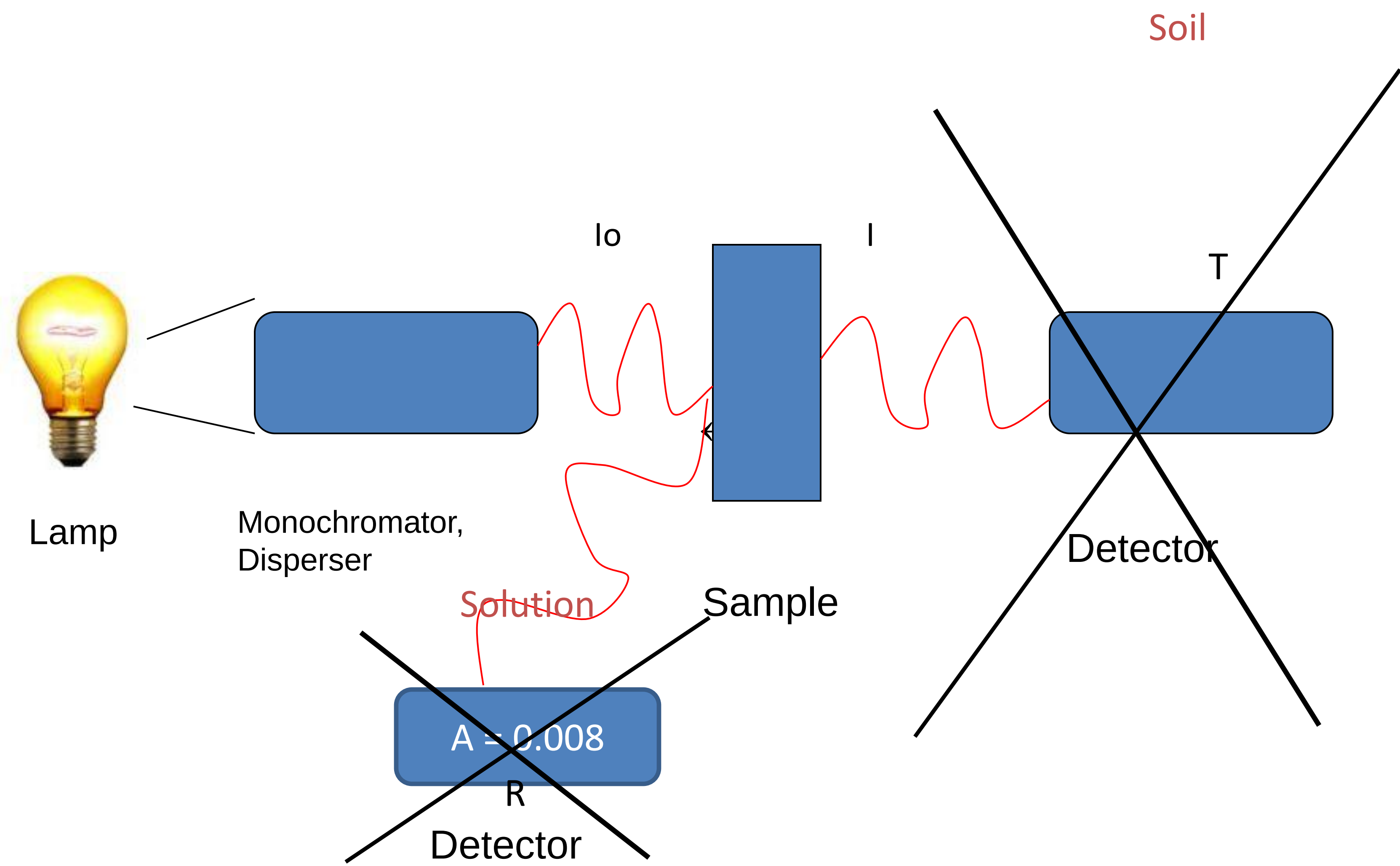


$$1 = \tau + \alpha$$

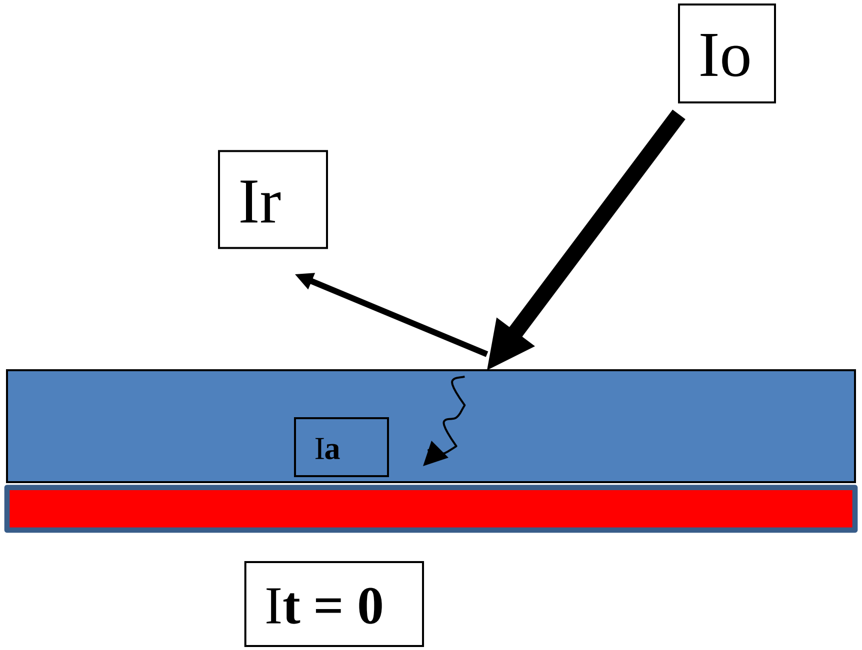
In Non Opaque material

$$\log 1/\tau = \alpha$$

Spectroscopy of Vegetation, Solution and Soil



A Soil Model



No transmittance !!

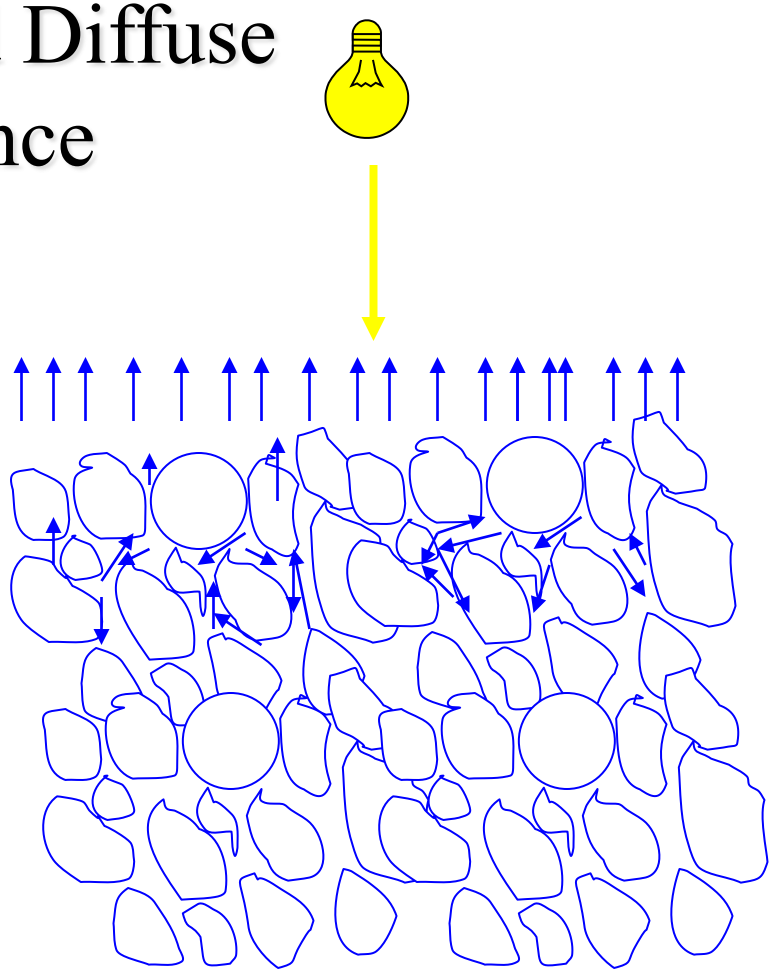
In Opaque material (such as soil)

$$1 = \rho + \alpha$$

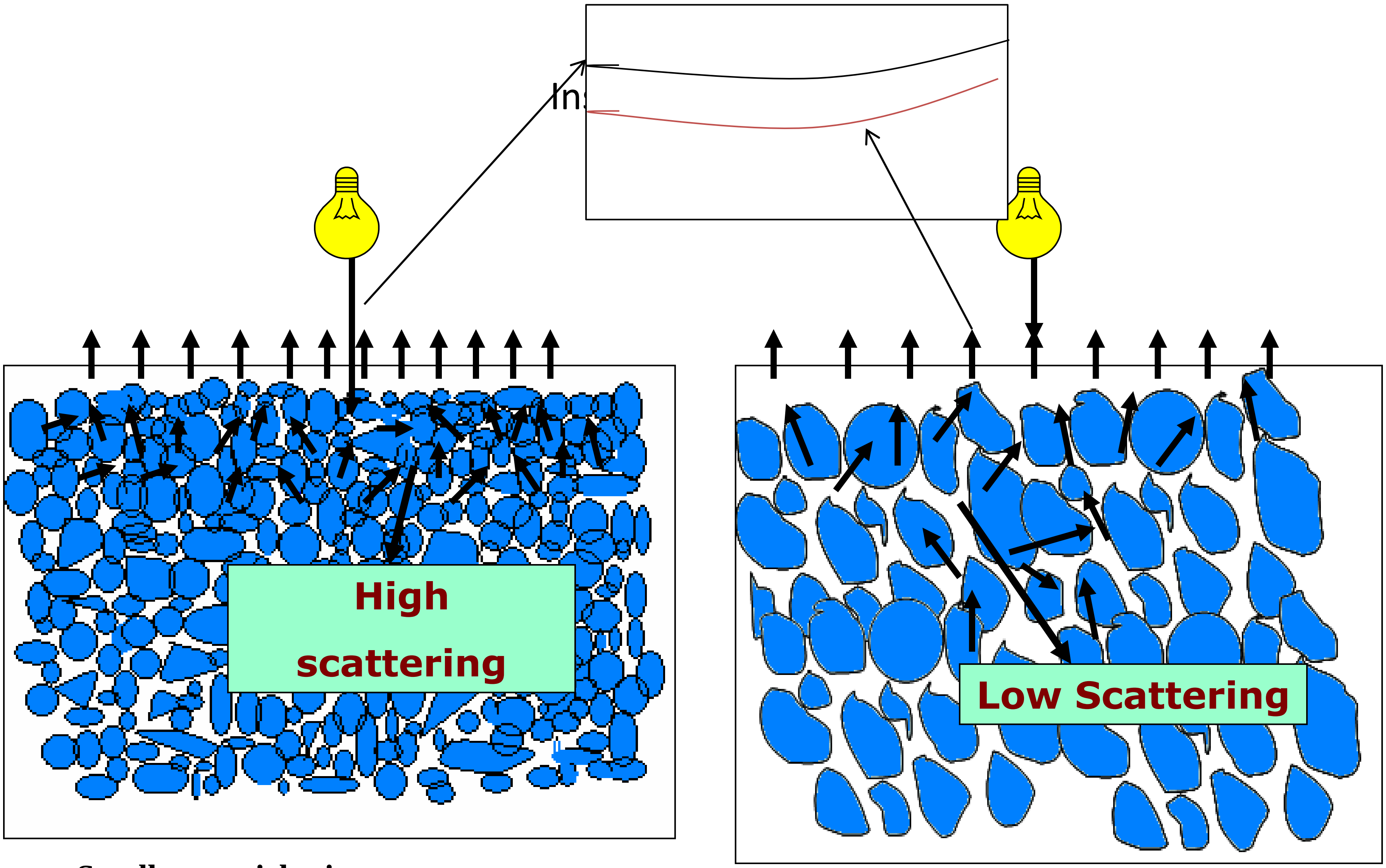
$$\log 1/\rho = \alpha$$

Scattering and Diffuse Reflectance

- Light propagates by scattering.
- As light propagates, both scattering and absorption occur, and the intensity of the radiation is reduced.



The radiation that comes back to the entry surface is called diffuse reflectance.



Smaller particle sizes

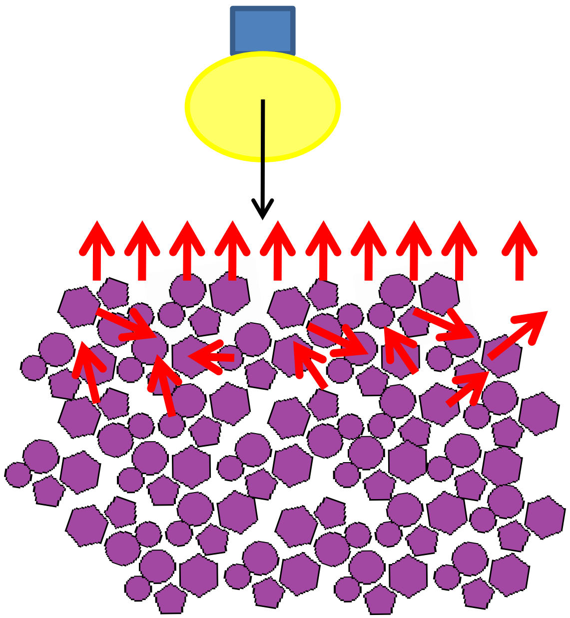
More remission, less transmission

Larger particle sizes

Less remission, more transmission

*Multiple path lengths are possible

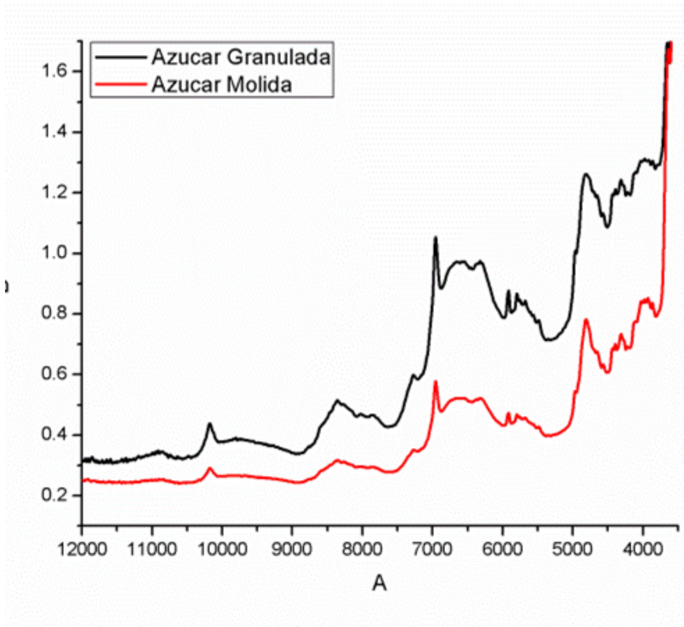
Particle Size and Scattering



High scattering

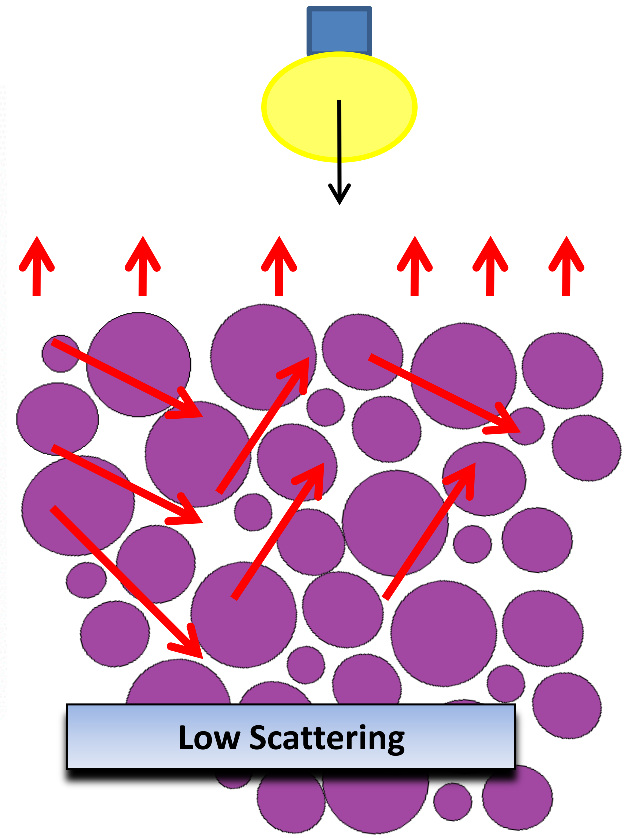
Smaller particle sizes

More remission, less transmission



Absorbing power (absence of scattering)

Absorption coefficient (includes effects of voids, surface reflection, distance traveled)

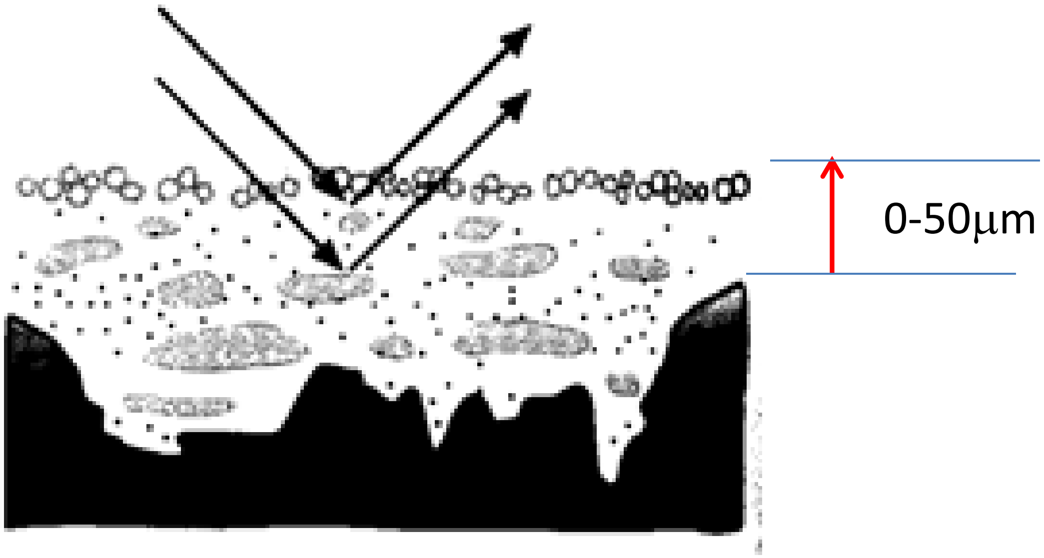


Larger particle sizes

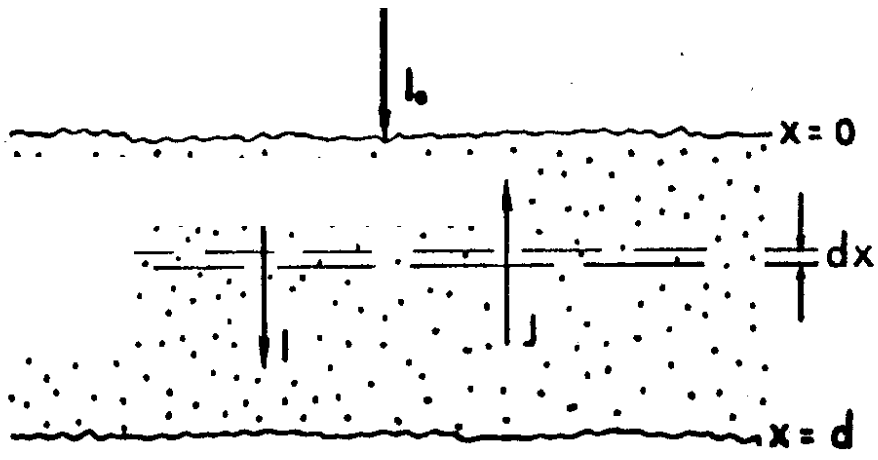
Less remission, more transmission

The real part is dominant the imagery part is constant

Soil and Radiation



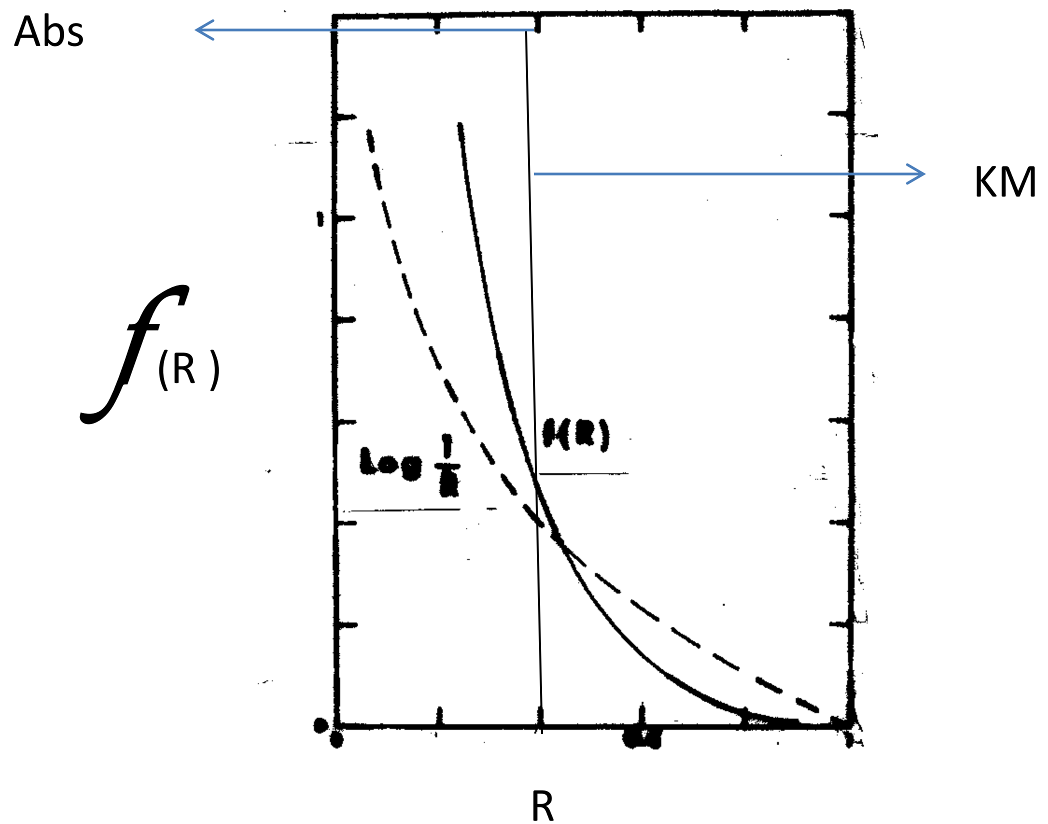
Kubelka Munk Theory



$$\frac{(1 - R_\infty)^2}{2R_\infty} = \frac{k}{s},$$

where R_∞ is the diffuse reflectance, k is the absorption coefficient, and s is the scattering coefficient.

$$k/s = \frac{(1 - Rd)}{2Rd} = f(Rd)$$



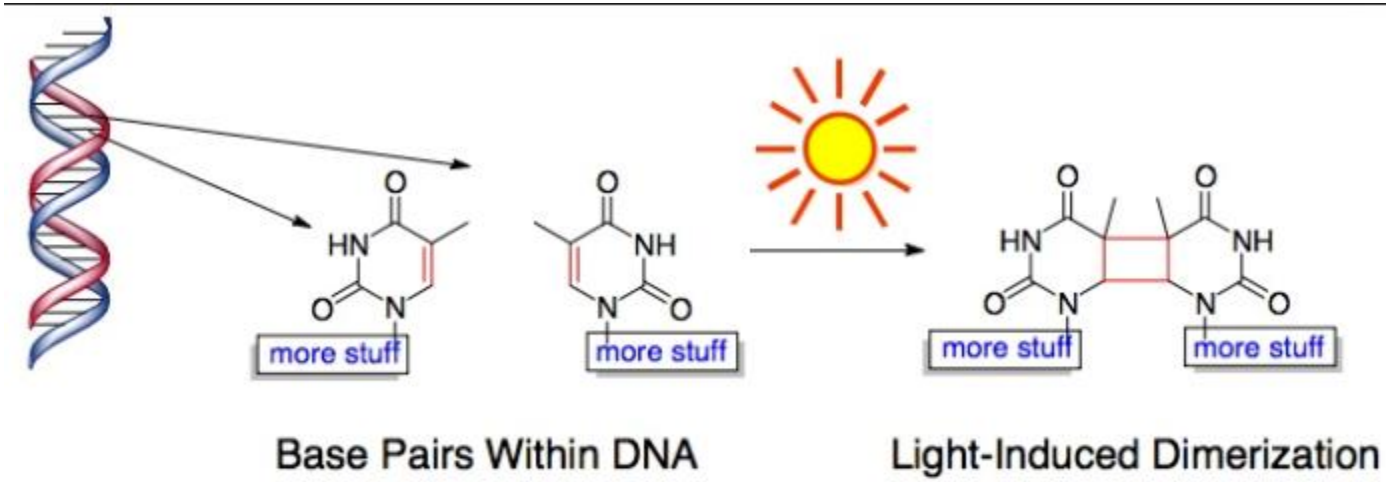
Spectrophotometers

- Light source (Lamp)
- Optical filters or prism(light dispression)
- Tube or cuvette (sample holder)
- Detector (photones counter)

A Chromophore

- A substance in the material that affect the incidence light

Melanin


O
HN
O
N
more stuff
O
NH
N
O
more stuff
O
HN
O
N
more stuff
O
NH
N
O
more stuff
Base Pairs Within DNA
Light-Induced Dimerization

Physical and chemical chromosphere

Physical: No absorption occur (real part of the refraction index)

Chemical: Absorption occurs (imaging part of the refraction index)

For quantity analysis of soils it is important to keep the physical property constant

Spectral Reflectance of Soils

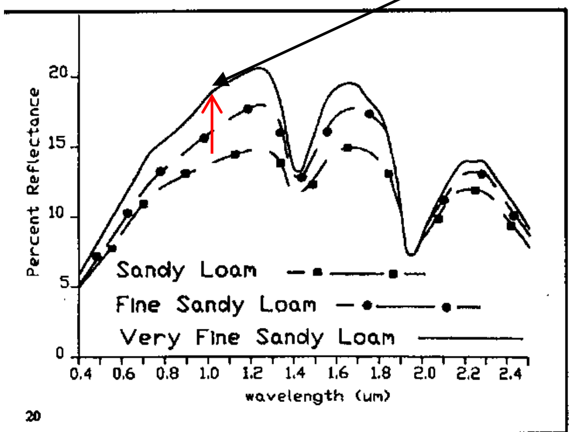
- Spectral Reflectance of Soils controlled by:
  - Soil moisture (physical and chemical n, k)
  - Particle size (physical, n)
  - Organic matter (chemical and physical k,n)
  - Mechanical Composition (physical and chemical, k,n)
  - Mineral contents, including Iron oxide and carbonates (chemical and physical k,n)
  - Surface roughness (physical n)

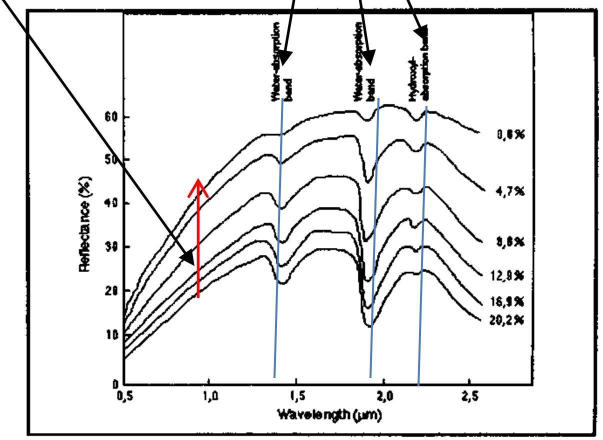
Soil Grain Size (mainly ***n***)

- Different size particles play different roles in soil:
  - Sand (0.05 to 2.0 mm): large air spaces, rapid drainage of water
  - Silt (0.002 to 0.05 mm): enhance movement and retention of soil capillary water
  - Clay (< 0.002 mm): enhance movement and retention of soil capillary water; carry electrical charges which hold ions of dissolved minerals (e.g. potassium and calcium)

Physical chromophore

Chemical chromophore

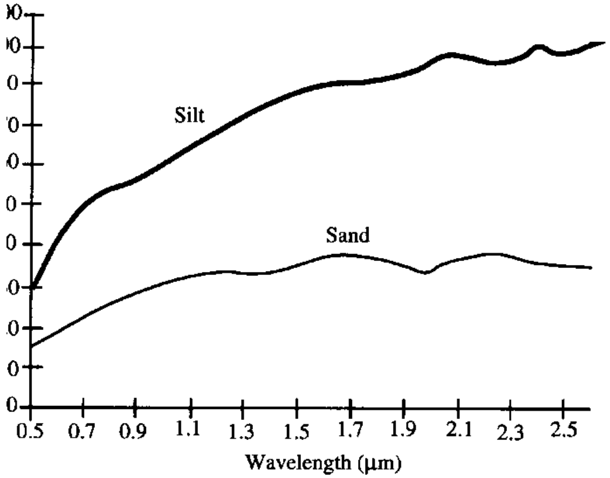




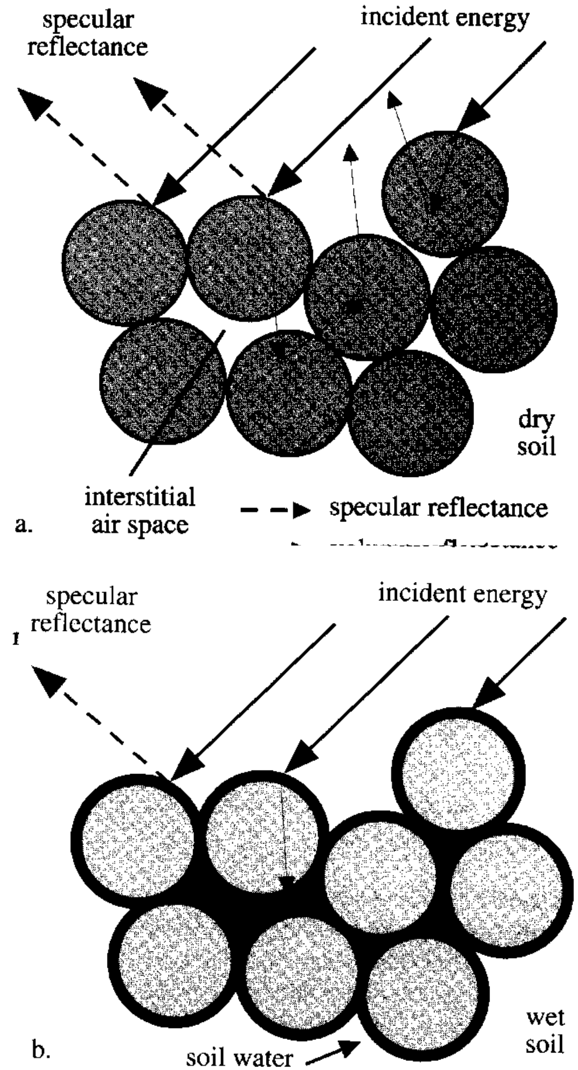
Grain size effect (n)

Moisture effects (k)

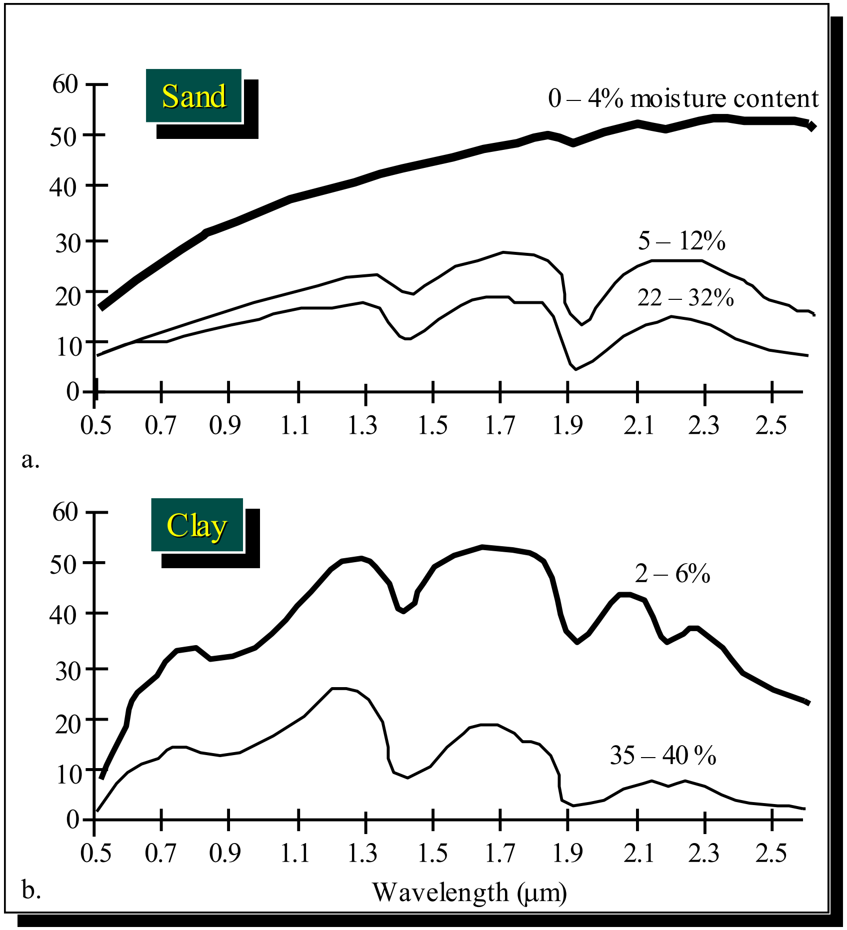
Another look on Grain Size and Soil Moisture



'e 13-5 *In situ* spectroradiometer reflectance curves for dry silt and sand soils. Reflectance generally increases with increasing wavelength throughout the visible, near- and middle-infrared portions of the spectrum.



Soil Moisture and Texture

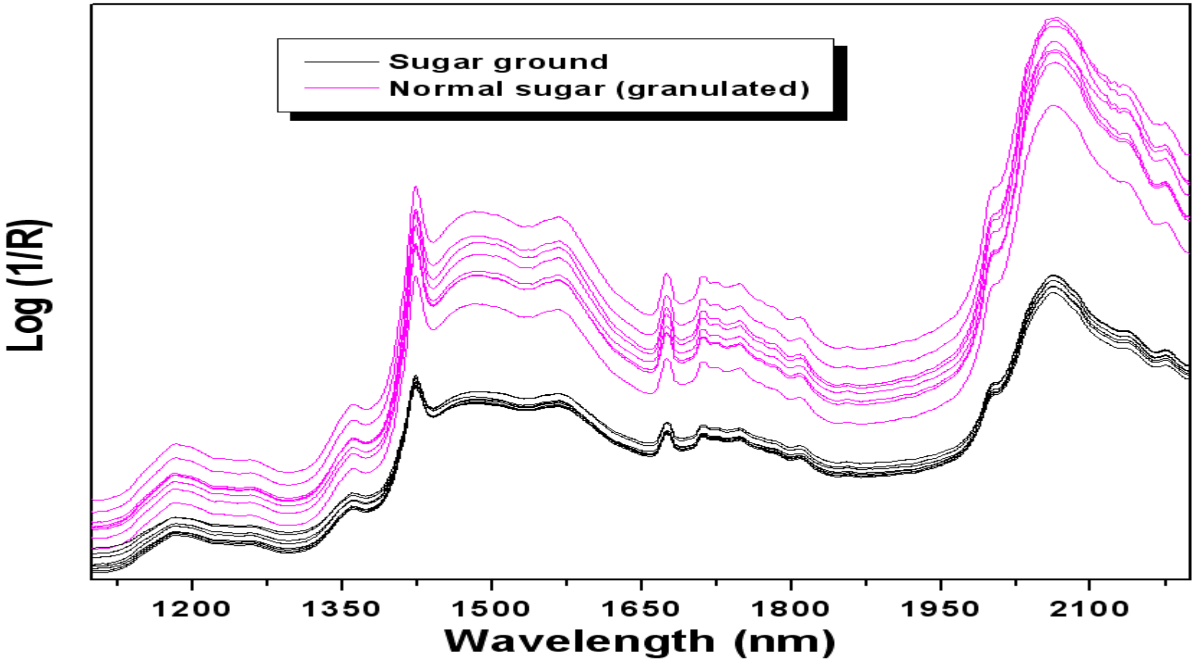


- -Clays hold more water more ‘tightly’ than sand.
- -Thus, clay spectra display more prominent water absorption bands than sand spectra.
- -AVIRIS can be useful for quantifying these absorption features.

Problems in Spectral Measurements of Reflectance

Changes in spectra due to physical properties of a material

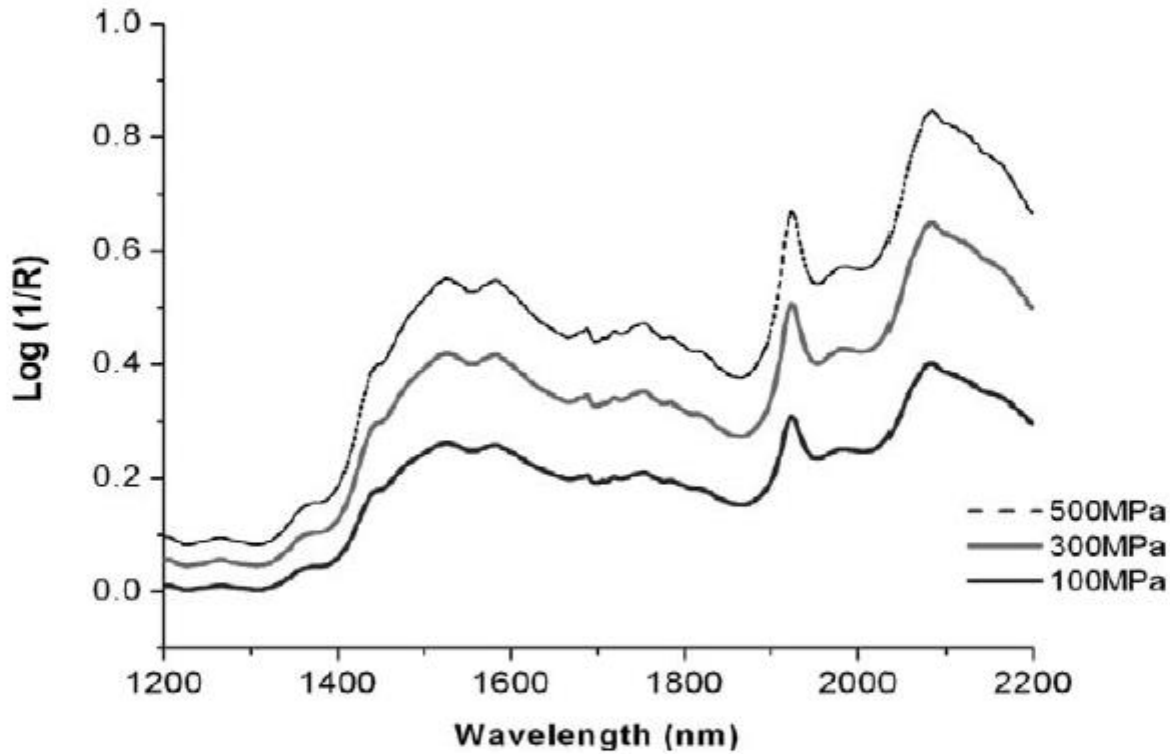
Particle size effect



Jackeline I. Jerez, Sept. 2009

Changes in spectra due to physical properties of a material

Tablet Packing density

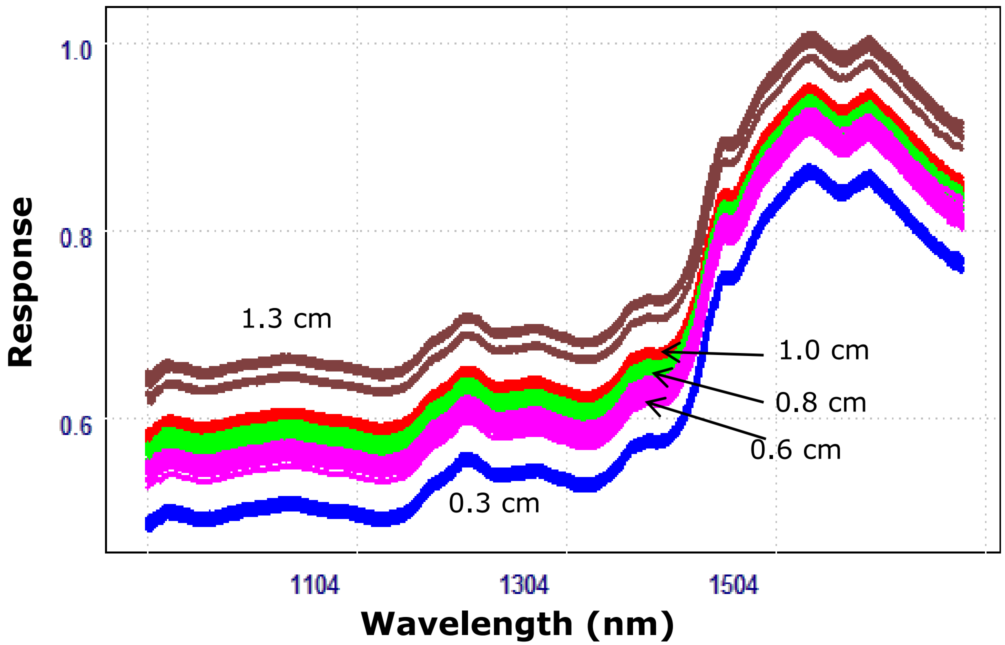


NIR spectra of pure lactose tablet at different packing density

Ropero, J. et al. 2011. Near-Infrared Chemical Imaging Slope as a New Method to Study Tablet Compaction and Tablet Relaxatio. Appl. Spect. 65, 4.

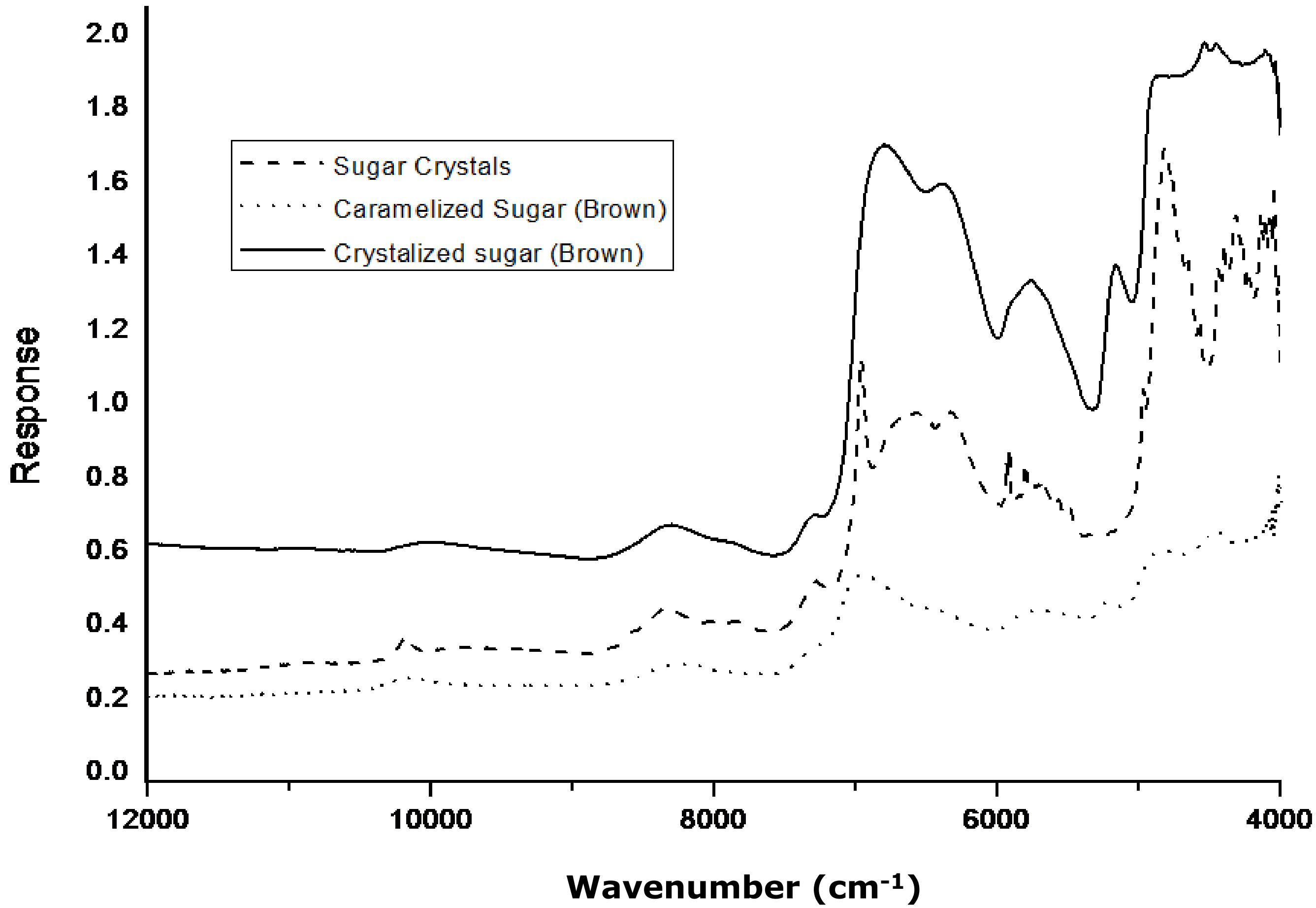
Changes in spectra due to variation in the measurement geometry

Probe-sample distance



NIR spectra of pure lactose analyzed at different distances

Changes in sugar spectra due variation in temperature



Effects of Organic Matter on Soils Spectrum

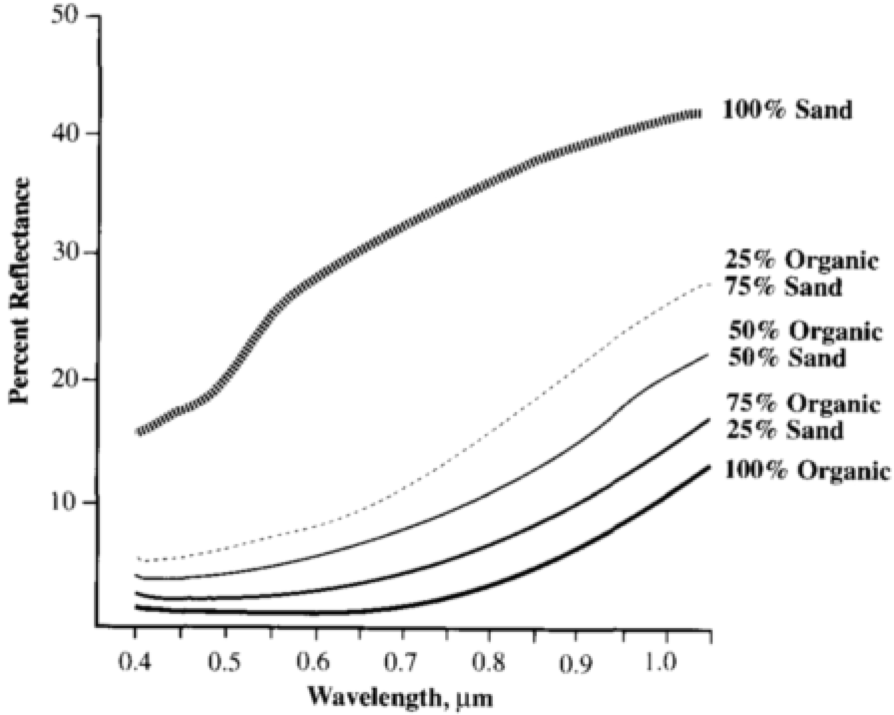


Figure 13-8 The greater the amount of organic content in a soil, the greater the absorption of incident energy and the lower the spectral reflectance.

Organic matter is a strong absorber of EMR, so more organic matter leads to darker soils (lower reflectance curves). Also the curve shape is changing

Effect of Iron Oxides on soil spectrum

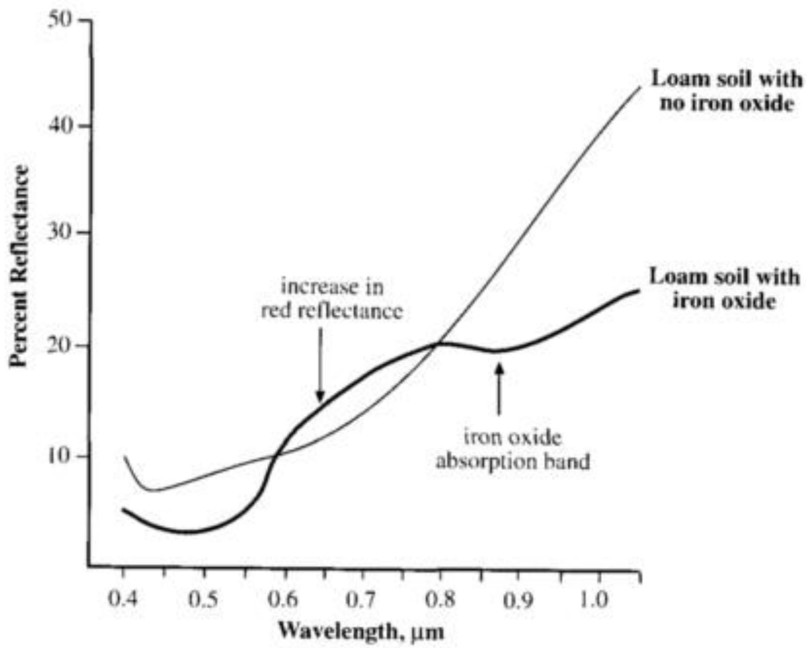
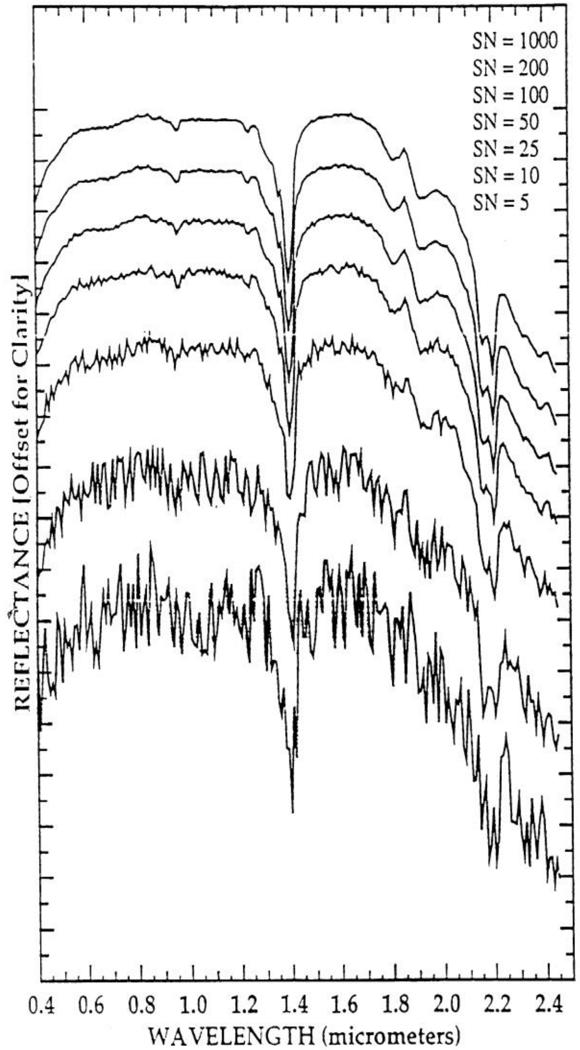


Figure 13-9 Iron oxide in a sandy loam soil causes an increase in reflectance in the red portion of the spectrum (0.6 – 0.7 µm) and a decrease in reflectance in the near-infrared region (0.85 – 0.90 µm).

Effect of Fe-oxide: Increase in the 600 – 700 nm reflectance, decrease in 400 – 600 nm reflectance, decrease in near-IR (absorption feature at ~875 nm)

Effect of the SNR on the soil spectrum



For applying quantities analysis of a chromophore we need to maintain the other chromophore constant

For example:
to track after chemical chromophors we need to keep the following factors constant (using measurement condition and post processing techniques):

Experimental

1) Maintain particle size (2mm>)
2) Maintain soil moisture (usually room temperature)
3) Maintain same material
4) Standard measurement protocol
5) Use the same spectrometer (SNR)

Mathematical

1) Base line correction
2) Derivation

Question: What are needed to track after soil aggregation capability?

- Spectroscopy?
- Instrumentation
- Modes of measurement

Modes of measurement

For soil which is a complex material an effort to reduce all physical effects (real part of the electromagnetic radiation interaction with material)

This can be done by using same protocol, same spectrometer, same geometry, same operator…..

Not always possible to maintain thus- standardization is needed

Feinstein method for soil measurements:

_

For that purpose we need a protocol

Soil Measurement Protocol
RSL-TAU

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<u>Soil Spectral Measurements</u>

<u>Problem</u>: A wide range of factors can affect soil reflectance spectra when using different spectrometers or even when repeating a specific sample's measurements in the same spectrometer. These factors result in subtle or strong alterations in wavelength location, peak absorption shape or albedo intensity. In addition to the instrumentation itself, internal electronic noise can affect the measurements and mechanical noise factors (e.g. homogeneity and purity of the white reference panel, or subtle movement when holding the fiber optic) can strongly affect the consistency of the resulting measurements. In soil samples, where very weak spectral features are monitored for chemometric purposes, these noise factors can alter the robust use of a selected spectral model for a wide range of spectrometers and users.

To test this issue and quantify it accordingly for soil environments, 12 soil samples were selected and three different materials were considered as internal standards. This population was measured in one laboratory with three identical spectrometers (Analytical Spectral Devices, Inc.) using a strict measurement protocol. The samples and spectrometers were then sent back to their laboratories of origin where the soils samples were measured using the respective labs' protocols and conditions, Pimstein A., **Ben Dor E.** and G. Notesco 2010 (*).

An exercise will be followed

A soil library (SSL)

Unlike rocks' library Soil Library MUST contains :

1) Chemical attributes (as done by wet chemistry standard methods)

2) Reflectance spectra acquired under a routine protocol and spectrometer

Several Soil Spectral Library are existed world wide

- Each were measured with a different protocol and spectrometers
- Still problematic to use as is for robust utilization

http://www.tau.ac.il/~rslweb/slis.htm

TEL AVIV UNIVERSITY אוניברסיטת תל-אביב

THE LESTER AND SALLY ENTIN FACULTY OF HUMANITIES DEPARTMENT OF GEOGRAPHY AND THE HUMAN ENVIRONMENT

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imaging spectroscopy technique

91 soils with 50 soil attributes

60 soil with 7 attributes

Israeli Soils Library: Home>SLIS

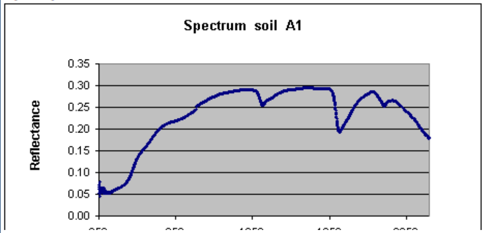
- **Chemical Analysis and Spectra Archive**
- **Map**

Soil Number	Symbol	Soil Type	Location	Great Soil Group (U.S.D.A)	color
35	A1	terra rosa soils	1569.1270 Nes-Harim	Xerochrept	5yr 4/4 dull reddish brown 7.5yr 4/6 brown

Clay %	Silt %	Send %	S.S.A (m2/g)	Organic Matter%	C.E.C (meq/100g)				
					Na	K	Ca	mg	C.E.C
33.5	40.3	26.1	236.8	6.65	0.47	0.9	32.35	5.74	39.45

EC (ds/m)	Cation Concetration (meq/l)				Anion Concetration (meq/l)				SAR
	Na	K	Ca	Mg	NO3	Cl	HCO3	SO4	
0.712	1.18	0.09	4.28	2.49	0.002	1.3	5.2	1.1	0.64

!--[if !vml]--

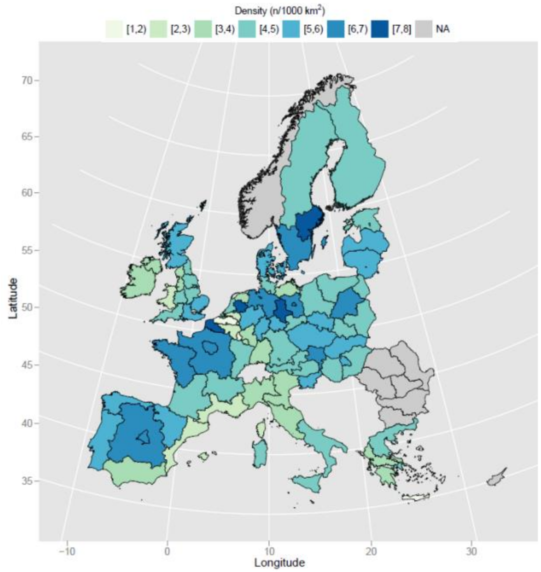


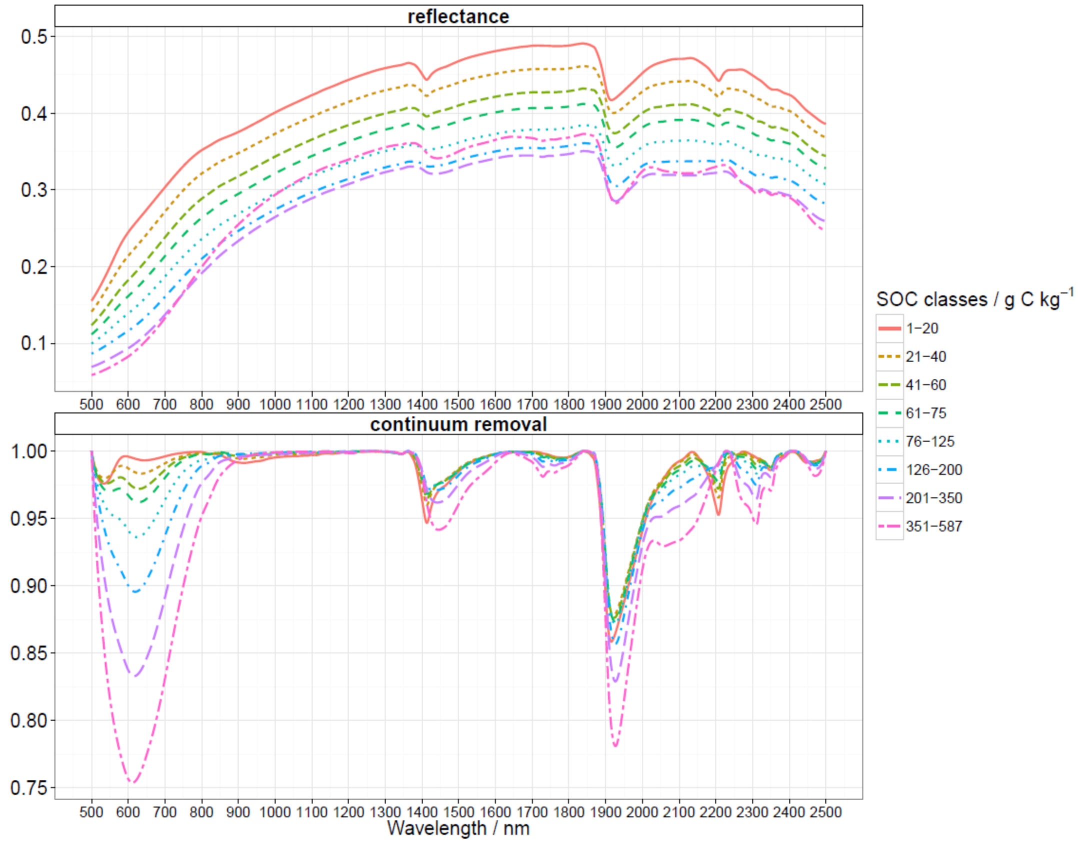
2mm>

Soil Classification According to S. Ravikovitz System

A	Terra Rosa Mediterranean
B	Brown Forest Soils
C	Rendezina Soils of Mountains
E	Brown Red Sandy Soils
H	Alluvial Soils
J	Colluvial Allouvial Soils
K	Rendezina Soils of Valley
O	Brown Desert Skeletal Soils
P	Desert Stoney Soils
S	Loess Raw Soils
W	Reddish Yellow Desert Soils

The LUCAS spectral library





- Current status:
  - 23 European countries
  - ~20,000 high quality spectral readings
  - Metadata: Clay, silt, sand, OC, pH, CEC, $CaCO_3$, Geographical coordinates, land use, etc

Creation of four subsets: Cropland, Grassland, Woodland, and Organic soils

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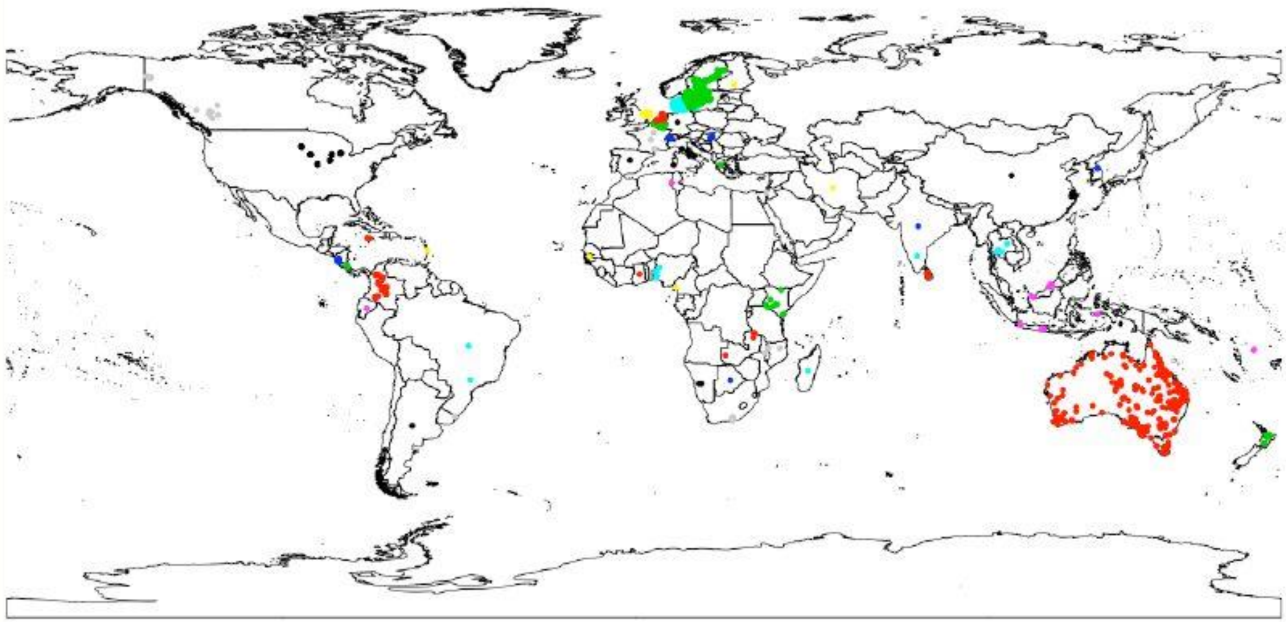
Soil Spectral Library

Current global distribution of spectra

Argentina	64
Australia	355
Belgium	262
Botswana	4
Brazil	528
Brunei	147
Cameroon	1
Canada	130
China	147
Colombia	172
Costa Rica	49
Cuba	15
Denmark	210
Ecuador	8
Finland	1
France	233
Germany	183
Ghana	1
Greece	1
Hungary	17
India	2
Indonesia	7
Iran	142
Israel	220
Italy	100
Jamaica	3
Kenya	100
Korea	92
Madagascar	18
Malaysia	2
Martinique	67
Mozambique	6
Namibia	4
Netherlands	95
New Zealand	210
Nicaragua	23
Nigeria	7
Samoa	3
Senegal	72
South Africa	113
Spain	493
Sri Lanka	6
Sweden	396
Switzerland	160
Thailand	6
Tunisia	89
UK	392
Uruguay	2
USA	1361
Zambia	6



Total of 6721 spectra

Not all representative – e.g. China only field-scale data

Coords for Brazil, Argentina and Ecuador coming

Coords for large part of USA still to be added

No samples in Russia and eastern Europe

CSIRO

http://groups.google.com/group/soil-spectroscopy/files

Recommended reading

- J. Coates, "Vibrational Spectroscopy: Instrumentation for Infrared and Raman Spectroscopy", Applied Spectroscopy Reviews, 1998, 33(4), 267 – 425.
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