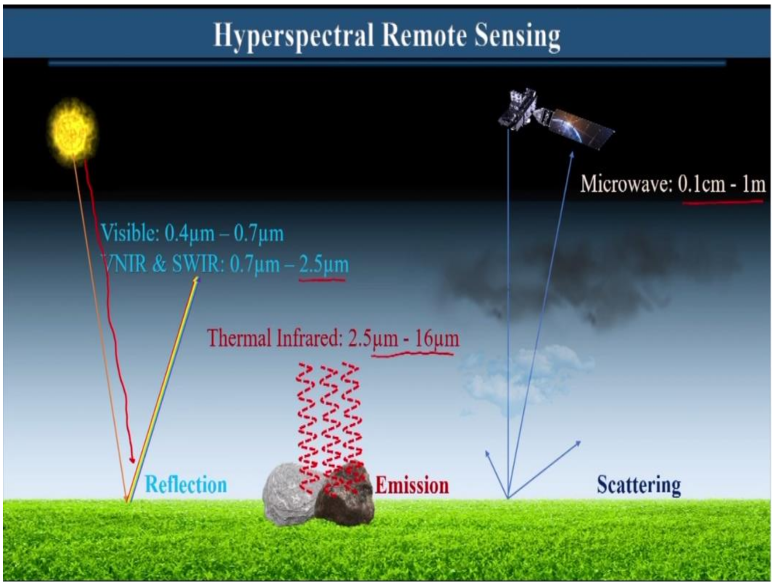
Remote Sensing and GIS
Rishikesh Bharti
Department of Civil Engineering
Indian Institute of Technology, Guwahati

Lecture - 16
Hyperspectral Remote Sensing - I

This is the first lecture on hyperspectral remote sensing. In this lecture, you will learn basics of remote sensing, the basics of hyperspectral remote sensing as well as why do we get spectral signature because that is the base of remote sensing right. So, let us start this lecture and the first slide actually this is the repetition but still I wanted to show you.

(Refer Slide Time: 00:59)



Hyperspectral Remote Sensing

Because this is the fundamental of remote sensing where in case of passive remote sensing we are using sun as our source. Sun is illuminating our surface right and which is getting reflected and the reflected energy we capture between 0.4 to 2.5 micrometer wavelength range whereas in emitted energy, we use 2.5 or 3 micrometer to 16 micrometer wavelength range and there we capture the emitted energy.

So, the information will be volumetric. Now, the third case where we are using microwave sensors which can measure the backscattered energy and here the range is 0.1 centimeter to 1 meter. So, this actually there are 3 major domain where we are doing the remote sensing and we are deriving the information about the target, does not matter whether it is Earth or any other planet but this is the fundamental how we are capturing this energy right.

(Refer Slide Time: 02:17)

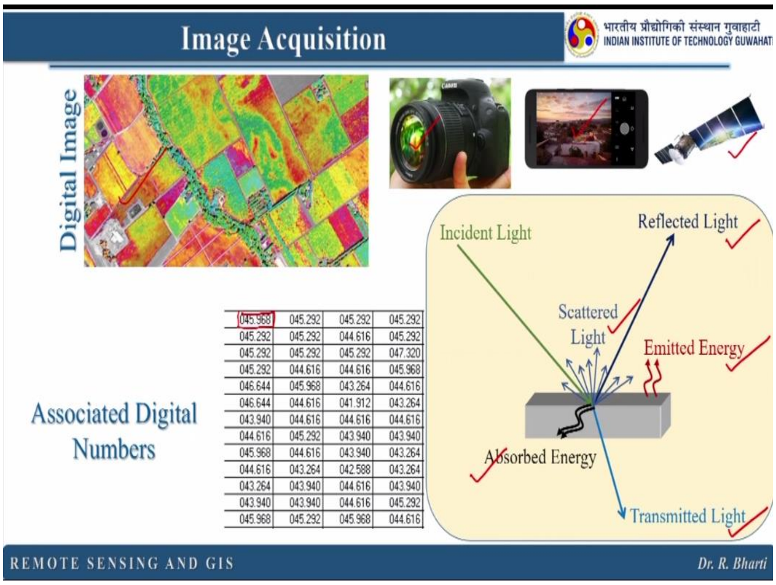


Image Acquisition

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

Digital Image

Associated Digital Numbers

045.968	045.292	045.292	045.292
045.292	045.292	044.616	045.292
045.292	045.292	045.292	047.320
045.292	044.616	044.616	045.968
046.644	045.968	043.264	044.616
046.644	044.616	041.912	043.264
043.940	044.616	044.616	044.616
044.616	045.292	043.940	043.940
045.968	044.616	043.940	043.264
044.616	043.264	042.588	043.264
043.264	043.940	044.616	043.940
043.940	043.940	044.616	045.292
045.968	045.292	045.968	044.616

REMOTE SENSING AND GIS

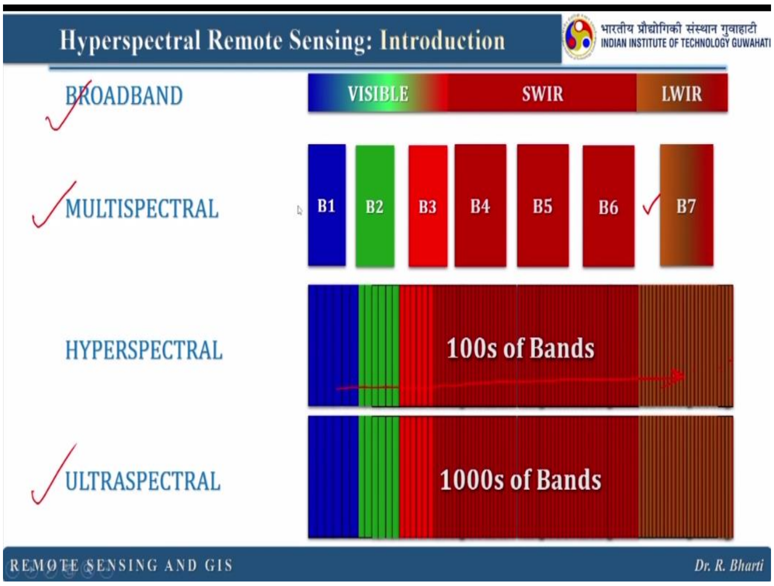
Dr. R. Bharti

So, if you remember, in my first lecture or second lecture, I must have mentioned this that these three are the source of images right. So, in normal cases, we use mobile phone to capture our activities and nowadays people are using DSLR, so the resolution of the image will be better and third case is in remote sensing, we are using sensors from a spaceborne satellite or in the fourth case we can mount it in our aeroplane or helicopters and then we can capture our images right.

So, doing this we are basically capturing the either reflected light or emitted light or transmitted light or absorbed light or scattered light. So, these are the fundamental, so this information can be captured by your specific type of

And basically this is a matrix and these matrix are basically associated with your pixels right and subsequently we display this in image form right and this is your output. So, this is the way we are doing our remote sensing.

(Refer Slide Time: 04:01)



Hyperspectral Remote Sensing: Introduction

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

BROADBAND
VISIBLE
SWIR
LWIR

MULTISPECTRAL
B1
B2
B3
B4
B5
B6
B7

HYPERSPECTRAL
100s of Bands

ULTRASPECTRAL
1000s of Bands

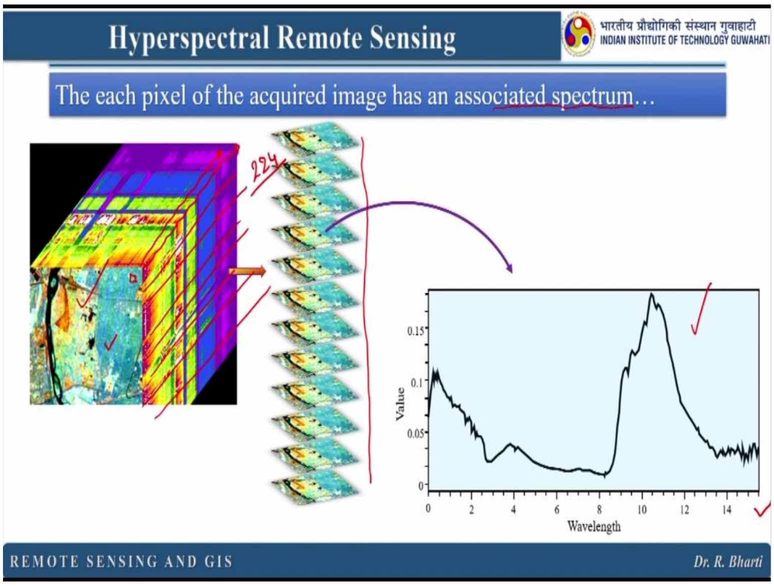
REMOTE SENSING AND GIS
Dr. R. Bharti

So, let us understand from the beginning that what are the different way we captured this. So, the first one is broadband. I hope you remember the panchromatic images where wavelengths are broad which is used to generate the image and this will be a single band image right. There will be only one image produced for an area right and the wavelength, the bandwidth will be more.

In the second case, where we have discussed the multispectral data, so here in a given wavelength, you can have 4, 5 or 6 different wavelength bands and in between it is allowed to have some gaps right. So, these gaps are there. In the third case, we have hyperspectral, so here basically you have 100s of bands and here you can see there is no gap at all here right. In the definition itself, hyperspectral says it is contiguous band in narrow band channels right.

So, here you have 100s of bands and there are many bands available here right. Now, the fourth case, where we have ultraspectral, in ultraspectral again there will be no gap in between the bands but here the numbers will be in order of 1000 right.

(Refer Slide Time: 05:37)



Hyperspectral Remote Sensing

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

The each pixel of the acquired image has an associated spectrum…

REMOTE SENSING AND GIS

Dr. R. Bharti

Now, in the next case, where we are using this hyperspectral remote sensing data, so basically let us understand how this remote sensing is divided into different image form like one is panchromatic, multispectral, hyperspectral and then ultraspectral. So, here if we see this hyperspectral remote sensing, so it says the each pixel of the acquired image has an associated spectrum right.

Generally, we use this kind of image cube to display our hyperspectral data right. So, here you can see this is the area and this is the another direction where we have projected all the bands. So, here all the bands are stacked behind. So, here it may be 100s of bands and they are actually stacked behind. Now, here if you want to know what is the property of this particular pixel then you will have enough information.

Why? Because here you have 100s of bands, so let us consider a case where we are using Hyperion data. Hyperion is a hyperspectral sensor. So, if you are using Hyperion image, then what will happen, you will have 224 image bands right. So, for each pixel at least you will have 224 values across the wavelength. So, starting from 0.4 micrometer to 2.5 micrometer, you will have 224 values right.

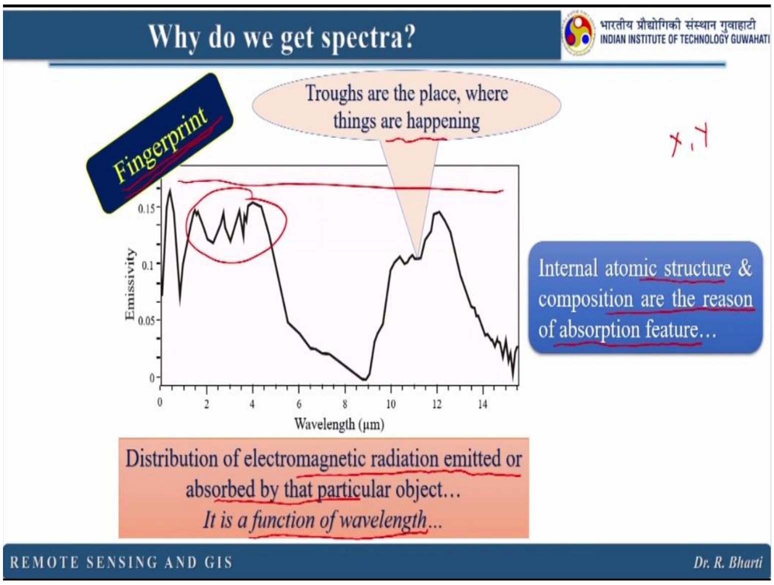
So, if you want to display this, so these are the images. So, this is just for an example I have given. So, these are actually stacked together here in this case. Now, ultimately what is our intention? We want to characterize the object or the surface. So, how we can do that? We can derive the information of individual pixel by deriving the reflected values across the wavelength.

So, here you can see this is another example. This is not the actual data. So, if you see for this particular pixel right, this is the information. So, let us assume this particular sensor is working between 0.42 maybe 15 micrometer or 16 micrometer right and these are the responses. So, if you have such information, then you can definitely characterize your object or material which is better than your multispectral information.

Because in multispectral you have low spectral resolution whereas in hyperspectral you have high spectral resolution. So, high spectral resolutions are useful for deriving the composition related information or the internal atomic structure related information of the target right. So, now you must be wondering that why we actually get this kind of spectral response from a material or from a target right.

So, as I told you this information can be used to extract the composition related information right. So, there is a correlation between the internal atomic structure as well as the chemical composition of the target and because of them only we are getting this kind of spectral signature right. So, these signatures are having peaks and troughs and they give the shapes of this spectral feature right.

(Refer Slide Time: 09:53)



Why do we get spectra?

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

Fingerprint

Troughs are the place, where things are happening

Internal atomic structure & composition are the reason of absorption feature…

Distribution of electromagnetic radiation emitted or absorbed by that particular object…
It is a function of wavelength…

REMOTE SENSING AND GIS

Dr. R. Bharti

Now, let us understand why do we get spectra right. So, first of all, if you are illuminating a surface then definitely it will eat some energy that means it will absorb some energy, it will reflect, it will transmit and then some energy will be reemitted to our atmosphere right and in remote sensing we are capturing this information. So, let us understand why actually these features are coming right.

So, internal atomic structure and composition are the reason of the absorption feature right. Remember this because of the atomic structure, internal atomic structure and the composition you are having this kind of features right and these troughs are the places where things are happening. That means if you get a straight line here that means nothing is happening right but here if you are getting undulation like peaks and troughs that says there is some interaction happening between the light which is illuminating the surface and the target.

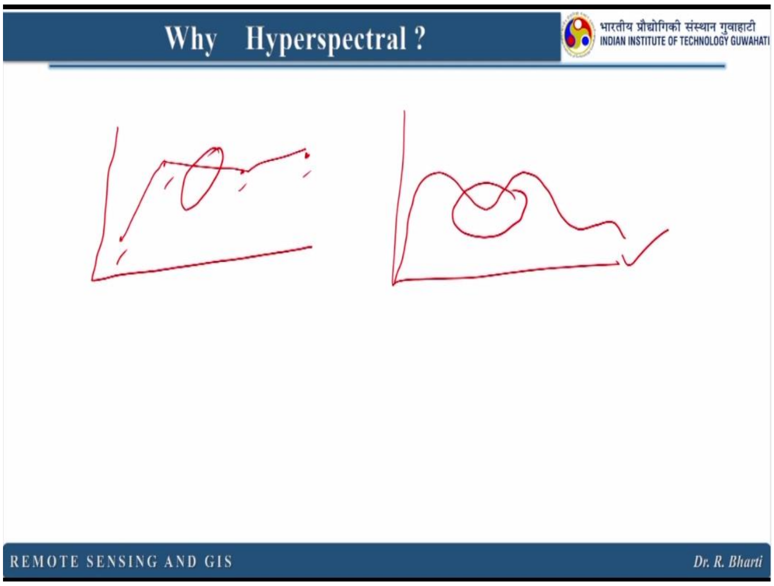
So, the material composition is playing significant role here right. So, the distribution of electromagnetic radiation emitted or absorbed by the particular object is a function of wavelength. Remember, if you have X composition or Y composition, they have different absorption feature right and that is why I have written this is actually like your fingerprint. So, with fingerprint you can identify any particular person right.

That is why now we are using biometric attendance and there are biometric applications where nobody can change your basic information right. So, here also if you have X and Y material, they are having different absorption feature located in different wavelength regions right. So, if you want to identify them then you use those particular absorption features at those particular wavelength region, then you can definitely identify in which material X is present, in which material Y is present right.

So, that is why I have written fingerprint here. So, remember these spectral signatures are unique for all the material present in our world even in other planet right. So, these are unique information and it can be used as a fingerprint to identify those materials or objects right. I hope this is clear to you. Now, why hyperspectral is very popular nowadays? Because hyperspectral is a technique how do we measure the information right.

Basically, if you compare with panchromatic and multispectral and hyperspectral, then you will find the spectral information available in hyperspectral is much more than any of those two. In panchromatic, you have only single reflected or emitted values of the broadband. Then, in the multispectral you have discrete values and in between you may have some gaps right.

(Refer Slide Time: 13:41)


Why Hyperspectral ?

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

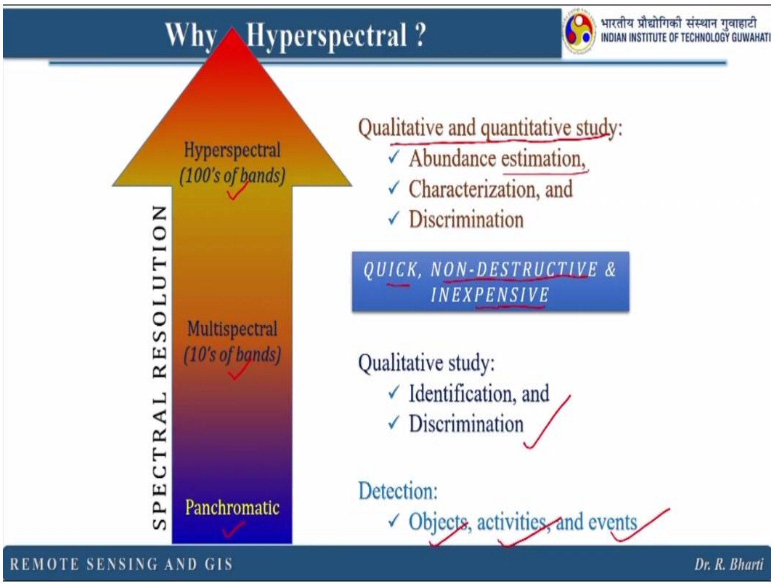
REMOTE SENSING AND GIS

Dr. R. Bharti

So, I will just this is for your memory refresh. So, in multispectral you may have 4 bands. If you have selected a pixel, then you will have only 1, 2, 3 and 4 values and if you connect them this will be like this but whereas in hyperspectral you have at least 100s of bands and they are contiguous in nature that means there is no gap in between that is why you have continuous spectra here right.

And this can depict or this can capture this absorption feature which was missing here right. So, that is why hyperspectral becomes very popular nowadays for quantitative analysis right.

(Refer Slide Time: 14:36)


Why Hyperspectral ?

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

Qualitative and quantitative study:
- ✓ Abundance estimation,
- ✓ Characterization, and
- ✓ Discrimination

QUICK, NON-DESTRUCTIVE & INEXPENSIVE

Qualitative study:
- ✓ Identification, and
- ✓ Discrimination

Detection:
- ✓ Objects, activities, and events

REMOTE SENSING AND GIS

Dr. R. Bharti

So, let us see what advantage we have when we are using hyperspectral compared to multispectral and panchromatic. So, we started with panchromatic, then we moved to multispectral, then we moved to hyperspectral and in panchromatic you have only one band, in multispectral you have 10s of bands but you have gap in between and the bandwidth can be little bit broad.

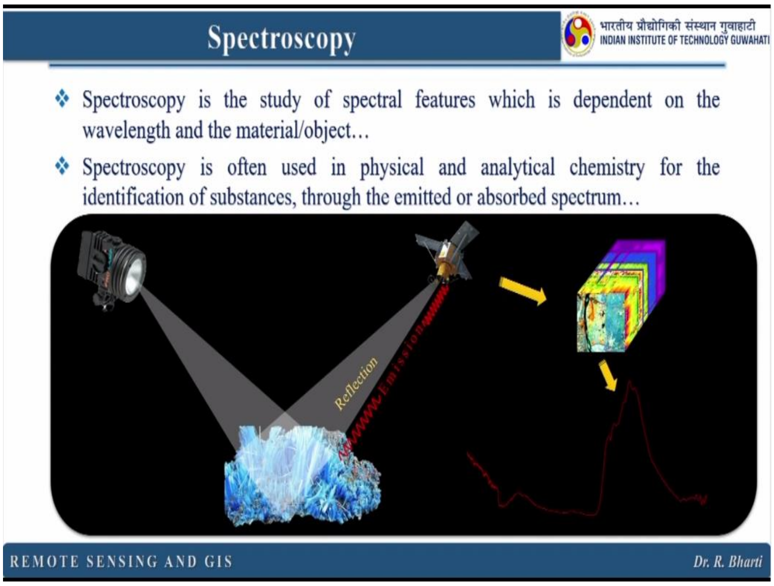
But whereas in hyperspectral, you have 100s of bands but you don’t have any gap in between the bands. So, you have contiguous information about the target across the wavelength right. So, when we started with panchromatic, we could able to do this object identification, activities and even detection right but when we move to multispectral, we could do identification and discrimination right.

Now, we have hyperspectral data and this hyperspectral data can be used for abundance estimation or characterization of a material or the discrimination also obviously we can do that right. So, that is why I have written qualitative and quantitative study. Now, there is one more very unique advantage we have with hyperspectral remote sensing. That is quick and non-destructive and inexpensive technique.

Because if you are using a spaceborne hyperspectral sensor data, then this expense will be very less because it is for the whole world. Now, it is quick and non-destructive. Why? Because you are not going to disturb the sample or the target, you are just going to acquire the spectroscopic information captured in those particular bands right. So, here you are not going to disturb or hamper the sample.

So, you don’t have to bring it to your lab, so as it is in the field you can measure this information and subsequently you can analyze for abundance estimation right.

(Refer Slide Time: 17:06)



Spectroscopy

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

- Spectroscopy is the study of spectral features which is dependent on the wavelength and the material/object…
- Spectroscopy is often used in physical and analytical chemistry for the identification of substances, through the emitted or absorbed spectrum…

REMOTE SENSING AND GIS

Dr. R. Bharti

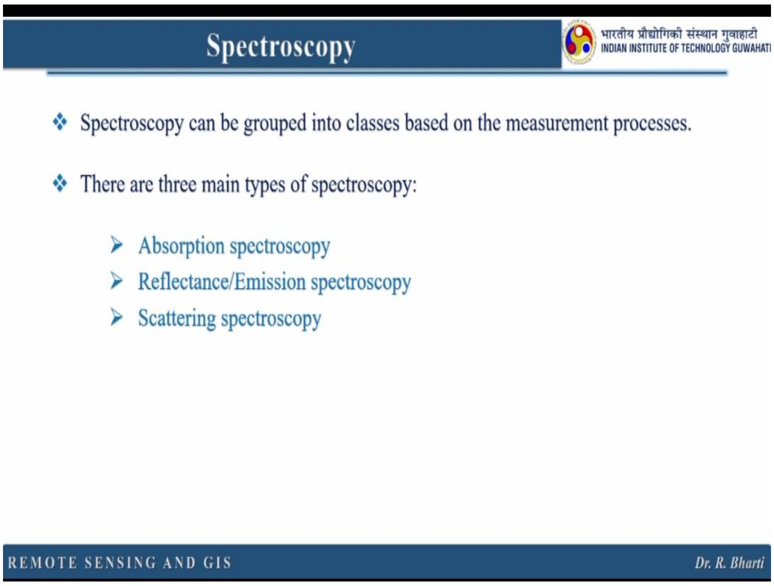
So, what exactly we mean by spectroscopy? So, spectroscopy is the study of spectral feature which is dependent on the wavelength and the material right. So, it can be object also. Spectroscopy is often used in physical and analytical chemistry for the identification of substances through the emitted or absorbed spectrum.

So, if you remember somewhere you might have heard about XRD, XRF, ICP they are actually using this spectroscopy technique right. So, there you have to bring the sample from the field to your lab, then you have to prepare the sample according to the requirement and then that instrument will give you information either it is absorbed information or reflected or transmitted information and that will be available in terms of spectra, spectral signature.

And again you will analyze those spectral signatures to identify the material composition. So, this is the spectroscopy where we study the spectral features, what is the position, shape, size right and then based on that we say this is X, Y, and Z material. So, just to refresh your understanding, suppose this is a target right and we have a source lamp, this is in case of lamp right but you can just imagine sun as source of light.

And then we can put our sensor here so either in the lab or maybe in the field. So, in field it will be spaceborne or airborne satellites or sensors and in case of lab it will be lab based instruments. So, in both the cases, we measure reflected or emitted energy from this sensor and then subsequently we produce images right. In remote sensing, we basically produce images and then for individual pixel we derive the spectral signature because we have contiguous spectral information about that target in narrow channels or bands.

(Refer Slide Time: 19:40)



Spectroscopy

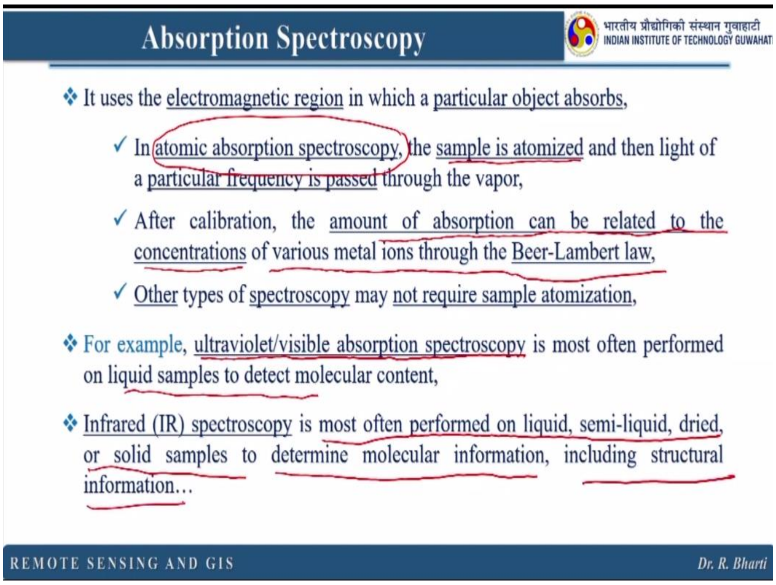
भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

- Spectroscopy can be grouped into classes based on the measurement processes.
- There are three main types of spectroscopy:
  - Absorption spectroscopy
  - Reflectance/Emission spectroscopy
  - Scattering spectroscopy

REMOTE SENSING AND GIS — *Dr. R. Bharti*

So, spectroscopy can be grouped into classes based on the measurement processes. So, there are 3 major types of spectroscopy. First one is absorption, second one is reflection or emission spectroscopy and third one is scattering spectroscopy.

(Refer Slide Time: 20:00)



Absorption Spectroscopy

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

- It uses the electromagnetic region in which a particular object absorbs,
  - ✓ In atomic absorption spectroscopy, the sample is atomized and then light of a particular frequency is passed through the vapor,
  - ✓ After calibration, the amount of absorption can be related to the concentrations of various metal ions through the Beer-Lambert law,
  - ✓ Other types of spectroscopy may not require sample atomization,
- For example, ultraviolet/visible absorption spectroscopy is most often performed on liquid samples to detect molecular content,
- Infrared (IR) spectroscopy is most often performed on liquid, semi-liquid, dried, or solid samples to determine molecular information, including structural information…

REMOTE SENSING AND GIS — *Dr. R. Bharti*

So, let us see what we mean or what we do in absorption spectroscopy. This is basically related to your lab based instruments. So, it uses the electromagnetic region in which a particular object absorb right. So, here a particular wavelength will be used where we know our material let us assume X. So, X absorb in 2.5 micrometer wavelength range. So, in absorption spectroscopy, we will use only 2.5 micrometer wavelength range.

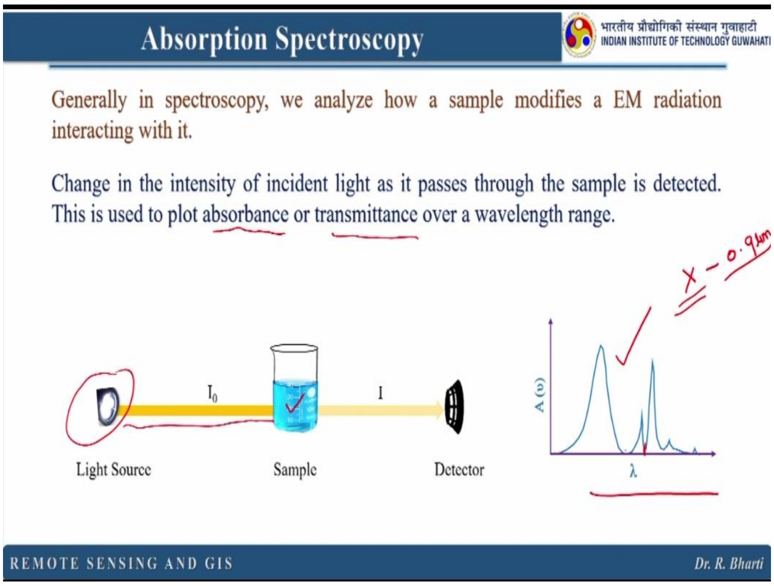
And then we will see how much energy it has observed and based on that we will identify the material composition. So, after calibration the amount of absorption can be related to the concentration of various metal ions through the Beer-Lambert's law. Other type of spectroscopy may not require sample atomization because it depends instrument and the technique which you are using.

So, in this atomic absorption spectroscopy, the sample was atomized right. So, it will reach to higher state and then it will come back to lower state. So, how much energy it has absorbed that you can derive right. So, it changes with the technique and the instrument, so don't get confused that sir has told me this but in this instrument it is happening in some other way. So, this is only in case of atomic absorption spectroscopy.

For example, liquid samples. Here we generally use ultraviolet, visible absorption spectroscopy right and infrared spectroscopy is most often performed on liquid, semi-liquid, dried or solid sample to determine the molecular information including structural information. Now, you can see just imagine how much information you can derive using this spectroscopy technique.

So, now you are going to molecule label, so you can easily determine what is the structure, is there any structural defect in the molecules right or is there any composition change, what is their behaviour, how much energy they are absorbing, how much energy they are transmitting right, those information can be easily identified or studied using this spectroscopy technique.

(Refer Slide Time: 22:51)



Absorption Spectroscopy

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

Generally in spectroscopy, we analyze how a sample modifies a EM radiation interacting with it.

Change in the intensity of incident light as it passes through the sample is detected. This is used to plot absorbance or transmittance over a wavelength range.

REMOTE SENSING AND GIS

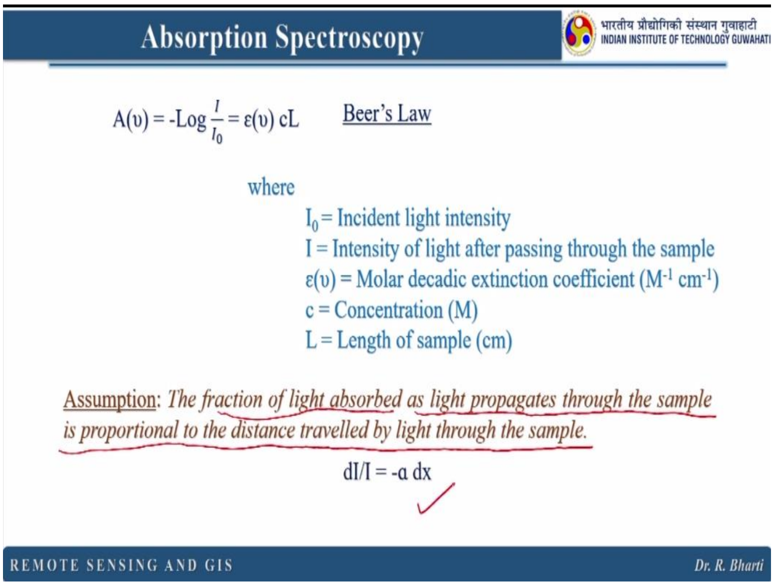
Dr. R. Bharti

In absorption spectroscopy, we analyze how a sample modifies a electromagnetic radiation interacting with it. So, basically we see how it is interacting and what is their end result right. So, change in the intensity of incident light as it passes through the sample is detected. This is used to plot absorbents or transmittance over a wavelength range right. So, here you have a source light and you are illuminating your sample and then some amount of energy will get absorbed, some amount of energy will get transmitted depending upon your sample.

So, those information can be captured and then subsequently you can plot absorbance spectra or transmittance spectra over a wavelength right. I hope this is clear. Again, see here you are going to further study this particular spectral signature. Then, only you will be able to identify the material composition. So, let us assume if you are going to identify X. So, weather X is having any absorbance in these wavelengths that is fundamental question.

So, let us assume X is having absorbance at 0.9 micrometer right. So, at 0.9 micrometer, if there is any absorbance that should be related to X because this is unique information. So, now we will look for that and suppose let us assume this is 0.9 micrometer then we can definitely say this is because of the presence of X in this particular sample right. Exactly, we cannot correlate directly.

(Refer Slide Time: 24:57)



Absorption Spectroscopy

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

$A(\upsilon) = -\text{Log}\frac{I}{I_0} = \varepsilon(\upsilon)\, cL$ Beer's Law

where

I_0 = Incident light intensity
I = Intensity of light after passing through the sample
$\varepsilon(\upsilon)$ = Molar decadic extinction coefficient ($M^{-1}\ cm^{-1}$)
c = Concentration (M)
L = Length of sample (cm)

Assumption: *The fraction of light absorbed as light propagates through the sample is proportional to the distance travelled by light through the sample.*

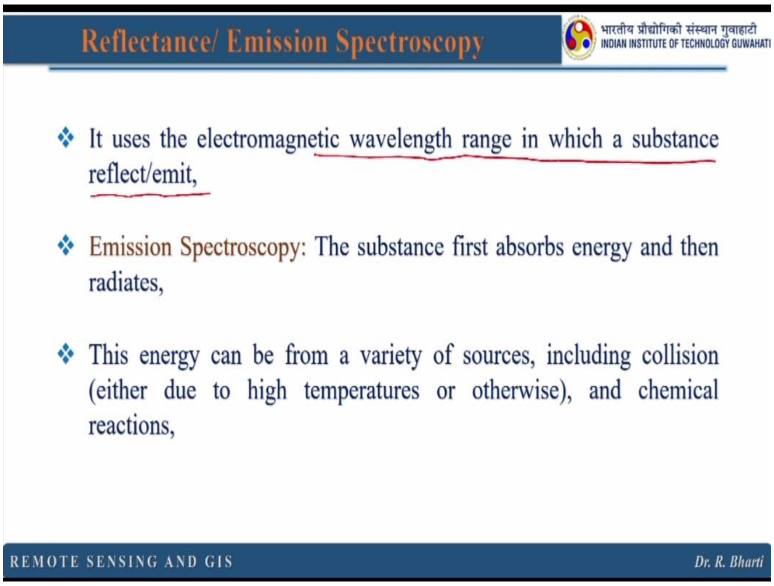
$dI/I = -\alpha\, dx$ ✓

REMOTE SENSING AND GIS Dr. R. Bharti

So, we use this Beer's law and then we identify what is the composition or what is the concentration of X in this. So, that will tell you the concentration that means it is a quantitative study. Now, here the assumption of this particular process is the fraction of light absorbed as light propagates through the sample is proportional to the distance travelled by light through the sample right.

Hence, finally we get this. Now, you have seen absorbance or transmittance spectroscopy. Now, let us see reflectance or emission spectroscopy because in general in remote sensing, we are using this reflected and emitted light right and here we want to acquire the contiguous information in narrow channels right and that will tell you the material composition and internal atomic structure.

(Refer Slide Time: 26:08)



Reflectance/ Emission Spectroscopy

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

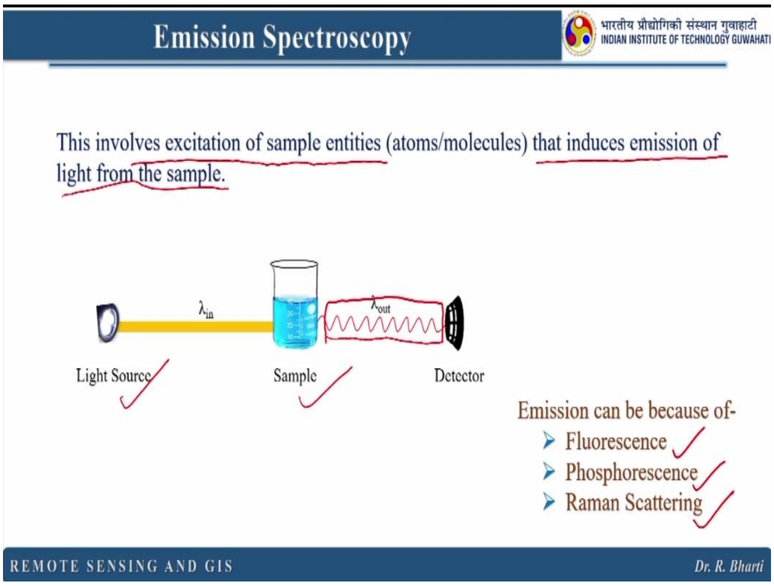
- It uses the electromagnetic wavelength range in which a substance reflect/emit,
- Emission Spectroscopy: The substance first absorbs energy and then radiates,
- This energy can be from a variety of sources, including collision (either due to high temperatures or otherwise), and chemical reactions,

REMOTE SENSING AND GIS Dr. R. Bharti

So, here if you see, it uses the electromagnetic wavelength range in which a substance reflect or emit. So, again you need to know whether your target is sensitive to this particular wavelength range or not. If so, then you can use this particular wavelength range and that particular instrument and then you can subsequently derive the reflected or emitted spectra right. In emission spectroscopy, the substance first absorbs energy and then radiates.

Because that is the fundamental of remote sensing when a light is illuminating a surface, some amount of light will get absorbed and to maintain the equilibrium with the surrounding what will happen, the sample will re-emit those absorbed energy in the longer wavelength region and that we measure in thermal remote sensing. I hope you remember that part. The energy can be from a variety of source including collision either due to high temperature or otherwise and chemical reaction within the sample itself right.

(Refer Slide Time: 27:25)



Emission Spectroscopy

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

This involves excitation of sample entities (atoms/molecules) that induces emission of light from the sample.

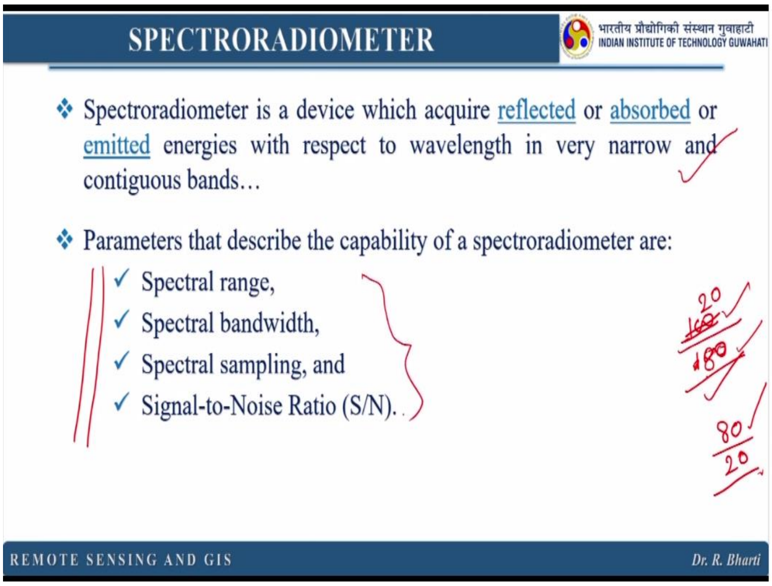
Emission can be because of-
- Fluorescence
- Phosphorescence
- Raman Scattering

REMOTE SENSING AND GIS
Dr. R. Bharti

So, in emission spectroscopy, this involves excitation of the sample entities that induce emission of light from the sample right. So, here again this light source, sample and assuming everything is absorbed and there is no transmittance and we are only using an instrument which can measure the emitted information and the emission can be because of fluorescence, phosphorescence and Raman scattering.

So, this is again for the lab based instruments but they does not qualify the definition of remote sensing because sample and the sensor both are actually close to each other and sometimes they are very close. So, they are not grouped into remote sensing. So, they are having other category like analytical chemistry or analytical spectroscopy technique right.

(Refer Slide Time: 28:32)



SPECTRORADIOMETER

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

- Spectroradiometer is a device which acquire reflected or absorbed or emitted energies with respect to wavelength in very narrow and contiguous bands…
- Parameters that describe the capability of a spectroradiometer are:
  - ✓ Spectral range,
  - ✓ Spectral bandwidth,
  - ✓ Spectral sampling, and
  - ✓ Signal-to-Noise Ratio (S/N).

20
~~160~~
180
80
20

REMOTE SENSING AND GIS
Dr. R. Bharti

In remote sensing basically we use spectroradiometer right. In spectroradiometer, it is not necessary to touch your sample, so that means we can still validate our remote sensing definition. So, spectroradiometer is a device, which acquires reflected or absorbed or emitted energy depending upon the configuration of your instrument with respect to wavelength in very narrow and contiguous bands right.

So, remember since beginning I am telling you this has to be very narrow bands or channels and contiguous band. Parameters that describe the capability of a spectroradiometers are spectral range. So, let us understand this, what do we mean by spectral range, whether my instrument is sensitive between 0.4 to 2.5 micrometer or 2.5 to 16 micrometer or in any other wavelength range.

So, that is the spectral range of your instrument. So, because here we are using this parameter to define the capabilities of our instrument. So, first thing you have to look is what is the wavelength range in which that spectroradiometer is working. Next is spectral bandwidth. So, what is the spectral bandwidth means let us assume you are having 224 bands between this right and they are located like this very close to each other.

So, there won't be any gap, then only it will be spectroradiometer right. So, if assuming there is no gap in between right and this instrument is sensitive from 2 to 2.5 micrometer right and you can easily derive, so what will be the wavelength difference between 2 and 2.5, so 0.5 micrometer right. In 0.5 micrometer let us assume you are having 500 measurements. So, what will be the bandwidth of that? That you can easily calculate.

So that defines what is the starting and end range of your measurement, individual measurement right. So, this is something like your image band in multispectral right. So, here you do not have any gap. So, this is the first band, second band and third band and this has to be very narrow that will be the third point. In spectral sampling, we basically see how frequently it is going to acquire the sample.

So, in a minute or in a second how many sample it will acquire? So, let us say 100 measurement per second or 1000 measurement per second because these instruments are very sensitive and they can measure 100 measurement in one second and you will get only one average value or you can have this flexibility, you can save all the 100 measurements data and then you will get 100 values for that particular material across the wavelength and then you can do average your own.

Signal-to-noise ratio; so I guess you are familiar with this because I have already covered in many other sections. So, signal-to-noise ratio indicates what is the strength of your signal or quality of the signal. So, if signal is 100 let us assume this and noise is also 100 that means both are equal 50-50 but if you reduce this let us assume this is 20 that means your signal is 20% and 80% is your noise right.

Then what will happen? The acquired information or the saved data will have more of noise but if you just invert this one let us say 80 is your information from the target and 20 is noise that means this is a good condition because you have more information than your noise. So, that is why we use this signal-to-noise ratio to define the capability of our instrument. So, these 4 or 5 parameters, they are used for any given spectroradiometer to define their capabilities or their strength.

Whether they are capable in identifying the material information across the wavelength and what information or what quality you will get that is defined by these right.

(Refer Slide Time: 33:55)

SPECTRORADIOMETER

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

Spectroradiometer is an optical instrument that uses detectors to measure the distribution of radiation in visible near-infrared (VNIR) and short-wave infrared (SWIR) wavelength region.

REMOTE SENSING AND GIS

Dr. R. Bharti

So, spectroradiometer is an optical instrument that uses detector to measure the distribution of radiation in visible near-infrared and short-wave infrared wavelength region right and you can see this. So, these examples I have put here to just get you familiar with all these spectroradiometer. So, this is I am not supporting any of these companies and their products.

This is just for example, how they look like actually when you get this instrument in your lab right.

So, these are basically available in the market and they are used worldwide. So, whenever you are going to buy or whenever you are going to work with them, then you have to assess their capabilities and their strength or their weaknesses by your own right. So, again just read this one. This is the definition of a spectroradiometer.

(Refer Slide Time: 35:00)

SPECTRORADIOMETER

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

Enhanced view of the front panel with the fiber optic cable connector, port for remote trigger, and accessory power port for probe.

Back panel showing Ethernet connection, power switch, and power input jack.

REMOTE SENSING AND GIS

Dr. R. Bharti

And remember these spectroradiometers are basically very powerful because the same sensor has been placed in the space right. The same sensor you are getting for your lab, so the same technology if you use to measure the spectral signature on Earth and from the space and if you can correct the space measurement for the atmospheric component then you can definitely match these two spectras.

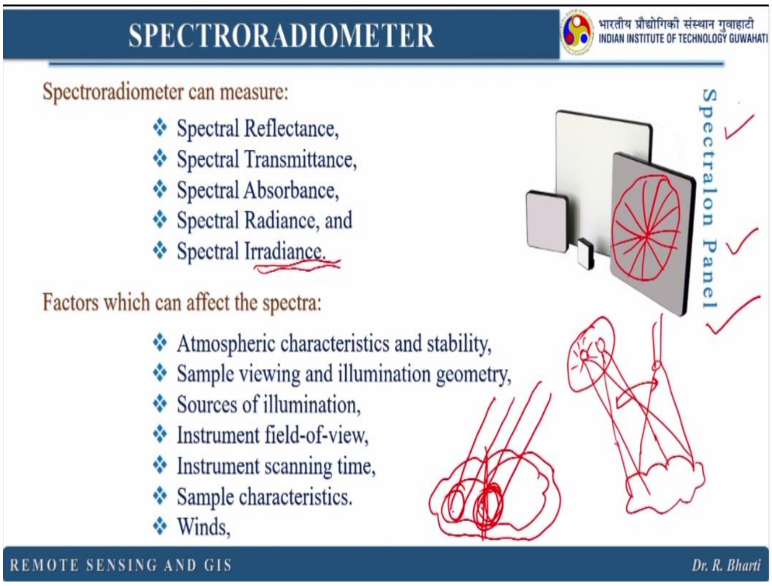
And then it will be very useful, you can upscale the ground information to the satellite scale and this is just again to get you familiar what are the things available in these instruments right. So, here this is the fibre optic cable through which your emitted or reflected energy will transferred to your detector right and they are fixed. Nowadays, it depends instrument to instrument how they have designed.

So, this is one example where your fibre optic cable is fixed and in this one most of them are having this internet connection facility. So, if you can have or you can connect with the network, then you can access this data set somewhere else remotely right and this is another attachment which comes with this spectroradiometer where you can focus your target because from here this pointer will sense the energy, reflected or emitted energy.

This is a fibre optic cable right and here you may have some field of view depending upon the instrument. So, let us assume here you have X field of view right and you are looking for a sample right. So, you have to decide what should be the h, then only it will cover this particular object and using this bubble you can make sure whether you are looking it vertically or it has some tilt angle right.

So, in these spectroradiometers what exactly we can measure, we can measure spectral reflectance.

(Refer Slide Time: 37:32)



SPECTRORADIOMETER

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

Spectroradiometer can measure:

- Spectral Reflectance,
- Spectral Transmittance,
- Spectral Absorbance,
- Spectral Radiance, and
- Spectral Irradiance.

Factors which can affect the spectra:

- Atmospheric characteristics and stability,
- Sample viewing and illumination geometry,
- Sources of illumination,
- Instrument field-of-view,
- Instrument scanning time,
- Sample characteristics.
- Winds,

REMOTE SENSING AND GIS

Dr. R. Bharti

And why we are calling it spectral reflectance because here we will have many bands, maybe 100s or 200s or 500s bands and in narrow bandwidth right. So, here you will have this kind of spectral signature right. So, suppose this is the one measurement, the next measurement will be just immediately after that. Why? Because you will not have any gap in between the measurements.

So, that is why you could able to produce this kind of spectra. So, that is why we are using this reflectance calculation for many wavelengths. So, that is why we are calling it spectral reflectance. Now, the next is spectral transmittance. Again, we can measure the transmittance, absorbance, then spectral radiance obviously because radiance will be captured and then spectral irradiance because irradiance is required to convert your radiance into transmittance, absorbance or reflectance right.

So, this is your incoming information or incoming light falling on your surface right. So, these are basically spectralon panel. So, these are actually having this capability to reflect equal amount of light in all the direction right. So, they are isotropic in nature. If you use this particular spectralon panel to measure your irradiance, then what we call them, we call them downwelling radiance, remember okay.

Now, factors which can affect these spectra, whatever we measure through our spectroradiometer does not matter which brand you are using right. So, what are the factors which plays very critical role. Atmospheric characteristics and stability; this is very important and this is required throughout the measurement. So, atmospheric characteristics means you need to know what kind of component or what kind of atmospheric constituents are present right.

And then stability means there should not be very strong wind or the atmosphere should not change drastically during your measurement right. Next is sample viewing and illumination geometry. So, if you are having this instrument and let us assume this is the opening of your fibre optic cable and you are looking vertically with some field of view and this is your sample right.

So, the viewing geometry that means your source is here somewhere right or you must be using some other source maybe halogen lamp or sun. So, this geometry should not get changed during the measurement right. So, this is very important, that is the source sensor geometry and then source of illumination. So, if you are using this sun as a source, then with time the intensity changes.

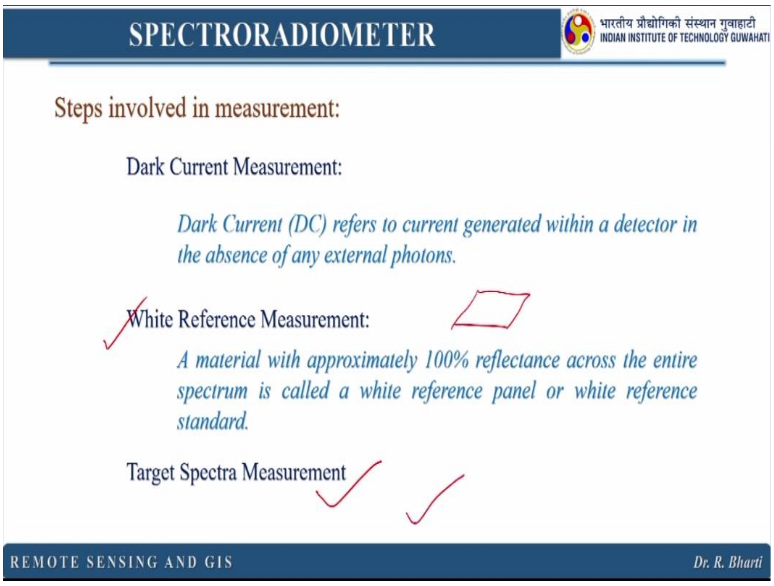
So, you have to take care of that. So, you should not plan for the whole day experiment. So, you plan accordingly so that one measurement can be over between very short period of time. Then, instrument field-of-view; so you should not change the field of view of your fibre optic cable within the or between the measurement right. Instrument scanning time; so scanning time is sampling rate, so if you are using 100 samples per second, then it should be consistent throughout the measurement.

Then, sample characteristics because this can severely affect your spectra. So, suppose if this is your target and if you are looking from here, the information will be something different than here. Why? Because in case if you are looking for a rock type, then the composition is not uniform from here, it will be different, here it will be different right. So, there will be minor change and that could influence your spectra.

So, you may get different spectral signature for a given target when you change the position of the acquisition right. So, this is we called field of view that sample falling within field of view and the last one which is very important wind. So, wind whether you have a strong wind or calm environment that also matters a lot here. So, you should make sure that you should not have strong wind during the measurement right.

Spectroradiometers are very sophisticated instruments, so you need to follow sets of procedure and you cannot avoid them.

(Refer Slide Time: 43:06)



SPECTRORADIOMETER

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

Steps involved in measurement:

Dark Current Measurement:

Dark Current (DC) refers to current generated within a detector in the absence of any external photons.

White Reference Measurement:

A material with approximately 100% reflectance across the entire spectrum is called a white reference panel or white reference standard.

Target Spectra Measurement

REMOTE SENSING AND GIS

Dr. R. Bharti

Why? Because if you change the way you calibrate or you measure the sample spectra, it will influence your final result right. So, in this spectroradiometer basically we use this dark current and what is this dark current. So, suppose assuming this is my spectroradiometer and this is the fibre optic cable. So, all the instrument components are actually here right. They are lying in their own position.

And since power is involved because we will start this instrument with battery power or maybe AC power right and over the time all the component will get heated and they will also produce some photons right. So, it is recommended that whenever you go for measurement, you should keep your instrument on for some time. Then, they will saturate and they will start emitting their own energy and that will be consistent throughout the measurement right.

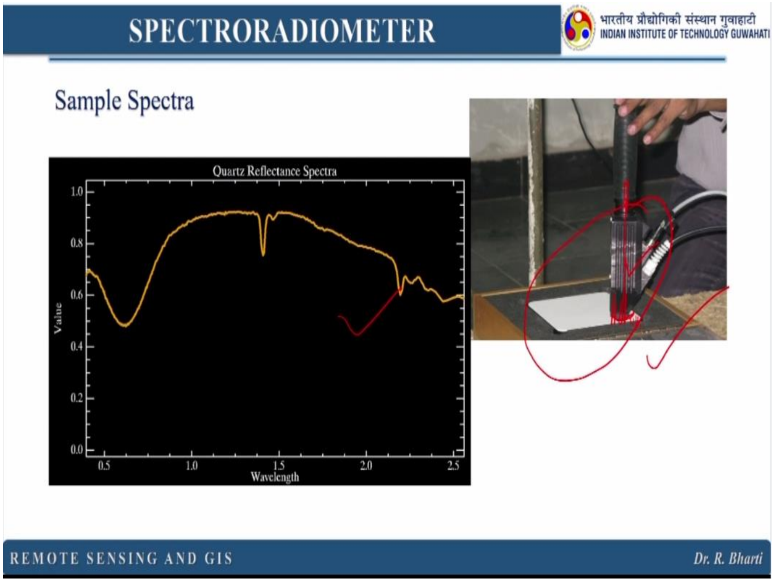
So, what we do, we close this slit and we don't allow any light or any photons to pass from our atmosphere to inside this instrument and then here we measure what is the photon or what is the energy which is produced by the instrument itself right and that we actually measure and that we subtract from our measurement. So, dark current refers to the current generated within a detector in the absence of any external photons.

So, we close the external slit and then measure the dark current then open again for our measurement. Then, white reference measurement; why do we need that, white reference is your spectralon panel. So, that is used to measure your irradiance because when you focus your fibre optic cable towards sun, it will get saturated right. So, it would not work, so what we do is instead of focusing it directly to sun, we use indirectly where sun is illuminating the surface, there we keep our panel and then this panel has a property of 100% reflectance right.

So, it will reflect equal amount of light in all the direction right and that will give you the downwelling radiance. So, here in white reference measurement, a material with approximately 100% reflectance across the entire spectrum is called a white reference panel or white reference standard. Using this white reference measurement, you can estimate the reflected energy from your target right.

And the last one is target sample measurement. So, target or sample measurement means the radiance measurement or the reflected energy from your surface or from your target that will be measured the same way we measure this white reference measurement but here we use spectralon panel but here we will remove that and we will directly focus on our sample right.

(Refer Slide Time: 46:50)



SPECTRORADIOMETER

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

Sample Spectra

REMOTE SENSING AND GIS

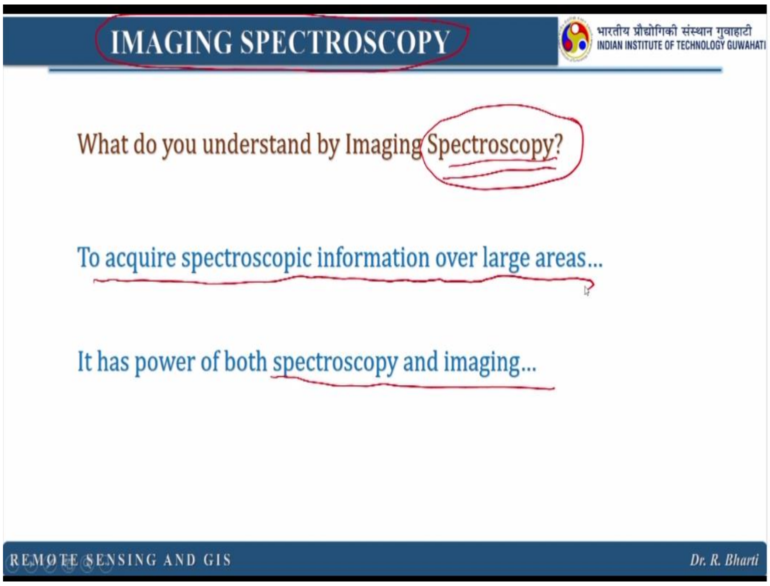
Dr. R. Bharti

And once you do that, then you will have this kind of spectral signature and here this is one example where you have a handheld pro right. So, this is contact pro where the sources also inside this right and this is illuminating this particular surface and here we keep this in close contact and the amount of light which is reflected from this that will tell you the amount of light incident on the target.

Why? Because the same handheld pro will be put on your sample and then we will measure the reflected and here why do we have design this kind of pro, to avoid the atmospheric constituents because here there is no atmosphere coming into the picture. So, when you have that you do not have 1.4 or 1.9 micrometer water vapour, atmospheric or terrestrial water vapour signature right.

So, this is when you want to identify or when you want to capture the real spectra of your target without any atmospheric intervention right. So, now you have understood this spectroradiometer part. So, how do we generate hyperspectral remote sensing data using a spectroradiometer right and then we analyze those spectral signatures that is why we are calling them into the spectroscopy category right but using this spectroradiometer you cannot produce an image right.

(Refer Slide Time: 48:39)



IMAGING SPECTROSCOPY

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

What do you understand by Imaging Spectroscopy?

To acquire spectroscopic information over large areas…

It has power of both spectroscopy and imaging…

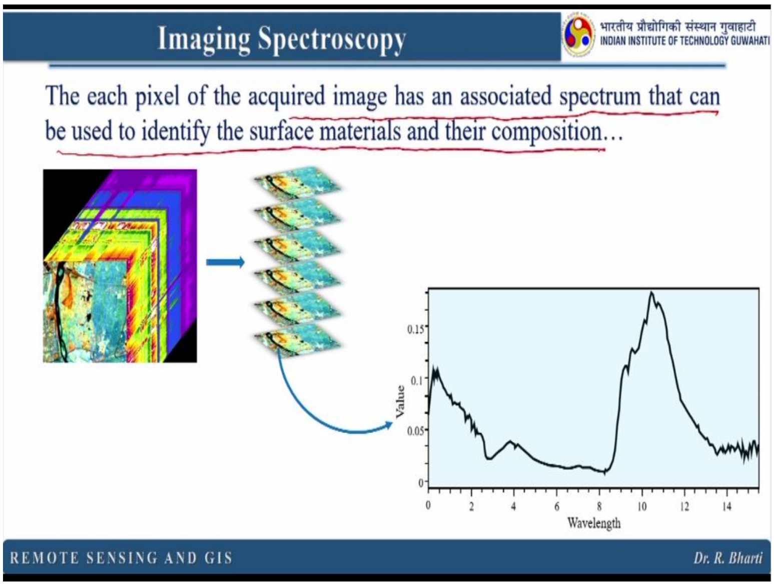
REMOTE SENSING AND GIS

Dr. R. Bharti

So, here that new term which is imaging spectroscopy has been introduced. What do you mean by this imaging spectroscopy? So, you have already understood this spectroscopy component using spectroradiometer and there are many other instruments which are actually used to derive the absorbance or transmittance or reflectance or emitted spectra right.

And once we analyze them that is known as spectroscopy but in imaging spectroscopy what extra information you will have, you will have images right plus spectral information. So, it has both spectroscopy and imaging power and it will be to acquire spectroscopic information over large area. So, that is actually your imaging spectroscopy.

(Refer Slide Time: 49:36)



Imaging Spectroscopy

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

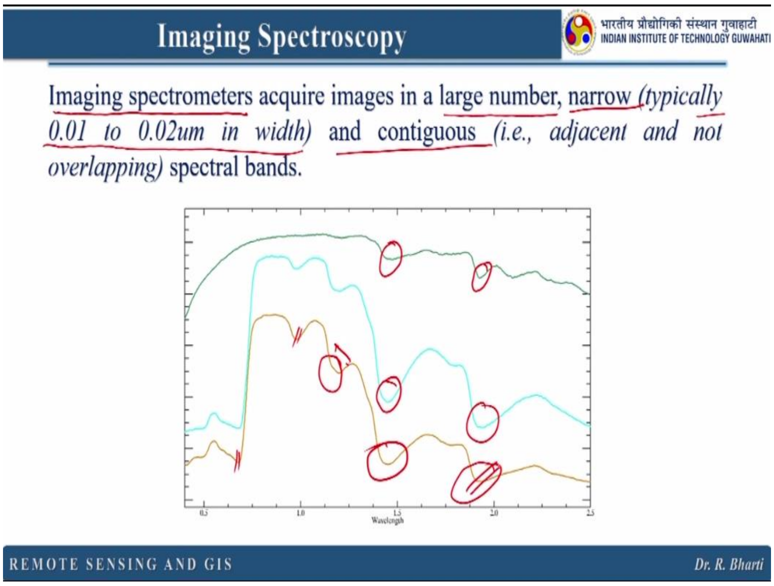
The each pixel of the acquired image has an associated spectrum that can be used to identify the surface materials and their composition…

REMOTE SENSING AND GIS

Dr. R. Bharti

So, in imaging spectroscopy, we have generated the hyperspectral image where we have narrow band, contiguous spectra right. So, the each pixel of the acquired image has an associated spectrum that can be used to identify the surface material and their composition right.

(Refer Slide Time: 50:00)



Imaging Spectroscopy

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

Imaging spectrometers acquire images in a large number, narrow *(typically 0.01 to 0.02um in width)* and contiguous *(i.e., adjacent and not overlapping)* spectral bands.

REMOTE SENSING AND GIS

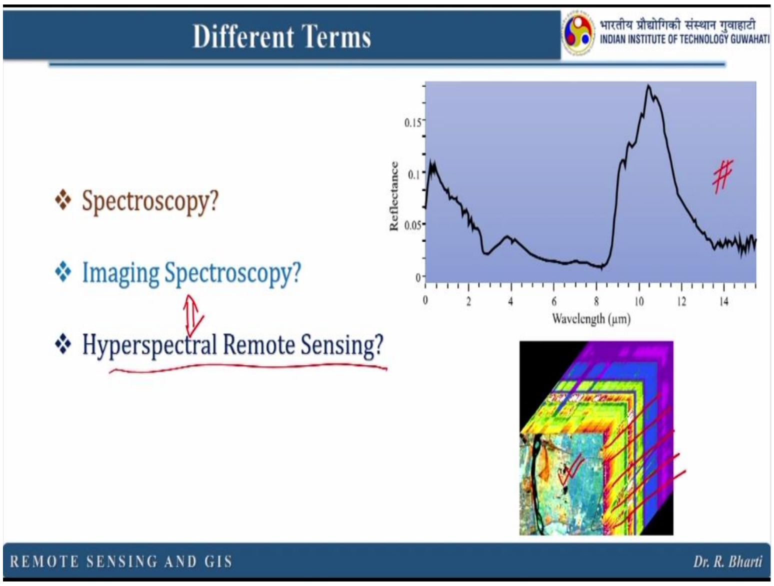
Dr. R. Bharti

Imaging spectrometers acquires images in a large number, narrow and contiguous spectral band. So, it is very important just to understand this one. So, here initially we had spectroradiometers. Now, we are having imaging spectrometers, that term has been changed. Why? Because here we are going to produce images. So, here we will produce large number, narrow and contiguous bands right.

So, typically it is in the order of 0.01 to 0.02 micrometer in bandwidth right. So, just imagine how small they are right. So, once you have that you can definitely capture all the information coming from the surface. So, then you could able to identify all the absorption features which are produced by your target. If you have little bit of the gap between the measurements, then you might have missed this particular, this particular, or this particular absorption feature.

But since our imaging spectrometer or spectroradiometers are designed to capture large number, narrow and contagious bands. We are able to identify all these absorption features right.

(Refer Slide Time: 51:30)



Different Terms

- Spectroscopy?
- Imaging Spectroscopy?
- Hyperspectral Remote Sensing?

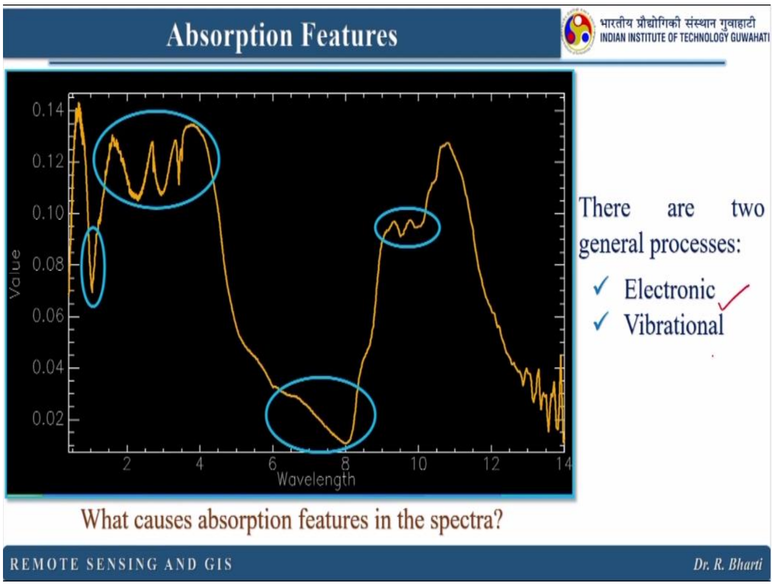
REMOTE SENSING AND GIS

Dr. R. Bharti

So, there are different terms which are used in remote sensing so like spectroscopy. So, spectroscopy basically we derive spectral information and then we analyze them right. So, this is only related to your spectra right. Now, next is imaging spectroscopy. So, here you have hypercube, this is the image cube of this hyperspectral data where these are your stacked bands which is behind this main image right.

And next term is hyperspectral remote sensing, so basically these two are same. So, sometimes you may find people are referring imaging spectroscopy; sometimes people will call hyperspectral remote sensing. So, do not get confused both are same right.

(Refer Slide Time: 52:34)



Absorption Features

There are two general processes:

- ✓ Electronic
- ✓ Vibrational

What causes absorption features in the spectra?

REMOTE SENSING AND GIS

Dr. R. Bharti

So, let us understand what causes absorption feature in the spectra. So, as I told you the internal atomic structure and composition that actually controls this absorption feature. So, whether how much amount of energy they will absorb at a particular wavelength that is decided by the composition and their internal atomic structure right. So, because of that we could able to get all this spectral information and these are basically your absorption bands.

So, here the shape, size and position they are very important, shape, size means shape is whether this is broad absorption feature or this is very narrow right and whether they have any doublet this kind of a spectral feature right. Then, size is clear, shape is clear. Now position, whether they are coming at this particular wavelength, this particular wavelength, this particular wavelength, this particular wavelength that actually tells about the material whether it is x, y or z right.

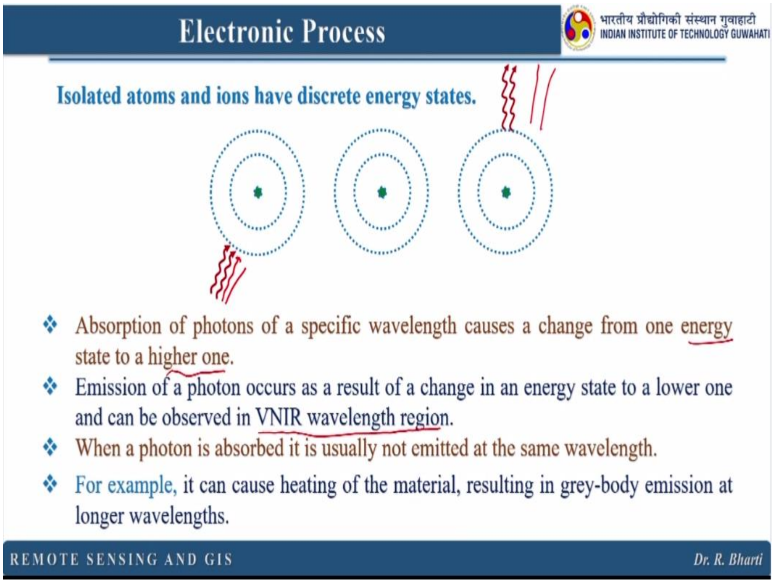
So, that is why I have mentioned this is basically your fingerprint right. So, it is unique for all the materials, so here not necessary, you will find only one absorption feature and you can say this is x. So, you can have set of absorption feature which can be used for x, y or z material. So, because in nature there are n number of materials right. So, for them absorption feature cannot be unique by identifying only one particular absorption feature.

So, what you have to do, you have to look for different sets so like maybe if in one example you can just see this, may be here you are getting one absorption feature right and the next is coming here. So, if you find these two, that tells about the x material right. So, it is very important to study this spectral behaviour and their composition of the material.

So, accordingly you have to identify what is the absorption feature for x, whether it has only one absorption feature in this particular wavelength range or it has multiples of absorption feature which should be studied together, then only we can say this is x, y and z. So, there are two different processes which is happening right and because of that only we are getting these spectral signatures.

So, one is electronic and the next one is vibrational process. So, if you know what is the electronic and vibrational process happening within your sample, then you can identify or you can directly tell at what wavelength they will give the spectral signature right.

(Refer Slide Time: 55:55)



Electronic Process

Isolated atoms and ions have discrete energy states.

- Absorption of photons of a specific wavelength causes a change from one energy state to a higher one.
- Emission of a photon occurs as a result of a change in an energy state to a lower one and can be observed in VNIR wavelength region.
- When a photon is absorbed it is usually not emitted at the same wavelength.
- For example, it can cause heating of the material, resulting in grey-body emission at longer wavelengths.

REMOTE SENSING AND GIS

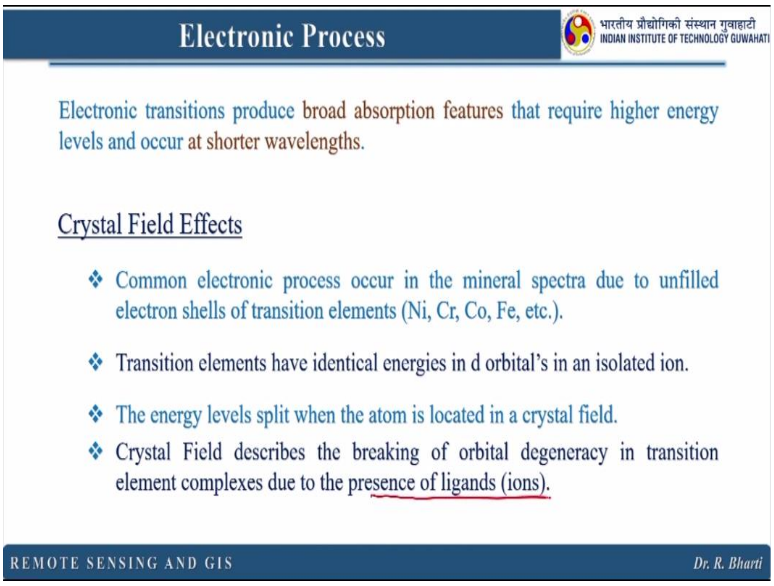
Dr. R. Bharti

Now, let us start with the electronic process. In electronic process, basically isolated atoms and ions have discrete energy states and absorption of photons of a specific wavelength causes a change from one energy state to another one right. So, the next energy state will be the higher one because it has some extra energy. Emission of a photon occurs as a result of change in an energy state to a lower one and can be observed in VNIR wavelength region.

So, here you can see we have given some extra energy right and that has resulted to change the energy state to the higher one and then ultimately what will happen, it will settle down and then it will re-emit or it will release the extra energy and that can be observed in VNIR wavelength region. When a photon is absorbed, it is usually not emitted at the same wavelength.

So, as I told you earlier also, suppose if it is observed it will be admitted in the longer wavelength region right. For example, it can cause heating of the material resulting in gray body emission at longer wavelength.

(Refer Slide Time: 57:17)



Electronic Process

Electronic transitions produce broad absorption features that require higher energy levels and occur at shorter wavelengths.

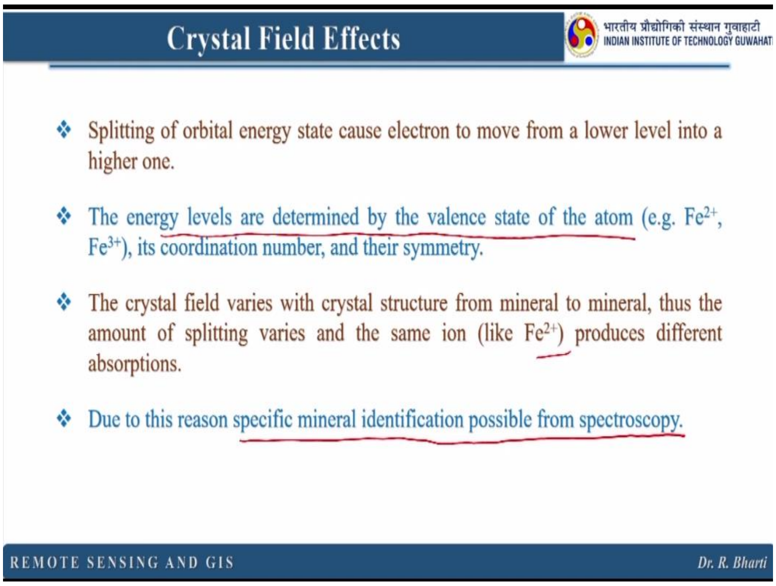
Crystal Field Effects

- Common electronic process occur in the mineral spectra due to unfilled electron shells of transition elements (Ni, Cr, Co, Fe, etc.).
- Transition elements have identical energies in d orbital's in an isolated ion.
- The energy levels split when the atom is located in a crystal field.
- Crystal Field describes the breaking of orbital degeneracy in transition element complexes due to the presence of ligands (ions).

Electronic transition produce broad absorption feature that requires high energy level and occur at shorter wavelength. So, remember these electronic processes result in short wavelength absorption features right. So, if your material is sensitive to this electronic process then you will find absorption feature in the shorter wavelength. So, the first one is crystal field effect.

This is inside this electronic process. So, what is happening here, the common electronic process occur in the mineral spectra due to unfilled electron shells of transition element like nickel, chromium, cobalt, iron etc. Transition elements have identical energy in d orbitals in an isolated ion right. The energy levels split when the atom is located in a crystal field. Crystal field describes the breaking of orbital degeneracy in transition element complexes due to presence of ligand right.

(Refer Slide Time: 58:32)



Crystal Field Effects

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

- Splitting of orbital energy state cause electron to move from a lower level into a higher one.
- The energy levels are determined by the valence state of the atom (e.g. Fe^{2+}, Fe^{3+}), its coordination number, and their symmetry.
- The crystal field varies with crystal structure from mineral to mineral, thus the amount of splitting varies and the same ion (like Fe^{2+}) produces different absorptions.
- Due to this reason specific mineral identification possible from spectroscopy.

REMOTE SENSING AND GIS

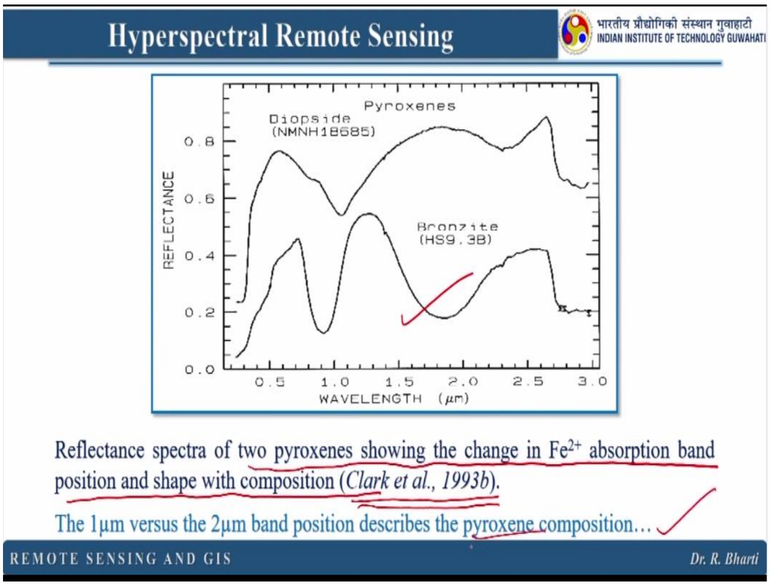
Dr. R. Bharti

Splitting of orbital energy state cause electrons to move from a lower level into a higher one. The energy levels are determined by the valence state of the atom, for example whether it is Fe^{2+} or Fe^{3+} its coordination number and their symmetry right. So, the energy levels are determined by the valence state of the atom. So, it is different for 2+ iron or Fe^{3+} right.

The crystal field varies with crystal structure from mineral to mineral, thus the amount of splitting varies and the same ion like Fe^{2+} produce different absorption. So, now it is different for Fe^{2+} and 3+, so for the same ion you have different valence state right and because of that also you are getting different position of the spectral feature. So, just imagine how accurate information it can give you right.

Due to this reason, specific mineral identification possible from spectroscopy. So, this is one example where I have put iron. So, iron does not matter whether it is from the same ion but the valence state is different. So, it is producing different absorption feature.

(Refer Slide Time: 59:59)



Hyperspectral Remote Sensing

Reflectance spectra of two pyroxenes showing the change in Fe^{2+} absorption band position and shape with composition (*Clark et al., 1993b*).

The 1μm versus the 2μm band position describes the pyroxene composition…

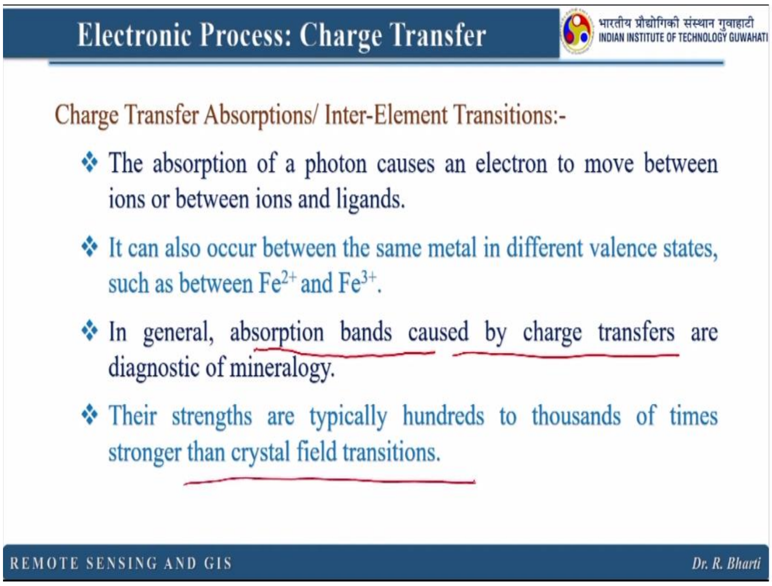
REMOTE SENSING AND GIS

Dr. R. Bharti

So, here you can see this example where reflectance spectra of two pyroxenes shows the change in Fe^{2+} absorption bands right position and shape with composition. This I have taken from this reference Clark et al 1993b right. The 1 micrometer versus the 2 micrometer band position describes the pyroxene composition. So, remember this 1 micrometer versus 2 micrometer band position describes the pyroxene composition.

Why? Now you have to analyze these spectra and you can just correlate with your band math right band ratios concept. Now, you see why we can use this particular combination to highlight this pyroxene.

(Refer Slide Time: 01:00:58)



Electronic Process: Charge Transfer

Charge Transfer Absorptions/ Inter-Element Transitions:-

- The absorption of a photon causes an electron to move between ions or between ions and ligands.
- It can also occur between the same metal in different valence states, such as between Fe^{2+} and Fe^{3+}.
- In general, absorption bands caused by charge transfers are diagnostic of mineralogy.
- Their strengths are typically hundreds to thousands of times stronger than crystal field transitions.

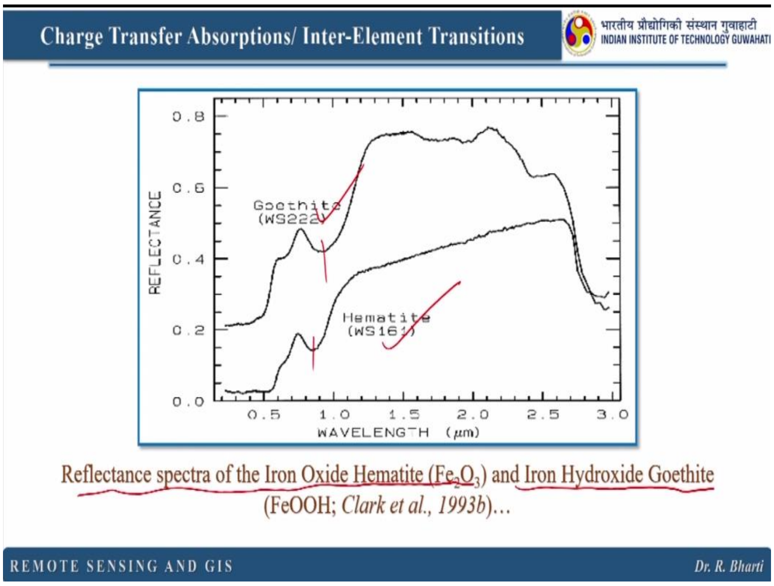
REMOTE SENSING AND GIS

Dr. R. Bharti

The next process in electronic is charge transfer. So, this is known as charge transfer absorption or inter-element transition right. So, the absorption of a photon causes an electron to move between ions or between ions and ligands right. It can also occur between the same metal in different valence state such as between Fe^{2+} and Fe^{3+}. In general, absorption bands caused by charge transfer are diagnostic of mineralogy.

So, here it is very important using this absorption band caused by this charge transfer can be used in mineralogy. Now, there is a slight change in mineral composition and we have a new name right in Earth Sciences in G eology. So, just imagine how accurate information it can give you and it is giving us so because of that reason hyperspectral remote sensing or imaging spectroscopy is very useful. Their strengths are typically 100s to 1000s of times stronger than crystal field transition right.

(Refer Slide Time: 01:02:07)



Charge Transfer Absorptions/ Inter-Element Transitions

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

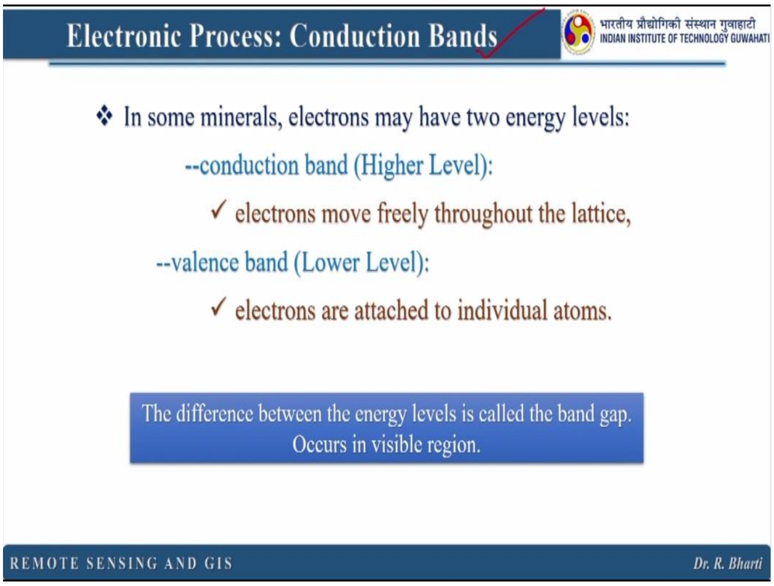
Reflectance spectra of the Iron Oxide Hematite (Fe_2O_3) and Iron Hydroxide Goethite (FeOOH; *Clark et al., 1993b*)...

REMOTE SENSING AND GIS

Dr. R. Bharti

Here, this is the example where you have reflectance spectra of iron oxide hematite and iron hydroxide goethite. Now, here you can see for goethite and hematite, the spectral signature has been changed right with the slight change in the composition.

(Refer Slide Time: 01:02:31)



Electronic Process: Conduction Bands

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

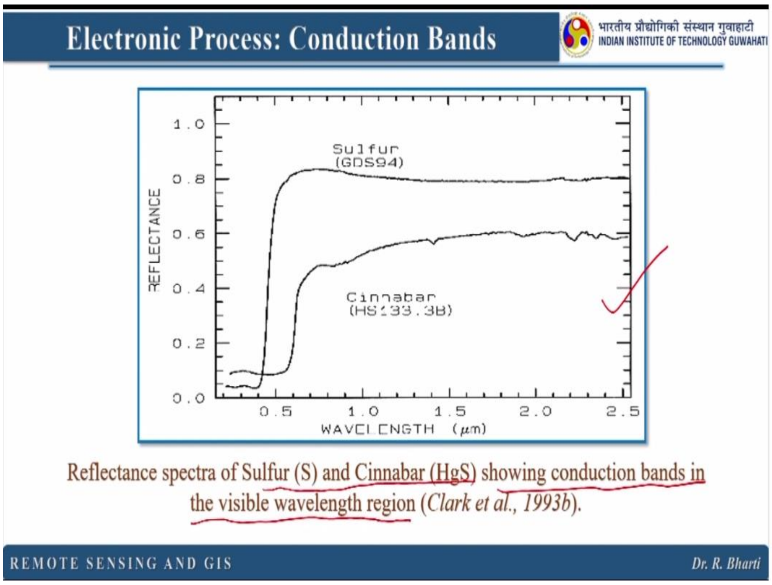
- In some minerals, electrons may have two energy levels:
  - --conduction band (Higher Level):
    - ✓ electrons move freely throughout the lattice,
  - --valence band (Lower Level):
    - ✓ electrons are attached to individual atoms.

The difference between the energy levels is called the band gap. Occurs in visible region.

REMOTE SENSING AND GIS | *Dr. R. Bharti*

In another process where we have this conduction band, here in some mineral, electrons may have two energy levels right. It is also possible, so the conduction band where we know that this is the higher level, the electrons move freely throughout the lattice whereas in the valence band which is the lower level and electrons are attached to individual atom right and the difference between the energy levels is called the band gap and it occurs only in visible region right.

(Refer Slide Time: 01:03:08)



Electronic Process: Conduction Bands

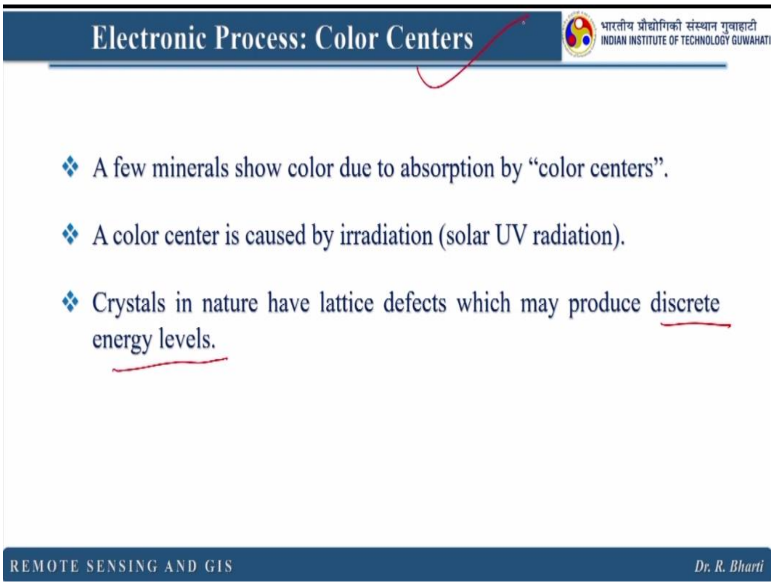
भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

Reflectance spectra of Sulfur (S) and Cinnabar (HgS) showing conduction bands in the visible wavelength region (*Clark et al., 1993b*).

REMOTE SENSING AND GIS | *Dr. R. Bharti*

So, this is the example of conduction band where the sulfur and cinnabar both are used showing conduction band in the visible wavelength region. So, here you can see how they are looking differently in the spectra right.

(Refer Slide Time: 01:03:27)



Electronic Process: Color Centers

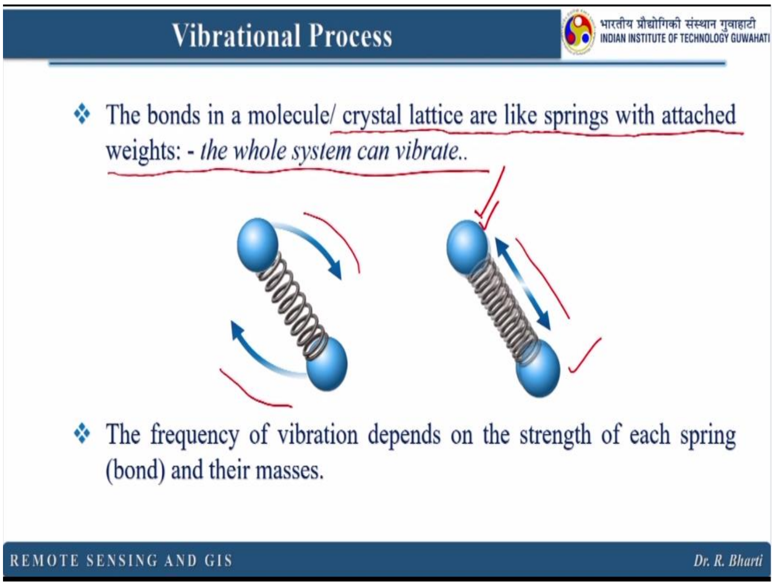
भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

- A few minerals show color due to absorption by "color centers".
- A color center is caused by irradiation (solar UV radiation).
- Crystals in nature have lattice defects which may produce discrete energy levels.

REMOTE SENSING AND GIS
Dr. R. Bharti

The next one is color center, a few minerals shows color due to absorption by color center right. A color center is caused by irradiation and that is caused by solar UV radiation right. I hope you know this that in nature there are minerals which are available in some defective form right. So, if you have defects in the lattice of those minerals or those crystals that can result in producing different energy levels right. So, this is discrete energy level that can be caused by this color center.

(Refer Slide Time: 01:04:15)



Vibrational Process

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

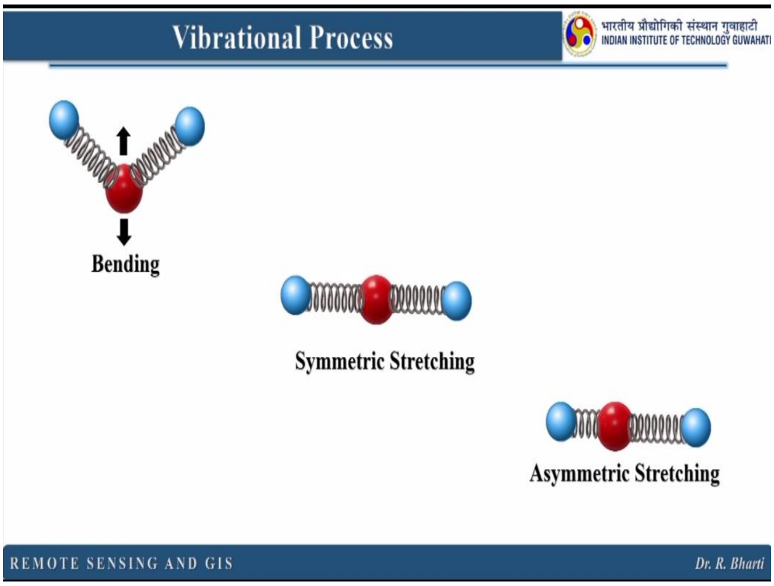
- The bonds in a molecule/ crystal lattice are like springs with attached weights: - *the whole system can vibrate..*
- The frequency of vibration depends on the strength of each spring (bond) and their masses.

REMOTE SENSING AND GIS
Dr. R. Bharti

Let us see the next part of this process that is the vibrational process where we study the molecular bonds right. So, the bond in the molecules are crystal lattice are like spring with attached weight. The whole system can vibrate. So, here if you visualize them, it will be like two molecules attached with a spring like structure and they are vibrating, so either in this direction right or here also, so it is possible.

So, the frequency of vibration depends on the strength of the each spring or bond and their masses. So, suppose if this is heavier and this is lighter than this want to move and this will vibrate and if the spring is very soft, then it will vibrate more but if the spring is basically very strong, then it will vibrate less. So, the spring is basically the bond which is present in the molecule whereas these masses are actually elements. So, here it depends on these two, what is the bond and what is their masses right.

(Refer Slide Time: 01:05:29)



Vibrational Process

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

Bending

Symmetric Stretching

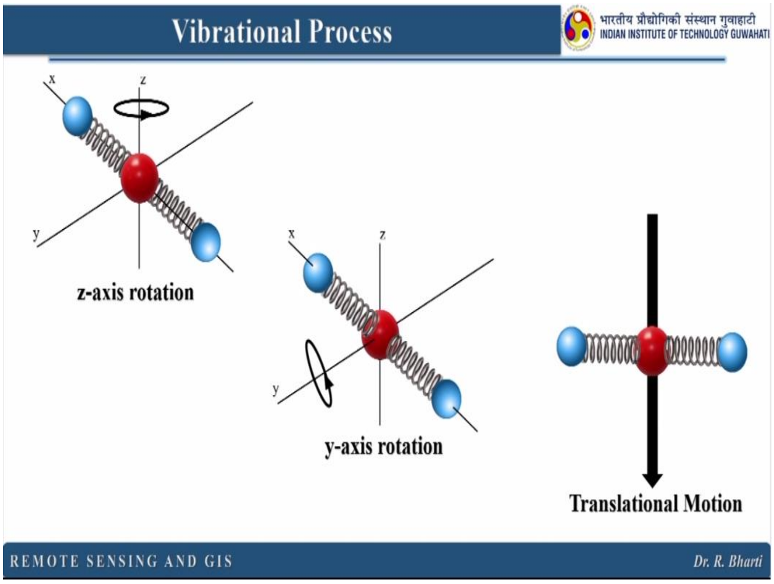
Asymmetric Stretching

REMOTE SENSING AND GIS

Dr. R. Bharti

So, here you can see this vibrational process can result in bending, systematic stretching and asymmetric stretching. So, I have animation phase for you that you can see all these things in the better way.

(Refer Slide Time: 01:05:46)



Vibrational Process

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

z-axis rotation

y-axis rotation

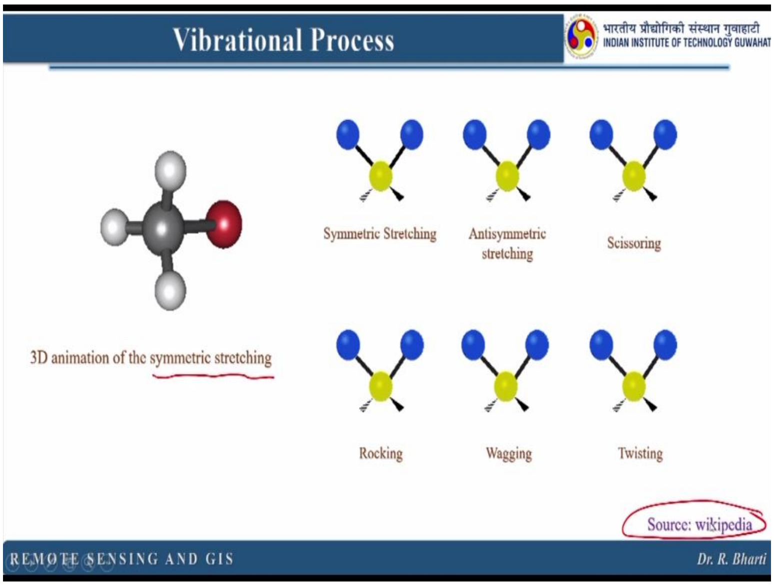
Translational Motion

REMOTE SENSING AND GIS

Dr. R. Bharti

Here, this is z-axis rotation, this is y-axis rotation and this is translation motion right. So, let us visualize this with the help of this animation.

(Refer Slide Time: 01:05:58)



Vibrational Process

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

3D animation of the symmetric stretching

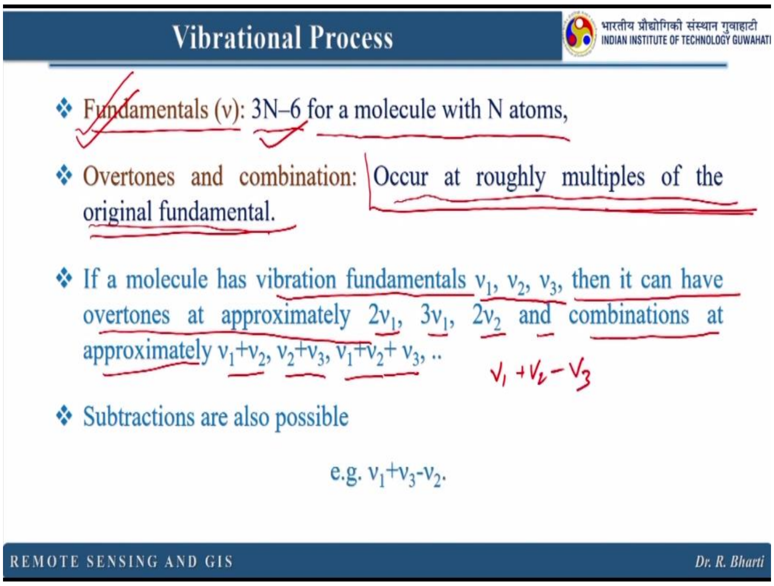
Source: wikipedia

REMOTE SENSING AND GIS

Dr. R. Bharti

So, here this is for the systematic stretching. So, here you can see how they are vibrating with each other right. The next one is symmetric stretching and third one is scissoring, then fourth one is rocking, then wagging and the last one I have is twisting right. So, this is available in Wikipedia, you can visit this Wikipedia, they have very beautifully defined and made this animation. So, let us thank Wikipedia and whoever has put that information in the Wikipedia.

(Refer Slide Time: 01:06:46)



Vibrational Process

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

- Fundamentals (v): 3N–6 for a molecule with N atoms,
- Overtones and combination: Occur at roughly multiples of the original fundamental.
- If a molecule has vibration fundamentals v_1, v_2, v_3, then it can have overtones at approximately $2v_1$, $3v_1$, $2v_2$ and combinations at approximately v_1+v_2, v_2+v_3, $v_1+v_2+v_3$, ..

$v_1 + v_2 - v_3$

- Subtractions are also possible

e.g. $v_1+v_3-v_2$.

REMOTE SENSING AND GIS

Dr. R. Bharti

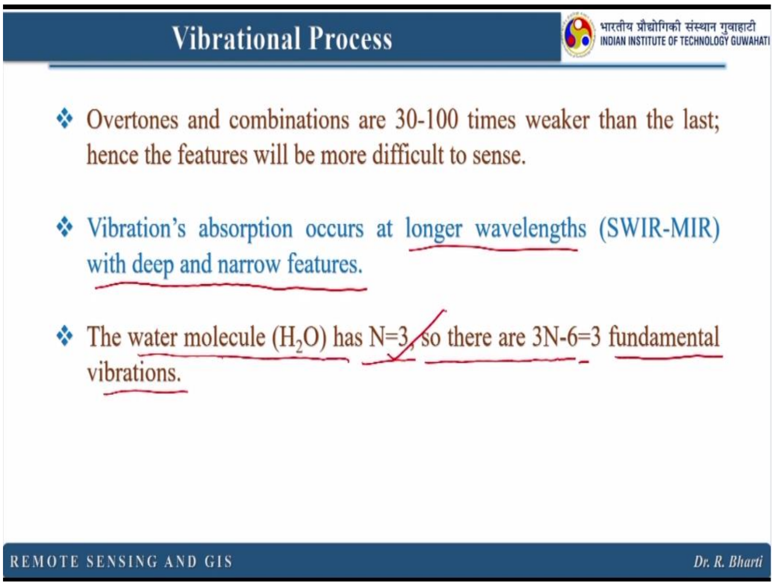
So, in vibrational process, the fundamental frequency that is this nu, so it is basically 3N - 6 for a molecule with N items. So, this is very important. This is a rule to identify how many fundamental frequency we can have for a given target right and overtone and combination;

these are basically it occurs at roughly multiples of original fundamentals, so multiples of fundamental.

So, if a molecule has vibrational fundamentals like v1, v2, v3 then it can have overtone at approximately 2v1, 3v1, 2v2 and combination at approximately v1 + v2, v2 + v3, v1 + v2 + v3. So, these are few examples right. So, what I mean to say the fundamental frequencies can be identified using this formula whereas the overtone and combination can be estimated by this information that they occur roughly multiples of the original fundamentals right.

So, subtraction is also possible here, so here you can have v1 + v2 – v3 right. So, for example here you have.

(Refer Slide Time: 01:08:22)



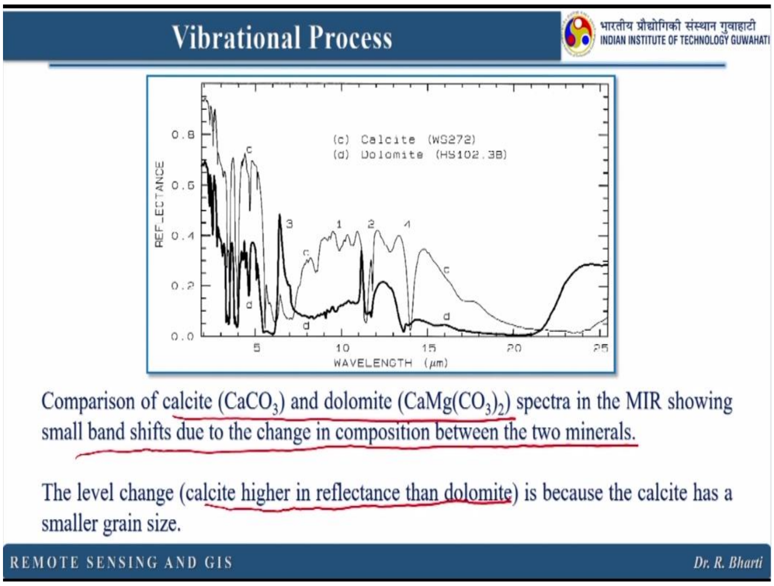
Vibrational Process

- Overtones and combinations are 30-100 times weaker than the last; hence the features will be more difficult to sense.
- Vibration's absorption occurs at longer wavelengths (SWIR-MIR) with deep and narrow features.
- The water molecule (H_2O) has N=3, so there are 3N-6=3 fundamental vibrations.

Now, the overtone and combinations are 30 to 100 times weaker than the last right. Hence, the features will be more difficult to sense. Vibrational absorption occurs at longer wavelength with deep and narrow features. So, remember electronic process gives absorption feature in the shorter wavelength whereas the vibrational process results absorption feature in the longer wavelength right.

The water molecule that is H_2O has N=3, so there are 3N - 6 which is basically 3. So, the water molecule will have fundamental frequency in 3 positions right.

(Refer Slide Time: 01:09:11)



Vibrational Process

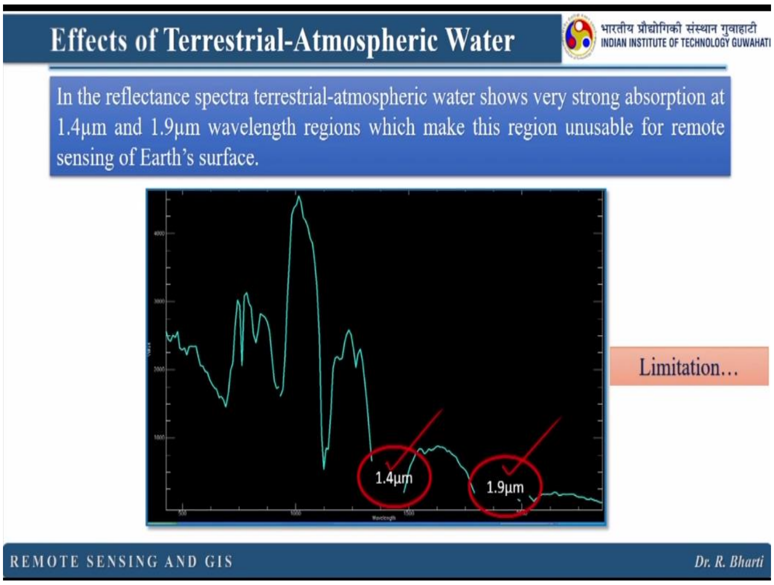
Comparison of calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$) spectra in the MIR showing small band shifts due to the change in composition between the two minerals.

The level change (calcite higher in reflectance than dolomite) is because the calcite has a smaller grain size.

REMOTE SENSING AND GIS Dr. R. Bharti

So, here this is one example where you have this calcite and dolomite. So, here you are seeing the small band shifts due to change in the composition between these two minerals right. The level change is because of the calcite has a small grain size right and calcite higher in reflectance than dolomite. So, the reflectance will be high for the calcite and the effect of terrestrial or atmospheric water in the hyperspectral remote sensing data.

(Refer Slide Time: 01:09:41)



Effects of Terrestrial-Atmospheric Water

In the reflectance spectra terrestrial-atmospheric water shows very strong absorption at 1.4µm and 1.9µm wavelength regions which make this region unusable for remote sensing of Earth's surface.

Limitation…

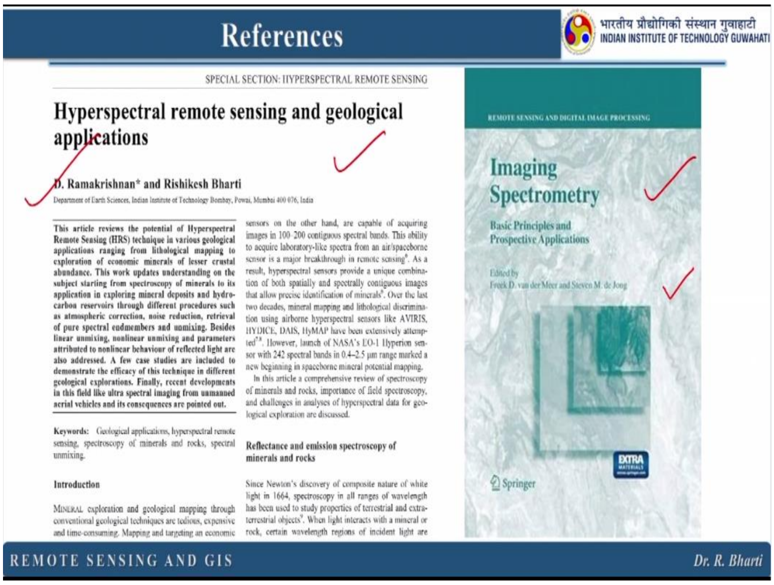
REMOTE SENSING AND GIS Dr. R. Bharti

Suppose, if you are generating a hyperspectral data from space what information or what error this terrestrial-atmospheric water can introduce right. So, in the spectra terrestrial-atmospheric water shows very strong absorption at 1.4 and 1.9 micrometer wavelength region which makes this region unusable for remote sensing of earth surface. Remember, this is I am telling when your target is surface but for atmospheric people, this error can be the data right.

So, here if you see the spectra which is acquired from this space, so basically we have captured the hyperspectral image. Then, we have generated the spectral signature of a given pixel and there you can easily find the missing data. Why? Because we have removed the noises, so initially it was here it was like this right. That we have removed because our target is different, our objective is different.

So, we do not have to analyze them. So, we can simply remove them and rest data we can analyze but for a person, who is interested to study this terrestrial or atmospheric water, then he should remove all this right and he should keep only the 1.4 and 1.9 information right and this will help him to study or identify the concentration of terrestrial or atmospheric water. This can be considered as limitation or advantage depending upon our application.

(Refer Slide Time: 01:11:41)



References

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

SPECIAL SECTION: HYPERSPECTRAL REMOTE SENSING

Hyperspectral remote sensing and geological applications

D. Ramakrishnan* and Rishikesh Bharti

Department of Earth Sciences, Indian Institute of Technology Bombay, Powai, Mumbai 400 076, India

This article reviews the potential of Hyperspectral Remote Sensing (HRS) technique in various geological applications ranging from lithological mapping to exploration of economic minerals of lesser crustal abundance. This work updates understanding on the subject starting from spectroscopy of minerals to its application in exploring mineral deposits and hydrocarbon reservoirs through different procedures such as atmospheric correction, noise reduction, retrieval of pure spectral endmembers and unmixing. Besides linear unmixing, nonlinear unmixing and parameters attributed to nonlinear behaviour of reflected light are also addressed. A few case studies are included to demonstrate the efficacy of this technique in different geological explorations. Finally, recent developments in this field like ultra spectral imaging from unmanned aerial vehicles and its consequences are pointed out.

Keywords: Geological applications, hyperspectral remote sensing, spectroscopy of minerals and rocks, spectral unmixing.

Introduction

MINERAL exploration and geological mapping through conventional geological techniques are tedious, expensive and time-consuming. Mapping and targeting an economic sensors on the other hand, are capable of acquiring images in 100–200 contiguous spectral bands. This ability to acquire laboratory-like spectra from an air/spaceborne sensor is a major breakthrough in remote sensing[6]. As a result, hyperspectral sensors provide a unique combination of both spatially and spectrally contiguous images that allow precise identification of minerals[6]. Over the last two decades, mineral mapping and lithological discrimination using airborne hyperspectral sensors like AVIRIS, HYDICE, DAIS, HyMAP have been extensively attempted[7,8]. However, launch of NASA's EO-1 Hyperion sensor with 242 spectral bands in 0.4–2.5 μm range marked a new beginning in spaceborne mineral potential mapping.

In this article a comprehensive review of spectroscopy of minerals and rocks, importance of field spectroscopy, and challenges in analyses of hyperspectral data for geological exploration are discussed.

Reflectance and emission spectroscopy of minerals and rocks

Since Newton's discovery of composite nature of white light in 1664, spectroscopy in all ranges of wavelength has been used to study properties of terrestrial and extra-terrestrial objects[9]. When light interacts with a mineral or rock, certain wavelength regions of incident light are

REMOTE SENSING AND DIGITAL IMAGE PROCESSING

Imaging Spectrometry

Basic Principles and Prospective Applications

Edited by
Freek D. van der Meer and Steven M. de Jong

Springer

EXTRA MATERIALS

REMOTE SENSING AND GIS

Dr. R. Bharti

So, I will end my lecture today here and you can go through these two. So, this is one book which is basic principle and prospective application by Freek D. van der Meer and Steven M. de Jong right and this is my paper where I have explained the basics of hyperspectral remote sensing. So, this is the review paper on this technology. So, if you want to understand more or if you want to start your research in this area, I will recommend you can start reading these two references.

And there are many other books available that is also good but you start with this and subsequently you can explore yourself. Thank you.