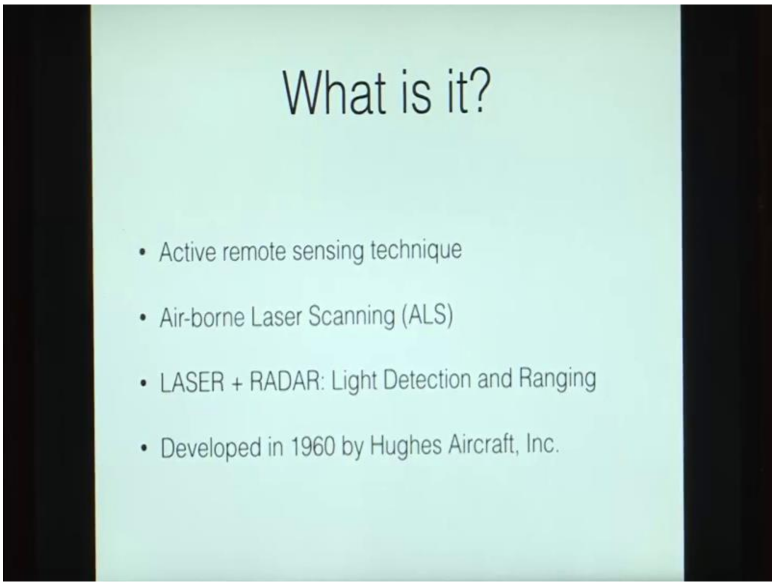
Forest Biometry
Prof. Mainak Das
Dr. Ankur Awadhiya
Department of Biological Sciences & Bioengineering & Design Programme
Indian Institute of Technology, Kanpur

Lecture - 20
Lidar

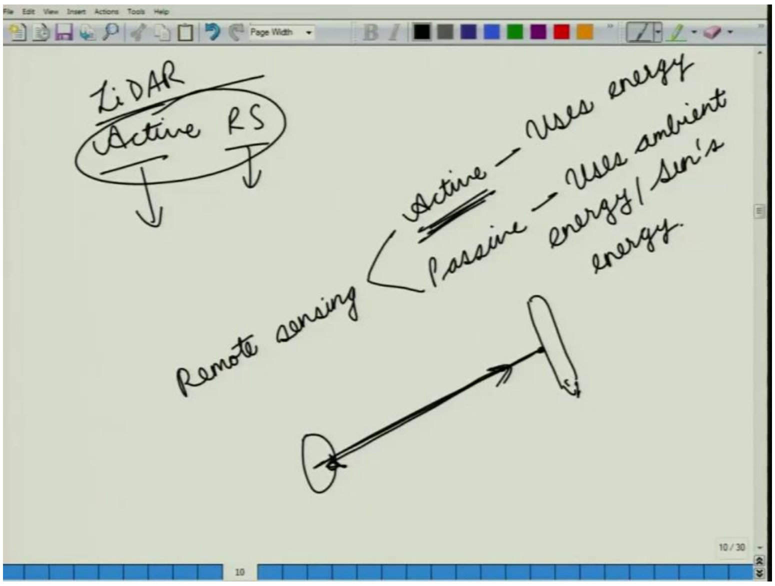
[FL]. Today we will have a look at a technique known as LIDAR light detection and ranging. So, this week covers the ways of measuring the height of a tree LIDAR is another method of measuring the height of a tree. So, what is LIDAR?

(Refer Slide Time: 30:00)



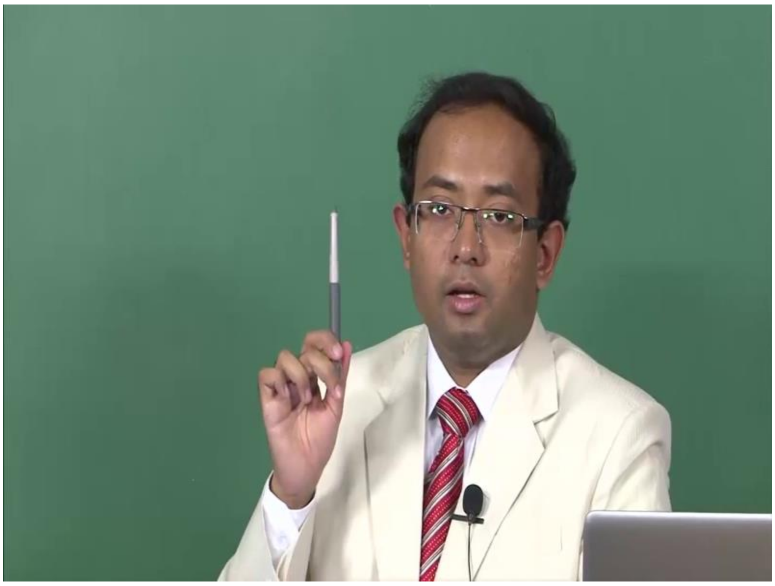
LIDAR is an active remote sensing technique. So, now to divide this word into parts, it is Active Remote Sensing.

(Refer Slide Time: 00:39)



What is remote sensing? Remote sensing is a technique in which you gather information about an object without getting into touch with the object.

(Refer Slide Time: 01:02)



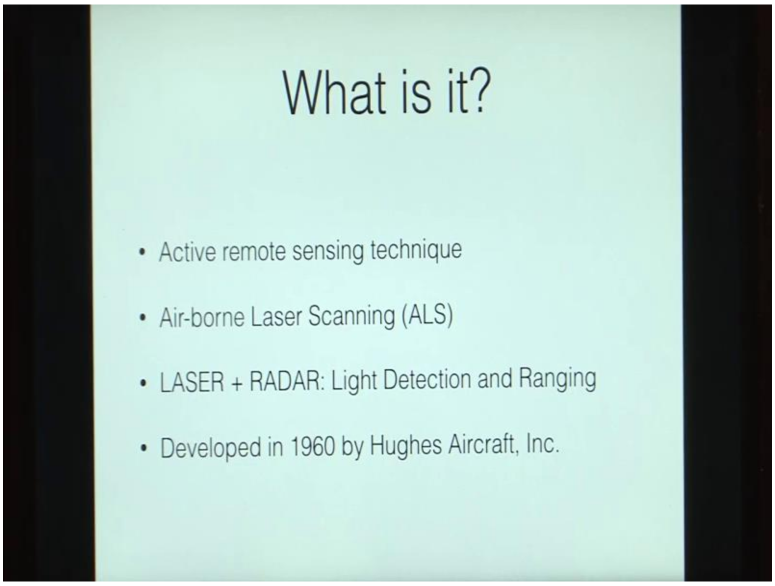
So, as we did it before if this is our object, if I am touching it, this is not remote sensing, but if I am seeing it from a distance and the light rays are interacting with this object and coming back to my eyes and I am getting information about this object regarding maybe its shape, its length and so on. Then that is a technique known as remote sensing gathering information from a distance.

So, LIDAR is a remote sensing technique. It is also an active remote sensing technique. So, remote sensing is divided into two parts. We have active and we have passive remote sensing. Now, passive remote sensing is something that we are doing every day. So, when we are using the energy of the sun or maybe the energy of the ambient light sources and we are trying to get information about something. So when I am looking at this pen, I am using the energy of the ambience and those light rays are getting reflected back to my eyes and I am getting information about this pen. So, that is passive remote sensing.

Active remote sensing on the other hand uses a a technique in which you fire some sort of a radiation to your device. So, suppose we had this pen here and suppose I throw some light sources for instance. Suppose I was throwing laser lights. Now, those laser lights would then interact with this object and then be reflected back and then, I would measure them again. So, that sort of a remote sensing in which we are using energy, active uses energy, passive uses ambient energy or sun's energy.

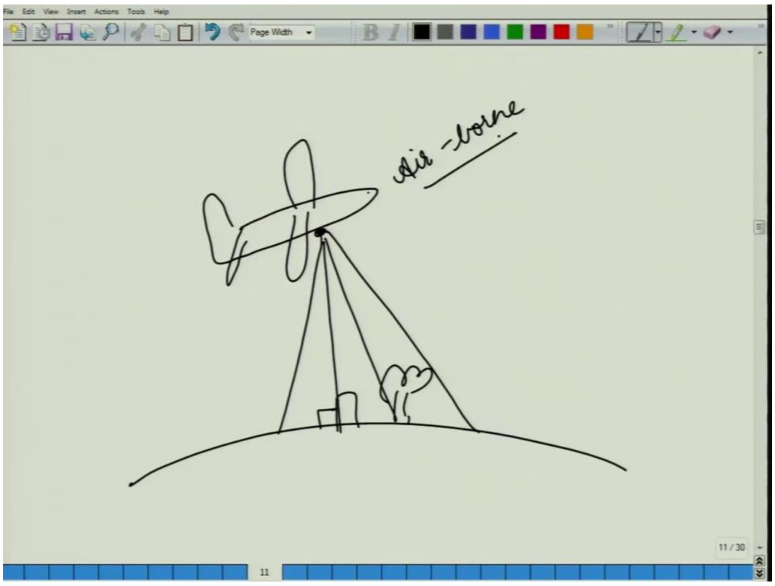
Now, LIDAR is an active remote sensing technique which means that when you are using LIDAR, you need an energy source to illuminate your object and with that energy source the radiation that are coming out, they will interact with your object and then, they will come back.

(Refer Slide Time: 03:12)



Now, coming to the slides again it is a technique of airborne laser scanning. So, it uses laser, it scans things using laser energy. It can be used in an airborne fashion.

(Refer Slide Time: 03:29)

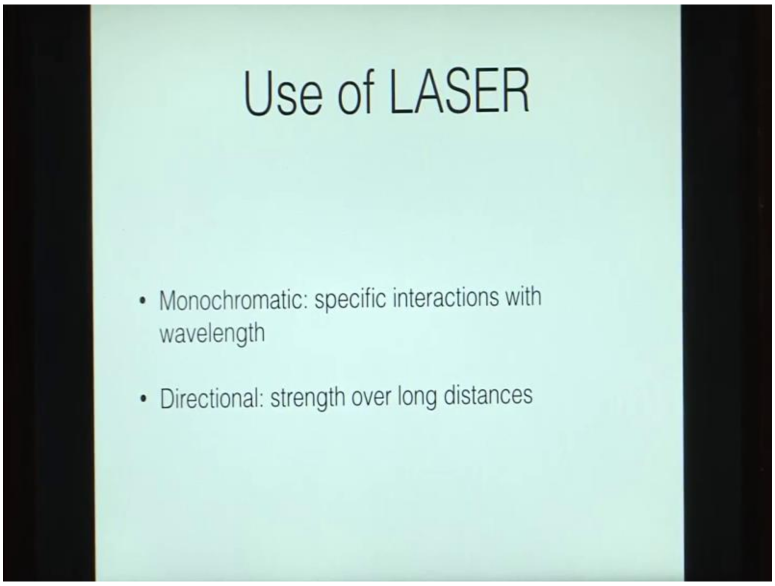


So, when we see an airborne fashion, what we mean is that suppose you have a plane and you can put your LIDAR device here and suppose it is going above the earth, it is getting some buildings maybe a few trees. So, now this laser light would be scanning the whole region in different ways that will come to in this lecture and it can be used in an airborne fashion

Now, coming back to the slides; so it is this world LIDAR, it comes from laser plus radar. So, radar technology was developed first and then, people thought about adding laser as the source of energy. Later on this term was also expanded to main light detection and ranging, but the origin of this term is laser plus radar. It was developed in 1960 by Hughes Aircraft Incorporated.

Now, why should we use lasers?

(Refer Slide Time: 04:31)

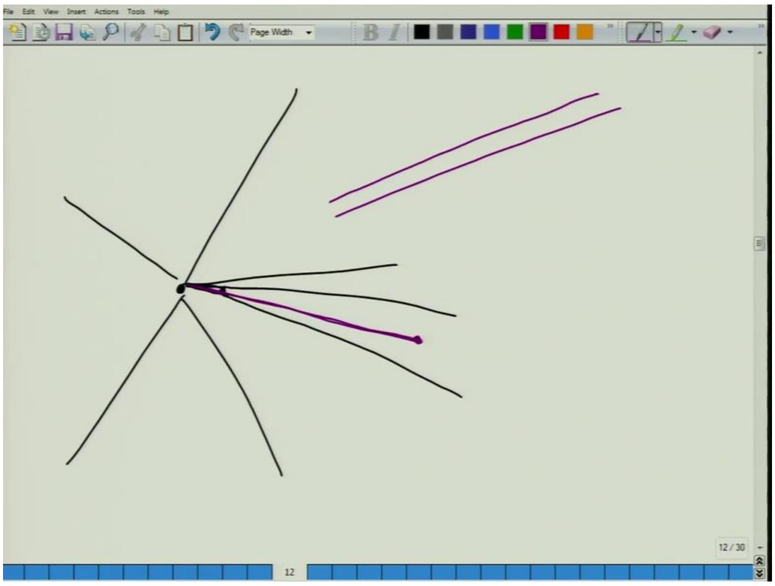


The use of laser is because of its two properties. One is monochromatic and two, it is directional by monochromatic. We mean that the laser light will have a single wavelength. Now, that single wavelength is completely known with the device, so why do we need a single wavelength? So, suppose you have a tree and suppose you illuminate it with say red coloured light. Now, leaves are green in colour which means that they reflect only the green portion of the spectrum. So, if you took a leaf into a dark room and if you illuminate it with red light, what would you see? You would see a black coloured leaf. If you illuminate it with a green coloured light, you would see a green colour leaf. If you illuminate it with say blue coloured light, you would again be seeing a black coloured leaf which is because different wavelengths interact with the same object in different manners.

So, by using a monochromatic beam of light, we ensure that we have specific interactions with that wavelength. So, if suppose you wanted to measure the properties of some object at different wavelengths, you would be using different wavelengths or laser beams of different wavelengths one by one.

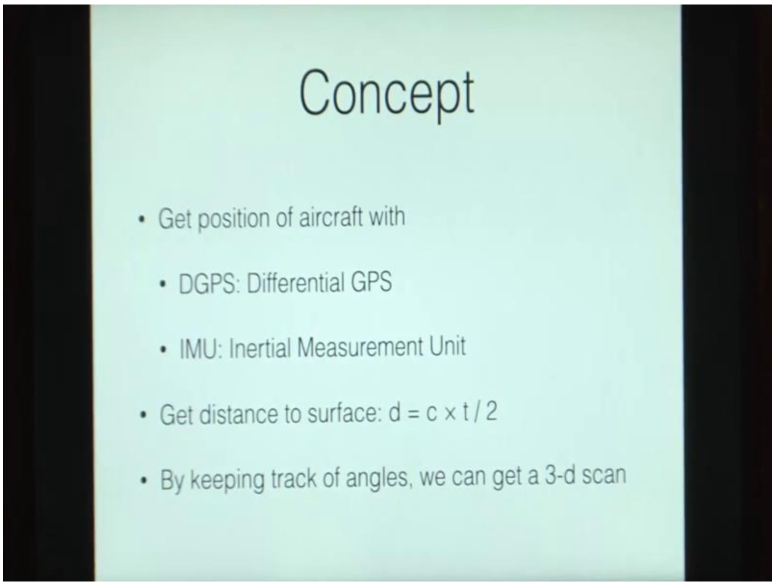
The second use of laser is that it is directional. So, by directional what we mean is suppose we consider a point source of light.

(Refer Slide Time: 05:58)



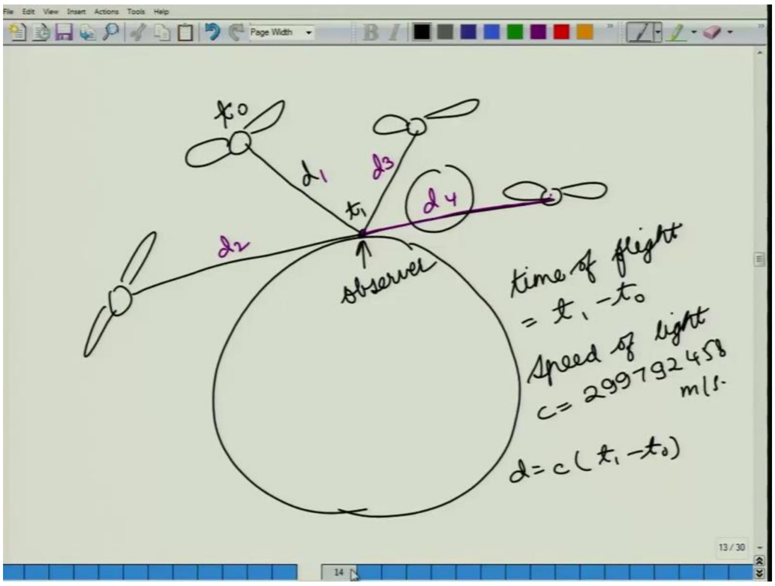
Suppose say say a light bulb. So, its energy is going out in all directions. Now, at this point the amount, the intensity of the energy would be highest compared to this point. Why? It is because this small portion of light that was coming here, it is diverged with distance suppose at this point. So, here you are getting this cone of light, but at this point you are getting a very small tiny cone of light like this. So, the intensity at this point would be less than the intensity at that point. In the case of lasers, they are highly directional. So, basically their beams are exactly parallel to each other. So, even at very large distances you do not see any divergence. So, its strength remains large over long distances.

(Refer Slide Time: 07:01)



So, what is the concept of using LIDAR and when we are using LIDAR, we need to get the position of the aircraft. Now, the position of the aircraft can be added using two systems. You can use a differential GPS or you can use an inertial measurement use unit.

(Refer Slide Time: 07:22)



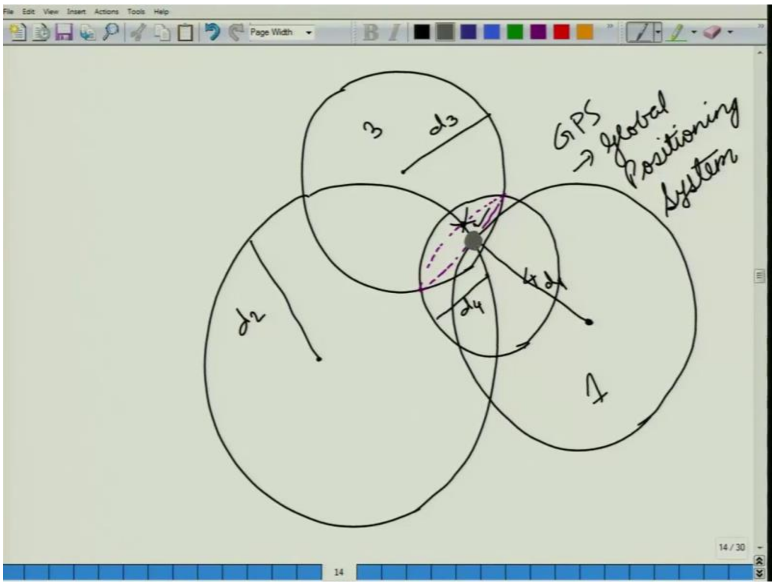
Now, in the case of a differential GPS, we have a constellation of satellites moving above us. So, suppose this is the earth and we have a number of satellites for GPS that are going all around it.

Now, if you want to know the position of this particular point, we can calculate its distance from a number of satellites. So, these satellites would be beaming energy from this point of the observer can be calculated by measuring the time difference this signal takes to reach this point.

So, suppose it started at time t 0 and it reached here at time t 1. So, the time of flight for this beam of energy which is an electromagnetic radiation moving at the speed of light, so that the time of flight is t 1 minus t naught. Now, we know the speed of light c is equal to 299792458 meters per second.

So, we can calculate this distance d as c times t 1 minus t naught. So, we can calculate this distance d. So, suppose let us call it d 1. We can also calculate distance from the other satellite, from another satellite from another satellite and so on. Now, when we have these measurements, if we can calculate considering the satellite, so we know that our point is at distance of d 4 from the satellite.

(Refer Slide Time: 09:08)



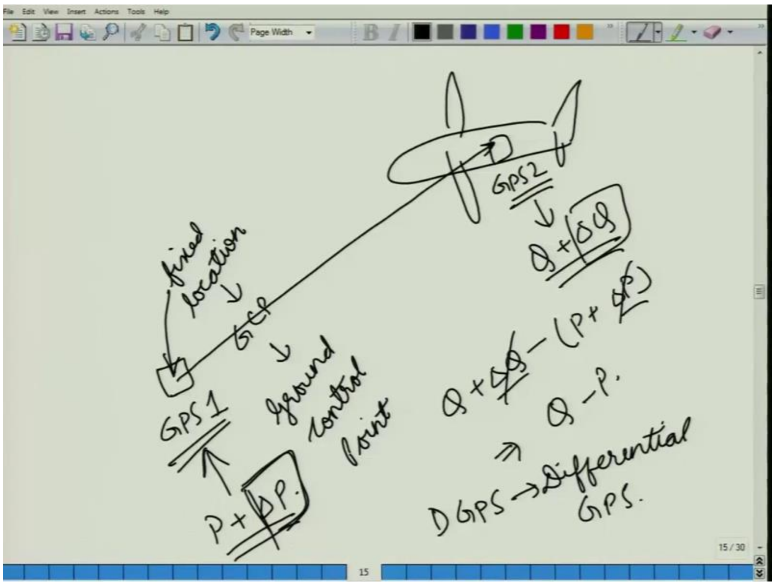
So, when we say that what we are getting is from this satellite, it is at a distance of d 4. So, we can draw a sphere all around it with a radius of d 4. We know that r point is somewhere on this sphere. Now, using another satellite, taking the measurement from another satellite, we know that it is at a distance of d 3. So, r point is at a distance of d 4 from satellite 4 and at a distance of d 3 from satellite 3. So, r point would lie in this circle that forms out of the intersection of these two spheres.

Now, if we knew that r point is at a distance of say d 2 from another satellite, so we have another sphere of radius d 2 and this sphere is going to cut r circle of position at two points. So, we would now know that r position is one out of these two. Now, if you took a fourth sphere. So, we know that we are at a distance of one from the position of the satellite 1. So, we would now be able to say that out of these two points, we are not at this point, but we are at this point.

Now, we generally require only three spheres because the fourth sphere is this sphere of the earth. Now, this would give us r position. So, this thing is known as GPS which stands for Global Positioning System, but these are catch with GPS. These readings, it is based on the calculation of these distances. These distances are based on the calculation of times of flight. Now, it also depends on the exact position of the satellite.

Now, we could have errors in all these measurements. We might not know exactly the position of that satellite or maybe we do not exactly know the time of flight or maybe there is some error in calculations. So, that would give us some difference or some margin of error. So, r point would not be a single point, but might be say a big circle. Now, to reduce that circle if you wanted to know r position with a greater precision, what we would do is we would take two devices.

(Refer Slide Time: 11:59)



So, we would have GPS1 that is kept at a fixed location also known as GCP that stands for Ground Control Point.

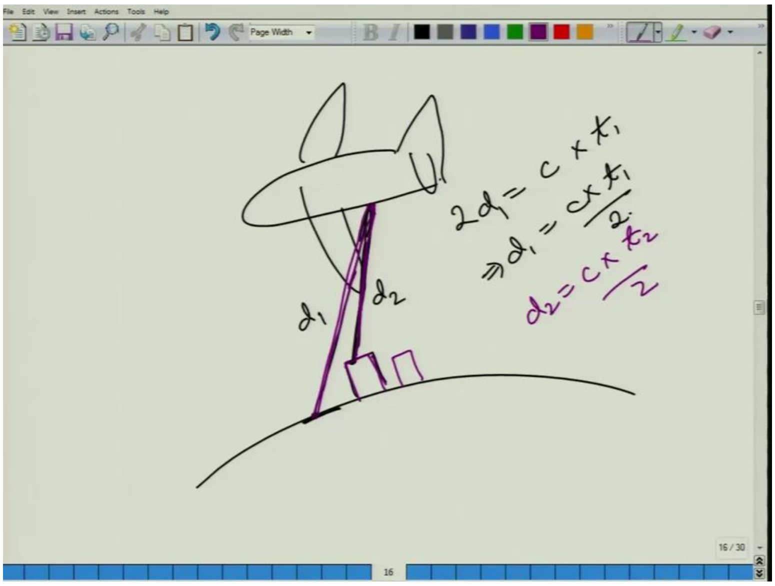
Now, we exactly know the position of this device on our aeroplane, we would keep the second GPS. So, we have GPS2 and whenever we are taking the the readers, we are taking the readings from GPS1 as well as GPS2 at all times.

So, suppose r reading of r position here had P plus delta P and this one had Q plus delta Q. So, P and Q are the positions and delta refers to the error margin. So, suppose we had this P plus delta P and Q plus delta Q. Now, if these two points are close by, then any delta P that is occurring here because of the positions of the satellite because both these instruments are the same, satellites are the same. So, this error would be the same in both the conditions.

So, if we calculate the distance, the position of GPS2 with respect to GPS1, we would be getting Q plus delta Q minus P plus delta P. Now, because delta Q and delta P are the same, they would get cancelled out and we would exactly be getting Q minus P. Now, use of these two instruments for calculating this difference is known as DGPS which stands for Differential GPS.

Now, coming back to the slide, we need to know the position of the aircraft in very high precision. We can use it, we can use a differential GPS. At the same time, we also use an inertial measurement unit. Now, an inertial measurement unit can tell us any small deviations and its position. So, suppose we were using a laser beam, then if this aircraft tilted a bit, we would need that tilt as well. So, that had with the initial inertial measurement unit.

(Refer Slide Time: 14:33)



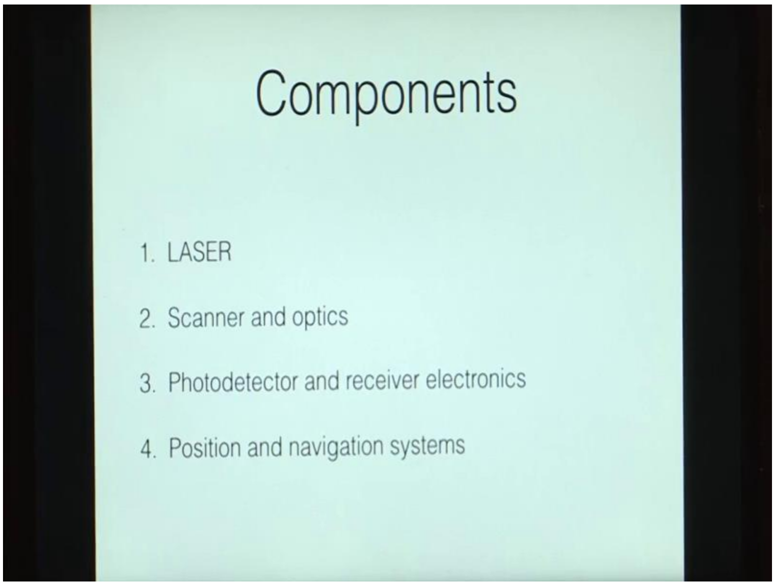
Now, what our aircraft is doing now is that it is flying overhead and then, it is using a laser beam to scan things. So, suppose our ground, suppose we had a building here. So, when the laser beam comes here, it comes and then, it interacts with the surface and then, it is reflected back here it interacts with the ground surface and it is reflected back. So, we can calculate this distance d 1 and calculate the distance d 2 as well.

How do we calculate that distance again because the speed of light is constant as it is c, we can get d. So, when this light is going from the aircraft to the ground, it is travelling a distance of d 1. When it is moving back, it is again covering a distance of d 1.

So, we have twice of d 1 is equal to c multiplied by the time of flight which would give us d 1 is equal to c times say t 1 c times t 1 upon 2. Similarly, from this position for the position of the building, we can calculate d 2 is equal to c times t 2 upon 2.

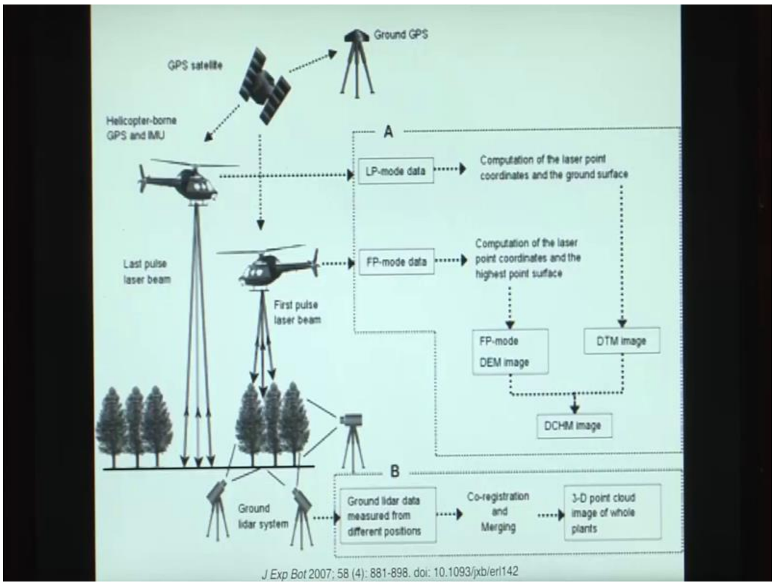
Now, if we exactly knew the position of our aircraft and it stealth on all the access very precisely, then just by knowing this d 1 and d 2, we would be able to reconstruct the scene computationally; so coming back to the slide again. So, by keeping track of the angles, we can get 3D scan of the whole scene.

(Refer Slide Time: 16:15)



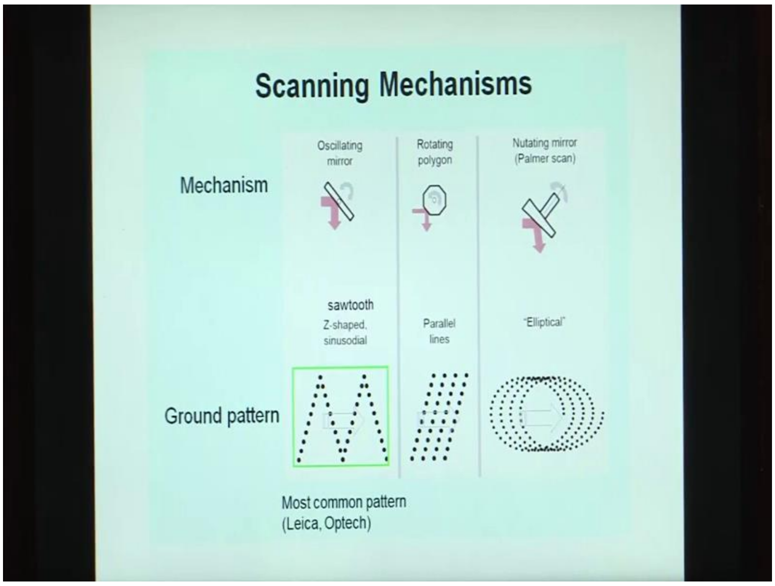
So, what are the components of a LIDAR? It consists of a laser, it consists of scanner and optics. So, scanner refers to the instrument that is used to move this pen plus you will have some optics to ensure that your beam is a very coherent beam. Then, once this beam has interacted with the surface and has move back, then you will need photo detectors and receiver electronics. So, you have sent this beam, it has interacted, it has moved back and now you need a photo detector here on the aircraft to sense that beam, and then you will require receive electronics to convert that into a signal plus. The fourth component is the position and navigational systems that we have already seen in the form of differential GPS and IMU.

(Refer Slide Time: 17:02)



So, this is how scanning would look like. We could go for ground based scanning which would be called a ground LIDAR system. We could put it on in aircrafts, in aeroplane or a helicopter. We could even put it on a satellite or you could put it anywhere essentially, but you need to know your position, you need to know all the angles and you need to calculate the time of flight of the laser beams.

(Refer Slide Time: 17:30)



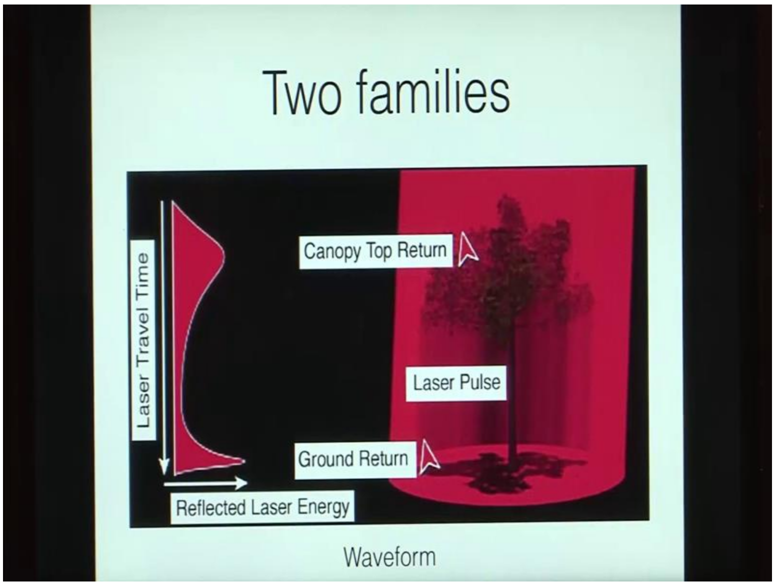
Now, when we are moving the laser beam to scan our surface like this; so this scanning can be done in a number of ways: so if we looked at the slide, now we can use an oscillating mirror. So, this mirror is going back and forth like this. So, in that case, it would be giving a scan in this direction. So, it will move from here to here and then, back here and back here and back.

Now, remember that our aircraft is moving on a direction. So, essentially this would be making out angles on the ground. So, if we looked at the side now, this makes these angles. We could also be using a rotating polygon. So, in the case of a rotating polygon, consider this to be the polygon.

(Refer Slide Time: 18:18)

This polygon is rotating. So, when it is rotating, the beam is interacting with the surface. Then, it moves at an angle, then it moves at an angle and then, it goes back to 0 when it gets to the other surface. So, coming back to the slide if we used a rotating polygon, we would be getting parallel lines or we could also be using a nutating mirror which would give us elliptical lines of scanning on the field.

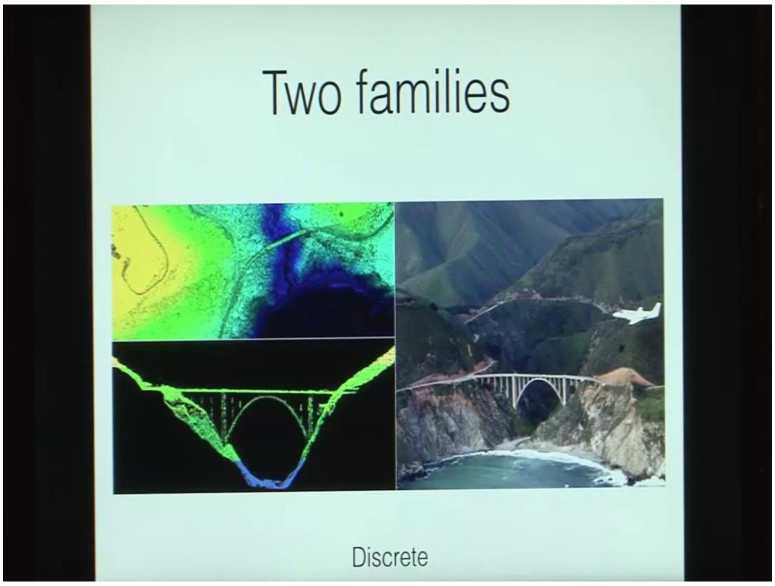
(Refer Slide Time: 18:48)



Now, LIDAR is divided into two families and one is called waveform LIDAR. So, in the case of a waveform LIDAR, you measure the amount of energy that is reflected with this laser travel time. So, for instance if in this figure, we look that on the right, we have a tree. Now, in this tree with the laser light interacts with the canopy, it would come back with the higher energy. Then, when it reaches to the bole portion, the most of the light from there does not come back. Only that amount of light that interacts with the bole is able to come back and then, when it reaches to the ground, then again you will be getting a high signal.

So, if we looked at our waveform, what will be getting here is that for this canopy, we are getting a huge amount of signal and then, for the bole we are getting a small amount of signal. Then, for the ground again we are getting a large amount of signal. So, this waveform LIDAR would give us the shape of the object.

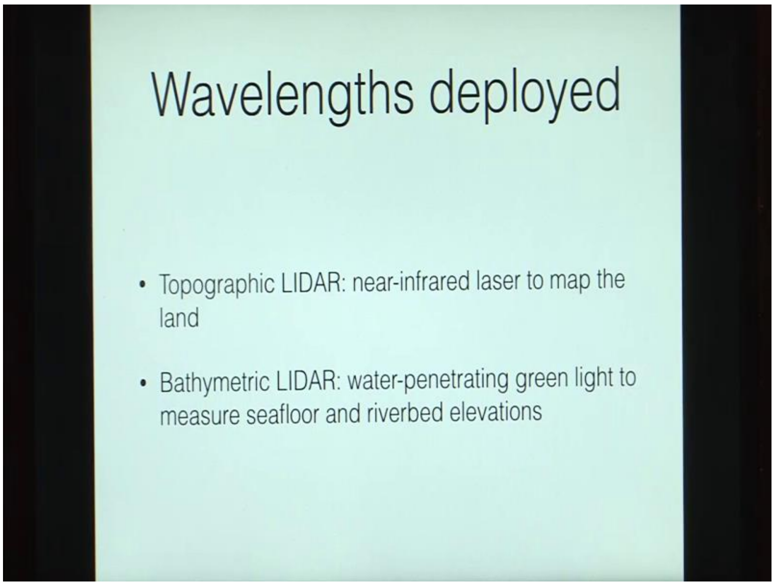
(Refer Slide Time: 19:58)



The other family is called as a discrete LIDAR. So, what a discrete LIDAR does is, it does not measure your amount of energy that comes back, but it just measures the actual position from where this energy is coming back; so if we did a discrete LIDAR, then it would get this point, it would get this point and it would get this point. So, how it would look is suppose we did it for a bridge. So, on the right we can see a bridge, on the left we are seeing a discrete LIDAR pattern.

Now, what sort of wavelengths to be used in LIDAR? So, remember that it is a laser system and a laser beam has a wavelength. So, what are the wavelength that we use? There are a number of considerations here. One is that your beam should be able to interact with the object. So, essentially we use those wavelengths that can interact with the object and two, is the safety criterion. For instance, if you are putting a laser light on an aircraft and it is shooting it down to the earth. So, if somebody is looking up onto the sky or if somebody is intercepting that reflected laser beam, then his or her eyes should not get damaged. So, those are the two considerations.

(Refer Slide Time: 21:16)



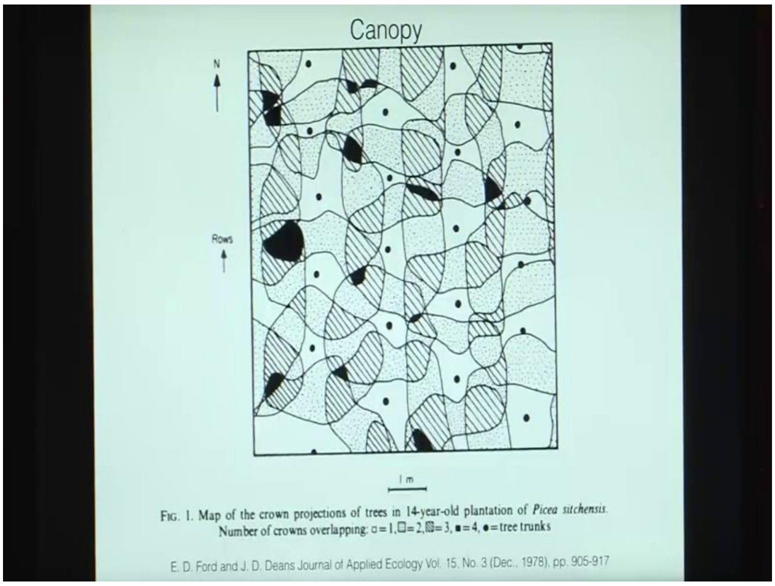
So, we deployed two kinds of wavelength and LIDAR in the case of topographic LIDAR that we use for ground surfaces, we use a near-infrared laser to map the land.

In the case of bathymetric LIDAR that is used to get the surfaces of seabeds or maybe rivers or maybe lakes, then we use water penetrating green light because green light does not interact with water whereas, red light would interact with water. So, if we are using a green laser, it would go right through the water and it would interact with the bottom surface and then, it would come back to give us the seafloor and riverbed elevations.

(Refer Slide Time: 22:01)

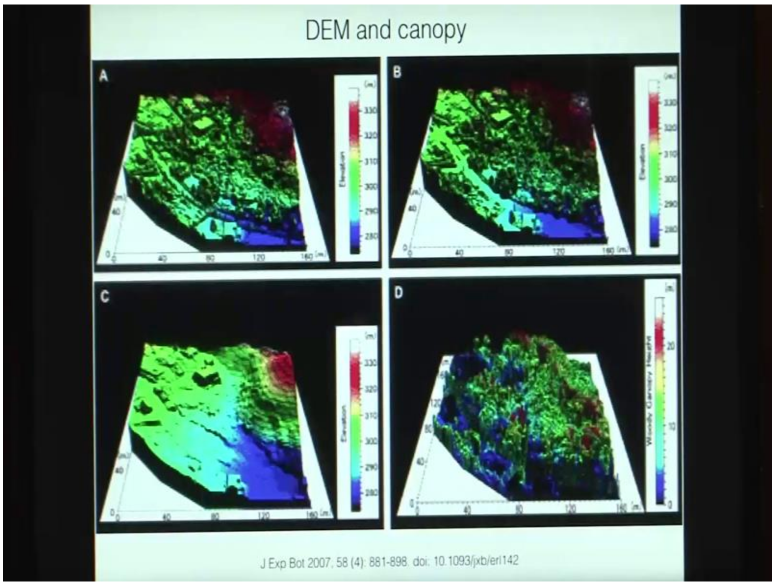
So far so good about LIDAR, but then what are the uses forestry.

(Refer Slide Time: 22:06)



Now, in the case of canopy measurements, for incidents this is an old paper. It talks about how canopy is overlapped over each other. So, the circles or the dots that you can see are the stem boles and then, we are seeing the canopy. So, they interact with each other. So, if actually wanted to know this physically, we could use a LIDAR.

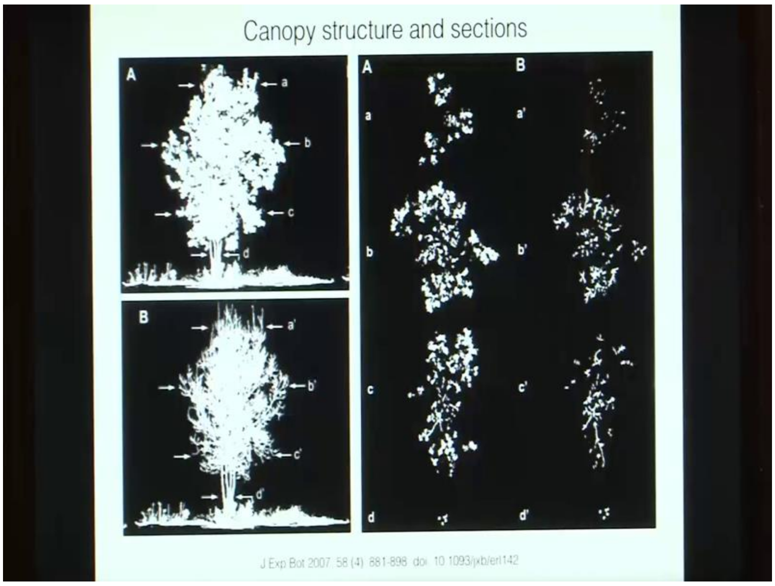
(Refer Slide Time: 22:28)



So, this is how a LIDAR would be used. So, here we are seeing DEM and canopy. Now, DEM stand for the Digital Elevation Measurement. So, on this slide in this figure C, what we are seeing is the bear ground surface. So, we are using those wavelengths that either do not interact with the trees or we are only using those radiations that are coming from the ground and then, we are packing up the caption between.

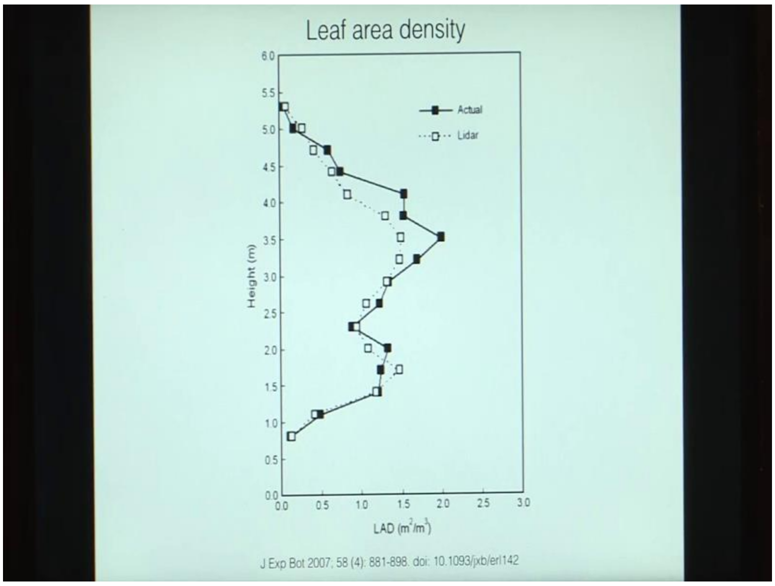
Now, the other ones show us the canopy. So, we can use both of these to get 3D scan of our tree.

(Refer Slide Time: 23:06)



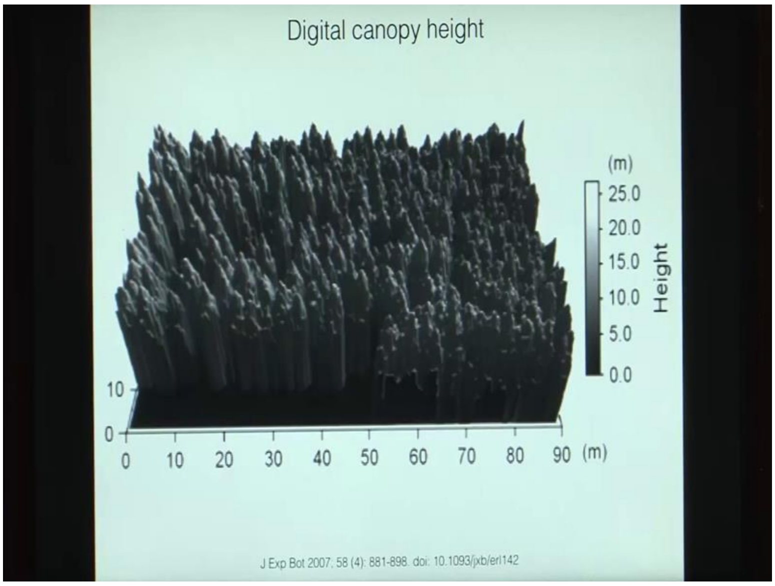
So, here we are seeing these trees. So, we are getting this 3D picture of the tree. We can also take a section from any of these and this is how the sections would look like. So, this is the top section. It is smaller as compared to the central section which is then again bigger than the other section and then, this d section which stands for the bole is a very small one. So, we are getting 3D picture of the tree.

(Refer Slide Time: 23:40)



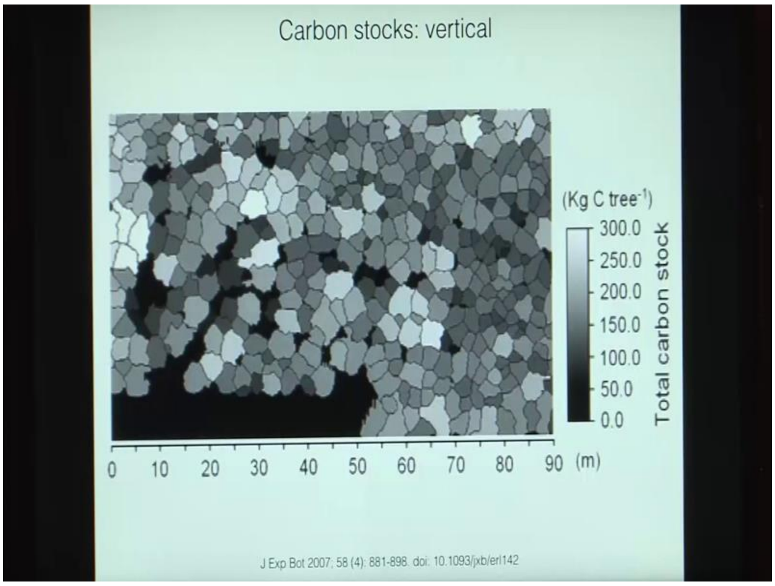
Now, this 3D picture can be used to to compute the leaf area density. So, in this graph we are seeing the leaf area density as computed from LIDAR and as computed physically from a tree. So, as we can see there is a very good correlation between both of these. Now, if we have this 3D picture of a tree, we can also use it to compute the canopy height.

(Refer Slide Time: 24:04)



So, in this case we are using all those radiations that are reflecting out from the treetops and then, we are also using this digital elevation measurement to get the elevation of the ground. So, we can get the height of the canopies and we can also use it to get the carbon stocks.

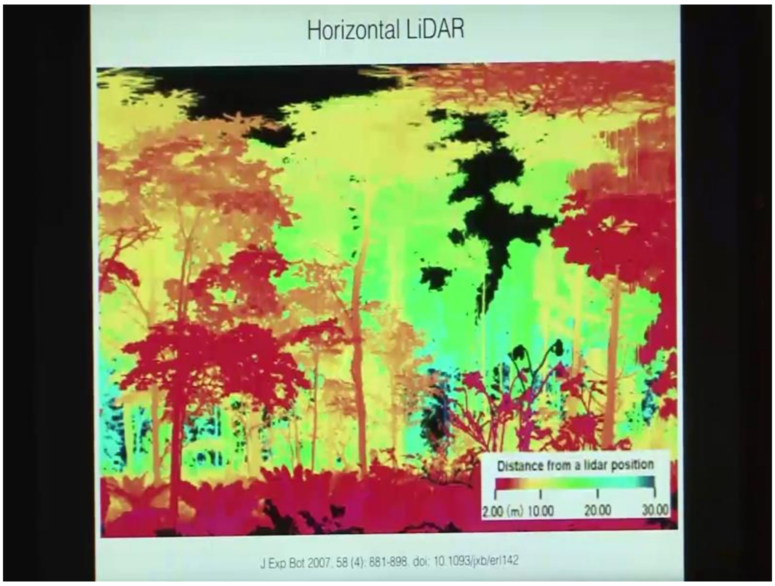
(Refer Slide Time: 24:25)



So, basically once you have a 3D model of your tree, you can multiply it with the density of various portions of the tree to compute the amount of mass that is there and then, you can multiply it with another factor to get the amount of carbon say in kilograms per tree.

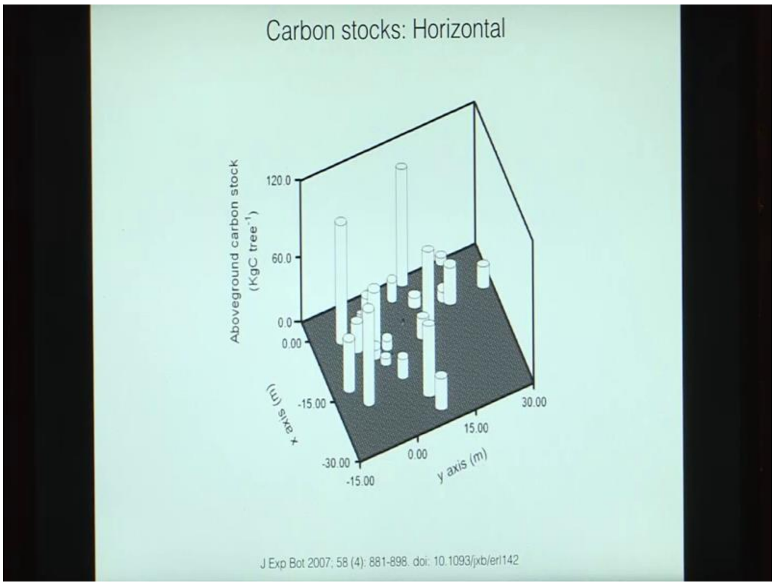
Now, all these information can be had from the airborne laser, but we can also use a horizontal LIDAR.

(Refer Slide Time: 24:52)



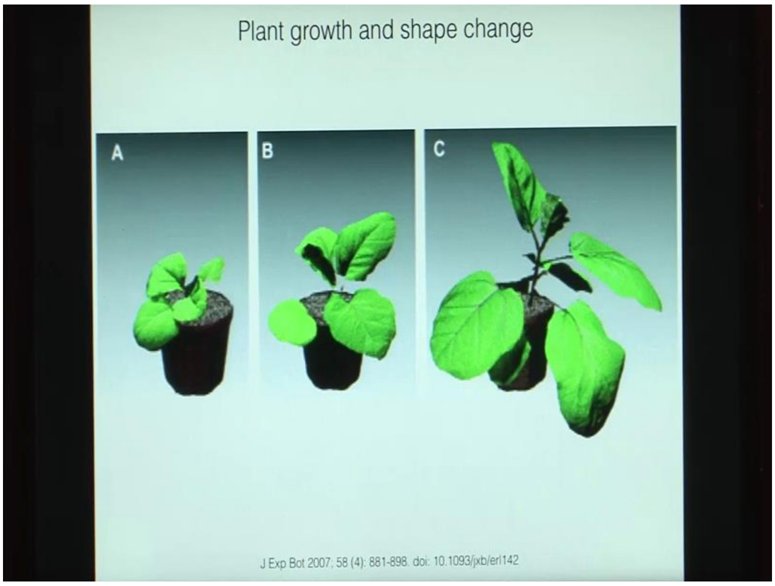
So, in the case of this horizontal LIDAR, these different colours are showing the distances from the LIDAR. So, for instance this tree is close by as compared to this tree. So, here we have put our LIDAR out there on the ground and that is scanning the whole forest region and once it has scanned the whole region, it will give you this picture of the forest.

(Refer Slide Time: 25:20)



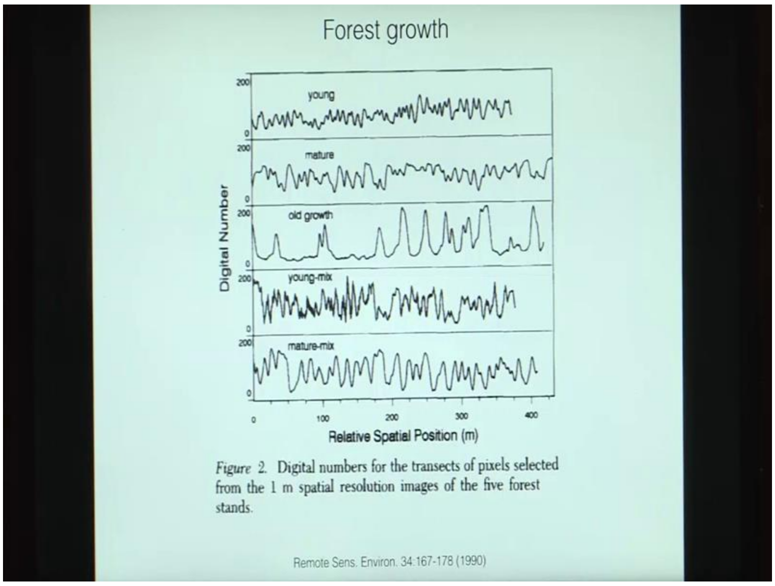
We can also use it to measure the carbon stocks.

(Refer Slide Time: 25:23)



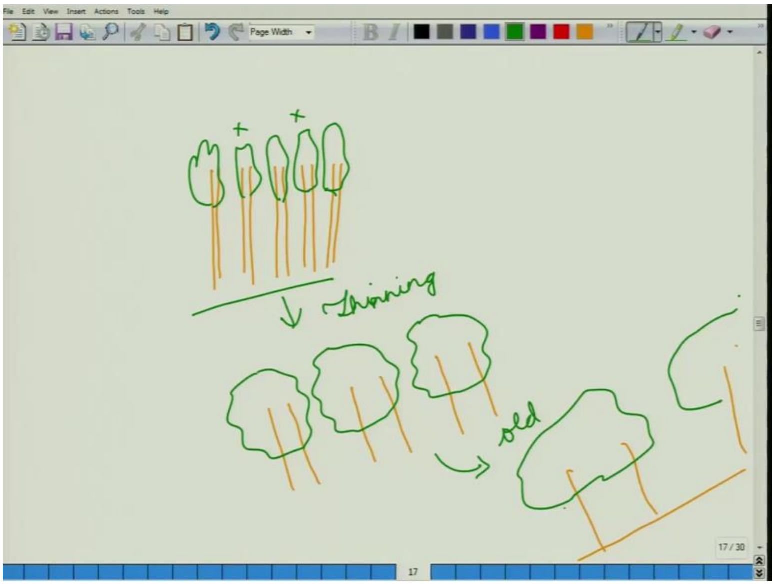
Now, LIDAR can also be used to understand plant growth and the shape change. So, for instance here in this picture, we are seeing over gene which is of the brinjal family and we are seeing a plant that has been modelled thrice using a LIDAR at three different points in its leaf. So, when we are using this LIDAR system, we can exactly compute the volumes of the leaves and for instance, we can compute the amount of carbon that is there in the leaves or we could also use it to predict to study the growth of this plant or how its shape changes with its age.

(Refer Slide Time: 26:02)



We can also use letter to understand forest growth. So, for instance in this figure on the top panel, we are seeing a young plantation followed by a mature plantation followed by an old growth. So, why do we get this image? So, for instance in a young plantation, we would be seeing very thin trees those are close together.

(Refer Slide Time: 26:22)



So, this is a young plantation. Now, later on we could put on this plantation through thinning. So, it could go through a thinning operation in which we remove some trees, so that any trees that are remaining are able to grow in their size. So, after a while will be getting trees that are much broader, but now their number is less, then in the case of an old plantation when it becomes very old, we would be seeing a few large size trees that are very much separated from each other. So, now coming back to the slide here, we see that in the case of a young plantation, we are saying that its boles, they are having very small diameter and they are having a good height and it is roughly continuous in the case of a mature plantation. We are saying that the bole diameter has increased.

So, essentially if we looked at this point, this is the diameter of this tree whereas, here this is the diameter of the larger tree. So, its diameter has increased and it is still making a continuous canopy even in the mature case, in the case of an old growth. So, here we are seeing that we have a tree here, we have a tree here, we have a tree here, we have a tree here, we have a tree here and so on, but so much of these spaces left in between these trees.

So, we are seeing some trees that are very much in diameter, but they are quite separated from each other. The next figure shows you a young plus a mix plantation and the last panel shows you a mature plus mixed plantation. So, essentially you can use your LIDAR information to get an idea of how your forest is at a particular point of time. You can use it to get the forest growth or you can also use it to calculate the amount of biomass that is there in your forest in different stages.

So, LIDAR is one of the most ground breaking technologies that we are using in the case of forestry today.

Thank you for your attention. [FL].