Introduction to Biomedical Imaging Systems
Dr. Arun K. Thittai
Department of Applied Mechanics
Indian Institute of Technology, Madras

Lecture - 29
Planar_Scintigraphy_Instru

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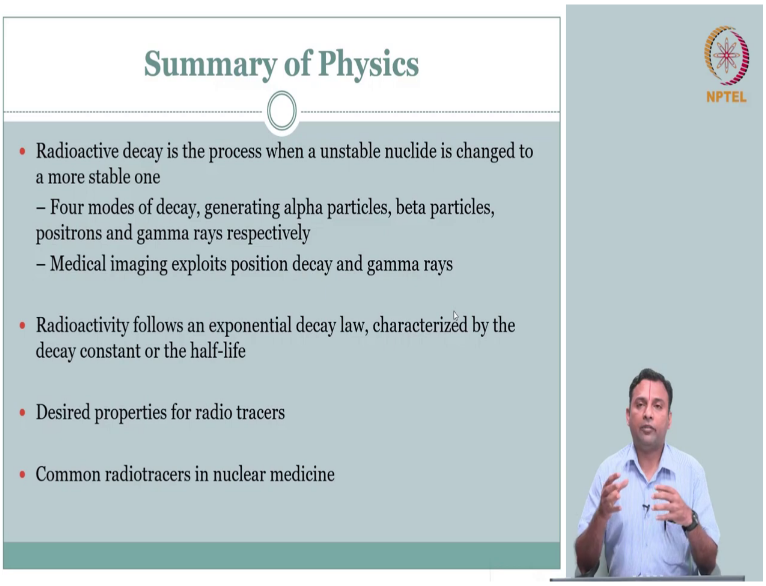

After the understanding the signal here, right, which is basically we are talking about radioactivity that is of interest and in the radioactivity we talked about different modes of decay and two of which will be exploited namely both of we are interested essentially in the gamma energy that is coming out, right.

So, there is this transition isomeric transition which gives out gamma and then you have this annihilation of positrons which again give out gamma. So, we are interested in radioactivity and the radioactivity giving out gamma rays right the source is inside the body.

So, now, the objective is how do we capture this on the outside and tell where the source is where the radioactivity is that is the big difference between the X-ray photons interaction with the tissue that we studied earlier and exploited in projection radiography and CT where attenuation was the material property of interest here we are not actually interested in the material property of the body we are giving radioactivity and we want to locate where the radioactivity is coming from the body, ok.

So, what we will do now is we will try to in some sense draw a parallel between how we did for X-ray after we completed the physics of X-ray, right. How is X-ray generated, how is it interacting with the tissue of interest, then we quickly talked about different modalities. One was simple projection radiography, the other was oh after you collect the data from different right projections in different views how do we back project and get the slice tomography.

Similarly, here when we come out when the gamma rays comes out from the source right, emitted from inside the body right, where we have to collect it. So, there are three different imaging modalities of interest here ok which exploits the gamma rays which essentially count the radioactivity.

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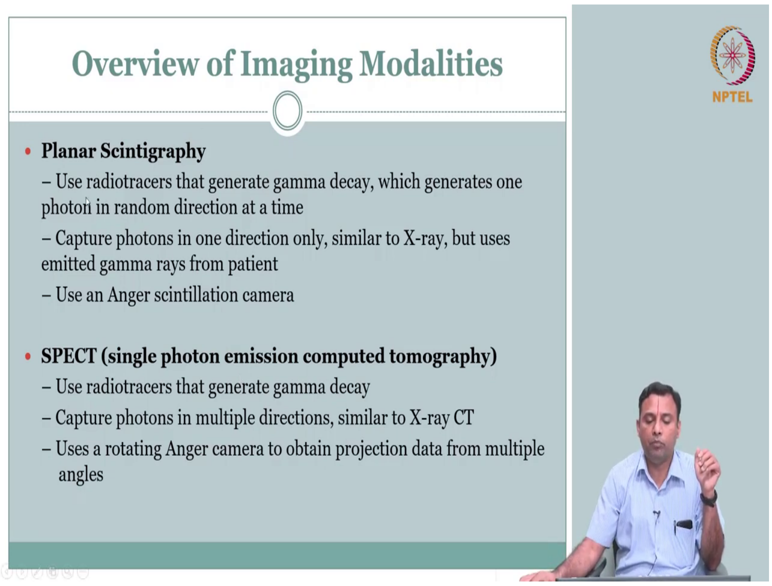

First is drawing parallels we have projection radiography. Similarly, we have what we call as planar scintigraphy. Here very straightforward you put the radio tracer in and this starts to give out gamma radiations, right. So, gamma photons of course, it will come out and it will give out throughout the body in all the directions. So, if you keep a detector on one side right, in one location what is going to happen these photons can be captured in that direction.

And, in some sense it is very similar to your X-ray projection radiography where you had a detector right a detector rectangular shaped detector behind the body. So, the whole area was captured the projection was captured, here you are going to have a detector that is going to detect where the gamma rays is coming from.

So, our interest is to from the image tell how much of activity came and from where it is coming ok. So, these are the two things for this we will use what is called as anger scintillation camera. In fact, this has been there from the beginning of using this nuclear medicine aspect. So, this camera is a important part of enabling the planar scintigraphy.

So, then what do we have ok planar scintigraphy is analogous to your projection radiography. So, therefore, we could think about ok what if I take right the detector from different views I could do reconstruction right, I could do tomography. So, when you do that right single photon emission computer tomography.

Why is this name single photon? Because this gamma ray photon is coming and you are detecting it on one side ok whichever angle you are keeping it is coming and falling on the detector single photon is counted and you get the image very similar to your planar scintigraphy. However, you collect this data from different views and back project it, ok.

So, here the same concept it is just that the anger uses a rotating anger camera right so that you can get it from different views. So, it is a single photon just to make it slightly different from what is the third one of the other modes of decay that we were interested positron. What happens in positron?

When the positron is generated it quickly bombards annihilates with an electron and gives out to 511 kilo electron volt electron, but which direction does it give? It gives 180 degrees, right. So, there you have two photons each travelling in opposite direction. So, here you are just catching one photon. So, it a single photon emission computed tomography.

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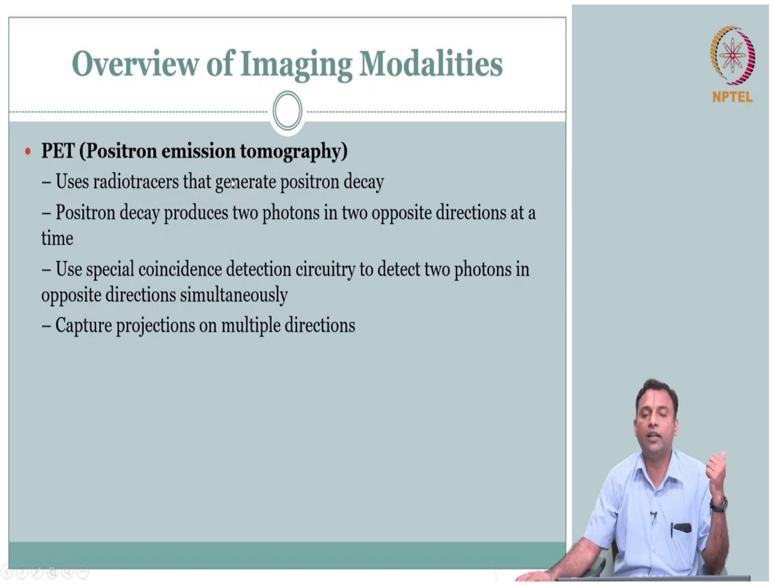

The third is positron emission tomography. In the positron emission you are not capturing the positron. The positron gives raise to two photons right 511 kilo electron volt that is 180 degree. So, you are catching two photons, right. So, it is two photon emission tomography, but you know that does not sound well and so, you call it as positron emission tomography because you capture these two photons and then say where probably the positron was positron decay happened your source ok.

So, this is your positron emission tomography, very similar to the tomography part right now you understand. So, you collect this data right it is going 180 degrees and random directions. So, if you are able to collect it from different views, then we could do the back projection and source localization. So, only additional detail here is it uses a coincident detection circuit. We kind of saw this circuit I mean saw the diagram when we talked about the positron.

We will talk about it again when we get into positron emission tomography. But, the logic is very similar right you get the views from different orientations and then do a back projection ok. So, let us start with the first one. So, we covered the physics. So, now, we will talk about the instrumentation for planar scintigraphy.

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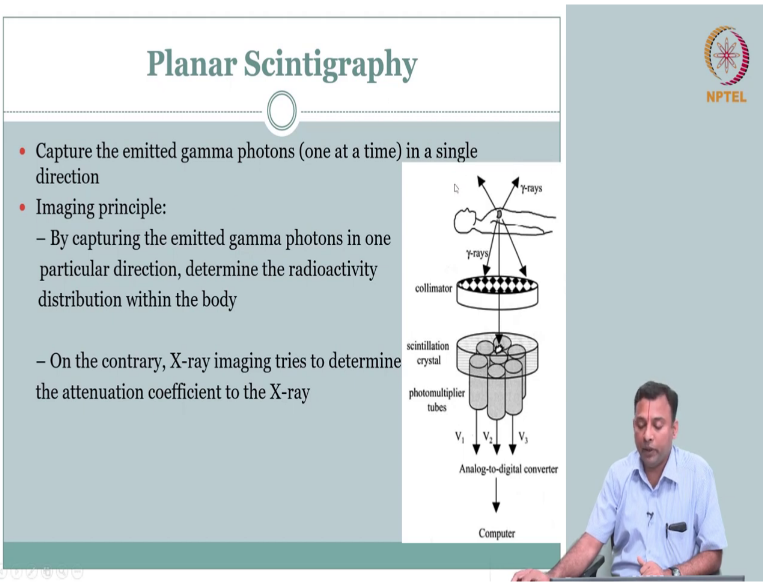

So, here is the big picture view of what is happening in planar scintigraphy quickly as we recognize this earlier the source is inside right you have a radioactive tracer you give enough time, after that what happens? After the patient is prepared right, you give the radio tracer he starts to emit gamma rays, right.

So, we talked about that desirable properties of your radio tracer. So, it is going to give so, you have enough radioactivity starting to come. So, when the gamma rays it can go any direction. So, typically what happens is you have a detector and the detector is going to catch the different gamma rays, again the same idea line of sight.

So, you want it to have a collimator so that you can eventually say where it is coming from after you have a collimator we will have gamma rays directly cannot be captured, right or you do not want that what do you want you want some light signal. So, the gamma rays gets interact with this scintillation crystal which converts your gamma energy to visible light photons. After you have visible light photons it is a weak signal so, we want to like we want to amplify it.

So, we have what is called as photo multiplier tube and based on the photo multiplier tube whatever values you are getting you digitize and do computer. So, why we put computer here is this same planar scintigraphy if you do it from different views this data can be used for back projection, ok. So, very big picture scheme.

So, what we will do is we will go one step at a time each of these right some of which we kind of know we could draw parallels or analog with our X-ray part ok X-ray projection radiography or X-ray CT. You can start to you know if you understood that logic there how we went ahead it is very similar wherever there is a small difference in the detail because of now what we want to do here we are counting the energy it is energy sensitive whereas, in X-ray right we were more interested in just the number of photons.

So, imaging principle you capture the emitted gamma photons in a particular direction after you capture that you want to say where that radioactivity is coming from within the body, what is the distribution of radioactivity in the body, ok. So, again first principle just to reiterate, even though we will draw similarities do not remember do not forget that in X-ray we were trying to go after this attenuation coefficient.

Mu hat we wanted to right get an estimate of how the mu is distributed; mu hat of x comma y was your reconstructed image whereas, here we are talking about how much activity comes, from where it is coming over time that is the key ok. And, we had lot of a engineering of the radio tracers so that we are we will be able to kind of tune or engineer our detection side so that we can say where it is coming from, right.

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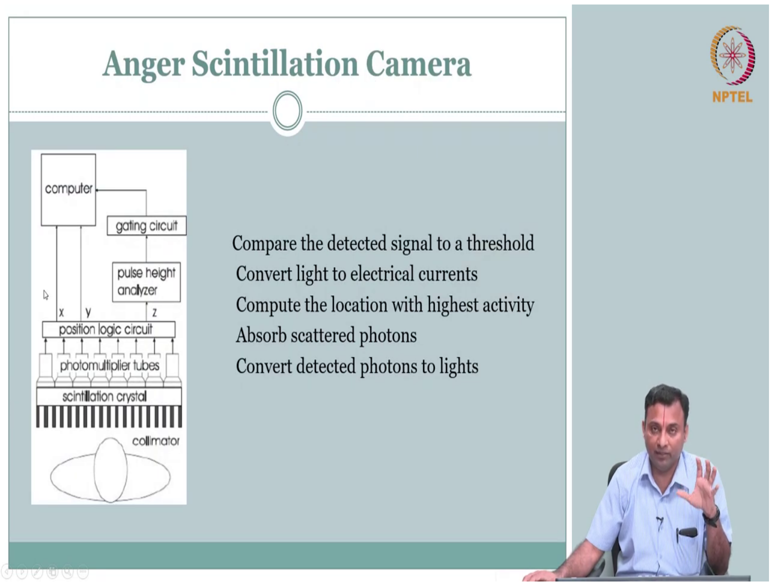

So, first part is call major part is camera anger scintillation camera that is your most important part. So, this will have right the whole block is very important, we will try to go because this is the key ok. So, what is happening here big picture? So, you have this patient, right. The patient is sending out gamma in different directions, but in one of the directions you have this camera in that direction you will start with collimator, ok.

So, the collimator gets in scintillation crystal scintillation crystal you have your conversion from gamma rays to light photons then the light photons have to be converted to electrical quantity and it starts to multiply. So, you have your photo multiplier tubes and then out from the photo multiplier tube you have to say position x and y where is it coming from in x and y right and what is the z? z is your amount of energy that is coming ok for that scintillation.

And, then you have additional circuits which can as named here pulse height analyzer and then gating circuit which energy you want to select and then this is fed into computer and then we will talk about what we can do visualization or do this and reconstruct. So, the important aspect is here. So, you have the compare the detected signal to threshold.

So, here whatever comes right not all of them you may want to use it. So, you have this height analyzer. So, the idea is you have this detected signal to a threshold whether we want to use that or not because we have engineered the radio tracer. So, we are kind of looking at a gamma energy that we know that we have engineered that radio tracer, right.

We showed the example of your technician 98 you get only one energy. So, the idea is from the detected energy you need to know whether that is a one that is because of the radio tracer that is coming through the interaction or see you have the scintillation crystal. So, maybe you know that is giving. So, photon is interacting with the crystal right that thick.

So, you could get Compton scattering there and you could get less energy that is coming out Compton scattered. So, now, the question is do you want to interpret that as a signal or is it Compton scattered? So, we can be energy sensitive if you are energy sensitive we can say because I know what is the gamma I am sent you know the radio tracer is sending out.

If it is within certain tolerance, I know it is the real signal coming from that source if it is less than that I know it is photon. So, you have some thresholding criteria we will look at it. The idea here is you convert the light signal which was. So, in your X-ray if you wanted to think about we had this intensifying screens.

So, the light photons were directly captured on the X-ray film whereas, here what happens? It is not directly it is that photo light photon is further converted to electrons and then right compute the location. So, based on this signal you have to say where is it coming from where is the highest activity. So, this is the rough logic what this anger scintillation camera the whole unit is supposed to do, right.

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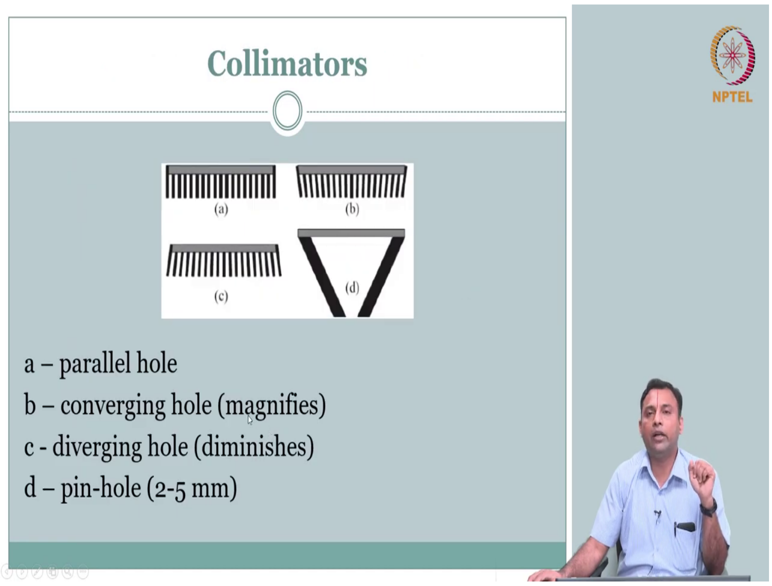

We will go one step at a time. First is your collimators. Collimators very similar. In fact, you know this what is this? These are lead strips, ok. So, you have different configurations, what is your objective here? The gamma photons are coming you want only the gamma photons that are coming through, right through the body in straight line that is the signal of interest. So, you want to allow for only that line of sight very similar to what we did for X-ray. So, the different configurations that are possible.

Now, you have instead of 1D, right or what is shown here is 1D, but you know this is a area, right. So, it is in some sense you are looking at the plan of it, right. So, you have gaps, ok. So, which is your called as a parallel hole. So, anything gamma rays that are coming through this line, it will come in rest of it will get blocked. Remember, this b by h the grid ratio and all those things very similar.

There are two – three configurations that are possible. This is parallel. What if you want to say for example, have a small region right, but I want it to be blown up zoomed in I want that region to be zoomed in. So, you could have right magnifies, you could have right b converging or diverging. So, this one diminishes. So, it kind of puts that big field of view into a small.

So, this is the different relationship between the field of view of the object and what is the detector area that is going to be captured, ok. So, you can small area you can blow it into the detectors full field of view or big larger field of view you can reduce it on the detector to a smaller region all these are possible using diverging or like.

So, typically what they do is it is the same thing you flip it in one configuration and if you want the other configuration you take it and flip it back. So, and then you have this pinhole kind of configuration as well. The objective of all of them are very similar how do I target my field of view into the detector.

So, we will kind of discuss more about the parallel hole, right because we need to form the imaging equation and then maybe for reconstruction we did pencil beam in X-ray. So, if we do that here right with parallel hole it might be lot easier to make use of some of the equations that we already have developed, ok. So, collimator, nothing new on that.

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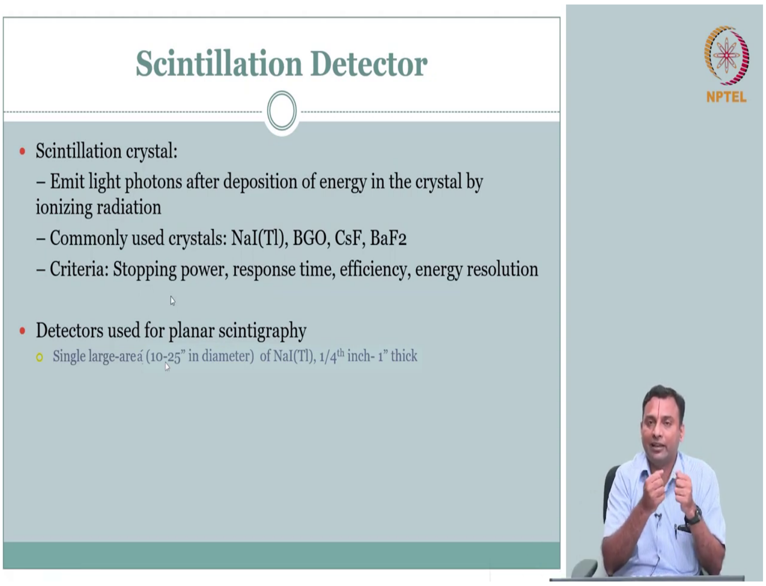

Scintillation detector again here if you really think about it is very similar to what our intensifying screens right go in X-ray what is the objective there? Convey convert the X-ray photons into visible photons. So, here you have scintillation crystal, even there we said in digital radiography which we did not cover that time. We said rare earth materials have come in. So, cesium iodides those are started to you know becoming usage and things like that.

So, here it is basically that part. So, here scintillation crystal what happens is for every gamma ray right ionization takes place and it gives out energy in the light photons, ok. So, some of the commonly used crystals are sodium iodide, right. We talked about cesium iodide at least I mentioned that when we did our when I mentioned about projection radiography you know digital X-ray or right which we did not cover fully I just said we will stick with the film, but nowadays digital radiography is popular, right.

So, rare earth material. So, I use sodium iodide which has a coating of thallium right dope and then there are few others. So, that what is the see here what is the you know the big picture. What is it supposed to do? Gamma rays is coming, it has to absorb the gamma rays right excite photoelectric and then difference energy when it comes back to the ground state reconfiguration it sends out energy which is in the photon light right range right.

So, what are the aspects that needs or the criteria that is used for having a detector or choosing a detector crystal material stopping power, right. So, you want the gamma rays coming; if it does not have a stopping power then the gamma rays will go out as well, right. So, stopping power in this case the stopping power is for the gamma, it has to be a higher energy right.

Response time, similar thing that we talked about speed of camera right that time efficiency of course, conversion how much photons, how much gamma photon is getting actually absorbed, conversion efficiency. And, energy resolution, this is another key because in you know gamma rays we know the radio tracer is sending out a particular energy. So, you want it to be having good energy resolution, so that when it comes out we know we can stick to only those photons that are supposed to have come from the radio tracer, all the Compton scattered should not affect.

So, the scintillation crystal is important because on one side is the raw data that is coming from the radio tracer, on the other side is the signal estimate that you are going to work with. So, you do not want it to you want it to have good energy resolution otherwise if it is going to already be lousy here. It will be very difficult to separate out which is the signal, which is Compton scattered signal. So, typically you have a large area this is supposed to be area what is that about 10 to 25 inch in diameter.

So, it is fairly right it is about 2 feet little over the 2 feet. So, it is a fairly big one and look at the thickness it can vary anywhere from quarter inch to an inch. Clearly you know the difference why this thickness is important parameter? You need to have a stopping power. So, you need this gamma rays to have time to interact and convert gamma photons to light photons.

So, this thickness and what is the other issue with the thickness that it is controlled by the thickness? If it is thicker your resolution right same thing affects here also. So, thicker the crystal your point spread function of this crystal rate or this when we talked about intensifying screens we kind of said that you can think about it as poor resolution or more spread out if it is thick.

If it is thin, then stopping power is reduced or right because the material is less to interact, but then your resolution could be better same tradeoffs are holding good here as well, but this is a little bulkier you can see about couple of inch thick and about 2 feet diameter. So, this is going to be bulky, ok.

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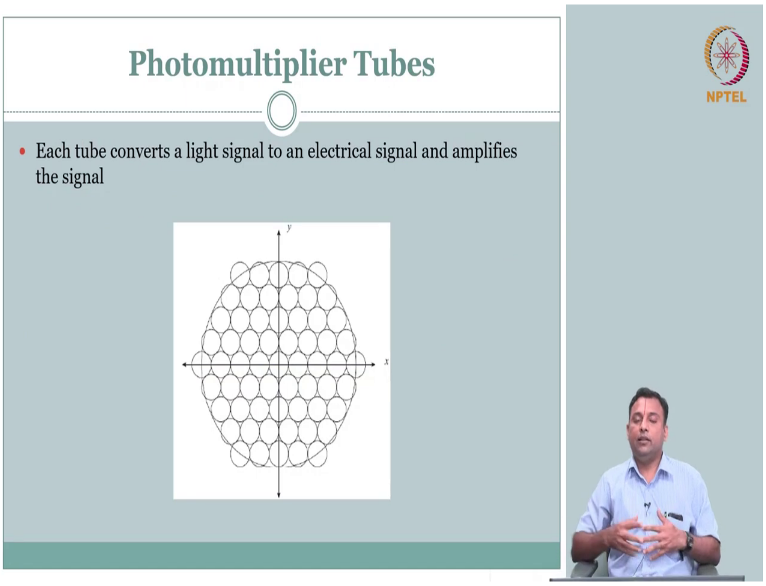

So, now what we need to do is get into the next. So, we know much about the scintillation crystal. So, the gamma rays come, first is collimated; after it is collimated the gamma photon is hitting the scintillator, right, scintillation crystal. Out of the scintillation crystal what do you have you get light photons, but that light photon now is you have some number right depending on the conversion.

But, then here we need to have two things worked out one is I need to be able to amplify the signal and the other thing is this is the plane x-y plane. So, what you see the circle is say for example, your detector crystal. So, out of the crystal is going to come your light photons in your X-ray instead of this photo multiplier tube right after your crystal in the X-ray you can imagine that you had a X-ray film that got exposed right photographic film that got exposed and then we talked about the conversion optical density blah blah blah.

Here instead of that we have photo multiplier tube arranged like this. So, that means, depending on the location where the light is coming out it will enter it is more of it will enter the nearest photo multiplier tube. The photons that are going in the side can enter the others as well, but predominantly majority will enter along the line of sight along the collimator crystal, out comes the crystal, it will enter the photo multiplier tube.

So, the objective of the photo multiplier tube is convert these light photons right into electrical quantity. So, we will now what we will do is we will s ee what is this photo multiplier tube, this is its configuration. It is arranged several of them are arranged, right on the other side of the detector what happens? So, when the light photon from the detector comes and hits the photo detector on one side what comes on the other side that is what we will see?

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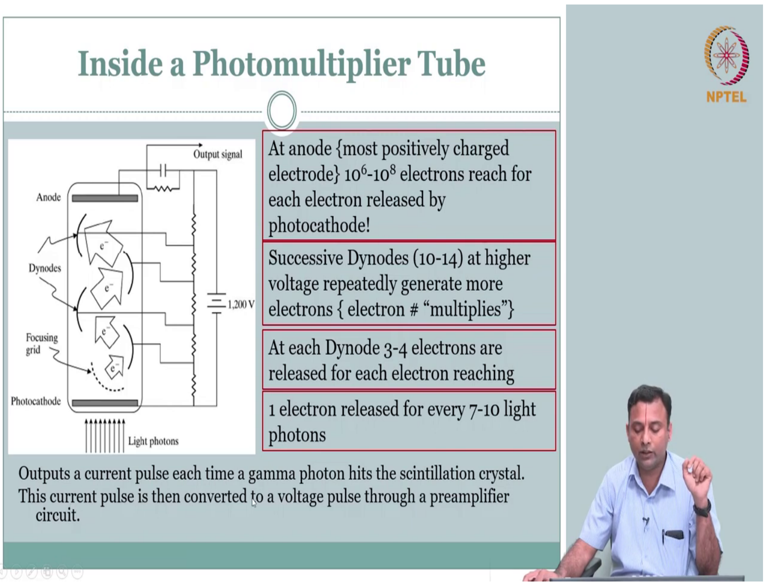

So, on one side you have light photons come ok. So, when it comes it is reflected it is going to hit your photocathode. So, here what is going to happen is this photocathode for every 1 electron right for every 1 electron that is released here it takes about 7 to 10 light photons.

So, in comes light photons about 7 to 10 light photons when it hits you get 1 electron that is given out by the photocathode. Once this is there you see these structures which are also called as focusing grids, these are dynodes, right. Each one is kept successively at higher voltage than the previous one.

So, what happens is this is kind of used to steer the electrons. So, you have for every 7 to 10 light photons you have one electron. This one electron now is steered; it goes near the dynode right. So, at each dynode more electrons are released for each. So, about 3 to more as in say 3 to 4 electrons are released for each electron reaching this guy each dynode. Likewise you have several dynodes, ok.

So, you have about 10 to 14 dynodes. When you have that what is happening? So, you start with 1 electron after the first dynode you get additional 3 – 4. That 3 – 4 goes into the next dynode there are chain effect. So, it starts to increase. So, after 10 to 4. So, this is why photo multiplier tube. So, you see how you kind of the electrons are multiplied, right.

So, you go on doing this, you have successive about 10 to 14 of them. Finally, you come to the anode, right anode is at the highest voltage highest positively charged electrode, right. So, in this case you have about each time it is multiplied. So, you eventually get about 10 power 6 to 10 power 8 electrons for each electron that was released here.

So, that is why it is multiplied right photo. So, now, you see the signal is actually amplified. So, now, this is a voltage signal. Of course, you can read this out as a voltage signal, right. So, you have successfully converted the gamma rays into light photons the light photons it converted to your electrical signal. So, you can read this out that is your output signal, ok.

So, you get some millivolts to volt right few volts you get that range. So, the whole idea is outputs are current pulse each time this is the gamma photon hits the scintillation screen. So, for each scintillation right gamma photon hitting the scintillator screen you get 1 pulse of voltage. So, this current pulse is then converted to voltage pulse ok.

So, this is your. So, one activity; so, we will start from the source from the body one activity right radioactive decay. So, one gamma photon comes that gamma photon interacts with the comes through the collimator scintillation; scintillation converts it to few light photons the few light photons converted to 1 electron, right and then that is multiplied through the photo multiplier tube and you get your electrical signal out which is supposed to be correlated to the gamma rays that came ok.

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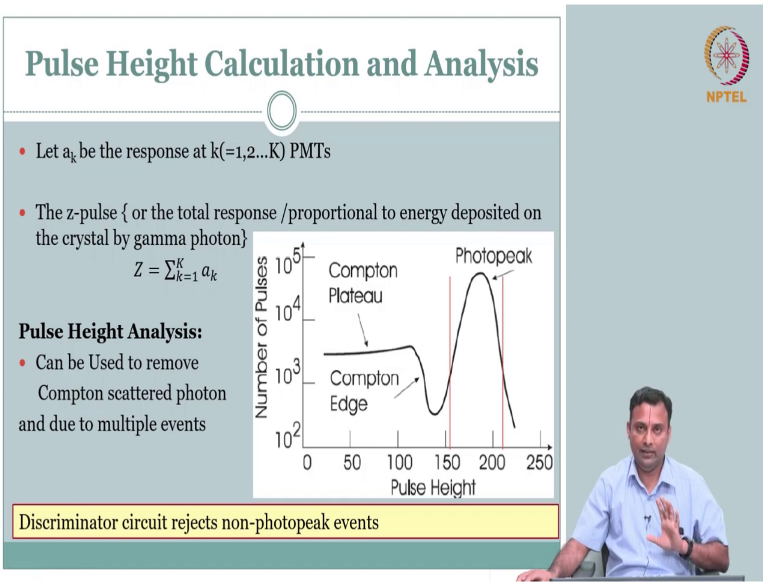

So, that is your photo multiplier tube then what happens after your photo multiplier tube I have the signal output signal. So, gamma rays came converted I have a signal. So, now, what I need to do how do I use this signal, right? First thing is we need to we had say several photo multiplier tube right you saw the configuration. Those configurations what was shown is circular, you can arrange it in rectangular, right so, either ways you want.

The idea is each one has an output. So, what would be the logic? The logic is if the gamma rays came, hit the scintillation crystal. So, the maximum intensity will be on the photo multiplier tube that is closest to the scintillation, right. Rest of it is going elsewhere.

So, in some sense your photo multiplier tube you have k of them, right. Each one has a output signal that is coming that output signal is to an input that came from a particular location in a crystal and that particular location in crystal is directly in front of your collimator in response to the gamma rays that entered through that.

So, what do I want? So, what is the value of this pulse height we talked about this pulse that we are recording, ok. What is the meaning of the pulse height? Pulse height is going to be related to the gamma photon energy that came, right. So, the z pulse or the total response. So, z pulse is nothing, but x comma y. So, there are three aspects here x, y and z. x, y is your location right in the x-y plane. So, we will talk about that. So, you have x y.

x y you can already think about which photo multiplier tube, right. I know where it is on the x y plane. So, roughly you can sense the location to be your x, y coordinate system. What is this z? z is your amplitude or the in this case what is the signal? z is your activity total activity.

So, if you think about it, I have several photo multiplier tube, I had my gamma come scintillation converts to the light. What happens to this light? The light is spread right because there is a thickness. So, light spreads and it hits the photo multiplier tube several of the photo multiplier. The closest one or the one that is straight will get the maximum intensity, rest of it will also get because there is a spread that is happening, right.

There is a interaction, there is a Compton scattering. So, maximum will be at the center or the closest a straight photo multiplier tube, but the rest of them will also get something. What is the z-pulse is nothing, but for each scintillation one gamma converted it scintillates conversion, for each scintillation you get several of the photo multiplier tube can give output. The maximum output will be the one that is the closest, but several of them will give outputs.

So, you sum all of that sum all of the output. So, your z-pulse if you sum what is happening oh that is in some sense the total response the energy that is going to be proportional to the gamma that was deposited in the crystal, right. So, your z-pulse is nothing but some of all the. So, this is the important concept because it is this will be you know we will have to analyze, we will have to do our image formation, we will have to explain what I mean unless you understand the z part of it, it will be very tricky.

So, this is nothing, but for scintillation one scintillation scintillates right your gamma one gamma photon scintillates gives out electrical signal in several photo multiplier tube. The maximum will be probably the line of sight where it does, but the others will also contribute. So, your Z is nothing, but sum of all the outputs of the different photo multiplier tube.

So, now the question is how do I place it, where do I place it, right? Where do I place it? Where is this activity? So, I have this is the net response in the detector, but where should I place where is this activity where coming from because our goal is to say where the activity came from.

The easiest way is whichever had whichever photo multiplier tube had the maximum, maybe that is the line of sight. So, you can keep it there, but the downside of that is your spatial resolution is only in the order of your photo multiplier tube dimension, right. So, better way would be to calculate where it is using some logic which we call it x-y logic, ok.

But, the z before we go to the x y logic and say where it is one more understanding of what the z is. So, if you do this for every scintillation right for every scintillation you get a z that is the, right. So, if you collect this during data collection you collect it and then you plot it, right? What happens? You have pulse height; pulse height is what? Pulse height is the in is correlated to pulse height is what z pulse height is. So, it is correlated to the energy that came in because it is a total, right.

So, pulse height and number of pulses that came if you plot this you will see this kind of a easy looking easy on eyes to look, but it has some strong markers to look at. What this says is what are we sending? Gamma with one energy. So, ideally what should happen? Only that energy should come right, but that is not the case this pulse height is related to the right because pulse height is nothing but sum of so, it has to be right you are adding everything, ok.

So, what you notice? When you add you also get energies that are low, right. When do you get energies that are low? When you have not the actual photon that is released gamma photon because that is engineered right your radio tracer, but this gamma tracer when it interacts with the crystal there could be Compton scattering, right or when this gamma which is interacting in the body the radio tracer has to come out of the body, right.

The radio gamma has to come through the tissue may be there at some energy level maybe there is some scattering happening as well Compton scattering, right. So, there is Compton scattering that could possibly happen when it is trying to exit the body depending on the energy conditions, and probably the interaction that is taking place in the scintillating crystal that could also because you get collimator and then this crystal the crystal can not all of them you know give light energy.

Maybe there is some energy that is interacting you get the Compton interaction not just photoelectric Compton scattered will go to a different location and there may be it is generating the light photons. So, what you. So, basically the z-pulse right pulse height is related to the energy. You see that you will have a strong plateau.

So, no matter what you are having Compton scattering which thankfully here the Compton scattering is there throughout, but we can kind of know it from the plateau, right. So, what happens here? When you have interaction we talked about Compton scattering when is the lowest Compton scattering signal, right. We talked about Compton scattering h mu comes h mu dash goes at a theta angle when is the lowest energy when the scattering is 180 degree.

So, this represents Compton edge represents some of the right back scattered. So, though there are also those ok. So, what is of interest to us? Our interest is define what is our signal our signal is photoelectric effect where the energy of the photon is in the direction or from the photoelectric effect where this conversion of those gamma is proportional to your light.

So, where there is peak that is the guy, but usually you have a tolerance, right. So, within a range of or within this gate. So, you get and you say this is my signal remember we did similar thing h mu dash h mu what is the angle along I mean until when the Compton scattering signal will also be considered as a signal. We did that in X-ray as well, right similar thing.

So, whether you want to allow for Compton scattering until 30 degree, 50 degree because your signal is going we cannot clearly stick with only one signal, you need more photons. So, your signal to noise ratio remember. So, the idea is you can have this analysis is important. You get one for one scintillation produces an output that output we call as z-pulse, right, sum of all photo multiplier tube.

Then we analyze this in relation to a threshold and say ok if z, right, if z value is beyond less than this for example, you do not bother about it. You think that is not your signal that is only Compton scattered signal. You do not want to waste your effort now to say where that signal came from because you cannot say it you know it is Compton scattered signal. So, you will be wrong to put that in the line of sight.

So, you kind of collect all the signal, do this z analysis right what we call as pulse height analysis and then we figure out what is the signal, right, which scintillation is produced because of the signal that is the gamma not the Compton scattered one and which is not, ok. So, it can be used to remove Compton scattered.

So, this analysis of height is used to remove scattered photon and also what ok Compton scattering we know energy is less. So, less side is fine, what is this greater side? You could have some sometimes you have multiple events simultaneously recorded multiple events that are coming from different directions multiple interactions.

You know sometimes if that happens you get more signal, but then you there is no meaning in saying which interaction you are talking about because you cannot tease that out. So, you have a region where you think based on the energy you can set the tolerance you can say that this scintillation is related to the radioactivity, meaning I can use this scintillation information to locate where it came from and therefore, in the crystal and then therefore, where it came from the object, ok.

So, discriminator circuit – so, you have a circuit. So, z-pulse height analyzer you have a circuit which will do this and detect the peak or within the threshold, anything beyond that,

that scintillation event will be discarded will not be used further, how can it be used further? What is the next step?

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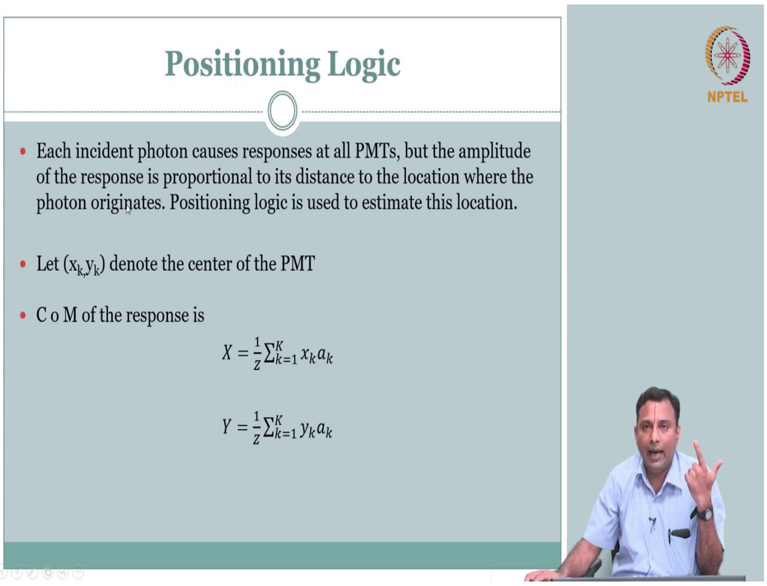

Next step is ok, if I believe this scintillation is not corrupted by Compton scattering. So, it is not some scattered signal for which I cannot tell from where the origin is, then if z analysis tells us that. So, if you collect your z only those events that falls within the whose z pulse falls within the threshold is a valid event. If that is the case then what we need to know we need to then talk about where it came from ok.

Now, this scintillation is valid, where did it come from, activity and location, where is the location. So, we have what is called as positioning logic. Like I said the easiest position is the photo multiplier tube that contributed the most right could be the easiest guess.

So, that is probably the closest one to the where this gamma rays came and 4 scintillation happened it is right, but then that is only give you a resolution in the order of your multiplier tube dimension rather we could go for center of mass, right. So, if you denote x and x k, y k as your location for your center of your photo multiplier tube we can use a center of mass instead of just using the photo multiplier tube with the maximum response as the location instead of that we could use center of mass.

How do we do that? So, you have your X location to be x k a k. So, this one z is what we calculated right total. So, 1 by z of partial contribution. So, this is waiting for location and the amplitude in x direction, location amplitude in y direction so, equivalent to your center of mass calculation, right. So, you can get your X and Y. So, now, we have our activity, right and where that possibly came from in X and Y location, clear?

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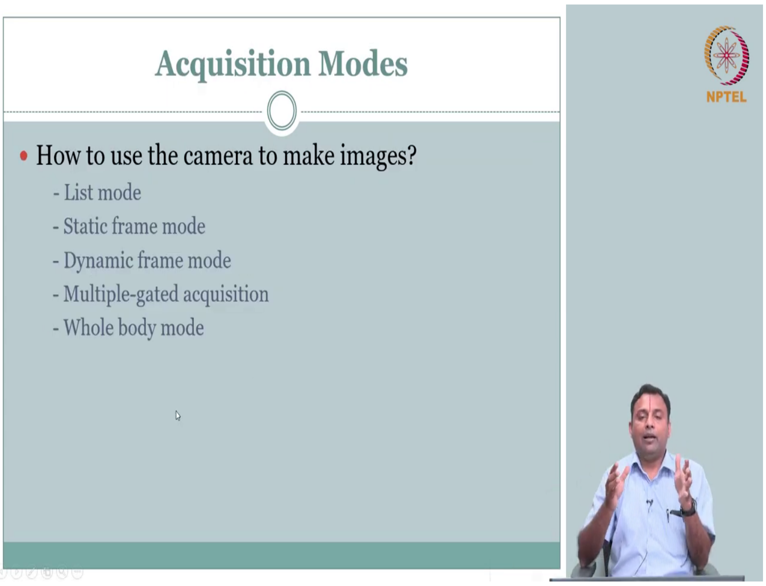

So, having, so, that is all, right? We got it. Now, the question is what are the different acquisition modes? So, when I do this the radio activity is coming there is you cannot stop the sources after you prepared the patient the radio tracer is giving out, no control over that. So, in the detection whatever we saw what are the different ways we can operate it or what are the different acquisition modes that are possible, right that will be meaningful that can be used to our advantage.

So, essentially you have different modes starting with the list mode to a whole body mode, we will go one mode at a time, right. These are very intuitive because you know the important aspects the z analyzer, x and y location if you know that and you understand how this is coming what is this signal, in relation to what is the source that is sending out right then all of this are pretty straightforward way of exploiting this information in a for a particular application.

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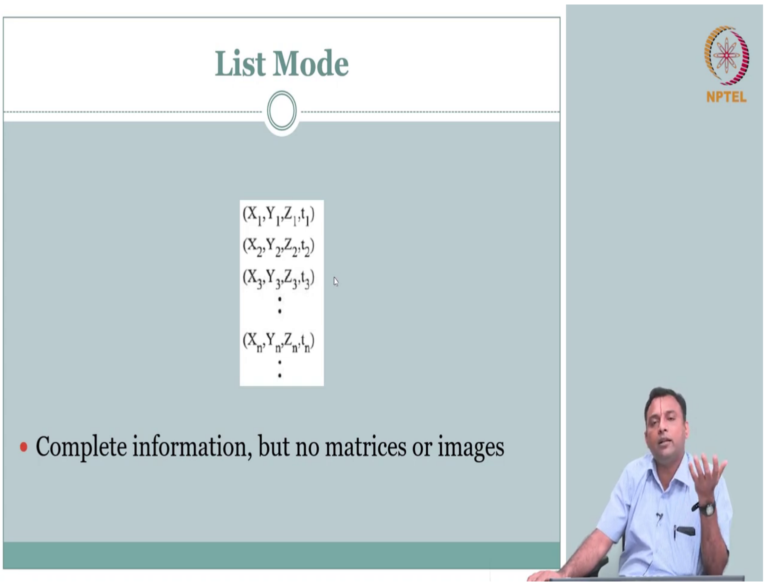

First is your list mode. What is the list mode? I am not giving any image or anything, this is just listing right. So, you collect this data and report the data in this form of list. So, I will have x 1 comma. So, each scintillation event, right, I have n scintillation. So many photons came out. So, X 1, Y 1 in that scintillation event amount of energy right what time it occurred.

So, I just have a list view of this. The advantage of this is, this is kind of raw data that is well organized, ok. Of course, it will have events that have passed the z-pulse analyzer, right. It has to go through only those events that you think are going to be contributing towards your because your X and Y you anyway contribute calculated only for those events.

So, this is your list mode it has complete information, but no matrices or images. This is just you print out, you look at it, ok. A more I mean this is useful because it has it is kind of a raw data that you have this information, they stored it. But, if you have this what is the; what is it that you want to do? You may want to visualize this, right.

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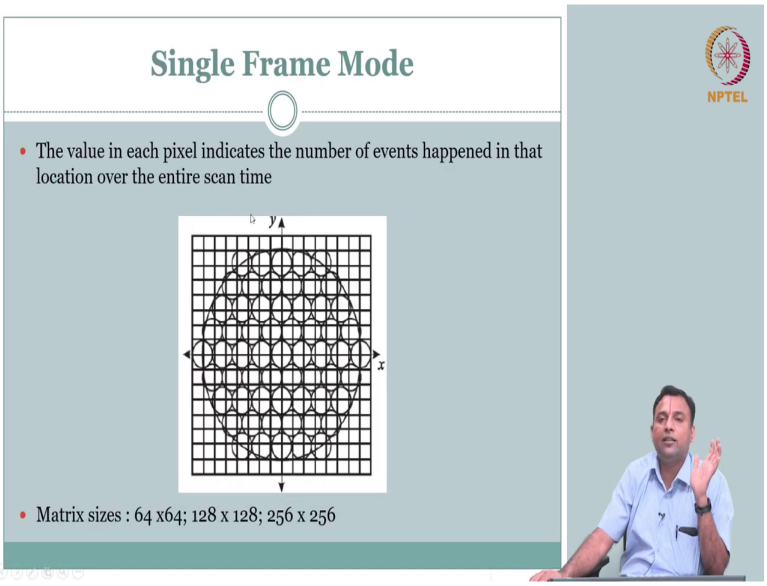

So, the easiest visualization is your single frame mode. So, this is your right mesh grid right of your imaging grid if you want to call it and this we know this is your detector and then all these little circles are your photo multiplier tube. So, based on the analysis you know x comma y what was the z, right. So, what can I do? The value in each pixel indicates the number of events happened.

So, if I keep the grid I have one scintillation I have one x comma y comma z next scintillation happens, I add it next scintillation happens I add it. So, I keep on adding. So, I have one frame the each pixel right x comma y comma z you add if each scintillation you map it to the same grid and keep on adding. What will happen? Over time because radioactivity is happening right radioactive decay is happening over time.

So, if you do this what is going to happen? It is going to catch. So, after some delta t you have a static frame where you can probably see which activity which location had collected maximum activity, right. So, in this way you have the entire. So, this is called a single frame mode because you just have one frame for the entire scan time.

So, the patient has been scanned for 10 minutes for example, at the end of it you have only one output, right. So, the advantage of this is I mean as the signal decays more signal is coming right your signal to noise ratio will be high, right. So, you can keep on accumulating the data. Of course, the downside is if there is any motion or anything, right because radio tracer is there the motion then there will be some blurring.

But, otherwise this is a mode where you could get single frame you can get all the signals added. So, your signal to noise ratio could be high. So, typical matrix size of 64 cross 64 or 256 cross 256 at the higher end will be used, ok. This is single frame, but then you see already the down limitation, limitations you have added everything, right.

What if there is motion in between what if I want to see the rate at which something so, I send the I want to see each time blood is circulating it goes into some activity and a heart is pumping. So, what if I want to see the rate of wash in or wash out of a contrast agent to do a particular organ, right.

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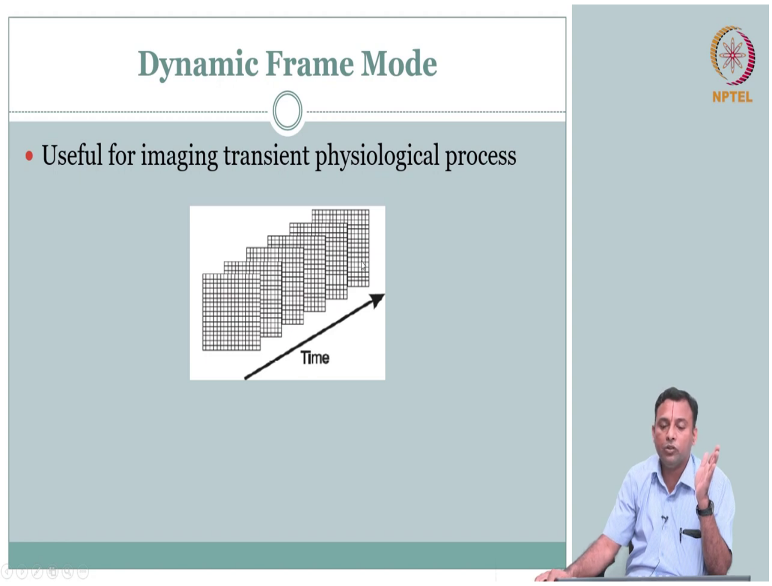

So, all those things if I want to do I want to go for a dynamic frame mode. What is this dynamic frame mode? Very similar to your previous one; previous one you added everything one not here you do not add you retain each of the frame with a time index. So, activity so, small delta t I have one static frame, right, one single frame I got and then next delta t after some time I have another frame next. So, if I have n delta t, right, then that is my n frames that I have ok.

So, the idea here is if you want to do some physiological process that are transient. So, I want like I said how something is washing in, right. I may want to use this more. Of course, you can synchronize this and use as well, right? You can restart. So, I can synchronize this some with external trigger I mean some other trigger. For example, cardiovascular which will again see in the next slide, but then I can get ECG, right.

So, I know with the high precision which part of ECG which part of heart cycle I am calculating this or imaging this. So, I can say ok I will trigger everything from the start of. So, I will start my your detector for you know scintigraphy, you start it at the start of say for example, r wave, so, right. So, I can time that. So, from there on I can acquire this delta t over the full cycle, right. So, this is one way of dynamic frame.

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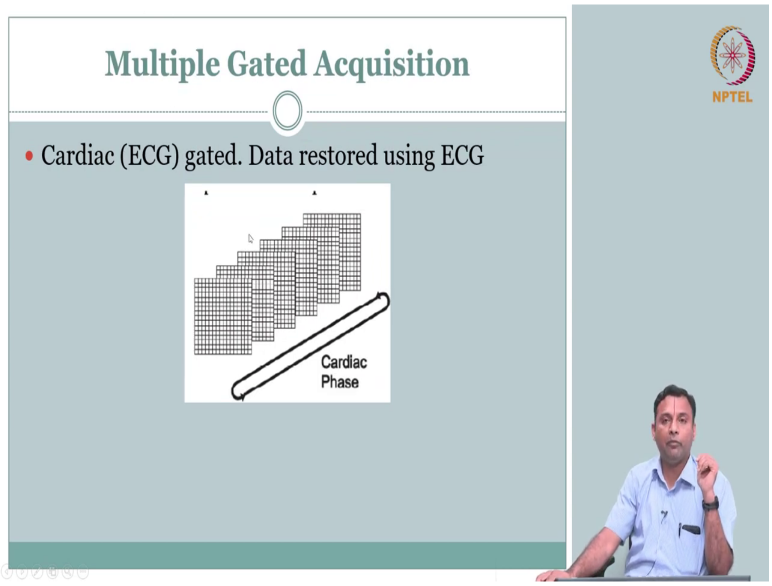

What is another so, you talked about dynamic frame already what is then multiple gated acquisition? So, extend this concept. So, for example, I am imaging heart. See, dynamics if it is just how the radioactivity is coming from some anatomy, right, that is static that is not moving, then ok the first image itself is good enough like single frame, right. After some time I know whether the activity is there or not.

Whereas, if I have dynamic like heart if you want to image we already saw the dynamic frame, but then what is this gated dynamic? Maybe the delta t that you are acquiring has only some signal to because you are see the idea thing is if I wait for long I can get more photon count my signal to noise ratio can improve, but then I want to catch this which is moving.

So, I have some I my inherently I have to have less delta t, right. So, that because it is moving. So, then how do I maximize this? How do I get good quality signal or signal to noise ratio, so that every phase of this pumping I can have good image? The good news is this is not stopping right, it is continuously doing. So, you have multiple cycles.

So, if I gate it correctly, then I can collect the data over multiple cycles and stack them correctly at their phase whichever right all the r phase from the multiple pumping, I can stack them together and then use that as one value. So, multiple gated data is right you have in ECG, you can use heart imaging like you could use ECG as a trigger signal you can align that based on that high resolution you can temporal resolution you can organize your frames, ok.

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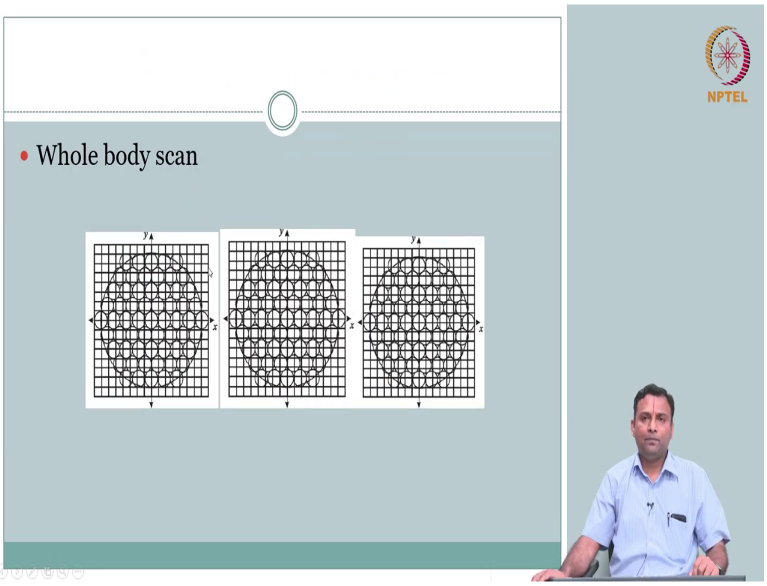

So, whole body scan this is not that difficult to essentially you have one frame register it move to the next, register it move to the next. So, you juxtapose, so that you have for the whole body of course, you can time this. So, that you know the idea is the radioactivity you put in you have engineered. So, it is going to give radioactivity, ok.

So, if you want to keep the count so, you know when to start, maybe the acquisition time is going to be little more because you have to locate I mean do this 2D frame at different locations in the body right till you cover the whole body, ok. So, that is for your different modes of imaging.

What we will wrap up is after you acquire all this data what is our imaging equation and what is our because we have to contextualize this. This is all now the detector frame right eventually we want it in the patient frame. So, we will go into imaging equation, right using one of these modes that we have talked about if you acquire the data, we will go to the imaging equation after that we will conclude with the quality of the images, ok.

Thank you.