Introduction to Biomedical Imaging Systems
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Lecture - 22
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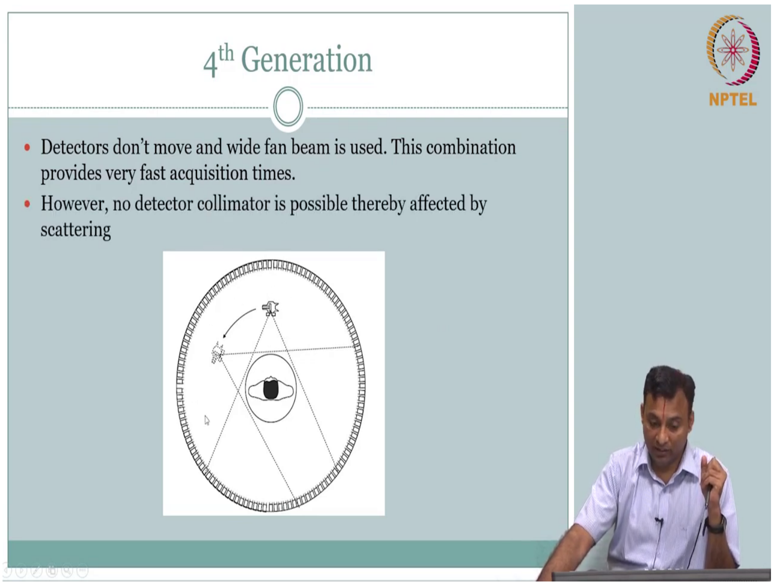

In which case the rotation of both the source and detector together we eliminated translation completely. Can I eliminate rotation? That is the next logical you know big step that you can think about. Well, if I have to rotate the eliminate the complete rotation the first ecosystem is I know how to make the detector. The problem with this is the source is X-ray tube that we have been using for decades you know right. I mean in this when this is all developing. So, detector technology is advancing.

So, now I could just get an array of detectors not only that because of that I could also get circular. So, I would first take arrest not moving both rotating both the source and the detector. I will have a stationary detector that is all surrounded the patient. So, here what is going to happen? I have completely done away with rotating. First translating motion was avoided. Now, even the rotation of the detector is avoided. So, instead of doing that what is done?

Only the source is now moved right circled around the patient and you have your detectors all of all around that patient. So, wherever the source is coming that fan beam the wide fan beam that is coming only that part I can record right. You could clearly see the advantage. It started giving exceptional right compare to where you started with 6 minutes or 5 minutes kind of acquisition time.

Quickly you see when you come to the fourth generation, now we are talking about few seconds ok. So, this is very powerful. So, lot of application started popping up from a clinical perspective because these tools these scanners were getting to a speed where it was meaningful that they could record some aspects physiologically right.

See you want to do heart beat. So, you want to be I said the respiration can be held, but then you have some other moving parts as well. So, I want to do some remember the contrast agent. So, you want it to go your blood vessel is moving your heart is pumping.

So, now if you get it to seconds right you have significant advantage ok. You can start to see things applications that you never imagined before. So, it became very powerful, but is there any I mean like how we did for the other generations, what is it that we are going to pay up for?

Of course, the cost and all is going to go up right. Do not worry about the cost per say, but yeah it is important, but technically what is happening? Technically you have gained in time. Is there anything else you are losing? Yes, two things you had worried about, scattering in the second generation and third generation because you had to have collimation.

Here you notice because the source is moving you can have any angle right. You cannot really have a detector with a fixed angle when the detector and the source were moving together you could have collimator based on the line of site right. From the source to detector you could have a collimator whereas, here that did I can change my step size for my rotation of my X-ray the tube source. So, in which case I cannot really have the same line of site.

So, the detector must be able to pick depending on where the source is shooting. So, you cannot really have a fixed collimator. So, the collimator aspect is done away with. So, the moment you do away with the collimator what is the problem? A problem is you are now you are having multiple lines and you do not have collimation.

So, even though you gain significantly with respective the time of acquisition your Compton scattering is going to be a huge role. The only advant the where do you gain because I am going to have this surrounding the in a circumference the detector size can be bigger.

So, if you have more area to pick the photon probably your signal is also going up. Your detector efficiency is increased, but then Compton scattering is going to be there. So, everything said and done. In fourth generation you are still able to get image quality comparable to your previous generation right with not so much significant improvement or significant increase in exposure, but very significant decrease in acquisition time.

So, these are very popular generations because you see you do not really lose much. CT itself you are seeing new aspects inside the body. So, you see new information at if you accepted the initial quality when you got trained with this modality as a doctor right. You are still seeing that quality, but now you are your clinical applications open because you can do it fast ok. You can start to see some anatomy which are moving which is a huge deal right. So, these are.

Now, the question is good, where is my next promotion right? Now, what do I do? How do I push the market? How do I help the physicians more and come up with the next generation?

Well, you look at it the only thing that we have not touched. So, far in this paradigm is your why is the source moving.

Only one X-ray tube is there in all the generation. We saw only one X-ray tube is there and the X-ray tube is moving. The challenge is unlike detector. Detector like I said you know we will talk about it, but the advancement started to happen. And so, they were, but X-ray tube has been there from you know from before even for projection radiography we use the same X-ray tube.

So, this is the active part right. So, it is heating, it is bulky, you have high voltage. So, this is cumbersome. So, you cannot have multiple X-ray tubes and you know try to rotate them. So, it becomes challenge. So, in some sense they did not work on the X-ray tube aspect to have multiple source because of the bulkiness of the X-ray tube and it is a very critical component unlike the detector which the evaluation was parallelly happening where because of advancement in semi conductor.

Whereas this one is still was a challenge. So, the next best thing would be I will go to my physics. What is the role of X-ray tube? Generates X-ray. How is it generated? I have a particulate right electron beam that electron beam goes hits the anode out comes the X-ray then you do filtering shaping all that we know that. So, now, you are saying asking the project manager look until now we have been doing the only problem I see is the source.

Instead of rotating the source right and you are saying rotating the source is challenging because it is bulky all those things. So, you cannot have even multiple source because its wear and tare. Instead how about if I can use the electron right, I can move the electron around that is easy.

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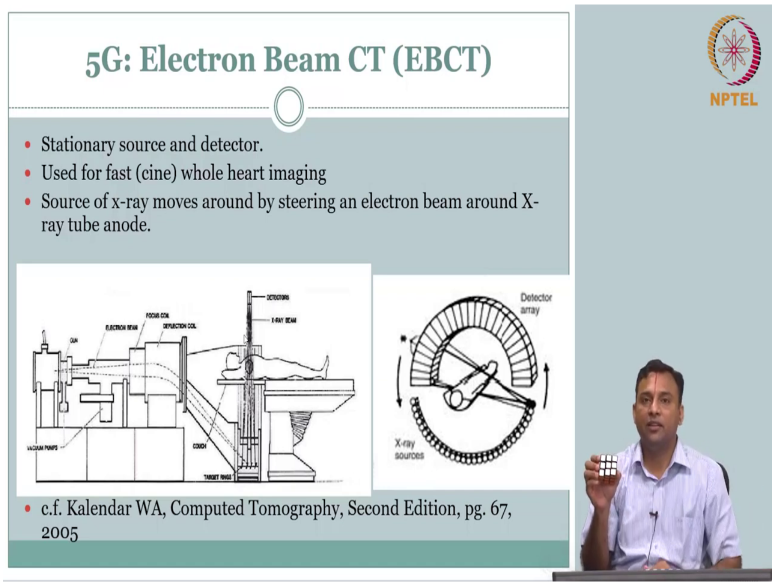

So, instead of having X-ray tube moving around I have come with the generation right, which is called as electron beam CT. So, instead of moving the X-ray tube what can I do? I can move around the electron and have my anodes at different locations. So, somehow if I can steer the charged electron the kinetic energy it will come and hit the anode and I can have X-ray generated.

So, you see this sophisticated instrumentation set up. So, it is extremely complicated, but the idea is instead of rotating the X-ray tube the source instead of doing that I will create my X-rays from different viewpoints by keeping anode at those locations and steering my electron beam to that anode. How neat, right.

I mean at least from a scientist point of view from a engineering point of view it looks cool right. Look at the thinking. Instead of just moving the thing you say do not do that X-ray tube manufacturing ecosystem is set we have vendor you know. So, do not do that. Now, you tell ok instead of doing that can I just have fixed anode plates at different locations right.

The patient will not know anything. Behind I will essentially have a big set up where I will have my electrons move round and go hit a particular anode where I want the X-ray view right. So, that is what this one is. So, you had stationary source and stationary detector. Look at the advantage used for fast. We call this as cine loop like cinema right. Cine loop means you can axis get the movie that is what it means.

Used for fast whole heart imaging. So, we could really get the whole heart pumping I could get the slice of that right. Whole heart imaging I could get that is cool right. Instead of just bone fracture maybe some abdomen is there as you know lump that is formed inside the body which is all important, but then look at this cardio vascular. I can get my heart which is moving dynamics, I could get it because of the speed fast acquisition times.

So, the idea here is you steer the electron rather than moving the X-ray tube. Fantastic, you can see very nice had its role it has its importance, but then always the engineering mindset and the application there are two things right. So, the doctors they started seeing things new newer applications started popping up.

So, it had real it really served a purpose, but then the reach right it was very cumbersome because look at the sophisticated instruments the maintenance all that was an issue, but it was a it was nice generation, but it was not probably you know as popular as the so, if I did not really have a need I would not go for this right.

So, if I want to do heart imaging yeah I will try to use it, but otherwise I will not I need a dedicated system set up where I know these patients are going to come and it is worth investing in this infrastructure only then I would go for this right. So, then what do you would say?

Ok. That is fine, but the part in me says how do I maximize the benefit of this advancements. So, that more people can come more affordable, what will I do, right? I mean that is a logic right what will you do.

Well I will go back to my drawing room and say a look drawing table and say look your detector technology is evolving right. Now, this is all fine. Where could I see the next advancement? I will say you are now talking about only one slice right. You are talking about only one slice. Go back to our projection radiography we saw the whole chest region chest radiography. So, now, I want to get greedy. I got the timing information I got new applications. So, can I now instead of getting one slice can I get more slice?

So, that I can do a volume imaging. I could have several slices, put next to each other actually I can do the whole volume. So, I can go from a head to toe right in slice. So, that I can have full 3D instead of just one slice right.

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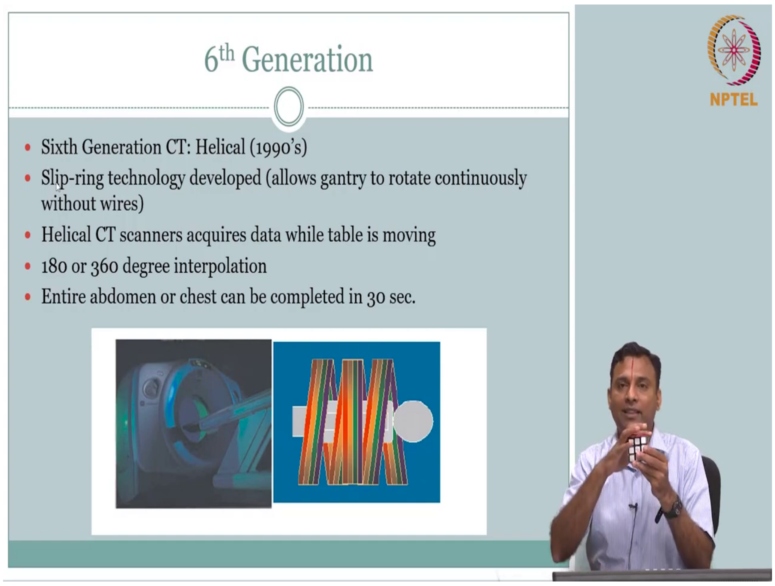

So, that is the idea right that is the idea. So, I want to get multiple slices right, good. The natural extension for that is just to hypothetically think if I want multiple slices can I have detectors, like I can have line detectors you saw. So, can I have detectors now in a you know several detector lines covering in area? Not so fast right. It was still evolving, but that would be prohibitively expensive. Then they looked at and said look what I want. I can do this slice right instead of moving.

So, when we started we were translating from left to right and then rotating the whole setup. Now, I got one slice. So, if I want to go from head to toe what will I do? You could either move right move the slice acquisition like this or instead of moving the instrument you can have the patient bed right where you are lying.

So, I can motorize that I can make it sophisticated so that the acquisition is still whatever the previous generation, but I can move the patient. So, that I can go head first like this right. So, that is what is shown here. So, why it derives its name as helical is imagine you are moving in this direction and it is scanning in the rotation right. It is scanning around the patient and the patient is moving. So, what will it look like?

It will look like a helices right that is why the name is helical scanner. So, the biggest you know this is not this is in the 90s. So, look at the progress from the 70s right when the initial work was done and they got the noble prize for that. 70s, 80s in the 90s you are talking about sixth generation. So, every few years you are really pushing it ok.

So, here the point is everything else is similar, but you have added this you know bench your patient bench also is part of your instrumentation for data acquisition. It is not just be patient lying that is also technically contributing to the registration because that is its position has to be recorded.

So, that in the recon you know how it is happening. So, in some sense technically it is a part of instrumentation ok. What are the other advantages that you other technical advances that apart from that you know the detectors that I talked about what are the other advancements.

See you have now too many wires right. So, many detectors each one is feeding out right you are reading the data out. Now, you have the whole thing has to the source has to move inside right. Now, we are saying the patient has to move the bed has to move in and out.

So, you are talking about lot of wires rotation translation. You do not want them to you know get clogged or anything. So, what happened is you had slip ring technology that was maturing right.

So, without is so you could rotate this gantry you could move do all this without the wires getting enter to end. So, the slip ring technology started to become really useful they adapted that to this instrumentation. So, the mechanical design and the electrical design for the control of both. You have two aspects right. One is your data coming out.

The other is all these control signals to move your translate, rotate your bed or your source that those wires. So, they were able to essentially use slip ring technology became very popular and very useful. And therefore, you could start to do all the integrate patient bench motion and other things without much trouble. So, helical scanner. So, you could get entire abdomen or chest completed in 30 seconds.

Fantastic, right. We talked about say in second generation; we were talking about some 30 seconds. Now, but that is for one slice. Now, you can get a whole chest or whole abdomen. So, you are talking about say for example, several centimeters right whole chest whole abdomen. We are talking about several centimeters; you could get in 30 seconds right, fantastic.

Well, so far so good. So, this is popular as well, but then I would still like to have multiple slices. Can I do even faster? How can I do even faster? Well, I can do even faster. The same logic. Instead of moving the patient right translating the patient can I go back to your first generation? You are doing translation. We wanted to avoid this translation to gain time.

Now, you are moving the patient in helical. So, you are getting 3D. You can get the whole different slices, but if I want to reduce the time even further. What will I do? Instead of moving the patient can I have multiple detectors right? One row of detectors you saw, can I have another row of detectors right. So, if I have two rows of detectors. I have two slices recorded at the same time. See I have three rows; I get three rows of slices recorded at a time right. So, again.

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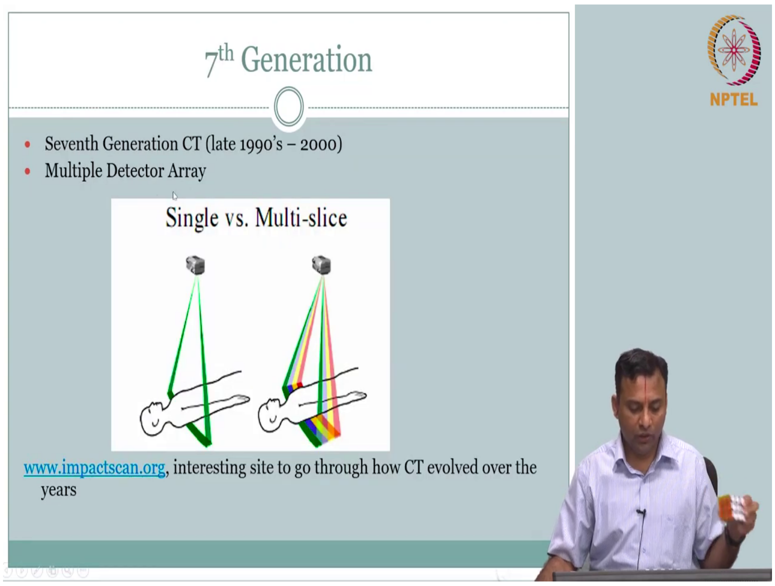

So, the logic was in the seventh generation right you got what is called as multiple detector array. So, when you have when they say array means, you have several elements array of elements. Now, you have multiple detector arrays. So, your single right. This is the fan beam. You have one full array. This was the thing in the fourth generation right, third generation, fourth generation. Fourth generation essentially you are rotating and getting it. So, third generation for example.

You got one array. Now, what you are doing is you can get multiple arrays you can position. Only thing is what you have to do? Instead of sending a fan right with only thickness proportional to one detector size remember how the X-ray tube generates. It generates a cone right. It is point source; it goes like a cone that is how we did in projection radiography right.

So, here deliberately I have to have make sure that I have this fan, but the fan should be spreading over how many hour detector array I have. If width of height of one detector is x and I have 4 arrays here then I have 4 x. So, I have to now my you know width has to be 4 x, ok.

So, the idea here is direct brute force extension of the previous generations with advancement in the array. So, you can have multiple detector array. So, there is a site which I accessed a year ago. I found it to be very useful. There are several more animations and sketches that I found to be useful right along with then the line of what we are discussing here ok.

I have no conflict of interest ok. So, it is just I found it to useful. So, maybe you may want to take a look at it. So, that is your seventh generation. So, good. Do you think is there anything else that we could do right? It is 2000s, anything else we could do right.

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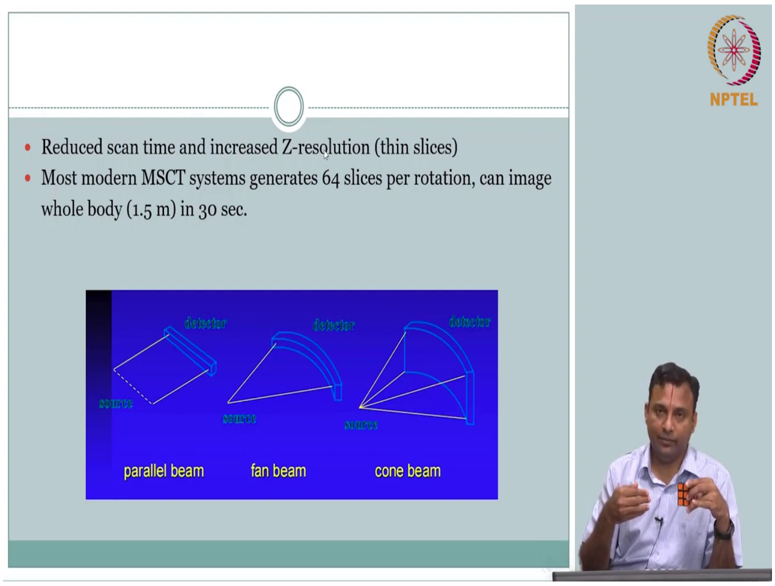

Well, not I mean the still you can do. You can you can what we are silence so far right, what happens after 2000 did nothing happen right. What has been happening in the last decade or two everything done. Not really. I mean these were developed in the 2000s and now it is becoming popular.

So, you would hear multi size scanners like, typically 64 slice scanners that are coming to the market. If you are in say India for example, these are still niche instruments that are there only in few select hospitals right. So, it is still becoming popular right. So, we are in that stage, but where is the lot of developments happening? We will come to it.

All until now we are talked about only data acquisition hardware and instrumentation. We have not really talked about the computation aspect of it right. After you get the data we have to recon get the images of the slice. Now, you are getting so much so many different slice volumes. So, you have so much data.

So, lot of efforts still is going on how do you digest this information right, how do you visualize this information 3D, 4D, how do I plot it, how do I see what is happening in certain applications right. So, I send contrast agent and I see the heart pumping. So, I have several aspects that I want to visualize, how does this perfuse into the tissue. So, you have higher order. So, you have so much data. So, much new information coming and you have to churn all this to do the computation.

And no guess here at this year 2021, you would have probably lot of bust word; you would see is all about big data deep learning AI right. So, you have lot of data coming in. So, lot of research in the last couple of decades has been essentially going towards how do we handle so much data, can be patient specific how do we you know do handle the data, visualize the data, process the data.

So, the second part of this module right to do with the image recon that will be very interesting in that sense. Now, we have just covered the data acquisition generations how was it come along ok. So, that is said essentially the idea is reduced scan time and increased Z resolution. Z is remember X, Y we used for the plane of the image. So, if that is what we are going to. So, the other direction was Z in our projection radiography coordinates if you look at it.

We will redefine the coordinate one more time when we actually do the recon because you need to know what you are where is the signal coming from. But generally if you vaguely remember how we did projection radiography we always use f of x comma y as the input source 3D object right, image of the 3D object. The g of x comma y; on the on the Z y we used it for a separation between the source and detector right.

So, Z is your thickness in this regard it is the thickness ok. So, we can get reduced scan time and increased. If you have multiple detectors I could get slice thickness can be improved because that will be about the size of the detector right. So, you can get 64 slice per rotation.

Look at this, whole body in about 30 seconds right. So, powerful these are the different geometries that we have talked so far.

Source right, you get this line first generation first generation then we talked about fan beam. This is called as your cone beam, when you did the 2D right. You had your detector array stacked volumetric ok. So, this is your cone beam. So, now the question is we got the data in this format. Along the line I get one value along the line I will get another value. So, I have collapsed I have projected this. This is the data I have.

Like this I have it at different angles. This is along this line, I have a value; along this line, I have a value, so, but it is arranged in a curvilinear fashion and I have it for different rotations. So, these are the raw data that you are measured using the different schemes different generation detectors the that we have talked about.

Of course we will right now the current generation you are talking about multiple detectors. So, it is a area. So, you have one detector next detector line third array fourth array. So, you have several of them, clear. So, this is about your data acquisition part of your instrumentation major development of the different generations. The different components in this thing several of this be we saw X-ray tube for example, is X-ray tube there is nothing new to cover. So, we have X-ray tube already.

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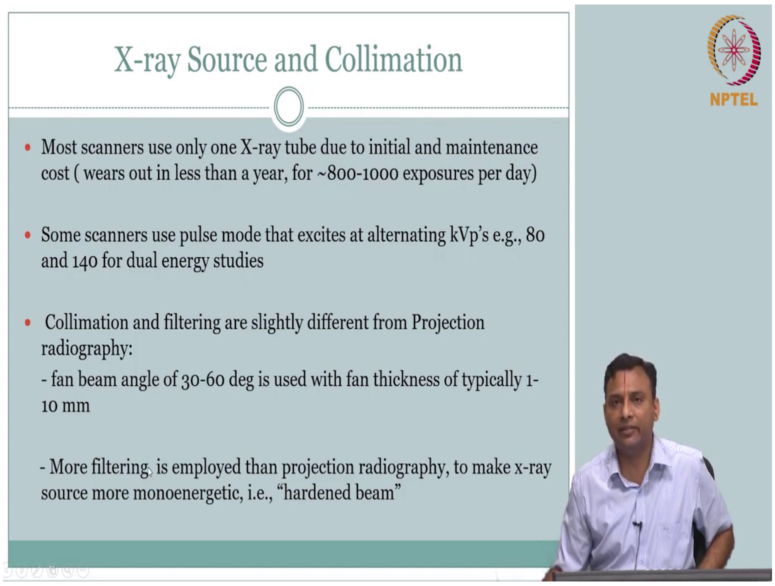

What what we need to still cover is some specifics that are there, but major components in the X-ray projection system that we covered will be used here as is. The major component that is slightly different is your detector part. So, most scanners use only X-ray tube right that is why. So, this is nothing different from what we have covered already because of this reason ok.

So, again improvisations, we could use multiple energy sources right. So, I could excite with 80 kilovolt peak. I could excite with the next 140 kilovolt peak. I could record the data two different energy levels that is where you talk about. So, you recall the basic plot that we had the hill type kind of energy versus X-ray intensity right when we talked about bremsstrahlung. So, that is the spectra that goes in right.

So, you could do that at two different energy levels because we know your mu is a function of energy also right, material property. So, you kind of do the data acquisition at two different energy levels then we could also use that information to piece out the difference in the material property.

So, dual energy X-ray you could do. You could do collimation and filtering are slightly different. You still have we saw some of the collimation. Why is it slightly different? Because in projection radiography we basically sent a cone, right. Here we talked about pencil beam or you know fan beam. Even if it is a cone it is not cone no your cone as in you do not have a curvature you do not want that.

What you are wanting is the slices. So, it is like this. The thickness direction is like this. So, if it was a cone it would be like this right, but you are talking about parallel, but it will be fan in the direction. In one direction it will be a fan the other direction it will be. So, it is not technically a cone, but it is.

So, you have to make special field you know. You remember about the collimators how we did. You have to shape it have a slit. So, that I can increase the; if I am doing only one detector array, I would want the cone that is coming out I want two leads. So, that only along that plane right along that slice X-ray goes.

If I want the slice to be thick I will make the. So, the filtration that is your you know field of you could be adjusted. When we talked about filtering, we talked about filtering in the context of removing the low energy right. So, here deliberately what you do is you make it hard ok. What do you mean by hard? Hardening the beam, beam hardening what does it mean? We covered this. You remove the low energy so that you are moving it to the right ok.

So, fan beam angle of 30 to 60 degree is used with fan thickness. So fan thickness is the thickness direction right, slice thickness direction. So, you are typically in the order of 1 to 10 millimeters. So, here most filtering; you know it is very similar, but its little more aggressive here. So, you get more hardened beam.

So, the concept of filtering all those things are very similar to what we did in projection radiography, but here we are making it more hard. Why? You when you mean making it more hard, what is happening? You are narrowing the spectrum and moving it right you are narrowing the spectrum. Initially it was wide you preferentially take the lower. So, the width of the spectra is reducing it becomings narrow.

That means you have only less number of energy distribution, you do not have wide range of energies. Why is this important here? Why am I aggressive? I want to really reduce it. In projection radiography right in projection radiography even though we wrote the equation we said monoenergetic, polyenergetic even though we recognize it is polyenergetic we were ok with not being aggressive.

Why because image was formed right image was formed and average energy equivalent to interpret was good enough because any way I am collapsing the whole dimension. So, that was good enough. Whereas, here the data that you are recording you have to now start to reconstruct at different locations. So that means, my assumptions right. I am going to start with the value that is detector I have to have a model I have to reconstruct.

So, there has to be the model right the image, the attenuation law the model that we made for the signal that has to be we have to practice be as close as possible to the model that we described and that happens if you have monoenergetic case, it is easier to handle. So, as far as possible you make it hardened so that even though you know it is poly energetic your estimate of a equivalent monoenergetic can be used in the recon right mathematics and you will not be too far away from the reality, ok.

So, that is the because ideally you know ideally you might say I want only one energy, but that is not going to happen. So, you can be as narrow as possible ok. So, source is more monoenergetic. It is not monoenergetic its more monoenergetic than before that is why you want to harden it ok. So, this is one thing that is specific to CT because we are going to start with the detected value and do reconstruction ok good. So, so much for so, X-ray source and collimation we talked about that.

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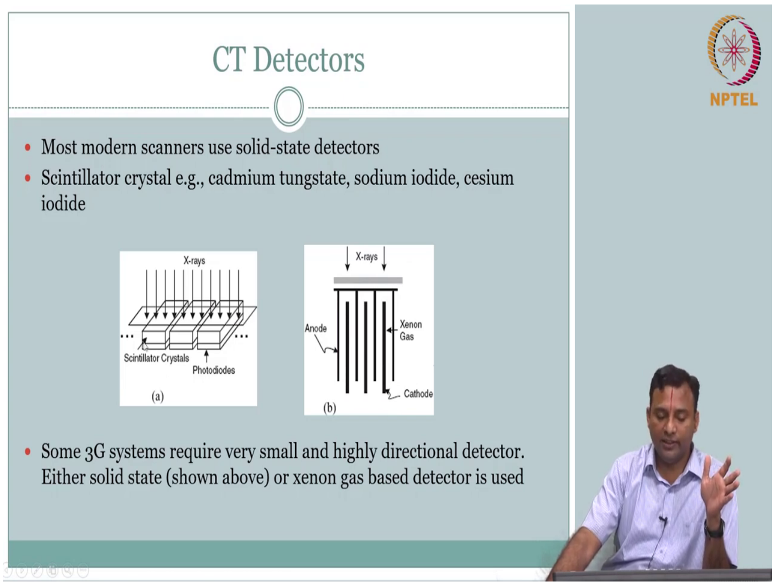

What are the other aspects? The most important aspect, I did say that. Advancement in detector right that is what we were exploiting, but you really think about it. The major difference between the projection radiography right, what was the bottleneck of projection radiography and it took so much time. It is not that people were not aware of the mathematics. In fact, you will be I was really and it is a moment to really appreciate these things. I learnt that the Radon the work by Radon tran Radon right.

Radon transform which will be heavily using in the recon right. Those lot of those theorems and work happened radon published in the early 20th century, 19, 15, 16. So, that is kind of contemporary right. About 10 years after your X-ray started coming for medical applications medical imaging application. So, in some sense the mathematics he was dabbling with how to reduce the dimensionality and recover the dimensionality from a mathematics perspective.

So, he has done lot of Radon theorem and other things happened those time. But when did you CT happen? And the problem of I am losing my depth is known to the you know the physicists that time also, but and the doctors would probably also share that opinion. I want to see what is there inside not just the projection, but the problem was they did not really have the they were used.

So, the parallelly the photography was also developing right. Photographic film, chemistry, development chemistry all that things were also developed rapidly progressing. Light was a big deal right in the early century last year last century early last century. So, the point is that need was there, but the biggest bottleneck was how do I record the data right.

So, the detection part rest of it same right X-ray tube the detector was the key. So, now, we wanted to have a detector, where I could actually record the value and take it for computation that is the key. So, what happened? Your semiconductor those started your diodes right transistors those started appearing they became very mature right. So, advances in solid state electronics essentially that translated to so, the idea of modern detectors right where you can do CT.

So, that transformation started post World War 2 perhaps right after you had semiconductor devices that were mature enough that they understood they could use for this. Then probably they work for a you know a decade or so, to put the come up with this idea of ok, I could use these detectors and collect the data the first generation right.

So, in some sense even though you would say CT was introduced the first shown to work in the 70s, but your X-ray projection radiography X-ray was you know about 75-80 years earlier than that. It is all because at that point of time what are the others. So, it s very interdisciplinary right, multiple disciplines have to progress. So, here big development came because of the development of the detector part of it mostly due to your semiconductor electronics.

So, silicon your scintillator crystal right you might look a what is. So, look at the objective of the projection radiography instrumentation on the detector side. What was it? X-ray photon came. It hit the photographic film, the conversion ratio was poor and therefore, they used some material phosphor active material right. Phosphor was there. What was it doing?

It was the intensifying screen, go look at that. So, it was trying to convert the X-ray energy to light energy and that light photon maintains spoil to the X-ray. Now, what I want? Same thing, I cannot measure the X-rays. So, here also I want to convert the X-rays. I want to convert the X-ray photons into visible light photons, but then I want to you measure that photon take it out read that. So, that I can do operations with it right.

So, you started getting these photon diodes right. So, essentially this advancement led to the scintillating crystals also like I said calcium tungstate what we used right what the Edison was using in the early developments, but once. So, that was still used in the X-ray film right.

Whereas, this detector you started getting rarer materials ok. So, you had all these which will use for scintillator. What is scintillator? It is converting your X-ray energy. So, inside. So, X-rays come and fall on the detector. What does it do? The scintillating crystal essentially convert this X-ray into light photons. And once that happens that goes feeds into your photo diode and then I can record right.

I can get my voltage I can record what is coming out each of the locations and do computation. So, two major advancements. One is yours detector part advancement of this and then having said that computation. I am not going to cover about that, but the idea is once you get that the generic advancement in computation started lending its way.

So, its a CT detector. This is a important advancement that enabled the acquisition of data so that it can be done for reconstruction ok. So, this is an important piece in the instrumentation. So, you not only had like this, you had several other versions as well. For example, if you look at third generation where you had collimator that was direction was very important. It was aligned with the source right.

So, in those cases we also talked about because of that the signal detection goes down because you have your collimator and it is in that. So, your scattering was supposed to be avoided, but also because of neighboring beams and you put collimation your efficiency also goes down. How do they?

So, essentially they also had few other ways mostly for the third generation, which this was very directional detector where you have xenon gas tightly packed chamber. So, the moment X-rays come and hit you have ionization that is taking place and then you had cathode that was at a very you know you had this cathode and anode right. So, you had a very high voltage differential that was kept.

Therefore, when X-rays came it ionize the xenon gas. When ionization happens you have a voltage difference, you have current. So, they could essentially you know use that conversion. So, this was very useful for when they needed very directional amplification of the signal mostly for the third generation ok. So, towards the end what happened? So, this was there. Line array was there.

The development of this basically led to. So, in 3G systems require very small directional. So, xenon gas base director was used, but like we said more advance scanners nowadays we are talking about not just one line.

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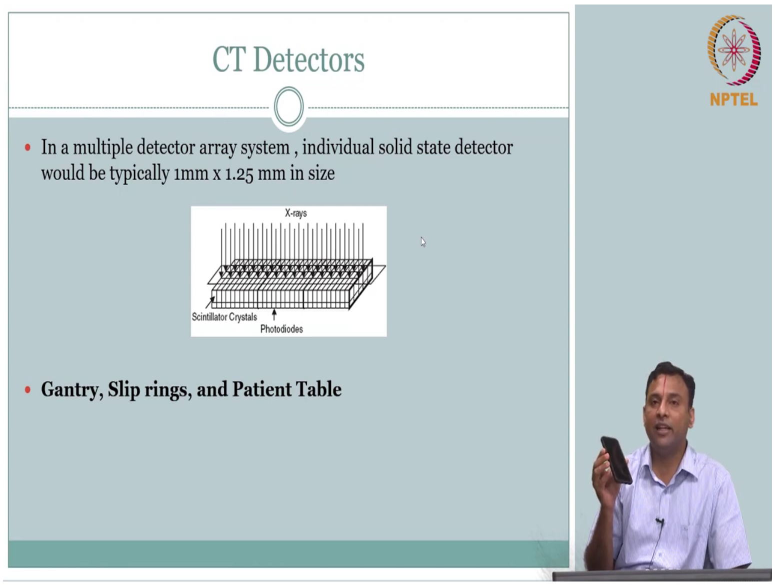

We are talking about arrays of this. I mean array two dimensional right. So, you have one array next. So, you see several of them; one row, next row ok. So, in multiple detector array system individual solid set detector. So, you are now talking about 1 mm cross 1.5. 1 mm is in the in the if you want to call it along the width right. Height is 1.25 mm; the slice thickness is in this range.

So, you still see its fairly small. I mean 1 mm 10 right. The crystal is only 1 mm in height. So, you could get as thin a slice as 1.25 mm which is pretty dam good right. So, the advancement is because of the advancement in the detector. So, not a surprise that is what we saw in our advantages right. You have these cell phones having cameras now with so much pixels right.

All this advantage we get with CCDs all that these advantage is also translate. I mean these are all happening parallelly. And also medical imaging CT detectors benefited out of those development not just the photography part ok. So, we are not going to really go in deep with the other instruments in the instrumentation. One is a gantry.

So, what is the gantry? The you saw the big. You when you see the photo of a CT right you see this housing where the source detector ring is there and the source has to move right. So, the whole thing has to rotate. So, that whole part the mechanical casing all that is called as your gantry ok and so these are kind of very matured and so, we are not really going to go into deep in this gantry slip rings like I said.

So, you have to have the gantry should rotate for example, then you have your data channel signal coming. So, slip rings that is another part that is used. So, this is mostly the other parts are patient table. Mostly, the these parts are in some sense traditional mechanical design, electrical design you know engineering which was which is well matured that was not the bottleneck. So, it kind of came along with that ok.

So, there is not some no real new sophistication that was required. This is a big deal. Why the generations changed and CT evolved your detector is a big deal. So, detection and the strategy of acquiring the data that is changed to address this big a limitation of how do I get through the slice right. That is changed and then most important part what do I do with this data. So, now, I acquire the data. What do I do with this data? I have to do the image formation.

In we do not call it we will cover it the title of image formation, but then here image is not formed by itself. You are actually doing reconstruction. You are forming the image by reconstructing. How what do you mean by reconstructing? I get the data right using these strategies, I have to now reconstruct what would be along the path right.

So, with respect to instrumentation I think we will stop here. Perhaps it will be a good point to stop now and start the imaging aspect the image formation module in the subsequent lecture ok.

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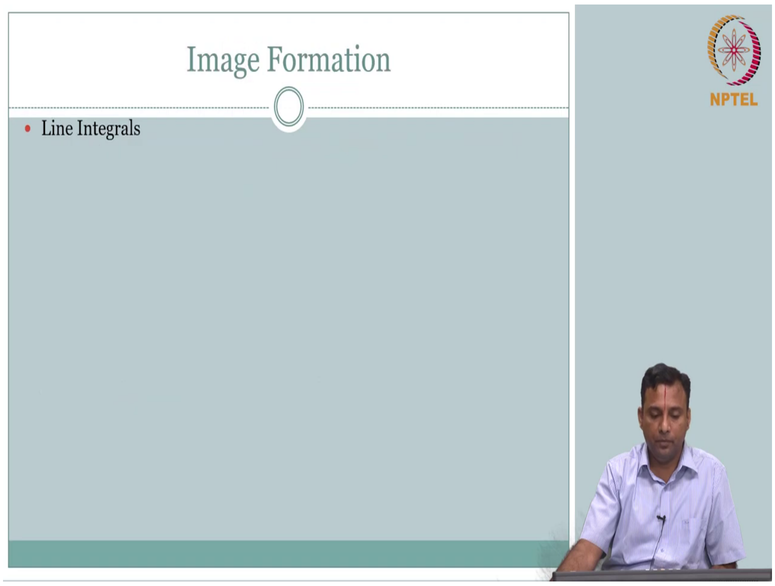

Thank you.