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

Lecture - 17
PR Image formation

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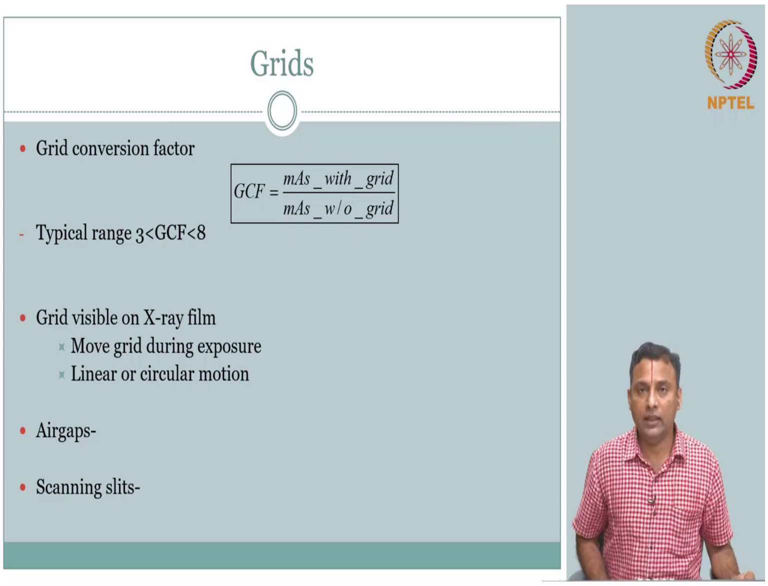

So, now coming to the last part of the instrumentation, right so, after completing with your instrumentation just before your detector, right. So, we have made all the effort now to use whatever physics we had, knowledge we had, we have engineered it so that we can get the signal on to the detector starting from the source we have now come to the detector. So, now, is that the end of the story.

So, what are the things that we need to, in fact, we did airgap and scanning stills all that just before it reads the detector. So, now, we need to talk about the instrumentation of what happens at the detector and finally, the output is going to be a image right that you are going to see. So, what are the components that are involved after it hits the detector and how it comes out that is what we are going to discuss now ok.

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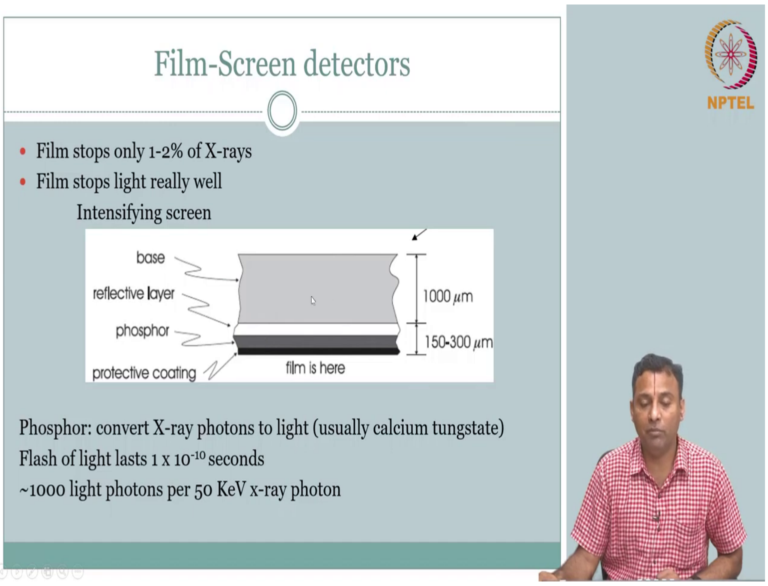

So, what we typically cover here is your film screen detector. Film screen detectors when I say this is something that you already have seen this is the same thing you would after you have a suspected bone fracture, right you would have gone took an x-ray and the radiologist will keep it in front of the white light and right you will see whether there is a fracture or not. So, that is a film screen.

So, film screen detectors is what we will talk about now. But we will have a separate module on digital detectors, ok. So, for now we will concentrate on the film screen ok. So, here it is actually pretty straight forward.

Now, you should think ok if he is going to talk about just film screen this is already there, how did Roentgen you know make a med first or at least supposedly the first medical image, right. He was working remember he was working with a Crookes tube, then he was having film photographic film and then that got spoilt by a mysterious ray and therefore, he named it as x-ray.

So, the question is fine we already know that you have a photographic film x-rays can spoil it which is what Roentgen himself discovered, right. So, that is it we know that so what is so specific about instrumentation for x-ray that we want to talk about, right. Yes, that did happen, but you know the efficiency it is only 1 percent 1 to 2 percent of the x-rays that can be stopped by a photographic film; that means, very poor, right.

Now, that we have already talked about terminologies to do with exposure and other things bio safety. We want to make sure that you have this conversion right where you want minimal x-ray the energies that come out you want whatever comes out should be used effectively to be captured effectively otherwise this is not acceptable from our a safety point of view, right.

So, the question is ok this is good, but directly taking x-rays on a photographic film seems very inefficient and then therefore, how all can we do what all can we do to improve the efficiency, right. So, in that regard I mean this is something that I always see which is we are inherently lazy, right. So, if I have solved a problem and you give me a new problem what will I do? First I will see oh, I have this solved already I have everything all the ecosystem ready I know how to solve this.

Now, you are giving me new problem. My mind is going to think ok how can I convert the new problem into a problem for which I know how to solve, right. I mean that is how you know engineering it is about having knowledge and then you have to be innovative in finding away to solve the problem right or applying it to domain. So, here that is what we will do.

We know all the photographic film is evolved. In fact, now as we speak it is all on the way out how many of you go take photo on a camera role and then go give it for development very few right. So, that you know field of photography and photography film development evolved very nicely. So, the idea is ok, so instead of directly getting x-rays to photography film, can I since that part is very well established can I find out ways where I can convert this x-ray to light.

And, maybe after it converts to light I can capture it on of photographic film and develop it and so on and so forth right. That is how you will think it is a natural you know at that point of time if you place yourself this is how human mind works, so that is what we will do. So, they said oh, we will have something called as intensifying screen. What is this intensifying screen try to do? The objective is simple.

Objective is on one side I have x-ray photons coming can I somehow convert this x-ray energy into may be visible light and then light photons can go spoil my you know photographic film, right. So, that is what your intensifying screen did. So, here what you see is just a cartoon or a sketch of a typical we will complete this by showing. So, when you go for chest x-ray for example, there will be a cassette or a disk that is put in the detector and they take and take the film out and they develop the film and that is the film that the doctor sees in front of white light, right.

So, there is a x-ray film, so the film is this guy right the film is here. So, film is here, but the film before x-ray hit the film we need something to convert x-rays to light, right and therefore, you have all this. So, this is the outer casing. So, there is a base material and then there is a reflective layer. So, the active layer in the intensifying screen is your phosphor here and then some protective coating is here.

So, as you can see you have films. So, for example, your x-rays right should come from one side, right. It should come from the outside, it will come through this base this all supposed to be transparent, right. It should not react the interact with x-rays it should pass because that is coming outside the body, right. So, it is coming outside the body.

So, these are all supposed to be transparent to the x-rays, but these are just providing you some mechanical study. Film as to be it cannot hang in air right. So, the intensifying screen is there to support you have some base. After that you have a reflective layer; what is reflective layer we will talk about it as after we talk about this phosphor.

What is this is the active gate, this is the active material in intensifying screen. What is active? What is the role of the intensifying screen? Convert x-rays to light, light photons; that means, this phosphor is a material that is going to convert take in x-ray energy and give out x-ray photons and give out photons in the light ranger. So, this is a active material. So, you have several like luminescence fluorescence. So, we are talking about fluorescence here.

So, there are different types of luminance. Fluorescence you gives you conversion the light conversion is comparable to speed of light right 3 into 10 power 8. So, this can convert right the light can be radiated generated at a time constant that is comparable whereas, you have phosphorescence where it will take some time after which it will give light.

So, the idea is this takes energy from one range. So, in our case it is x-ray energy and it creates for light energy. So, clearly x x-ray energy is higher than the light energy. So, you are expecting that a few x-ray photons or few photons with x-ray energy which is coming can potentially logic wise can potentially produce more number of light photons right. So, this is your active material for that reason.

So, now, the question is what is this reflective layer? Oh, you create this light, right. This phosphor converts the x-ray to light the light photons can go front and back. But you ideally wanted to go spoil the film here. If it goes on the other side you are wasting right why should you waste? So, you have a reflecting layer so that if it goes there it will again get reflected back.

So, clearly you want to capture all the light photons that are generated from the phosphor which is converting the x-rays into the film here. Protective coating is just so that there is no you do not damage the x-ray film itself ok. So, the intensifying screen you understand the role of a intensifying screen, it is intensifying. What is it intensifying? Number of photons in x-ray whatever is coming is coming and hitting, but then number of light photons that come out is way more and that light photon when it comes then you can use a photography film.

Because light photon you know the efficiency of spoiling photography film and a whole ecosystem of photography film what chemicals to be used, how do you develop it, all that is well established, right. At least the ecosystem is there. So, this is the solution, so idea is you have a intensifying screen and get the job done ok.

So, phosphor convert the x-ray photons to light. So, what material? I mean again this is not something that happened recently when Roentgen discovered this and photography work was going on you may recall Edison, right. So, he was working you know light bulb, right. So, he was working on several of this light kind of physics to do with that and therefore, materials. So, he was working with materials that can capture do this. So, he was working and he characterize developed calcium tungstate as an alternative to do this conversion ok.

And, this is quite popularly used until recently right when your digital x-rays started to come and your rare earth metals right rare earth materials started gaining, prominence calcium tungstate one of the staple that is the one that is mostly used right. So, it is well characterized and it has been used for a long time and profitable so, and that is why it is which stood the test of time ok.

So, convert that is the active material. So, the idea is this flash of light last only one into 10 power minus 10 seconds. So, you get this brief light ok, so this is very useful also. You do not want to light to last for a long time, then what is going to happen? The light is there for a long time; that means, it can spoil the film for a long time, right. So, natural disadvantage is you may have blurring you remember about the motion artifact and all those things. So, you may have temporal blurring because of that. So, you want it to be as quick as possible ok.

So, instant so, you want the one of the desirabilities is you are going to exploit when the x-ray photons are converted to light photons it has to come, it has to flash out in time that is very short. What is short? 1 into 10 power 10 seconds that is the order it takes, right. So, you want to catch this flash of light or rather the film needs to be exposed to this flash of light ok.

So, clearly you can understand; that means, there are we are talking about similar principles x-ray is interacting with the material. Now, that our objective of the material is to do this interaction that the output should be some characteristic radiations, right characteristic photons that come out in light ranger. So, you have about thousand light photons. So, it has to be dependent on I mean without even just by what we have covered so far, right.

You should be able to guess what are the factors that going to determine this. Oh, there should be a energy right, what energy is coming is going to have a role to play with the interaction, right. What interaction you want? You want the interaction such that the x-ray photons that are coming has to be absorbed by the material and then it has to transition give out light photons, but you want one photon to give many light for one x-ray photon to give many light photons. So, what are the conditions?

So, it will depend on the energy of the x-ray photon, it will depend on the material property, right of this how can it absorb, that is one thing; then its conversion efficiency, how efficient is it to convert this energy into the photon energy, right. So, all these are factors. In fact, you will hear the term called a speed of screen, right. Speed of screen, you might wonder speed of screen, speed means typically we will think it is in the time right.

What is speed of screen? We will think ok, what does speed got to do here right, it will look odd. But, what it means is typically this conversion right I told about the material energy level its interaction, right and its conversion materials ability to convert one energy to give many photons.

So, the speed of screen typically is used to refer to this conversion, why? Because if I have high speed of screen; that means, it takes a small time little time, because more number of photons are created the conversion is high then more number of light photons are generated. If more light photons are generated the film can get exposed quickly. So, more the right photon lesser the time to expose, right the full film right the film that you are the thing and so, to spoil this film you need only less time.

So, speed of screen actually refers to the conversion efficiency of this material to converting x-ray energy to number of light photons many number of light photons if it can produce. So, here typically you get about thousand light photons per 50 kilo electric volt when, right. That is the range when you operate your that is determined by your tube x-ray tube right at that level. So, the energy comes out this is typical.

So, you are going to have variation depending on the energy level that is used right again this is from the x-ray tube, but then a spectra goes into the body comes out right all of this is going to determine your light energy light photons that are going to come and spoil the film, ok.

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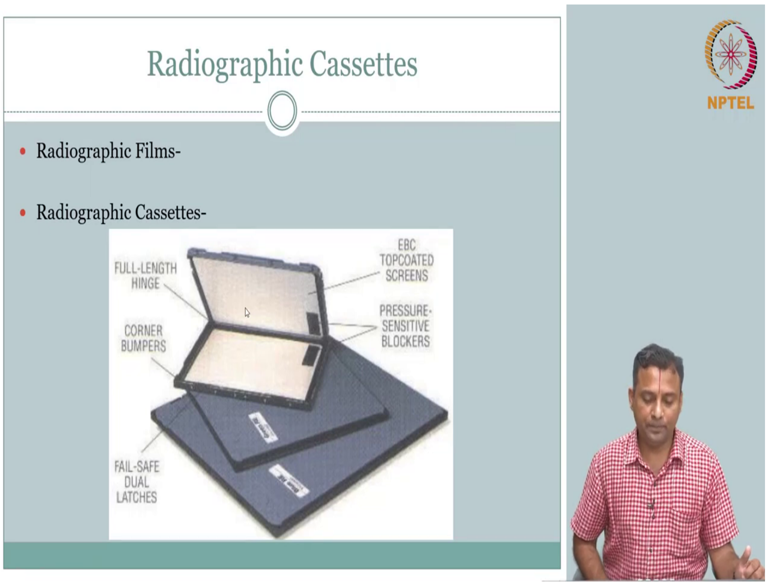

So, last, but now so, radio graphic films actually are nothing, but we are not going to talk too much about this because as we just spoke about is just photographic film that is there. We have intensifying screen and then that is used. So, there is nothing much that we will talk about radio graphic films.

So, what is radiographic cassettes? When you have this film right you saw the previous intensifying. So, all of this put together is your cassette. So, this cassette should be easy to open, you can slide the screen in. So, top part you will have one intense film, bottom part you will have another intense film. So, that light and you saw that reflective layer, right. So, that light goes in it maximizes the chance of it interacting spoil the film.

So, naturally one side it has to allow the x-rays to go in, the other side you do not want the x-rays to come out of the cassette. So, on one side of the case it will be transparent to x-ray, the other side of the case basically they can have a led coating or whatever. So, that it does not exist to the cassette. So, is a typical cassette and the film will be taken out of this and developed separately ok.

Of course, so, it has all these mechanical design aspects so that the when you handle it you do not squish it on things like that, but otherwise it is a radio this is something that is very common. In fact, it is very common in most centers for quick x-ray diagnosis. But, here also mostly we are nowadays there is a rapid transition to digital x-ray ok that we will cover separately clear.

So, so much so for the instrumentation of it, we have gone systematically from source instrumentation to what are we can manipulate with the object human beings giving the contrast agent, right that aspect and then of course, some instrumentation before the source and the object in the form of filters, restrictions.

And, then from the object to the detector again some of filtering and collimation right, we talked about that and then last about the detector system which consists of a intensifying screen and the regular film. So, this is with respect your projection radiography instrumentation.

What we will see next is from instrumentation we need to move to imaging. Physics instrumentation, so, now, we will go to imaging where we know the physics. Now, if these are the instrumentation, the output that you are getting right the image how is it formed can we use the imaging equations that we derived or not derived. In the physics we said this is the fundamental law that governs, using this instrumentation have we been able to engineer it so that we can capture the object as a output image of a parameter, that is what we will do in the next lecture.

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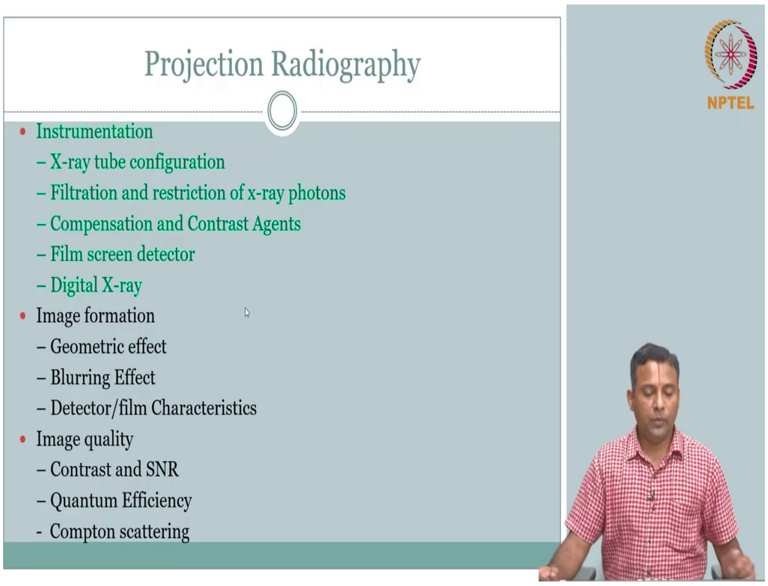

Well, so, we have covered the instrumentation aspect of projection radiography. So, all the greens are things that we have covered. What we will now focus on is this image formation.

Like we discussed instrumentation, image formation and image quality these are the three big modules we will cover in each of the modality. So, before we jump into this we will cover the physics of the modality, ok.

So, with respect to x-ray projection radiography, we will now start to deal with image formation. So, here unlike your we you know we will use the same x-ray physics, right. So, the subtle differences subtle, but very important differences come when we talk about image formation between x-ray based projection radiography and x-ray based CT, right that we will cover subsequently.

Why I say that is here when we talk about image formation, in some sense in some sense you are not gathering the data and recomputing the image. What you get is you have the film, right. What is recorded on the film is the image. Now, the question is when I say about image formation how all we can manipulate the instrumentation so that whatever we are getting on the image as the output, right.

How does this influence what we see on the output that is what in projection radiography because of film is formed right you just have to develop that and view it. So, in some sense what are the operations that you can what are the parameters that you can control to form an image has to mostly to do with the instrumentation that we have covered so far and how we exploit it rather than explicit reconstruction, ok.

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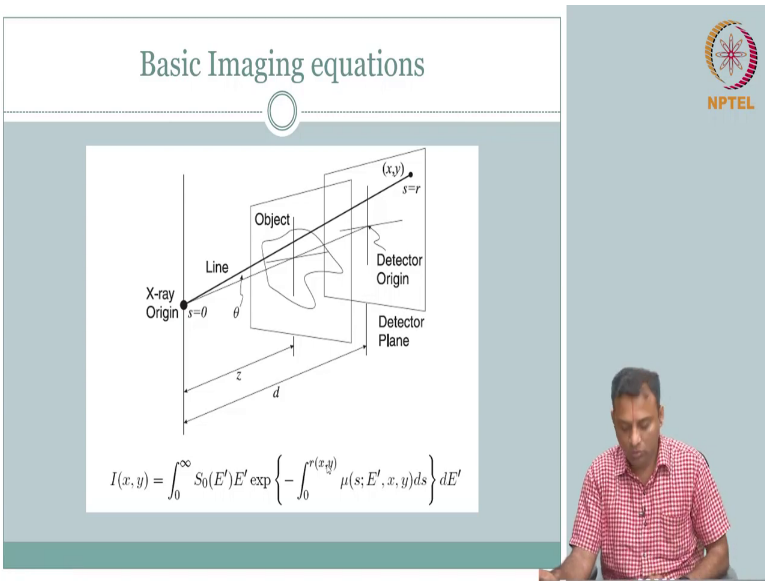

That will come clear as we go along. So, this is the paradigm that we are interested in. So, when we talk about image formation, what you already know from physics is oh, ok we are going to deal with a source an object right a source and object and a detector in the behind. Whatever you are capturing on the detector now, that we cover the instrumentation the detector if it is going to be your x-ray film whatever you are going to capture on the x-ray film, the doctor is going to see that as an image in a light and make diagnosis right that is the through.

So, this is called as through transmission image. The output that you are using is a through transmission image and the set up that you see here that we discussed even instrumentation is a through transmission set up. That means, you have a source on one side, detector on the other side of the object. So, what we are going to deal now is you may think, ok what do I know about this, right when we talk about imaging from the physics point of view we covered all the instrumentation now just you know recently. So, from the physics point of view what do we know about this image that we are talking about, what are the physics that covers oh.

We talked about signal and noise; interaction of x e electromagnetic, right, with the tissue slab remember; then we talked about fundamental attenuation law, the photon law right exponential minus mu delta x, where x that delta x we denoted for a thin slab, remember? So, that means, your image is formed if I give a source right n photons on the input side the object is going to what is going to come out of the object it is going to be attenuated version.

How much it is going to be attenuated? Oh, it is going to be attenuated by the law photon law e power minus mu delta x right depending on the material property and the thickness. That is what is going to come out and we already talked about instrumentation oh if that comes and falls on the detector there is a film conversion and photography is developed. So, we know that so, what is you know new in imaging here. So, that is so, the concept is same the physics is same, right.

But, now what we need to do is that law that we had e power minus mu delta x I equal to I naught e power minus mu delta x right exponential decay model how are we going to account for. So, that pretended whatever is falling on the material whatever came out of the material that is the loss that we modeled.

So, where all it is falling on the material, where all it is coming out of the material that is when is coming out and what all goes and hits the detector we need to put that in that is why it is important, right.

Otherwise it is easy x photon n remember we use this n and n naught n minus n naught is equal to minus small n that is proportional to your material mu and delta x. We cover this homogeneous slab non homogeneous slab narrow beam all that. Now, is the real question when you have a instrumentation is it narrow beam? Ok, we will instrument that to narrow beam because that is the model we developed. Now, the question is it actually hitting the delta x everywhere it is hitting is hitting the same way or because of the instrumentation something is not?

You already have some answers right we already saw that the x-ray source is giving out diverging cone. So, we had filtration, we had restriction of field of u, right. So, because of divergence right and because of this setup you have several factors that we need to incorporate in our imaging equation that is what we will focus in this imaging module of projection radiography, this is the grand setup. So, you are going to see I have a source, I have a distance between source and the object I am going to have distance between the source and the detector.

So, the idea is I have a object plane right I have an object the object is going to be collapsed to a plane. So, this is my object plane if you will and this is my imaging that the film where the detector is the detector plane ok. So, now, we need to see what are the factors that are going to play from the instrumentation point of view, what are the factors and how are they going to get into our the law that we fundamental law that we wrote.

So, we need to update the fundamental law or we need to use the fundamental law for a given setup like this which is what we will do now ok. So, in order to do that just recall. So, this is something that we knew from before. Your intensity at any point x comma y right, we talked about this, right.

So, it is the spectrum of energy that goes in. So, number of photons n 1 number of photon at energy level E 1, n 2 number of photon in energy level E 2 so on and so forth, right. You have a spectrum this is the you know rough sketch of spectrum that I was using, right.

So, this spectrum goes into the body. So, these are all number of photons this is the energy locations. So, I bremsstrahlung right so, he have a host of different energies and you have different number of photons at each energy. This is going into the body right that is coming out of the x-ray tube. Now, intensity at x comma y, right on at a location is whatever goes in.

So, S 0 into that energy level whatever goes in exponential of minus. This is integrated over the path length r of x comma y of this mu which is deliberately written as a function of x and y energy that it is dealing with right. So, and ds; ds is the your sigma, so your path length that you are talking about ok. So, this is fine. This accounts for what we want to do, but this is too generic.

So, we need to customize this to the setup that we have; that means, what is the path length we need to be explicitly able to write and is this all is there any other effect that comes into modifying this equation because of the way the instrumentation is set up that we need to be able to accommodate, ok. So, that is what we will do now.

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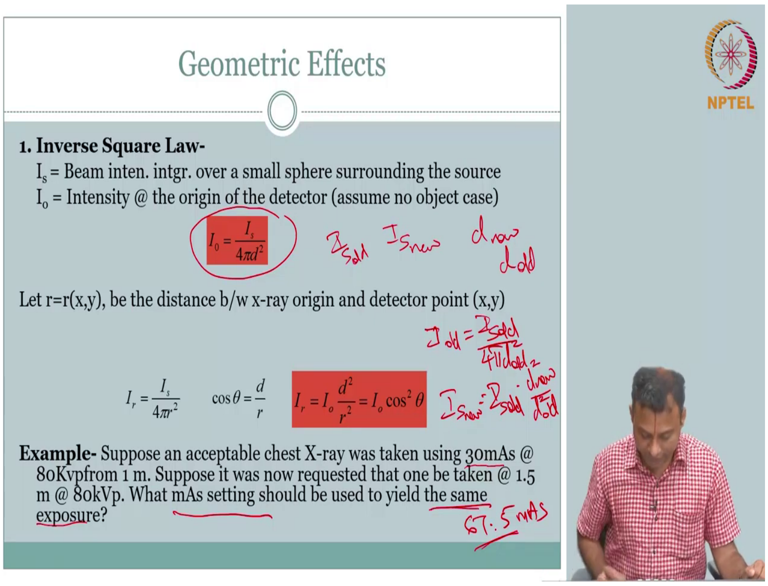

Broadly we will start with what we call as geometric effect. What do we mean by geometric effect? The effects that you see on the so, this is all to do with what you are going to see.

What you are going to see suppose to be a accurate version of the unknown underlying body, right. You have this what you are going to see is your g of x comma y what is the underlying unknown as f of x comma y remember back to our big picture systems diagram. g of x comma y should be as close as possible to your f of x comma y right that is our thing.

So, here what we are talking about is what are the effect you are having a system. You have some instrumentation that is capturing this f of x, y or transforming this f of x, y to g of x comma y. What we mean by geometric effect is because of the setup that is trying to capture are we seeing any effect on g of x comma y, not because of fundamental f of x comma y, but because of the geometries that are involved.

So, the output is different from the input due to the geometric regions right that is what we want to categorize as geometric affect. So, first thing first and foremost this is something that we probably used earlier also right something called as inverse square law that is I have a source. What is going to happen to the source the recall from the sketch that we have and previously it seems like it is diverging, right.

So, when it is diverging what do you expect to happen? Oh, at this point you have all of them concentrated. As it is diverging right as it is diverging what is going to happen? As it move away from the source oh, your intensity is going to drop. How is it going to drop? Oh, it is going to drop not linearly non-linearly how, square inverse square. So, it is going to drop with the distance the farther you move, remember we did this even when we talked about exposure and stuff, right.

So, farther you move from the source because this is diverging that we are talking about the intensities are going to fall off at square inverse square law, ok. So, if you have a beam intensity at the source to be denoted as I s, ok. You have a source it is integrated as a small sphere. So, whatever you have sum total is your I s and the intensity at the origin of the detector. Remember, you have this intensity I do not even have the object, just the geometry that I am worried about.

I have a source I do not have the object, I have a detector. What should happen? What is there in the source should be at the object right I mean should be at the detector, but it is not. Only at the center you have one value and as you move away from center because this is diverging right depending on the distance you can already see you have a center and it is changing from the center.

So, your I naught if you call it as the intensity at the origin of the detector plane, right, because this is diverging and the intensities are going to go down a square of the distance what are we going to see, right.

So, if that is the case then your I 0 is I s by 4 pi d square. So, what is this d? Oh, this is the distance between the source and the center of the detector. So, at the center of the detector you are going to have an intensity that is reduced I have no object. So, technically it should be I s, but it is not going to be. It is going to be reduced, how much? It is going to be reduced by 4 pi d square that is a distance of separation between your source and the center of the detector.

And, this is very handy, this will be used again and again. Why because it is a very simple formulation, right and it is very powerful. So, just to complete our analysis what is our oh, we are not interested just at the center. We are interested there is a detector plane, right. I have a detector plane. So, what are the values that I will see in the detector plane. Clearly, what you are saying is this is source, the source is diverging.

So, what will I see at different locations at I naught at the center it is I s by 4 pi d square because the distance of separation is there. So, at other locations what could it be? Same, measure that the distance right of this point from the source; if this point right you have center of that plane at distant to the center of the plane and then you could use the d to calculate this diagonal, right. So, let r b r of x comma y is a it is a point in the plane of the detector.

So, let that be the distance between x-ray origin and the detector point x comma y. You can clearly write your I r whatever is there at I r intensity r is nothing, but source by 4 pi r square.

When it is perpendicular distance to the center that was defined as d and therefore, it is d square if it is r it is r square, right. So, this you can actually calculate. So, therefore, given the diagram in fact, the previous slide the proposition you see theta is the angle.

So, you can have your cos theta. What is cos theta? Oh, I have the center of source to the center of detector plane. So, that is my shortest distance, that is by d. So, this r is your hypotenuse. So, the angle included so, cos theta is adjacent by hypotenuse. So, d by r ok straight forward. So, I have inverse square law that can be captured like this. So, I can tell that each point in the detector how much of intensity I will get, right, fine.

This is fine, but then if you substitute what happens? I r is equal to right I naught all I am doing is I am just incorporating it making it more general because I know my I naught that is 4 I s by 4 pi d square. So, I am just writing my I r in terms of I naught using cos theta. So, what is this saying? I mean is mathematically it straightforward right, but just spend that extra few seconds to understand what this is saying. This form is easy intuitive or is inverse square law that you would have convinced.

But this mathematically straight forward, but it is very what is it what does this physically imply? That means, this is saying on the receiver plane right on the detector plane on the detector even though I have a source the source is sending diverging, right what is it that you are capturing? You are capturing I naught at the center there is one intensity value as you move away from the center in any direction right you have a cos square variation in the intensity.

So, you are going to see a cos square path you are going to see a fluctuation spatial fluctuation in terms of cos square theta right depending. So, the theta is basically it is telling you can look at it at the angle the r, right, so, different locations in the plane. So, you are going to actually see a nice cosinusoidal of square of cosinusoidal variation. So, if you look at the image of the at the detector of a source that was a point source you are going to actually see a fluctuation that is not homogeneous that is going to have this is without a object.

So, now, you see the problem if I have an object and I see this fluctuation will I interpret that as the object having a very patterned attenuation coefficient or the object having cosinusoidal shape if mu is same? Does it say the object is cosinusoidal rate in 2-dimensional the plane is not a plane. But it is having a cos cosine square variation, right.

So, with you see the complexity now. Without even having object you are receiving something at the detectors only because of the geometry where the source is sending out a diverging wave and therefore, depending on the distances involved the geometries involved you could actually see a pattern. In this case it is a cosine square theta right nice pattern that you are going to see.

So, this is something that we need to worry about, but more importantly we need to update our equation to incorporate this or no matter. So, why is this important this inverse square law per se? Just an example here right this is very common, commonly used because it is a very common scenario. So, you have a acceptable chest x-ray right they have some setting right a 30 milli ampere second at peak voltage applied is 80 kilo volts, right. This is your x-ray tube configuration.

So, now the person is standing at 1 meter. We are saying ho now you need to move the patient, you have to take the patient at 1.5 meter from the tube. But, the settings same 8 80 kilo volt peak, that is what you want to apply. Question is what is the mAs setting should be used to yield the same exposure, right. So, the idea is you are asking the patient to move in which case exposure right it is going to change.

Because it is dropping off with respect to d what is going to face right is drop of with respect to d. So, if he is moving closer you can reduce the exposure if he is moving back like away from the source you have to increase because it does now diverged, right. So, the question is suppose, it is now request if is moving what is the mAs setting to yield the same exposure, ok. How do you approach this?

Well, is the same law that you need to use. Only thing you have to recognizes I know this is at intensity. So, I can have this as a old and new, right. So, I can have my source I had one source. So, I will call this say for example, source new and I source old. I know my d new I know my d old is given, right. So, if this is given then what do I need to do? Well, I can I have to make one thing make use of this fact same exposure.

So, we can say ok, it is all proportional and therefore, right I it does not matter. I can do my I old right is nothing, but your I s old by 4 pi d old square. Likewise you can write it for new as well, right. I s new I new d new we can do that. All I can say is because I want to use the same exposure I could say this could be proportional. So, I can write I s new is equal to I s old times your d square new by d square old right that is all we need to do.

So, you substitute you are given the all the other aspects you substitute and you will get some numerical value. What is more important is of course, we substitute I will just you can punch in for the given values you can punch in, you will see that it is coming out to some 67.5 milli ampere second ok. So, you notice why is this is important you are using thirty milli ampere second.

Now, you have to pump up to 67.5 milli ampere second to keep the same exposure because we know the image quality will depend on the exposure. So, if I am keeping the expose, if I asked him to move it has all these repercussions. So, I have to operate my x-ray tube to get out at 67.5 milli ampere second ok because he is moving back if I have to have the same exposure I have to generate more. So, this is very rot, so you cannot just say ok I was asked to take any move 2 feet back and repeat the experiment.

If you need to feedback you have to change your x-ray settings. So, all this is involved, then the question is you know how much exposure do we have to redo it. So, it is because all this biological safety issue is there. So, this is a very important routinely used formulation ok.

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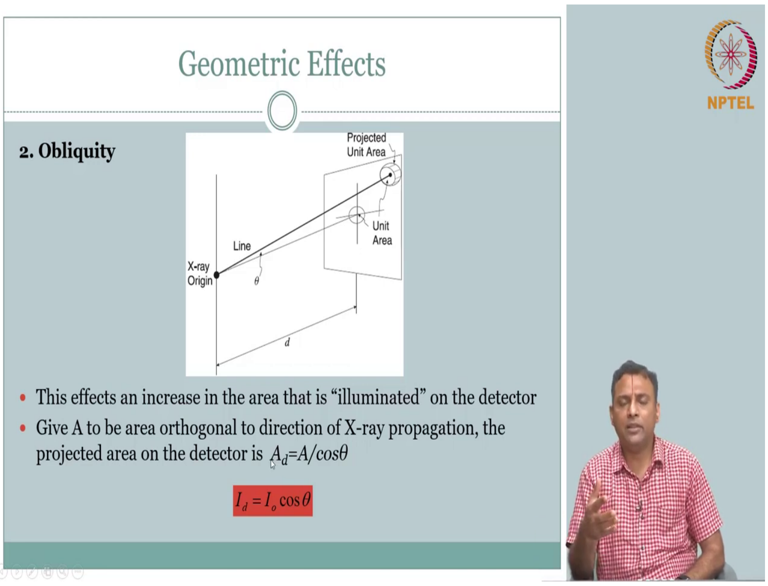

Next is your geometric effect is a obliquity. As a what is oblique? As you can see here in the I have a detector we were talking about detector being perpendicular so that the source is coming and hitting and the object plane and your detector plane are parallel to each other right that is what we were drawing in. But, what if there is some angle right if it is not perfect some angle that is called as your obliquity, but when we talk about some angle, where is its effect?

Oh, if it is going to have theta tilt what is going to happen? I have a center; center to center it is there if it is slightly tilted like this, you can see from the cartoon here that if you have a center unit area right if that is the unit area at the center, if it is going towards the edge because it is oblique if it is going towards the end that same area will be projected on to a larger area, right. So, it will be projected over to a larger area on the edge because there is a obliquity.

So, it is perfectly perpendicular no issues whereas, if it is going to have an angle it is like your shadows, right. You will become your shadow will grow tall or short depending on where the sun is right as it moves on you may become taller and taller your shadow will become taller and then you shorter. So, it is a similar thing. So, there is angle that is involved. So, we calculate that based on or incorporate that based on this unit area A that is marked and we will say ok the effect it increases the illuminated area in the detector.

So, if there is small obliquity then you have to understand that the detector is going to get hit in a larger area compared to what it would get hit without when if it is perpendicular ok. So, if you have A to be the area orthogonal to the direction of x-ray projection the projected area will be now on the detector is going to be A by cos theta. So, the idea now is we need to incorporate. So, one we already had distance, the other is with the detector. So, we can start to put it together.

So, what we are interested is in our intensity. So, I a I d on the detector will be equal to I naught cos theta, right because this cos theta area is coming in. So, your intensity is going to be varying with respect to cos theta. So, at the center you will have minimum, as you move away from the center you are going to have more distortion right that is what this is going to suggest. So, I d is I naught cos theta. Again, these are some somethings that you can do at the time of calibration ok.

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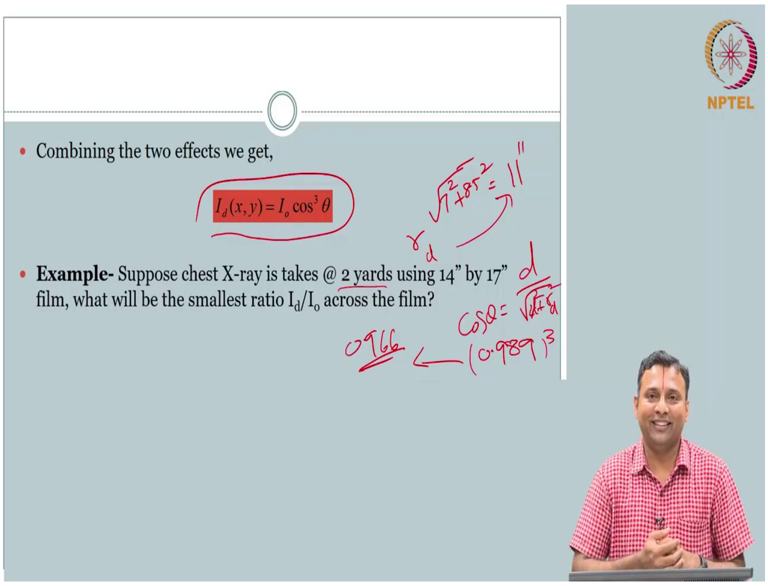

So, combining these two effects one is cos square theta the other was cos theta. So, combining these two we get the variation to be I naught cos cube theta, ok. So, just based on this geometry we have not included any object so far, right, without even the object just because of the distances involved that is why is called as geometric effects.

The distances involved you get this effect on the detector you see that the intensity is not just whatever is just falling I naught it is I naught is at the center. It is not I it is not the same intensity throughout the detector plane, it is varying with a cos cube theta.

So, quickly we will have a ok this is fine is this how detrimental is this, right? Yeah, we understand there is a formulation, you have this effect in terms of cos cube theta is this detrimental or is it ok how do we get a feel for the level of acceptance or tolerance for this, right. So, let us just do a example right typical your chest x-ray. So, there we have standard sizes right you are standing at 2 yards and using a 14 cross 17 inch x-ray that is your field of you, right in the detector.

So, what is be the smallest ratio? This I d by I naught across the film right; that means, you are saying that it is varying from the center it is varying and in the form of cos cube theta. What is the maximum variation? That is what in some sense this is asked, right. What will be the smallest ratio? Right, smallest ratio means you will have the maximum variation that you can expect. So, your what is your cos cube theta first if you can find this that is what we want, right. So, what information do we have or we have the dimensions and d distance.

So, first identify what is the point where you have which is the farthest point from the center, oh this is a rectangle. So, the farthest point is going to be along the diagonal that corner. So, that is going to be square root of right you are going to have square root of 14 by 2 plus 17 by 2 is going to be 8.5 square whatever the number is. This is turns out to be about 11 inches ok, so that is that point. So, what do you want? Oh, I want what is my theta cos theta we had writing that, right? It was in terms of the r and d, what is d? d is given that is your distance.

So, you can write your r suffix d right, which is this guy you have that. What you need to do is your cos of theta which you want to be the maximum say you have your d by square root of this guy d square plus this r d square d square plus r d square. So, you can get that and if you substitute you will get a value to be around 0.989, but that is cos theta what we want this cos cube theta. So, that turns out to be about 966, so cube of this is this. This is the ratio that is asked.

So, about 3 percent variation, not a big deal, right? Well, it depends on if this is the only contributor, then we will have to see how best we can reduce this 3 percent or as we add on other effects if there are more dominant guys maybe we want to address that and then this we will say ok in relation to that this is just 3 percent ok.