Computational Electromagnetics and Applications
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Lab Tour - 2

As Publication electromagnetics to simulate 2 kinds of problems the first problem is in the optical range and the second problem is in the microwave range.

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So for example in the optical range what we are interested is a kind of a dielectric mirror which is basically constructed using scraps of glass and this different permittivity and permeability.

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In fact we are stacking them in order to create a kind of a dielectric mirroring effect. So basically what happens here is you have an incoming light that gets reflected based on the wavelength it gets reflected on different layers. So in fact you can physically see that some of the Waves get reflected directly from the top part of the dielectric slab.

Whereas are some other part of the light gets penetrated and gets reflected at the deeper layer so daring the real physics so what we are going to see here is a physical phenomena where the light coming is getting reflected from different layers and we are trying to model this problem using the finite difference method to see what is the real physical phenomena and how does the numerical method capture that real phenomena as I told you there are possibilities to model this problem of using various methods right now we are going to focus on very simple basic method which we have covered which is a finite difference method. So we will simulate this problem and see how the discretisation can vary what is the impact of discretisation and how the Physics can be replicated in a virtual problem so that will be the first example we are looking at this lab tour and for interest I have also asked him to simulate microwave examples for a waveguide in X band.

So to see how does the microwave waveguide is being modelled in a virtual environment using finite difference method how we can see the impact of the radius of curvature or the band of a waveguide is being replicated and how the Physics is represented in a virtual platform so that is what we are going to see in this lab tour so let us go and see what the student has worked for us.

Student Teacher Conversation Starts

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So Mayur You have been working on 2 problems using finite difference method;

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So could so could you please explain us about this Bragg's reflector and also the kind of virtual problem we are looking at taking the physical problem and modelling it on a virtual environment.

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So in the first example we are modelling a Bragg 's reflector this is nothing but a dielectric mirror so dielectric mirror means it reflects incident energy so whichever wave is incident in coming part of it will reflect and this is required for applications wherein we get our beam to beam................

So basically what we are doing is we are staggering slabs of dielectric constants and kind of we are trying to slide them up so light is going to come and it is going to reflect.

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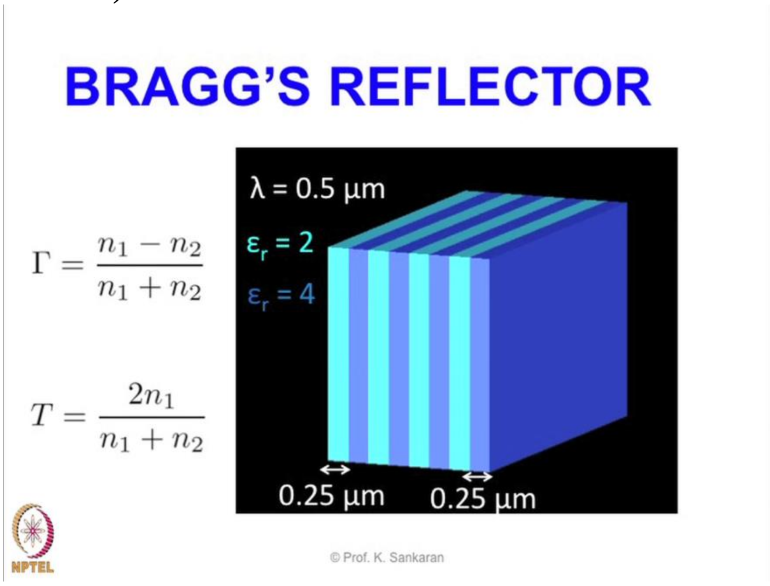

So let's go into the physical Modelling how you have done it . This is the diagram of this model so in this basically we are taking two different layers with different permittivity values and we are stacking them periodically. So as you can see first layer which is marked in different colours as second layer. So the red one is having permittivity or relative permittivity and then the white one is having relative permittivity.

And then the thickness of that is 0.25 micro meter. And wave guide which are using for this particular simulation is 0.5 micro meter. So its a 0.5 micro meter we can try to understand physics behind it which is a wave is coming from 1 medium with one particular permittivity and it is going to some other medium with different permittivity. So it is seeing an abrupt change so it will undergo insulation so part of the will undergo reflection and others will be transmitted.

So basically these are through fantasy as you have the gamma and then T. It is gamma is a reflection coefficient and this is a transmission coefficient and you are modelling them using n 1 and n 2 or index of the first maker this is a refined index of the different mediums. So n1 is for first medium and n 2 is for second medium. It is going to example which I have simulated.

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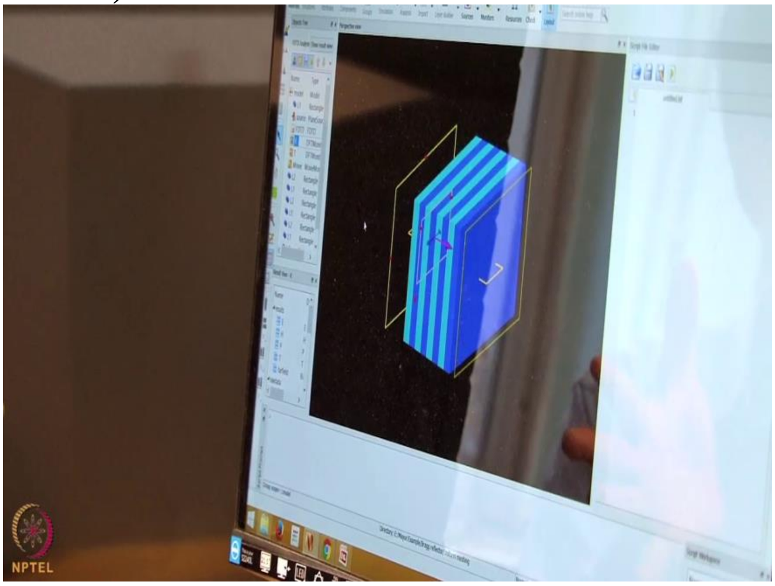

So this is basically same problem I have done it using three different discretisations. So first discretisation is unit by 10 so lambda by 10 discretisations and second one is lambda by 5 and third one is lambda by 3. So basically what you are seeing is there are there you have done the same problem for three different cases.

In the first case we have 10 cells sitting in the wavelength of the incoming light. And for the second case its 5 cells per wavelength and the third one will be 3 cells per wavelength. We will be looking at 2D simulation of that we will see the wavelength so you have kind of translated 3D problem into a 2D problem and then you are trying to simulate it. Show us first the 3 lambda square wave length..

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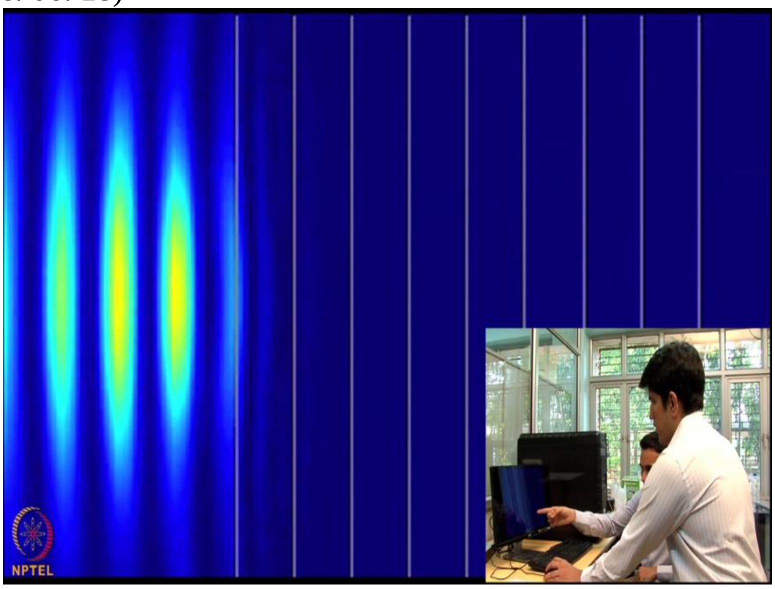

So this simulation is for lambda by 3 discretisation So the incoming directon the light is coming this direction coming from the side direction and we are recording transmittance here and we will be recording reflectance at the back of the source. So basically what you have is your different slabs here and you are sensor to measure the reflected beam and then you have to sensor here to the measure the transmittance. So we can see that the incoming wave is getting reflected from the first wave itself there is nothing going inside so almost transmittance is 0 which is not physical. Because (())(07: 01) .

This example is for discretisation lambda by 5 So again we are seeing that the beam is looking not continuous but still it is better in the case of lambda by 3. But still when we see our coefficients the transmittance is 0.

We will see now for lambda by 10 In this case you will observe that some part will be transmitted to successive layers and that will again get reflected from that layer. So that is what is happening in this case you have something coming and then this getting transmitted and it is getting reflected from the second layer. So it will get transmitted here. So it is important for you to explain how this physical problem is good to see the physics of it but for us to model this in a finite difference method can you explain the simulation setup itself.

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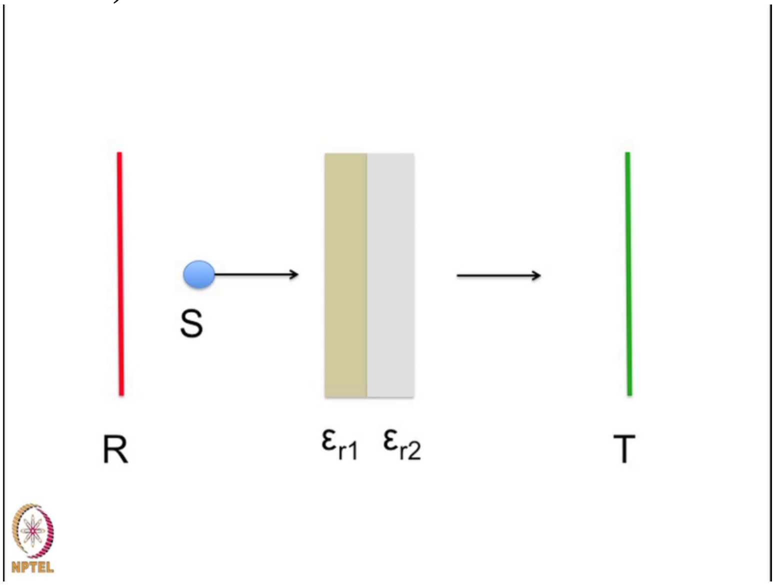

We are taking two slabs with permittivity Epsilon r 1 and Epsilon r 2 for which we are taking (())(08: 25) and then we are rejecting a pulse a Gaussian pulse from this place. And at the other side we are seeing transmittance using one of the monitors. And at the passage of source we are seeing reflectance. So basically what you are telling is this is the source side and then the source is a Gaussian pulse roughly what frequency you are talking about I am talking about 600 terra hertz. And then this is the point where it meets the first slab with relative permittivity of Epsilon r 1. And then the second slab is Epsilon r 2. And we can increase the slab by stacking them one over the other. So then this is the reflection side this is the transmission side. So what you are basically modelling is Maxwell equation and you have the basic source information.

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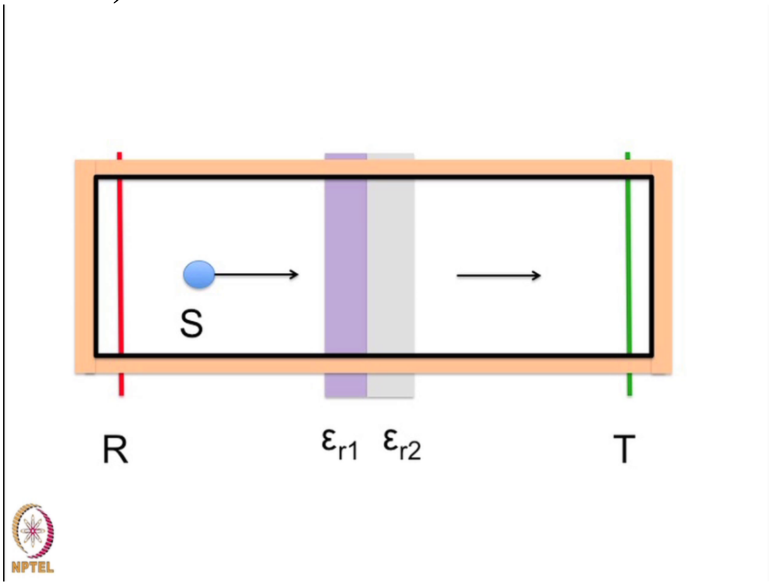

You have specific boundary condition I am forcing the boundary condition which I can show here on simulation boundary so by truncating the physical domain. What kind of boundary condition you are forcing here. So here I am putting PML on all sides. ok we will follow the PML later on. For now it is enough to know that there is a boundary condition that is being forced. And there is a input pulse which is coming this is Gaussian pulse roughly in the 600 (())(09: 52)optical range. And then you have the reflection that is being measured at this point and then you have a transmission that is measured on this point. These are basically sensor that you define in the domain itself. And basically you are solving this using a kind of a tool called (())(10: 07) which is the finite difference solution.

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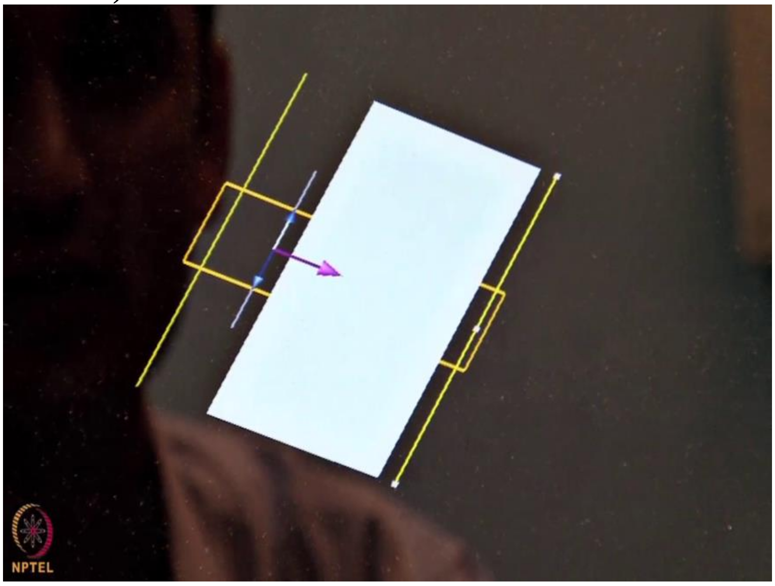

So is it possible that you give the simulation one more time? So that we can see the physical aspect of this. So this is the second you can see I will show you (())(10: 25). So this is source this is our resource and then this is measuring reflectance here this monitor and this monitor I am measuring transmittance and this is the (())(10: 43) simulation region. So I am truncating these slabs are looking bigger in my simulation region so this is your simulation region.

So I will put it on simulation. So we are simulating we will check transmittance and reflectance

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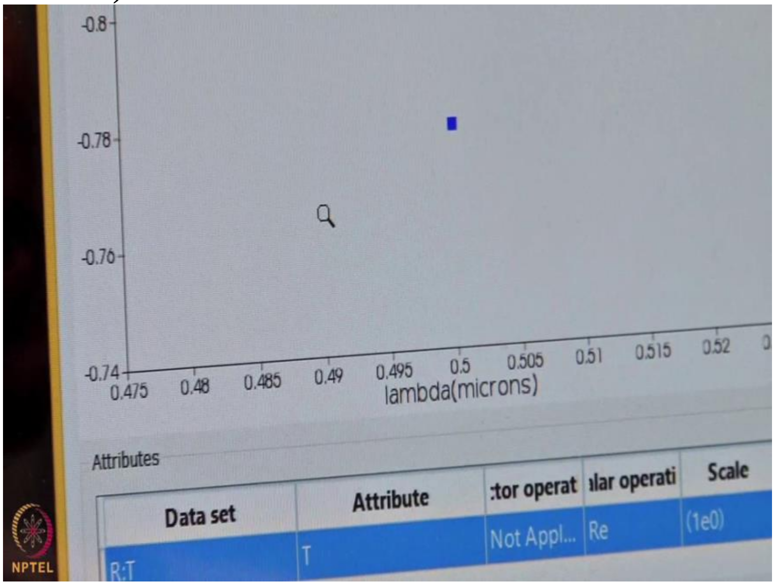

So as you can see I had this 0.5 micron value which has (())(11: 14)frequency. The transmittancy is (())(11: 20) 10 raise to minus 91 it is very less.

And we will check reflectance.

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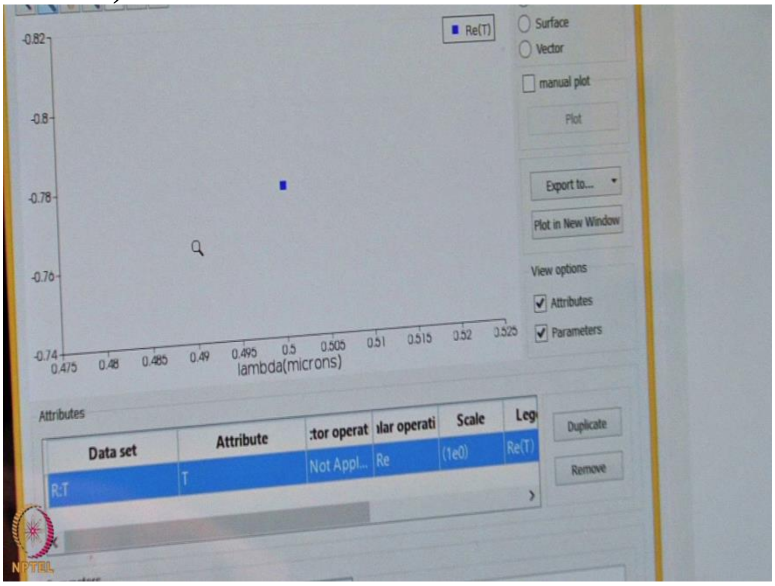

It is of the order of minus 0.78 almost like everything is getting reflected. So if we change the frequency this order is going to change as if. And this is pretty much reflecting the physics of the reflection. And thanks for explaining us this problem.

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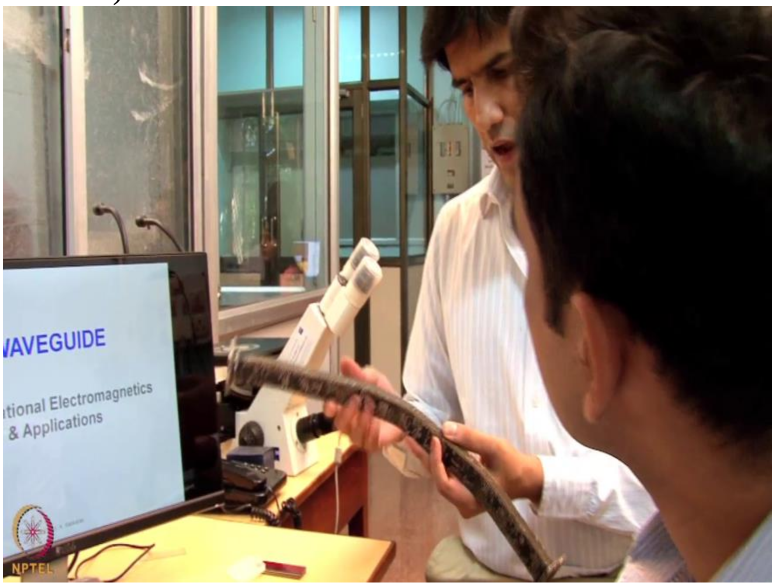

Mayur I also that you have simulated the x band wave guide which is roughly 3 to 12 GHz in microwave radial and I have asked you to also simulate this particular problem using the finite difference method. So could you please explain I how we have done it?

So I have taken first isolated (())(12: 12) So first is a wave guide without any bend straight waveguide like this. And second one will be the waveguide (())(10: 23). So basically you are looked at different kinds of bending. We have a rectangular bending like this or a curve like this. So you are trying to see so what he is trying to do is basically trying to see how much amount of the power is getting transmitted on our side and what is the impact of the bend.

We are going to simulating the modes inside the waveguide. We will be saying the effect of this bending power that is transmitted on the output. So can you explain the problem itself.

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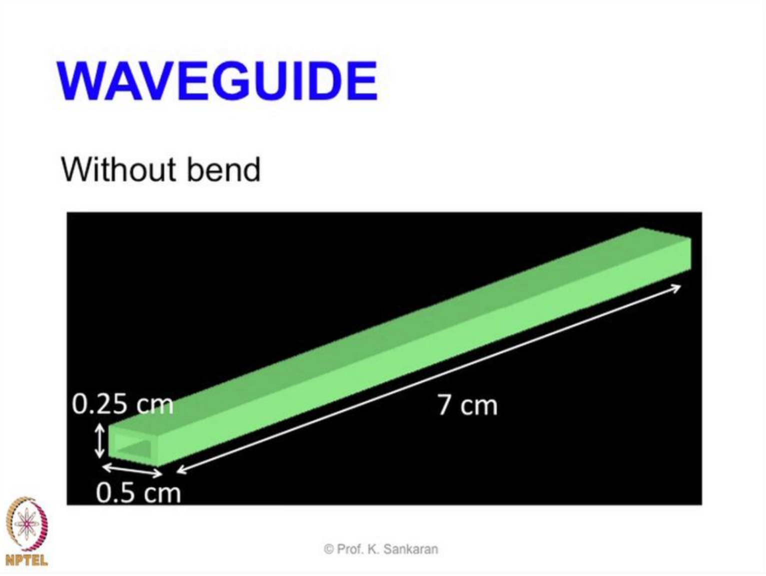

So these are the dimensions for waveguide which we have simulated. So this is without the bend. This is without the bend.

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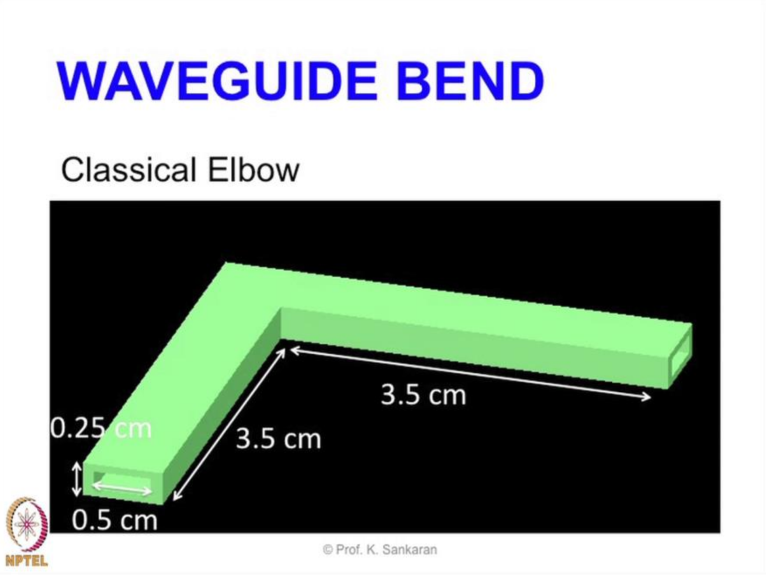

Then this is the second simulation which we are doing. So you have taken a perpendicular bending classical elbow.

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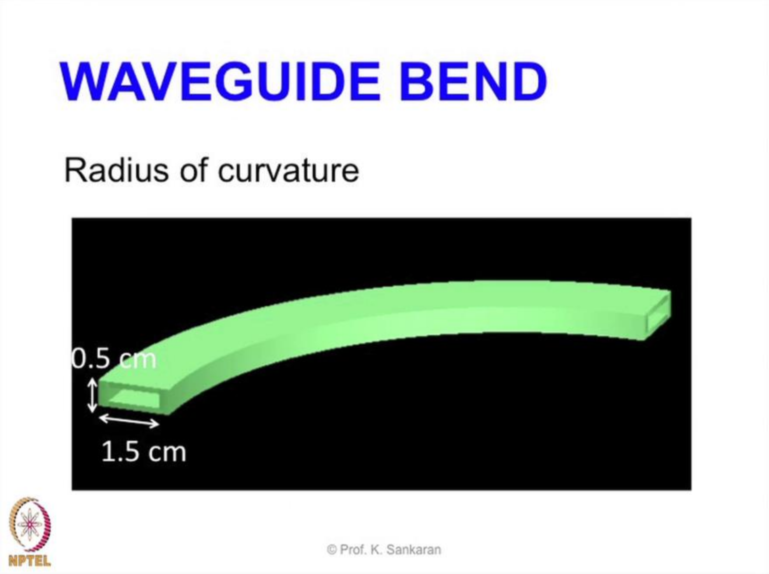

And then you have done also the radius of curvature so basically this is pretty much like curving it like this. And the dimensions are pretty much the dimensions that you have taken it from. These dimensions correspond to a maximum wavelength of 3 centimeters. So that corresponds to 10 Giga hertz.

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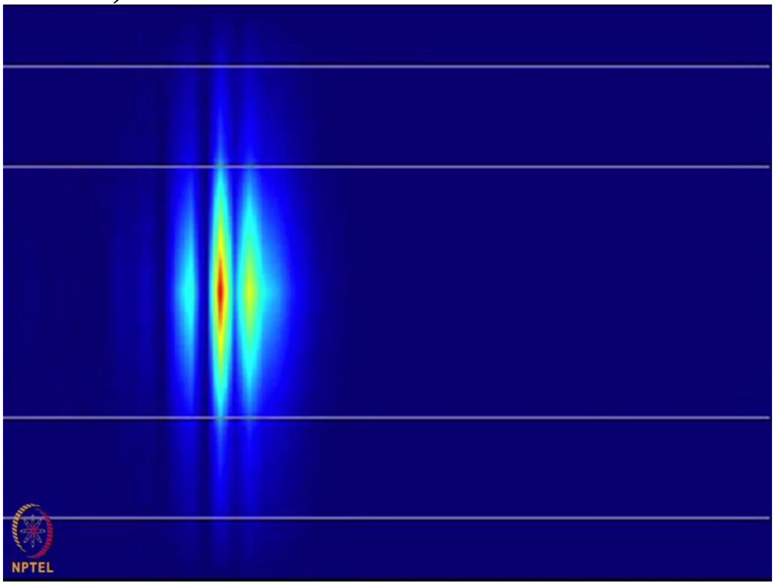

So let us see how the simulation is looking for this particular problem and how we have done this using finite difference tool.

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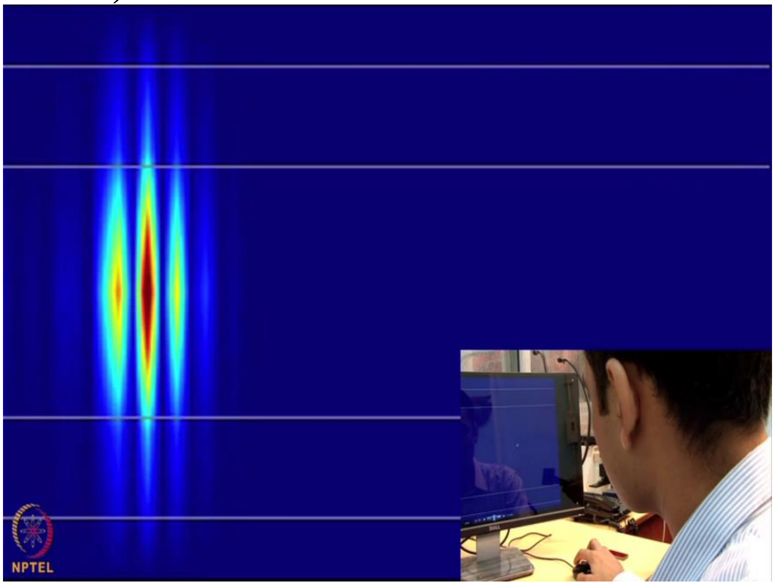

So this lambda by 3 this is pretty much kind of a straight wave guide and you are trying to send a kind of a Gaussian pulse, I am sending a Gaussian pulse I am looking inside the modes and pulse propagating. So go little bit finer in the discritization we have more lambdas. This example was for lambda by 3.

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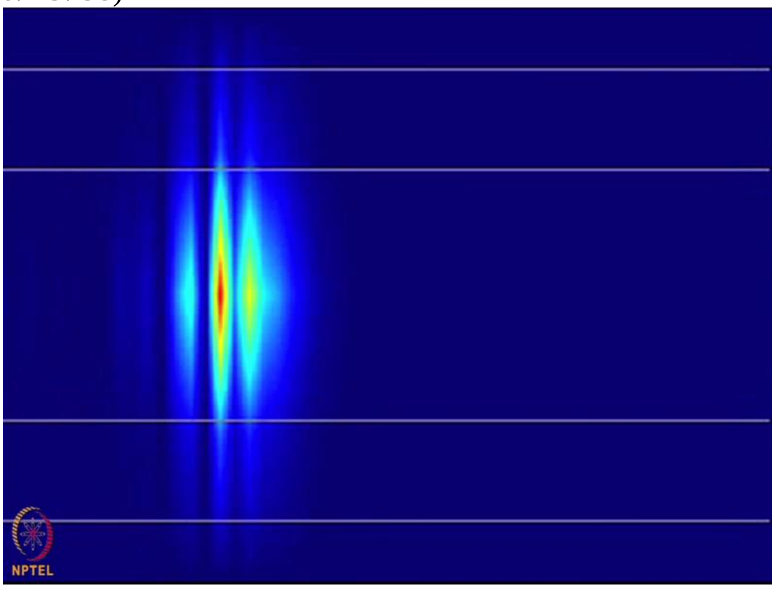

So we have more cells for lambda. This is for lambda by 5 So we can see that we are able to see that we are able to see the mode little clear as compared to lambda by 3. So in the case of lambda by 3 there are enough grid points to sample the points so it is not really simulating the real physics. Where as in lambda by 5 we have the points with lambda. So you could see the wave actually propagating. And obviously there are some errors which might be reduced, reduced and succesful for this lambda by 10. So can you show the lambda by 10.

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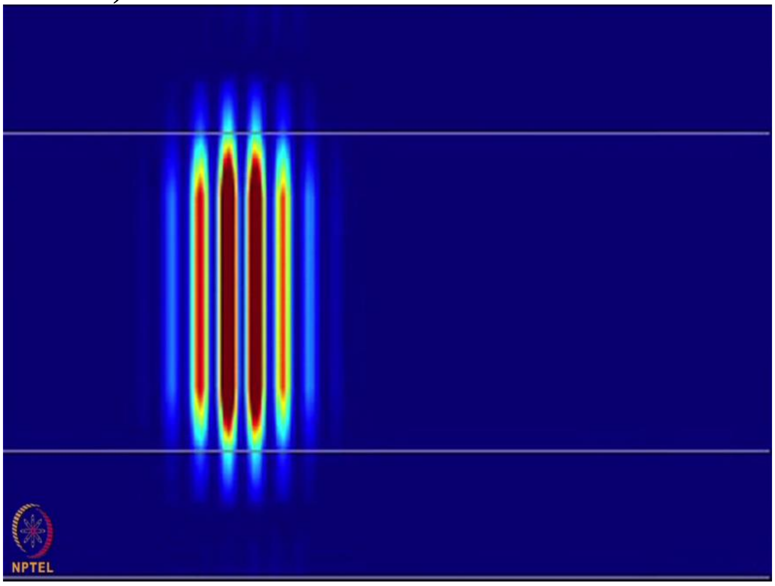

You can see a clear operating mode inside. So we can go higher or is there any other lambda 20 you have done? Yes I have done using non uniform mesh. So you have done this is for the uniform mesh and then you have taken the non uniform mesh. So that means the rectangular or the (())(14: 50) grid what you are using is going to be non uniform. As in there will be small cubes and big cubes so on and so forth. At the edges where the boundary conditions are there it is taking very small (())(10: 02). So it is really simulating in a much more resolved way so you are able to see either with the more propagation.

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Obviously when you see the comparison of error compared to more fine you might be able to see what is the actual error that is also coming in these kind of simulations.

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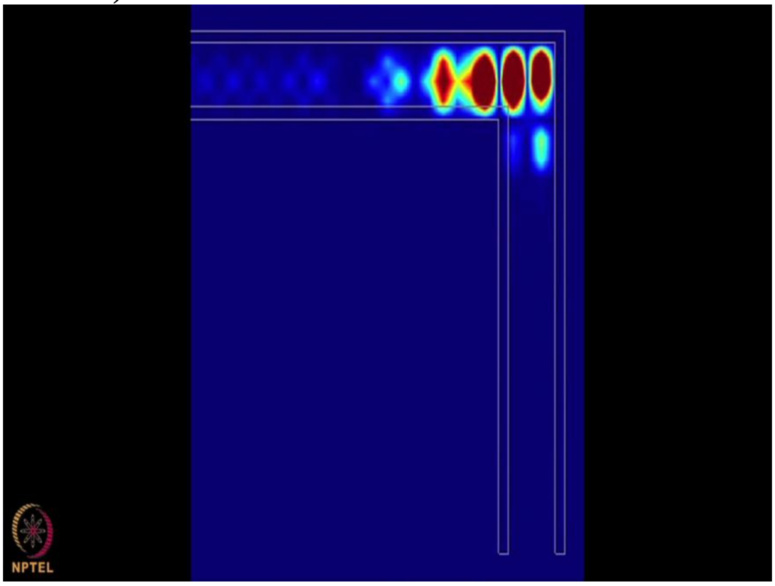

So now can we see also the bend.

So this is for lambda by 3 so this is the classical bend so when you have a kind of a perpendicular bend and you see that (())(15: 33)and is not able to properly simulate the mode inside. So we can go finer with the discretization.

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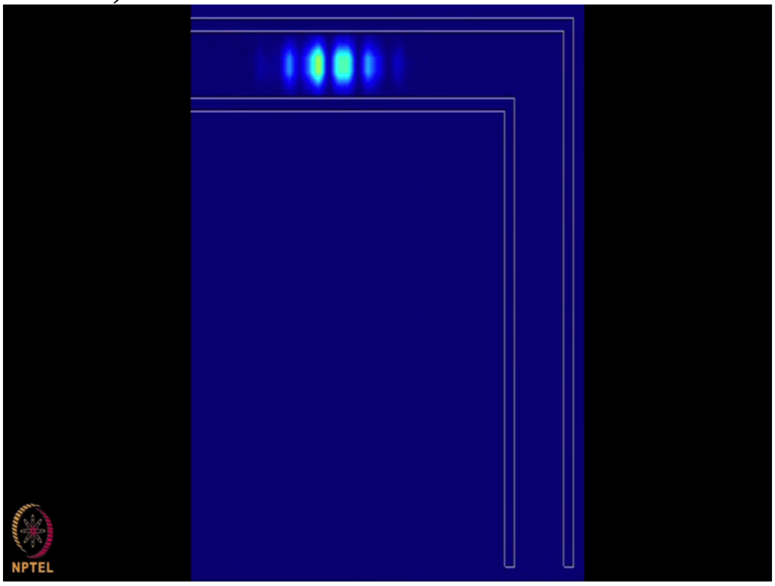

So this is lambda by 5 so you are able to see that you are able to get and there is kind of reflection and then once it is getting reflected then its kind of a contribution.

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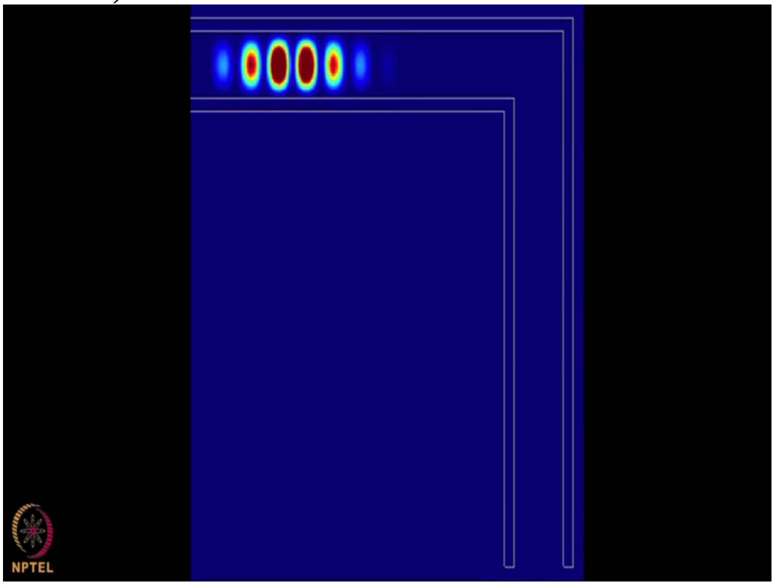

This is for lambda by 10. So as you can see this is complete Gaussian pulse you can see and you see that its getting reflected so it actually acts as a perfect reflector perfect conductor. Can you also show us when you have a bend instead of an elbow a kind of a bend with certain radius of curvature.

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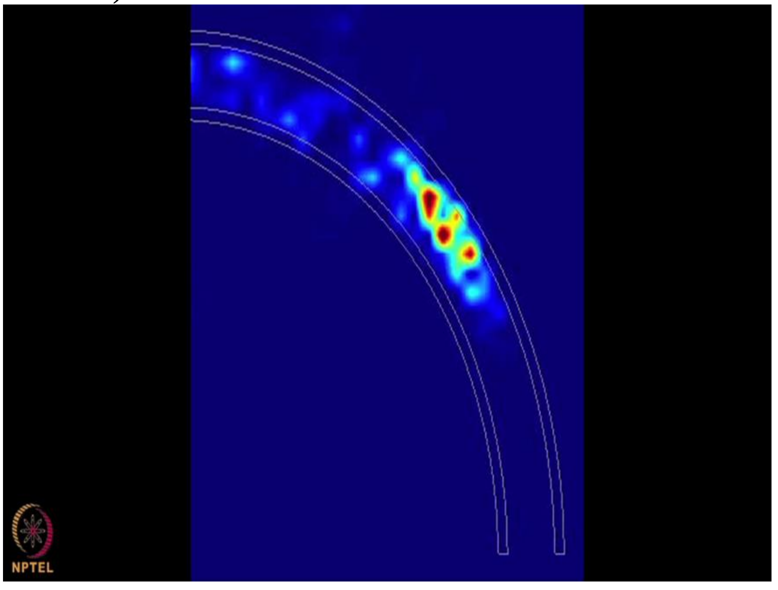

This is for lambda by 3 discretisation So again here the physics is not replicated properly by the discretisation. So when you have lambda by 3 whatever you are getting simulated it is kind of a noise which is not really clear and there is so much numerical error (())(16: 34) And you can see the profile of this if we plot electric field by such distance it is travelling and profile is not clear it is not a Gaussian profile which we are putting inside.

So let us go a little bit finer in the resolution.

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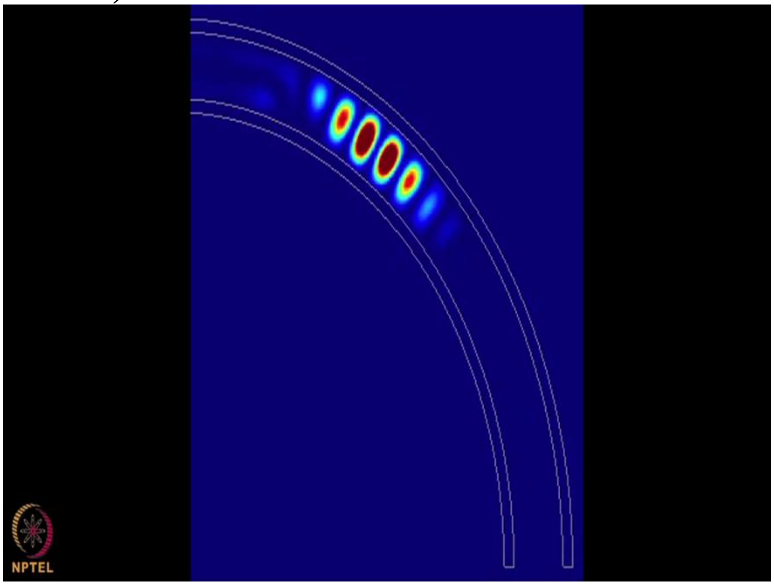

So this is lambda by 5 now we are able to see a little bit better but still there is a bit of resolution issue so can you go a little bit more finer. So this is the one last you have done. So you have a much resolve much more clean more dense propagating and you see that its propagating and you see that it is propagating nicely.

So that sort of a problem that you have done is you know you basically a waveguide that is bend and you are trying to simulate nicely. And you are saving z dimension is infinitely long so you are basically simulating as from 3D problem to 2D problem.

Excellent so thanks Mayur thanks for doing these nice simulations on the numerical finite difference. And it is quite helpful for the students to know how you can do modelling using finite difference on a commercial Thank you! Student teacher conversation Ends