Semiconductor Optoelectronics
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Lecture – 37
Quantum Well Laser

So today we will discuss quantum well lasers.

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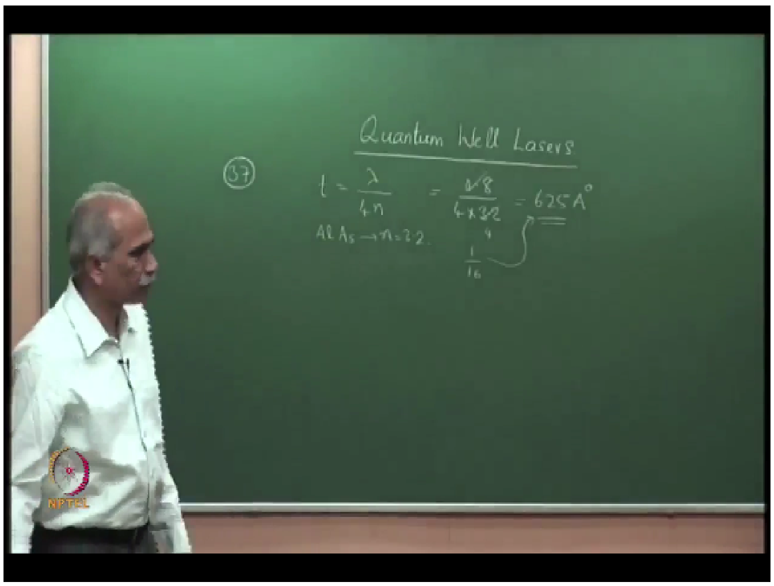

It is a very important class of lasers, quantum well lasers. I mentioned that most of the lasers today have quantum well structures in their active region because of certain advantages. Just before I proceed, in the last class, that is in lecture 37, I made a small calculation error. I was calculating the water wave thickness t=lambda/4n for aluminium arsenide n I have taken as 3.2 and therefore, this was 0.8/4*3.2, up to this it was right but this is exactly = 625 angstroms.

I had written 500 angstroms because what I did was I did this and therefore 1/16, it was 1/16 is this much but what I did was 0.8/16, so I wrote 500, okay. So please make this correction. Everything else is fine. Therefore, the thickness will be slightly different. I just saw that I had made a mistake so I thought I will correct it. So quantum well lasers. We have studies most of the essential basics of quantum well lasers.

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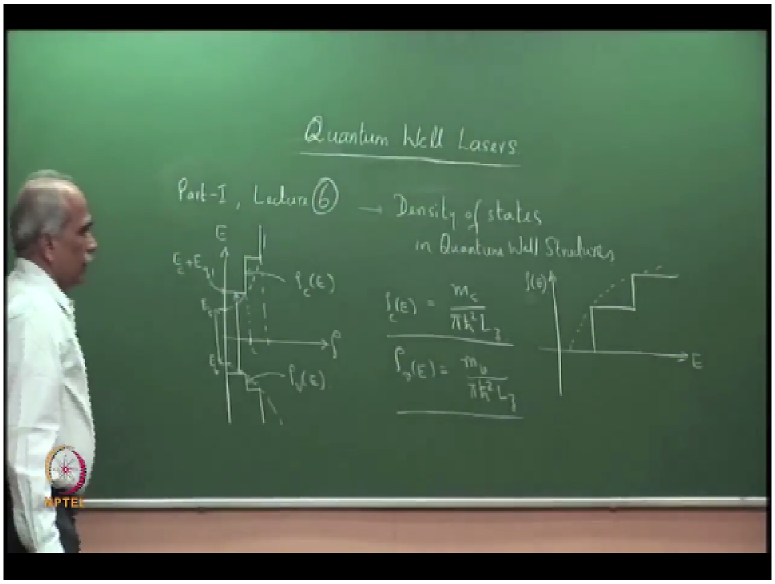

Let me very quickly recall quantum well lasers, what we have already studied. So the quantum well laser. First in part 1 lecture 6 if you see, part-1, lecture 6, we had discussed in detail the density of states in quantum well structures. What we had seen I may recall that this was the energy axis and this is rho, the density of state, then for bulk, we had the square root of E dependence which was like this.

And for quantum well structures, we had density of state which was like step function. So this is in the valance band and in the conduction band. 2 points to see here and that is this is Ec, this is Ev. The density of state start. Up to this axis is density of state. So what I have plotted here is rho c. So this is rho c of E and this is rho v of E that is density of state in the valance band. So up to this first subband energy that is Ec+Eq1, I am just recalling what we had studied.

There was no density of state and therefore effectively, although this is the band gap of the material Eg=Ec-Ev, the effective band gap is from here to here because before this energy, there are no density of states. So the effective band gap was different in the case of a quantum well structure and we have seen this value here, the density of states. So here the value is rho c of E for the first subband was = mc/pi h cross square*Lz.

We had considered Lz as the thickness of the quantum well in the z direction, okay and this is 2 times and so on. This is the density of state and for the valance band, rho v of E=mv where mv is the effective mass of holes*in the valance band*Lz. So this is what we had seen. The important point so if I may rotate this in terms of energy axis, so because here gain, bandwidth, everything we had plotted h nu along this axis, so if I rotate this, then the density of state would look like this, step function.

This is the density of state. Now here, it is rho of E, energy versus rho of E, rho nu of E. In fact, this is rho nu of E. Rho nu of E, sorry rho of nu or rho of E is a step function like this.

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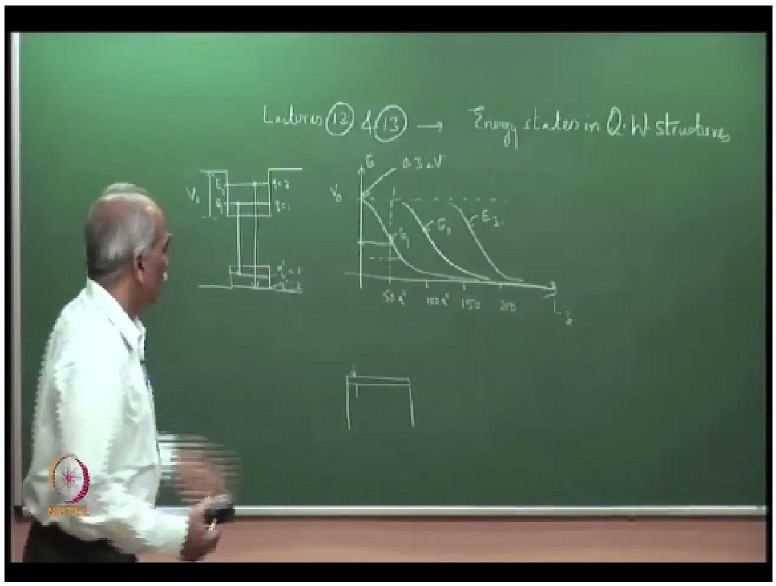

In lecture subsequently, you may recall that in lectures 12 and 13, this is just to indicate to you that we have already discussed almost all the essential physics of quantum well laser. So we will directly go to device characteristics. So lecture 12 and 13, we have discussed about energy states in quantum well structures. What we have seen, a very quick recap, is that the allowed energy values are discretized being a potential well, being a quantum well, the allowed energy values for electrons in a quantum well are discretized.

And therefore, we have, if you take a quantum well, so this is the quantum well. If this is height is V0 in terms of potential, then there are discrete energy values here, allowed values are discrete. Similarly allowed values for holes are also discrete. So this is for q=1 q=2, q dash=1 q dash=2 and so on. So this is for the holes and this is for the… and allowed transitions are from here to here or from here to here.

The allowed transitions, selection rules require that allowed transitions are these. These are the allowed transitions. Further we had seen that the energy, if I take the upper potential well here for the electrons, then if this is V0, this is the energy, allowed energy values versus thickness Lz, thickness of the quantum well structure, then we have energy varying like this. So what are these?

These are the allowed energy values for E1. E1 is this one, E1. The variation of E1 and E2, E3 and so on with Lz, the thickness of the potential well, thickness of the well. This has some very important implications in practical devices. So the numbers could be typically, this is 50 angstrom, this is 100, this is 150, 200 angstroms, typical numbers and what could be V0? V0 could be 300 MeV.

Or I will take an example and show you this may be about 300 MeV or 0.3 eV for example or 0.4 eV, 0.5 eV, that kind of numbers we will get and what we see is the allowed value which means if you take the well width as 50 angstrom, then this is the value of E1. Here is the value of E1 and you see that at 50 angstrom, the second state is not there or the potential well supports only one state.

So it is a single mode state. So this potential well here has only 1 allowed energy value and if you change this width, the energy comes down. If you increase the energy, energy comes down which means this level moves down. So from an engineer's point of view, what is important is if you change this dimension, the effective band gap changes because this level starts coming down as I increase the width, this level goes up, so effective band gap is this, that changes.

If the effective band gap changes, then the emission wavelength changes, although the same material systems are used by simply changing the width of the quantum well, we can change the emission wavelength. This is a very important result and very important consequences or its applications are very important because from a material systems point of view, that in a fabrication process, changing the material composition is not easy.

Because it takes some time for the whole process to reach some steady state and whereas changing the thickness is very easy because thickness of the layered, what I am referring to is. If you are on the substrate, if you are depositing a layer by epitaxy, then changing this thickness is very easy, simply control the time of deposition and this can be precisely controlled in techniques like MBE.

We can control the thickness very precisely correct to 1 monolayer, 1 atomic monolayer but changing the composition, it is possible but it is not convenient; therefore, if you want to change the emission wavelength slightly, the same material system can be used but little bit variation in the thickness of the quantum well.

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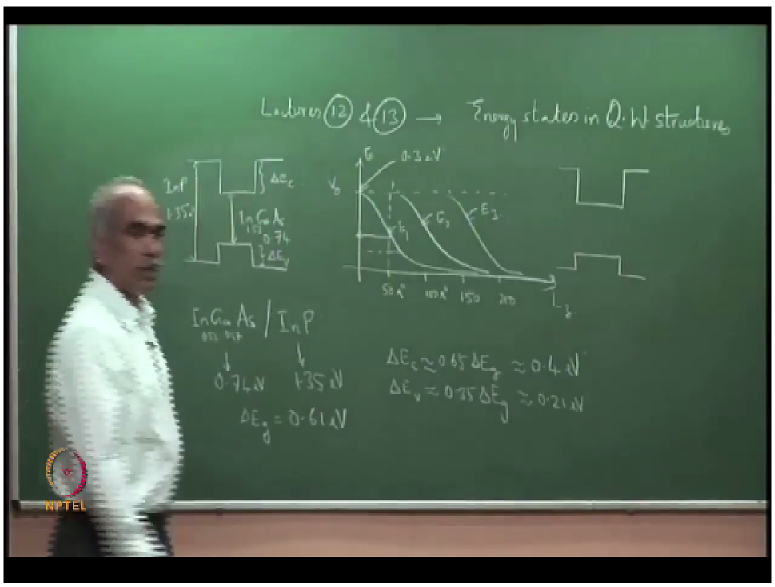

So this point I would like to illustrate with the help of an example, a very important laser material combination used is indium gallium arsenide versus indium phosphide substrate. So this is high n 0.53, gallium 0.47 and arsenic. Why we chose this combination is? This material is lattice matched to indium phosphide. So it is a lattice matched combination. The band gap Eg of this is approximately 0.74 eV.

I want to illustrate this point, an indium phosphide is 1.35 eV which means in this diagram here, let me erase this and draw the diagram corresponding to this. So this is indium phosphide, this is indium gallium arsenide and this is indium phosphide. So this is indium phosphide. This is 0.74.

So what is the Eg difference. The difference in Eg here is, so delta Eg=0.61 eV, okay, 0.26 and 35, so it is 0.61 eV.

And we know that delta Ec and delta Ev are approximately 35% here of delta Eg and 65% of delta Eg which means if you substitute 0.61 and 65, this will be approximately, please verify this, 0.4 eV and this will be approximately 0.21 eV. What is delta Ec and delta Ev? Please see this. This is delta Ec and this is delta Ev that is energy gap difference at the valance band, change in eV value for the 2 materials.

I had written here 0.3, you can see this is what I have written as 0.3 but you get with my calculation here, it is 0.4, so that is 0.4. If I take a bulk indium gallium arsenide that is a double heterostructure, okay. Before I discuss, I had written the title quantum well laser? What is quantum well laser?

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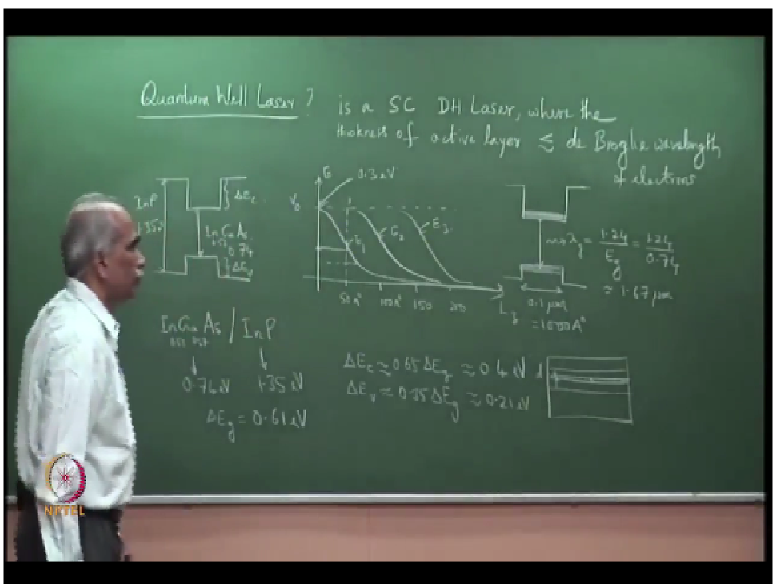

I had written the title quantum well laser. What is quantum well laser? Quantum well laser is a semiconductor laser, is a semiconductor double heterostructure laser, DH laser, where the thickness of the active layer is less than or of the order of the de Broglie wavelength of electrons. So it is a double heterostructure laser, quantum well laser is a normal semiconductor double heterostructure laser except that the thickness of the layer is very small, small very small is quantified in terms of this relation.

So typically 10 nanometers, 5 nanometers, 50 angstroms, 200 angstroms is the typical thicknesses used so that there are quantum size effects. Quantum size effects which lead to discretization of energy levels in this potential well. This forms a potential well which is the quantum well. Now when the thickness is of the order of, let us say this is 0.1 micrometer, that is a normal double heterostructure, 0.1 or this is the width of the active region.

If you see the layer structures like this, then the double heterostructure is here. This is the active region, followed by a cladding region and we have discussed this but just I am recalling this several classes before. So this is the active region, the width that I am refereeing to is this which we had called now as d. Earlier when we started the physics, it was Lz where Lz is nothing but this d, here and these are the cladding layers.

So the example that I am taking is this is indium gallium arsenide active layer and these are indium phosphide. So the band gap corresponds to these. If the thickness is of the order of 0.1 micron which means this is = 1000 angstroms, this is a double heterostructure laser, it is not a quantum well laser, it is a double heterostructure laser because this is very large. Recall that the de Broglie wavelength is of the order of 100, 200 angstroms and we are more than that.

And therefore it is a double heterostructure laser which means allowed levels are continue almost continued of allowed levels here. They are discrete but they are so close that it is essentially continue and therefore the effective band gap is this. So this is Eg. The emission wavelength lambda, lambda g here=1.24/Eg which is = 1.24/0.74 for this example, 0.74 here and that is equal to you can check, I think it is 1.67 micron, approximately 1.67 micrometer. If you now reduce this from 1000 angstrom to 100 angstrom, alright let me erase this.

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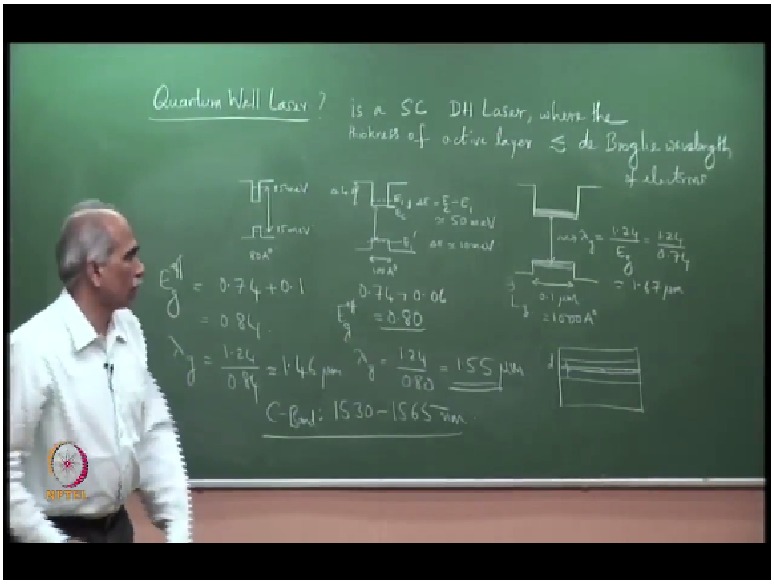

So now I am reducing it to 100 angstrom. This is not exact to scale but just. So this width now is 100 angstrom. This is a quantum well now and therefore; energy levels are discretized. So if I look at E1, E1 is here. So this is E1 and E1 dash is also here which means the lowest allowed energy is here, lowest energy is here. We had used some typical numbers, you can calculate some typical numbers that this delta E here that is from Ec, the difference between Ec and E1 which is delta i=Ec-E1 or E1-Ec the difference is typically = 50 MeV that is 0.05 eV.

Please see that this height is 0.4 eV. This is 0.4 eV. So the shift that you got E1 is 0.05 eV, typical numbers so that we have a figure and here the shift is relatively less and this delta E is typically about 10 MeV. Why do you think the difference is less? The difference is less because of the effective mass. If you recall the energy E=Ec so q=1 if I put, Ec+Eq, so here Eq=1, the energy corresponding to q = 1.

This is = Ec+h cross square K, K is pi/d whole square/2M, 2Mc for conduction band, 2Mv for valance band and Mv is mass of whole which is much higher usually compared to mass of electrons. Electrons have a lower effective mass compared to this. So the number is small, means this number is large, that is why normally you will see that the energy here are different. So what is the effective band gap now?

Please see here from here to here, it was 0.74. Now 0.05 0.01 added is 0.74+0.06=0.80. This is the effective Eg. When it was bulk, the Eg was 0.74. Now the effective Eg is 0.80 and therefore what is the corresponding wavelength? Lambda=1.24/0.80=… These are indeed typical number used for optical communication quantum well lasers are generally about 100 angstroms thick. You see the wavelength of emission has come as 1.55 micrometer.

Low loss lowest loss window of optical fiber communication. If you reduce this further to 0.8, let us say I reduce this to 80 angstrom. So if you reduce it further, the level further goes up here, the level further comes down here, so the effective Eg is now this. From 100 angstrom to 80 angstrom if you go, they may change from whatever number, so I am just taking some typical numbers, this may become 80 MeV or 85 MeV and this may become 15 MeV, I am just taking number so that they add nicely.

So this becomes 100 MeV and therefore we had 0.74+100 MeV that is 0.1. So Eg effective=0.84 and therefore lambda g=1.24/0.84, I think it is 1.4 something, you can check. May be about 1.46 I think, please check, approximately. So through this example what I have illustrated is you can change the wavelength from 1.67 to 1.46 or 1.55 to 1.46 by changing from 80 angstroms to 100 angstroms.

A very small change can change a lot. This means a lot for optical communication because in optical communication, the C band is 1530 nanometer to 1565 nanometer that is 1530-1565 nanometers, is the C band. The conventional band for WDM is here and this change is only 30 nanometers but we have got almost 100 nanometer change by changing from 80-100. So the point is I can make all lasers required for WDM by simply changing the well width little bit, quantum well, each one of them is the same material.

So the material scientist has nothing to do, he does not have to change any process parameters, everything is there. Only deposition time is controlled from 80 angstroms to 85, 90, 95 and you can change the wavelength. This is a very important advantage in technology. So this we have discussed earlier that modification of band gap by quantum well structures. So we come to the typical advantages of quantum well lasers. So why quantum well lasers? We have relatively low threshold.

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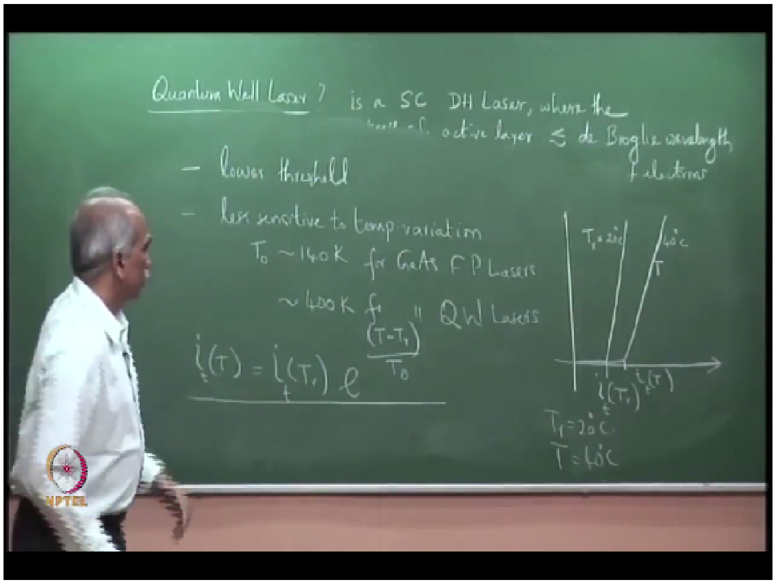

So quantum well lasers, lower thresholds, less sensitive to temperature variations, lower threshold currents. This can be quantified by, if you recall, that the character I had introduced a characteristic temperature T0 which is approximately 140 K for gallium arsenide Fabry-Perot lasers, FP lasers. We have discussed this earlier. This is the order of 400 K for same gallium arsenide quantum well lasers.

What is this T0? Recall that i of T, i threshold, this was i threshold, I used i small, iT, this T is temperature, was = sum i0 of iT of 0 or iT of some reference temperature Tr*e to the power T-Tr/T0. So this is the kind of relation we can write for the threshold current iT at a given temperature T=iT at a reference temperature*e to the power of T-Tr/T0. Tr is the reference temperature.

What do I mean by this? If you see this, so let us say this is at 20 degree Centigrade and this is at 40 degree Centigrade, okay. So T here, this is T, this is Tr. If you know at a reference temperature, the threshold, so this is iTr, iT threshold current is this at the reference temperature. I am just illustrating what does this mean. So this is the threshold current now, here for i or iT at T. So T=40.

In our case, Tr=20 degree Centigrade and T=40 degree Centigrade. I am taking an example to illustrate what it means and T0 is the characteristic temperate. A large T0 means e to the power of a smaller number and therefore, iT will be very close to iT, smaller number, e to the power of 0 is 1. So iT at T would be = iT at reference, means there is no change in temperature if T0 was infinity.

Larger the value of T, smaller will be the shift to this side. Do you follow this. So this is, for quantum well structures, this is very large. Why it is so? There are several reasons. One of most important reason is that because of the discrete energy levels, the electron distribution, the carrier distribution within the quantum well structure is not so sensitive to temperate.

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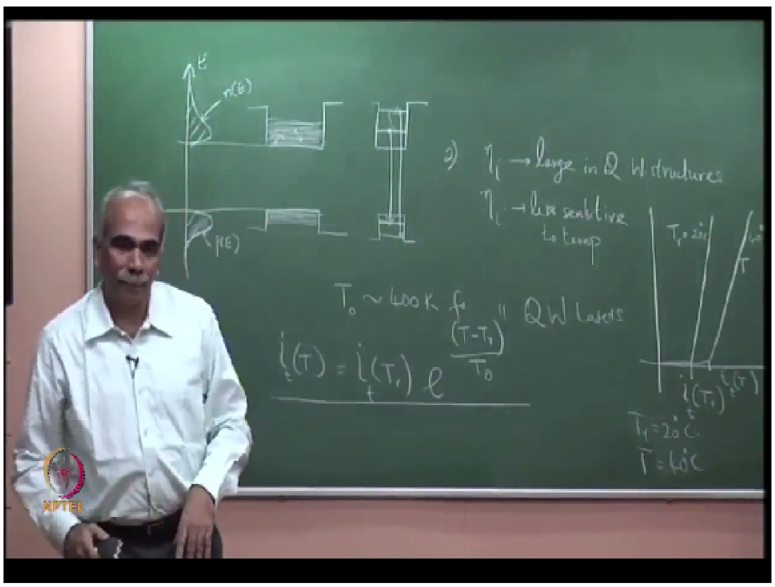

If you take a bulk double heterostructure structure, I am illustrating this, so plenty of allowed space, continuously plenty of allowed space. At any finite temperature, there are phonons which cause electrons to go up down and so on. An electron comes down by emission of a phonon and an electron can go up by absorbing a phonon, phonon transmissions, intraband transitions, phonon transitions.

If you draw by this side the quantum well structure, this is not to scale. Let us say there are only 2 levels or 1 level. For transition, here transitions are continuous, a small change in temperate changes the carrier distribution. You recall the carrier distribution we had drawn sometime back that n and p distribution like this, distribution of carriers, what we had plotted if you recall, this axis is energy, this was n of E and this is p of E.

The carrier distribution is very sensitive to temperate because temperature, the phonons can induce transitions and distribution changes rapidly. If the distribution changes, the peaks will change and therefore the maximum gain positions will change in energy. Whereas in this case, that the phonons have to make this transition because there are discrete levels. It is not continued and therefore it is much less sensitive.

Unless phonons have sufficient energy to get this transition, they cannot cause that transition. In other words, the carrier distribution in quantum well is much less sensitive to temperate and consequently the threshold is also much less sensitive to temperature. So this is in terms of transitions. The second point is in bulk if the temperature increases, non-radiative transitions increase.

In the case of a quantum well structure, the transitions are allowed transitions here. There are very little non-radiative transitions. So eta i is 1, eta i is relatively large in quantum well structures, relatively large in quantum well structures and the eta i is less affected by temperature again because these are quantum mechanically allowed transitions, discrete allowed transitions. Non-radiative transition has to be a phonon transition.

Whereas these are quantum mechanically allowed transitions which means they are radiative transitions and therefore eta i is also less sensitive to temperate. The combined effect of these 2-points lead to a larger characteristic temperature T0. At another feature of quantum well structures is, so I had written low threshold and second one is less temperature sensitive. I have described the first, the less temperature sensitive aspect. Low threshold. Why do we have low threshold?

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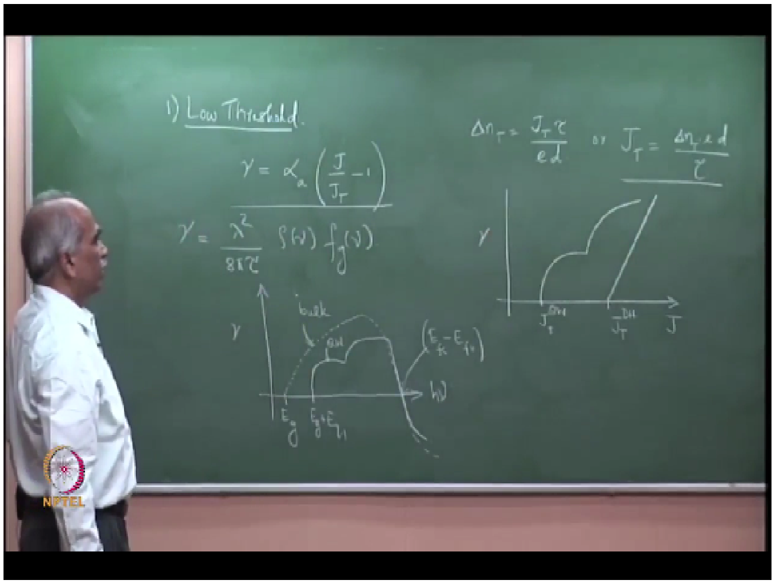

Low threshold, the first point. Let me now discuss the first point. Why do we have low threshold? If you recall, we had an expression for delta nT=JT*tau/e*d or JT=transparency current density=delta nT*e*d/tau, d is the thickness of the quantum well structure and then if you plot the gain coefficient, JT and if you see the gain coefficient gamma=alpha a*J/JT-1. In the case of quantum well structures, JT, d is very small compared to double heterostructure structure.

And therefore JT is a small number. So this axis if I show J, then JT for a double heterostructure structure is here, JT for dh, then for a quantum well structure, it is somewhere here. JT for a quantum well structures. The corresponding gamma is here. So JT is very small and therefore, as a function of J, this is the material loss coefficient and if you see gamma, this is gamma, and gamma=lambda square/8 pi tau*rho of nu*fg of nu, the fermi inversion factor.

This is an expression for gain coefficient, rho of nu*fg of nu. Rho of nu here is the density of states which is staircase like function. This is a staircase function and therefore if you recall the class 23, the lecture 23 we have discussed gain in a quantum well structure. So gamma versus energy h nu we had plotted. For the bulk ball, it was, if you recall, for the bulk, it was varying like this, then for the quantum well structure, it was step like because it was a product of, gamma was a product of rho nu and fg of nu.

Rho nu for the bulk case is varying like this that is E to the power of 1/2 whereas for quantum well structures, it was a step function and this is if you recall, this is Eg, this is Eg+Eq1 and what is this energy? This energy was Efc-Efe, gain coefficient for bulk, this is bulk and the other one is for quantum. The gamma here, the gain coefficient if you change JT, okay let me, just one second, how will I bring that, with the gain coefficient here increases linearly that is with current, the gain increases linearly, I wanted to...

Just a minute, this is J, so as J increases, JT is fixed, as J increases, gamma increases linearly, please see this. This is for the case at any particular frequency, at any particular frequency, as J increases, gamma increases linearly. In the case of a quantum well structure, JT is very small but as J increases, gamma will also increase like a step function. Gamma increases like a step function, that happens because of the density of states.

Because the density of states varies like this. You will see that gamma varies like this but the important point is, at a low value of current, we have sufficiently large gain. Please see the gain is much larger at low currents and therefore, although I wanted to bring in here 2 concepts, that is one confinement factor.

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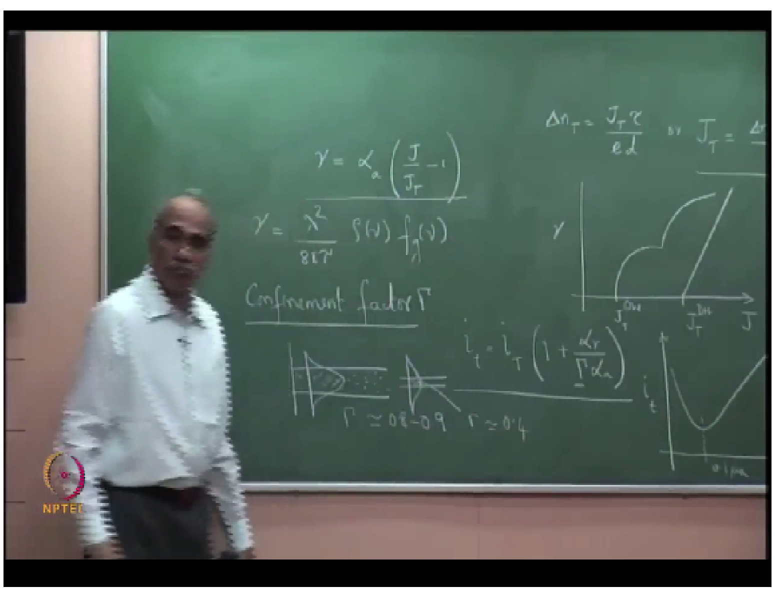

We have discussed the confinement factor. It will become clear just in a minute, confinement factor gamma. With this we had an expression for threshold, it=iT or J, you can write for J*1+alpha R, we have derived this gamma*alpha a and we had seen that, we have discussed this that the threshold current comes out to be a minimum at a value which is approximately 0.1 or 0.2 micron and that is why double heterostructure lasers had a thickness d=0.2 micron, we have discussed this in detail, okay.

So what I have plotted is thickness d here and iT, threshold current for JT, anyone of them. In the case of a quantum well structure, the d is on this side because this is about 0.2 micrometer or 0.1 micrometer. The minima come out around here; whereas in the quantum well structure, it is 0.01 micrometer, that is 100 angstrom, 10 nanometer. This is 0.1 micrometer which means 100 nanometer whereas for the quantum well structure, it is further down here therefore, we would expect the threshold to go up but why does this threshold go up?

Because of the factor gamma, confinement factor. We have discussed this in detail that the confinement factor decreases which means in the double heterostructure here, this is the double heterostructure, the optical mode is like this, this is the active region, this is the active region. The optical mode is in this fashion, it varies like this which means the fractional energy in the code, gamma is the fractional energy in the code and typically gamma is 0.8 to 0.9.

The fractional energy inside the code, this one, that is the confinement factor gamma. If we reduce this thickness, this will spread further. So if I reduce this here to a small value, this mode will spread like this which means gamma now reduces, this is gamma now. Gamma typically in a quantum well laser, gamma is of the order of 0.4. Here it was 0.8 to 0.9, this has now reduced because the thickness has reduced which means, those of you who are familiar with optical waveguides, V decreases.

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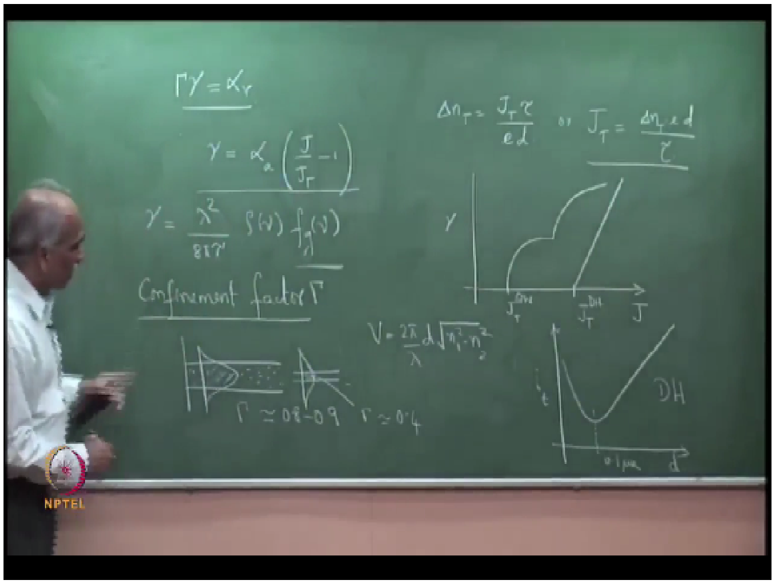

V=2pi/lambda*d* square root of n1 square-n2 square, d decreases means V decreases, the normalized frequency V decreases. If V decreases, the mode spreads out and therefore, the confinement factor decreases. If the confinement factor decreases, the threshold will go up because in the expression, gamma is in the denominator. This is the discussion that we had for double heterostructure lasers.

But in the case of quantum wells, although the confinement decreases, the gain is very large and therefore the threshold current is still low. Although gamma decreases, the gain is very large at low currents and therefore the gain is able to compensate for loss. What is the laser equation? Gain=loss, here and cavity gain, gamma*gamma=alpha r which is what we will do. Although the confinement factor is small for a quantum well, gain at the same current is much larger for a quantum well because eta i is very high and, there is one more factor that is fg varies rapidly.

Fg increases rapidly to 1. This has to be appreciated how this varies. I cannot easily show you and that is why the gain becomes very high at small currents and consequently the net effect is although we are here. So this is for a double heterostructure, DH. For a quantum well, this is not true. Quantum well even at a lower value, we have a low threshold. So gain at a low current is relatively large and therefore, the threshold is low. One last point with quantum well lasers is multiple quantum well structures.

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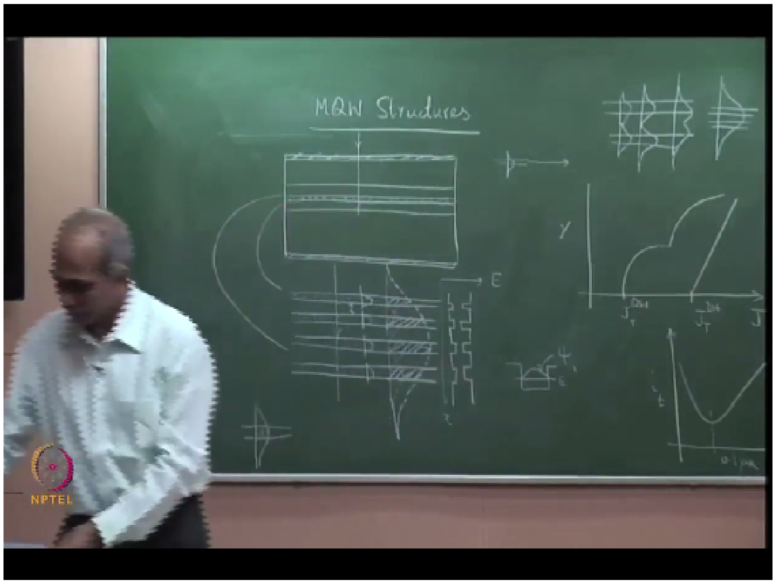

MQW structures. This is the last point I want to discuss for quantum well. The active region of a general laser today comprises of MQW. This is the active region and this is the cladding region of any laser. I have drawn this diagram many many times. This active region if I zoom, today it comprises of MQW structures that means multiple quantum well structure. MQW structure comprises of wells and barriers, potential wells and barriers.

So these are the active region. So if I draw the band diagram, it will be wells, barriers, well, identical, all of them identical. So this is for the valance band and exactly similarly for the conduction band and this is for the valance band. I hope you appreciate that I have just rotated that band diagram, energy-band diagram. So this is Eg, this is E versus depth, x or d whatever. Current flows like this as toe there is a contact here, this is a longitudinal cross-section of a typical laser diode, current flows like this.

These are the current strips. So current is flowing in this direction, which means current is flowing across this. These are the quantum well and these are the barriers. In an MQW structure, the barrier thickness is sufficiently large so that the electron wave function does not interact, they are isolated. What I have now plotted is not optical mode. Please remember, this is electron wave function.

This is electron wave function. Whenever you have doubt, you just rotate this. In a potential well, so if I rotate this, this is the allowed energy level and where is the electron wave function? So this is the electron wave function, fundamental electron wave function, (()) (49:38) energy. So this is E1 and this is i1, the wave function. So that is what I have plotted. If the barriers are sufficiently apart, sufficiently wide, then there is no interaction between the wells and this is called a quantum well structure, a multiple quantum well structure.

An MQW structure comprises of several quantum wells which are identical but non-interacting, non-interacting identical wells. Why do we use this? If I had gone drawn just 1 well here, 1 well, the optical mode I had shown you is this and I said that it is 0.4, confinement factor is very poor because the optical mode is wide. If I draw on the same diagram, please appreciate this. The optical mode here would look like this.

This is optical mode of the first one. Optical mode of the second one would look like this. Optical mode of the third would look like this and optical mode... So what is the point? The point is the optical field, optical mode Em wave, this is electron function, this is the Em wave field. They are overlapping so strongly that this leads to the formation of a single optical wave like this, single optical field.

The wells are interacting so strongly as far as optical field is concerned. As far as the electron field is concerned, they are isolated, it is like 2 directional couplers. If you take a directional coupler, there is a mode here and there is a mode here. The tails interact and you have a symmetric mode which is like this, 1 field, symmetric mode but if you bring this closer, if you bring this further closure, the mode will do this little bit and then like this and if you bring further closure the 2, it will simply become 1.

You have 2 waveguides but they are so close that it will see it as one structure. That is what I am showing here. You have multiple quantum well structure where as far as the electronic is concerned, they are isolated but whereas for the optical field, it treats it as one. What is the advantage? You make use of all properties of a quantum well structure and enhance the gamma. Now what is gamma?

You see here also it is in the gain region. Here also it is in the gain region. So gamma will increase for this effective field and to you can get more power from this multiple quantum well structure. If you take 1 quantum well, the dimension is so small that the power that you would get is limited but in an MQW structure, there are several active regions which are contributing to the optical power generated and consequently higher output power can be obtained.

So 2 advantages of an MQW structure, one enhancement of effective gamma by having 1 single optical field and 2, to achieve higher optical power outputs because overall active area is now much more. If you had only 1 well, this is the only active volume of the semiconductor is very very small but now you have, you can increase the volume by taking 4, 5, 6. Typically 3 to 6 wells are used in the active layer of a standard double heterostructure laser, less temperature sensitive is a good property of quantum well you are making use; lower threshold, you are making use of that property and yet you are enhancing gamma and a higher output power.

I will stop here for quantum well structures. There are several books on quantum well structures. Lot of study on quantum well structures, is just to motivate that you go through this literature if you are interested. We come to a very quick quiz as to be answered in 1 minute, okay. Very very simple 1 sentence answer, 1 minute. Please focused only on your answer. Please write your name and keep it ready, okay.

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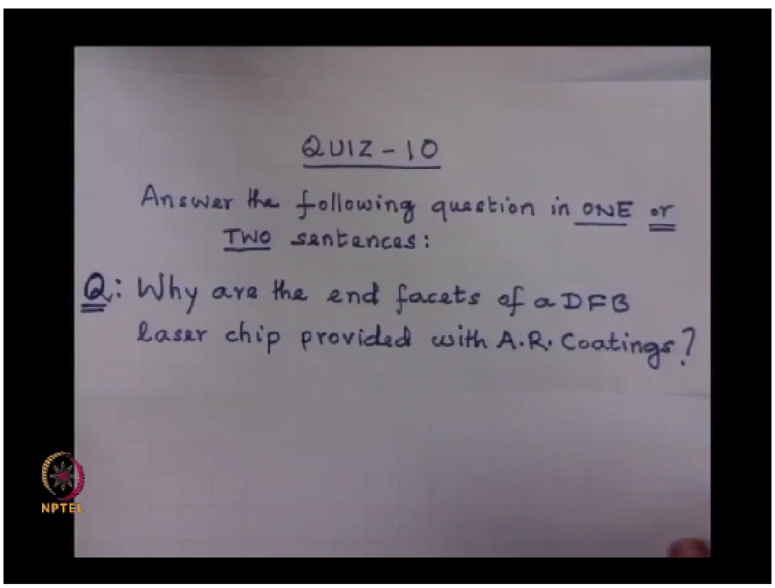

There is the question. I have covered because I have written the answer also with. So answer the following question in 1 or 2 sentence. Why are the end facets of a DFB laser chip provided with antireflection coating? Why are the end facets? end facets mean end face, of a DFB laser chip are provided with, the end face is coated with antireflection coatings. So why are the end facets coated?

Answer in 1 sentenced, maximum 2. The end facets of a DFB laser are always coated with antireflection coatings, AR coatings, why? Do not write a big paragraph, that is why I have said, answer in 1 sentence. It should not take more than one minute to write one sentence. So those of you who have finished, please give me. You have to give now, 10 seconds. Okay you have to give now. So the question is, I repeat, why are the end facets of a DFB laser chip provided with AR coatings, antireflection coatings.

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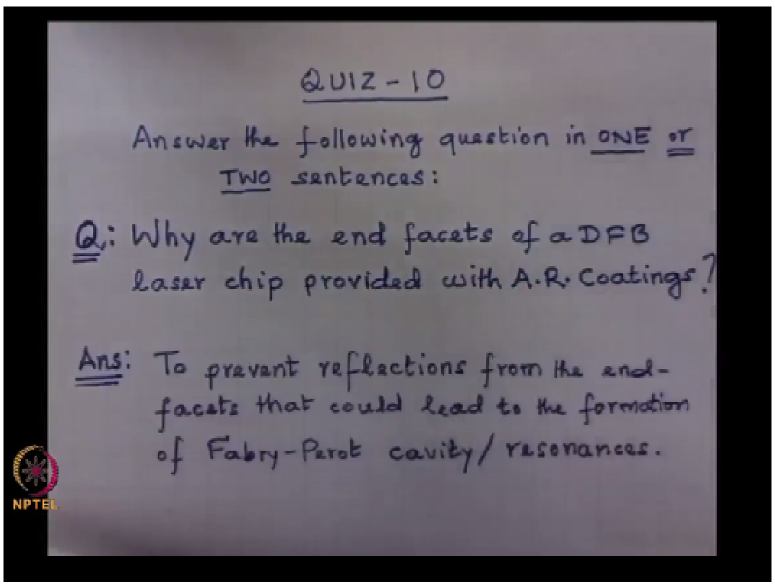

The answer is, here is the answer. To prevent reflections from the end facets that could lead to the formation of Fabry-Perot cavity or resonances. It is very clear that AR coating as the name indicates, it is an antireflection coating to block reflections coming from the ends. If the reflections come from the end, there will be feedback from the ends and the cavity will also form a Fabry-Perot cavity and therefore there will be allowed resonances at those frequencies.

To avoid this and to select only one frequency that is selected by the grating, we need antireflection coatings at the ends. That is the answer. I hope it is clear.