Semiconductor Optoelectronics
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Lecture – 38
Practical Laser Diodes & Handling

Okay, today we will discuss about practical laser diodes that is practical device, how the device looks like? What kind of packages? And, what kind of specifications? If you see a typical data sheet or a specification sheet, do you understand what the parameters stand for and we will also discuss about handling issues. There is some safety related issues, safety to the device as well as safety to the user and these issues we will discuss.

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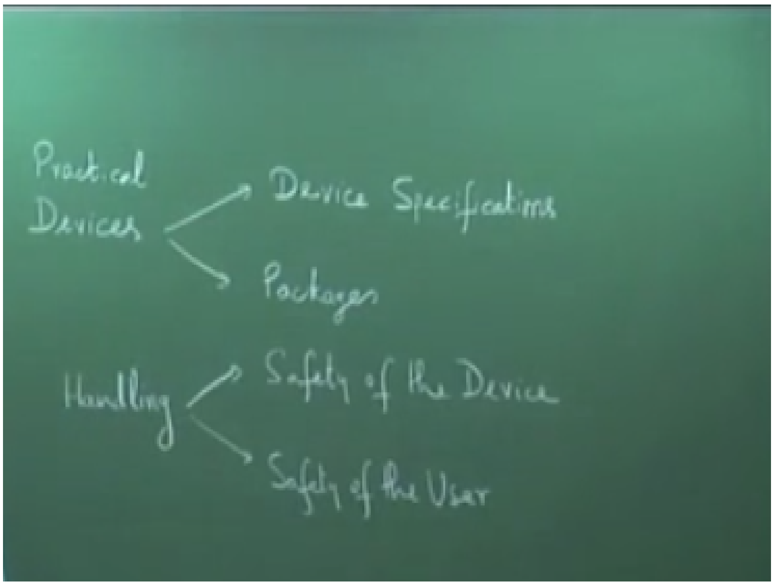

So practical devices, in devices I would like to discuss about device specifications, so practical devices, practical device specifications and device packages. What kind of packages are used and in handling? there are 2 issues which is safety of the device and safety of the user. Let us start first with the device specifications. So, let me keep a typical laser device specification, it is a little big slide there, but I hope you can see that, okay.

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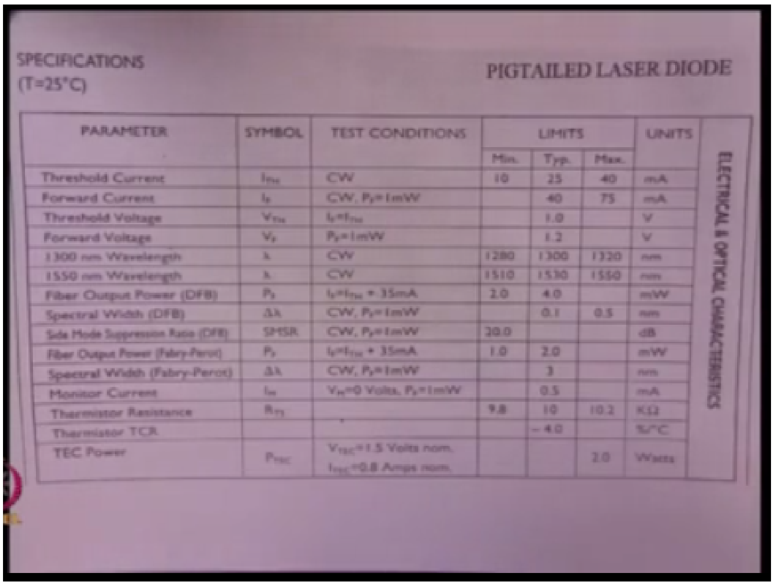

SPECIFICATIONS
(T=25°C)

PIGTAILED LASER DIODE

PARAMETER	SYMBOL	TEST CONDITIONS	LIMITS			UNITS
			Min.	Typ.	Max.	
Threshold Current	I_{TH}	CW	10	25	40	mA
Forward Current	I_F	CW, P_F=1mW		40	75	mA
Threshold Voltage	V_{TH}	I_F=I_{TH}		1.0		V
Forward Voltage	V_F	P_F=1mW		1.2		V
1300 nm Wavelength	λ	CW	1280	1300	1320	nm
1550 nm Wavelength	λ	CW	1510	1530	1550	nm
Fiber Output Power (DFB)	P_F	I_F=I_{TH} + 35mA	2.0	4.0		mW
Spectral Width (DFB)	$\Delta\lambda$	CW, P_F=1mW		0.1	0.5	nm
Side Mode Suppression Ratio (DFB)	SMSR	CW, P_F=1mW	30.0			dB
Fiber Output Power (Fabry-Perot)	P_F	I_F=I_{TH} + 35mA	1.0	2.0		mW
Spectral Width (Fabry-Perot)	$\Delta\lambda$	CW, P_F=1mW		3		nm
Monitor Current	I_M	V_M=0 Volts, P_F=1mW		0.5		mA
Thermistor Resistance	R_{TI}		9.8	10	10.2	KΩ
Thermistor TCR				−4.0		%/°C
TEC Power	P_{TEC}	V_{TEC}=1.5 Volts nom. I_{TEC}=0.8 Amps nom.			2.0	Watts

ELECTRICAL & OPTICAL CHARACTERISTICS

Let us first see specifications one by one. This is specifications at T = 25 degree C, it is a fiber pigtailed laser diode, what it means; I will show you in a minute fiber pigtailed laser diode. So, the first parameter which is written threshold current here, I threshold, test condition CW, CW standing for continuous wave mode of operation, a laser can be operated in CW mode. CW standing for continuous wave and pulsed.

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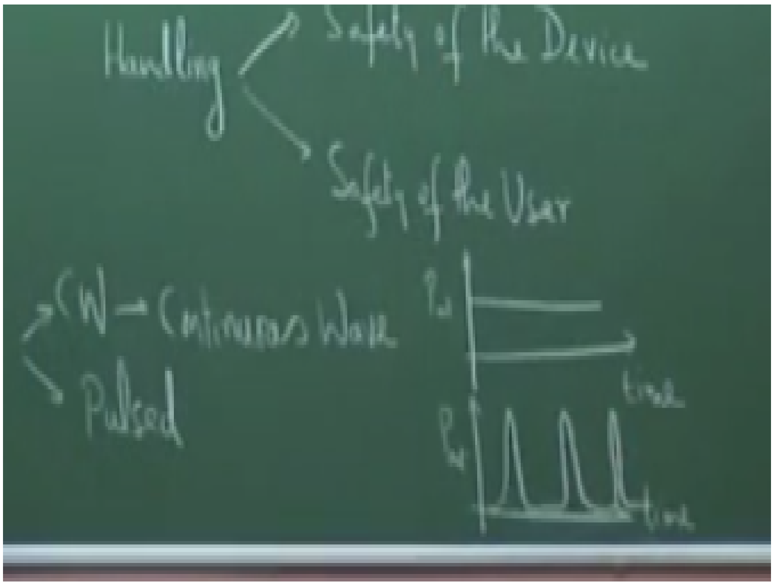

So, 2 modes of operation for all laser diode CW, continuous wave and pulsed. So, CW means if you plot with a time, time versus power, so Pout if you plot, you will have a certain level fixed that is CW, continuous wave and for pulsed laser, if you plot, time versus power, Pout then you will have power varying and so on. So that is the pulsed output, Pout versus time, so CW and pulsed.

So, the threshold current typical parameter you can see that it is 25 milliampere CW units are given, minimum is 10, maximum is 40 because there could be some variations in the device. Therefore, usually they specify minimum and maximum. Forward current that is the operating current IF, for CW to get 1 milliwatt power, P output 1 milliwatt; you pass a current of 40 milliampere.

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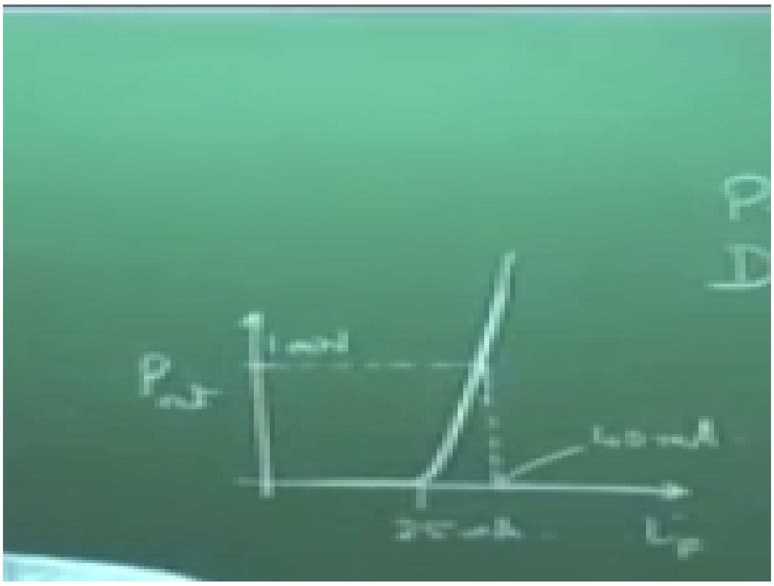

At 40 milliampere, a 25 milliampere is the threshold current that is when power output starts, then at what has been shown there is this. So, we recall the characteristics that we have IF, forward current versus Pout and we have almost 0 output and then output going like this. So, this is the threshold value. So, in this particular example 25 milliampere is here and when the output is, when the current is 40 milliampere here, output is 1 milliwatt.

So, we understand this and to get 1 milliwatt, you may require sometimes 75 milliampere because there may be some device degradation, but typically about 40 milliampere. Forward voltage, the voltage because is the forward diode and it is a diode forward biased diode, forward voltage is 1.2 volt. Wavelength, there are 1300 nanometer wavelengths, 1550 nanometer wavelengths.

So, 1300 nanometer typical wavelength is here, minima and maxima that is +- 20. It does not mean a particular device will give that. A particular device when maintained at a particular temperature and current will give a fixed power output and a fixed wavelength, but in a lot that is in the batch of several devices, some devices may have slightly varying characteristics that is what they mean by minimum and maximum.

So fiber output power, this is 1550 nanometer CW and this is the typical output and fiber output power for a DFB laser, DFB here, we are familiar with DFB now, distributed feedback. The forward current at a forward current of I threshold + 35 milliampere, you have an output of 4 milliwatt is the output and the spectral width of the DFB, so we know now DFB laser, distributed feedback, so I am discussing this, so let me erase the remaining ones.

A DFB laser spectral width as you can see the spectral DFB and fabry-perot are very different. Distributed feedback laser, the output of a distributed feedback laser if you recall that you have some side lobes, what I have plotted is frequency nu or wavelength lambda, normally in light, we discuss in terms of wavelength, so wavelength lambda here versus the power output, so Pout that is full width at half maximum.

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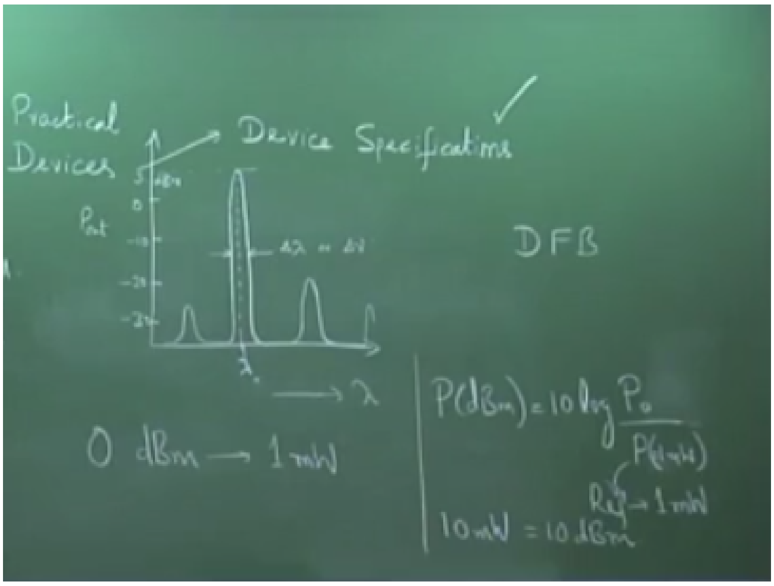

So, whatever is the full, the width at half maximum is delta lambda here, so delta lambda or delta nu and this is the center wavelength, lambda c or lambda 0, the center lambda wavelength of the DFB. These are the power in, so typical power if you see here that this may be 3 dB, 0 dB, so 3 dBm, this is 0, this is -10, -20, -30 dBm. DBm, I hope you know the definition of dBm. One dBm is, so 0 dBm here refers to implies 1 milliwatt.

The power in dB those of you are not familiar power in dBm is defined as 10 log P, P here in milliwatt, so P in watts here divided by with respect to, so P1/P2, whatever is P1/P2, so here 10 log P1/P2 here, P2 is reference and therefore, so P2 is reference to 1 milliwatt. Please see, this is the actual output, power output, which is the definition in general, but definition of dBm is Pout actual power with respect to P2 here that = 1 milliwatt.

What it means is, if the output power is 10 milliwatt, those of you are familiar, if the output power is 10 milliwatt, then if in the denominator is 1 milliwatt, this ratio is 10. So log 10 is 1, so multiplied by 10, so this is 10 dBm, = 10 dBm. So, 10 milliwatt power = 10 dBm. If the output power is 1 milliwatt, so if you substitute 1 here this is 1, log 1 is 0, so 0 dBm. So, 0 dBm is 1 milliwatt and so on.

Please those of you are not familiar, put some numbers and be familiar with it. So, the fiber output here is, in this case is it is given in milliwatt, so 4 milliwatt. The spectral width delta lambda is given here for CW at 1 milliwatt power is 0.1 nanometer. Delta lambda is 0.1 nanometer. If you look at fabry-perot lasers, normal fabry-perot lasers it is about 2 to 3 nanometers.

If this being a DFB laser, the spectral line width is very narrow. Then, you see the side mode suppression ratio, I have discussed about this for a DFB, SMSR at CW output of 1 milliwatt, the SMSR is 20 dB, 20 dB is the ratio of this power to this power. In my diagram, for example this is 3 dBm and this is -20, therefore what is the SMSR, so SMSR = 23 dB. In my diagram, it is 23 dB, output is 3 dBm, 3 dBm those who are not familiar is 2 milliwatt. 2 milliwatt is 3 dBm.

You put here, log of 2 milliwatt/1 milliwatt log 2, log 2 if you know the number it is 0.3010, multiplied by 10 is 3.01 which is 3 dBm, alright. So, 3 dBm is 2 milliwatt here and the power in the side lobe is -20 dBm, so the difference is 23 dB, it is the ratio, so please see it is dB not, dBm. SMSR is the ratio, so it is in dB. If you go for the spectral width for fabry-perot is given here 3 nanometer just now I mentioned.

For a fabry-perot laser, the spectral width is delta lambda = 3 nanometer, so typically 2-3 nanometer is for a fabry-perot and 0.1 or less if the current DFB is even much < 0.1 nanometer as the line width. The next one is monitor current, you see there is the parameter written, monitor current at VM = 0 volt that is monitor voltage = 0, output power = 1 milliwatt, the monitor current is 0.5 milliampere.

I will discuss this in a minute, so let me finish the remaining parameters here. Thermistor resistance, there is the thermistor here and the resistance of the thermistor is given 1 kilo-ohm typical and thermistor temperature coefficient of resistance, these 2 are required to maintain the temperature of the device. I will discuss in a minute, but you can see thermistor temperature coefficient of resistance is -4% per degree centigrade, which means as temperature increases, thermistor resistance decreases.

It is -4% of the resistance. Originally if it was 100 ohms of the thermistor then 1 degree increasing is -4% that is it will come down to 96 ohms. So, the resistance is changing with temperature, so that is the temperature coefficient of resistance and this is TEC power, the thermoelectric cooler power, all laser diodes are operated with a temperature controller and it is a TEC that is thermoelectric cooler, the power taken by the cooler is typically about 2 watts.

So, this is a sheet of specifications, so now and when we look at the specification, the only thing that I have not discussed so far is the monitor photo diode and the thermistor; we will come to this in a minute, alright. Let me show, let me discuss the packages and then I will come to this monitor photo diode, alright. Maybe I will first discuss monitor photo diode because when we go to packages, you will see that there are leads which are connected to thermistors and monitor photo diode.

So, it is better to discuss the monitor photo diode, alright. So, if we see a typical data sheet and if we understand all the parameters, technical parameters of a device, it means that we have reasonably understood the device and its operation. Otherwise, it simply means we know only the theory, we have no idea about what is it in practice, okay. So, let me take device package, the thermistor.

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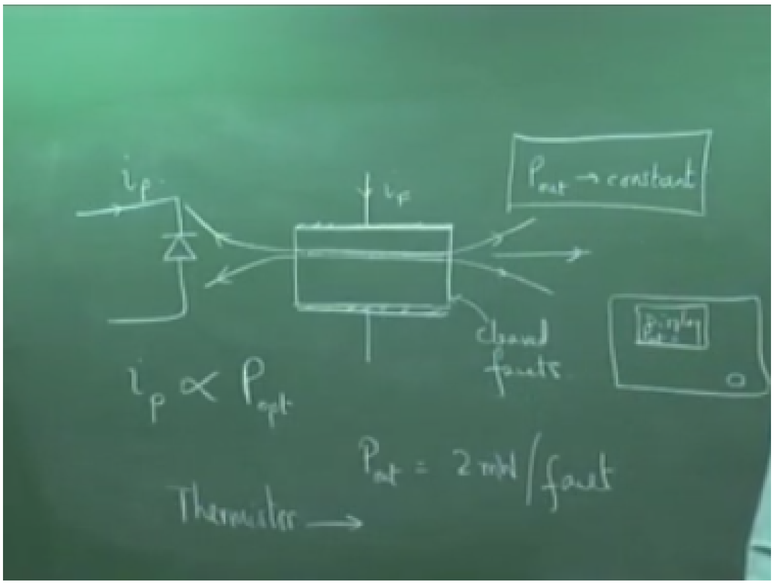

You see here, the monitor photo diode. What is this monitor photo diode? A typical fabry-perot laser or DFB laser, so you have I shown only the active region and other layers are understood, so I am not showing it again. This is our active region and the current is flowing here and output is coming from here, please see these are cleaved facets, 32% reflection both the sides, so obviously output will come from both directions.

Output comes from both the directions in a laser diode. In fact, the early laser diodes in the specification, it used to be today it does not say, it simply says output power. In the early laser diodes, it was always specified Pout = 2 milliwatt per facet. In the 1970s and 80s, the power was specified as per facet, facet means per face, which means 2 milliwatt comes from here and milliwatt comes from here, 2 directions.

But in any application, we need light coming from one direction, you do not imagine a torch light, the light is coming from among way in front and behind, so you want to light to come from one direction normally and therefore, but in a normal device, light will come from both the directions unless you coat this, coat this with a mirror, which is a difficult proposition, expensive proposition and therefore, what is to intern is, this output is incident on a photo detector.

So, I am showing this photo detector as a diode here, which is actually integrated with a chip, but I am showing it as separate, the output is incident on a photo detector. The photo detector will generate a reverse current Ip. What is the advantage? By measuring this current Ip, this

Ip is proportional to incident power. The Ip, the reverse photo current is proportional to P optical power incident on it.

And therefore, by measuring this Ip, we can find out what is the power which is coming. We can calibrate it and then we know simply by measuring the current, we know what is the output power. What is the advantage? The output power coming from the other side is the same as the output power which is coming here. So, if you know this you know the output. Without disturbing the output when a laser is on, you know what is the output power.

So, today's laser drivers will have an output here and there is a display here. In the display, there are several parameters which comes, but it also tells you what is the Pout, how will it say what is the P out. If the output is coming from here without measuring this Pout, who does it say this P out. It is saying this P out by measuring the power coming from the other end. So, monitor photo diode and the monitor current is very important measure for the device. Why?

If you want to maintain the power constant, many applications required that the output power Pout should remain constant. If you monitor the photo current here, you can find out what is the power which is coming. If the monitor current starts dropping, it tells you that the output is dropping even without measuring separately what is the output coming from here. So, the output power is constant if the monitor current is constant.

So, this monitor current is independent of the output which is coming from the device. So by monitoring this current, you can find out what is the output. There is not just finding out the output if the power starts falling down, the current starts dropping here. Then, there is a feedback which is given so that this current I is increased, so that the output again is jacked up. When the power starts dropping, the monitor current drops that is why it is called monitor photo diode.

And this is monitoring continuously and as the current drops for whatever reason if the output goes down, you can increase the forward current or the biased current through the diode and raise it back, so that the output power remains a constant. This is very important in the case of constant output power devices. The monitor current is the one which gives you the different signal, so that by bringing maintaining the difference signal constant, you can maintain the output power constant.

So that is the monitor photo diode. So, this photo diode is integrated with the laser chip and there are terminals provided for the monitor photo diode, separate terminals. When I talk about the device package, I will show you that there are terminals provided for this photo diode. So that you can also take out the current for some other external circuit, which will maintain the power output constant by measuring the different signal or the change in the monitor current.

This is the monitor photo diode. The second thing that we encountered is thermistor. The thermistor is a temperature dependent resistor with the temperature coefficient of resistance. It is a temperature dependent resistance, which means if you change the temperature, the resistant changes and this thermistor is also integrated along with the laser chip, in the same chop.

So that if the temperature of the chip changes that means if the temperature of the laser diode changes, there will be a change in this resistance. The change in resistance can be used as a different signal again a far to the thermoelectric cooler TEC, the change resistance of the thermistor can be used to power the thermoelectric cooler. What is the thermoelectric cooler? The Peltier cooler, where by passing a current, you can change the temperature between 2 junctions.

The 2 junctions sitting a 2 different temperatures will give rise to a voltage signal and by changing the current, you can change the voltage or by changing the voltage, you can change the temperature. So, this TEC is a thermoelectric cooler based on the junctions and the current to this TEC, the TEC was consuming about 1-watt power, the current to this TEC can be controlled by this resistor temperature dependent resistor.

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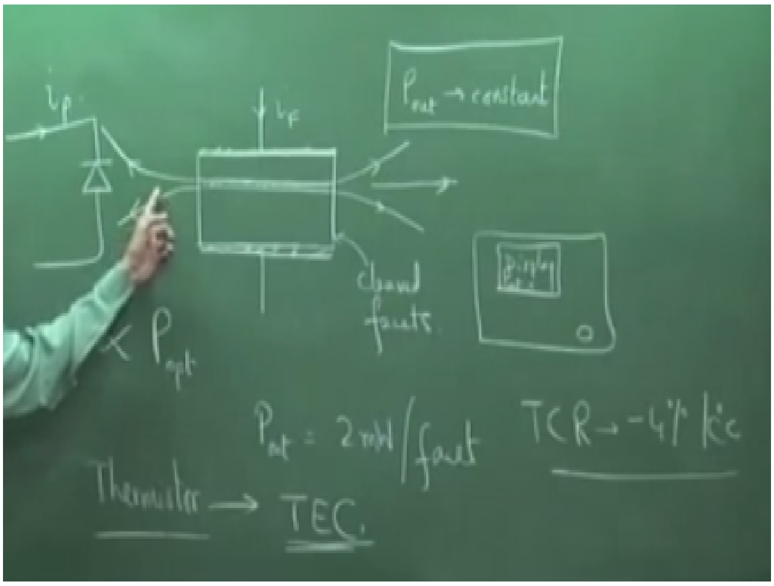

So, if the temperature of the chip changes, the resistance changes and therefore, there was a parameter TCR, which was -4% per degree centigrade, which means if the temperature changes to 1 degree, the resistance changes by -4% that is it decreases. All these thermistors are basically photoconductors. If you increase the temperature, the resistance drops because more number of carriers are generated, thermally generated carriers.

And therefore resistance drops, that is why you see here -, there is a -4%. So, that controls the current which goes to the TEC and TEC can again pass more current and make it cooler, so that the temperature is maintained. So, both the thermistor and the monitor photo diode are to maintain constant temperature and constant power output of the device, okay. So, we have seen now all the specifications here.

So, let me remove this and we will go to the device packages. So, we understand now all the specifications which are there, there are some more specifications in data sheets of certain manufacturers, I would not go into those details. These are the basic things which are there in general in almost all laser diodes. There may be specific parameters relevant to specific devices in addition.

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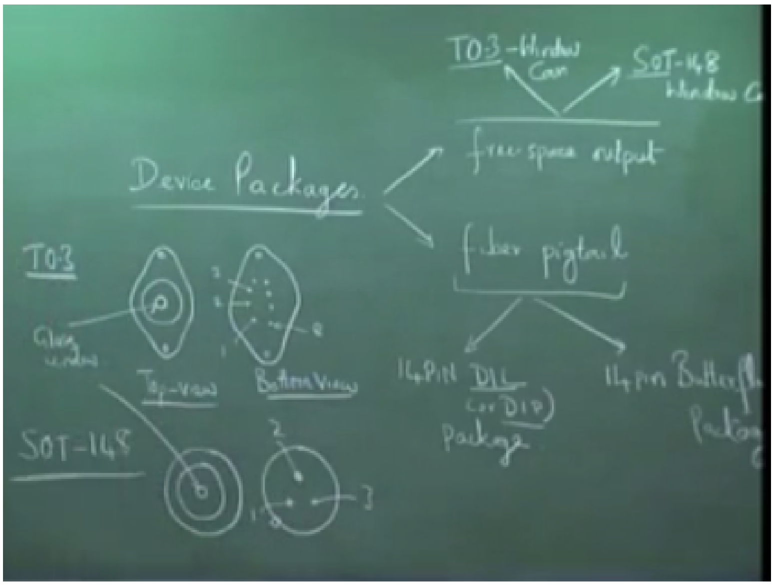

So, let us look at device packages and then, we will go to handling. So device packages, all the packages either they give free space output. Packages which give free space output or packages which have fiber pigtail, almost all the laser diodes used in communication are fiber pigtailed laser diodes because you can directly splice it to the fiber which is on the line, fiber pigtailed are free space output.

Fiber pigtailed output, there are 2 specific packages here, one is called the 14 pin DIL, dual inline or sometimes DIP, 14 pin DIL package usually for low power applications and for high power applications, it is in variably, 14 pin butterfly package. I will show you this, I have brought a butterfly package, but DIL, I will show you, this is just like an IC, the typical IC.

The free space output here, there are 2 common packages that are used, one is called the TO3 window can package and the other one is SOT-148 window can. The 4 types of packages which you see in common, so first let me show the TO3 window type package. So TO3, it may be interesting to find out what are the abbreviation standing for, you find out what are these TO3 and SOT-148.

So, the TO3 package looks like typical power transistor, those who of you who have seen power transistor, it looks almost the same shape. I hope you have seen a power transistor. In the top view, there are 2 holes here to mount the power transistor. These are slots to mount the, this is the top elevated this one and the bottom view looks like this, typically these are 8 pin devices. This is the bottom view.

So, top view and the bottom view, the pin starts from 1 from here, 1, 2, of course, these are all provided in the data sheet and 8 comes here. It is usually in a clockwise direction when you look from the bottom, 1, 2, 3, 4, 8. It is the top and at the top, there is always a window. So, this is a glass window, but we need a glass window because light has to come out. So, light comes out from here, in this direction.

So, this is the light comes out perpendicular to the board. There is a glass window. Otherwise, it looks if the glass window was not there, it will just like power transistor, so that is the glass window from which light comes out like this. I will show you the next one, SOT-148 because I also have those SOT-148 packages, so this is SOT-148. This looks like this; the top it is circular. The top you, is this, the window.

If we place these transistors, electronic transistors, diodes and upper electronic components like laser diodes, there is no difference except that there will always be a glass window on top because light has to come out from a source and for a photo detector, light has to be incident. Otherwise, they look like just a can of a transistor, the familiar device, so I will show you in a minute.

So, this is the top and from the bottom, there are different 4 pin devices, 3 pin devices, so usually there is a cut provided which will tell you that this starts with 1, 2 and 3. So, this is the top view and this is the glass window as before. So, here is the glass window and this is the bottom view here, so I will show the packages. So, you can see the packages here. They are not supposed to touch those, but there are one or 2 things what I have kept along with this is a normal LED here.

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An LED which is 2-pin diode, light emitting diode and this is a spoilt one, so I can touch that, but it is important that you see that there are 3 terminals there. There are 3 terminals and these are the same 3 terminals here, 1, 2, 3 and that is the bottom view and the top view as you can see, there is a glass window in each one of the devices. This is the laser diode used in CD writing device.

And this gives an output power of about 20 milliwatts, this small device give power of about 20 milliwatts. There are 3 terminals, they are its like this. The first one is 1, okay. Let me write 1, laser diode anode. 2 is common ground, ground that is K's ground + cathode of laser diode and monitor photo diode, MPD, I am writing MPD, monitor photo diode. Cathodes of LD and MPD and 3 is the anode of monitor photo diode.

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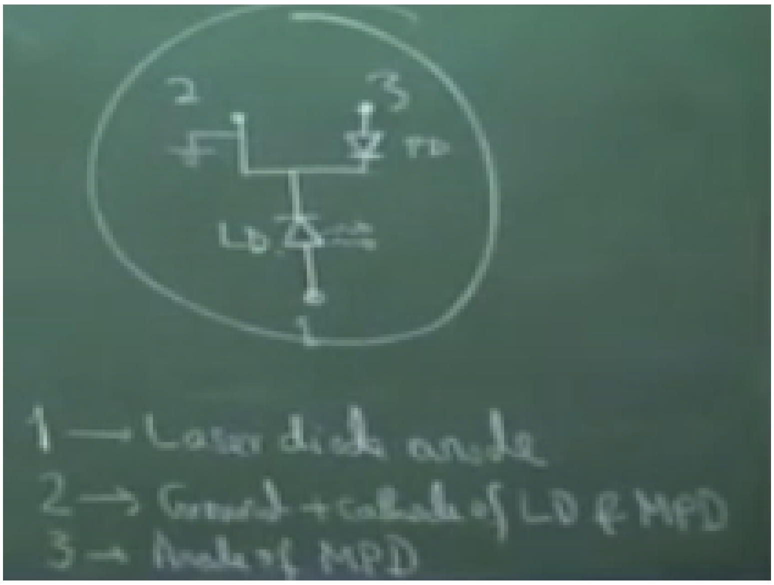

I will show a schematic, how it looks like. Where can I show? Alright. Because next we will discuss the, so it looks like this. It is a 3 terminal device, so this is 1, the laser diode, terminal 1. This is terminal 2, which is actually grounded to K's ground, so this is K's ground and here at terminal 3, we have the monitor photo diode. So anode of, so this is 1, 2, 3. This 1, 2, 3, I have now shown is 1, 2, 3. 2 is which the common cathode here.

This is the monitor photo diode. So, this is the photo detector MPD and this is the laser diode. So, the 3 terminals that you see on the device here, the 3 terminals are I hope you can see all the 3 terminals and let me, this is the used one. It is a defective one. So, you can see that is now not really is a good view because you will not see the lead if I completely keep it, it is sitting in that slot.

Alright, let met, but do not touch the device why you should not touch, I will discuss in a minute. So, this is SOT-148 package typical laser diode. If we give you, there is another small laser diode here. It is a low power one and let me take it out and you can see this is just like a transistor. There are 3 terminals; it is like transistor except that at the top, there is a glass window. In a transistor, you simply have a can, metal can.

There is no window. Here in every optoelectronic device, there will be a window at the top. Let me go other 2 packages because we have to wind it up and very important are the DIL and butterfly package. Again, I have brought a butterfly package to show you, this is also a used one, a defective one. Otherwise, cannot touch this. Let me take this out and show you the butterfly package and you will know why it is called a butterfly package.

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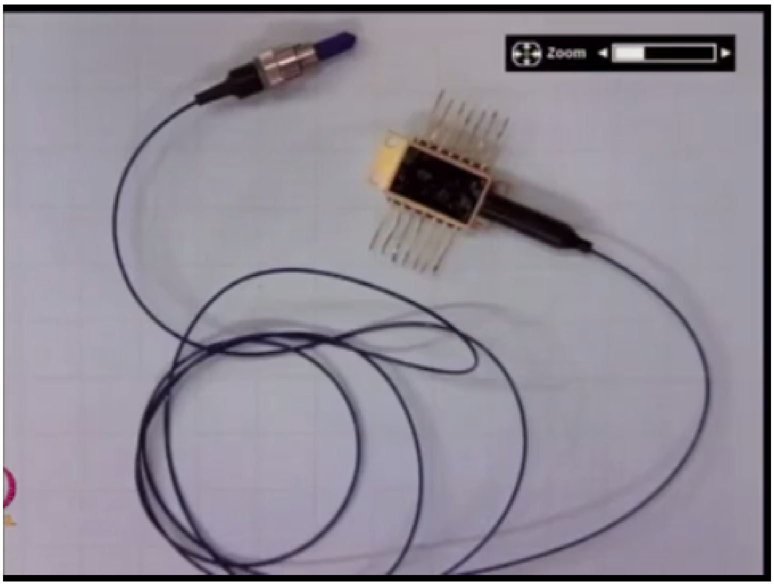

It is a fiber pigtailed device; this is the fiber pigtailed butterfly package. I hope you can see it. So what you have is a 14 pin device, you can see 7 pins here, 7 pins on the other side and fiber is coming out. So, this is already pigtailed to a fiber and this is the connectorized output of the fiber because in all fiber and optoelectronic instrumentation, you need connectorized output and therefore, this is the fiber and it is connectorized and here is the butterfly device.

It is called butterfly because butterfly when open its wings, it looks like wings on the butterfly. Hence the name butterfly and fiber pigtailed, fiber is already pigtailed here. Pigtailed means if you have the device, which is coming out here, so there is the light which is coming out here, then the fiber there may be a micro lens usually there are different techniques of coupling right into the fiber. The fiber end, there is micro lens made at the end of the fiber.

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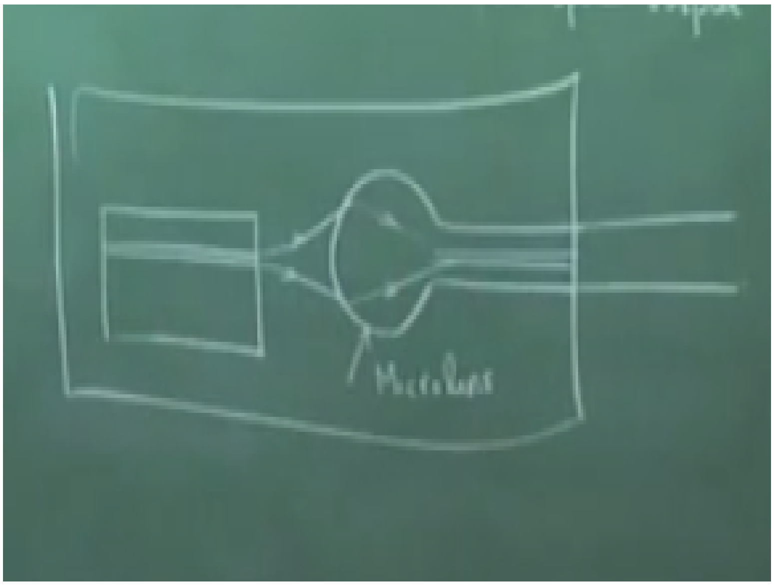

This is the optical fiber, micro lens, the fiber and it is made in the shape of micro lens. So that the light which is coming out of the diode is immediately coupled into the fiber core and the whole thing is sealed, so that there is no relative displacement. It is already completely ready and the fiber is coming out from here. So, this is called fiber pigtailed. Fiber pigtailed laser diode is a device where the fiber is already aligned, pre-aligned and hermetically sealed.

It is pre-aligned and sealed in the package. So, this has 14 pins. I will show you another diagram. This is a very nice device because you can see its bottom. It can be mounted with 4 screws on a heat sink and it has a very good contact with a heat sink. The bottom, its belly, this is its belly, the bottom is in good contact with the heat sink and that helps in maintaining the temperature. So, you can mount it with the 4 screws here at the 4 corners and gives very good contact with the heat sink.

I will show a diagram of the 14 pin DIL package or DIP. So here is the, it looks like an IC at the back, there is a connector or a connecting plate which is again for providing heat sink. So this is for heat sink here, I hope the diagram is clear. This is schematic and you can see the fiber connector and fiber pigtail and here also the pin diagrams are shown, you can again see what the pin stand for monitor photo diode negative, monitor photo diode positive.

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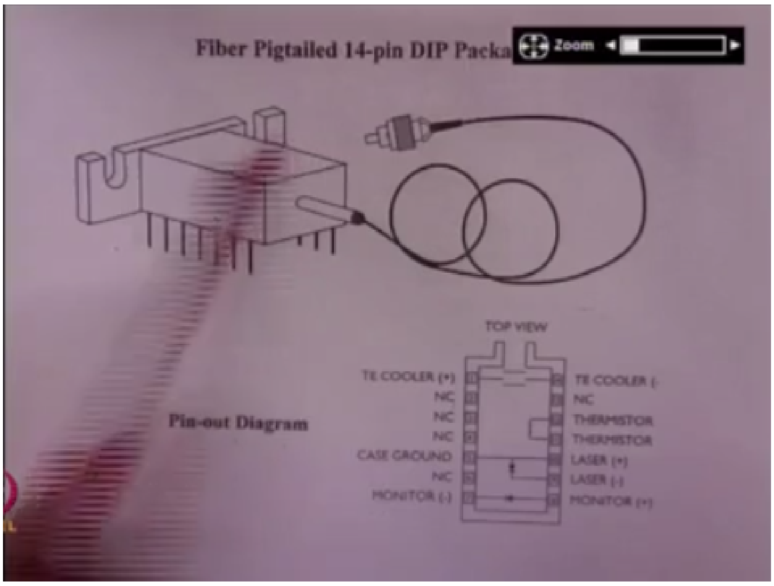

Here is the monitor photo diode. The laser diode positive anode and cathode, there is a thermistor shown here. NC standing for not connected, although there are 14 pins, all pins are not connected. So, NC standing for not connected and the top 2 electrodes are for the TEC. So, this is the pin diagram and if you see this, if you understand what is there in a practical device, I hope you know all the device looks like. So, this is a 14 pin DIP package.

Let me very quickly come to the laser handling safely to the device and safety to the user. Very briefly, safety is a very big topic, so laser handling, safety of the device and safety of the user. Every user is supposed to be aware of the laser safety aspects. In fact, these are mandatory by law that those who use laser diodes are lasers in general must know the safety aspects. So, let me first discuss the safety of the user.

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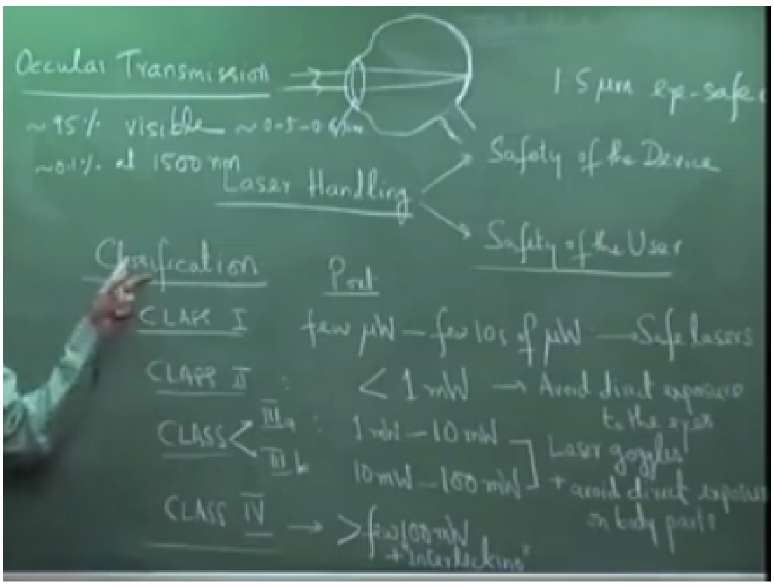

The safety of the user is of course because of the power output of the laser, the damage that the laser output can cause. The damage is primarily because it is a highly monochromatic coherent radiation can be focused to very small spot sizes and therefore, the intensity at the focus to spot can be very large and can cause burns and if it is incident on the ice, then ice can get damaged and therefore, lasers are classified based on the output power, classification of lasers.

These are called class I, class II, class III, class III has usually 2 subclasses, class IIIa, class IIIb, this is 2 for all lasers, not just semiconductor lasers and class IV lasers. Actual classification will also depend on what is the wavelength of the machine, but typical approximate range of powers class I, the power is a typically few microwatts, P output, so this is P output, few microwatts to few tens of microwatts. These are safe lasers.

Most of these are used at the research level and there are materials which give very small amount of power, class I laser. Class II here stands for power < anywhere, but < 1 milliwatt. P out < 1 milliwatt. Reasonably safe, but avoid direct exposure to the eyes, means if the laser being goes directly into the eyes, it could have damaged the eye. So avoid, otherwise with the reasonable precautions, you can handle these lasers without going to special safety measures.

But care to note, take care to avoid direct exposure to eye or metallic reflections from metals which are as good as high reflection entering you eye. Class IIIa here stands for typically 1 milliwatt to 10 milliwatt and class IIIb is typically 10 milliwatt to 100 milliwatt. Please let me make it clear that the numbers are varying with the wavelength and the damage that the particular laser can cause, but these are the approximate power ranges.

Most of the lasers which we handle in applications other than may be nonlinear optics experiments or in industrial applications, we handle class IIIa, class IIIb lasers. In most of our laboratories, communication applications, the power involved are here, class IIIa and class IIIb. So, class IIIa and IIIb here eye wear is a must laser goggles, so laser goggles are laser safety wear.

So, laser goggles + avoid direct exposure on body parts. Avoid direct exposure on your hands, body parts, they could be harmful to the skin, but laser goggles is a must, you must use laser goggles when you are handling class III lasers because they are definitely harmful to the eyes.

They are scattering, the amount of scattering that would come or reflections which could enter your eye could be large enough to damage your retina.

Again, as I said it will depend on the ocular transmission. There is something called ocular transmission. Ocular transmission is the fraction of energy transmitted from the eye lens to the retina. The energy transmitted from the lens of the eye, if you alright let me, this is your eye, alright or my eye, so the retina is here, at the back and this is the lens, eye lens. So, the fraction of energy transmitted, so light is incident from here.

This is the cornea and the eye lens, the dimensions are not alright, just to, so the light which is incident on the retina here, so retina is at the back, the fraction of light which is incident is called ocular transmission. So, the ocular transmission is very high for visible, almost 95% in the visible region that is approximately 0.6, so around 0.6, 0.5 to 0.6 micrometer, whereas this is about 0.1% at 1550 nanometer or 1500 nanometer.

Fortunately for optical communication, people this is the fraction of light which is incident on the retina is much smaller and therefore, most of the light is observed here in between that is actually over a wide region and therefore, it is not so harmful, but here at the focused spot, the amount of light incident is only 0.1% at 1550. In fact, those who work with the defense they call it as an eye safe laser, 1.5 micrometer is called eye safe laser.

There are many places they need to use lasers for aligning or for a rain finding, so you would like to use the lasers, but they should not harm the eye and therefore, they tend to use the eye safe laser wavelength to mark target, they have to use lasers and usually it around 1.5 micrometer because they are relatively harm free. Class IV laser, let me come to class IV laser, it is mandatory to wear laser goggles and definitely you need to, so power P out > few 100 milliwatts.

It depends on the laser, as I said you see the ocular transmission is different. Similarly, the transmission through the skin, the absorption of a body skin depends on the wavelength and therefore, exactly you cannot specify numbers, but few 100 milliwatt, several watts, the Nd: YAG laser which we use in the lab, several watts' power, you must wear all the safety goggles, safety wear and it is necessary to use interlocking system for the laser lab that is + interlocking arrangement.

What is this interlocking that I am referring to? That is you are working in a laser lab, there has to be a red light, blinking red light. If the laser is on, there has to be a red light which is blinking such class IV lasers. These are requirements by law that there has to be a red light blinking and which means any user or anyone, any visitor cannot enter that lab when the red light is blinking. By chance, by mistake if he or she opens the door, the laser would automatically shut down.

There is an interlock with that, you open the door and the laser will shut down there automatically. So that is called interlocking arrangement. So, this is also mandatory by law. For some reasons, if the interlocking is not working, sometimes it happens in our lab, then we bolt the room from inside so that nobody by mistake enters. So, someone has to knock and wait there and then you will switch off the laser or put the shutter on and then open the door.

So, this is the safety measures depending on the classification of lasers, so safety of the user, last point safety of the device. I hope we have couple of minutes' safety of the device. I will stop here. All these high speed devices are sensitive to ESD, electrostatic discharge. May be we will discuss it in some other class because we do not have time, but all high speed devices including CMOS devices.

You maybe knowing that they are static sensitive, so the environment has to be static free, you have to use grounded mats, the user has to wear grounded straps and the wire has to go to a central node where it is grounded. It is grounded means you are not directly grounded, grounded through a 1 megohm resistance. Please remember there has to be a 1 megohm resistance. Otherwise, you will be a ground.

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And by chance, if there is a short circuit it will just all the current will go through you and therefore, it goes through a 1 megohm resistance, okay. So, these are straps which need to worn and I will show it here for those of you who are not able to see. It is a metallic strap with the pin and that goes to a point where you are grounded. Grounded means there is a ground path provided.

So that any static charge which is there in the environment, which is on your body does not pass through the device. You please see the basic idea, what is current I? I is dq/dt. Current is dq/dt. If the charge passes through in a very short time, current will be very large that is the whole idea about ESD. There are some charges which are on your body or on the work table and when you touch the device, the charge will pass through the device because the device is very fast, dt will be very small.

It will pass through at a very fast time and therefore, if you put here nanosecond and this charge may be very small. The current will become very large and therefore, this ESD problem is only with the high speed devices including electronic devices as CMOS devices, very high speed devices. This is very, very important laser diodes; otherwise you are bound to damage the laser diode.

I will stop here. More details you can see from the literature, this is basically to give you an idea about the various practical issues, practical aspects of the devices.