Laser-Fundamentals and Applications
Prof. Manabendra Chandra
Department of Chemistry
Indian Institute of Technology, Kanpur

Lecture – 26
Gas LASERs

Hello and welcome, we were discussing about different types of lasers and we were discussing about helium neon laser. So, we will start from there, so on your screen you have the energy state diagram I am sorry about the picture quality that is what I got.

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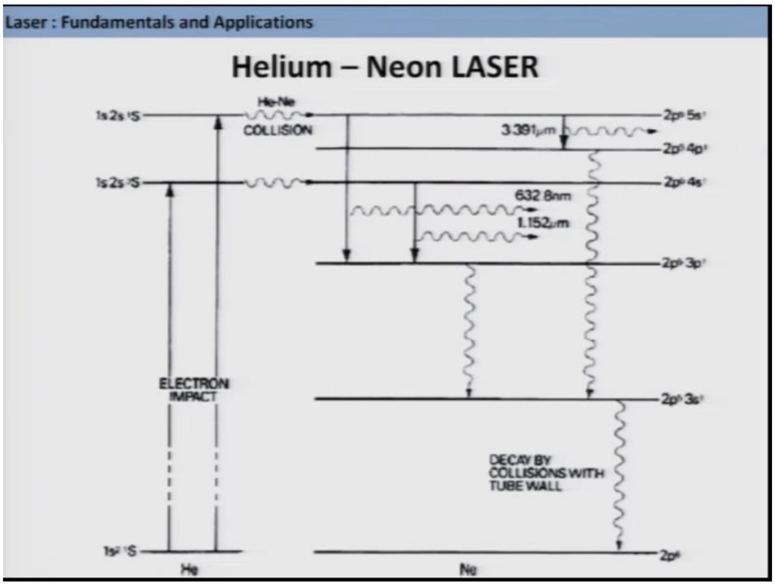

Now, so the initial excitation is achieved using electron discharge; through electron impact and the populated excited helium atom transfers the energy to the neon atom. So, in that way essentially one is creating a population transfer as well. So, thus you actually create a population inversion within the energy states of the neon atom. So, this populated energy levels of neon; they lie above the lowest excited state.

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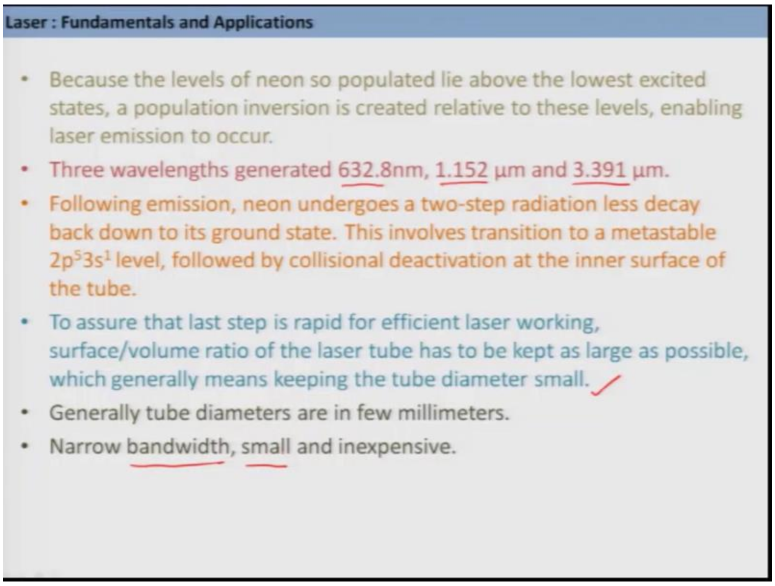

And as I said a population inversion is created with respect to these states and as a result we can have laser action there. And there are three possible laser wavelengths that can be obtained; this 632.8 nanometer, 1.152 micrometer and 3.391 micrometer. The most common wavelength for helium neon or any laser is 632.8 and there are a lot of applications of this hene lasers and for any optical alignment, hene laser is the one that is used.

A few more things, I would like to talk about here is that following emission; neon undergoes a two step radiation less decay back down to his ground state, and this involves a transition to a metastable 2 p 5; 3 s 1 level, followed by a collisional deactivation at the inner surface of the tube which contains the gas that is the helium neon mixture.

Now, note this one you have to depopulate the lowest excited state involved in the lasing action. Because that will ensure that you have population inversion; so, and this rapid decay from the lowest excited state is achieved through collisional deactivation of this excited neon atoms, and this collision that I am talking about is a collision between the excited gas molecules with the inner surface of the tube.

Therefore, if you have to achieve efficient deactivation of this lowest excited state which is necessary, you need to provide much more surface area compared to the volume of this container. So, this container essentially is a tube; a cylinder, so what you need to do?

You need to increase the surface to volume ratio, which essentially means that you reduce the diameter of this cylinder. So, that is what it is stated here; so, the tube either has to be extremely long and also the diameter should be extremely small. And practical number would be like couple of millimeters 1 to 2 millimeters, the diameter I am talking about. Now, the advantage of hene laser is that; we already mentioned it has a very narrow bandwidth; this hene laser is quite small and it is inexpensive.

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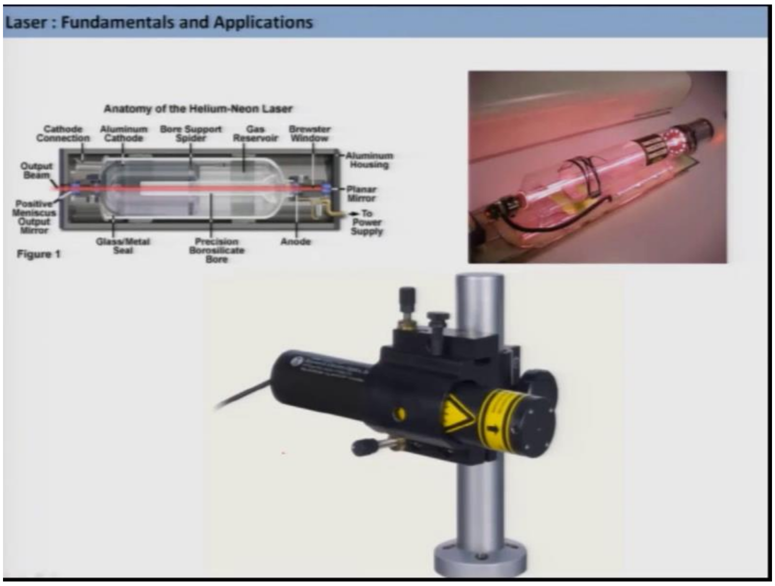

So, we will show you the actual picture of this hene laser. So, on your left there is as you know schematic of this hene laser, so this white part is essentially holding everything together and inside there you have the gases and you have the cathodes and anodes placed at different different region. So, this is the aluminum cathode kept here; while the anode is right here. So, due to this (Refer Time: 05:41) you get laser emission which is shown by this red colour line.

And you have either a plane mirror here and then out problem here, so you get an output through this one. So, this is an overall geometry and this whole tube which contains the gas must be sealed well; otherwise your laser properties will degrade in no time. So, this is another view of a real tube containing hene and this electric discharge system. So, this is essentially a electric discharge tube and all around this one you have gas moving around in a overall sealed container.

And this part actually is inside; so this commercial hene laser; so, this is commercially available hene laser. So, these are really small and they are really handy, they can be like you know just few inches long. So, from this picture itself you will get an idea like you know how small it is; I mean this are like normal screws. So, with respect to that you can easily gauge the dimension of this particular laser. So, this laser is really portable, handy you can put it in your pocket also; if you can carry the power supply which gives power to this electric discharge system.

And also this is quite narrow bandwidth and it is quite collimated also; you can achieve both polarized or depolarized light output from hene lasers. So, this is extremely useful in various applications.

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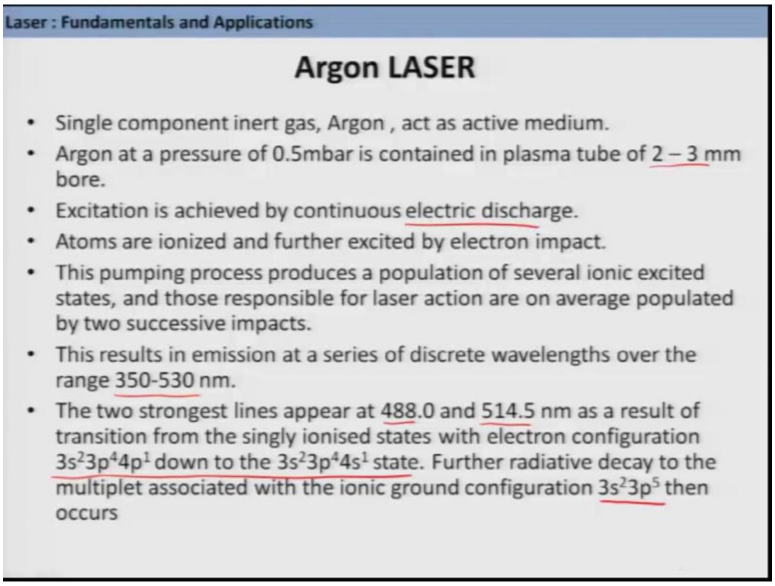

Now after talking about hene; we will talk about another atomic gas laser or ionic gas laser rather. So, we will talk about argon laser or very commonly called argon ion laser. So, the simple the component of this laser is just one inert gas that is argon and this is our active medium and the pressure that is maintained for this argon; it is also kept in a sealed container like helium neon is 0.5 millibar.

And the diameter is approximately 2 to 3 millimeter diameter of that container and similar to hene here also the excitation is achieved by electric discharge. Now, what is done here first unlike in hene; in argon laser, the electron impact first ionizes the argon atom and then this argon plast or argon ion is further excited. And this particular excitation, it produces population of several ionic excited states and these states are responsible for laser action.

Now, there are several emission wavelengths that are achieved from this argon ion laser and; however, this is not a continuously tunable laser system, but you know over a range they can give rise to several different discrete frequencies. And this range is roughly around 350 to 530 nanometer and there are certain emission lines, which are really famous they are like a 488 nanometer and 514 nanometer; which results from a transition from the singly ionized states with electron configuration of 3 s 2; 3 p 4, 4 p 1 down to the 3 s 2; 3 p 4 s 1 state and further radiative decay to multiplet associated with the ionic ground configuration of 3 s 2; 3 p 5 did not express.

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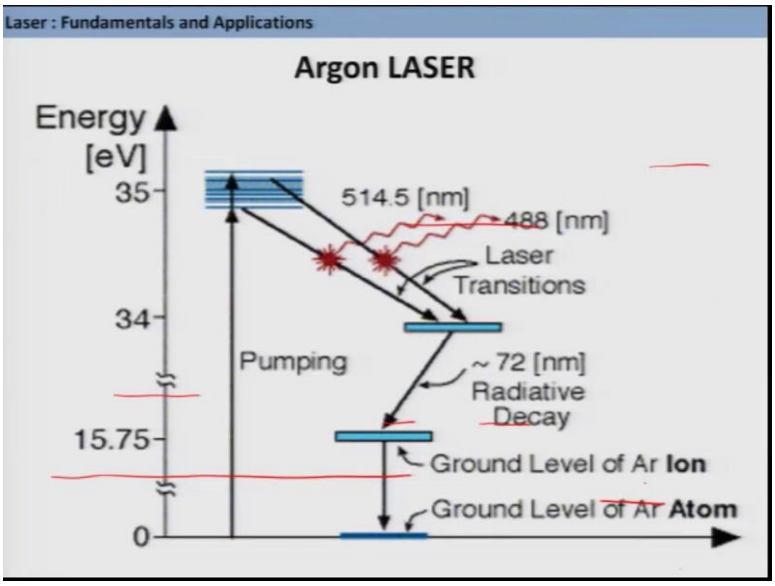

So here is the energy level diagram; so, how it is done, so you first ionize the ion system and then you play with the energy levels of argon ion system and the argon ion system have a ground state here and you have a population inversion created here essentially; so, from these states it can come down to this state here. And corresponding two lights; so, whether it is coming from here or here you get different output. So, you can see that I can get either 488 or 514 nanometer laser light from this two different transitions.

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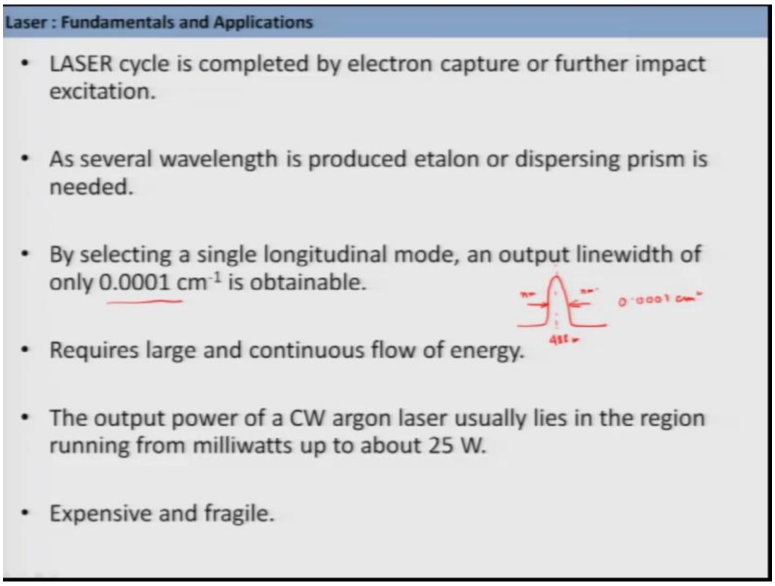

A few important things about this argon laser; this laser cycle is completed by electron capture or further impact excitation. So, also several different wavelengths is produced by etalon, we mentioned it earlier in one of the earlier classes; what etalon is, you can use also you know a prism to disperse them. So, you know if all of the lights are coming together; then you need to use something like; which will act like a creating and it will dispersal the light so that you can utilize different different wavelengths for your work.

Now, one can select a single longitudinal mode and by that you can achieve extreme narrow line width as small as 0.0001 centimeter inverse; you can figure out taking 488 nanometer as the central wavelength of the emission line, and using this value of 0.001 centimeter inverse full with half maxima, you can see; and you can exactly calculate what is the range of wavelength that one single line corresponds to. So what I essentially mean, that if I draw this; laser line like this, so this width corresponds to 0.0001 centimeter inverse; center line it corresponds to 488 nanometers say. Then what is this wavelength in terms of nanometer here and also here; you will see they will vary in third or fourth decimal. So, it is literally really really narrow band like; now this is advantage. What disadvantage we get here in case of argon ion laser; it requires large and continuous flow of energy. Because you have to maintain the population inversion there continuously; so, you need to pump it really hard.

You can get quite decent power from argon ion lasers; it can range from few milli watts to few watts like 20, 25 watts. Now, we have seen in case of hene laser; they are like very handy, they are you know good quality laser beam, they are comparatively quite cheap, you hardly have any kind of maintenance. On the other hand, this argon and lasers are extremely expensive compared to hene.

It is little difficult to maintain in that way it is little fragile, but you know in spite of this disadvantages; this argon ion laser is widely used particularly in the field of spectroscopy because of its extreme narrow line; width spectral line with particularly in case of Raman spectroscopy; this is very commonly used.

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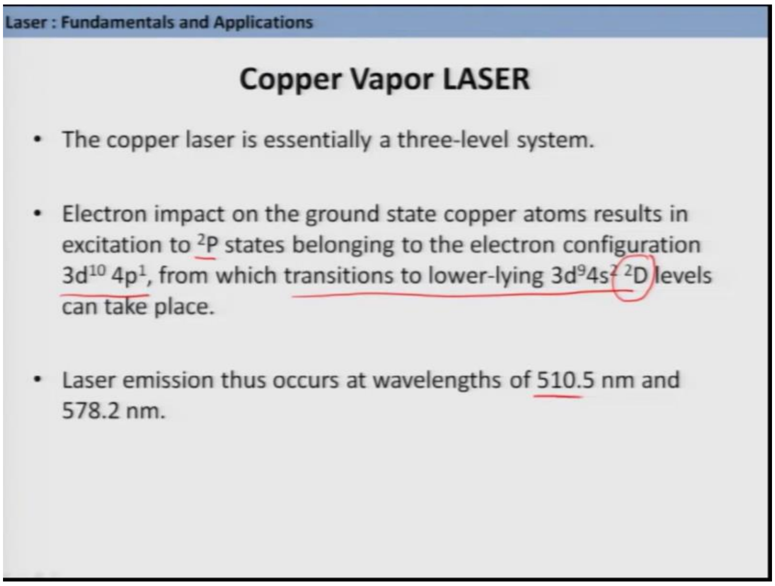

Next, we will go through real quick this copper vapor laser system; this is another atomic gas laser. So, this copper vapour laser is essentially three-level system and like any other gas laser, here also the electron impact plays the role. So, the electron impact the ground state copper atoms results in the excitation to 2 p states; which belongs to the electron configuration of 3 d 10; 4 p 1 and from this state, the transition to a low lying 3 d 9; 4 s 2 state which has this symbol 2 d; can take place. And the corresponding laser emission is achieved at 510.5 and 578.2.

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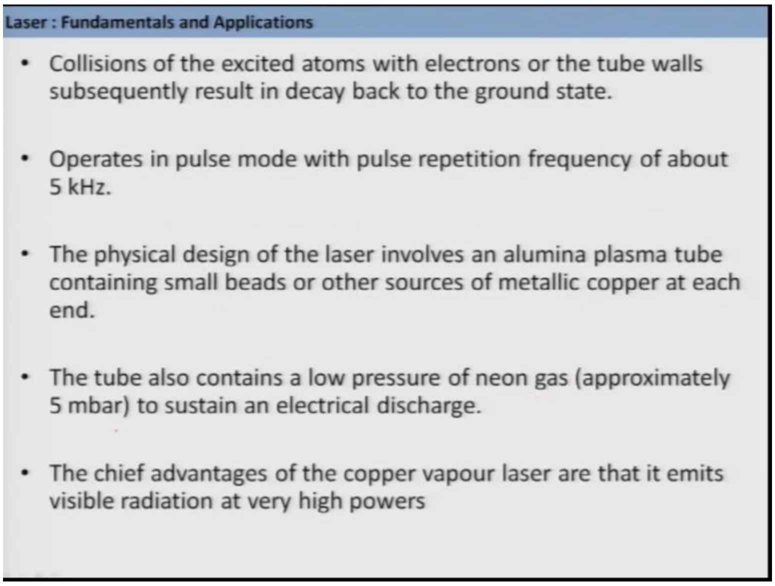

In this case also the de excitation takes place due to the collision of the excited gas molecules with the wall of the tube back which contains these gases. And this copper vapour laser, it operates in pulse mode with repetition rate of about 5 kilo hertz; so, it is quite high rate laser.

So, how you design this laser; so, the physical design it involves an alumina plasma tube containing small beads of; some flecks of metallic copper and this tube also contains in a low pressure of neon gas, which is approximately kept at nearly 5 millibar; which helps to sustain the electrical discharge. So, now the basic advantage of copper vapour laser is that it emits a very high power of visible laser light. So, this is used in various metallurgical applications because it uses visible light and having very high power.

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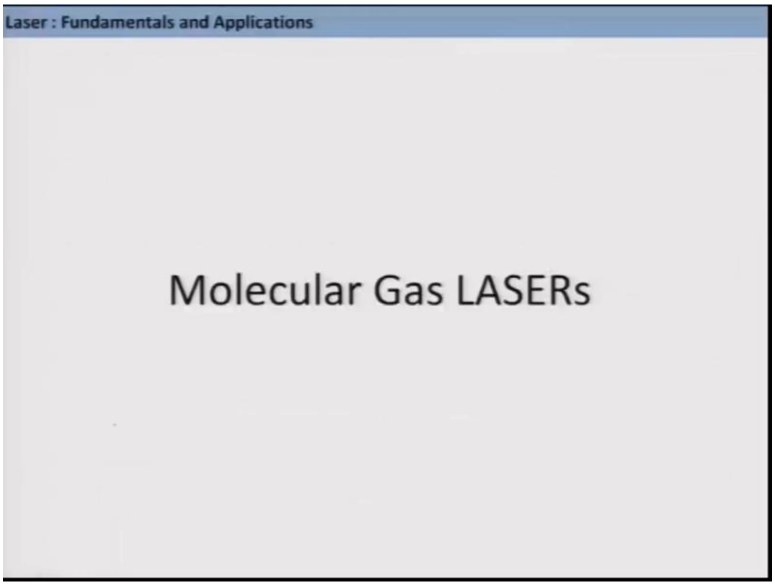

Now, let us move on to.other type of gas lasers which contains molecules. So, far we have used say like helium and neon; so helium neon is not a molecular gas laser. This helium is an inert gas, neon is an inert gas; they do not react, do not form a molecule. So, they are individual atoms just mix together; argon, copper vapour they are individual atoms or ions. So, now we will consider certain gas laser system which uses small molecules as active medium.

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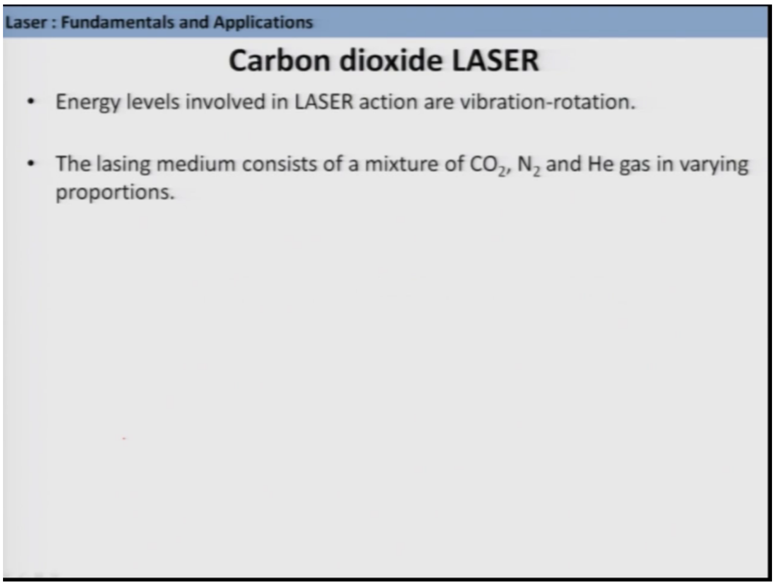

So, one of them is a carbon dioxide laser and here. So, mostly we can talk about the electronic energy levels, which involves in laser action. Here even the vibration rotation levels are involved in laser action, so this is something which you should note. The lasing medium consists; a mixture of carbon dioxide, nitrogen and helium gas in varying proportions. We will see what other molecules or atoms do here.

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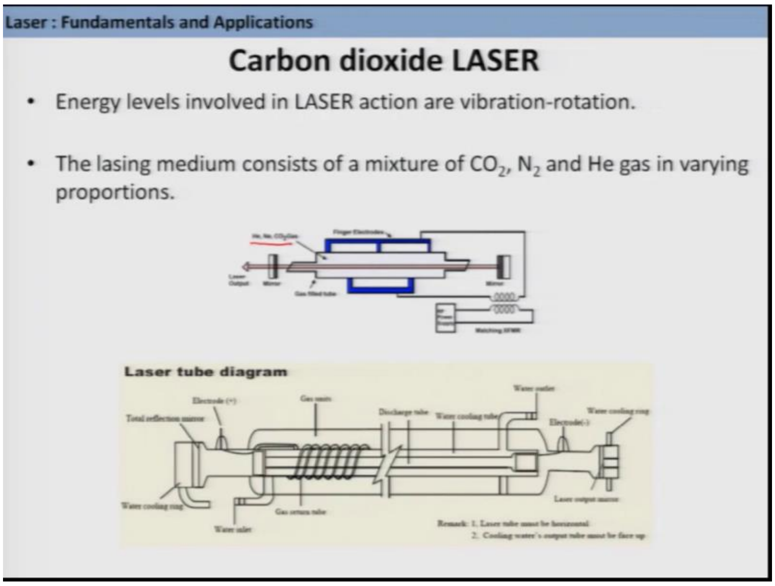

Now, this picture shows you the basic design of this laser. So, like any other gas laser you also have a sealed tube here and you provide the electron impact by putting some electrodes accordingly and at a given voltage difference, you create electric discharge; excite the gas molecules and ultimately get emission and hence the laser.

So, you have this helium neon and carbon dioxide gas all mixed up here and you put an end mirror here and output coupler here and ultimately you get the laser output; quite simple design. And this is another design here I shown reason is; that this laser also needs to be cooled down. So, it is cooled down by supplying water; so, this water goes in through this inlet and then water goes out from this outlet. And there is like a (Refer Time: 20:31) of water all around and it continuously cools down this whole system comprising of electric discharge and this gas cylinder; this is required like other solid state lasers that we discussed earlier.

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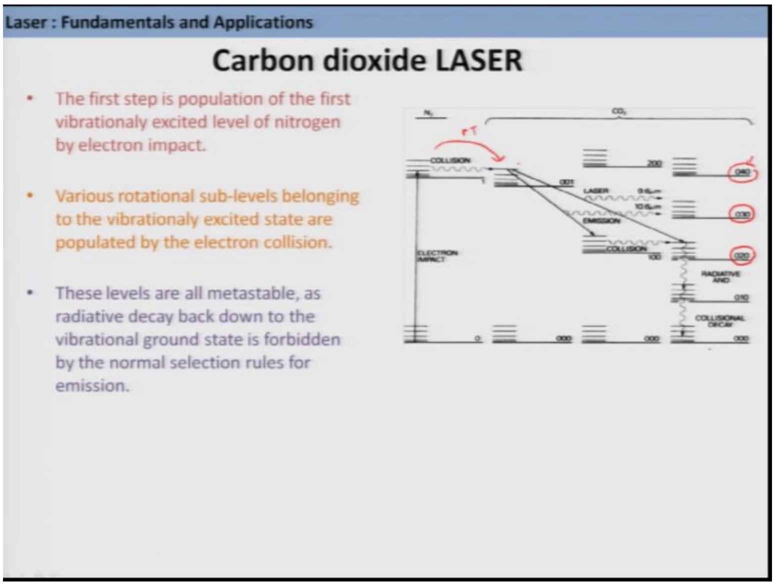

This is the energy level diagram of carbon dioxide and it shows how the lasing takes place here and what are the labels which are involved; what are the row vibrational level that are involved in this lasing action. Now, here again you see different types of nomenclature for the states. So, these are particularly used for low vibrational levels and unfortunately we will not be able to discuss about this particular type of nomenclature, how this term symbols are formed. Anyone interested, you can look at a standard spectroscopy book or standard quantum mechanics book, you can find how to get these particular symbols. So, right now you just take them at different different low vibrational states corresponding to different electronic states.

So, what we have here for this energy level diagram. So, first of course, you give the electron discharge; so electron impact will take the molecule from the ground to the excited state of nitrogen molecule. So, the first electron impact takes place in the nitrogen molecule; molecular states. And then this excited nitrogen electronic state and the corresponding vibrational and rotational state; transfer their energy and hence the population to the levels of carbon dioxide molecule.

Because this rotational sub levels belonging to vibrational excited states are populated by this electron by this collision. So, ultimately what happens these states where the population is being transferred? So, this is essentially you are doing the population transfer by transferring the energy. Now, this state where it is coming is a metastable state; so because it is a metastable state.

So, after every excitation and following collision the number of you know carbon dioxide molecule in this excited state is increasing and then it can come down to the low line energy states. And this low lying energy states like here or here, they undergo very rapid relaxation; ultimately to the ground state, thereby you can achieve sufficient population inversion and hence you can get that laser action. So, the laser action gives you this 9.6 micron and 10.6 micron; two different lines and you can see these are in infrared and certainly it involves the vibrational levels.

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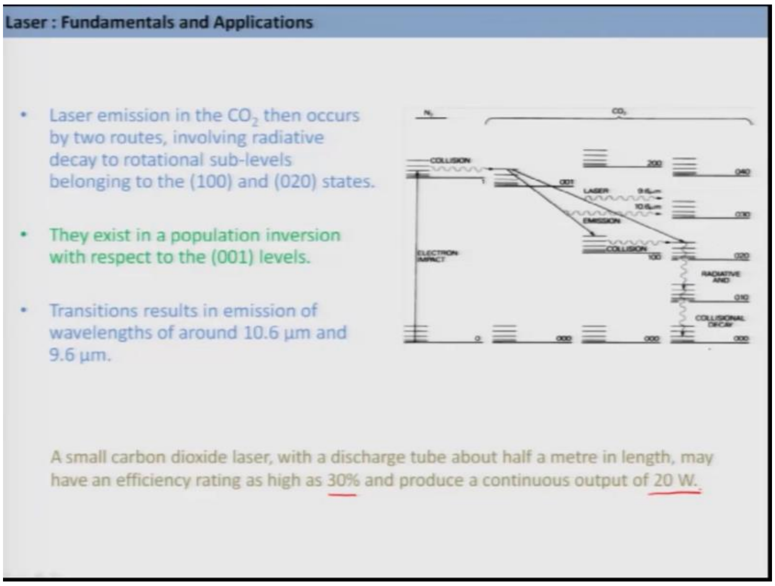

So, we have already discussed this; so, one more information here that a small carbon dioxide laser with a discharge tube about half a meter in length; may have an efficiency rating as high as 30 percent and it produces a continuous output of 20 watt.

So, a continuous wave laser having a 20 watt energy is amazing; this can be used for welding or cutting metals and all these things. So, in metallurgy it finds a tremendous applications; if you get access to a good machine shop or workshop; you will see that many places this carbon dioxide lasers are used to do a lot of machining and micro machining.

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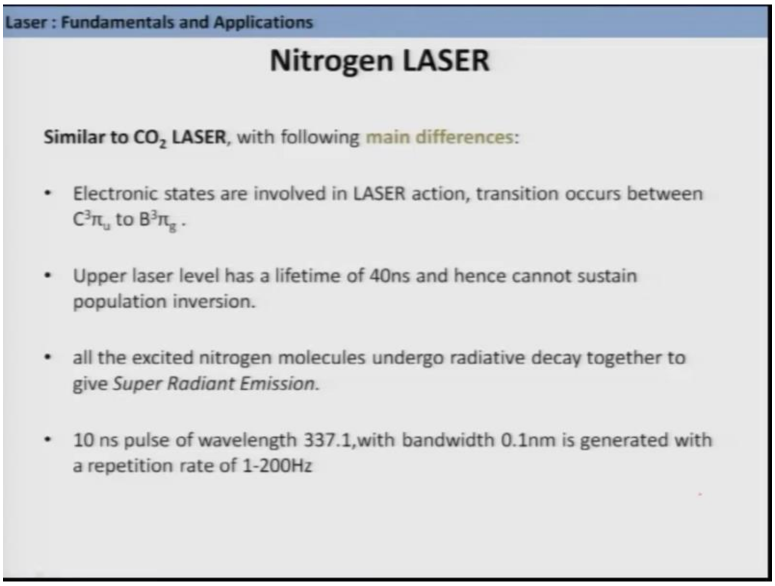

So, the last laser in this particular section we will discuss about is nitrogen laser and nitrogen laser; the principle is very much similar to carbon dioxide with certain differences; what are those differences? The electronic states are involved in case of nitrogen and the states, the transition occurs between 3 pi u to 3 pi g. The upper level that is 3 pi u has a lifetime of 40 nanosecond and hence cannot sustain population inversion.

All the excited nitrogen molecules undergo radiative decay together to give super radiant emission and short pulses around 10 nanosecond pulses of wavelength 337.1 with a bandwidth of 0.1 nanometer is generated and the repetition rate that is obtained from this nitrogen laser can be varied between 1 to 200 hertz ok.

So, you can see here that the differences here is slick in the near UV region, we have the output from nitrogen laser. And otherwise this all these gas lasers has a very similar kind of configuration. So, next we will talk about a totally different types of laser which is chemical laser. So, from the name itself you can understand that there are certain chemical reaction takes place, which provides the systems that give rise to levels or energy states that ultimately cannot give us laser action.

So, under chemical lasers we will look at two particular type of systems; one is iodine laser and second thing is called an excitement laser. So, in the following class we will talk about these two laser systems in quite detail.

Thank you very much.